Influence of pasture renewal, soil factors and climate on black beetle abundance in Waikato and Bay of Plenty

P. J. GERARD, N.L. BELL, T.M. EDEN, W.M. KING, N. R. MAPP, M.R. PIRIE and G.M RENNIE
AgResearch, Ruakura Research Centre, PB 3123, Hamilton 3214
pip.gerard@agresearch.co.nz

Abstract

An outbreak of the sporadic pest black beetle caused major damage on farms throughout Waikato and Bay of Plenty regions from 2007 to 2010. Two projects were initiated in these regions to gain an understanding of the interaction of black beetle with endophyte/cultivar combinations and pasture renewal strategies. Monitoring of black beetle populations on the project farms showed that overall, abundance steadily declined from 2009 to 2013, possibly due to cool temperatures, and in the case of Bay of Plenty, high rainfall in 2010. In Waikato, pasture renewal in 2012 had no significant effect on beetle abundance in the following year compared to the unrenewed paddocks. Greater population levels in the Waikato sites were associated with lower soil pH. El Niño and La Niña weather events appear to be associated with changes in black beetle population levels, which may assist prediction of future outbreaks and damage risk.

Keywords: *Heteronychus arator*, pasture, La Niña

Introduction

Black beetle (*Heteronychus arator* (Fabricius)) is a subtropical pasture pest of southern African origin that was first observed in the 1930s around Auckland and by the late 1950s had spread as far north as Dargaville and south-east to Gisborne (Todd 1959). The pest appears to be confined to areas with a mean annual surface air temperature of 12.8°C (Watson 1979), which includes Northland, Waikato, Bay of Plenty and coastal areas of the northern North Island from Whanganui in the west around to Cape Kidnappers in the east (Bell *et al.* 2011).

A major outbreak of black beetle occurred in the Waikato and Bay of Plenty regions in 2007/08 and persisted into 2010 (Bell *et al.* 2011) and beyond on some farms. Important factors contributing to black beetle outbreaks are above average temperatures and availability of favourable food resources. Warm spring temperatures (growing degree days above 15°C) (King *et al.*1981b) encourage population increase while wet conditions are unfavourable for early instar larval survival (King *et al.* 1981c). The dominant grass species in a paddock affects population growth: C_4 grasses, as well as ryegrasses (*Lolium* spp) without a deterrent endophyte, are favourable hosts (Blank & Olson 1988; King *et al.* 1981a; Ball & Prestidge 1992). In contrast, adult feeding, and in turn survival and oviposition are reduced by ryegrasses containing standard, AR37, NEA2 or Endo 5 endophytes (Ball *et al.* 1997; Bell *et al.* 2011; Popay & Baltus 2001).

The severity of the recent black beetle outbreak initiated the Sustainable Farming Fund Project SFF 11/035 "Beating Black Beetle: developing pest-resistant dairy pastures in the Waikato". As part of this project, on-farm demonstration trials of best-practice endophyte/cultivar selection, establishment and pasture management as outlined in the DairyNZ Pasture Renewal Guide (DairyNZ 2012) were commenced in late 2011. This aspect of the project is closely linked to an existing Pasture Renewal project (SFF 11/089) that was also carried out on Waikato and Bay of Plenty dairy farms (Tozer *et al.* 2013).

In this paper we investigate pasture renewal, soil and climate factors which may contribute to the variation in abundance and persistence of black beetle populations using data from both projects. In particular, as La Niña events are associated with warmer than normal temperatures, we investigate the possibility of predicting black beetle outbreaks using Southern Oscillation climate data.

Methods

On farm demonstration trials

Six farms affected with large black beetle populations in 2011 were selected: Sites 1–5 in the Waikato (Tokanui, Cambridge, Matamata, Te Aroha and Gordonton) and Site 6 at Awakeri, Bay of Plenty (BOP). On each farm two similar paddocks were selected, one to be renewed using best practice and a second to act as a control. The Waikato unrenewed paddocks were between 5 and 8 years old, while the BOP paddock was of unknown age. The best species/cultivar/endophyte/seed treatment options were selected for each farm by the farmer in consultation with the project team, based on the region and existing farming systems (Table 1). Four of the Waikato renewed paddocks were sown in autumn 2012 following a summer crop, while the fifth paddock (5/2 Table 1) was cropped a year later. The Bay of Plenty paddock was renewed grass-to-grass by spray-drilling.

