Biological Control of Wireworm *(Agriotes lineatus)* damage to potato with *Metarhizium brunneum*

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Abstract The larval stage of *Agriotes lineatus,* wireworm, is a challenging agricultural pest with a broad host range. It is a soil-dwelling arthropod that may live up to 5 years before pupating. Wireworms negatively affect crop yields and render produce un-saleable. Organic production systems have few means of managing this pest and this study explores the use of an entomopathogenic fungus, *Metarhizium brunneum*, as a bio-control. Three treatments - *M. brunneum, M. brunneum* with oats, and a non-treated control - were applied beneath seed potatoes. Damage to the tubers was classified by counting tuber hole abundance (Brandl et al., 2017). No statistically significant treatment effects were observed, but the proportion of potatoes that suffered wireworm damage was 33% lower in the *M. brunneum* and oat treatment than the control treatment and was numerically trending towards significance.

Key words: *Metarhizium*, biocontrol, potato, wireworm, *Agriotes lineatus*, entomopathogenic fungi

Introduction

Pest development of resistance to chemical insecticides is currently a pervasive issue in agriculture and it is paramount to advance alternatives that do not threaten the environment or our future capacity for agriculture. One solution to this issue that will be explored through this study is the use of non-persistent, non-toxic biological controls, often in the form of bacterial, fungal or nematode microbial agents. The pest that our research targets is the wireworm *(Agriotes lineatus),* the larval stage of the click beetle, which has a broad host range including carrots, cucurbits, rutabagas, onions, sweet corn, potatoes, sugar-beets, beans and peas (Chaput, 2000). In regards to potato crops, wireworms will damage the tuber so that it is unsalable and will reduce crop yields (Agriculture and Agri-Food Canada [AAFC], 2010). The organophosphate pesticides that have historically been used to control wireworms are detrimental to the ecosystem, threaten human health and wellbeing, and are unavailable to organic farming operations (AAFC, 2010).

Our research sought to test the efficacy of the fungal agent *Metarhizium brunneum* as a means of reducing damage to potato crops from wireworm populations in Richmond, British Columbia. *M. brunneum* is a entomopathogenic fungus that is found naturally in British Columbian soils and parasitizes wireworms, effectively destroying them. Wireworms are attracted to CO_2 (Source), so decomposing oats were used to attract them to *M. brunneum* in one experimental treatment.

Materials and Methods

This field study took place on the Kwantlen Polytechnic University research and working farm, located at the corner of Gilbert and Dyke roads in Richmond, B.C., during the summer of 2017. The experiment area totaled 200 m^2. A Randomized Complete Block Design was used, with six replicates and three three treatments:

i) MetOat = *Metarhizium brunneum* LRC112 + rolled oats 'MetLRC112 GR-O'

ii) Metarhizium = *M. brunneum* LRC112 'MetLRC112 GR'

iii) Control = Untreated

Seed potatoes (cv. 'Orchestra') were planted into all plots on July 23rd. Seed pieces were spaced 30 cm apart in rows spaced 1 m apart. Each plot was 2 m long and spanned three rows (21 seed pieces per plot). Four grams of *M. brunneum* culture (LRC112, Todd Kabaluk, AAFC) was placed directly under each seed potato in the MetOat and Metarhizium plots. Twenty five grams of rolled oats was blended with the fungus in the MetOat treatment only.

Potatoes were harvested from the center row of each plot on October 13th. Plant count, potato count, total yield, damaged tuber yield, and wireworm damage were record for each plot. Wireworm damage was considered present when tunneling into potato flesh >5 mm. Wireworm damage was assessed using the classification system outlined in Brandl et al (2017) that evaluates the number of holes found in the potato: Class 1 (1-2 holes), Class 2 (3-5 holes), Class 3 (>5 holes), and Class x (no holes).

Data were the analyzed using ANOVA ($p < 0.05$) in R software.

Results

No statistically significant treatment effects were observed, most potatoes suffered some wireworm damage (Figure 1). Although, the proportion of potatoes that suffered wireworm damage was 33% lower in the MetaOat treatment than the Control treatment, and this difference approached statistical significance (*p*=.067) (Figure 1). *M. brunneum* and oats treatment plots tended to produce fewer undamaged potatoes, and more damaged potatoes, than control plots (Figure 2), but results were highly varied.

