Farm Innovation Program

Final Reporting Templates

Please note that the Knowledge Transfer Plan and Translation section may require input from both the commodity association and the researcher, if both parties are undertaking knowledge transfer activities.

Farm Innovation Program - Final Report

Please note that the final payment for projects will not be released until a final report has been submitted and accepted by the AAC. Final Reports must be a minimum of two pages and should answer all of the questions outlined below and be **submitted by the completion date of the project and/or no later than December 1st, 2012.**

Applicant Name:	Fresh Vegetable Growers of Ontario
Project Title:	Controlling clubroot on cruciferous vegetables
FIP Project Number:	FIP 1060
Reporting Period:	January 1 2010 to April 30, 2011
Date of Submission:	April 28, 2011
AAC Program Coordinator:	Daryl Vermey

Executive Summary

Executive Summary should be one page maximum and include a brief summary of activities to date, objectives or goals accomplished and highlights of achievements and reach of project to date and/or issues that have affected success of the project to date:

Clubroot of cole crops is caused by *Plasmodiophora brassicae*, a persistent soil borne pathogen that can survive in soil for several years, with some reports suggesting that it can survive for up to 20 years. This is a very destructive disease that is often difficult to control because most control recommendations are not always effective. ALLEGRO is the only registered fungicide available to control clubroot. New resistant lines of Green cabbage, Napa cabbage and broccoli became available in small quantities from seed companies. These cultivars were evaluated in field trials for their reaction to clubroot and were compared to the commercially available varieties. Green cabbage cultivars: Kilaton, Tekila, Kilaxy, Kilaherb, Bronco and Bronco treated with ALLEGRO 500 F (fluazinam 40%) were tested in field trials conducted in organic soils at Muck Crops Research Station (MCRS) and in mineral soils in a grower cooperator field in Orkney, Ontario. Both trial sites had history of Clubroot (*Plasmodiophora brassicae* Woronin) infection with *P. brassicae* pathotype 6. Napa cabbage cultivars: Emiko, Mirako, Yuki and China Gold, and broccoli cultivars: BC 7540 and Diplomat were evaluated at Muck Crops Research Station for their resistance to clubroot, while Shanghai pak choi cv Mei Qing and Napa cabbage cv Mirako were used in the evaluation of the efficacy of several fungicides and biofungicides in controlling clubroot.

All tested Napa cabbage, Green cabbage and broccoli; cultivars were seeded into 128-cell (MCRS)/200-cell (Orkney) plug trays, grown in the greenhouse and hand transplanted into the field. Shanghai pak choi was hand-seeded using a peg board with pegs 4 cm apart (25 seed/m). In both trial sites and on Green and Napa cabbages, the fungicides ALLEGRO and the biofungicides MYCOSTOP, ACTINOVATE, PRESTOP and SERENADE ASO were applied as a drench immediately following transplanting, while on Shanghai pak choi the treatments were applied to the seeds in the open furrow.

Mature heads of green cabbage, Napa cabbage, broccoli and the plant tops of Shanghai pak choi were harvested and weighed for yield assessment. The roots of each crop were washed and rated for clubroot incidence and severity.

Results indicated:

a) Clubroot resistance of the Green cabbage cultivars Kilaton, Tekila, Kilaxy, Kilaherb and a slight reduction of root clubbing of Bronco cabbage treated with ALLEGRO. The fungicide treatment also improved the yield of Bronco cabbage. Total, marketable and weight per cabbage head of cultivars Kilaton, Tekila, Kilaxy, Kilaherb were similar and higher than those of untreated Bronco cabbage.
b) Clubroot resistance of Napa cabbage cultivars Emiko, Yuki and China Gold, and susceptibility of cultivar Mirako. All Napa cabbage cultivars had similar yield (cabbage head weights).
c) Clubroot resistance and high yield of broccoli cultivar BC 7540 and susceptibility of cultivar Diplomat.
d) Efficacy of RANMAN and ALLEGRO in reducing cabbage clubroot incidence and severity of Napa Cabbage.
e) Inefficacy of the biofungicides MYCOSTOP, ACTINOVATE, PRESTOP, SERENADE ASO, and the fungicide, PRESIDIO in controlling clubroot on Napa cabbage.
f) Inefficacy of the fungicides RANMAN, PRESIDIO, ALLEGRO and the biofungicides MYCOSTOP, ACTINOVATE, PRESTOP and SERENADE ASO in controlling clubroot on Shanghai pak choi.
g) Fungicides and biofungicide applications did not improve yield of Shanghai pak choi cv Mei Qing or Napa Cabbage cv Mirako.

