Integrated Approach for Management of Nematodes on Flue-Cured Tobacco in Ontario, Canada

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Presentation Outline

- Nematodes in tobacco production
- Approaches to managing nematodes
    - Resistant varieties
    - Fumigation
    - Nematicides
    - Rotational crops
    - Future Research

Nematodes in Tobacco Production

1-Root Lesion Nematode-*Pratylenchus penetrans*

- Considered the main and economically important nematode of tobacco in Ontario
- Widespread with a broad host range
- Hosts include among other crops potato, ginseng, rye
- Rye is a common rotational crop in tobacco production in Ontario

Nematodes in Tobacco Production

2-Tobacco Cyst Nematode-*Globodera tabacum*

- Recently found and identified in Ontario
- Cyst production makes it difficult to manage
- Fumigants are applied pre-planting and root exudates stimulate Tobacco Cyst Nematode eggs to hatch
- At this time, fumigants have dissipated from the soil and will provide little or no control of Tobacco Cyst Nematode

Nematodes in Tobacco Production

Symptoms

Above ground: symptoms are similar for both Root Lesion and Tobacco Cyst nematodes

Stunting

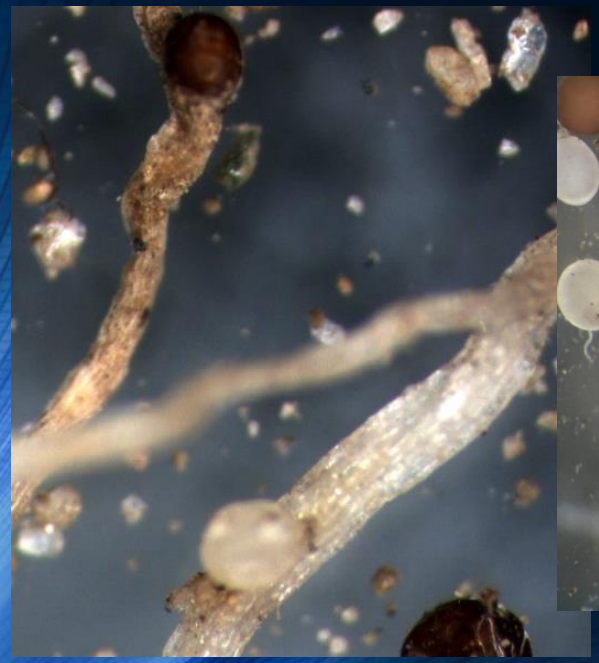
Chlorosis

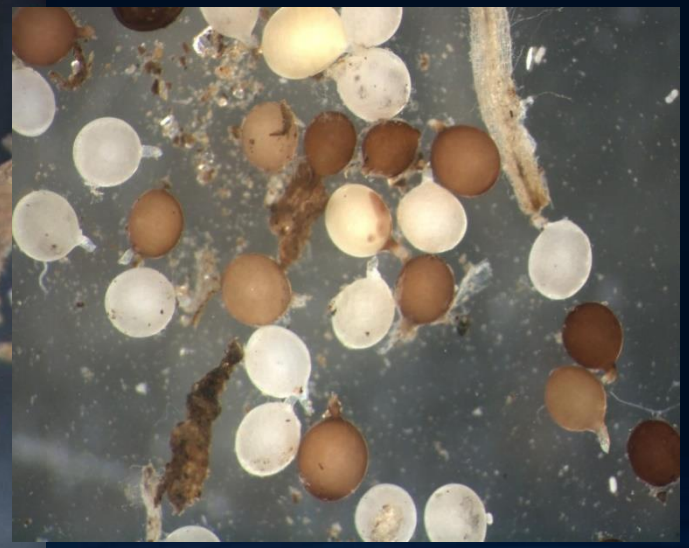
Wilting

Nematodes in Tobacco Production

Symptoms below ground:

- **Tobacco Cyst Nematode**: Reduced root mass and cyst production





- **Root Lesion Nematode**: Brown and girdled root lesions

Nematodes in Tobacco Production

Management

- Resistant varieties, Crop rotation
- Fumigants, Nematicides

Challenges

- Targeting the nematodes when they are exposed
- Crop protection products: Availability, cost, registration, re-evaluations and removal from market

