2019 OTRI Reports			
	Title	Researcher	$ Amount Funded
1	Crop Tolerance Evaluations in Processing Tomatoes to Support Minor Use Herbicide Submissions (Robinson $5,000 - Nurse $3,000)	D Robinson / R. Nurse	$8,000
2	Problem Weed Control and Herbicide Tank Mix Interactions in Tomatoes (Robinson $5,000 - Nurse $3,000)	D. Robinson / R. Nurse	$8,000
3	Fungicide efficacy evaluations for early blight, Septoria leaf spot and anthracnose in processing tomatoes	C. Trueman	$4,000
4	Evaluation of Oxidate 2.0 for transplant sanitation prior to shipping	C. Trueman	$4,000
5	Neonicotinoid alternative for Colorado potato beetle in tomatoes	C. Trueman	$3,750
6	Management and extent of Phytophthora fruit rots in Essex County, 2019	C. Trueman	$1,500
7	Late blight surveillance and management - Part I (requested on a 3 year term at same levels) (Trueman $4,640 - Tomecek Agronomic Services $9,085)	C. Trueman/ Tomecek Agronomy	$9,085*
8	Late blight surveillance and management - Part II (requested on a 3 year term at $5,000 initial year and $7,500 subsequent)	C. Trueman/ Tomecek Agronomy	$5,000**
9	Investigation into variables affecting tomato solids - labour	J. Zandstra	$10,000***
10	Processing tomato cultivar trial, 2019	S. Loewen	$5,000
11	Long-term Impact of Cover Crops on the Production of Processing Tomatoes	L. VanEerd	$11,375
12	Breeding to protect plant health for Ontario's processing tomato industry (see note)	S. Loewen	$55,375

EXECUTIVE SUMMARY – WEED CONTROL IN TOMATOES (2019)

BY: DARREN ROBINSON, RIDGETOWN CAMPUS, UNIVERSITY OF GUELPH

Research Goal: The first goal of the tomato weed management research program is to provide data needed to support minor use (URMULE) submissions for new herbicide registrations in tomatoes, and examine how these potential new registrations fit with currently registered herbicides. The second objective of this research program is to examine tomato tolerance to new herbicide active ingredients being developed for use in major field crops (soybean, corn and wheat. All experiments are now conducted on two soil types each year to account for effect of soil characteristics (OM, pH, texture, CEC) on herbicide activity.

Experiment 1. Weed Management with Authority, Sandea and Sencor PRE-Transplant Tank-Mixes

Objective: Determine whether adding Authority or Sandea to Sencor will improve residual control of broadleaf and grass weeds in tomatoes.

Conclusions: The two-way tank mixes of Authority+Sencor, Authority+Sandea and Sencor+Sandea provided equivalent control of common ragweed and common lambsquarters to the three-way tank mix of Authority+Sencor+Sandea. Adequate rainfall in 2019 (compared with 2018, in which all treatments provided poor weed control) illustrate the importance of rainfall to "activate" these herbicides (ie. dissolve in soil water solution so they are available for uptake by weeds) Results of this study did show that postemergence grass control is necessary when a residual grass herbicide is not included in pre-transplant herbicide applications. None of the herbicides caused injury to tomato, and yields were similar to those in the weed-free check.

Experiment 2. Tolerance of Tomato to POST Applications of Sandea and Prism

Objective: Determine the effect of different rates of POST applications of Sandea + Prism on tomato tolerance.

Conclusions: The purpose of this study was to determine the tolerance of tomatoes to different rate combinations of Sandea (between 14 and 28 g/ac) and Prism (between 24 and 56 g/ac) applied POST to tomatoes. None of the tank mix combinations caused commercially significant injury, nor did they reduce plant dry weight (at late flower) or yield of tomato. Tomato yield was

41 T/ac in the untreated weedfree check, and ranged from 39 to 47 T/ac among all treatments – none of which were significantly different than one another.

Experiment 3. Tolerance of Tomato to POST Applications of Sandea and Sencor

Objective: Determine the effect of different rates of POST applications of Sandea + Sencor on tomato tolerance.

Conclusions: The purpose of this study was to determine the tolerance of tomatoes to different rate combinations of Sandea (between 14 and 28 g/ac) and Sencor micro-rates (between 120 and 180 ml/ac) applied POST to tomatoes. None of the tank mix combinations caused commercially significant injury, nor did they reduce plant dry weight (at late flower) or yield of tomato. Tomato yield was 45 T/ac in the untreated weedfree check, and ranged from 40 to 49 T/ac among all treatments – none of which were significantly different than one another.

Experiment 4. Tolerance of Tomato to PRE-Transplant Herbicides – Broadleaf Herbicides

Objective: This trial was established to determine tolerance of transplanted tomato to pre-transplant applications of Reflex, Valtera and tank mixes with Dual II Magnum and Sencor.

Conclusions: This trial was established to determine tolerance of transplanted tomato to pre-transplant applications of Reflex, Valtera and tank mixes with Dual II Magnum and Sencor. Treatments containing Valtera (alone or in tank mix) caused significant injury AND yield loss, as has been seen in previous years. Tomato showed excellent tolerance to Reflex.

Experiment 5. Tolerance of Tomato to PRE-Transplant Herbicides – Grass Herbicides

Objective: This trial was established to determine tolerance of transplanted tomato to pre-transplant applications of Prowl H2O, Zidua (pyroxasulfone), Shieldex (tolpyralate) and pethoxamid (in development).

Conclusions: Treatments containing Shieldex caused slight bleaching (up to 2%) and treatments containing Zidua caused leaf puckering. Tomato plant dry weight at late flower and marketable yield were not different than the untreated, weedfree check. Tomato showed excellent tolerance to all herbicides at 1X and 2X the proposed label rates.

WEED CONTROL IN TOMATOES

RESEARCH RESULTS – 2019

PREPARED BY DARREN ROBINSON,
UNIV. GUELPH, RIDGETOWN
CAMPUS

FOR THE ONTARIO TOMATO
RESEARCH INSTITUTE

NOVEMBER 1, 2019

ACKNOWLEDGEMENTS

Purpose Of This Report
This report is provided as a guide to the 2019 tomato weed control research control plots. The experiments outlined in this booklet are located at the Ridgetown Campus of the University of Guelph. We appreciate the funding, cooperation and assistance provided by the Ontario Tomato Research Institute (tomato growers and processing companies). As well, we would like to thank the OMAFRA-UG Alliance, chemical companies and their representatives, agextension personnel, and other research scientists for their ideas, plant material and herbicide samples that were used in these trials. Funding for the 2019 research program was provided by:

Ontario Tomato Research Institute
Agchemical Companies
Ontario Food Processors Association
OMAFRA-UG Alliance

Technical Assistants

Research Technician
Kristen McNaughton

Research Assistants
Renee Driesse
Carlene Scott

We trust that the information provided by this research will further the science of weed control by assisting with the registration of herbicides through the minor use system. We also hope this information will be of use in the extension of proper herbicide recommendations, thereby enabling growers to achieve consistent, broad spectrum weed control with a minimum of crop damage.

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Trial 1: Weed Management with Authority and Sandea Pre-transplant Tank Mixes with Sencor

Objective: Determine whether adding Authority or Sandea to Sencor will improve residual control of broadleaf and grass weeds in tomatoes.

Materials & Methods:

Crop: *Tomato*
Variety: CC337
Planting rate: 11803 plants/ac
Row spacing: 1.5m
Planting date: May 27/19
Depth: 5 cm
Plant spacing: 45 cm

Design: Randomized Complete Block Design
Plot width: 1.5m
Plot length: 10m
Reps: 4

Field Preparation: Field was worked with an S-tine cultivator and fertilizer was applied at 120 kg N/ha on May 26.

Soil Description:
Sand: 50% and 82%
Silt: 28% and 10%
Clay: 22% and 8%
OM: 4.1% and 2.8%
pH: 6.2 and 7.7
CEC 12.4 and 16.0

Texture: Sandy Clay Loam and Loamy Sand
Soil: Both in the Watford/Brady series

Application Information:

	A
APPLICATION DATE	MAY 26/19
TIME OF DAY	8:00 AM and 9:00AM
TIMING	PRE-T
AIR TEMP (c)	17 and 19
RH (%)	70 and 70
WIND SPEED (KPH)	6 and 8
SOIL TEMP (c)	20 and 23
CLOUD COVER (%)	0

Spray Equipment:
Application Method: CO_2 Backpack
Nozzle Type: Air Induction
Nozzle Spacing: 50 cm (20")
Spray Volume: 200 L/ha (20 GAL/AC)
Pressure: 207 KPA (30 PSI)
Nozzle Size: ULD120-02
Boom Width: 1.5 m (60")

Table 1.1. Effect of Authority, Sandea and Sencor herbicide tank mix treatments on control of common ragweed (AMBEL), common lambsquarters (CHEAL) and large crabgrass (DIGSA).

TREATMENT	PERCENT CONTROL		
	AMBEL	CHEAL	DIGSA
AUTHORITY	30D	61B	25B
SENCOR	53CD	90A	25B
SANDEA	83AB	88A	23B
AUTHORITY + SENCOR	75ABC	88A	21B
AUTHORITY + SANDEA	85A	95A	44A
SENCOR + SANDEA	88A	94A	22B
AUTHORITY + SENCOR + SANDEA	90A	98A	49A
LSD (P <0.05)	23	21	12

Note: Means followed by the same letter are not significantly different (P=0.05, LSD).

Table 1.2. Effect of Authority, Sandea and Sencor herbicide tank mix treatments on tomato injury at 7 and 28 days after treatment and marketable yield in the treated, weedfree sub-plots.

TREATMENT	VISUAL INJURY 7D	28D	YIELD (T/AC)
AUTHORITY	0C	0B	42A
SENCOR	0C	0B	43A
SANDEA	1C	0B	44A
AUTHORITY + SENCOR	5B	0B	43A
AUTHORITY + SANDEA	7AB	0B	45A
SENCOR + SANDEA	4BC	0B	40A
AUTHORITY + SENCOR + SANDEA	10A	4A	43A
LSD (P <0.05)	3	2	NS

Note 1: Means followed by the same letter are not significantly different (P=0.05, LSD).

Note 2: Marketable yield in the untreated, weedfree check was 43 T/ac

Conclusions: Two trials, each on a different soil type (ie. sandy clay loam and loamy sand), were conducted to determine differences in weed control and crop tolerance to two- and three-way tank mixtures of Authority, Sencor and Sandea. Despite the differences in soil type, data were similar enough in each trial to allow for them to be combined (ie. weed control and injury were similar in both trials).

The two-way tank mixes of Authority+Sencor, Authority+Sandea and Sencor+Sandea provided equivalent control of common ragweed and common lambsquarters to the three-way tank mix of Authority+Sencor+Sandea. Adequate rainfall in 2019 (compared with 2018, in which all treatments provided poor weed control) illustrate the importance of rainfall to "activate" these herbicides (ie. dissolve in soil water solution so they are available for uptake by weeds). Results of this study did show that postemergence grass control is necessary when a residual grass herbicide is not included in pre-transplant herbicide applications. None of the herbicides caused injury to tomato, and yields were similar to those in the weed-free check.

Trial 2: Tolerance of Tomato to POST Applications of Sandea and Prism

Objective: Determine the effect of different rates of POST applications of Sandea + Prism on tomato tolerance.

Materials & Methods:

Crop: *Tomato*
Variety: CC337
Planting rate: 11803 plants/ac
Row spacing: 1.5m
Planting date: May 27/19
Depth: 5 cm
Plant spacing: 45 cm

Design: Randomized Complete Block Design
Plot width: 1.5m
Plot length: 10m
Reps: 4

Field Preparation: Field was worked with an S-tine cultivator and fertilizer was applied at 120 kg N/ha on May 26.

Soil Description:
Sand: 50% and 82%
Silt: 28% and 10%
Clay: 22% and 8%
OM: 4.1% and 2.8%
pH: 6.2 and 7.7
CEC 12.4 and 16.0

Texture: Sandy Clay Loam and Loamy Sand
Soil: Both in the Watford/Brady series

Application Information:

	A
APPLICATION DATE	JUN 17
TIME OF DAY	8:00 AM and 9:00 AM
TIMING	POST (21DAYS AFTER TRANSPLANTING)
AIR TEMP (c)	23 and 27
RH (%)	70 and 55
WIND SPEED (KPH)	4 and 8
SOIL TEMP (c)	26 and 29
CLOUD COVER (%)	0
CROP STAGE	9 LEAF

Spray Equipment:
Application Method: CO2 Backpack
Nozzle Type: Air Induction
Nozzle Spacing: 50 cm (20")
Spray Volume: 200 L/ha (20 GAL/AC)
Pressure: 207 KPA (30 PSI)
Nozzle Size: ULD120-02
Boom Width: 1.5 m (60")

Table 2.1. Effect of different rates of Sandea plus Prism treatments on percent injury at 7 and 28 days after treatment (DAT) and tomato marketable yield (T/ac).

SANDEA RATE	PRISM RATE	PERCENT INJURY 7 DAT	28 DAT	Yield (T/ac)
14 G/AC	NA	1A	0A	42A
21 G/AC	NA	2A	2A	44A
28 G/AC	NA	7A	3A	40A
NA	24 G/AC	0A	0A	39A
NA	56 G/AC	3A	2A	43A
14 G/AC	24 G/AC	2A	1A	47A
21 G/AC	24 G/AC	4A	1A	42A
28 G/AC	24 G/AC	8A	1A	41A
14 G/AC	56 G/AC	3A	1A	43A
21 G/AC	56 G/AC	5A	2A	42A
28 G/AC	56 G/AC	9A	5A	44A
LSD ($P < 0.05$)		NS	NS	NS

Note: Means followed by the same letter are not significantly different (P=0.05, LSD).

Conclusions: The purpose of this study was to determine the tolerance of tomatoes to different rate combinations of Sandea (between 14 and 28 g/ac) and Prism (between 24 and 56 g/ac) applied POST to tomatoes. None of the tank mix combinations caused commercially significant injury, nor did they reduce plant dry weight (at late flower) or yield of tomato. Tomato yield was 41 T/ac in the untreated weedfree check, and ranged from 39 to 47 T/ac among all treatments – none of which were significantly different than one another.

Trial 3: Tolerance of Tomato to POST Applications of Sandea and Sencor

Objective: Determine the effect of different rates of POST applications of Sandea + Sencor on tomato tolerance.

Materials & Methods:

Crop: *Tomato*
Variety: CC337
Planting rate: 11803 plants/ac
Row spacing: 1.5m
Planting date: May 27/19
Depth: 5 cm
Plant spacing: 45 cm

Design: Randomized Complete Block Design
Plot width: 1.5m
Plot length: 10m
Reps: 4

Field Preparation: Field was worked with an S-tine cultivator and fertilizer was applied at 120 kg N/ha on May 26.

Soil Description:
Sand: 50% and 82%
Silt: 28% and 10%
Clay: 22% and 8%
OM: 4.1% and 2.8%
pH: 6.2 and 7.7
CEC 12.4 and 16.0

Texture: Sandy Clay Loam and Loamy Sand
Soil: Both in the Watford/Brady series

Application Information:

	A
APPLICATION DATE	JUN 17
TIME OF DAY	10:00 AM and 11 00 AM
TIMING	POST (21DAYS AFTER TRANSPLANTING)
AIR TEMP (c)	28 and 30
RH (%)	70 and 85
WIND SPEED (KPH)	4 and 8
SOIL TEMP (c)	28 and 32
CLOUD COVER (%)	0
CROP STAGE	9 LEAF

Spray Equipment:
Application Method: CO2 Backpack
Nozzle Type: Air Induction
Nozzle Spacing: 50 cm (20")
Spray Volume: 200 L/ha (20 GAL/AC)
Pressure: 207 KPA (30 PSI)
Nozzle Size: ULD120-02
Boom Width: 1.5 m (60")

Table 3.1. Effect of different rates of Sandea plus Sencor treatments on percent injury at 7 and 28 days after treatment (DAT) and tomato marketable yield (T/ac).

SANDEA RATE	SENCOR RATE	PERCENT INJURY 7 DAT	28 DAT	Yield (T/ac)
14 G/AC	NA	1A	0A	48A
21 G/AC	NA	2A	1A	46A
28 G/AC	NA	6A	3A	45A
NA	120 ML/AC	1A	1A	49A
NA	180 ML/AC	1A	0A	47A
14 G/AC	120 ML/AC	0A	0A	43A
21 G/AC	120 ML/AC	1A	0A	44A
28 G/AC	120 ML/AC	7A	4A	42A
14 G/AC	180 ML/AC	2A	0A	40A
21 G/AC	180 ML/AC	2A	2A	45A
28 G/AC	180 ML/AC	8A	5A	42A
LSD (P <0.05)		NS	NS	NS

Note: Means followed by the same letter are not significantly different (P=0.05, LSD).

Conclusions:

The purpose of this study was to determine the tolerance of tomatoes to different rate combinations of Sandea (between 14 and 28 g/ac) and Sencor micro-rates (between 120 and 180 ml/ac) applied POST to tomatoes. None of the tank mix combinations caused commercially significant injury, nor did they reduce plant dry weight (at late flower) or yield of tomato. Tomato yield was 45 T/ac in the untreated weedfree check, and ranged from 40 to 49 T/ac among all treatments – none of which were significantly different than one another.

Trial 4: Tolerance of Tomatoes to Pre-Transplant Herbicides – Broadleaf Herbicides

Objectives:

1. Determine the efficacy and tolerance of tomato to Reflex, Valtera and tank mixes with Dual II Magnum and Sencor.

Crop: *Tomato*
Variety: CC337
Planting rate: 11803 plants/ac
Row spacing: 1.5m
Planting date: May 27/19
Depth: 5 cm
Plant spacing: 45 cm

Design: Randomized Complete Block Design
Plot width: 1.5m
Plot length: 10m
Reps: 4

Field Preparation: Field was worked with an S-tine cultivator and fertilizer was applied at 120 kg N/ha on May 26.

Soil Description:
Sand: 50% and 82%
Silt: 28% and 10%
Clay: 22% and 8%
OM: 4.1% and 2.8%
pH: 6.2 and 7.7
CEC 12.4 and 16.0

Texture: Sandy Clay Loam and Loamy Sand
Soil: Both in the Watford/Brady series

Application Information:

	A
APPLICATION DATE	MAY 26/19
TIME OF DAY	10:00AM and 11:00AM
TIMING	PRE-T
AIR TEMP (c)	23 and 28
RH (%)	70 and 80
WIND SPEED (KPH)	6 and 11
SOIL TEMP (c)	20 and 23
CLOUD COVER (%)	0

Spray Equipment:
Application Method: CO2 Backpack
Nozzle Type: Air Induction
Nozzle Spacing: 50 cm (20")
Spray Volume: 200 L/ha (20 GAL/AC)
Pressure: 207 KPA (30 PSI)
Nozzle Size: ULD120-02
Boom Width: 1.5 m (60")

Table 4.1. Effect of herbicide treatment on tomato visual injury 7, 14 and 28 days after planting, plant dry weight 28 days after planting, and yield.

HERBICIDE	RATE	VISUAL INJURY 7D	14D	28D	YIELD T/AC
1. Check (WEEDFREE)		0C	0C	0D	43A
2. REFLEX	400 ML/AC	1C	0C	0D	46A
3. REFLEX	800 ML/AC	2C	3C	0D	48A
4. VALTERA	42 G/AC	7BC	14B	11C	22B
5. VALTERA	84 G/AC	15A	32A	22B	18B
6. DUAL II MAG +	0.5 L/AC	2C	0C	0D	42A
SENCOR	200 ML/AC				
7. REFLEX +	400 ML/AC	3C	3C	0D	42A
DUAL II MAG +	0.5 L/AC				
SENCOR	200 ML/AC				
8. VALTERA +	42 G/AC	8B	18B	29A	20B
DUAL II MAG +	0.5 L/AC				
SENCOR	200 ML/AC				
LSD (P <0.05)		4	8	5	9

Note: Means followed by the same letter are not significantly different (P=0.05, LSD).