Detailed Description of the Project

1. Identify overall project objectives reached:

The overall objective of the proposal was to identify and develop effective controls for clubroot of crucifer crops for Ontario vegetable growers by:

1. Testing new cultivars of Green cabbage, Napa cabbage and broccoli that have resistance to clubroot.

2. Evaluating new products and identifying effective materials for the control of clubroot of crucifers. These products include new reduced risk fungicides and biofungicides. Comparing the efficacy of the fungicides and biofungicides to resistant cultivars and the registered fungicide ALLEGRO (fluazinam).

3. Providing data on effective control measures to support registration and make recommendations about resistant cultivars.

All objectives have been completed.

2. Identify <u>all activities</u> undertaken to reach the project objectives (link these activities to the Milestone Performance as per Schedule "B" Part III of the Agreement):

Milestone 1: Establish and maintain clubroot plots at Muck Station and Simcoe, spring and summer 2010

Muck Crops Research Station:

a) ***Green Cabbage trial***. On 5 May, green cabbage cultivars Kilaton, Kilaxy, Tekila, and Kilaherb were seeded into 128-cell plug trays and grown in the greenhouse. On 8 June plants were hand-transplanted into two 7.5 m rows 86 cm apart with 45 cm in-row spacing. A randomized complete block design with four replicates per treatment was used. ALLEGRO fungicide at 50 mL/100L was applied as a drench at the rate of 100 mL per plant immediately following transplanting (8 June) to green cabbage cultivar Bronco as a commercial standard treatment. Mature cabbage heads were harvested on 11 (Tekila and Kilaherb) and 24 (Bronco, Kilaton and Kilaxy) of August and weighed for yield assessment.

b) ***Napa Cabbage trial***. On 6 May, Napa cabbage cultivars Emiko, Mirako, Yuki, and China Gold were seeded into 128-cell plug trays and grown in the greenhouse. On 8 June plants were hand-transplanted into three 7.5 m rows, 55 cm apart with 30 cm in-row spacing. A randomized complete block design with four replicates per treatment was used. Mature heads were harvested on 15 July and weighed for yield assessment.

c) ***Broccoli trial***. On 11 May broccoli cultivars BC 7540 and Diplomat were seeded into 128-cell plug trays and grown in the greenhouse, and hand–transplanted on 8 June into three 7.5 m rows, 55 cm apart with 30 cm in-row spacing. Mature heads were harvested on 5 August and weighed for yield assessment.

d) ***Efficacy of biofungicides and fungicides for reduction of clubroot incidence and severity on Napa Cabbage trial.*** Napa cabbage cv. Mirako was seeded on 21 May into 128-cell plastomer plug trays and hand-transplanted on 17 June into three rows 5 m long and 30 cm apart. There were three plants per meter. A randomized complete block design with four replicates per treatment was used. Treatments were applied as a drench application to the seedlings at the time of transplanting. The eight treatments were: four biofungicides, three fungicides and one non-treated control. The biofungicides, PRESTOP at 10 g/L, SERENADE ASO at 40 mL/L, ACTINOVATE at 0.6 g/L and MYCOSTOP at 0.5 g/L were applied in solution at the rate of 100 mL/plant. The fungicides PRESIDIO at 9 mL/100 L, ALLEGRO at 50 mL/100 L and RANMAN at 30 mL/100 L were also applied in solution at the rate of 100 mL/plant. On 26 July all the heads from each replicate plot were harvested and assessed for yield.

e) ***Evaluation of biofungicides and fungicides for clubroot control on Shanghai Pak Choi tria*l.** On 25 June Shanghai pak choi, cv. Mei Qing, was hand-seeded using a peg board with pegs 4 cm apart (25 seed/m). A randomized complete block design with four replicates was used. Each experimental unit consisted of four rows 5 m in length, 40 cm apart (25,000 linear m/ha). Fungicide treatments were: ALLEGRO at 2.9 L/ha and RANMAN at 1.85 L/ha. The biofunigicide treatments were: ACTINOVATE at 3.6 kg/ha, MYCOSTOP 0.05% suspension, PRESIDIO at 560 mL/ha, PRESTOP 1% solution, and SERENADE ASO at 50 L/ha. A water check was also included. All treatments were applied as a drench application to the seeds in the open furrow at the rate of 50 mL/m using a CO_2 backpak sprayer equipped with a single TeeJet 11004 nozzle except MYCOSTOP which was applied at the rate of 200 mL/m by hand using a beaker. The furrows were then closed with a rake. On 5 August, plants from two 1 m sections were dug and the tops were weighed for yield assessment.