Resistant Varieties

Integrated Management Approach

Resistance

- Use of resistant varieties – important for successful management of nematodes
- Currently there are no registered varieties that are resistant to Root Lesion or Tobacco Cyst nematodes developed in Canada, however, there is one US resistant variety that is registered in Canada but not widely used
- Working with the Breeding Program to develop methods for screening varieties for nematode resistance
- Focusing on tobacco varieties with resistance to other pathogens

Fumigation

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Pre-Planting Fumigation

- Soil fumigation is essential in tobacco production for nematode control
- Effective management of Root Lesion Nematode
- Also controls other soil borne pathogens (e.g. *Thielaviopsis basicola*) and germinating weed seeds (muck soil)

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Soil Fumigants Registered for Nematode Control (2019)

Fumigant	Active Ingredient	Application rate	Greenhouse/ Field
Basamid	dazomet 97%	3.1kg/100 m2	Greenhouse (muck bed)
Vapam HL	metam sodium 42%	7.1 L/100 m2	Greenhouse (muck bed)
Busan 1020	metam sodium 33%	65-85 L/ha	Field
Busan 1236	metam sodium 42%	50-66 L/ha	Field
Vapam HL	metam sodium 42 %	50-66 L/ha	Field
Chloropicrin 100	chloropicrin 99%	93 L/ha	Field
Pic Plus	chloropicrin 85.1%	108 L/ha	Field

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Dominus (a.i. allyl isothiocyanate = AITC)

A Biofumigant, evaluated in the field in 2017 and 2018

Treatments:

- Non-fumigated
- Chloropicrin 100 (rate: 23 L/ha – band applied)
- Dominus 96% AITC (rate: 59 kg/ha- band applied)
- Dominus 67% AITC + 33% Chloropicrin 100 (rate: 62 kg/ha- band applied)

- RCBD, 4 replications

Evaluations:

- Plant growth
- Leaf measurements
- Nematodes (early, mid and late-season)
- Yield (dry weight 2017; cured leaf 2018)
- Cured tobacco leaf chemistry (2018)
- Mean separation: Tukey's (HSD)
- SYSTAT 13

Dominus AITC - Results (2017)

	Root Lesion Nematode (#/kg soil)			Tobacco Cyst Nematode (#/kg soil)			Yield (g/plant)
Treatment	Early Season	Mid Season	Late Season	Early Season	Mid Season	Late Season	
Non-Fumigated	220	60	165 b	-	205 b	1,635	271.16 b
Chloropicrin 100	185	40	115 b	-	945 c	1,725	**289 .90 a**
Dominus 97%	150	**0**	**20 a**	-	**105 a**	680	**316.80 a**
Dominus 67%+ 33% Chloropicrin	195	**0**	**15 a**	-	**10 a**	1,455	**296.45 a**
P	0.756	0.047	0.012		0.033	0.667	0.025

Dominus AITC - Results (2018)

	Root Lesion Nematode (#/kg soil)			Tobacco Cyst Nematode (#/kg soil)			Yield (kg/ha)
Treatment	Early Season	Mid Season	Late Season	Early Season	Mid Season	Late Season	
Non-Fumigated	195	90 b	80	-	20	145	3,014
Chloropicrin 100	100	20 a	220	-	**0**	160	2,943
Dominus 97%	140	**15 a**	**40**	-	**25**	**10**	2,968
Dominus 67%+ 33% Chloropicrin	115	**5 a**	**40**	-	**0**	**55**	3,037
P	0.739	0.035	0.325		0.555	0.321	0.744

Dominus AITC - Results

Dominus 97%, Dominus 67% + 33% Chloropicrin

- There was a reduction in Root Lesion Nematode counts mid and late-season
- Tobacco Cyst Nematode counts mid and late-season high in 2017
- Nematode counts highest for Chloropicrin 100 mid and late-season
- Yield comparable to Chloropicrin 100 treatment

Nematicides

Integrated Management Approach

Nematicide Evaluations

Aim: target nematodes before and soon after transplanting

- Trials conducted at growers' fields with known nematode pressure
- Two types of experiments:
  - . Small plot efficacy trial
    - Yield evaluated as dry weight per plant
  - . Large plot efficacy and quality trial
    - Leaves are harvested, cured, and chemistry and smoke characteristics are evaluated
- Experimental design for all trials: RCBD, replicated 3-4 times

Evaluations:

- Plant growth and leaf measurements
- Nematode counts (early, mid and late - season), yield
- All treatments compared to fumigation (Chloropicrin 100)