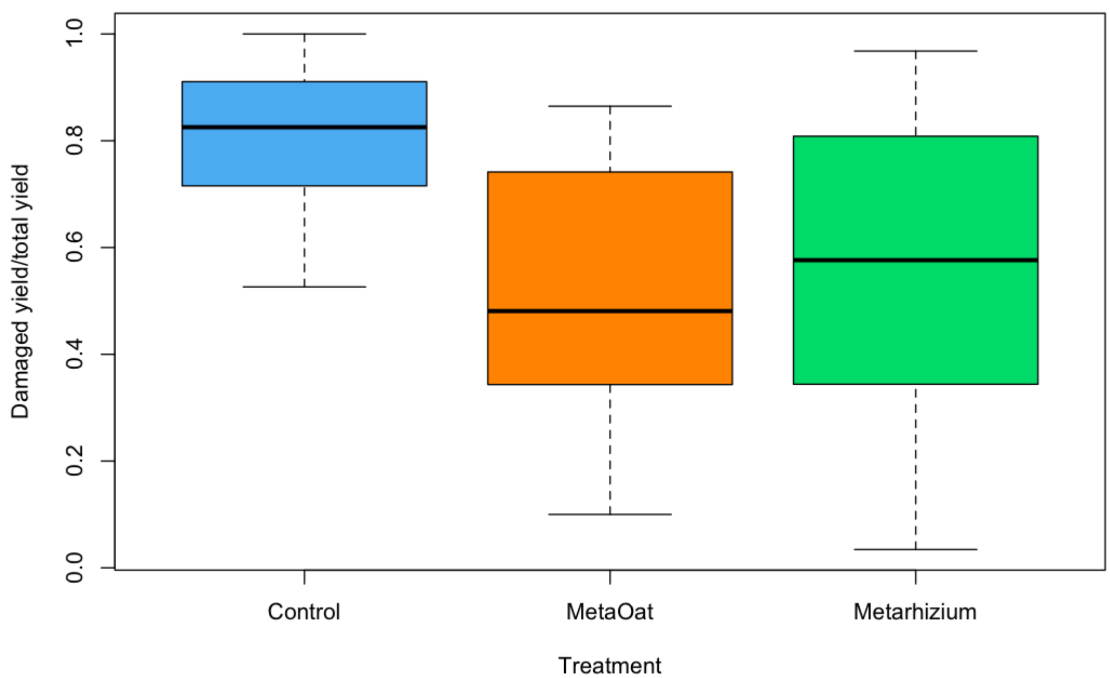

Figure 1. Damaged potato yield/total potato yield for the control, *M. brunneum* and oat (MetaOat), and *M. brunneum* (Metarhizium) treatments . The difference between the control and *M.brunnuem* and oats treatments approached statistical significance (*p*<.1).