Orkney - Grower cooperator field:

Green Cabbage trial. Cabbage cvs Bronco, Kilaxy, Kilaherb, Kilaton, and Tekila were seeded on 21 May into 200 cell plastic plug trays filled with a commercial soil-less mix. Seedlings were raised in a greenhouse under ambient light and temperature conditions and were transplanted by hand into the field on 29 June. Soil type was a clay loam. Crop nutrition, weeds, insects and diseases were managed according to recommended commercial practices. There were six treatments: the susceptible and untreated cultivar Bronco, Bronco treated with the fungicide ALLEGRO 500 F, and the resistant cultivars, Kilaton, Kilaxy, Kilaherb, and Tekila. For the Bronco + ALLEGRO treatment, the fungicide was applied immediately after transplanting as a drench at a rate of 50 mL in 100L water with 100 mL of solution applied per plant. Treatments were arranged in a randomized complete block design with four replications. Each replicate consisted of one row 8.6 m in length. Rows were spaced 81 cm apart with the plants within the row spaced 43 cm apart.

Prior to planting 225kg/ha 11-52-0, 169kg/ha 0-0-60, 56kg/ha 34-0-0 and 11kg/ha 10% Boron were broadcast and incorporated. An additional 309kg/ha 43-0-0 was broadcast and incorporated on 10 days after planting. A 6.9 m section of each plot of treated and non treated Bronco, Kilaherb and Tekila was harvested on 22 September and Kilaton and Kilaxy were harvested on 21 October. On each harvest date before harvesting, cultivars were evaluated for varietal characteristics such as: stock uniformity, length of stalk, growth habit, head protection and savoying of leaf. Cabbage heads were weighed and graded into marketable and unmarketable categories. Five randomly selected marketable cabbage heads were evaluated for the following head characteristics: head shape, external color, internal color, core size and internal breakdown.

Milestone 2: Disease assessment

At both sites and for all trials, roots of all harvested plants were dug, washed and weighed (Orkney green cabbage trial) and examined for club root incidence and severity. Clubroot incidence was determined as the percent of plants with clubbed roots and clubroot severity was assessed using a rating scale of 0 to 3, where: 0= no root clubbing, 1= <1/3 of root clubbing, 2= 1/3 to 2/3 of root clubbing and 3= > 2/3 of root clubbing. Clubroot severity ratings were used to calculate the disease severity index (DSI) using the following equation:

DSI= ———————————

Milestone 3: Statistical analysis and report preparation

For all trials data were analyzed using the General Linear Model procedure of SAS ver. 9.2. Means separation was obtained using Tukey's Standardized Range (HSD) Test.at *P*= 0.05 level of significance.

Milestone 4: Technology transfer

Oral presentations of the of these trials were presented at Ontario Fresh vegetable growers national meeting on 16 December, 2011, the Ontario Processing Vegetable Growers 67th Annual meeting on 25 January, 2011 and at the Ontario Fruit and Vegetable Growers convention on 23 February, 2011 and at the Annual Muck Vegetable Growers Conference, March 30 & 31. A poster was prepared and presented at the Ontario Fruit and Vegetable Grower's convention, February 23 and 24

Milestone 5: Final report

A final report was submitted to the Fresh Vegetable Growers on 2 December 2010. Articles for grower publications: The Hort Matters and Ontario Fruit and Vegetable Magazine will be written and published in 2011.

3. Identify the outputs created as a result of the activities undertaken (if materials are produced, a sample should be included in the report):

See Appendix A for results of the research trials.