Pasture dry matter was assessed at intervals based on growth rate (21 days in spring, to 73 days in winter). Four animal exclosure cages were randomly located within each paddock following a pregrowth cut to 2 cm in height. All sites were cut during the same week with hand shears. Following the required interval, pasture within a 0.122 m^2 quadrat was cut (to 2 cm) from each cage and bulked for herbage dissection and dry matter (DM) analysis. Samples were dissected into sown grass, other grass, clover, and broadleaved species.

Soil samples from the Waikato sites were taken in 2012 during early spring and sent to commercial laboratories for nutrient analysis. The timing corresponded with the black beetle oviposition period (King *et al.* 1981c).

Mean black beetle abundance in each paddock was assessed in February 2012 and 2013 by taking ten 20 × 20 cm spade squares of turf to *ca.* 20 cm depth. These were broken up by hand and the number of larvae, pupae and adults counted in each square. The relationship between black beetle abundance and soil and pasture attributes was investigated by regression analysis of 2012/13 seasonal data.

In the pasture persistence project SFF 11/089, the black beetle abundance was also surveyed in February, in an identical manner. The data from unrenewed paddocks in both trials were pooled to allow assessment of population trends from 2009 to 2013. Details of SFF 11/089 methods and sites are provided by Tozer *et al.* (2013).

Influence of La Niña events

To investigate the relationship between El Niño and La Niña climate conditions and black beetle outbreaks, Southern Oscillation Index (SOI) measurements from 1930 to 2013 (NOAA 2013) were plotted against New Zealand black beetle population data reported in the literature (Todd 1959 and references therein; King *et al*. 1981b and references therein; Popay & Baltus 2001; Popay & Thom 2009; Bell *et al*. 2011). The beetle outbreaks each year were classified as being one of four events: “none” = no reported black beetle outbreaks; “pop > 40” = records of an isolated population >40/m^2; “Local” = records of localised black beetle damage such as pasture pulling, and; “Mass” = mass flights and widespread damage across northern North Island districts. A yearly average SOI was calculated for the period from May to April, where a high positive yearly average corresponds to a La Niña year and a negative yearly average corresponds to an El Niño year. Analysis of Variance (ANOVA) was performed to investigate if there was a difference between the average yearly SOI for the four classifications of beetle outbreaks.

Results and Discussion

On farm demonstration trials

In February 2013, black beetle populations (total of larvae, pupae and adults) were below damaging levels in all monitored paddocks (considered to be 40 larvae/m^2 in ryegrass pasture in summer (King & East 1979)) and no relationship was found between black beetle density and pasture dry matter production (Table 2). More pasture growth was measured from June 2012 to May 2013 in renewed compared to unrenewed pastures (13.3 *vs* 12.1 t DM/ha), but with comparative data available from only five farms over this period, the result was

Table 1 Description of SFF 11/035 demonstration sites and renewed paddock treatments

Site/paddock	*Soil type*	*Renewal*	*Crop*	*Cultivar(s)*	*Endophyte(s)*
Waikato					
1/ 1	Peat	N		Bealey	NEA2
1/ 2		N		Bealey	NEA2
1/ 3		Y	Sorghum	Trojan	NEA2
2/ 1	Ash	N		Trojan/Alto	NEA2/AR37
2/ 2		Y	Maize	Trojan/Alto	NEA2/AR37
3/ 1	Silt loam	N		Commando/Extreme	AR37
3/ 2		Y	Turnips	Prospect/ 1228	AR37
4/ 1	Peat	N		Kamo	AR37
4/ 2		N		Samson	AR37
4/ 3		Y	Rape	Samson	AR37
5/ 1	Ash	N		Ohau	AR37
5/ 2		Y	Chicory	Not yet sown	
Bay of Plenty					
6/ 1	Sandy loam	N		Bealey	NEA2
6/ 2		Y	Annual ryegrass	Prospect	AR37

not significant ($P=0.054$). However, the greater than 1 t DM/ha advantage to pasture renewal is comparable to the results of Tozer *et al.* (2013). In addition, there was no significant difference in black beetle abundance between renewed and unrenewed pastures (Table 2). The combination of sorghum as break crop on at Site 1, low populations, and that Site 5 was still in crop, could have contributed to this outcome. Sorghum and maize are known host plants for black beetle adults (de Villiers 1984) and there may be carryover into subsequent pasture, but their value within the farm system often dictates their use. Most summer crops are poor hosts for black beetle larvae, so it is possible that black beetle adults sought out pastures prior to oviposition. The high mobility of adult black beetle, both through mass flights and crawling, is regarded as one of the reasons insecticide applications targeted against adults in pasture do not reduce subsequent larval populations (Eden *et al.* 2011). This mobility reinforces the need to use treated seed when sowing new pasture (DairyNZ 2012) and vulnerable summer crops such as maize or sorghum.

