Re-evaluation of the optimum nitrogen rates for processing tomato production

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Objectives: re-evaluate nitrogen rates on newer and existing processing tomato cultivars on 2 soil types.

Methodology: Two similar experiments were established at Ridgetown Campus Research Farm in 2023 on two different soil types; a sandy loam (65.7% sand, 5.6% silt, 28.7% clay) and clay loam (32.0 % sand, 31.0%silt, and 37.0% clay). The three cultivars were used in this trial - C339, H1014, and H3406. On these cultivars, 6 nitrogen rates were superimposed - 0, 50, 100, 150, 200, and 250 kg actual N per acre. Nitrogen was applied in the form of urea and fertilizer treatments were applied by hand. Additional P and K were applied when required based on soil nutrient analysis. Tomato transplants were sourced from local transplant growers. Each plot consisted of one twin-row bed, 8 m long by 1.5 m wide with a "2 buffer" bed between each N treatment. Transplanting was completed using a commercial twin row RJ transplanter with a row spacing of 45cm and an in-row spacing of 45 cm. On the clay loam site, transplanting was completed on May 19, 2023, whereas on the sandy loam site, transplanting occured on May 26, 2023. A pre-emergence herbicide tank mix of Dual Magnum & Sencore at the recommended rates was applied to control weeds. Broad spectrum fungicides (Bravo and Zampro) were continuously applied at 10 -12-day intervals starting from June 29, 2023, until 3 weeks before harvest. After transplanting, a plant survival count was taken, and 8 weeks after transplanting, 3 plants per plot were used to collect plant dry weight. Plots were harvested (6 plants per plot) when 80% of the fruit across all the cultivars appeared red; Ethrel was not used. Increasing nitrogen rates reduced plant stand so care was taken to harvest from an area that had a complete complement of plants. Fruit was graded into red, green, breaker, and rot and expressed as tons/acre as well as % red fruit. The experimental design was as a strip plot with two main factors consisting of cultivar (vertical strip) and nitrogen rate (horizontal strips) treatments.

Results and Discussion: There was a significant effect of nitrogen treatment on the percent survival of tomato transplants in both the sandy loam and clay loam sites. The highest survival (89.60 % in clay loam and 91.70% in sandy loam) was found in the control treatment across all cultivars. The lowest transplant survival (62.7 % in clay loam and 78.6% in sandy loam) was found in the 250 kg ha^{-1} nitrogen treatment across all cultivars (Tables 1 and 2). Poor survival of tomato transplants in high nitrogen treatments might be due to the 'salt effect', in which higher concentrations of salts in fertilizers causes higher osmotic pressure in the soil and result in the movement of the water out of the plant, causing the death of the plant.

Dry matter accumulation 8 weeks after transplanting did not differ in response to nitrogen rate when averaged across cultivars. However, the dry matter accumulation of cultivar differed when averaged across nitrogen rates; this significant in both sandy and clay loam soil types (Tables 1 and 2). In both soil types, maximum dry matter accumulation was recorded in the H1014 cultivar treatment, and the lowest was in C337 (Tables 1 and 2). The difference in dry matter accumulation might be due to the different growth characteristics of the cultivar.

No significant differences were noted in the percentage of red fruit when averaged across cultivars indicating the plots were harvested at relatively the same maturity. There were no significant interactions between cultivar and N fertilizer rate in any variables evaluated on the clay loam site; red and total fruit yields increased as the N rate increased (Table 2) except for a drop in yield at the 150 kg N ha^{-1} rate; the reason for this is unknown. A significant interaction between cultivar and N rate was found on the sandy loam site; on this site red and total yields were higher at the 0 kg N ha^{-1} rate when compared to the clay site, but tended to be lower at the highest N rate. Yield response to N rate on the sandy loam site tended to be more variable overall (Table 3).

On the clay site the highest red and total fruit yields were found at the highest N rate and yields tended to increase as the N rates increased; on the sandy loam site, 0 kg N ha^{-1} produced yields almost 2.5 times greater than the same rate on the clay site, suggesting significant N reserves in this soil type. Yield responses on the sandy loam site were more erratic in response to N rate than on the clay site.

In 2024 we need to use split N applications on the higher N rates to avoid plant mortality that was seen in 2023; we anticipate this is needed at rates of 150 kg N ha^{-1} and higher and will confirm this after grower consultations. We also decided not to use Ethrel in 2023 as we wanted an indication of the delay in maturity caused by the N treatments; we will also need to consult with the research committee to see if this is acceptable.