4. Explain changes or issues affecting completion of activities:

Although the proposed objectives of this project were all completed, there were minor changes in the implementation of the project activities and research protocol. Cauliflower, Polyversum and Sylgard were not evaluated due to lack of cauliflower variety seed and unavailability of the chemicals. Instead, Presidio (39.5% fluopicolide) a new product in the registration process in Canada was used . (Presidio has been registered in Canada for several crops including brassicae, but mostly for Downy mildew and Phytophthora)

5. Identify the project inputs used to complete the activities and during the course of the project (include: farmer(s) involved, funding level, financial contributions, staff resources, other resources, etc.). If you did not access all of the FIP funding, or If your actual budget is different from the approved budget, please explain why and outline the reason(s) for those variances. All categories that are over/under budget should be discussed:

Two staff members, one graduate student and 2 summer students were involved in this project. All FIP funding has been utilized. A full accounting of the project's financial status will be sent by the University of Guelph – Office of Research.

Benefits & Impact

6. Compare final project results with the expected short term results and explain any differences:

Short term results expected were:

a) Information on the resistance of Green cabbage, broccoli and Napa cabbage cultivars.
b) Information on the relative benefit of using a susceptible cultivar plus ALLEGRO, RANMAN and PRESIDIO.
c) Information on the performance of the fungicides and biofungicides in controlling cabbage clubroot on Napa cabbage and Shanghai pak choi.

Results of this project are consistent with the expected short term results.

7. Explain if the final project results are satisfactory:

Final project results were satisfactory. Resistant cultivars of Green cabbage (organic and mineral soils), Napa cabbage and broccoli (organic soils) were tested were either clubroot free or clubroot root infection was very low. The resistant cultivars also had better yield than the untreated commercial standard Bronco. However, treatments of the susceptible cv Bronco with ALLEGRO fungicide slightly reduced club root incidence and severity and improved yields of Bronco Green cabbage on mineral soils. Fungicides and biofungicides were evaluated but they were not efficient in reducing clubroot of Green, Napa and Shangai pak choi in the trials conducted on organic soils at the Muck crops Research Station.

8. Identify the public good/benefit of the project to date:

The project will contribute to a competitive vegetable sector by providing new, effective and economical solutions to managing clubroot and ensuring consistent yields and high quality produce. The innovative on-farm technology is resistant cultivars, which will control the disease with low cost. Where the resistant varieties are not available or suitable for the specific market, a single drench application of the fungicides ALLEGRO and or RANMAN soon after transplanting can be used to protect yield and increase quality. The information on green cabbage resistant cultivars from this research was generated from experiments conducted in two different regions and different soil types in Ontario, therefore, this information will be relevant to a wide range of growers. Although the resistant cultivars are new to Ontario, they appear (particularly Green cabbage) to have agronomic characteristics similar to those of the traditional and susceptible green cabbage cultivars Bronco, Napa Cabbage Mirako and the broccoli cultivar Diplomat.

9. Explain how many on farm technologies the project has assessed:

N/A

10. Explain how the project success will be measured in the long-term (include the indicators outlined in Schedule "B" of the Agreement):

Long term results are further development of resistant cultivars of Green cabbage, Napa cabbage and Broccoli for Ontario and long term stability of the resistant vegetable lines. Where the resistant cultivars are not available, applications of the fungicide (s) ALLEGRO and RANMAN (if registered these crops) may help reduce clubroot severity and eventually reduce crop losses due to clubroot.

11. If applicable, indicate how this initiative will be economically viable and self-sustaining from this point forward. Explain what the next steps are for this initiative:

N/A

12. Indicate the current actual financial impact to farmers who may adopt the technology versus the estimated impact (see question '6.e.' in the application):

The project will result in consistent yield and quality of cole crops. Farm gate value of cabbage in Ontario in 2010 was estimated at $16.642.000, 00 so the potential financial impact of clubroot disease free or less susceptible crops is considerable. Where resistant lines are acceptable, this will reduce the cost per acre to the grower, since no fungicide will have to be applied. Where fungicides are used, ALLEGRO fungicide can be used to improve green cabbage yields when resistant cultivars are not available and the grower will have higher income, since there will be less crop loss to clubroot.

