IMPROVING THE MANAGEMENT OF REDHEADED COCKCHAFER IN RYEGRASS PASTURES THROUGH IMPROVED SURVEILLANCE TECHNIQUES

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Keywords: remote sensing, altitude, rainfall, ryegrass, cockchafers

Introduction

The redheaded cockchafer (*Adoryphorus couloni*) (Burmeister) (RHC) is a native insect scarab beetle which is regarded as a significant economic pest in ryegrass-based dairy pastures in South East Australia (Berg et al., 2014). Over 3 million hectares of land has been damaged by RHC in Victoria alone and it also occurs in other Australian states. Infestations are usually detected once signs of extensive plant damage are visible and the predominant management measure utilised at that point is to remove and re-sow pasture. Other pest cockchafers such as *Heteronychus arator* African Black Beetle (ABB) and *Acrossidius tasmaniae* Black Headed Cockchafer (BHC), are more easily managed using endophytes or chemical insecticides. These pest cockchafers can occur either singly or in combination with RHC and can be easily misidentified resulting in inappropriate management. Although anecdotal evidence suggests that soil and climatic factors may influence distribution and subsequently the level of damage from cockchafers, relatively few studies have been conducted to determine the influence of these factors on their distribution.
Even though factors which influence the distribution of pest cockchafers in soil are largely undescribed, for other root feeding pests distribution has been linked to physical and chemical properties of the soil (Powell et al., 2003) and this information can lead to the development of improved detection approaches using remote sensors (Bruce et al., 2009, 2011) which would allow early intervention to reduce economic damage. An improved understanding the influence of both soil and climate characteristics on cockchafer distribution, coupled with appropriate identification guides, could lead to improved opportunities for early detection, surveillance and targeted management of these pests.

In this study four regions were surveyed in Gippsland (East, West and South) and Western Victoria where all three cockchafers have been reported to be causing varying levels of damage to dairy pastures. The surveys aimed to (i) determine if remote sensing could aid in determining the spatial distribution of three cockchafer species (RHC, BHC and ABB) in ryegrass paddocks, (ii) quantify the relative abundance of each species in the three regions, (iii) collect preliminary data to determine seasonal and in-paddock distribution of cockchafer life-stages in each region, (iv) determine the effectiveness of light traps for monitoring cockchafers, and (v) examine the relationship between rainfall and cockchafer abundance.

Methods

Telephone Survey

To select representative sites a telephone survey, with 384 respondents, was conducted in 2011 across five regions of Victoria (David Williams, DEDJTR unpublished data). The survey also analysed grower perceptions on distribution of cockchafer pests. Based on the survey results nine sites were selected for further study in four regions East, West and South Gippsland and Western Victoria.

Baseline Mapping

Between 2011 to 2013, surveys using remote sensors were conducted at the nine commercial dairy pasture sites in Western Victoria, Western Gippsland, East Gippsland (2011 only) and South Gippsland. At all sites data on (i) apparent electrical conductivity EM38H (horizontal dipole), (ii) apparent electrical conductivity EM38V (vertical dipole), (iii) vegetation (normalised digital vegetation index (NDVI)) and (iv) altitude were collected.

Insect Sampling

At each study site 20 x 1 m^2 quadrat samples were collected at each site at selected points in the season December, February and April over three successive seasons from 2011 to 2014 (Powell, 2011, 2014). Quadrat soil samples were sorted *in situ* and examined for the presence of cockchafer larvae, pupae and adults which were identified using morphological keys. Light traps were also used in 2012 only to determine their effectiveness as early predictors of cockchafer abundance (Powell, 2014).

Climate data

Rainfall records from the nearest Bureau of Meteorology (BOM) weather station to each trial site were accessed from www.bom.gov.au.

Soil Chemical Analysis

The study sites varied in general soil type including dermosols (Western Gippsland), kurosols (South Gippsland) and volcanic sodosols (Western Victoria). In February 2012 soil samples (200 g) were collected from all quadrat sampling points at all trial sites in Western Victoria, South Gippsland and West Gippsland. Soils were analysed by a commercial laboratory using standard techniques. The variables measured included nitrogen, phosphorus, potassium, sulphur, organic carbon, conductivity, pH, copper, iron, manganese, zinc, exchangeable ions (aluminium, calcium, magnesium, potassium and sodium) and boron.

Results and Discussion

Telephone Survey

Of the three cockchafer pests RHC was reported as the predominant pest particularly in West Gippsland. ABB was of minor importance and only reported in West and South Gippsland and BHC was the least commonly reported. Various management approaches were taken by dairy farmers including resowing pastures, insecticide sprays and lime application.

Geographic and Seasonal Distribution of Cockchafer Pests

Cockchafer pest species were identified to species level from sampled quadrats at all sites in February and April of 2011, 2012 and 2013. When datasets from 2011, 2012 and 2013 were combined it included cockchafer collections all samples from 893 quadrats representing over 4000 pest pasture cockchafers collected and over 2700 identified as RHC.