Table 1: Effect of tomato cultivars and nitrogen rates (kg ha^{-1}) on survival count and tomato crop yield (tons ha^{-1}) in clay loam soil texture during 2023 at University of Guelph, Ridgetown, Ontario.

Treatment	Survival	Dry wt.	Yield (tons ha^{-1})				Percent of red tomato
Cultivars (C)	%	(g)	Red	Green	Breaker	Total	
C 337	78.5	58.9 b	116.2 b	12.1	7.1	135.3	86.0 ab
H 1014	81.3	86.4 a	142.5 a	8.97	5.9	157.4	90.4 a
H 3406	79.5	82.0 a	112.1 b	13.8	11.0	137.0	81.9 b
[z]SE	**1.91**	**4.54**	**5.78**	**1.28**	**1.02**	**7.22**	**1.15**
Nitrogen (kg N ha^{-1})							
0	89.60 a	57.6	58.4 d	6.4 b	5.2 b	70.0 d	82.4
50	91.38 a	86.4	91.9 cd	6.9 b	4.3 b	103.1 cd	88.8
100	85.72 ab	93.6	128.6 bc	14.6 ab	10.3 ab	153.6 bc	83.7
150	77.07 abc	69.5	124.4 bc	8.5 b	6.3 ab	139.3 bc	89.5
200	72.03 bc	61.1	144.8 b	12.1 ab	8.8 ab	165.7 b	86.9
250	62.7 c	87.5	193.5 a	21.2 a	16.8 a	227.8 a	85.4
SE	**3.58**	**13.3**	**10.03**	**2.29**	**2.33**	**12.36**	**2.02**
Effects	---------------------------------------*P values*------------------------------------						
C	NS	0.0070	0.0130	0.0790	0.0299	NS	0.0077
N	0.0004	NS	<0.0001	0.0052	0.05	<0.0001	NS
C x N	NS	NS	NS	NS	NS	NS	NS

[z]SE indicates standard error of means.

[a-d]In each column and for each effect, means followed by a different letter indicate statistically significant effect at $P<0.05$ per Tukey-Kramer adjustment.

Note: Six plants per plot crop were harvested on different dates in September based on >80% visually red tomato, and the experimental design was strip plot design. Treatment 0 (kg N ha^{-1}) harvested on Sept 6, 50 (kg N ha^{-1}) harvested on Sep 11, treatment 100 (kg N ha^{-1}) was harvested on Sept 12, treatment 150 (kg N ha^{-1}) was harvested on Sept 18, treatment 200 (kg N ha^{-1}) was harvested on Sept 18, and treatment 250 (kg N ha^{-1}) was harvested on Sept 2023.

Table 2: Effect of tomato cultivars and nitrogen rates (kg ha^{-1}) on survival count and tomato crop yield (tons ha^{-1}) in sandy loam soil texture during 2023 at University of Guelph, Ridgetown, Ontario.

Treatment	Survival	Dry wt.	Yield (tons ha^{-1})				Percent of red tomato
Cultivars (C)	%	(g)	Red	Green	Breaker	Total	
C 337	82.6	61.9 b	142.9 b	8.58 b	6.21 b	162.0 b	88.4 a
H 1014	86.3	98.3 a	160.4 ab	4.53 b	4.07 b	177.8 b	90.4 a
H 3406	87.5	75.3 b	166.28 a	19.48 a	17.12 a	212.0 a	79.9 b
[z]SE	**1.30**	**4.50**	**4.21**	**2.26**	**1.08**	**4.38**	**1.54**
Nitrogen (kg N ha^{-1})							
0	91.7 a	85.5	132.8 b	7.49	5.5	145.7 b	92.1
50	89.3 ab	75.6	155.6 ab	13.58	11.2	180.5 ab	86.2
100	85.1 abc	82.6	168.3 a	11.40	9.5	201.6 a	83.8
150	87.2 ab	73.6	147.0 ab	11.23	9.5	174.0 ab	85.2
200	81.0 bc	79.0	162.1 ab	11.07	10.9	204.8 a	81.7
250	78.6 c	74.8	173.5 a	10.40	8.3	197.0 a	88.6
SE	**1.81**	**5.88**	**6.24**	**3.40**	**2.56**	**8.85**	**2.14**
Effects	------------------------------------*P values*--						
C	NS	0.0057	0.0338	0.0016	<0.0001	0.0006	0.0082
N	0.0013	NS	0.0068	NS	NS	0.0039	NS
C x N	NS	NS	0.0401	NS	NS	NS	NS

[z]SE indicates standard error of means.