13. Indicate the target audience and the total number of people reached by this project:

Results of this project will be of use to growers, agri-business and government personnel. A conservative estimate would be around 400-500 people. (400 producers of cruciferous in Ontario)

Knowledge Transfer Plan & Translation

14. Indicate how information has been communicated with industry for the duration of the project (refer to the plan developed as part of question 7 in the final funding application):

Information Requested	Commodity Association Activities	Researcher Activities
Indicate the type and number of communication materials that were developed (i.e. brochure, display, CD/DVD, poster, website, handbook, etc.) and how they were distributed:		- A poster will be presented at the OFVC in February 2011 (800 participants) - Results will be posted on the FVGO website - Results will be posted on the University of Guelph website - A copy of the report has been submitted to the seed companies
Indicate the number of presentations that were made and the total audience reached:		- 16 December 2010, FVGO annual meeting, estimated audience of 50 people, - Muck Crops Conference, estimate audience: 100 people - Ontario Fruit and Vegetable Growers convention, 23 &24 February, 2011. Estimated audience 200 people

Indicate the number of scientific and popular press articles that were developed and how they were distributed:		- A manuscript for Canadian Journal of Plant Sciences is being prepared. - Two popular press articles will be submitted for publication in 1) The Grower and 2) Ontario Fruit and Vegetable Magazine in 2011
Identify any other communication activities, including but not limited to internet publications, advertising, billboards, radio and television broadcasts:		The results of this study will be posted on the website of the Fresh Vegetable Growers and have been published in the Annual Report of the Muck Crops Research Station, which is also published on the web and there will be a television and web broadcast through the SPARK program at the University of Guelph
Indicate if any project materials have been made available for use in the French language:		The results from the project can be made available in French language if requested.

15. Indicate when AAFC/OMAFRA/AAC were identified as a supporter throughout the period of the project:

AAFC, OMAFRA and AAC were identified as supporters on all written material.

Conclusion & Final Comments

16. Provide a discussion of lessons learned, recommendations and overall perception of project success:

In overall the project was successful. Clubroot resistant cultivars were evaluated and a considerable number of cultivars of Green and Napa cabbage and one broccoli cultivar were resistant to clubroot. These results can be used immediately by growers as the disease management method at low coast.

The agronomic characteristics of the green cabbage resistant cultivars were evaluated at one trial site, other physiological characteristics such as storability and growth cycle need further investigation. In fact the differences observed in green cabbage yields were more likely due to differences in growth cycle of each cultivar rather than to genomic/varietal characteristic.

The nature of clubroot resistance gene incorporated in the resistant cultivars tested does not allow a durable and non-specific resistance to all *P. brassicae* pathotypes, and because other pathotypes different from pathotype 6 may occur in fields, it will be important to monitor these new varieties for clubroot resistance durability.

Treating the susceptible green cabbage Bronco with the fungicide ALLEGRO improved yields at one mineral soil site. Having a trial set and run in a growers' field was a very important and positive experience.

Unfortunately, the evaluated fungicides and biofungicides were not effective in reducing clubroot incidence and severity and improving yield of Shangai pak choi cv Mei Qing, but treatments of Napa cabbage with RANMAN reduced clubroot incidence and severity.

Media Coverage – *If possible please provide a copy of the media coverage for our files*				
Date	**Source**	**Title**	**Reach**	**FIP Recognition (Yes/No)**

(Add additional rows if needed)

APPENDIX A: Results and Discussion

MUCK CROPS RESEARCH STATION TRIALS (Organic soils)

1. Napa cabbage, Green cabbage and Broccoli trials

Clubroot incidence and severity was high in the susceptible cultivars in this trial. Significant differences were found among cultivars of Napa cabbage in susceptibility to clubroot. The three resistant Napa cabbage cultivars, Yuki, China Gold and Emiko, had significantly less clubroot and lower disease severity than Mirako, the susceptible cultivar. Cultivars China Gold and Emiko had no incidence of disease. No differences were found in harvest weights among the Napa cultivars (Table1).

Among the green cabbage cultivars, significant differences were found in disease incidence, disease severity and yield. The four clubroot resistant cultivars, Kilaton, Tekila, Kilaxy and Kilaherb had significantly lower clubroot incidence and severity than Bronco, the susceptible check or Bronco + ALLEGRO transplant drench. Cultivars Kilaxy and Kilaton had no disease and other resistant cultivars (Kilaton and Tekila) had ≤ 1% disease. There were no significant differences in disease incidence or severity between Bronco untreated and Bronco treated with the ALLEGRO transplant drench. Differences in harvest weight were also observed among the cultivars. All the resistant cultivars had significantly higher weights per head than Bronco, but there were no significant differences between the resistant cultivar Kilaxy and Bronco untreated or treated with ALLEGRO (Table 2).