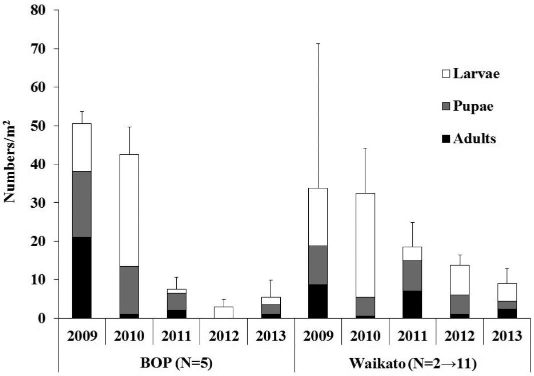

Figure 1 Mean number of black beetle larvae, pupae and adults in unrenewed paddocks in February, in projects SFF 11/089 and SFF 11/035. Error bars denote standard error of the mean. Brackets denotes number of paddocks in region, with increasing numbers in Waikato.

Soil type had no significant influence on 2013 black beetle abundance. However, greater population levels in the Waikato sites were associated with lower soil pH ($y = -26x + 169$; $R^2 = 0.49$; $P<0.05$) and there was a tendency for higher populations to be found in sites with high phosphate levels (Table 2). The range of soil pH across sites was from 5.6 to 6.3 and there was no apparent relationship with soil type. Some soils were outside the recommended pH range for optimal pasture growth. However, further research is needed before it can be determined if soil pH has any direct effect on beetle abundance and, if it does, the mechanisms behind this.

Table 2 February 2013 black beetle populations*, soil pH, P and Ca levels at time of oviposition (December 2012), and cumulative dry matter production between June 2012 (post establishment phase) and May 2013. Cumulative dry matter production is not applicable where crops have been sown during the period of monitoring.

Site/ paddock	*Renewed*	*Black beetle /m^2 ± SE*	*pH*	*P (mg/L)*	*Ca (me/100 g)*	*DM grown (t DM/ha) Jun 12 to May 13*
Waikato						
1/ 1	N	10.0 ± 7.6	5.9	40	23.4	13.3
1/ 2	N	25.0 ± 7.5	5.7	38	16.9	12.3
1/ 3	Y	22.5 ± 7.9	5.9	32	20.6	13.9
2/ 1	N	20.0 ± 10.4	5.6	100	10.9	14.3
2/ 2	Y	0	6.0	33	12.8	13.8
3/ 1	N	0	6.3	38	16.2	14.6
3/ 2	Y	2.5 ± 2.5	6.1	29	9.5	16.7
4/ 1	N	0	5.9	25	82.3	n/a
4/ 2	N	2.5 ± 2.5	6.4	24	90.9	11.2
4/ 3	Y	2.5 ±2.5	6.2	22	90.1	11.7
5/ 1	N	7.5 ± 5.3	6.3	49	16.2	15.7
5/ 2	Y	10.0 ± 5.5	6.0	38	14.8	n/a
Bay of Plenty						
6/ 1	N	7.5 ± 5.3				7.6
6/ 2	Y	2.5 ± 2.5				10.4
Regression (black beetle × factor)			P = 0.016	P = 0.114	P= 0.183	P = 0.893

* SE from 10 spade square samples

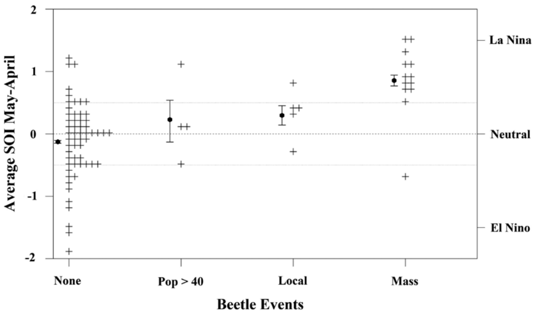

Figure 2 Dot plot of the average yearly SOI, calculated as the average from May to April, classified into recorded beetle outbreak scale. "none" = no reported black beetle outbreaks, "pop > 40": record of a population >40/m², "Local": records of localised damage, and "Mass" wide spread damage from high populations. The bars show the 95% confidence intervals about the mean within each classification.