RHC was the predominant pest species found at all field sites regardless of time of collection, with the exception of two sites in East Gippsland where no RHC was detected (data not presented). West Gippsland sites had at least threefold higher population levels than the Western Victoria and South Gippsland field sites. BHC and ABB were less common and found in negligible numbers (i.e. <10 per field site) in all geographic regions but not at all field sites or sampling dates. The highest abundance of both ABB and BHC were recorded in 2012 (Table 1). No ABB was detected at any field site from quadrat samples in 2013.

RHC Life-stage Seasonal Abundance

Sampling of RHC at three sampling times (December, February and April) for two consecutive years (2012 and 2013) enabled comparison of total and relative life stages abundance of RHC by region and site. Total and individual life stage abundance varied between regions and sample time. The collected data indicated that February and April are the optimum times to survey for RHC as it is most abundant as second and third instars and therefore more readily detected.

Light Trap Efficacy

Light traps were monitored from September 2012 to April 2013 at seven field sites and were effective at trapping a number of Coleopteran adults (Powell, 2014). A difficulty in using light traps is their non-selective nature as they require extensive sorting. Once samples were sorted they appeared to be only useful for collecting BHC as no RHC were found in any of the traps (Table 2). The reasons for this are unclear. However in the season (2012–2013) in which the light traps were tested RHC total abundance in field collected samples was generally low at all sites. Despite these results this does not preclude the future evaluation of light traps either as a research tool to monitor flight activity of RHC adults or for use as an early warning system for forecasting RHC abundance. Further studies would need to be conducted when RHC is more abundant and using modifications to trap density, trap location, light wavelength and trap height to optimise trap efficacy as a detection tool.

Cockchafer Distribution and Altitude

Elevation measurements at all sites were derived from RTK DGPS (differential global positioning system) mapping. RHC larvae preferred higher altitude regions of undulating paddocks and were geographically more abundant in lower altitude sites of West and South Gippsland. Using a simple two-sample t-test analysis (assuming unequal variance) the relationship between RHC and altitude across regions and seasons was explored and this demonstrated significant differences ($P<0.001$) in total mean redheaded cockchafer numbers (across all sample periods) by altitude, with higher mean abundance at the lower altitude sampling sites.

Altitude significantly influenced RHC abundance over a broad geographic range. In this study the altitude ranges for each region studied were West Gippsland (33–38 masl), South Gippsland (8–21 masl) and Western Victoria (144–187 masl). West Gippsland consistently had the highest abundance of RHC. Within paddocks however minor altitude changes can also influence RHC larval abundance as shown in a study at two South Gippsland sites in 2011 (Cosby et al., 2012) with third instar RHC showing a preference for higher altitude areas within a paddock. Presumably this is because the soils are lighter, more free draining and larval survival is enhanced in drier areas of the paddock.

Cockchafer Spatial Distribution in Relation to Soil and Vegetation Characteristics

One of the aims of this investigation was to determine whether there is any evidence of relationship between RHC population distribution and the pasture environment they establish in using measurements obtained using Precision Agriculture (PA) sensors including: soil apparent electrical conductivity (soil ECa) derived from EM38; normalised difference vegetation index (NDVI) derived from an Active Optical Sensor (AOS). ECa is related to the relative amounts and types of clay, salts and water in the soil. NDVI quantifies the relative difference between the near infrared reflectance 'peak' and the red reflectance 'trough' in the spectral reflectance profile of vegetation. Healthy vigorous plant biomass would exhibit strong near infrared reflectance and low red reflectance.

Field observations conducted in 2011 (Powell, 2011) suggest that RHC are more likely to establish in areas of high elevation and low soil ECa. On some trial sites RHC were also associated with low NDVI values whereas on other sites high NDVI were associated with RHC abundance suggesting more complex relationships may exist between NDVI and RHC populations. In a more recent study conducted on a single property, with more sample quadrats (n=100) the red wavelength reflectance appears to be a useful indicator of third instar RHC larvae abundance (Cosby et al., 2013). Overall previous results (Powell, 2011, 2014) suggest that it is likely that there is a complex relationship between RHC, NDVI, soil ECa and elevation which would require further study, at multiple sites and over more than two concurrent seasons (due to the RHC 2-year life cycle and potential influence of high summer rainfall on reducing RHC larval abundance). In a recent study a combination of these variables was used to produce risk maps with an accuracy of 88 % at predicting likely RHC density-categories on a dairy property in the Gippsland region of Victoria, Australia (Cosby et al., 2016).

Rainfall

The geographic distribution of RHC is primarily within areas with an average annual rainfall of 500–800 mm (Berg et al., 2013). Seasonal distribution of rainfall is likely to impact on RHC population dynamics. For example when soils are waterlogged and anaerobic this may reduce larval and egg survival. High soil moisture could also influence the development of entomopathogenic soil microbes which could increase larval mortality.