Significant differences in clubroot incidence and severity were found between the susceptible (Diplomat) and resistant (BC 7540) broccoli cultivars. Broccoli cultivar BC 7540 had significantly lower clubroot incidence and severity index compared to Diplomat. Weight per head was significantly higher for BC 7540 compared to Diplomat (Table 3). All resistant cultivars tested had high levels of resistance to clubroot.

Table 1. Comparison of various Napa cultivars for susceptibility to clubroot, grown in soil naturally infested with the clubroot pathogen at the Muck Crops Research Station, Ontario, 2010.

Cultivar	Clubroot Incidence (%)	DSI[1]	Weight/Head[2] (kg)
Emiko	0.0 a[3]	0.0 a	1.7 ns[3]
China Gold	0.0 a	0.0 a	1.4
Yuki	1.0 a	1.0 a	1.6
Mirako	98.0 b	82.8 b	1.7

[1] Disease severity index (DSI) was determined using the following equation:

$$DSI = \frac{\sum [(\text{class no.})(\text{no. of plants in each class})]}{(\text{total no. plants per sample})(\text{no. classes} - 1)} \times 100$$

[2] Average of 24 heads

[3] Numbers in a column followed by the same letter are not significantly different at $P = 0.05$, Tukey's Standardized Range (HSD) Test.

Table 2. Comparison of various green cabbage cultivars for susceptibility to clubroot, grown in soil naturally infested with the clubroot pathogen at the Muck Crops Research Station, Holland Marsh, Ontario, 2010.

Cultivar	Clubroot Incidence (%)	DSI[1]	Weight/Head[2] (kg)
Kilaxy	0.0 a[3]	0.0 a	1.7 abc
Kilaherb	0.0 a	0.0 a	2.0 ab
Kilaton	0.8 a	0.8 a	2.3 a
Tekila	1.3 a	1.3 a	2.1 ab
Bronco + ALLEGRO	100.0 b	97.6 b	1.2 bc
Bronco	100.0 b	98.1 b	1.0 c

[1] Disease severity index (DSI) was determined using the following equation:

$$DSI = \frac{\sum [(\text{class no.})(\text{no. of plants in each class})]}{(\text{total no. plants per sample})(\text{no. classes} - 1)} \times 100$$

[2] Average of 20 heads.
[3] Numbers in a column followed by the same letter are not significantly different at $P = 0.05$, Tukey's Standardized Range (HSD) Test.

Table 3. Comparison of two broccoli cultivars for susceptibility to clubroot grown, in soil naturally infested with the clubroot pathogen at the Muck Crops Research Station, Ontario, 2010.

Cultivar	Clubroot Incidence (%)	DSI[1]	Weight/Head[2] (g)
BC 7540	29.1 a[3]	9.7 a	322.9 a
Diplomat	100.0 b	93.3 b	84.7 b

[1] Disease severity index (DSI) was determined using the following equation:

$$DSI = \frac{\sum [(\text{class no.})(\text{no. of plants in each class})]}{(\text{total no. plants per sample})(\text{no. classes} - 1)} \times 100$$

[2] Average of 30 heads.
[3] Numbers in a column followed by the same letter are not significantly different at $P = 0.05$, Tukey's Standardized Range (HSD) Test.

2. Efficacy of biofungicides and fungicides for reduction of clubroot incidence and severity on Napa Cabbage trial

None of the treatments reduced the incidence of clubroot as compared to the untreated check. Napa cabbage treated with RANMAN had lower clubroot severity than Napa treated with any of the biofungicides, PRESIDIO and the untreated check. The biofungicides were not effective in reducing clubroot incidence or severity and all had clubroot incidence higher than plants treated with RANMAN. The fungicide PRESIDIO did not reduce clubroot incidence or severity. There were no differences in yield among the treatments Table 4.

Table 4. Evaluation of biofungicides and fungicides for control of clubroot in Napa cabbage, grown at the Muck Crops Research Station, Holland Marsh, Ontario, 2010.