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Nematicide Evaluations

Nematicide	Active ingredient	Rate	Application time	Year Evaluated
Velum Prime	fluopyram	500 mL a.i./ha	Transplanting	2014-2019
Nimitz (MCW)	fluensulfone	4 kg a.i./ha 1.2 kg a.i./ha	Prior to transplanting Transplanting	2017
Majestene	*Burkholderia* spp. strain A396	18.7 L/ha	Transplanting,14 and 28 DAT	2019
MBI 306	*Burkholderia* spp. strain A396	3L/ha 6L/ha	Transplanting, 14 and 28 DAT	2019

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Velum Prime (a.i. fluopyram)

- Nematicide/fungicide. Evaluated from 2014 to 2019
- Efficacy, quality trials and observation trials were conducted
- Multiple methods of application tested:
  - Pre and post transplanting soil incorporation
  - At transplanting
  - After transplanting
  - Following millet cover crops
  - Following fumigation

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Velum Prime (a.i. fluopyram)

- 2018-2019

  Treatments:

  - Non-fumigated control
  - Chloropicrin 100 (rate: 23 L/ha – band applied)
  - Velum Prime 500 mL a.i./ha transplant water
  - Velum Prime 500 mL a.i./ha transplant water + Chloropicrin 100
- Product applied into the tobacco root zone
- RCBD, 4 replications

Velum Prime - Results (2018)

	Root Lesion Nematode (#/kg soil)			Tobacco Cyst Nematode (#/kg soil)			Yield (kg/ha)
Treatment	Early Season	Mid Season	Late Season	Early Season	Mid Season	Late Season	
Non-Fumigated	195	90 b	80	-	20	145	**3,014 b**
Chloropicrin 100	100	**20 a**	220	-	**0**	160	**2,943 b**
Velum Prime TW	70	**15 a**	**10**	-	55	80	**3,324 a**
Velum Prime TW+ Chloropicrin 100	110	**5 a**	**0**	-	**5**	80	**3,372 a**
P	0.440	0.026	0.226		0.554	0.726	0.000

Velum Prime - Results (2019)

	Root Lesion Nematode (#/kg soil)			Tobacco Cyst Nematode (#/kg soil)			Yield (kg/ha)
Treatment	Early Season	Mid Season	Late Season	Early Season	Mid Season	Late Season	
Non-Fumigated	50	45	150	-	20	100	**4,091 b**
Chloropicrin 100	290	**15**	145	-	1,840 (1 plot)	1,290	**4,260 b**
Velum Prime TW	160	**125**	**40**	-	1,080 (1 plot)	810	**4,089 b**
Velum Prime TW+ Chloropicrin 100	330	**15**	**50**	-	-	85	**4,593 a**
P	0.412	0.270	0.699			0.417	0.000

Velum Prime - Results

- **Velum Prime:** there is a reduction in Root Lesion Nematode counts mid and late-season
- Nematode counts highest for fumigation treatment mid and late-season
- Plant phytotoxicity=stunted plants
- Yield: High in 2018 for both Velum Prime treatments. 2019 highest for Velum Prime and fumigation
- Fumigation followed by Velum Prime? Cost!

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Majestene/MBI 306 (a.i. *Burkholderia* spp. strain A396)

Bionematicides (2019)

- Efficacy trial-small plots
- Treatments applied with the transplant water and banded 14 and 28 days after transplanting
- Banded treatments applied with a CO_2 backpack sprayer
- RCBD replicated 3 times

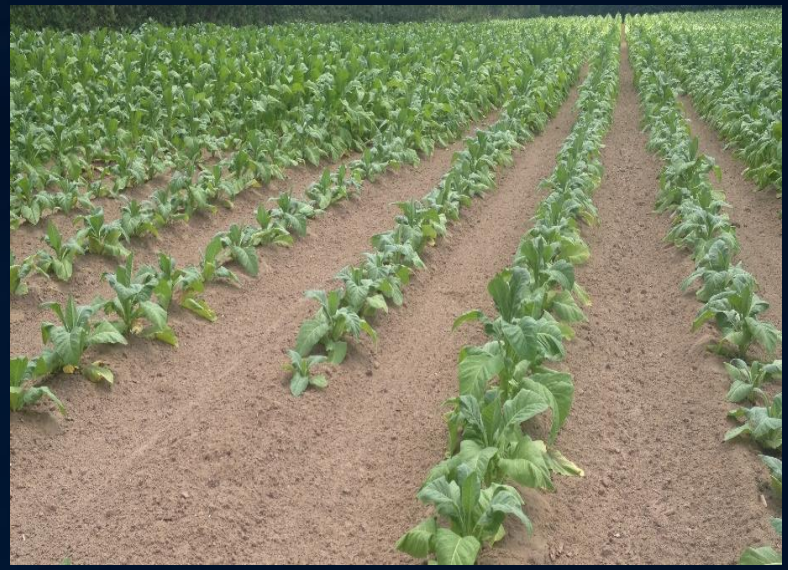
Treatment	Rate
Non-Fumigated	
Chloropicrin 100	23.9 L/ha
MBI 306 1X	3L/ha
MBI 306 1X + Chloropicrin 100	3L/ha + 23.9 L/ha
MBI 306 2X	6 L/ha
Majestene	18.7 L/ha

