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Colorado potato beetle response to soil amendments: A case in support of the mineral balance hypothesis?

Andrei Alyokhin [a,*], Gregory Porter [b], Eleanor Groden [a], Francis Drummond [a]

[a] Department of Biological Sciences, University of Maine, 5722 Deering Hall, Orono, ME 04469, USA
[b] Department of Plant, Soil, and Environmental Sciences, University of Maine, 5722 Deering Hall, Orono, ME 04469, USA

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Abstract

The mineral balance hypothesis [Phelan, L.P., Norris, K.H., Mason, J.F., 1996. Soil management history and host preference by *Ostrinia nubilalis*: evidence for plant mineral balance mediating insect–plant interactions. Environ. Entomol. 25, 1329–1336] suggests that the organic matter and microbial activity associated with organically managed soils afford a buffering capability to maintain nutrient balance in plants. An optimal nutrient balance, in turn, results in both good plant growth and resistance to herbivory. Effects of soil amendment practices on Colorado potato beetle populations in potato fields and their interactions with crop rotation and two pest management approaches were investigated in the present study. Beetle densities were generally lower in plots receiving manure soil amendments in combination with reduced amounts of synthetic fertilizers compared to plots receiving full rates of synthetic fertilizers, but no manure. Crop rotation and pest management approaches had little or no effect. Unlike beetle abundance, plant height and canopy cover were comparable between plots receiving manure and synthetic fertilizer. Furthermore, tuber yields were higher in manure-amended plots. In direct accordance with the mineral balance hypothesis, there was a dramatic dissimilarity in mineral composition of potato leaves collected from manure-amended and synthetic fertilizer-treated plots. Overall, there were differences in concentrations of nitrogen, calcium, magnesium, phosphorus, aluminum, boron, copper, iron, manganese, and zinc. Boron concentration was most dramatically affected by the soil amendment. Mineral content of potato leaves explained 40–57% of the variation in the Colorado potato beetle populations observed among the experimental plots.

Keywords: Mineral balance; Plant nutrients; Soil fertilization; Manure; Insect herbivory; Colorado potato beetle; Sustainable agriculture

1. Introduction

One of the foundations of organic farming is an assumption that the organic production systems create a generally unfavorable environment for pest populations (Oelhaf, 1978; Beanland et al., 2003). Indeed,

* Corresponding author. Tel.: +1 207 581 2977; fax: +1 207 581 2969.
E-mail address: andrei.alyokhin@umit.maine.edu (A. Alyokhin).

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insect populations are often comparable between organic and conventional fields, even though organically certified insecticides are usually less effective than their conventional counterparts (Feber et al., 1997; Gallandt et al., 1998; Letourneau and Goldstein, 2001; Delate et al., 2003). Furthermore, plants grown on organically managed soils fertilized with manure and compost have been shown to be less favorable hosts for phytophagous insects than plants grown on conventionally managed soils fertilized with synthetic fertilizers (Eigenbrode and Pimentel, 1988; Phelan et al., 1995, 1996).

In an attempt to explain apparent reductions in pest pressure in organic systems, Phelan et al. (1996) and Phelan (1997) formulated the mineral balance hypothesis. This hypothesis suggests that the organic matter and microbial activity associated with organically managed soils afford a buffering capability to maintain nutrient balance in plants. An optimal nutrient balance results in both good plant growth and resistance to herbivory. In contrast, crops growing in soils without these biologically based buffering capabilities are more likely to take up either excess or insufficient levels of certain nutrients. In some instances, resulting imbalance in the ratio of certain mineral nutrients may result in rapid plant growth. However, affected plants may have their primary and/or secondary metabolism impaired, thus compromising their ability to resist or tolerate insect damage. A number of experimental studies (Clancy et al., 1988; Clancy, 1992; Clancy and King, 1993; Phelan et al., 1996; Busch and Phelan, 1999; Beanland et al., 2003) provided empirical support to the formulated hypothesis.

Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is the most important insect defoliator of potatoes (Weber and Ferro, 1994). None of the control techniques developed against this pest during the past 135 years has provided long-term protection of potato crops (Casagrande, 1987), and the beetle continues to be a major threat to potato production. High fecundity, a diverse and flexible life history, and a remarkable ability to develop insecticide resistance make Colorado potato beetle management a challenging task (Weber and Ferro, 1994). If soil management practices decrease beetle pressure, they may provide a valuable addition to the chemically skewed arsenal that is currently used to control this pest.

2. Materials and methods

The study was conducted during the 1999–2003 growing seasons at the Maine Agricultural and Forest Research Station's Aroostook Research Farm in Presque Isle, Maine. The land used for the study had a long history of commercial and research potato production. The soil for the entire site was a gravely, well-drained Caribou loam (fine-loamy, mixed, frigid, Typic Haplorthods) that contained extensive coarse fragments (Porter, 1996; Gallandt et al., 1998).

The site was separated into 96 plots arranged in four statistical blocks. Thirty-two plots were in potato production during each year of the study. The remaining plots were planted to rotation crops as described below. Each plot was 41.0 m long and 14.6 m wide. Potatoes in all plots were planted in late May using a "pick"-type planter at the depth of 5–10 cm. Seed tubers were hand cut into ≈50 g pieces prior to planting. The distance between the rows was 90 cm, and tuber spacing within the rows was 23 cm. Blended fertilizer was applied in a band 5 cm below and 5 cm to the side of the seed pieces at planting. Potatoes were ridged ≈4 weeks after planting.

The study consisted of two experiments, both of which were laid out following a randomized complete block, fully factorial design. Treatments tested in each of the experiments are described in the following sections. The main objective of Experiment 1 was to determine effects of different rotation schedules and their interaction with soil amendments on pest populations and crop development. Crop rotation and soil amendment system were the main factors randomly assigned within each of the four blocks. Pests on all plots in this experiment were managed using a conventional IPM approach.

The main objective of Experiment 2 was to determine effects of different pest management systems and their interaction with soil amendments on pest populations and crop development. Correspondingly, pest management system (conventional IPM or biorational IPM) and the soil amendment system were the main factors. All plots in this experiment were on the integrated rotation schedule. Because of the space constraints, plots designated as conventional IPM plots in the second experiment were the same plots designated as plots on the integrated rotation schedule in the first experiment. There were