A PLS analysis of cumulative rainfall across all months and sites found a minor positive correlation with the rainfall over the previous two and three months (Table). Our analysis shows that cumulative rainfall over the three months preceding sampling is a moderately reasonable predictor of RHC abundance. This finding, if developed further, could be used to develop a system to determine (a) whether to sample in any given season, (b) when to sample, and (c) the likelihood of RHC larval survival and ability to reach damaging levels in any given season.

Soil Chemistry

Overall there were very weak to negligible correlations between individual soil chemistry parameters and RHC abundance. There were only minor positive correlations with % organic carbon (0.128), iron (0.102) and Zn (0.114) and minor negative correlations with nitrate nitrogen (-0.148), boron (-0.115) and exchangeable calcium (-0.187).

Generally stronger correlations were observed when comparing soil conductivity with some soil chemistry parameters. Positive correlations were observed with nitrogen (0.677), iron (0.320), zinc (0.257) and calcium (0.132) and a negative correlation with boron (-0.267). Although in our analysis overall soil chemistry parameters did not appear to be good predictors of RHC abundance and therefore not useful as a predictive tool for detection, there were some parameters with minor correlations. These minor correlations do suggest that soil chemistry may have some influence on RHC abundance albeit minor. As electrical conductivity has been shown to be influencing RHC abundance it would be beneficial to further explore the relationship between soil chemistry, electrical conductivity and RHC abundance.

Summary

Studies conducted to-date on abiotic and biotic factors that influence spatiotemporal distribution of RHC and other pest cockchafers, which would inform effective implementation of timely and effective management strategies, are limited. This study provided preliminary insights into some factors including rainfall, vegetative index and soil electrical conductivity which could ultimately lead to improved detection and timely intervention.

Acknowledgements

The information used in this paper is based on research funded through the Geoffrey Gardiner Dairy Foundation, the Department of Primary Industries and GippsDairy which were conducted by the Victorian Department of Primary Industries between 2011 and 2014 in collaboration with the University of New England, Armidale.

Table 1.
Relative total abundance of pasture cockchafers from quadrat soil sampling at six sampling locations in Victoria.

	Feb 2012 Sampling		
	RHC	BHC	ABB
SOUTH GIPPSLAND			
Site 1	58	1	10
Site 2	44	3	0
WEST GIPPSLAND			
Site 1	143	1	0
WESTERN VICTORIA			
Site 1	30	0	6
Site 2	32	0	5
Site 3	74	0	19

	Feb 2013 Sampling		
	RHC	BHC	ABB
SOUTH GIPPSLAND			
Site 1	28	0	10
Site 2	38	0	0
WEST GIPPSLAND			
Site 1	138	0	0
WESTERN VICTORIA			
Site 1	22	0	6
Site 2	7	0	5
Site 3	30	9	19
	APRIL 2012 Sampling		
	RHC	BHC	ABB
SOUTH GIPPSLAND			
Site 1	24	1	0
Site 2	27	6	0
WEST GIPPSLAND			
Site 1	267	1	0
WESTERN VICTORIA			
Site 1	28	20	0
Site 2	39	0	0
Site 3	81	49	0
	APRIL 2013 Sampling		
	RHC	BHC	ABB
SOUTH GIPPSLAND			
Site 1	27	0	0
Site 2	15	0	0
WEST GIPPSLAND			
Site 1	154	0	0
WESTERN VICTORIA			
Site 1	36	0	0
Site 2	10	0	0
Site 3	32	2	0

Where RHC = Red Headed Cockchafer, BHC = Black Headed cockchafer and ABB = African Black Beetle

Table 2.
Relative total abundance of Coleopteran adults caught in light traps between September 2012–April 2013 at selected field sites in Victoria, Australia.

	RHC	ABB	BHC	Other beetles
Western Victoria – Site 1	0	0	>625	>1160
Western Victoria – Site 2	0	0	35	>3176
Western Victoria – Site 3	0	0	0	>255
West Gippsland – Site 1	0	0	10	>9380
South Gippsland – Site 1	0	0	113	>2335
South Gippsland – Site 2	0	0	0	>350
North East Victoria	0	6	0	>215

Where RHC = Red Headed Cockchafer, BHC = Black Headed cockchafer and ABB = African Black Beetle.

Table 3.
Correlation matrix for RHC abundance with cumulative rainfall in months (1, 2 and 3) preceding sampling.

Variables	Rainfall1	Rainfall12	Rainfall123	RHC
Rainfall1	**1.000**	0.837	0.754	0.183
Rainfall12	0.837	**1.000**	0.910	0.225
Rainfall123	0.754	0.910	**1.000**	0.252
RHC	0.183	0.225	0.252	**1.000**

Where RHC = Red Headed Cockchafer

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