Conclusions:

This trial was established to determine tolerance of transplanted tomato to pre-transplant applications of Reflex, Valtera and tank mixes with Dual II Magnum and Sencor. Treatments containing Valtera (alone or in tank mix) caused significant injury AND yield loss, as has been seen in previous years. Tomato showed excellent tolerance to Reflex.

Trial 5: Tolerance of Tomatoes to Pre-Transplant Herbicides – Grass Herbicides

Objective: This trial was established to determine tolerance of transplanted tomato to pre-transplant applications of Prowl H2O, Zidua (pyroxasulfone), Shieldex (tolpyralate) and pethoxamid (in development).

Crop: *Tomato*
Variety: CC337
Planting rate: 11803 plants/ac
Row spacing: 1.5m
Planting date: May 27/19
Depth: 5 cm
Plant spacing: 45 cm

Design: Randomized Complete Block Design
Plot width: 1.5m
Plot length: 10m
Reps: 4

Field Preparation: Field was worked with an S-tine cultivator and fertilizer was applied at 120 kg N/ha on May 26.

Soil Description:
Sand: 50% and 82%
Silt: 28% and 10%
Clay: 22% and 8%
OM: 4.1% and 2.8%
pH: 6.2 and 7.7
CEC 12.4 and 16.0

Texture: Sandy Clay Loam and Loamy Sand
Soil: Both in the Watford/Brady series

Application Information:

	A
APPLICATION DATE	MAY 26/19
TIME OF DAY	1:00PM and 2:00PM
TIMING	PRE-T
AIR TEMP (c)	28 and 30
RH (%)	80 and 70
WIND SPEED (KPH)	12 and 8
SOIL TEMP (c)	20 and 23
CLOUD COVER (%)	0

Spray Equipment:
Application Method: CO2 Backpack
Nozzle Type: Air Induction
Nozzle Spacing: 50 cm (20")
Spray Volume: 200 L/ha (20 GAL/AC)
Pressure: 207 KPA (30 PSI)
Nozzle Size: ULD120-02
Boom Width: 1.5 m (60")

Table 5.1. Effect of various preemergence herbicides on injury (at 7, 14 and 28 days after transplanting), plant dry weight and yield of tomato.

HERBICIDE	RATE	PERCENT INJURY			DRY WT	YIELD
		7D	14D	28D	G	T/AC
1. Check (WEEDFREE)		0A	0A	0A	92A	43A
2. pethoxamid	1200 G/HA	0A	0A	1A	93A	41A
3. pethoxamid	2400 G/HA	0A	0A	2A	88A	44A
4. ZIDUA	47 G/AC	0A	0A	1A	94A	44A
5. ZIDUA	94 G/AC	0A	0A	0A	88A	42A
6. PROWL H20	0.96 L/AC	1A	1A	0A	86A	43A
7. PROWL H20	1.92 L/AC	2A	1A	0A	94A	45A
8. SHIELDEX	16.3 G/AC	1A	1A	1A	95A	42A
9. SHIELDEX	32.6 G/AC	1A	1A	2A	84A	40A
LSD (P <0.05)		ns	ns	ns	17	6

Note: Means followed by the same letter are not significantly different (P=0.05, LSD).

Conclusions:

Treatments containing Shieldex caused slight bleaching (up to 2%) and treatments containing Zidua caused leaf puckering. Tomato plant dry weight at late flower and marketable yield were not different than the untreated, weedfree check. Tomato showed excellent tolerance to all herbicides at 1X and 2X the proposed label rates.

2019 Executive Summary

Dr. Rob Nurse (Robert.Nurse@Canada.ca)

Trial 1 – **Weed control and tolerance of processing tomatoes to Authority, Dual II Magnum, Sandea and pethoxamid applied PRE.**

Pethoxamid is a new group 15 herbicide. Therefore, it's spectrum of weed control and mechanism of action is similar to Dual II Magnum. Authority is a group 14 herbicide that has recently been registered in processing tomato. This trial evaluates the efficacy of these products on nightshade when applied alone or in tank-mix with Authority. There were no crop injury concerns. Control of eastern black nightshade was excellent (>90%) for all treatments except Sandea which did not provide any nightshade control. In general the tank-mix options did not improve control of nightshade except when Authority was tank-mixed with Sandea. Common lambsquarters and redroot pigweed were also present in the trial. Surprisingly, both Dual II Magnum and pethoxamid provided less than 50% control of lambsquarters when applied alone; however, control was excellent when tank-mixed with Authority. Authority provided equal or better weed control when applied alone in comparison to the tank-mixes. This translated into yield where the highest yield was in the Authority alone and tank-mix treatments.

Trial 2 – **Weed control and tolerance of processing tomatoes to POST tank-mixes with pethoxamid.**

In this trial pethoxamid was tank-mixed with Sandea, Prism, Pinnacle, Poast Ultra, Venture L or Sencor POST at the 6-8 leaf stage of the tomato. The appropriate surfactants were added to each treatment according to label specifications. Data summarized below are from 2017 to 2019. There was marginal injury observed in some of the treatments that persisted through to 28 days after treatment (DAT), but the injury never exceeded 10% in 2017 and 2018, but no injury in 2019. The most common weed species in the trials were large crabgrass, and common lambsquarters. Control of all species was excellent (>90%) across all treatments, except for POST applications of pethoxamid and/or Sandea POST where control was <80%. Marketable yields did not differ among treatments, although treatments containing pethoxamid alone had yields that were up to 10% lower than the weed-free control.

Trial 3 – **Weed control and tolerance of processing tomato to POST tank-mixes with Sandea**

In this trial Sandea was tank-mixed with Sencor, Prism, or Pinnacle and applied postemergence on processing tomatoes at the 6-8 lf stage. There were no injury concerns for any of the treatments tested. The most common broadleaved weed in this trial was common lambsquarters. Postemergence control of lambsquarters was poor with all treatments except Prism or Pinnacle. Control was improved with the tank-mix partners. Yields were improved in treatments that contained tankmix treatments other than Pinnacle

Trial 4. - **Weed control and tolerance of processing tomatoes to Authority, Dual II Magnum and pethoxamid applied PPI.**

Pethoxamid is a new group 15 herbicide. Therefore, it's spectrum of weed control and mechanism of action is similar to Dual II Magnum. Authority is a group 14 herbicide that has recently been registered in processing tomato. This trial evaluates the efficacy of these products on nightshade when applied alone or in tank-mix with Authority. There were no crop injury concerns. Control of eastern black nightshade was excellent (>90%) for all treatments except Authority alone which provided only 53% control. In general the tank-mix options all improved control of nightshade in comparison to their stand-alone treatments. Common lambsquarters and redroot pigweed were also present in the trial but were controlled well by all treatments. Tomato yields were highest in treatments where Dual II Magnum or pethoxamid were tank-mixed with Authority.

2019 Research Report

Dr. Rob Nurse (Robert.Nurse@Canada.ca)

Trial 1 – Weed control and tolerance of processing tomatoes to Authority, Dual II Magnum, Sandea and pethoxamid applied PRE.

Objective: Determine effective PRE treatments for eastern black nightshade control.

Pethoxamid is a new group 15 herbicide. Therefore, it's spectrum of weed control and mechanism of action is similar to Dual II Magnum. Authority is a group 14 herbicide that has recently been registered in processing tomato. This trial evaluates the efficacy of these products on nightshade when applied alone or in tank-mix with Authority. There were no crop injury concerns. Control of eastern black nightshade was excellent (>90%) for all treatments except Sandea which did not provide any nightshade control. In general the tank-mix options did not improve control of nightshade except when Authority was tank-mixed with Sandea. Common lambsquarters and redroot pigweed were also present in the trial. Surprisingly, both Dual II Magnum and pethoxamid provided less than 50% control of lambsquarters when applied alone; however, control was excellent when tank-mixed with Authority. Authority provided equal or better weed control when applied alone in comparison to the tank-mixes. This translated into yield where the highest yield was in the Authority alone and tank-mix treatments (Figure 1).

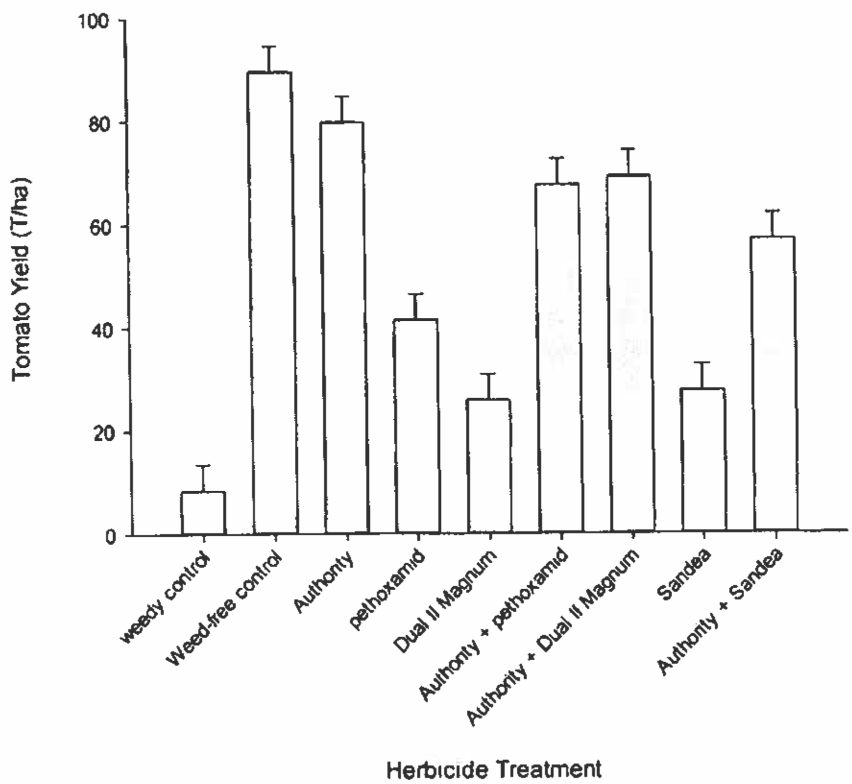

Figure 1. Processing tomato yield for several PRE herbicide treatments at Harrow, ON in 2019.

Conclusion: For nightshade control there was no0 benefit to tank-mixing Authority with Dual II Magnum or pethoxamid. However, there was a benefit for control of lambsquarters or redroot pigweed.

Trial 2 – Weed control and tolerance of processing tomatoes to POST tank-mixes with pethoxamid.

Objective: Identify postemergence tank-mix partners for pethoxamid that will improve weed control, especially common lambsquarters and large crabgrass.

In this trial pethoxamid was tank-mixed with Sandea, Prism, Pinnacle, Poast Ultra, Venture L or Sencor POST at the 6-8 leaf stage of the tomato. The appropriate surfactants were added to each treatment according to label specifications. Data summarized below are from 2017 to 2019. There was marginal injury observed in some of the treatments that persisted through to 28 days after treatment (DAT), but the injury never exceeded 10% in 2017 and 2018, but no injury in 2019. The most common weed species in the trials were large crabgrass, and common lambsquarters. Control of all species was excellent (>90%) across all treatments, except for POST applications of pethoxamid and/or Sandea POST where control was <80%. Marketable yields did not differ among treatments, although treatments containing pethoxamid alone had yields that were up to 10% lower than the weed-free control. (Figure 2).

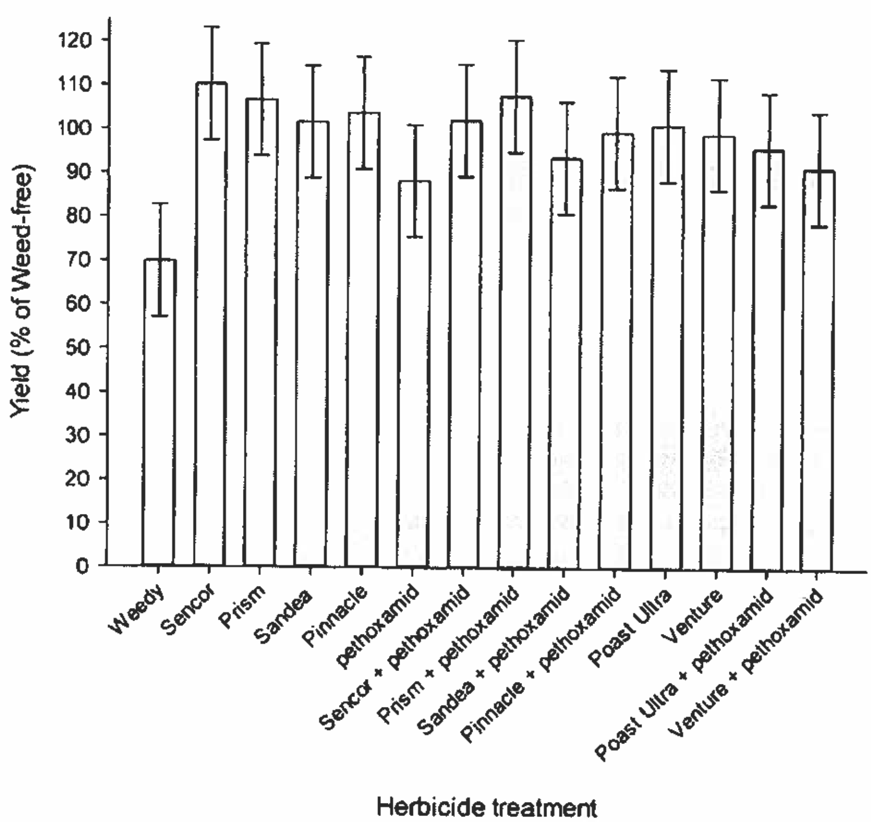

Figure 2. Processing tomato yield as a percentage of a weed-free control. Pethoxamid was applied with various tank-mix partners in trials between 2016 and 2019 at Harrow, ON.

Conclusions: Weed control and yield were improved when pethoxamid was tank-mixed with another herbicide.

Trial 3 – Weed control and tolerance of processing tomato to POST tank-mixes with Sandea

Objective: Identify tank-mix partners that will improve control of common lambsquarters when Sandea is applied postemergence.

In this trial Sandea was tank-mixed with Sencor, Prism, or Pinnacle and applied postemergence on processing tomatoes at the 6-8 lf stage. There were no injury concerns for any of the treatments tested. The most common broadleaved weed in this trial was common lambsquarters. Postemergence control of lambsquarters was poor with all treatments except Prism or Pinnacle. Control was improved with the tank-mix partners (Figure 3). Yields were improved in treatments that contained tankmix treatments other than Pinnacle (Figure 4).

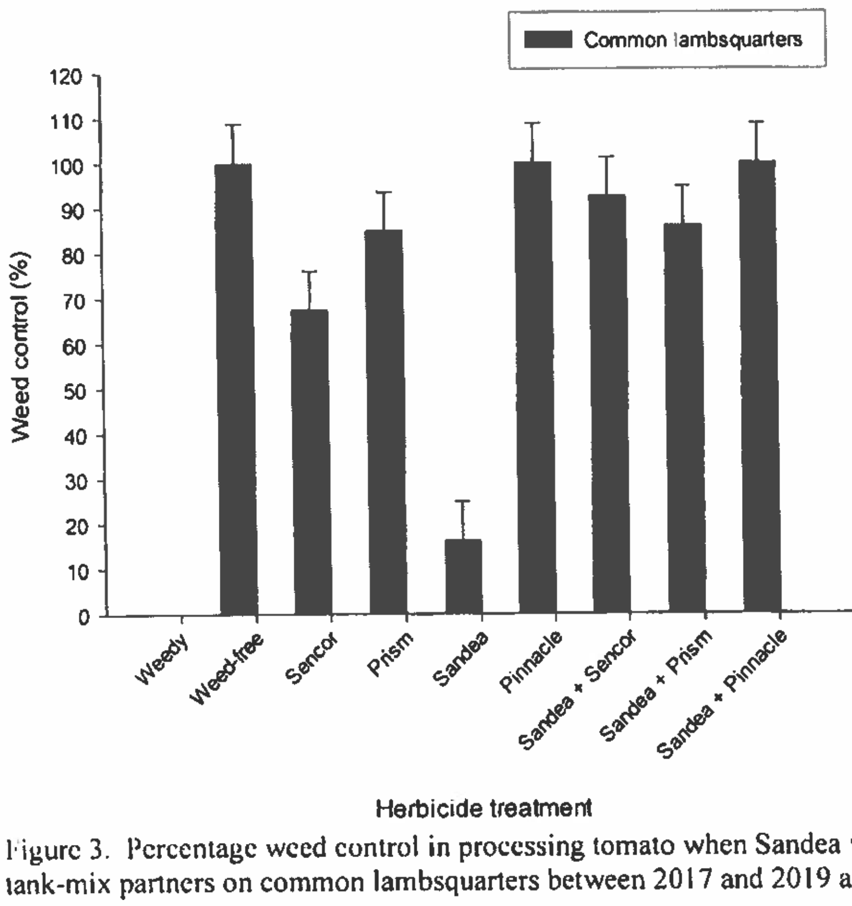

Figure 3. Percentage weed control in processing tomato when Sandea was applied postemergence with tank-mix partners on common lambsquarters between 2017 and 2019 at Harrow, ON.

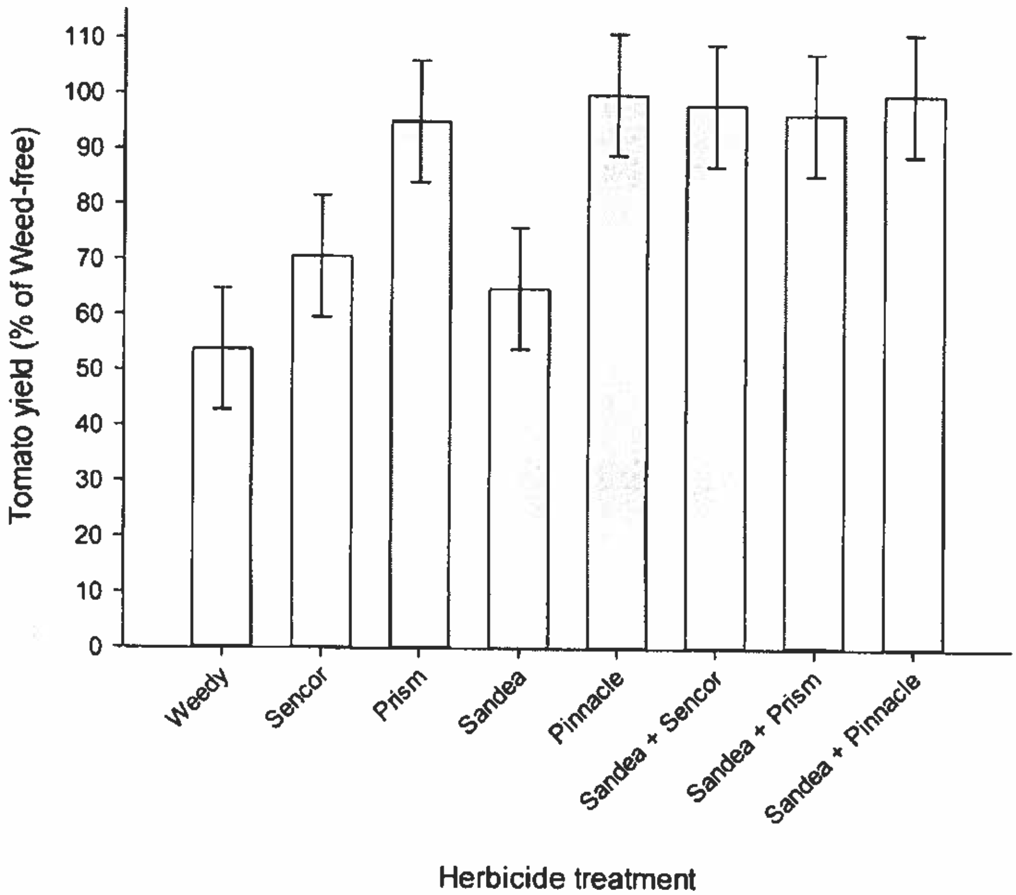

Figure 4. Processing tomato yield as a percentage of a weed-free control. Sandea was applied with various tank-mix partners in trials between 2017 and 2019 at Harrow, ON.