[a-d]In each column and for each effect, means followed by a different letter indicate statistically significant effect at $P<0.05$ per Tukey-Kramer adjustment.

Note: Six plants per plot crop were harvested on different dates in September based on >80% visually red tomato, and the experimental design was strip plot design. Treatment 0 (kg N ha^{-1}) and 50 (kg N ha^{-1}) harvested on Sep 13, treatment 100 (kg N ha^{-1}) was harvested on Sept 25, treatment 150 (kg N ha^{-1}) was harvested on Sept 26, treatment 200 (kg N ha^{-1}) was harvested on Sept 27, and treatment 250 (kg N ha^{-1}) was harvested on Sept 29.

Table 3. Interaction between cultivars and N rate treatments on the red tomato yield (kg ha^{-1}) at the experiment conducted in the sandy loam soil texture at Ridgetown, Ontario.

N treatments (kg N ha^{-1})	Cultivars			
	C337	H1014	H3407	Means across cultivars
0	129.65 b	140.58 ab	128.13 b	132.8 b
50	142.32 ab	182.77 ab	141.78 ab	155.6 ab
100	163.55 ab	159.58 ab	181.65 ab	168.3 a
150	128.88 b	143.68 ab	168.45 ab	147.0 ab
200	143.98 ab	160.32 ab	181.90 ab	162.1 ab
250	149.22 ab	175.45 ab	195.77 a	173.5 a
Means across N treatments	142.9 B	160.4 AB	166.28 A	

Within each column, means followed by a different lowercase letter indicate statistically significant effect at $P<0.05$ per Tukey-Kramer adjustment.

In each row, treatment means followed by a different uppercase letter indicate statistically significant effect at $P<0.05$ per Tukey-Kramer adjustment.

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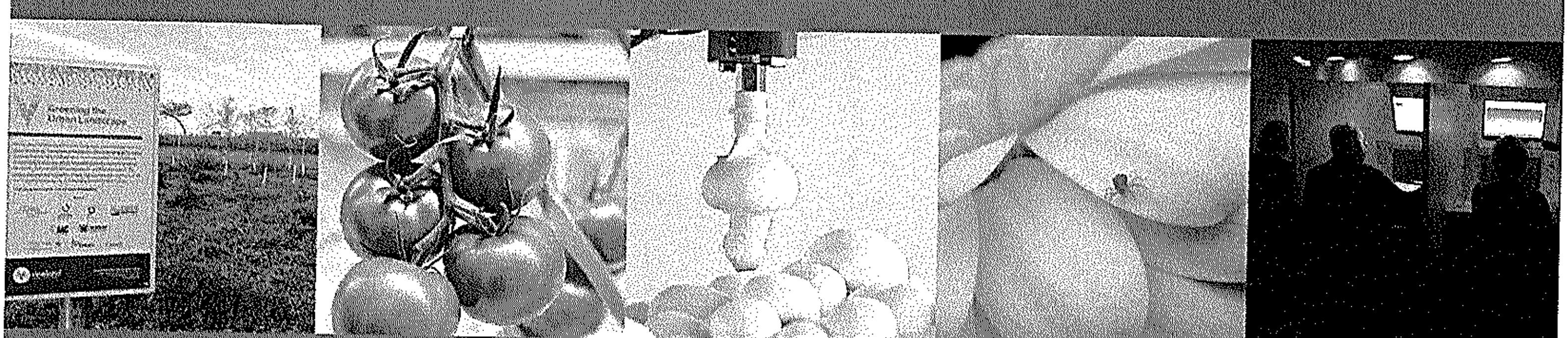

Flume Repurposing Research Project

Exploring the application of flume repurposing in vegetable processing

[INTERNAL] Interim Report delivered to the Ontario Tomato Research Institute

November 2023

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Executive Summary

Vegetable processing companies generate large volumes of soil sediment through the washing and preparation of field grown vegetables harvested from multiple farms. The resulting sediment is generally landfilled at a cost to processors given that it is classified as industrial waste. With its current classification, the aforementioned sediment or 'flume' can not be reused without a Non-Agricultural Source Materials (NASM) application and corresponding approval. Where a single 150,000 square meter processing facility can generate over 2 million kilograms of flume per year, there is a need to identify alternate pathways for the reuse and application of this material, so as to reduce cost to processors and create opportunities for a more sustainable and environmentally responsible practice at an industry level.