Treatment	Rate	Clubroot Incidence (%)	DSI[1]	Weight/ Head (kg)
Susceptible check	-	87.0 ab[2]	71.5 ab	1.4 ns[3]
Bio-fungicides				
MYCOSTOP	0.5 g/L	95.0 a	72.7 ab	1.2
ACTINOVATE	0.6 g/L	99.0 a	74.3 ab	1.3
PRESTOP	10 g/L	100.0 a	84.0 a	1.2
SERENADE ASO	40 mL/L	100.0 a	91.0 a	1.1
Fungicides				
RANMAN	30 mL/100L	51.0 b	25.7 c	1.3
ALLEGRO	50 mL/100 L	68.0 ab	35.3 bc	1.4
PRESIDIO	9 mL/100L	95.0 a	71.3 ab	1.1

[1] Disease severity index (DSI) was calculated as:

$$DSI = \frac{\sum [(\text{class no.})(\text{no. of plants in each class})]}{(\text{total no. plants per sample})(\text{no. classes } -1)} \times 100$$

[2] Values in the column followed by same letter are not significantly different at $P = 0.05$, Tukey's test.
[3] Not significant at $P=0.05$

3. Evaluation of biofungicides and fungicides for clubroot control on Shanghai Pak Choi trial

No significant differences in clubroot incidence or severity were found among the treatments. There were no significant differences in pak choi top weights among the treatments (Table 5). The incidence of clubroot was relatively high in this trial, but incidence varied within the plot area, regardless of treatment.

Table 5. Clubroot incidence and severity index (DSI) for Shanghai pak choi, cv. Mei Qing, treated with various biofungicide and fungicide soil drenches at seeding, grown at the Muck Crops Research Station, Holland Marsh, Ontario, 2010.

Treatment	Rate[1]	Clubroot Incidence (%)	DSI[2]	Weight/plant (g)
PRESTOP	1% solution (10 g/L)	72.7 ns	68.3 ns	59.8 ns
MYCOSTOP	0.05% suspension	75.9	58.4	45.3
ALLEGRO	2.9 L/ha	83.9	63.2	43.7
SERENADE ASO	50 L/ha	94.6	75.7	45.7
RANMAN	1.85 L/ha	95.4	73.7	53.3
ACTINOVATE	3.6 kg/ha	95.9	77.4	45.5
PRESIDIO	560 mL/ha	99.2	94.1	63.6
Check	--	96.8	79.7	57.4

[1] Treatments were applied as a seed furrow drench at the rate of 50 mL/m (1,250 L/ha) except for MYCOSTOP which was applied at 200 mL/m (5,000 L/ha). Pak choi row spacing of 40 cm = 25,000 linear m/ha.

[2] Clubroot disease severity index was determined using the following equation:

$$DSI = \frac{\sum [(\text{class no.})(\text{no. of plants in each class})]}{(\text{total no. plants per sample})(\text{no. classes}-1)} \times 100$$

ORKNEY - GROWER COOPERATOR FIELD (MINERAL SOIL)

Clubroot incidence was very high in the Bronco and Bronco treated with ALLEGRO plots (Table 6). There were significant differences in disease severity between the two Bronco treatments, with Bronco treated with ALLEGRO resulting in significant lower disease severity than the untreated Bronco. The resistant cultivars Kilaxy, Kilaton, Kilaherb and Tekila had normal, healthy roots with no clubroot symptoms. Root clubbing resulted in excessive root weights of the clubroot infected cabbages with no significant differences in root mass between the two Bronco treatments. Bronco treated with ALLEGRO had young, fresh and more proliferate roots with smaller clubs than the roots of the untreated Bronco, which had older, decaying clubbed roots. Root mass of the resistant cultivars were significantly lower than the root mass of both Bronco treatments.

There were significant differences in total, marketable yields and weight per head between the resistant cultivars and the susceptible cultivar Bronco (Table 7). Total yield of the resistant cvs and Bronco treated with ALLAGRO were higher than the untreated Bronco. Total yield of cv Kilaxy was similar to that of the untreated and treated Bronco. Marketable yields of the resistant cvs were significantly higher than those of the two Bronco treatments, which had similar marketable yields. The untreated Bronco had the highest percent of small and undeveloped cabbage heads and the lowest percent of marketable cabbage heads. Treating Bronco with ALLEGRO fungicide improved total and marketable yields, resulting in yields that were double the yields of the untreated Bronco (Table 7).

There were significant differences in the percent of marketable and small or undeveloped cabbage heads between the resistant cvs, Bronco treated with ALLEGRO and the untreated Bronco. The untreated Bronco had the lowest percent marketable and the highest percent of small cabbage heads. There were no significant differences in percent stand between treatments (Table 7). Plant and cabbage head characteristics varied among the cultivars (Table 8).