Conclusions: Sandea is known to provide poor control of common lambsquarters when applied postemergence. This trial did show that there was an increase in common lambsquarters between the tank-mix treatments and standalone Sandea. This resulted in a yield benefit for all tank-mix combinations.

Trial 4. - Weed control and tolerance of processing tomatoes to Authority, Dual II Magnum and pethoxamid applied PPI.

Objective: Determine effective PPI treatments for eastern black nightshade control.

Pethoxamid is a new group 15 herbicide. Therefore, it's spectrum of weed control and mechanism of action is similar to Dual II Magnum. Authority is a group 14 herbicide that has recently been registered in processing tomato. This trial evaluates the efficacy of these products on nightshade when applied alone or in tank-mix with Authority. There were no crop injury concerns. Control of eastern black nightshade was excellent (>90%) for all treatments except Authority alone which provided only 53% control. In general the tank-mix options all improved control of nightshade in comparison to their stand-alone treatments. Common lambsquarters and redroot pigweed were also present in the trial but were controlled well by all treatments. Tomato yields were highest in treatments where Dual II Magnum or pethoxamid were tank-mixed with Authority. (Figure 5).

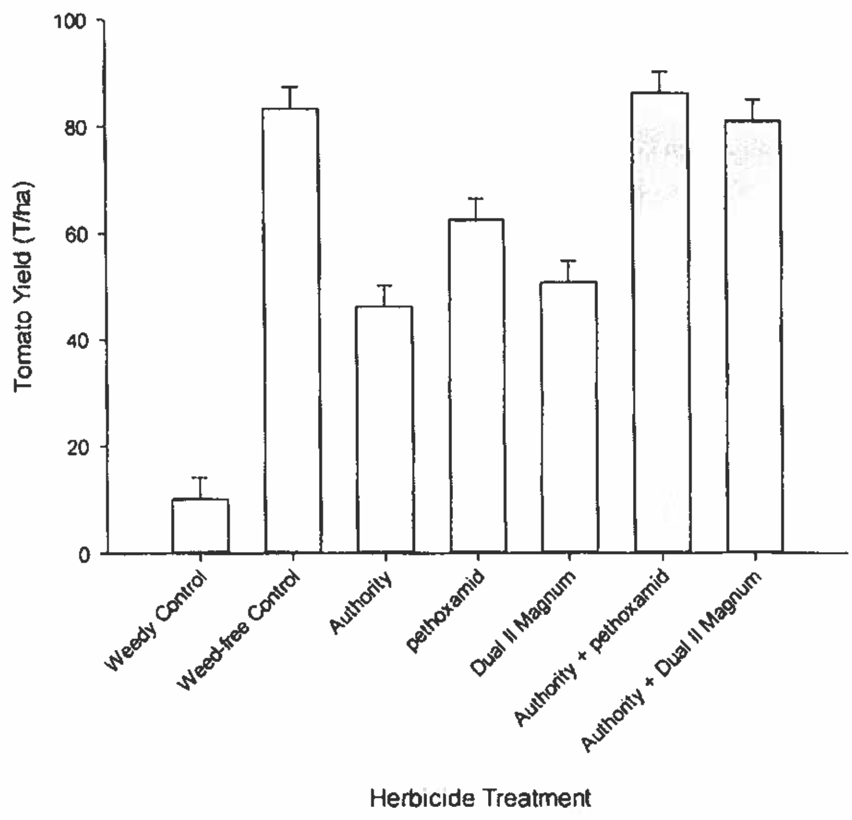

Figure 5. Processing tomato yield when Dual II Magnum or pethoxamid was applied with or without Authority at Harrow, ON in 2019.

Conclusion: Control of eastern black nightshade was improved when Dual II Magnum or pethoxamid were tank-mixed with Authority and applied PPI.

2019 Research Report

Fungicides for management of early blight, Septoria leaf spot, and anthracnose in processing tomatoes

Prepared for the Ontario Tomato Research Committee (OTRI)
October 20, 2019

Research Team:

- Cheryl Trueman (Ph.D.), Assistant Professor, Department of Plant Agriculture, University of Guelph – Ridgetown Campus
- Phyllis May, Research Technician
- We thank Dr. Kris McNaughton for preparing this report

Highlights/Summary:

- The objective of this research was to evaluate the efficacy of new and recently registered fungicides for management of early blight, Septoria leaf spot, and anthracnose.
- Both early blight and Septoria leaf spot were present. Total foliar disease was lower in treatments Bravo ZN (both rates), Manzate Pro-stick, Quadris, Tanos, Sercadis, Fontelis, Aprovia TOP, Miravis Duo, Luna Privilege, Phostrol + Bravo ZN, and Cevya compared to the nontreated control. The Manzate Pro-stick, Aprovia Top, and Luna Privilege treatments also yielded better than the nontreated control. The Cueva and Phostrol alone treatments were ineffective at preventing defoliation compared to the control. When mixed with Bravo ZN, Phostrol provided better control than Phostrol alone, but similar control to Bravo ZN (either rate). These results will be used to update fungicide efficacy tables presented on ONvegetables.com and elsewhere. Anthracnose incidence was very low and there were no differences among treatments.
- Both the low and the high rate of Bravo ZN treatments showed similar levels of defoliation and tomato total yield. This is an important observation since the high rate represents the middle rate under the previous label for chlorothalonil, while the low rate is the rate approved for seven applications under the new chlorothalonil label in Canada.

Funding:

- Ontario Tomato Research Institute

TITLE: Fungicides for management of early blight, Septoria leaf spot, and anthracnose in processing tomatoes

PEST(S): early blight (*Alternaria solani*), anthracnose (*Colletotrichum coccodes*), Septoria leaf spot (*Septoria lycopersici*)

MATERIALS: Bravo ZN (chlorothalonil 500g L^{-1}), Quadris Flowable (azoxystrobin 250 g L^{-1}), Manzate Pro-Stick (mancozeb 75%), Fontelis (penthiopyrad 200 g L^{-1}), Aprovia TOP (benzovindiflupyr ('Solatenol') 100 g L^{-1}, difenoconazole 117 g L^{-1}), Sercadis (fluxapyroxad ('Xemium'), 26.55%), Miravis Duo (pydiflumetofen ('Adepidyn') 75 g L^{-1}, difenoconazole 125 g L^{-1}), Cueva (copper octanoate 1.8%), Tanos (famoxadone 25%, cymoxanil 25%), Phostrol (mono- and di-potassium salts of phosphorous acid 53.6%), Luna Privilege (fluopyram 500 g L^{-1}), and Cevya (mefentrifluconazole 98.5%).

METHODS: The trial was completed at Ridgetown Campus, University of Guelph. Tomato transplants cv. H9706 were transplanted into twin rows on June 4 using a mechanical transplanter at a rate of 3 plants per metre. Each twin row was spaced 2 m apart. Each treatment plot was 7m long and consisted of one twin row. The trial was setup as a randomized complete block design, with 4 replications per treatment. Applications were made using a hand-held CO_2 sprayer with nozzles ULD 120-03, and a water volume of 300 L Ha^{-1}. The trial was drip irrigated throughout the growing season as required.

The trial was inoculated with *A. solani* As56C-R19, As99-R19, and As95-R19 on July 2. This was done by removing and replacing one healthy seedling at the back of each plot with a tomato seedling inoculated with *A. solani* and incubated on benches outside the greenhouse for approximately two weeks. A set of greenhouse seedlings was also inoculated for Septoria leaf spot. One seedling inoculated for Septoria was exchanged for one healthy seedling at the front of each plot. Overhead irrigation was applied every night, Monday through Friday, for 15 minutes, unless it rained during the day. Overhead irrigation began on July 8 and continued until August 7 to encourage disease development.

Whole plot defoliation was estimated Aug 7, 13, 22, and Sept 4 using an incremental 5% scale (i.e. 0, 5, 10, etc.). These values were used to calculate the area under the disease progress stairs (AUDPS) using the following equation: AUDPC + $[(Y_1 + Y_n)/2 \times (D/n-1)]$, where Y_1 is the disease level at first assessment, Y_n is the disease level at last assessment, D is the difference in the number of days from the last assessment to the first assessment, n is the number of assessments, and AUDPC = $\sum [((Y_i + Y_{i+1}) (X_i - X_{i+1}))/2]$. For AUDPC, Y_i is number of infected leaves at day X_i and Y_{i+1} is number of infected leaves at day X_{i+1}.

Tomatoes were harvested from a 2 m section of each plot on Sept 17; red fruit, green fruit, and rots were separated and weighed. Fifty randomly selected red fruit were assessed for anthracnose after three days in storage by sorting into the following classes: 0 = no lesions, 1 = one lesion, 2 = two to three lesions, 3 = four or more lesions. A disease severity index (DSI) was calculated using the following equation:

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

Statistical analysis was conducted using ARM 2019 (Gylling Data Management, Brookings, SD). Data were tested for normality using Bartlett's homogeneity of variance test. Analysis of variance was conducted using Tukey's HSD and mean comparisons were performed when $P \leq 0.05$.

RESULTS & CONCLUSIONS: AUDPS, a measure of total defoliation over the growing season, was lower in treatments Bravo ZN (both rates), Manzate Pro-Stick, Quadris, Tanos, Sercadis, Fontelis, Aprovia TOP, Miravis Duo, Luna Privilege, Phostrol + Bravo ZN, and Cevya compared to the nontreated control (Table 1). Defoliation on the final assessment date, September 4, was lower than the nontreated control in all treatments than the Cueva and Phostrol alone. The Cueva and Phostrol alone treatments were ineffective and had similar levels of defoliation, at all assessment dates, as the nontreated control. The addition of Bravo ZN to Phostrol decreased defoliation compared to the Phostrol only treatment. However, the level of defoliation observed in the Phostrol + Bravo ZN treatment was the same as that observed in the Bravo ZN treatments (both rates). Both the low and the high rate of Bravo ZN treatments showed similar levels of defoliation and tomato total yield.

Anthracnose incidence was very low and there were no differences among treatments (Table 2).

Five of the treatments that had lower AUDPS values than the nontreated control also had increased total tomato yields compared to the control; Manzate Pro-stick, Aprovia, Miravis Duo, Luna Privilege, Phostrol + Bravo ZN, and Cevya (Table 3). While the addition of Bravo ZN to Phostrol decreased defoliation compared to the Phostrol alone treatment, it did not result in greater red or total tomato yields.

Table 1. Percent defoliation and area under the disease progress stairs (AUDPS) in tomatoes inoculated with *A. solani* and *S. lycopersici* and treated with different fungicides, Ridgetown, ON, 2019.

Treatment (per Ha)[a]	Defoliation (%)[b]				
	Aug 7	Aug 13	Aug 22	Sept 4	AUDPS
Nontreated control	22 a	45 a	96 a	100 a	3799 a
Bravo ZN @ 3.2 L	5 bcd	12 bc	48 cd	90 cd	2516 cd
Bravo ZN @ 2.4 L	6 bcd	13 bc	47 cd	90 cd	2577 cd
Manzate Pro-Stick @ 2.5 kg	7 bcd	12 bc	56 bcd	91 bcd	2697 bcd
Cueva @ 0.5% v/v	26 a	39 a	91 a	100 a	3780 a
Quadris @ 400 mL	1 d	7 c	32 d	85 cd	2160 d
Tanos @ 560 g	11 abc	15 bc	65 bc	96 abc	2987 bc
Sercadis @ 250 mL	1 d	6 c	32 d	85 cd	2177 d
Fontelis @ 1.5 L	3 cd	11 bc	48 cd	91 bcd	2563 cd
Aprovia TOP @ 805 mL	1 d	5 c	30 d	80 d	2037 d
Miravis Duo @ 1 L	6 bcd	10 bc	37 cd	85 cd	2336 cd
Luna Privilege @ 225 mL	1 d	7 c	32 d	84 d	2143 d
Phostrol @ 2.9 L	15 ab	25 ab	81 ab	99 ab	3369 ab
Phostrol @ 2.9 L + Bravo ZN @ 2.4 L	5 bcd	7 c	37 cd	85 cd	2301 cd
Cevya @ 190 mL	2 cd	7 c	37 cd	85 cd	2245 d

[a] Treatments were applied on A = Jun 27, B = Jul 10, C = July 19, D = Jul 30, E = Aug 9, F = Aug 20, G = Aug 30.

[b] Data was transformed using an arcsine square root transformation and the back-transformed means are presented.

[c] Numbers in a column followed by the same letter are not significantly different at $P \leq 0.05$, Tukey's HSD.

Table 2. Anthracnose incidence and severity in tomatoes inoculated with *A. solani* and *S. lycopersici* and treated with different fungicides, Ridgetown, ON, 2019.

Treatment (per Ha) [a]	Anthracnose	
	Severity (DSI)	Incidence (%)
Non-treated control	0.5 a [b]	1.5 a
Bravo ZN @ 3.2 L	0.0 a	0.0 a
Bravo ZN @ 2.4 L	0.5 a	0.5 a
Manzate Pro-Stick @ 2.5 kg	0.5 a	1.0 a
Cueva @ 0.5% v/v	1.0 a	2.0 a
Quadris @ 400 mL	0.0 a	0.0 a
Tanos @ 560 g	1.0 a	2.0 a
Sercadis @ 250 mL	0.0 a	0.0 a
Fontelis @ 1.5 L	0.0 a	0.0 a
Aprovia TOP @ 805 mL	0.0 a	0.0 a
Miravis Duo @ 1 L	0.0 a	0.0 a
Luna Privilege @ 225 mL	0.0 a	0.0 a
Phostrol @ 2.9 L	0.8 a	1.5 a
Phostrol @ 2.9 L + Bravo ZN @ 2.4 L	0.0 a	0.0 a
Cevya @ 190 mL	0.3 a	1.5 a

[a] Treatments were applied on A = Jun 27, B = Jul 10, C = July 19, D = Jul 30, E = Aug 9, F = Aug 20, G = Aug 30.

[b] Numbers in a column followed by the same letter are not significantly different at $P \leq 0.05$, Tukey's HSD.

Table 3. Yield in tomatoes inoculated with *A. solani* and *S. lycopersici* and treated with different fungicides. Ridgetown, ON, 2019.

Treatment (per Ha) [a]	Yield (tons/acre)			
	Reds	Greens [c]	Rots [c]	Total
Non-treated control	29.2 b [b]	0.7 bc	0.47 a	30.4 c
Bravo ZN @ 3.2 L	35.7 ab	3.4 a	0.16 ab	39.9 abc
Bravo ZN @ 2.4 L	39.2 a	3.3 ab	0.18 ab	42.8 ab
Manzate Pro-Stick @ 2.5 kg	37.4 ab	2.3 abc	0.14 ab	40.0 abc
Cueva @ 0.5% v/v	34.0 ab	0.5 c	0.32 ab	34.9 bc
Quadris @ 400 mL	34.2 ab	4.0 a	0.14 ab	38.5 abc
Tanos @ 560 g	35.9 ab	2.1 abc	0.36 ab	38.5 abc
Sercadis @ 250 mL	36.5 ab	3.7 a	0.09 b	40.3 abc
Fontelis @ 1.5 L	35.4 ab	2.2 abc	0.27 ab	38.1 abc
Aprovia TOP @ 805 mL	39.9 a	4.9 a	0.14 ab	45.2 a
Miravis Duo @ 1 L	35.8 ab	4.2 a	0.13 ab	40.7 ab
Luna Privilege @ 225 mL	39.4 a	5.4 a	0.24 ab	45.2 a
Phostrol @ 2.9 L	31.0 ab	2.1 abc	0.17 ab	34.6 bc
Phostrol @ 2.9 L + Bravo ZN @ 2.4 L	39.6 a	3.6 a	0.22 ab	43.5 ab
Cevya @ 190 mL	36.9 ab	3.4 a	0.16 ab	40.9 ab

[a] Treatments were applied on A = Jun 27, B = Jul 10, C = July 19, D = Jul 30, E = Aug 9, F = Aug 20, G = Aug 30.

[b] Numbers in a column followed by the same letter are not significantly different at $P \leq 0.05$, Tukey's HSD.

[c] Data was transformed using the logarithm transformation and the back-transformed means are presented.

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2019 Research Report

Evaluation of Oxidate 2.0 for transplant sanitation prior to shipping

Prepared for Ontario Tomato Research Institute (OTRI)
October 23, 2019

Research Team:

- Cheryl Trueman, Ph.D., Assistant Professor, Department of Plant Agriculture, University of Guelph – Ridgetown Campus
- Phyllis May, Research Technician
- We thank Dr. Kris McNaughton for preparing this report

Highlights/Summary:

- Bacterial spot (*Xanthomonas* spp.) is an economically important disease of tomatoes in Ontario. Due to a lack of effective biological and chemical controls and limited host resistance, bacterial spot management is challenging.
- The objective of the research was to evaluate the use of Oxidate 2.0 as a 'sanitizer' of outgoing tomato transplants prior to shipping. *Xanthomonas* spp. inoculated tomato plants were treated with Oxidate 2.0, and depending on experiment, the plants grown in either a greenhouse or field situation. Disease pressure was low in the greenhouse trial and no differences between Oxidate 2.0 treated plants and untreated plants could be identified. No treatment differences were observed for the field Oxidate 2.0 trial either. The number of days from tomato transplant and the observation of bacterial spot leaf lesions was the same for the Oxidate 2.0 and inoculated control treatment. Based on 2019 greenhouse and field data, application of Oxidate 2.0 does not appear to reduce the occurrence of bacterial spot in tomato transplants. Additional research is required to support this finding.

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TITLE: Evaluation of Oxidate 2.0 for transplant sanitation prior to shipping

PEST(S): Bacterial spot (*Xanthomonas gardneri* DC00T7A)

MATERIALS: Oxidate 2.0 (Hydrogen Peroxide 27% + Peroxyacetic acid 2.5%).

METHODS: The trials were conducted at Ridgetown Campus, University of Guelph in both the greenhouse and field. Treatments for both trial locations included a non-inoculated control, an inoculated control, and an inoculated treatment sprayed with Oxidate 2.0 (1% v/v).

Plant innoculation: *Xanthomonos gardneri* isolate DC00T7A was streaked on tryptic soy agar and incubated at room temperature on May 18. The DC00T7A isolate was used as it was confirmed pathogenic in February 2019. On May 23 tomato plants, cultivar H5108, were inoculated with *X. gardneri*. Inoculum was made using cotton swabs to transfer the plated *X. gardneri* to distilled water and then the inoculum was adjusted to a concentration of 1.0×10^{6} CFU ml^{-1}. Inoculum was sprayed on tomatoes designated for the two inoculated treatments. As both the greenhouse and field trials had the same treatments, tomato plants for both trials were inoculated at the same time. Plants were watered 7 hours after inoculation.

Trial establishment: On May 24 Oxidate 2.0 was applied to the appropriate treatment. Both the greenhouse and field trials were designed as a randomized complete block with four replications per treatment.

For the greenhouse trial each replicated treatment consisted of one half of a 200-cell tray. Plywood barriers 30 cm high and painted with a water repellent paint were used to separate plots and prevent inter-plot interference. Trays were watered regularly using overhead irrigation. To further prevent cross-contamination between plots, hands were disinfested with 70% alcohol whenever trays or plants were handled. On June 6 treatments were evaluated to determine if *X. gardneri* was present. As disease incidence was low, the experiment was allowed to run for one more week. On June 13 treatments were evaluated for disease again. Plants were removed from the tray and the percentage of tomato plants infected with the disease and the percentage of leaf area affected was determined. Unfortunately the level of infection was low, with the percentage leaf area affected calculated at less than 0.1%.