Bionematicides - Results (2019)

	Root Lesion Nematode (#/kg soil)			Yield (g/plant)
Treatment	Early-Season	Mid-Season	Late-Season	
Non-Fumigated	933	367	1,300	240.36
Chloropicrin 100	**207**	**53**	1,267	**298.52**
MBI 306 1 X	793	507	1,193	202.46
MBI 306 1 X TW+ Chloropicrin 100	**347**	**27**	2,367	**295.27**
MBI 306 2X	953	607	1,667	237.47
Majestene	1,700	497	1,640	230.58
P	0.494	0.300	0.239	0.056

Bionematicides - Results

- **Nematode:** Root Lesion Nematode
- Treatment effect on Tobacco Cyst Nematode not evaluated
- Root Lesion Nematode mid-season reduction, particularly when the fumigant was applied
- **Yield** similar for all treatments-slightly improved when the fumigant was used



Integrated Management Approach

Rotational Crops - Millet vs Rye

Rye: (*Secale cereale)*- Commonly used rotational crop in tobacco production. One - year rotations (tobacco - rye - tobacco)

- Rye is a host of Root Lesion Nematode
- Economic value of other possible crops an issue

Millet: Common Millet (*Panicum miliaceum*) and Forage Pearl Millet Hybrid (*Pennisetum glaucum*) are being evaluated

- Nematode reduction in other crop systems in rotations with Forage Pearl Millet, including Root Lesion Nematode in tobacco

Question: Can millet reduce Tobacco Cyst Nematode when used as a rotational crop?

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Rotational Crops - Millet vs Rye

- Rye, Pearl Forage Millet and Common Millet grown in 2018 and tobacco in 2019
- Plot had tobacco grown in 2017
- Rye plots were used for fumigation and non-fumigation treatments in 2019
- RCBD, 4 replications

Evaluations

- Nematode counts
- Yield (Dry weight/plant)

Rotational Crops - Results

	Root Lesion Nematode (#/kg soil)			Tobacco Cyst Nematode (#/kg soil)			Yield (g/plant)
Treatment	Early Season	Mid Season	Late Season	Early Season	Mid Season	Late Season	
Non-Fumigated	25	25	160	238	263	2,450	288.50
Chloropicrin 100	115	30	280	313	388	3,125	**313.60**
Common Millet	**15**	**30**	**100**	613	525	2,900	**303.97**
Forage Pearl Millet	**20**	**10**	**35**	338	450	3,575	**343.49**
P	0.058	0.734	0.132	0.676	0.852	0.821	0.554

Rotational Crops - Results

- **Nematode counts:** RLN Early, mid-season reduction and increase late-season
- Tobacco Cyst Nematode about the same early and mid-season and high late-season
- Yield similar for all treatments, however, slightly higher for fumigation and the millet crops
- Repeating this evaluation: Millet crops in 2019 and tobacco in 2020

Integrated Management Approach

Summary

Resistant Varieties

- Developing a screening methodology focused on varieties with resistance to other pathogens

Fumigation

- Provides control for early to mid-season, however, late-season nematode counts approach initial populations
- Dominus shows good control in preliminary evaluations

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Summary

Nematicides

- Velum Prime seems to provide good control, especially when used in combination with fumigant
- Bionematicides were not successful in 2019

Cover Crop

- Millet appears to lower Root Lesion Nematode pressure but not Tobacco Cyst Nematode
- There seems to be an inverse/competitive relationship between Root Lesion and Tobacco Cyst Nematode

Future Work

- Screening for resistant varieties to both nematodes
- Evaluation of:
  - Biofumigants (mustard derived)
  - Nematicides / bionematicides:
    - application methods
    - timing
- Explore more cover crops