Table 6. Root weights, incidence and severity of clubroot for resistant and susceptible cabbage cultivars grown in soil naturally infected with clubroot at a grower site near Troy, ON 2010.

Treatment	Incidence of clubroot (%)	Disease Severity Index[2]	Root weight (g)
Kilaxy	0 a[1]	0.0 a	101.9 a
Kilaton	0 a	0.0 a	79.7 a
Kilaherb	0 a	0.0 a	53.3 a
Tekila	0 a	0.0 a	47.7 a
Bronco + ALLEGRO	100 b	92.2 b	224.6 b
Bronco	100 b	98.5 c	195.3 b

[1] Numbers in a column followed by a different letter were significantly different at P = 0.05, Tukey's Standardized Range (HSD) Test.

[2]

$$DSI = \frac{\sum [(\text{class no.})(\text{no. of plants in each class})]}{(\text{total no. plants per sample})(\text{no. classes}-1)} \times 100$$

Table 7. Yield of clubroot resistant and susceptible cabbage cultivars grown in soil naturally infected with clubroot at a grower site near Troy ON, 2010.

Treatment	Total yield (t/ha)	Marketable yield (t/ha)	Weight per head (kg)	Percent marketable	Percent small (< 1 kg) or undeveloped	Percent stand
Kilaton	69.4 a[1]	68.7 a	2.6 a	98.9 a	1.1 a	92.2 ns
Kilaherb	69.2 a	68.1 a	2.5 ab	97.8 a	1.6 a	96.9
Tekila	65.4 a	64.5 a	2.3 ab	98.4 a	1.6 a	98.4
Kilaxy	51.2 ab	50.3 a	2.0 ab	98.1 a	1.9 a	87.5
Bronco + ALLEGRO	43.8 ab	38.3 ab	1.5 bc	86.8 a	11.1 a	98.4
Bronco	21.0 b	13.9 b	0.8 c	52.9 b	46.0 b	96.9

[1] Numbers in a column followed by a different letter were significantly different at P = 0.05, Tukey's Standardized Range (HSD) Test.

Table 8. Plant and head characteristics for clubroot resistant and susceptible cabbage cultivars grown in soil naturally infected with clubroot at a grower site near Troy, ON 2010.

Treatment	Stock uniformity[2]	Plant habit[3]	Leaf savoying[4]	Stalk length[5]	External colour[6]	Head protect-tion[7]	Head shape[8]	Inter nal colour[9]	Internal breakdown[10]	Core size[11]
Tekila	4.5 a[1]	1.2 b	1 ns	3.0 ns	2.2 ab	2.7 b	3.6 b	4.0 a	4.9 ns	1.0 c
Kilaherb	4.0 ab	1.2 b	1	3.2	2.2 ab	3.5b	4.2 a	3.2 bc	5.0	1.5 bc
Kilaton	3.2 ab	3.5 a	1	4.2	3.2 a	5.0 a	3.1 bc	4.0 a	5.0	2.0 b
Kilaxy	3.0 abc	3.0 a	1	4.0	3.0 a	5.0 a	3.0 c	3.0 c	5.0	2.0 b
Bronco + ALLEGRO	2.7 bc	1.2 b	1	3.2	1.7 bc	3.0 b	3.0 c	3.9 ab	5.0	2.1 b
Bronco	1.5 c	1.0 b	1	2.7	1.0 c	3.0 b	3.0 c	3.4 abc	5.0	3.0 a

[1] Numbers in a column followed by a different letter were significantly different at P = 0.05, Tukey's Standardized Range (HSD) Test.

ns: indicates no significant differences were found among the treatments.

[2] Stock uniformity (size, maturity etc.) = 5 - very uniform, 1 - very uneven
[3] Plant habit = 5 - sprawling, 1 – compact
[4] Leaf savoying = 5 - very crinkled, 1 – smooth
[5] Stalk length = 5 - very long, 1 - very short
[6] External colour = 5 - very dark green, 1 - pale green
[7] Head protection = 5 - good protection, 1 - poor protection
[8] Head shape = 5 flat, 4 slightly flat, 3 globe, 2 slightly pointed, 1 pointed
[9] Internal colour = 5 - white, 1 - green
[10] Internal breakdown/tip burn = 5 - none, 1 - severe
[11] Core size = 5 - small, 1 – large