For the field trial, tomato trays were brought to the field on May 24, one treatment at a time, to restrict cross-contamination. Plants were planted using a mechanical transplanter. In an effort to minimize contamination between treatments, the non-inoculated control plots were planted first, followed by the inoculated control and finally the inoculated control plants treated with Oxidate 2.0. The transplanter was disinfected between the planting of the two inoculated treatments using a 10% Dettol solution and the Dettol rinsed off prior to planting. Plots were 7 m long and 6 m wide. Each plot consisted of three twin rows, with only the center twin row planted using the treated plants. The two outside twin rows for each plot acted as a physical barrier between plots to minimize contamination. On May 31 ten plants per plot were flagged; 5 plants from each side of the center twin row. Each flagged plant was scouted for disease 2 to 3 times per week. Leaves with suspect lesions were removed and placed in a ziplock bag. In the lab, collected leaves were removed from the bag and rinsed with tap water. Lesions were photographed and excised from the leaf with a sterile scalpel. Lesions were cut into smaller pieces, placed in a centrifuge tube with 0.5 ml sterile distilled water and stored at 4 C for one hour. Tryptic soy agar plates were then streaked using the lesion inoculum and plates incubated for 3-5 days. Any probable *X. gardneri* colonies were then isolated and sent to Laboratory Services at University of Guelph for positive identification using PCR (DNA analysis). Sampling ended on August 9 as the trial was mature.

Statistical analysis was conducted using ARM 2019 (Gylling Data Management, Brookings, SD). Data were tested for normality using Bartlett's homogeneity of variance test. All data presented was normal and did not require transformation for analysis. Analysis of variance was conducted using Tukey's HSD and means comparisons were performed when $P \leq 0.05$.

RESULTS & CONCLUSIONS: The greenhouse trial had very low disease pressure (Table 1), and no differences for the percentage leaf area affected rating were observed between treatments. There was a treatment difference for the percentage of infected plants rating. The non-inoculated control had zero infected plants while both inoculated treatments had similar, but significantly greater infection rates. This highlights that our methods to prevent cross contamination were sufficient and that the *Xanthomonos* isolate used was viable.

Application of Oxidate 2.0 to tomato transplants did not delay the development of *Xanthomonos gardneri* in the field trial. There was no difference in the number of days between tomato transplant and the observation of bacterial spot symptoms on tomatoes for any treatment (Table 2). Based on greenhouse and field observations, it does not appear that the application of Oxidate 2.0 reduces or delays the development of *X. gardneri* symptoms in tomato transplants. Additional research is required to confirm these findings.

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Table 1. Greenhouse trial of tomato inoculated with bacterial spot and treated with Oxidate 2.0, Ridgetown, ON, 2019.

Treatment	Symptomatic Plants (%)	Leaf area (%) on Affected Leaves[b]
Non-inoculated control	**0.0 b**	0.0 a
Inoculated control	**4.1 a**	0.0 a
Oxidate 2.0 (@ 1% v/v)	**4.7 a**	0.0 a

[a] Numbers in a column followed by the same letter are not significantly different at $P \leq 0.05$, Tukey's HSD.

[b] Very low levels of bacterial spot (< 0.01% leaf area affected) was observed.

Table 2. Field trial of tomato inoculated bacterial spot and treated with Oxidate 2.0, Ridgetown, ON, 2019.

Treatment	Days to Symptomatic Leaves[b]
Non-inoculated control	58 a
Inoculated control	44 a
Oxidate 2.0 (@ 1% v/v)	31 a

[a] Numbers in a column followed by the same letter are not significantly different at $P \leq 0.05$, Tukey's HSD.

[b] Mean number of days, after tomato transplant, until bacterial spot leaf lesions were observed.

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2019 Research Report

Neonicotinoid alternatives for in-furrow management of Colorado potato beetle in tomato

Prepared for the Ontario Tomato Research Institute
October 24, 2019

Research Team:

- Cheryl Trueman, Ph.D., Assistant Professor, Department of Plant Agriculture, University of Guelph – Ridgetown Campus
- Phyllis May, Research Technician
- We thank Dr. Kris McNaughton for preparing this report

Highlights/Summary:

- The objective was to evaluate the efficacy of in-furrow applications of Sivanto Prime (flupyradifurone, group 4D) and Verimark (cyantraniliprole, group 28) for management of Colorado potato beetle in tomatoes. These insecticides are potential in-furrow alternatives to the neonicotinoid Admire (imidacloprid), which is under review by PMRA for future phase out.
- There was good CPB pressure in the trial and we completed extra ratings beyond the proposed six weeks post transplanting to obtain additional data on product efficacy.
- Treatments Admire, Sivanto Prime (high rate) and Verimark (low and high rate) provided good control of CPB and improved tomato yield compared to the untreated control. Generally Sivanto Prime (high rate) and Verimark (low and high rate) had similar adult and larvae CPB counts, and percent feeding damage and defoliation as the industry standard, Admire.
- It is suggested that this research be repeated for a second year to obtain additional information on efficacy, especially the duration of efficacy.
- Data from this work will be shared with the registrants of Sivanto Prime and Verimark this fall and winter. Representatives from both companies (Bayer and FMC) visited the trial in July and are supportive of this work.

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TITLE: Neonicotinoid alternatives for in-furrow management of Colorado potato beetle in tomato

PEST: Colorado Potato Beetle (*Leptinotarsa decemlineata*)

MATERIALS: Sivanto Prime (flupyradifurone 200 g L^{-1}), Verimark (cyantraniliprole 200 g L^{-1}), and Admire (imidacloprid 240 g L^{-1}).

METHODS: The trial was completed at the Ridgetown Campus, University of Guelph. Tomato cultivar 'Bugbait' was transplanted into twin-rows on May 31 using a mechanical transplanter. Bugbait was developed by Jim Dick, Tomato Solutions, and is more attractive to Colorado Potato Beetle (CPB) than other cultivars. Rows were spaced 2.0 m apart, and within row spacing was 33 cm. Each plot consisted of one 7m twin-row (approximately 40 plants per plot). The trial was established as a randomized complete block design with 4 replications per treatment.

In-furrow treatments were applied at the time of planting using 72 mL of water per meter of twin row. In-furrow treatments were applied using a Lurmark 015-F110 nozzle that was installed in the shoe before the kicker on the transplanter. The applications were applied using CO_2 pressure of 30 psi. Treatments included an untreated control and applications of Admire, an industry standard, applied at a rate of 10 ml per 100 m row, Sivanto Prime applied at two rates, 15 ml and 20 ml per 100 m row, and Verimark also applied at two rates, 7 ml and 10 ml per 100 m row.

The trial was irrigated using a drip irrigation system as required during the growing season. Maintenance pesticide applications were made for fungal disease control using Quadris (Azoxystrobin) on June 27 and Bravo ZN (chlorothalonil) on July 9, 19, 30, and August 7.

The number of CPB adults, larvae, and egg masses in each plot were counted on June 3, 6, 10, 13, 17, 20, 24, July 2, 8, 11, 15, 18, 22, 25, 29, and August 2 as appropriate. Percent feeding damage and defoliation was also assessed on each of the evaluation dates. Percent feeding damage was determined by dividing the total number of plants with feeding damage by the total number of plants in the plot and multiplying by 100. Yield was assessed with a 2 m row harvest and fruit separated by red, green, and rot. Total yield was also calculated.

Statistical analysis was conducted using SAS 9.4 (SAS Institute Inc., Cary, NC). Data were tested for normality and homogeneity of variance using the PROC UNIVARIATE procedure in SAS. Data which were not normal ($P < 0.05$) were transformed. Analysis of variance was conducted and means comparisons were performed when $P < 0.05$, with Fisher's protected LSD. Data compared on the transformed scale were converted back to the original scale for the presentation of results.

RESULTS: During the nine week evaluation period, the treatments generally had the same number or more living, adult CPB than the nontreated control for most of the assessment dates (Table 1). The July 11 and 15 rating dates differ from this finding, in that the treatments typically had fewer adult CPB than the untreated control. The number of adult CPB per plot was relatively low throughout the evaluation period, with only one treatment reaching a count of 10 on July 22. Similarly the number of egg masses counted per plot was also low throughout the trial period, with numbers appearing to peak on July 22 (Table 2). The Admire, Sivanto Prime (high rate), and Verimark (low and high rate) treatments had fewer

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egg masses than the untreated control for the June 17 rating, while only the Admire treatment had fewer egg masses on the June 20 rating. There were no other differences among treatments for the number of egg masses on any other evaluation dates.

No larvae was observed in the trial until June 17, approximately 1.5 weeks after the first adult CPB was counted. The two Verimark treatments had fewer larvae than the untreated control for the June 17, 20, July 2, 11, 18, and 25 evaluations (Table 3). Additionally, on August 2, when the number of larvae in the trial peaked, the number of larvae for either applied rate of Verimark was lower than the untreated control and the high rate of Verimark had fewer larvae than any other treatment, including Admire. Generally the low and high rates of Sivanto Prime had similar larvae numbers to the untreated control, with the exception of the June 17 and 20 evaluations. The high rate of Sivanto Prime also had fewer larvae than the untreated control on the July 15 rating.

As expected, the percentage feeding damage observed peaked on August 2, along with the greatest CPB larvae counts. Again, the two Verimark treatments had less observed feeding damage than the untreated control, with the high Verimark treatment showing less damage than the Admire or Sivanto Prime treatments as well (Table 4). When feeding damage differences were noted (June 17, 20, 24, July 2, 8, 15, 18, 22, and August 2) plots treated with any of the insecticide treatments typically had less feeding damage than the untreated control. Exceptions to this occurred on June 17, 24, July 8, 18, 22, and August 2 when the low Sivanto Prime rate had similar amounts of feeding damage as the untreated control. The high rate of Sivanto Prime also had the same amount of feeding damage as the untreated control on the July 18 and August 2 rating. Percent defoliation results were similar to the feeding damage findings in that damage peaked at the August 2 evaluation and that the two rates of Verimark had less observed defoliation than the untreated control at most evaluation dates (Table 5).

The Admire, Sivanto Prime (high rate) and Verimark (low and high rate) treatments had greater red and total fruit yields than the untreated control (Table 6).

CONCLUSIONS: Treatments Admire, Sivanto Prime (high rate) and Verimark (low and high rate) provided good control of CPB and improved tomato yield compared to the untreated control. Generally Sivanto Prime (high rate) and Verimark (low and high rate) had similar adult and larvae CPB counts, and percent feeding damage and defoliation as the industry standard. Admire, treatment. While not reflected in increased tomato yield the Verimark (high rate) treatment resulted in the lowest defoliation damage and larvae counts when larvae numbers peaked on August 2, 63 days after the initial in-furrow treatment.

[illegible]

Table 1. Mean number of adult Colorado Potato Beetle (CPB) in tomatoes treated with different insecticides, Ridgetown, 2019.

Treatment	CPB Adult (number per 7 m plot)[a]															
	Jun 3	Jun 6	Jun 10	Jun 13	Jun 17	Jun 20	Jun 24	Jul 2	Jul 8	Jul 11	Jul 15	Jul 18	Jul 22	Jul 25	Jul 29	Aug 2
Nontreated control	0.0 ns	0.7 ns	1.5 bc	0.0 d	0.9 cd	1.0 ns	0.2 ns	0.2 ns	0.7 ns	3.6 a	6.3 a	2.9 ns	7.9ns	3.7 ns	1.5 b	1.9 ns
Admire (10 mL per 100 m row)	0.0	0.4	0.2 c	0.6 cd	0.0 d	1.0	1.6	0.4	0.0	0.0 b	1.1 b	4.2	6.6	8.3	9.2 a	1.3
Sivanto Prime (15 mL per 100 m row)	0.0	0.7	1.5 bc	1.1 bc	1.8 abc	2.0	1.1	0.6	0.2	0.6 b	2.1 ab	3.9	10.0	8.1	8.9 a	1.8
Sivanto Prime (20 mL per 100 m row)	0.0	0.9	1.6 ab	0.9 bc	1.1 bcd	1.9	1.1	0.0	0.2	0.7 b	0.7 b	4.0	6.2	4.1	5.4 a	0.5
Verimark (7 mL per 100 m row)	0.0	0.3	0.6 bc	2.3 ab	3.2 ab	3.4	2.1	0.2	0.0	0.2 b	2.6 ab	4.2	7.4	4.4	8.3 a	3.4
Verimark (10 mL per 100 m row)	0.0	1.4	4.4 a	3.1 a	4.4 a	3.9	2.0	0.0	0.2	0.0 b	0.7 b	7.4	7.2	5.8	6.1 a	2.0

All data in this table were transformed using a log transformation, data presented here are the back transformed means.

[a] Means followed by the same letter within in a column are not significantly different according to Fisher's protected LSD at $P \leq 0.05$. ns = not significant.

Table 2. Mean number of Colorado Potato Beetle (CPB) egg masses in tomatoes treated with different insecticides, Ridgetown, 2019.

Treatment	CPB Egg Masses (number per 7 m plot)[b]														
	Jun 6	Jun 10	Jun 13	Jun 17	Jun 20	Jun 24	Jul 2[a]	Jul 8	Jul 11	Jul 15	Jul 18	Jul 22[a]	Jul 25[a]	Jul 29[a]	Aug 2
Nontreated control	0.3 ns	0.8 ns	0.3 ns	3.3 a	3.8 ab	2.3 ns	0.0 ns	2.0 ns	0.5 ns	0.3 ns	2.5 ns	4.0 ns	1.6 ns	3.3 ns	1.0 ns
Admire (10 mL per 100 m row)	0.0	0.3	0.5	0.8 bc	0.3 c	0.8	0.3	0.6	0.0	0.8	3.0	8.3	0.7	1.4	0.0
Sivanto Prime (15 mL per 100 m row)	0.0	0.3	0.3	2.3 ab	4.8 a	3.3	0.5	1.8	0.3	4.0	6.0	8.3	0.2	0.2	0.4
Sivanto Prime (20 mL per 100 m row)	0.0	0.5	0.0	0.3 c	0.9 bc	1.7	0.0	0.0	0.0	0.0	6.4	6.9	0.0	0.2	0.0
Verimark (7 mL per 100 m row)	0.3	0.8	0.3	0.8 bc	2.3 abc	2.5	0.0	0.0	0.0	2.5	4.3	10.5	0.9	0.6	0.0
Verimark (10 mL per 100 m row)	0.0	0.5	0.0	1.3 bc	3.5 ab	2.3	0.3	0.0	0.0	0.3	3.0	8.0	0.7	0.2	0.7

[a] Data in this column were transformed using a log transformation, data presented here are the back transformed means.

[b] Means followed by the same letter within in a column are not significantly different according to Fisher's protected LSD at $P \leq 0.05$. ns = not significant.

Table 3. Mean number of Colorado Potato Beetle (CPB) larvae in tomatoes treated with different insecticides, Ridgetown, 2019

Treatment	CPB Larvae (number per 7 m plot)[a]															
	Jun 3	Jun 6	Jun 10	Jun 13	Jun 17	Jun 20	Jun 24	Jul 2	Jul 8	Jul 11	Jul 15	Jul 18	Jul 22	Jul 25	Jul 29	Aug 2
Nontreated control	0.0 ns	0.0 ns	0.0 ns	0.0 ns	8.3 a	15.8 a	12.5 ns	10.4 ab	5.9 ns	10.3 a	5.9 a	6.7 a	11.6 ns	25.6 a	35.8 ns	67.8 a
Admire (10 mL per 100 m row)	0.0	0.0	0.0	0.0	0.0 b	0.0 b	0.7	3.4 bc	3.6	1.6 ab	2.2 abc	1.3 abc	2.9	5.6 b	19.2	56.0 ab
Sivanto Prime (15 mL per 100 m row)	0.0	0.0	0.0	0.0	0.0 b	0.9 b	1.1	19.2 a	18.3	10.8 a	3.0 ab	4.0 ab	13.5	27.4 a	18.8	69.6 a
Sivanto Prime (20 mL per 100 m row)	0.0	0.0	0.0	0.0	0.9 b	0.0 b	1.1	2.8 bcd	6.1	3.0 ab	1.3 bc	6.0 a	14.9	27.7 a	22.6	77.0 a
Vermark (7 mL per 100 m row)	0.0	0.0	0.0	0.0	0.8 b	0.5 b	0.7	0.0 d	1.6	0.7 b	0.2 c	0.2 c	8.0	2.1 b	13.8	32.8 b
Vermark (10 mL per 100 m row)	0.0	0.0	0.0	0.0	0.0 b	0.4 b	0.9	0.2 cd	0.2	0.0 b	0.4 bc	0.5 bc	2.2	2.7 b	6.5	13.6 c

All data in this table were transformed using a log transformation, data presented here are the back transformed means

[a] Means followed by the same letter within in a column are not significantly different according to Fisher's protected LSD at $P = 0.05$. ns = not significant

Table 4. Mean percentage of feeding damage caused by Colorado Potato Beetle (CPB) in tomatoes treated with different insecticides, Ridgetown, 2019

Treatment	Feeding Damage (%)[a]															
	Jun 3	Jun 6	Jun 10	Jun 13	Jun 17	Jun 20	Jun 24	Jul 2	Jul 8	Jul 11	Jul 15	Jul 18	Jul 22	Jul 25	Jul 29	Aug 2
Nontreated control	0.0 ns	0.0 ns	0.5 ns	11.9 ns	48.0 a	37.2 a	23.2 a	56.0 a	21.9 a	34.3 ns	55.0 a	48.3 a	48.5 a	38.9 ns	29.7 ns	82.5 a
Admire (10 mL per 100 m row)	0.0	0.0	0.0	1.5	17.2 b	0.9 b	1.0 b	0.5 c	0.9 b	6.2	5.6 b	11.4 b	14.3 bc	18.4	40.0	69.9 ab
Sivanto Prime (15 mL per 100 m row)	0.0	0.0	0.0	0.5	26.7 ab	8.3 b	4.8 ab	20.3 b	19.8 a	24.7	14.4 b	33.1 ab	31.4 ab	45.3	50.1	78.7 ab
Sivanto Prime (20 mL per 100 m row)	0.0	0.0	0.5	0.9	19.7 b	5.0 b	3.6 b	0.5 c	0.0 b	3.6	2.7 b	22.0 ab	13.9 bc	36.2	54.5	79.4 ab
Vermark (7 mL per 100 m row)	0.0	0.0	0.0	0.5	15.4 b	0.5 b	0.5 b	0.0 c	0.0 b	0.9	4.2 b	8.0 b	1.8 c	6.1	47.6	49.0 bc
Vermark (10 mL per 100 m row)	0.0	0.0	0.0	0.9	17.2 b	1.3 b	0.0 b	0.5 c	0.0 b	0.0	0.5 b	7.7 b	15.0 bc	4.3	29.0	21.0 c

All data in this table were transformed using an arc sine square root transformation, data presented here are the back transformed means

[a] Means followed by the same letter within in a column are not significantly different according to Fisher's protected LSD at $P = 0.05$. ns = non significant

Table 5. Mean percentage defoliation caused by Colorado Potato Beetle (CPB) in tomatoes treated with different insecticides, Ridgetown, 2019

Treatment	CPB Adult (number per 7 m plot)[a]															
	Jun 3	Jun 6	Jun 10	Jun 13	Jun 17	Jun 20	Jun 24	Jul 2	Jul 8	Jul 11	Jul 15	Jul 18	Jul 22	Jul 25	Jul 29	Aug 2
Nontreated control	0.0 ns	0.0 ns	0.0 ns	0.0 ns	3.0 ns	11.1 a	11.8 a	7.5 a	13.8 a	8.1 a	10.1 a	10.9 a	10.6 a	7.1 a	12.1 ns	18.8 a
Admire (10 mL per 100 m row)	0.0	0.0	0.0	0.0	1.0	0.2 b	0.2 b	0.0 b	0.2 b	0.2 b	1.4 b	1.4 b	3.8 ab	0.4 bc	1.8	9.1 ab
Sivanto Prime (15 mL per 100 m row)	0.0	0.0	0.0	0.0	1.2	0.7 b	1.5 b	0.2 b	5.1 b	1.4 b	2.8 b	3.9 b	5.8 ab	2.8 ab	3.5	14.3 a
Sivanto Prime (20 mL per 100 m row)	0.0	0.0	0.0	0.0	1.4	4.1 ab	2.2 ab	0.0 b	0.0 b	0.0 b	0.4 b	2.4 b	1.6 bc	1.2 bc	2.7	13.6 a
Verimark (7 mL per 100 m row)	0.0	0.0	0.0	0.0	0.9	0.2 b	0.2 b	0.0 b	0.0 b	0.0 b	0.4 b	0.9 b	0.2 c	0.0 c	0.4	1.4 bc
Verimark (10 mL per 100 m row)	0.0	0.0	0.0	0.0	0.9	0.5 b	0.0 b	0.0 b	0.0 b	0.0 b	0.2 b	0.9 b	1.7 bc	0.0 c	0.2	0.0 c

All data in this table were transformed using an arc sine square root transformation; data presented here are the back transformed means

[a] Means followed by the same letter within in a column are not significantly different according to Fisher's protected LSD at $P \leq 0.05$. ns = not significant

Table 6. Yield (kg) in tomatoes treated with different insecticides for Colorado Potato Beetle (CPB) control, Ridgetown, 2019.