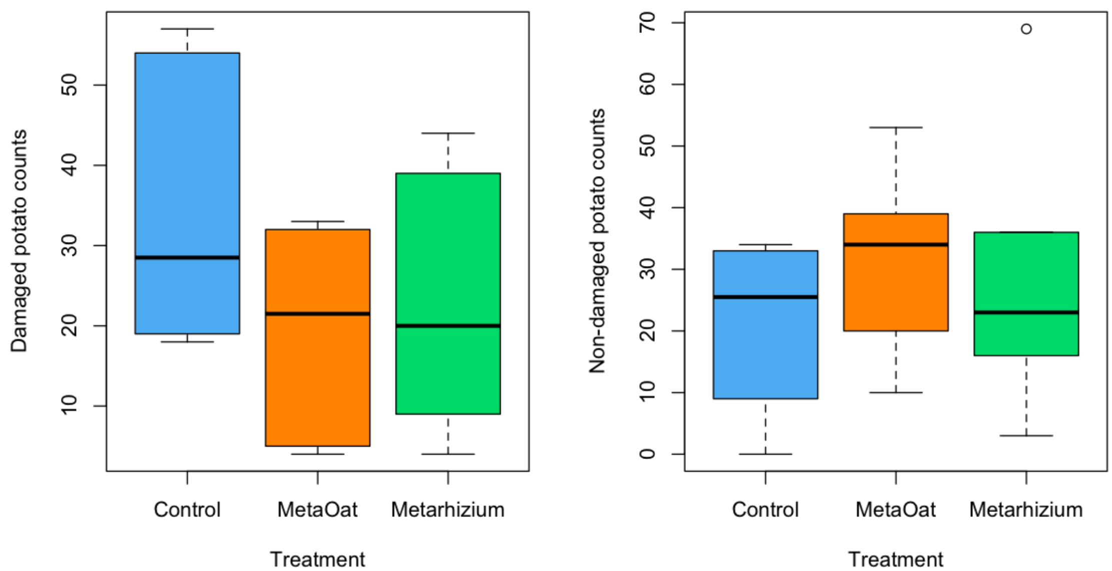

Figure 2. Damaged potato counts (left) and non-damaged potato counts per plot for the control, *M. brunneum* and oat (MetaOat), and *M. brunneum* (Metarhizium) treatments. No significant difference was found between treatments.

Discussion

Wireworms (*A. lineatus)* are well-established agricultural pests that are difficult to control. Andrews et al (2008) provide an amalgamation of historical information relevant to wireworm and a suite of common techniques used in their management including. Interestingly, they mention the lack of information available on the use of biological controls and reference the work carried out in British Columbia by Todd Kabaluk at the time (Andrews, 2008). Since Andrews et al (2008) there have been a few experiments carried out with the interest of testing the efficacy of *Metarhizium* as a method of pest management against *A. lineatus.* In a laboratory setting Ansari et al (2009) found very hates rates of mortality (90-100%) with two strains of *M. anisopliae* against *A. lineatus.* Recent field trials observed significant wireworm mortalities with the application of *M. anisopliae* treated wheat seed, the wheat seed being a CO_2 releasing attractant (Kabaluk et al, 2017). Brandl et al. found evidence of wireworm control by *M. brunneum* at highest rates when applications were placed directly under seed potatoes, influencing our decision to test this method with our treatments. Reddy et al. (2014) found, in field trials on spring wheat, that the most effective method of application of *Metarhizium* for the management of wireworms to be granule treatments. In two separate studies mortality from fungal infection was observed after live wireworm samples were removed and incubated from test plots (Kabaluk, 2017; Brandl et al., 2017). The literature overwhelmingly shows that *Metarhizium* has good potential for wireworm control, the numerical trends in our study support this.

Potato germination was poor throughout the study site. This may have been an effect of the variety we chose to use ("orchestra") seeing as neighboring potato plots that weren't involved in the study but were planted on the same day saw much greater germination. It would be interesting to run a similar trial with a better-suited variety.

Conclusions

No significant treatment effects were detected in this experiment. Numerical trends suggest that M. brunneum and oats may have reduced wireworm damage to potato, but this effect did not achieve significance, due to considerable variability within treatments. The observed trends were consistent with reports from previous studies, in which M. brunneum and oats have reduced damage due to wireworm feeding. Future studies into the use of *M.brunneum* for wireworm control are likely to be able to demonstrate, with statistical significance, the numerical trends observed in our study.

Data

Table 1. Raw data for all treatments (A=*M. brunneum* and oats, B=*M.brunneum*, C=untreated control)

Treat-ment	Rep	Plant Count	Potato Count	Total Weight (lbs)	Damage Weight (lbs)	Class 1	Class 2	Class 3	Class x
A	A	5	46	21.94	18.97	15	7	10	10
C	A	7	65	29.77	27.11	25	11	18	9
A	A	5	42	11.9	7.29	16	6	1	20
C	B	5	69	22.74	16.27	20	6	8	33
C	B	3	19	7.9	7.9	4	1	14	0
B	B	3	17	7.79	7.54	7	3	5	3
C	C	6	76	25.6	20.88	26	16	15	19
B	C	6	59	23.86	19.29	14	14	16	16
C	C	6	57	24.44	12.86	14	6	3	34
A	D	6	24	30.06	10.5	18	1	1	53
B	D	7	94	34.2	11.76	18	3	4	69
C	D	5	54	29.1	24.3	13	4	1	32
B	E	5	63	25.14	18.53	23	5	11	23
A	E	6	73	17.56	13.02	22	3	8	37
B	E	2	32	8.23	3.42	5	4	0	23
B	F	4	43	16.34	0.56	4	0	0	36
A	F	4	44	17.59	1.76	5	0	0	39
A	F	3	37	12.76	4.38	3	0	1	31

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