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Abstract

small earthen cells. The adults emerge during spring and live for up to a month, feeding on a wide range of host plant leaves and fruits, including those of apple trees (Lysaght 1930; Miller 1971; Rogers et al. 2006). Bronze beetle was a major orchard pest during the early 20th century (Miller 1926), but became rare after the introduction of organo-chlorine and other broad spectrum insecticides in fruit production (Clearwater & Richards 1984).

Bronze beetle damage has been shown to vary greatly between and within organic apple orchards in Hawke's Bay. This variation was not attributable to orchard management practices or site physical characteristics, and the population variations remained fairly consistent over 2 years of observation (Rogers et al. 2006, 2007). This suggests some other ecological factor may be influencing bronze beetle populations in different orchards. The aim of this research was to investigate whether soil invertebrate community structure in organic apple orchards correlated to different bronze beetle population densities.

MATERIALS AND METHODS

Study sites

Eight certified organic orchards containing blocks of 'Royal Gala' apples in Hawke's Bay were selected. Among these, four orchards had a history of high bronze beetle damage (will be referred to as "High bronze beetle orchards" from hereon) and the other four orchards had a history of low damage (will be referred to as "Low bronze beetle orchards"). The beetle damage histories were established through previous studies by Rogers et al. (2006, 2007) and by talking to orchard owners.

Soil sampling

Five soil samples per orchard were collected once a month for 4 months, starting from October 2007 to January 2008. Soil samples (18 × 18 cm, 14 cm deep) were obtained by digging with a spade beneath a branch within a 1 m radius from the five randomly selected apple tree trunks (Rogers et al. 2007). The samples were transferred to the lab in clear plastic bags and stored at 4°C until processed for macro-invertebrates.

All soil samples were hand-sorted and macro-invertebrates found were counted, identified to species/genus/family level and stored in 70% ethanol.

Pitfall trap sampling

Pitfall traps were set up beneath the tree line within a 1 m radius from the trunk of five randomly selected trees during October 2007. The pitfall traps comprised a small plastic cup (250 ml capacity) inserted into a PVC pipe (8.0 cm diameter) sunken into the soil and flush with the soil surface level. A corrugated iron lid was placed on top to protect the trap from rainwater flooding, allowing a gap for crawling invertebrates. The trap was half-filled with Polyethylene Glycol (PGPLUS Concentrate – Fleetguard, Australia) to preserve invertebrates (Minor & Robertson 2006). The traps were permanently positioned for the entire sampling period.

Captured invertebrates were retrieved from all traps once a month for 4 months from November 2007 to February 2008. A small quantity of 70% ethanol was added to each sample once brought to the lab. The samples were then stored at room temperature until processed. All macro-invertebrates collected were counted and identified to species/genus/ family level.

Statistical analysis

All macro-invertebrates were grouped into three main trophic groups based on their feeding habits (herbivores, detritivores and predators) for data analysis according to the following references (Petersen & Luxton 19(0( )]TJT*a49(1)]TJD17(o)
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datasets; χ^2 and P-values from type3 likelihood ratio analysis were used to compare the effects.

RESULTS

Both the sub-soil and surface-dwelling macro-invertebrate samples obtained by soil sampling and pitfall trapping, respectively, were numerically dominated by detritivores. Herbivores were the second largest group found in the sub-soil, whereas predators were second largest group in the surface-dwelling macro-invertebrate community.

Bronze beetles

The density of bronze beetles (cumulative total of larvae, pupae and adults) in soil samples varied

DISCUSSION

Table 1 Sub-soil macro-invertebrates (mean number/m^2) in orchards with a history of high and low bronze beetle damage.

Previous	Predators				Bronze beetle				Other herbivores				Detritivores			
history	Oct	Nov	Dec	Jan	Oct	Nov	Dec	Jan	Oct	Nov	Dec	Jan	Oct	Nov	Dec	Jan
High bronze beetle	274.7	106.5	185.2	120.4	592.6	265.4	34.0	12.3	561.7	402.8	188.3	216.0	899.7	409.0	696.0	478.4
Low bronze beetle	142.0	66.4	29.3	37.0	66.4	24.7	4.6	1.5	242.3	189.8	104.9	57.1	935.2	429.0	521.6	273.1
χ^2 value	27.88	6.09	81.8	30.1	313.0	151.18	16.31	6.2	84.56	50.72	15.56	63.88	0.44	0.31	16.24	36.79
P-value	<.0001	.014	<.0001	<.0001	<.0001	<.0001	<.0001	.013	<.0001	<.0001	<.0001	<.0001	.505	.577	<.0001	<.0001

Table 2 Surface-dwelling macro-invertebrates (mean number/trap) caught over the preceding month in pitfall traps in orchards with a history of high and low bronze beetle damage.

Previous	Predators				Bronze beetle				Other herbivores				Detritivores			
history	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb
High bronze beetle	23.79	35.35	66.60	35.45	0	0.95	0.1	0	4.1	3.15	2.55	1.85	83.79	56.6	137.35	71.15
Low bronze beetle	40.75	44.85	84.68	45.55	0	0.15	0	0	4.6	3.25	2.84	1.80	114.75	97.85	221.37	125.4
χ^2 value	87.69	22.56	42.27	25.25		12.97			0.51	0.03	0.31	0.01	94.34	223.04	387.85	303.4
P-value	<.0001	<.0001	<.0001	<.0001		.0003			.46	.86	.58	.91	<.0001	<.0001	<.0001	<.0001

Table 3 Abundance of different surface-dwelling generalist predator taxa (mean total number/trap) in orchards with a history of high and low bronze beetle damage.

month of January are responsible for containing the population growth of bronze beetle populations in Low BB orchards needs more research. Observation of specific predation by spiders on bronze beetles emerging from the ground is needed to add support this hypothesis. The current findings could not explain conclusively why some orchards have more spiders than others.

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