Treatment	Yield (kg per 2m of single row)[a]			
	Red Fruit	Green Fruit	Rotted Fruit	Total Fruit
Nontreated control	8.1 b	2.1 ns	0.3 ns	10.7 b
Admire (10 mL per 100 m row)	12.8 a	2.9	0.3	16.0 a
Sivanto Prime (15 mL per 100 m row)	11.4 ab	2.4	0.4	14.1 ab
Sivanto Prime (20 mL per 100 m row)	13.3 a	2.5	0.4	16.2 a
Verimark (7 mL per 100 m row)	13.7 a	3.6	0.5	17.9 a
Verimark (10 mL per 100 m row)	12.8 a	3.1	0.5	16.5 a

All data in this table were transformed using a square root transformation; data presented here are the back transformed means

[a] Means followed by the same letter within in a column are not significantly different according to Fisher's protected LSD at $P \leq 0.05$. ns = not significant

2019 Research Report

Management of Phytophthora fruit rots in Essex County, 2019

Prepared for the Ontario Tomato Research Committee (OTRI)
November 4, 2019

Research Team:

- Cheryl Trueman (Ph.D.), Assistant Professor, Department of Plant Ag, U of G – Ridgetown
- Grower cooperator (to be kept confidential)
- Amanda Tracey, OMAFRA Vegetable Specialist

Highlights/Summary:

- The objective of this research was to complete a strip trial to evaluate high (five targeted fungicide applications) and low input (three targeted fungicide applications) foliar management options for Phytophthora fruit rot with an affected grower cooperator in Essex County.
- A strip trial was completed at a commercial tomato field in Essex County infested with *P. capsici*. The low input fungicide program consisted of three applications beginning at early fruit set (Orondis Ultra + Phostrol, Zampro + Phostrol and Torrent + Phostrol). The high input program consisted of five applications beginning at early fruit set (Orondis Ultra + Phostrol, Zampro + Phostrol, Torrent + Phostrol, Orondis Ultra and Zampro). Fruit rot yield averaged more than 6% of total yield in the control plots. Both fungicide programs reduced rot yield by an average of 78%, which was equivalent to a reduction of 2 tons/acre. There was no advantage of the high input program compared to the low input program. The foliar fungicide programs tested add a significant cost to tomato disease management, since none of these fungicides control early blight, Septoria leaf spot, or anthracnose. Results for the high input program were consistent with 2018, where we also observed a reduction in rot yield compared to the control. We have also now identified that a reduced number of foliar applications can result in a similar reduction in fruit rots, with less financial burden on the grower. Future research should explore fungicide application timing and intervals to determine the most efficient use of fungicides for successful Phytophthora fruit rot management.

Funding:

- Ontario Tomato Research Institute
- Ontario Ministry of Agriculture, Food, and Rural Affairs
- In-kind support from: cooperating grower, Syngenta Canada, Belchim, BASF

TITLE: Management of Phytopthora fruit rot in processing tomatoes, Essex County strip trial

PEST(S): Phytophthora fruit rot (*Phytophthora capsici*)

MATERIALS: Orondis Ultra (oxathiapiprolin 30 g/L, mandipropamid 250 g/L), Phostrol (mono- and dibasic sodium, potassium, and ammonium phosphites 53.6%), Zampro (ametoctradin 300 g/L, dimethomorph 225 g/L), Torrent (cyazofamid 34.5%)

METHODS: The strip trial was established at a commercial processing tomato field in Essex County, where soil was known to be infested with *P. capsici* and previous tomato crops had significant issues with Phytopthora fruit rot. The trial was arranged in a randomized complete block design with three replications. The treated area for each plot was a minimum of six beds wide and 1000 feet long. Tomatoes of the 'H1014' variety were transplanted on May 23, 2019. The crop was grown according to normal grower practices for the duration of the trial. Maintenance applications for fungal diseases were applied on June 26 (mancozeb), July 15 (chlorothalonil), and July 30 (chlorothalonil). The cooperating grower used standard field equipment to apply fungicide treatments beginning at early fruit set. Treatments were applied on June 29 (A), July 9 (B), 19 (C), 29 (D) and Aug 10 (E). At the end of July two 2 m harvest areas per block were marked. Harvest areas were determined by walking a transect perpendicular to the length of the treated plots. Harvest areas were marked with flags, and care was taken to avoid areas that introduced additional variability, particularly low spots or areas with low plant stand. Tomatoes were harvested on August 29, 2019 from all harvest plots. All tomatoes within each 2 m harvest area were sorted into reds, greens, and rots (fruit with no structural integrity) and weighed.

Statistical analysis was conducted using ARM 9 (Gylling Data Management, Brookings, SD). Data were tested for normality using Bartlett's homogeneity of variance test. Analysis of variance was conducted using Tukey's HSD and mean comparisons were performed when $P \leq 0.05$.

RESULTS & CONCLUSIONS: Fruit rot yield was more than 6% of total yield in the control blocks. Both fungicide programs reduced rot yield by an average of 78%, which was equivalent to a reduction of 2 tons/acre. There was no advantage of the high input program compared to low input program. Future research should explore fungicide application timing and intervals to determine the most efficient use of fungicides for successful Phytophthora fruit rot management.

Table 1. Yield (tons/acre) of tomatoes treated with different fungicides for management of Phytophthora fruit rot – Essex County, 2019.

Program (product rate per Ha (ABCDE)) [a]	Yield (tons/acre) [b]			
	Reds	Greens	Rots	Total
Control	33.8 a [c]	2.0 a	2.5 a	38.4 a
Orondis Ultra @ 600 mL + Phostrol 2.9 L (A) Zampro @ 1 L + Phostrol @ 2.9 L (B) Torrent @ 200 mL + Phostrol @ 2.9 L (C) Orondis Ultra @ 600 mL (D) Zampro @ 1 L (E)	38.8 a	2.7 a	0.6 b	42.1 a
Orondis Ultra @ 600 mL + Phostrol 2.9 L (A) Zampro @ 1 L + Phostrol @ 2.9 L (B) Torrent @ 200 mL + Phostrol @ 2.9 L (C)	41.0 a	2.0 a	0.5 b	43.5 a

[a] All treatments received the standard grower program which did not include fungicides with activity against *P. capsici*. Application timings: A = June 29, B = July 9, C = July 19, D = July 29, E = Aug 10.

[b] Two 2 m sections per plot were harvested.

[c] Numbers in a column followed by the same letter are not significantly different at $P \leq 0.05$, Tukey's HSD.

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2019 Research Report

Enhancing Late Blight Surveillance and Management in Tomatoes – Annual Report YEAR 1

Prepared for the Ontario Tomato Research Committee (OTRI)
November 19, 2019

Research Team:

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- Phyllis May, Research Technician
- We thank Dr. Kris McNaughton for preparing this report

Highlights/Summary:

- The objectives of this research was: a) compare the efficacy of the Spornado passive spore trap and the Rotorod active spore trap for early capture of *P. infestans* sporangia from the air, causal agent of late blight, in one of the Ontario processing tomato production regions, and b) conduct a field trial to validate the use of spore trapping versus current methods used to identify high-risk late blight periods and modify fungicide programs. The spore traps tested were established in eight locations in Kent County.
- The Spornado first detected the presence of *P. infestans* on July 18. Despite the positive detection, no late blight symptoms were observed on sentinel tomato plants or in Ontario tomato fields by August 26, the last day of sampling. The positive identification occurred one month after the BliteCast forecasting system first recommended protectant fungicide applications for late blight. Thus, using the Spornado would have reduced fungicide use and saved producers the cost of applying the more specific late blight fungicides earlier in the season. However, it would have increased fungicide use and cost compared to the current method of applying high-risk fungicides when symptoms are reported in the Great Lakes Region.
- The Rotorod first detected *P. infestans* on July 25, seven days later than the Spornado trap. Thus, using the Rotorod would also have reduced fungicide use and saved producers the cost of applying the more specific late blight fungicides earlier in the season. This year, we used a threshold of 10 sporangia m^3 to initiate fungicide applications using the Rotorod traps. Using this approach, fungicide use was reduced further and was similar to the current approach of applying high-risk fungicides when symptoms are reported in the Great Lakes Region. However, since this

threshold, based on work by Fall et al. 2015 is not field validated, we will review its use for the 2020 field season. An alternative is to base applications on positive/negative detections, similar to the Spornado. This would also allow for a more consistent comparison among traps but result in a loss of resolution (ie. not taking advantage of the ability to quantify pathogen load). A compromise may be to use a quantitative threshold with the Rotorod and a semi-quantitative threshold with the Spornado (ie. low/med/high). However, it is important to note that since the Spornado is a passive trap, it is impossible to calculate the pathogen concentration per volume of air.

- We intended to test the SporeCam at one site in 2019. However, since the company had not completed the work for the technology to identify *P. infestans*, we were unable to test it. We are assisting the company in finding a research group that can aid them in this, since it is beyond the scope of the current project and the facilities in Ridgetown are not appropriate for this testing and validation.
- Regular updates regarding spore trap detections were posted on ONvegetables.com as requested by OTRI. It should be noted that although we reported positive detections, as observed in 2019, positive detections alone do not always mean that late blight will develop.
- Research will continue in 2020 and 2021 to further validate spore traps as a decision support tool compared to other methods to determine high risk periods for late blight. Results from 2019 should be interpreted with caution as no late blight symptoms developed during the study period.

Funding:

- Ontario Tomato Research Institute
- Ontario Agri-Food Innovation Alliance
- Fresh Vegetable Growers of Ontario
- In kind support from: Sporometrics, Weather Innovations Inc. Tomato Solutions

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TITLE: Comparison of spore trap technology for *Phytophthora infestans* surveillance

PEST(S): late blight (*Phytophthora infestans*)

MATERIALS: Sporometrics passive spore traps 'Spornado', Rotorod

METHODS: Spornado passive spore traps (Figure 1) and Rotorod active spore traps (Figure 2) were situated at the edge of eight commercial processing tomato fields near Ridgetown (PI-01), Cedar Springs (PI-02), Kent Bridge (PI-03), Chatham (PI-04), Erieau (PI-05), Dover (PI-06), Wallaceburg (PI-07), and Dresden (PI-08), Ontario. Traps were setup along field edges as close as possible to the tomato crop without interfering with spray applications and other field work. All traps were installed on a metal pole 2.9 m high and placed 36" from the soil line. Data collection from the Spornado trap began June 10, while Rotorod data collection began June 20 due to an equipment shipping delay. Spornado traps function when air moves passively through a removable cassette with a fine mesh filter. Conversely, Rotorod traps have a consistent volume of air passing through or over the area collecting spores. Rotorod traps were set to operate from 6:00 to 15:00, alternating between 10 minutes on and 10 minutes off. The cassettes and glass rods for the Spornado and Rotorod traps, respectively, were changed twice a week, placed individually in a plastic bag to avoid cross-contamination, and shipped by overnight courier for same-day detection of *P. infestans* DNA using quantitative PCR. Spornado cassettes were shipped to Sporometrics while Rotorod rods were sent to Phytodata. The final cassettes or rods for each spore trap were collected on Aug 26. Based on the DNA copy number qPCR limit of detection (LOD) for Spornado traps, results for *P. infestans* identification were expressed as positive (*P. infestans* DNA detected, ≥LOD) /negative (*P. infestans* DNA not detected, >LOD). Identification from Rotorod traps was provided as sporangia per m^3. Sentinel tomato plots were also established at the Ridgetown, Cedar Springs, and Kent Bridge locations in order to visually determine the presence of *P. infestans*. Sentinel plots consisted of 3, twin rows of tomatoes planted on 2.0 m centers. Tomato variety TSH 34 was selected for its susceptibility to *P. infestans*. While the Sentinel plots were treated with Quadris to control early blight and Septoria leaf spot, no fungicides with late blight activity were applied.

RESULTS: Unfortunately there were a few issues with the Rotorod spore traps this summer. Initially equipment shipment was delayed so the traps were established June 20 rather than the June 10 Spornado trapping start date. This was partially due to the fact that funding from the Ontario Agri-Food Innovation Alliance was not confirmed until the third week of May, leaving only a couple weeks to obtain traps when the supplier (Phytodata) was also trying to plant research trials during an extremely wet spring. Additionally at some Rotorod trapping locations there were sampling dates when the rods did not properly extend to sample.

During the 5th week Spornado sampling period the first positive results for *P. infestans* occurred on July 18 (sampling period July 15-18), while the next sampling period on July 22 (sampling period July 18-22) had four of the eight traps test positive for *P. infestans* (Table 1). Over the same sampling period there were no sporangia noted at any location from the Rotorod traps. The first documented sporangia count from a Rotorod trap occurred on July 25 (sampling period July 22-25). There was no corresponding Spornado positive result for *P. infestans* for same location, on that sampling date. During the entire sampling period there was only one sampling date (August 15-19), and two locations, PI-02 and PI-05, where both the Spornado and Rotorod produced matching positive results for *P. infestans*.

Despite identifying the presence of *P. infestans* on July 18 and 25 with the Spornado and Rotorod traps, respectively, no late blight symptoms were observed on any of the sentinel tomato plants, nor was late blight reported in any Ontario tomato fields during the sampling period. Late blight was finally identified in potatoes in Norfolk county August 27. The lack of late blight symptoms on tomatoes was surprising as this year's environmental conditions were conducive for infection by *P. infestans*.

CONCLUSIONS: The traps first detected the presence of *P. infestans* mid- to late July; the 18th (Spornado) and 25th (Rotorod). Their detection of *P. infestans* DNA occurred approximately a month later than when BliteCast would have recommended the first late blight fungicide treatment, of June 15 (DSV of 18 reached, see field trial report 'Validation of fungicide programs for late blight based on pathogen surveillance' for further information). While sporangia were detected by the Rotorod, counts were not sufficient to trigger the application of high-risk late blight fungicides. We are reviewing the use of this threshold for the 2020 field season, as it is not field validated. Use of either spore trap would have delayed the application of high-risk late blight fungicides, resulting in savings of input costs for growers and reducing pesticide use compared to BliteCast. Additional research is required to validate spore traps as a decision support tool compared to other methods to determine high risk periods for late blight, particularly because late blight symptoms did not develop during the sampling period this year.

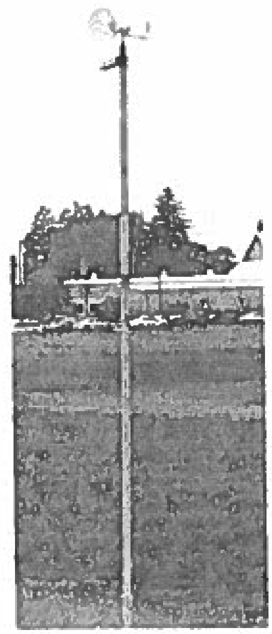

Figure 1. Sporometrics passive spore trap ('Spornado') at the Ridgetown (PI-01) sampling location. 2019.

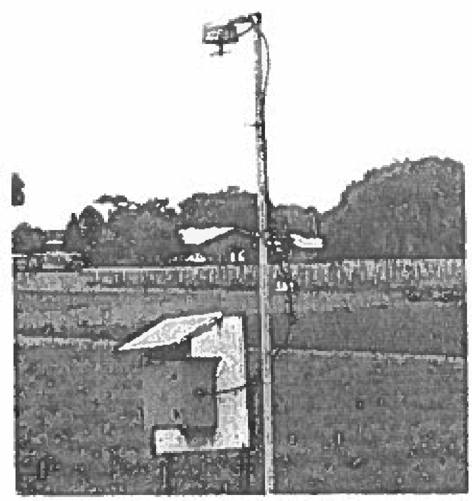

Figure 2. Phytodata's active spore trap ('Rotorod') at the Ridgetown (PI-01) sampling location. 2019.

Table 1. Results for the presence of *P. infestans* in Spornado and Rotorod spore traps collected near Ridgetown (PI-01), Cedar Springs (PI-02), Kent Bridge (PI-03), Chatham (PI-04), Erieau (PI-05), Dover (PI-06), Wallaceburg (PI-07), and Dresden (PI-08), Ontario 2019.

		Detection of *P. infestans* in Spornado and Rotorod																					
		June [c]					July [c]									August [c]							
ID [a]	Trap [b]	13	17	20	24	27	1	4	8	11	15	18	22	25	29	1	5	8	12	15	19	22	26
PI-01	S	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+		-
	R				-	-	-	-	-	-	-	-	-	-							-	+ (1)	
PI-02	S	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	+	-	-
	R				-	-	-	-	-	-	-	-	-	-	-	-	+ (3)	-	+ (5)	+ (1)	+ (1)	+ (1)	-
PI-03	S	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
	R									-	-	-	-	-		-	-	+ (4)	-	-	-	+ (1)	-
PI-04	S	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-
	R									-	-	-	-	-							-	-	-
PI-05	S	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	+	-	+	-	+	-	-
	R										-	-	-	+ (3)	-	+ (2)	-	+ (4)	-	+ (3)	+ (2)	+ (1)	-
PI-06	S	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	+
	R				-	-	-	-	-	-	-	-	-	-	-	-	+ (1)	+ (1)	+ (1)	+ (2)	-	-	-
PI-07	S	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	+	-	+	-	-
	R				-	-	-	-	-	-	-	-	-	-	-	-	-	+ (5)	-	+ (1)	-	+ (1)	-
PI-08	S	-	-	-	-	-	-	-	-	-	-	-	+	-	+	+	+	-	-	-	-	-	-
	R				-	-	-	-	-	-	-	-	-	-							-	+ (1)	-

[a] Trap locations were Ridgetown (PI-01), Cedar Springs (PI-02), Kent Bridge (PI-03), Chatham (PI-04), Erieau (PI-05), Dover (PI-06), Wallaceburg (PI-07), and Dresden (PI-08). [b] Cassettes or rods were collected two times a week. S = Spornado, R = Rotorod. [c] Empty cells represent missing data due to a Rotorod malfunction. Numbers in parentheses represent sporangia m^3.