Regional black beetle population trends

Figure 1 shows the mean February densities of black beetle larvae, pupae and adults from pastures 5 years or older in both this project from 2012 and the aligned SFF project that commenced 3 years earlier. From 2009, 2 years after the black beetle outbreak began (Thom *et al.* 2013), black beetle abundance had declined in Bay of Plenty and Waikato (Fig. 1). The pattern of decline fits well with the model developed by King *et al.* (1981b) based on adult maturation. The percentage of the black beetle population that were adults in February was directly related to the growing degree days above 15°C from the previous September to December. For example, for Waikato populations, using Ruakura meteorological data: $y = 0.21x - 4.15$; $R^2 = 0.82$; $P < 0.01$. The large proportion of beetles that were at the larval stage in February 2010 (Figure 1) indicated population development had been retarded. Therefore the subsequent adult population had limited time to build up fat reserves before winter, which in turn would have impaired survival and fecundity, and thus recruitment into the following generation.

Unlike the steady decline in black beetle populations since 2010 seen in the Waikato region, a sharp and persistent decrease was observed in the Bay of Plenty region (Figure 1). This was associated with flooding on the trial sites. Black beetle has reduced survival in saturated soils (King *et al.*1981c) and there was double normal rainfall in August 2010 (NIWA 2010) and a wetter than average summer 2010/2011 (NIWA 2011) in this region. For example, Whakatane recorded 928 mm rainfall from 1 May to 31 August 2010, and 468 mm from 1 December 31 to January 2011, compared with 555 mm and 320 mm at Ruakura over the same periods.

Influence of La Niña events

Given the sensitivity of black beetle populations to temperature and moisture, it is not surprising that black beetle outbreaks may be aligned with La Niña weather patterns which, on average, bring warmer than normal temperatures over the northern North Island in spring and autumn, along with increased rainfall in summer and autumn in Northland and Bay of Plenty (Kidson & Renwick 2002). These conditions lead to increased pasture growth and, provided soils are not saturated, beetle populations build up in the summer and autumn seasons. In contrast, El Niño years bring cooler temperatures to the North Island from autumn to spring along with decreased rainfall in summer and winter (Kidson & Renwick 2002). Droughts can occur during both El Niño and La Niña events. However, as the larvae are drought-tolerant and thrive on C_4 grasses, a drought during a La Niña summer promotes population growth and accentuates larval damage. A measure of ENSO (El Niño and La Niña events) is the Southern Oscillation Index (SOI), which is based on the difference in atmospheric pressure at sea level between Tahiti and Darwin. ENSO events begin to establish around May, are typically strongest during the southern summer and last for one or more years. The four major outbreaks of black beetle resulting in widespread black beetle damage occurred during La Niña conditions. The largest outbreak began in the summer of 1970/1971 and continued for six summers (Blank & Olson 1988; King *et al.* 1981b). La Niña events occurred in all years except for the summer 1972/73 when there was an El Niño year. Similar outbreaks associated with high La Niña events are seen with the brown locust *Locusta napardalina* (Walker) in South Africa (Todd *et al.* 2002).

Figure 2 shows the average yearly SOI (May to April, i.e., centred on summer) versus the classification of the scale of each black beetle outbreak. The majority of years with a reported black beetle outbreak corresponded to a positive yearly average SOI, whereas years where there was no reported outbreaks contained both positive and negative SOI. There is evidence that average yearly SOI (May to April) differs significantly among the four classifications of beetle outbreaks (ANOVA for comparing mean yearly SOI for each of the four classification, F-stat 9.3, df 3, 72 and $P < 0.001$), with the average yearly SOI for the years classified as mass outbreaks being higher than the yearly average SOI for years with no reported outbreaks. It is estimated that the average yearly SOI is between 0.5 and 1.5 higher for years where there was mass outbreaks recorded compared to years when no outbreaks were recorded. While groupings of mass outbreaks appeared to be associated with long or closely clustered La Niña events, there was no evidence of an increase of outbreak intensity with time in this analysis.

Past records of ENSO events gleaned from kauri tree ring records suggest that from the 13th century to present ENSO is becoming more active (Fowler *et al.* 2012). With climate change projections indicating New Zealand's climate will become warmer and is likely to be dominated by more active ENSO, hence more La Niña and El Niño years (Fowler *et al.* 2012), black beetle outbreaks may become more frequent and intensify, especially as the beetle's distribution extends into new areas as climate warms.

In conclusion, La Niña weather patterns are significantly associated with the likelihood of black beetle outbreaks. An increase in ENSO events is predicted as a result of climate change, which increases the likelihood of black beetle outbreaks. Therefore the need to implement management strategies to cope with black beetle outbreaks may be able to be predicted from global weather patterns. However, local conditions on farm are likely to determine the rate of change in populations. These include soil type, pasture species, endophyte selection, soil moisture levels and drainage.

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