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TITLE: Validation of fungicide programs for late blight based on pathogen surveillance

PEST(S): late blight (*Phytophthora infestans*)

MATERIALS: Bravo ZN (chlorothalonil 500g L^{-1}), Quadris Flowable (azoxystrobin 250 g L^{-1}), Aprovia Top (benzovindiflupyr ('Solatenol') 100 g L^{-1}, difenoconazole 117 g L^{-1}), Orondis Ultra (oxathiapiprolin 30 g L^{-1}, mandipropamid 250 g L^{-1}), Torrent (cyazofamid 400 g L^{-1}), Tanos (famoxadone 25%, cymoxanil 25%), Revus (mandipropamid 250 g L^{-1})

EQUIPMENT/FORECASTING SYSTEMS: Spornado passive spore trap (Sporometrics), Rotorod (Phytodata), BliteCast (as per Krause, 1975)

METHODS: The trial was completed at Ridgetown Campus, University of Guelph. Two tomato cultivars, 'TSH39' and 'TSH34', were used to identify differences between host resistance to *P. infestans*. TSH39 has host resistance to +*Ph-3* while TSH34 is susceptible to -*Ph-2*, and -*Ph-3*, both cultivars have similar maturity dates. Tomatoes were transplanted into twin rows on May 21 using a mechanical transplanter at a rate of 3 plants per metre. Each twin row was spaced 2 m apart. Each treatment plot was 7m long and consisted of one twin row. Transplanted between each plot twin row was a guard row, cultivar H2301, to ensure treatment separation. The trial was designed as a 2 x 8 factorial with four replications. Factor A was the host resistance to *P. infestans* and factor B was the trigger initiating the application of high-risk fungicides for late blight management. The triggers tested were: late blight symptoms reported on tomato or potato in Ontario, Michigan, or Ohio, a Spornado positive finding for *P. infestans* at any trap location, a Rotorod sporangia count of 10 per m^3 or greater at any trap location, the accumulation of a DSV value of 18 from BliteCast, BliteCast DSV value of 18 and a positive Spornado result, and BliteCast DSV value of 18 and a positive Rotorod result. In addition to the triggers there was also a non-treated control and a control that was only sprayed with fungicides applied during low *P. infestans* periods. Trap locations were those outlined in the previous study 'Comparison of spore trap technology for *Phytophthora infestans* surveillance'; Ridgetown, Cedar Springs, Kent Bridge, Chatham, Erieau, Dover, Wallaceburg, and Dresden, Ontario. BliteCast was calculated by Weather Innovations Inc. using weather data collected at Ridgetown Campus according to the parameters of Krause (1975). A threshold of 18 DSV used to initiate a change in fungicide program. With the exception of the non-treated control, each treatment was sprayed with a standard, low-risk fungicide *P. infestans* management program throughout the season. Once the respective high risk trigger was initiated treatments were sprayed with the required 'high-risk' fungicides in addition to the low-risk. Fungicide treatments, application date, and their 'risk' level are listed in Table 1. Applications were made using a hand-held CO_2 sprayer with nozzles ULD 120-03, and a water volume of 300 L Ha^{-1}. The trial was drip irrigated throughout the growing season as required.

Trials were assessed for disease intensity on foliage by estimating the percent of leaf canopy affected. Defoliation ratings were taken approximately every two weeks on July 16, 31, August 13 and 26. These values were used to calculate the area under the disease progress stairs (AUDPS) using the following equation: $AUDPC = [(Y_1 + Y_n)/2 \times (D/n-1)]$, where Y_1 is the disease level at first assessment, Y_n is the disease level at last assessment, D is the difference in the number of days from the last assessment to the first assessment, n is the number of assessments, and AUDPC = $\sum [((Y_i + Y_{i-1})(X_i - X_{i-1}))/2]$. For AUDPC, Y_i is number of infected leaves at day X_i and Y_{i-1} is number of infected leaves at day X_{i-1}. A 2 m section of each plot was harvested by hand on August 28; red fruit, green fruit, and rots were separated and weighed. Since there was no late blight in the trial, the percentage of fruit with symptoms could not be calculated.

Statistical analysis was conducted using Proc Glimmix in SAS v9.4 (SAS Institute Inc., Cary, NC). Means comparisons were performed when $P \leq 0.05$ using Tukey's HSD. Either a Gamma or a lognormal error distribution was applied to the analysis. The back-transformed means are presented for ease of interpretation. There was no interaction between the two factors, host resistance and fungicide treatment, meaning any differences observed were either a result of cultivar or fungicide treatment singly, and not a combination of the two.

RESULTS: Unfortunately no late blight symptoms were observed in the trial despite a growing season conducive to the development of late blight, a BliteCast DSV accumulation of 18 reached by June 15 (Appendix A) the first positive Spornado result being recorded on July 18 (see previous report 'Comparison of spore trap technology for *Phytophthora infestans* surveillance'. The accumulated DSV value and positive Spornado result triggered the initiation of the high-risk sprays beginning on June 26 for treatment 6 and July 22 for treatments 4 and 7 (Table 1), respectively. While *P. infestans* sporangia were also detected by the Rotorod trap, no sample sporangia count reached the required threshold, 10 per m^3, to trigger the application of high-risk fungicides. Similarly, there were no reported late blight symptoms on either potato or tomato which would have initiated the application of high-risk fungicides for treatment 3.

Defoliation rating values were a result of bacterial disease, not late blight. Interestingly, defoliation was greater with the TSH39 cultivar for the July 31 and August 13 evaluations compared to the TSH34 cultivar, suggesting the late blight tolerant variety was more susceptible to bacterial disease. However, by the final defoliation rating both cultivars had similar levels of defoliation (Table 2). Overall, using the AUDPS value, bacterial disease intensity was greatest for the TSH39 cultivar. In general fungicide treatments behaved similarly with respect to defoliation level and disease intensity. The only differences observed occurred for the August 26 defoliation evaluation, where the treatments triggered by a positive Spornado result (treatment 4) and BliteCast DSV value of 18 (treatment 6) had less defoliation than the non-treated control. This finding was not unexpected as these treatments had been sprayed with 10 to 11 fungicide applications, including fungicides better suited for fungal disease control.

Reported total tomato yield, is the combined yield of both red and green fruit. As expected in the absence of late blight, both tomato cultivars had similar yields (Table 2). Additionally, all fungicide treatments had similar yields to the non-treated control.

CONCLUSIONS: As late blight did not occur during the experiment, we were unable to identify if any of the high-risk spray triggers decreased late blight damage. However, treatment initiation triggers of a Rotorod sporangia count of 10 per m^3 or the identification of late blight symptomology in potato or tomato elsewhere in ON, MI, or OH most closely aligned with the lack of late blight observed in the trial. The use of the Rotorod threshold of 10 sporangia m^3 may be replaced with a positive/negative threshold

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next year, since this threshold is not field validated and it does not allow for a direct comparison among traps. Alternatively, it might be possible to compare the current Rotorod threshold to a semi-quantitative value (ie. low/med/high) with the Spornado. Use of a positive/negative threshold for the Rotorod treatments would have resulted in a similar number of fungicide applications as the Spornado treatments. Use of BliteCast disease severity values to determine initiation of higher-risk, late blight fungicides began on June 26, while the Spornado trap tested positive and initiated high-risk fungicide use on July 22. As several of the high-risk *P. infestans* fungicides are more costly than the low-risk, producers would have begun a more costly management program earlier than required this year using Blitecast or the Spornado systems compared to the Rotorod with a 10 sporangia m^{3} threshold or the current practice of waiting for reports of symptoms from the Great Lakes Region. However, this is the first year of research and further data is required to best identify appropriate application triggers of high-risk late blight fungicides.

Table 1: Fungicides applied to processing tomato to validate fungicide programs based on *Phytophthora infestans* surveillance methods.

Trt [a]	Trigger	Fungicide Application (in Ha) [b]
1	Non-treated Control	
2	Control	Bravo ZN @ 2.4 L (A), Quadris @ 400 ml (D), Bravo ZN @ 2.4 L (E), Aprovia Top @ 805 ml (G), Bravo ZN @ 2.4 L (I), Bravo ZN @ 2.4 L (K)
3	Symptoms reported in ON, MI, OH	Bravo ZN @ 2.4 L (A), Quadris @ 400 ml (D), Bravo ZN @ 2.4 L (E), Aprovia Top @ 805 ml (G), Bravo ZN @ 2.4 L (I), Bravo ZN @ 2.4 L (K)
4	Positive Spornado result	Bravo ZN @ 2.4 L (A), Quadris @ 400 ml (D), Bravo ZN @ 2.4 L (E), Orondis Ultra @ 600 ml (F), Aprovia Top @ 805 ml (G), Torrent + Sylgard 309 @ 150 ml + 112.5 ml (H), Bravo ZN @ 2.4 L (I), Tanos @ 560 g (J), Bravo ZN @ 2.4 L (K), Revus + Sylgard 309 @ 500 ml + 750 ml (L)
5	Positive Rotorod result (sporangia count > 10 m^3)	Bravo ZN @ 2.4 L (A), Quadris @ 400 ml (D), Bravo ZN @ 2.4 L (E), Aprovia Top @ 805 ml (G), Bravo ZN @ 2.4 L (I), Bravo ZN @ 2.4 L (K)
6	BliteCast DSV accumulation of 18	Bravo ZN @ 2.4 L (A), Orondis Ultra @ 600 ml (B), Torrent + Sylgard 309 @ 150 ml + 112.5 ml (C), Quadris @ 400 ml (D), Bravo ZN @ 2.4 L (E), Tanos @ 560 g (F), Aprovia Top @ 805 ml (G), Revus + Sylgard 309 @ 500 ml + 750 ml (H), Bravo ZN @ 2.4 L (I), Torrent + Sylgard 309 @ 150 ml + 112.5 ml (J), Bravo ZN @ 2.4 L (K), Tanos @ 560 g (L)
7	BliteCast + positive Spornado	Bravo ZN @ 2.4 L (A), Quadris @ 400 ml (D), Bravo ZN @ 2.4 L (E), Orondis Ultra @ 600 ml (F), Aprovia Top @ 805 ml (G), Torrent + Sylgard 309 @ 150 ml + 112.5 ml (H), Bravo ZN @ 2.4 L (I), Tanos @ 560 g (J), Bravo ZN @ 2.4 L (K), Revus + Sylgard 309 @ 500 ml + 750 ml (L)
8	BliteCast + positive Rotorod (sporangia count > 10 m^3)	Bravo ZN @ 2.4 L (A), Quadris @ 400 ml (D), Bravo ZN @ 2.4 L (E), Aprovia Top @ 805 ml (G), Bravo ZN @ 2.4 L (I), Bravo ZN @ 2.4 L (K)

[a] The trigger, initiating the start of high risk fungicide applications, for treatments 3, 5, and 8 was not reached during trial evaluation dates.

[b] Application dates: A=June 21, B=June 26, C=July 2, D=July 5, E=July 15, F=July 22, G=July 25, H=July 30, I=August 5, J=August 9, K=August 16, L=August 20. Treatments in black represent 'low risk' *P. infestans* fungicide applications, while those in red represent 'high risk' applications.

Table 2: Defoliation severity (% leaf area affected), area under the disease progress stairs (AUDPS), and yield in two tomato cultivars (TSH 39, TSH 34) grown under low- and high- *Phytophthora infestans* risk fungicide schedules initiated by eight environmental triggers. Ridgetown, ON, 2019

Main Effects[a,b]	Defoliation Severity (% bacterial disease)[c]				AUDPS (bacterial disease)[c,d]	Total Yield[e]
	July 16	July 31	August 13	August 26		(ton/acre)
Host Late Blight Resistance	NS	*	*	NS	*	NS
TSH 39	0 a	**27 a**	**55 a**	87 a	**3479 a**	30.3 a
TSH 34	0 a	**12 b**	**43 b**	84 a	**3046 b**	30.5 a
SE	0.0	1.5	2.0	1.0	69.5	0.9
Fungicide Treatment Trigger	NS	NS	NS	*	NS	NS
Non-treated Control	0 a	20 a	58 a	**94 a**	3650 a	25.9 a
Control	0 a	16 a	49 a	**86 ab**	3228 a	30.7 a
Symptoms reported in ON, MI, OH	0 a	19 a	52 a	**88 ab**	3378 a	29.4 a
Positive Spornado result	0 a	13 a	41 a	**82 b**	2983 a	33.4 a
Positive Rotorod result	0 a	22 a	46 a	**85 ab**	3246 a	29.1 a
BliteCast DSV accumulation of 18	0 a	18 a	49 a	**81 b**	3085 a	32.1 a
BliteCast + positive Spornado	0 a	19 a	48 a	**85 ab**	3239 a	33.3 a
BliteCast + positive Rotorod	0 a	22 a	49 a	**85 ab**	3273 a	30.1 a
SE	0.0	1.5	2.0	1.0	69.5	0.9
Interaction						
Variety x Fungicide treatment Trigger	NS	NS	NS	NS	NS	NS

[a] Significance at $P < 0.05$ denoted by an '*' and a non-significant difference by 'NS' for each main effect factor and their interaction

[b] Numbers in a column followed by the same letter are not significantly different at $P \le 0.05$, Tukey's adjustment. Means for a main effect were separated only if there was no significant interaction involving that main effect

[c] Defoliation severity rating and AUDPS calculation are based on bacterial disease, not *Phytophthora infestans*.

[d] AUDPS = area under the disease progress stairs. A lower number is better

[e] Total tomato yield includes both red and green fruit

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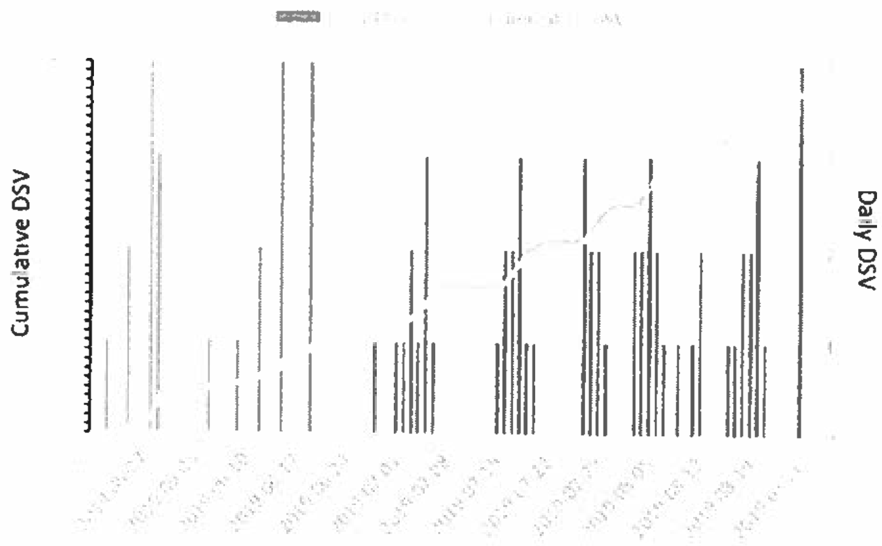
APPENDIX A: BliteCast DSV accumulation at Ridgetown Campus in 2019. A threshold of DSV 18 was used to initiate a high risk program for late blight.



Executive Summary – Investigations Into Variables Affecting Tomato Solids

Project Lead: John Zandstra† (jzandstr@uoguelph.ca)

Research Team: Sydney Boersma†, Kris McNaughton†, Darren Robinson†, Cheryl Trueman†, Steve Loewen†, Anne Verhallen‡, Laura Van Eerd†

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Introduction

Some processing tomato contracts in Ontario now include bonuses for higher than average Natural Tomato Soluble Solids (NTSS) and penalties for lower than average NTSS as an incentive for producers to produce more solids. This can be problematic as factors which influence solids and are controllable by tomato producers are not well understood. Other than high soil moisture levels close to maturity, which are known to depress NTSS levels, growers are unsure of practices to use to maintain high NTSS levels without affecting tonnage.

This project involved collecting a range of soil, plant, and weather variables from select locations in processing tomato fields, and harvesting fruit for NTSS determination. The resulting data set will be analyzed through Principal Component Analysis in an attempt to better understand production factors which influence NTSS and are controllable by tomato growers.

Materials and Methods

Due to natural field variability, as well as variability in NTSS levels within a load of tomatoes going to the processor, tomato fruit samples were taken by hand at small, specific locations within grower fields just prior to harvest. Harvest was conducted when at least 80% of the fruit was fully red ripe. Five (5) plants were harvested per location and the fruit was graded into 3 categories: red ripe + processing green, rots + grass green, and everything else, so total and marketable yields can be determined. From this, a subsample of red ripe fruit was forwarded to Steve Loewen's lab for analysis of Agtron, colour (L*,a*,b*), Hunter a, Hunter b, tomato sauce score, soluble solids. Soil samples and plant samples were taken in the immediate vicinity of the harvested plot; a complete soil health test will be completed which includes the parameters: organic matter, pH, buffer pH, phosphurous, potassium, magnesium, calcium, sodium, sulphur, boron, copper, manganese, iron, zinc, aluminum, Cation Exchange Capacity, % saturation of cations, potassium:magnesium ratio, electrical conductivity, %phosphorous, % aluminum, chlorine, Soltiva CO_2–C, PMN, Active C, Soil health index, NO_3-N and soil texture. Plant tissue was collected prior to harvest and analyzed for phosphorous, potassium, nitrogen, magnesium, zinc, manganese, calcium, copper, iron and boron. Disease and insect ratings were completed midsummer to avoid Ethrel (ripening agent) masking disease pressure at harvest. Weather Innovations Inc. provided weather data for each site (maximum, minimum temperature, heat units, precipitation). Our goal was to collect a minimum of 20 individual samples from 10 growers (200 samples total) each year throughout the harvest period. Growers who have a history of high and low solids will be included. Information collected from the growers included crop rotation, use of cover crops, fertility program, pest control program, source of plants (ie: greenhouse transplant grower), planting date, starter fertilizer, cultivation prior to planting and during crop development, and rate and timing of Ethrel. Overall, 200 leaf tissue and soil samples were collected, as well as 188 yield samples. Unfortunately due to time constraints and changes in growers harvest schedules twelve samples were lost total between four growers.

Soil and leaf samples are currently being analyzed by A&L Laboratories in London. Grower surveys are being revised to make it easier to complete as well as to provide data which is easier to analyze. Once these are completed, Principal Component Analysis will be completed with the 2 years of data. Since we now have a year of experience with the process and the data, this process will go faster and a final report will be available sooner than last year.

Processing tomato cultivar trials, 2019

A report to Ontario Tomato Research Institute, 2019-11-01

Steve Loewen, University of Guelph Ridgetown Campus

Introduction:

Processing tomato cultivar performance trials were conducted during the 2019 growing season. The primary objective was to measure performance of new processing tomato cultivars to assist processors in identifying hybrids that merit more extensive evaluation. Ridgetown coordinated extensive, multi-location processing tomato cultivar trials in 2007 and prior years. Rather than re-launch a large-scale evaluation program, the purpose of the 2019 effort was to conduct a modest program with the potential for possibly scaling up the work in future years.

Methods:

Seed companies were invited to submit seed of hybrids that were already listed in their catalogues.

A field plot was established in a grower's field on Howard Road in Chatham-Kent. The weather patterns in spring 2019 resulted in a challenging planting season and the Howard Line site was not planted until June 12. There were 16 entries plus 3 checks originally in the trial but the prolonged delay in transplanting was detrimental to transplant quality and only 13 new entries plus 3 checks were planted out. The trial was arranged as a randomized complete block design with 3 replications. Plot maintenance was provided by the grower co-operator. The plots were not sprayed with Ethrel, and harvest was targeted when the plots reached 80% red ripe fruit. Harvest began on September 18 and ended on September 30.

At harvest 5 plants, with no adjacent plants missing, were cut from each plot and the fruit were shaken from the vines and hand-sorted into different grade categories. The fruit weights were converted to yield in tons per acre. In addition to individual grade categories, yields were calculated for combined grade categories (e.g. red + breakers). A 2 kg sample of fruit was taken back to the lab for determination of average fruit size, distribution of fruit size, percent stems retained. Firmness was estimated by expressing as a percent, by weight, of fruit with cracks extending into the flesh after being dropped onto a concrete floor from a 4-foot height. Fruit quality determinants Agtron colour, Tomato Sauce Score (based on CIELab colour), natural tomato soluble solids (Brix), and pH were measured.

A second field plot was established in the tomato breeding plots on Kenesserie Road in Chatham-Kent. This site was planted on May 27 and 13 entries plus 3 checks were established in a split-plot design with 3 replications. Cultivars were the main plot treatments and 2 sub-plot treatments were unsprayed and sprayed with 2x rate of Pinnacle applied June 21. Plots were harvested at 80% red ripe and harvest began on September 16. Maturity of some hybrids appeared to be delayed by Pinnacle treatment and harvest continued until October 17. Yield, fruit size and firmness, and fruit quality were measured as described above.

Results

There was so much variability in the trial at the Howard Road site that, even though numerically different, most yield measurements (Table 1), other than days to harvest, and yield of limited use and rots, were not truly different. The numerical differences were due to random variation.

Table 1. Processing tomato cultivar trial, 2019. Yields from the Howard Road site. Entries arranged by maturity. Means within a column followed by the same letter are not different (Tukey's HSD, α = 0.05).

Entry	Source	Days to harvest	Red ripe yield	Breakers yield	Proc green yield	Grass green yield	Limited use/rots yield		Red + breakers yield	Red + breakers + proc green yield	Red + breakers + Proc green + grass grn yield	Potential yield
			Tons /acre	Tons /acre	Tons /acre	Tons /acre	Tons /acre		Tons /acre	Tons /acre	Tons /acre	Tons /acre
H5108	HeinzSeed	98	35.4	2.9	1.5	1.5	0.6	b	38.4	39.9	41.4	42.0
HM_1892	Harris-Moran	98	32.1	2.9	1.9	2.4	1.3	ab	35.0	36.9	39.4	40.7
HM_5900	Harris-Moran	100	33.9	1.4	0.9	1.3	1.4	ab	35.4	36.3	37.5	38.9
PUMATIS	Harris-Moran	101	34.1	2.9	1.1	1.2	0.9	ab	37.0	38.1	39.3	40.2
H1765	HeinzSeed	105	42.3	3.4	0.9	1.5	1.1	ab	45.7	46.6	48.1	49.1
H1879	HeinzSeed	105	41.4	3.1	0.6	1.9	1.1	ab	44.5	45.0	46.9	48.0
H1301	HeinzSeed	105	35.3	4.0	0.8	1.9	1.5	ab	39.2	40.1	42.0	43.4
H3406	HeinzSeed	107	34.6	1.7	1.0	3.8	0.4	b	36.3	37.3	41.1	41.5
EZ_7088	Enza Zaden	108	32.7	2.2	1.5	2.2	1.9	ab	34.9	36.4	38.6	40.5
H1178	HeinzSeed	108	38.7	3.2	1.1	3.4	1.5	ab	41.9	43.0	46.4	47.9
H1648	HeinzSeed	108	39.5	1.3	1.2	1.8	0.5	b	40.8	42.0	43.8	44.4
H1766	HeinzSeed	108	39.8	1.9	0.7	0.9	1.5	ab	41.6	42.3	43.2	44.7
HMX_61P4123	Harris-Moran	109	35.4	3.3	1.2	1.1	1.0	ab	38.7	39.9	41.0	41.9
EZ_7077	Enza Zaden	110	27.5	4.8	2.4	3.4	2.9	a	32.3	34.7	38.2	41.1
H1418	HeinzSeed	110	35.7	3.8	1.3	2.2	1.1	ab	39.4	40.8	42.9	44.1
H1881	HeinzSeed	110	30.9	4.6	1.4	2.4	0.6	b	35.5	37.0	39.4	40.0
		p=0.0001	ns	ns	ns	ns	p=0.05		ns	ns	ns	ns

Table 2 shows the results for the fruit handling experiments, arranged according to the days to harvest similar to Table 1. The hybrid Pumatis had almost half (49%) of the fruit cracking and was different from a small group of hybrids that were significantly firmer. Fruit size 1 (1 inch diameter or less) is generally too small. Fruit size 2 (greater than 1 inch and less-than or equal-to 1 ½ inches diameter) is a typical size for wholepeel tomatoes. Fruit size 3 (greater than 1 ½ inches and less-than or equal-to 1 ¾ inches diameter) is also a typical size for whole, canned tomatoes. Fruit size 4 (greater than 1 ¾ inches) tend to be too large for wholepeel use, depending on the size of the can. They may be suitable for diced product. Real differences were found in fruit size 3. For example, Heinz 1301 had only 17.3 percent of the fruit in size 3 and a much higher percent of the fruit in size 4. Conversely, H1178 and H3406 had a higher percentage of fruit in size 3 category.

Table 2. Processing tomato cultivar trial, 2019. Fruit characteristics, Howard Road site. Entries are arranged by maturity date. Means within columns followed by the same letter are not significantly different (Tukey's HSD, α = 0.05).

Entry	days to harvest	Average fruit size grams	Stems attached percent	cracking percent		fruit size 1 percent	fruit size 2 percent	fruit size 3 percent		fruit size 4 percent
H5108	98	74.2	2.5	20.0	ab	0.0	15.4	30.4	abc	54.6
HM_1892	98	74.2	0.0	25.2	ab	0.0	14.8	49.1	abc	35.5
HM_5900	100	78.6	0.0	36.8	ab	0.0	9.5	24.0	bc	68.2
PUMATIS	101	65.5	1.2	48.9	a	0.0	17.7	41.0	abc	40.9
H1765	105	73.3	1.3	41.5	ab	0.0	23.0	43.1	abc	46.4
H1879	105	62.6	6.1	19.4	ab	0.0	39.1	29.6	abc	30.9
H1301	105	83.5	4.5	25.4	ab	0.0	17.5	17.3	c	64.7
H3406	107	60.4	1.1	14.1	b	0.0	36.0	50.8	ab	13.5
EZ_7088	108	72.1	6.4	9.9	b	0.0	27.3	28.3	abc	44.9
H1178	108	68.1	1.0	19.5	ab	0.0	18.3	58.6	a	23.1
H1648	108	79.4	7.8	32.8	ab	0.0	19.6	30.4	abc	52.0
H1766	108	67.4	1.1	31.6	ab	0.0	27.7	37.1	abc	35.9
HMX_61P4123	109	74.6	2.6	21.9	ab	0.0	10.9	24.2	bc	62.9
EZ_7077	110	74.7	0.0	6.8	b	0.0	13.3	34.5	abc	51.9
H1418	110	60.9	3.0	11.6	b	0.0	47.4	31.2	abc	21.6
H1881	110	78.1	0.0	8.5	b	0.0	11.8	39.6	abc	49.1
	p=0.0001	ns	ns	p=0.01		ns	ns	p=0.01		ns

Table 3 shows the fruit quality measurements, arranged by days to harvest similar to the previous two tables. Random variation was reduced in these assessments and real differences were detected in each of the four measurements. In order to facilitate comparison with previous cultivar trial work, we measured Agtron colour and the Tomato Sauce Score and calculated by the Konica-Minolta colourimeter. In general, the colour of EZ_7077 and EZ_7088 tended to be slightly less red than some other hybrids but they were not different from checks H5108, H1301 or H3406.

Table 3. Processing tomato cultivar trial, 2019. Fruit quality, Howard Road site. Entries arranged by maturity. Means within columns followed by the same letter are not significantly different (Tukey's HSD, $\alpha = 0.05$)

Entry	days to harvest	Agtron colour		Tomato Sauce Score		Brix percent		pH	
H5108	98	21.8	a	26.8	cde	4.4	d	4.32	b
HM_1892	98	21.3	a	28.9	abcde	5.0	abc	4.34	ab
HM_5900	100	22.0	a	28.2	abcde	5.1	abc	4.36	ab
PUMATIS	101	18.7	abc	29.2	abc	4.9	abcd	4.43	ab
H1765	105	19.0	abc	28.9	abcd	5.2	ab	4.39	ab
H1879	105	16.0	c	30.5	ab	5.3	a	4.43	ab
H1301	105	21.5	a	26.0	e	5.0	abcd	4.34	ab
H3406	107	19.3	abc	27.5	cde	4.6	bcd	4.41	ab
EZ_7088	108	22.0	a	26.1	e	4.6	bcd	4.41	ab
H1178	108	19.8	ab	27.7	bcde	4.8	abcd	4.43	ab
H1648	108	16.3	c	30.9	a	4.8	abcd	4.44	ab
H1766	108	19.0	abc	29.6	abc	5.0	abcd	4.47	a
HMX_61P4123	109	19.0	abc	28.3	abcde	4.5	cd	4.38	ab
EZ_7077	110	21.7	a	26.1	de	4.7	abcd	4.42	ab
H1418	110	19.3	abc	28.2	abcde	4.6	cd	4.41	ab
H1881	110	17.8	bc	29.5	abc	4.8	abcd	4.38	ab
	p=0.0001	p=0.0001		p=0.0001		p=0.0001		p=0.01	

Results for the Pinnacle trial were unclear. Based on the significant sub-plot effect (unsprayed or sprayed with 2x rate of Pinnacle) Table 4 shows clearly that the application of the 2x rate of Pinnacle affected the yield of all grade categories except limited use and rots. On average, plots sprayed with Pinnacle were later maturing and tended to have a higher yield of fruit although that higher yield was due to delayed maturity, which gave the plants more time to continue to produce fruit. In Table 4 the entries are organized in sequence by the days to harvest of the unsprayed sub-plots.

Table 4. Processing tomato cultivar and Pinnacle herbicide tolerance trial, 2019.
Means within a column followed by the same letter are not different (α = 0.05).

Entry	Pinnacle treatment	Days to harvest		Red ripe yield tons/acre	Breakers yield tons/acre		Proc green yield tons/acre	Grass green yield tons/acre	Limited use/rots tons/acre	Proc green + grass grn tons/acre	Potential yield tons/acre
EZ_7077	unsprayed	115	d	40.8	4.0	ab	2.0	3.1	1.4	5.1	51.4
EZ_7077	Pinnacle	143	a	27.2	7.8	ab	2.4	4.1	1.1	6.5	42.6
H5108	unsprayed	118	cd	38.8	3.2	b	1.5	1.7	1.9	3.2	47.1
H5108	Pinnacle	134	abcd	40.2	4.0	ab	1.1	2.5	0.9	3.6	48.8
PUMATIS	unsprayed	120	bcd	36.7	2.5	b	1.0	1.7	2.0	2.8	44.0
PUMATIS	Pinnacle	140	abc	32.7	5.6	ab	2.1	2.3	1.7	4.4	44.4
HM_5900	unsprayed	122	abcd	33.3	4.2	ab	1.8	2.3	2.9	4.0	44.4
HM_5900	Pinnacle	127	abcd	41.2	3.3	b	0.9	1.7	3.0	2.6	50.2
EZ_7088	unsprayed	123	abcd	41.6	2.9	b	0.6	2.1	1.4	2.7	48.5
EZ_7088	Pinnacle	125	abcd	45.5	2.7	b	0.9	2.2	1.4	3.1	52.6
HMX_61P4123	unsprayed	123	abcd	46.2	3.2	b	1.2	3.6	1.7	4.8	55.9
HMX_61P4123	Pinnacle	141	ab	24.6	4.7	ab	2.0	3.3	1.0	5.3	35.5
HM_1892	unsprayed	123	abcd	44.2	5.0	ab	2.8	5.1	2.6	8.0	59.9
HM_1892	Pinnacle	143	a	32.9	7.6	ab	4.8	8.7	1.0	13.5	55.0
H1648	unsprayed	126	abcd	52.9	4.8	ab	2.1	3.0	1.4	5.1	64.2
H1648	Pinnacle	129	abcd	48.2	3.6	b	1.7	2.3	1.9	4.0	57.7
H1879	unsprayed	126	abcd	48.0	1.9	b	1.0	2.0	1.2	3.0	54.1
H1879	Pinnacle	143	a	32.3	7.4	ab	2.9	7.0	0.9	9.9	50.5
H1301	unsprayed	128	abcd	49.0	4.0	ab	2.0	2.3	2.1	4.3	59.4
H1301	Pinnacle	135	abcd	38.1	5.1	ab	3.0	4.4	2.0	7.4	52.6
H1178	unsprayed	129	abcd	41.8	4.3	ab	3.0	5.5	1.6	8.4	56.1
H1178	Pinnacle	133	abcd	44.2	4.9	ab	3.5	5.8	1.7	9.3	60.1
H1765	unsprayed	131	abcd	38.1	2.5	b	0.9	2.2	1.6	3.2	45.4
H1765	Pinnacle	134	abcd	29.1	6.7	ab	2.6	4.3	2.7	6.9	45.4
H3406	unsprayed	132	abcd	40.6	4.0	ab	1.6	3.0	1.3	4.6	50.5
H3406	Pinnacle	133	abcd	49.4	6.8	ab	1.7	4.0	1.5	5.6	63.3
H1766	unsprayed	132	abcd	39.6	1.8	b	2.0	2.2	1.4	4.2	47.0
H1766	Pinnacle	143	a	38.2	5.3	ab	4.4	4.8	0.5	9.2	53.3
H1881	unsprayed	136	abcd	39.3	5.6	ab	2.3	5.6	3.4	7.9	56.2
H1881	Pinnacle	141	ab	28.1	9.9	a	3.0	8.4	0.9	11.5	50.3
H1418	unsprayed	137	abcd	47.3	3.6	b	2.1	3.9	1.1	6.1	58.0
H1418	Pinnacle	143	a	38.8	7.4	ab	4.1	6.2	0.8	10.3	57.4
main plot (entry)		p=0.01		ns	p=0.01		ns	ns	ns	ns	ns
subplot (unsprayed or sprayed)		p=0.001		p=0.01	p=0.001		p=0.01	p=0.01	ns	p=0.001	ns
interaction (entry x pinnacle treatment)		p<0.05		ns	p=0.05		ns	ns	ns	ns	ns

Based on analyses completed to date, while there are trends, the results do not permit the clear distinction between Pinnacle tolerant and Pinnacle susceptible hybrids (other than EZ_7077 which showed a clear and specific delay in maturity). The results suggest that H1765, H1648, EZ_7088, H3406, might possibly be tolerant to Pinnacle.

In an effort to determine if application of Pinnacle could result in a larger yield of green fruit that didn't ripen due to delayed maturity, a new category of processing green yield + grass green yield was created. While it was found that, on average, application of the 2x rate of Pinnacle did result in a higher green fruit yield, there was no interaction (hybrid x Pinnacle application) that might give evidence of differences between hybrids in tolerance to this herbicide.

Conclusions

Howard Road site

The delay in planting and resulting poor quality of the transplants contributed to challenges in the field this year. While numeric differences in performance between hybrids were detected for many parameters, the amount of random variation made it difficult to detect real differences. Furthermore, the results represent only a single growing season and so they cannot be generalized over other seasons.

In a year like 2019, the results showed that Pumatis may be at risk for fruit cracking but the other hybrids from Harris Moran Clause could be candidates for further evaluation. While the Enza Zaden hybrids 7077 and 7088 showed a slight tendency to have reduced colour in year like 2019, they were not worse than the checks H5108, H1301 or H3406. Based on the analyses completed to date, in a growing season like 2019 none of these hybrids tested could be ruled out for evaluation in larger-scale trials.

Kenesserie Road site

In general the trial site at Kenesserie Road was much later maturing than the Howard Road site. This may have been due, in part, to the abundant growth resulting from the farm not having tomatoes grown on it previously. While an interaction was detected between hybrid and maturity (which is expected susceptibility to Pinnacle) only EZ_7077 can be clearly identified as susceptible to Pinnacle based on the results.

Additional data analysis planned

There are several additional, calculated variables that may be explored to determine if clear differences in Pinnacle tolerance can be detected.

Further data analysis on cultivar performance is also planned using both a Best Linear Unbiased Predictor (BLUP) method and an Additive Main Effects and Multiplicative Interaction (AMMI) method that are designed to determine reliable estimates of cultivar performance in multilocation trials. The two sites used in 2019 provide data to enable this kind of analysis and these methods are of particular interest because they have been shown to be better at detecting the treatment effects while removing random experimental "noise" (Piepho, 1994) than more commonly used methods.

Acknowledgements

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Long-term Impact of Cover Crops on the Production of Processing Tomatoes
Executive Summary 2019 to OTRI

Dr. Laura L. Van Eerd
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Executive Summary:

Soil health is closely linked to soil function and crop productivity, which relates to plant health. Long-term fall planted cover crops significantly improved soil health in a cover crop experiment established in 2007 at the University of Guelph, Ridgetown Campus. Having previously quantified greater soil health and yields with cover crops (fall rye, radish, mix of radish and rye, oat) compared to the no cover crop control, the objective of this study was to evaluate if these differences might translate to enhanced plant health. We quantified plant health by evaluating tomato fruit quality (Steve Loewen), and insect and disease incidence (Dr. Cheryl Trueman) and we will also assess antioxidant and bioactive phytochemicals (Dr. Rong Cao AAFC Guelph) and fruit nutritional content (micro-/macro-nutrients).

The research trial was managed according to typical Ontario processing tomato production practices on a fertile, sandy loam soil with fall annual cover crop grown since 2007. In 2019, rye, radish and mix of radish+rye had numerically greater yields than the no cover treatment. In 2019 and previous years (2010, 2011, 2015, 2016), processing tomatoes **yields with cover crops were greater or as good as yields without cover crops**. The no cover crop treatment defoliated quicker and plants matured quick (greater % red fruit) than with cover crops. Similarly, plants without N fertilizer had more defoliation and were more mature than those plants with preplant broadcast incorporated N fertilizer. It is not possible to differentiate if the defoliation was due to greater disease or natural plant senescence brought on by quicker maturity. But given that the no N fertilizer plants defoliated (i.e., plants shut down earlier in the season) it appears the effect of **greatest defoliation/maturity in the no cover crop treatment** was real. The **no cover crop control had more red fruits with anthracnose lesions** and a greater anthracnose disease index than all cover crops. While one expects anthracnose to increase with crop maturity, the pathogen is soil borne and thus observed effects may reflect cover-crop induced benefits on plant health due to better soil health. The fruit quality analysis (Agtron colour, pH and natural tomato soluble solids) indicated that all values were within acceptable ranges for commercial processing tomato requirements and the cover crop treatments did not lower fruit quality. **Radish had a significantly greater NTSS** (4.11 vs. 3.83) than the no cover treatment; NTSS with radish was the same as oat and radish+rye cover crops. Note that no differences in NTSS were observed in the previous 4 yrs. It is not known if increased NTSS was due to better soil health and plant health or something else. Retaining or removing winter wheat straw and N fertilizer rate did not have a negative nor positive effect on any parameter measured except N fertilizer delayed defoliation and maturity as mentioned. The lack of straw management and N fertilizer effect was consistent with other years and likely reflects the high fertility of the field. It also suggests cover crop specific N fertilizer rates are not justified.

2019 Executive Summary

Dr. Rob Nurse (Robert.Nurse@Canada.ca)

Trial 1 – **Weed control and tolerance of processing tomatoes to Authority, Dual II Magnum, Sandea and pethoxamid applied PRE.**

Pethoxamid is a new group 15 herbicide. Therefore, it's spectrum of weed control and mechanism of action is similar to Dual II Magnum. Authority is a group 14 herbicide that has recently been registered in processing tomato. This trial evaluates the efficacy of these products on nightshade when applied alone or in tank-mix with Authority. There were no crop injury concerns. Control of eastern black nightshade was excellent (>90%) for all treatments except Sandea which did not provide any nightshade control. In general the tank-mix options did not improve control of nightshade except when Authority was tank-mixed with Sandea. Common lambsquarters and redroot pigweed were also present in the trial. Surprisingly, both Dual II Magnum and pethoxamid provided less than 50% control of lambsquarters when applied alone; however, control was excellent when tank-mixed with Authority. Authority provided equal or better weed control when applied alone in comparison to the tank-mixes. This translated into yield where the highest yield was in the Authority alone and tank-mix treatments.

Trial 2 – **Weed control and tolerance of processing tomatoes to POST tank-mixes with pethoxamid**.

In this trial pethoxamid was tank-mixed with Sandea, Prism, Pinnacle, Poast Ultra, Venture L or Sencor POST at the 6-8 leaf stage of the tomato. The appropriate surfactants were added to each treatment according to label specifications. Data summarized below are from 2017 to 2019. There was marginal injury observed in some of the treatments that persisted through to 28 days after treatment (DAT), but the injury never exceeded 10% in 2017 and 2018, but no injury in 2019. The most common weed species in the trials were large crabgrass, and common lambsquarters. Control of all species was excellent (>90%) across all treatments, except for POST applications of pethoxamid and/or Sandea POST where control was <80%. Marketable yields did not differ among treatments, although treatments containing pethoxamid alone had yields that were up to 10% lower than the weed-free control.

Trial 3 – **Weed control and tolerance of processing tomato to POST tank-mixes with Sandea**

In this trial Sandea was tank-mixed with Sencor, Prism, or Pinnacle and applied postemergence on processing tomatoes at the 6-8 lf stage. There were no injury concerns for any of the treatments tested. The most common broadleaved weed in this trial was common lambsquarters. Postemergence control of lambsquarters was poor with all treatments except Prism or Pinnacle. Control was improved with the tank-mix partners. Yields were improved in treatments that contained tankmix treatments other than Pinnacle

Trial 4. - **Weed control and tolerance of processing tomatoes to Authority, Dual II Magnum and pethoxamid applied PPI.**

Pethoxamid is a new group 15 herbicide. Therefore, it's spectrum of weed control and mechanism of action is similar to Dual II Magnum. Authority is a group 14 herbicide that has recently been registered in processing tomato. This trial evaluates the efficacy of these products on nightshade when applied alone or in tank-mix with Authority. There were no crop injury concerns. Control of eastern black nightshade was excellent (>90%) for all treatments except Authority alone which provided only 53% control. In general the tank-mix options all improved control of nightshade in comparison to their stand-alone treatments. Common lambsquarters and redroot pigweed were also present in the trial but were controlled well by all treatments. Tomato yields were highest in treatments where Dual II Magnum or pethoxamid were tank-mixed with Authority.

Long-term Impact of Cover Crops on the Production of Processing Tomatoes

Research Report 2019

Prepared for Ontario Tomato Research Institute

30 October 2019

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Collaborators:	Dr. Cheryl Trueman: Insect and Disease Monitoring Steven A. Loewen: Quality Assessments
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Introduction:

This is an annual report for the long-term cover crop research trial initiated in 2007 (site L2E) and repeated in 2008 (L2W) at the University of Guelph, Ridgetown Campus. The emphasis of this report is to summarize data collected from the 2019 processing tomato harvest (L2E), including: yield, tomato fruit quality, and insect and disease incidence. Fruit bioactive phytochemical and antioxidant activity by Dr. Rong Cao at AAFC Guelph and fruit micro- and macro-nutrients, are currently being processed. Results are expected by at the meeting in January. In addition, a more thorough analysis will be completed next year after 2020 tomato harvest.

Methods:

Location: Ridgetown Campus Research Plots Trial: L2E 2019

Design:

Split-split randomized complete block design with four replications

Main effect: Cover crop species (plot size 6 x 16 m)

Split-plot: Winter wheat straw removal or retained

Split-split-plot: 1) N rate of 0 lbs/ac 2) N rate of 125 lbs/ac

Fall Planted Cover Crops:

1) no cover
2) oat (seeding rate 72 lb/ac)
3) oilseed radish (12 lb/ac)
4) cereal/fall rye (60 lb/ac)
5) oilseed radish and cereal/fall rye (9 + 30 lb/ac)

Pest Control: Tomatoes were grown according to typical Ontario production practices (Pounce®, Bravo®, Quadris® and Manzate® were applied throughout the season)

Crop Rotation since 2007:

peas, sweet corn, spring wheat, tomatoes, grain corn*, squash, soybeans**, winter wheat, tomatoes, peas, sweet corn**, winter wheat, tomatoes (2019 and 2020). * No cover crops planted after grain corn (stover removed) ** Winter wheat planted in the fall; therefore, no cover crops are planted

Field Operations:

- August 2018, winter wheat was harvested. For the straw retained treatment, straw was evenly raked within plot. Straw was removed with a rake from plot area in the straw removed treatment.
- Cover crops were planted with a drill, as soon as possible.
- Cover crop biomass and soil was sampled October 2018 and May 2019.
- Cover crops were left over winter.
- May 2019, rye was terminated (glyphosate sprayed on whole trial). Herbicide was applied again one day before transplanting.

- Cover crop residue was incorporated into the soil, two passes with a field cultivator.
- Prior to transplanting, starter fertilizer (500 lbs/acre of 0-23-30) was spread on the entire trial.
- Preplant broadcast incorporated fertilizer N was applied at 125 lbs/ac actual (treatment 2); whereas, no N was applied for treatment 1. Transplant fertilizer was not used due to the late planting date.
- On 20 June (morning; 6lf stage) and 02 July (evening; flowering) one bed was inoculated with bacterial spot *Xanthomonas gardneri* (DC00T7A; 10^6 concentration at 200 L/ha, Sylgard (0.02% v/v)).
- Ethrel® was not sprayed to test the effect of cover crops on maturity

Table 1. Tomato production practices and trial conditions:

Production:	Cover crop planting date	August 10, 2018	
	Tomato variety	CC337	
	Plant population (plants/ac)	10,670	
	Plant spacing	14.7" b/w plants, 3 twin rows/20 ft.	
	Planting date	June 4, 2019	
	Harvest date	September 9 -10, 2019	
Monthly Rainfall (mm) and Average Mean Temp. (°C):	June	58.4 mm	17.7 °C
	July	169.5 mm	22.4 °C
	August	103.4 mm	20.0 °C
	Sept 1-10	5.2 mm	16.9 °C
Soil Characteristics:	Soil texture	Sandy Loam	
	% sand:silt:clay	68:21:11	
	% organic matter	3.6	
	CEC (MEQ/100g)	8.8	
	pH	6.7	
Nutrients (ppm):	P	19	Ca 1171
	K	185	Mg 154

Results:

In-season defoliation (Table 2) Data from Dr. Cheryl Trueman's research group

- Plots were scouted throughout the season, where bacterial disease was noted but there were no treatment differences. No fungal disease lesions were noted, likely due to the fungicide program.
- By mid August, plots without cover crops had the greatest percentage of defoliation. This trend continued and was easily visibly observed the week before harvest and at harvest (9-10 Sept).
- Plots without cover crops had the greatest AUDPC and AUDPS (between June 18-August 26), indicating the greatest amount of disease/senescence occurred in the no cover crop control plots.
- Radish plots had the least defoliation, followed by radish+rye and rye. All plots had less defoliation than no cover plots.
- Straw management did not impact defoliation (expressed as % or AUDPC(S))
- Plots without nitrogen had a significantly greatest AUDPC(S) values as well as a greater percentage of defoliation on August 7th and 13th. This was consistent with visual observations.
- It is not possible to separate if defoliation was due to disease or if it was due to plant senescence. Regardless of the mechanism, **tomatoes in plots without cover crops had more defoliation than those with cover crops**. Likewise, tomatoes grown without N fertilizer had more defoliation than those plants with N fertilizer. Difference in defoliation was not observed in the previous 4 years, perhaps because there were less differences in soil health.

Table 2. Impact of long-term cover crop type, N fertilizer rate, and 2-year winter wheat straw management treatments on crop defoliation, AUDPC* and AUDPS** at site L2E in 2019.

	Treatment	7-Aug-2019	13-Aug-2019	20-Aug-2019	AUDPC	AUDPS
		--% Defoliation--				
Long-Term Cover Crop	No Cover	20.0	57.8 a	74.4 a	1300 a	4370 a
	Oat	16.6	53.1 ab	66.3 ab	1180 ab	4240 ab
	Radish	14.1	30.9 d	46.9 d	853 d	3410 c
	Radish+Rye	14.1	38.4 cd	56.3 cd	971 cd	3610 c
	Rye	15.3	43.1 bc	62.5 bc	1070 bc	3940 b
SE		2.09	6.30	5.71	98.3	197
Straw Mgt.	Stays	17.1	46.1	62.5	1100	3940
	Removed	14.9	43.3	60.0	1050	3850
SE		1.51	5.51	5.17	87.0	176
N Fertilizer to tomatoes	125 lbs/ac	14.5 b	42.0 b	59.5	1020 b	3790 b
	0lbs/ac	17.5 a	47.4 a	63.0	1130 a	4000 a
SE		1.43	5.31	5.12	84.9	173
Effect* **		--*P* values--				
	Cover Crop	0.1697	**0.0003**	**<.0001**	**0.0001**	**<.0001**
	Straw Mgt.	0.1945	0.4230	0.3782	0.3028	0.3508
	N Fertilizer	**0.0306**	**0.0131**	0.149	**0.0065**	**0.0126**

*AUDPC= Area Under the Disease Progress Curve (quantitative measurement of disease over time, June 18-August 26). Greater numbers indicate more disease/defoliation.

**AUDPS= Area Under the Disease Progress Stairs (improved formula that gives a weight closer to optimal to the first and last observations)

***No 2-or 3-way interactions.

Processing tomato yield (Table 3)

- Ethephon was not applied. If it was, the differences in maturity and defoliation might not have been observed.
- Maturity was expressed as % red ripe fruits. By Sept 9-10, the no cover crop and rye plots reach >70% fruit maturity, which was greater than the other cover crop treatments. The no cover had the greatest defoliation and rye among the greatest. It is not clear if the defoliation brought on maturity or if the crop was mature and therefore dropped leaves.
- Plants grown without N fertilizer were more mature and greater defoliation, suggesting that there were differences in the soil that affected plants.
- Marketable yield is the best indication of crop productivity. **Rye, radish+rye and radish had numerically greater yields** than the no cover treatment. Comparable to other years, there was no yield penalty to growing cover crops.
- At harvest, the no cover crop plots had the greatest percentage of rots; whereas, radish had the lowest percentage.
- Similar to previous years, yield was not significantly affected by straw management. In a system without long-term cover cropping, this effect may be apparent.
- There was no interaction between N fertilizer and cover crop species. This reflect the high soil fertility of the site and suggest there may not be a need to adjust N fertilizer rates according to the cover crop species.

Table 3. Impact of long-term cover crop type, N fertilizer rate, and 2-year winter wheat straw management on processing tomato yield* at site L2E in 2019.

	Treatment	**Total**	**Market**	**Reds**	**Rots**
		--------ton/ac--------		-----------%-----------	
Long-term Cover Crop	No Cover	39.4 ab	38.4 ab	71.0 a	2.56 a
	Oat	34.4 b	34.0 b	49.1 bc	1.38 b
	Radish	41.3 a	41.0 a	39.1 c	0.83 b
	Radish+Rye	41.8 a	41.2 a	52.6 b	1.37 b
	Rye	43.9 a	42.8 a	66.6 a	1.92 ab
SE		1.92	6.36	4.59	0.42
Straw Mgt.	Stays	39.5	38.8	54.7	1.67
	Removed	40.8	40.2	56.7	1.56
SE		1.62	5.48	3.39	0.30
N Fertilizer to tomatoes	125 lbs/ac	40.4	39.9	52.4 b	1.39
	0 lbs/ac	39.9	39.1	58.9 a	1.84
SE		1.56	5.32	3.09	0.28
Effect**		----------------------*P* values----------------------			
	Cover Crop	**0.0096**	**0.0089**	**<.0001**	**0.0334**
	Straw Mgt.	0.4293	0.3628	0.5763	0.745
	N Fertilizer	0.6288	0.4624	**0.0068**	*0.0688*

*Marketable yield= Red + Orange + Breaker + Green. Total yield= Red + Orange + Breaker + Green + Rots
**No 2-or 3-way interactions

Tomato fruit quality (Table 4). Data from Steven Loewen's research group

- All results were within acceptable ranges for processing tomato requirements; therefore, treatments did not negatively effect tomato fruit quality (colour, soluble solids and pH).
- Cover crop treatments did not impact colour of red ripe fruits.
- Radish had the greatest NTSS, followed by oat and radish+rye.
- This is the first year out of five that a cover crop effect was noticed in this long-term trial, therefore caution should be used. Regardless, **cover crops had greater or equal to NTSS.**
- Differences among pH were significant (P<0.1); however, not a concern at a practical level as differences are minor (4.30 and 4.33).
- There was an observed interaction between cover crop and nitrogen rate. At this time and based on one year of data, it is difficult to conclude a specific implication of the cover crop by N interaction.
- Similar to other years, straw management did not impact fruit quality.
- Plants grown with N fertilizer had better colour but the lack of cover crop by N rate interaction suggest that there is no need to modify N fertility based on cover crop grown

Table 4. Impact of long-term cover crop type, N fertilizer rate, and 2-year winter wheat straw management on processing tomato quality at site L2E in 2019.

	Treatment	**Agtron colour**	**NTSS**	**pH***
Long-Term Cover Crop	No Cover	29.4	3.83 bc	4.32 a
	Oat	31.8	4.01 ab	4.30 b
	Radish	31.3	4.11 a	4.32 a
	Radish+Rye	31.1	3.99 ab	4.31 ab
	Rye	30.0	3.78 c	4.33 a
SE		0.932	0.064	0.011
Straw Mgt.	Stays	31.1	3.93	4.32
	Removed	30.3	3.96	4.31
SE		0.664	0.041	0.01
N Fertilizer to tomatoes	125 lbs/ac	29.8 b	3.98	4.32
	0 lbs/ac	31.6 a	3.91	4.31
SE		0.645	0.035	0.01
Effect		----------------*P* values----------------		
	Cover Crop	0.2861	**0.0058**	*0.0553*
	Straw Mgt.	0.2636	0.5467	0.107
	N Fertilizer	**0.0168**	*0.0592*	0.2685

*significant CC x N interaction for pH; values were between 4.35 to 4.29, which likely has little impact to the industry.

Insect and Disease Damage on Fruit (Table 5 + 6) Data from Cheryl Trueman's research group

- The no cover crop plots had a significantly greater fruits with anthracnose (expressed as number of fruits without lesions, fruits with 4+ anthracnose lesions, and as an index) when compared to cover crop plots.
- **All cover crop treatments had a lower anthracnose** incidence and severity than no cover crop control plots. Oat and radish treatments had the in the lowest incidences of anthracnose
- Anthracnose is a soil-borne disease. It is important to note that cover crops were tilled in before planting and there was no differences among treatments in the amount of crop residues on soil surface.
- Straw management and N fertilizer rate did not significantly impact anthracnose incidence and severity.
- The incidences of bacterial speck and spot were very low as was stink bug (Table 6). Statistical analysis is ongoing.

Table 5. Impact of long-term cover crop type, N fertilizer rate, and 2-year winter wheat straw management on the incidence and severity of anthracnose fruit lesions at site L2E in 2019.

	Treatment	Fruit w/ zero anthracnose lesions	Fruit w/ 4+ anthracnose lesions*	Anthracnose Index**
		---------------%	---------------	
Long-Term Cover Crop	No Cover	74.1 c	8.88 a	16.9 a
	Oat	90.4 a	2.25 b	5.69 c
	Radish	92.5 a	1.63 b	4.31 c
	Radish+Rye	88.2 ab	3.25 b	7.38 b
	Rye	81.6 b	4.56 b	11.1 b
SE		2.59	1.21	1.85
Straw Mgt.	Stays	84.4	4.50	9.78
	Removed	86.4	3.73	8.38
SE		1.83	0.838	1.29
N Fertilizer to tomatoes	125 lbs/ac	86.6	3.78	8.15
	0 lbs/ac	84.1	4.45	10.0
SE		1.78	0.823	1.26
Effect		--------------------	*P* values--------------------	
	Cover Crop	**<.0001**	**<.0001**	**0.0001**
	Straw Mgt.	0.3579	0.931	0.3656
	N Fertilizer	0.2021	*0.0511*	0.1995

*one outlier removed. There was a 3-way interaction; the nature of this is still being investigated.

**Anthracnose index is a calculation for disease severity, used to rate the number of fruits with anthracnose lesions (1, 2-3, and 4+ lesions) i.e. fruit with few lesions have a low value; whereas, fruit with many lesions have a greater value.

Table 6. Impact of long-term cover crop type, N fertilizer rate, and 2-year winter wheat straw management treatments on percent of fruit with damage caused by bacterial speck, bacterial spot and stink bug at site L2E in 2019.

	Treatment	Bacterial Speck	Bacterial Spot	Stink Bug
		--------------------------%--------------------------		
Long-Term Cover Crop	No Cover	3	7	1
	Oat	4	4	3
	Radish	2	6	2
	Radish+Rye	4	6	3
	Rye	2	5	1
Straw Mgt.	Stays	2	6	2
	Removed	4	6	2
N Fertilizer to tomatoes	125 lbs/ac	4	6	2
	0 lbs/ac	3	5	2

Due to an uneven dataset, statistical analysis is ongoing.

Report to OTRI: Breeding to protect plant health for Ontario's processing tomato industry, 2019 (CAP 0026)

S. Loewen, University of Guelph Ridgetown Campus, 2019-11-01

Description of the project

The processing tomato breeding program at Ridgetown has had a longstanding objective of developing breeding lines, based on wild tomato species, to provide a means to increase genetic diversity of the hybrids grown for processing in Ontario. Disease resistance breeding has received relatively little attention.

The number of different disease resistances incorporated by seed companies into hybrids has increased in recent years. The emergence of late blight as a risk earlier in the season and the limits placed on the use of some control products suggest that genetic resistance to late blight is an important management strategy.

The primary goal of this project is to begin incorporating a core set of resistance genes into all adapted lines in the breeding program. A secondary goal is to gain experience using molecular markers as a routine tool for screening for disease resistance and to facilitate stacking resistance genes.

Specific project activities and outcomes to date, in Year 2 (2019)

Establish and advance nematode and late blight resistant breeding lines in the field

Nine acres of breeding plots were established at a site on Kenesserie Road in Chatham-Kent. There were 226 plots established specifically for advancing generations in nematode resistance breeding and late blight resistance breeding. As of this date seed is still being collected from the field and the final number of selections is not yet known.

Establish late blight resistant selections in the greenhouse for backcrossing

Inventory lists are being prepared to enable screening with molecular markers to determine which selections carry resistance genes. Resistant selections will be backcrossed to well-adapted parents during Fall 2019 and Winter 2020 in order to have segregating lines ready to plant out in 2020.

Isolate DNA from 188 additional breeding lines to screen for disease resistance

One of the goals in Year 1 of the project was to develop the in-house capability for screening breeding lines with molecular markers using PCR thermalcycler. This goal was not completed in the first year but it was completed in 2019. We successfully assayed a group of 107 breeding lines for KASP markers for Ve-1 (Verticillium race 1) and I-2 (Fusarium race 2) to develop our capacity to do this kind of work.

While this capability is important in our own lab, custom genotyping by labs like LGC group has become very inexpensive and convenient. The scale of operation of commercial marker labs like this one make the cost of DNA extraction and assaying markers very attractive for routine disease screening. Most screening work in the future will be done using this custom service.

Release of breeding lines

Breeding lines released in 2019

Twenty F_7 generation breeding lines, selected in fall 2018, were released in time for 2019 field planting. There were 19 out of 20 that were based on pedigrees started at AAFC-GPCRC, Harrow and most had S. habrochaites in the recent pedigree. Yield, fruit colour and elevated soluble solids were important factors in determining which lines would be released.

Breeding field plots

Nine acres of breeding plots were established on a farm on Kenesserie Road northeast of Ridgetown. There were 893 breeding lines from F_2 to F_6 generations planted (736 in 2018; 843 in 2017; 584 in 2016) in addition to the 226 lines noted above.

The exceptionally wet spring planting season resulted in a planting start date of May 27, and planting end date of June 21. This was, by far, the latest we have planted in 31 years. Field selection began on August 29 (2018 August 20; 2017 August 28; 2016 August 29) and continued until October 10 (2018 September 21; 2017 September 28; 2016 Sept 22). Field seed collection is anticipated to be completed by November 5.

The harvest season was relatively warm and dry. The soil and weather conditions fostered the developing of blotchy ripening and provided good conditions to select against this ripening defect in 2019.

Technician transitions

At the end of 2018 Richard Wright, technician, with 31 years of excellent support to the program, retired. A new technician, Satinder Chopra, started in 2019. In addition to providing technical support, he has started training to participate in the breeding selection work.