In May 2023, Vineland Research and Innovation Centre (Vineland) entered into an agreement with the Ontario Processing Vegetable Growers, Tomato Research Institute to evaluate the prospective re-use and application of flume sediment derived through vegetable processing. The objective of this project is to evaluate the physical, chemical, biological, biochemical and hydrological properties of flume material for the purpose of reducing odor and clarifying potential reuse opportunities, with particular focus on horticultural and landscape applications.

This report covers activities related to characterization, testing and analysis of flume material conducted by Vineland between May and November 2023. Vineland prepared, processed and analyzed flume samples to present the current interim report outlining progress and key findings derived through a range of project activities.

The current report includes:

- An overview of Vineland's comprehensive literature review, highlighting key findings and resources used to inform the material testing and evaluation and biochemical characterization of flume
- An update on Vineland's progress as it pertains to material testing and evaluation of the physical, chemical, biological and hydrological properties of flume
- A preliminary characterization of the biochemical properties of flume, including high level recommendations for controlling flume odor using additives

Project Description

Although there is precedent for the reuse and application of flume as a feedstock or base material in the development and production of soil products, opportunities to divert flume to soil suppliers interested in using the sediment to develop soil materials are currently limited by the various approvals processes upheld by the Ontario Ministries of the Environment, Conversation and Parks and Agriculture, Food and Rural Affairs. This particular reuse application requires that an Environmental Compliance Approval (ECA) be granted to permit the transfer of flume between vegetable processors and soil suppliers. Additional research is required to identify novel opportunities for the reuse and application of flume at an industry level, as well as to clarify the processes and requirements for preparing and submitting NASM and ECA applications as it relates specifically to the flume generated by the vegetable processing industry. Additional research is also required to support the development and implementation of comprehensive strategies for reducing the severity of flume odor through the use of additives, which may contribute toward minimizing or eliminating the often harsh, unpleasant smell associated with flume derived through vegetable processing.

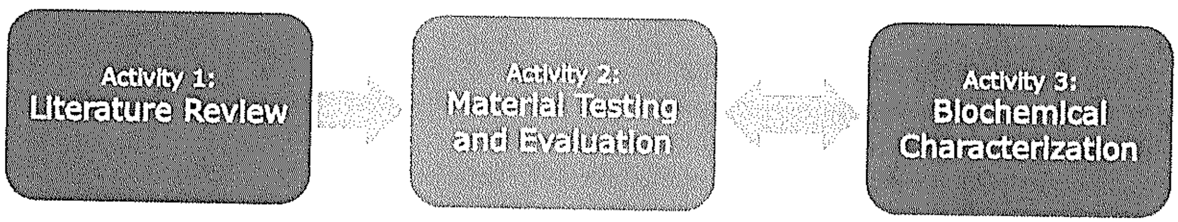


Figure 1. Overview of project process used to evaluate flume for the purpose of reducing odor and clarifying potential reuse opportunities, with particular focus on horticultural and landscape applications. Note that Activities 2 and 3 were conducted concurrently by Vineland's Plant Responses and the Environment and Biochemistry teams, respectively.

The Flume Repurposing Research Project consists of three activities, namely (i) Literature Review (ii) Material Testing and Evaluation and (iii) Biochemical Characterization.

1. **Activity 1, *Literature Review*** involves the comprehensive review of existing literature to identify empirical, evidence-based research that can be used to inform the Materials Testing and Evaluation (Activity 2) and Biochemical Characterization (Activity 3) of flume derived through vegetable processing.
2. **Activity 2, *Materials Testing and Evaluation*** involves the preparation and comprehensive testing of key physical, chemical, biological and hydrological properties of flume. Testing and evaluation will work to establish an empirically derived evidence-base that can be directly used to inform the potential reuse and application of flume at an industry level.
3. **Activity 3, *Biochemical Characterization*** involves the testing and evaluation of the baseline biochemical properties of flume to support the effective characterization of prospective odor mitigating additives. Biochemical characterization will be used to inform the management of flume material, particularly as it relates to controlling flume odor.

Preliminary findings corresponding to each of the aforementioned activities are presented in the current report. Full reporting, including all data, analysis and recommendations will be provided at a later date, in Vineland's final report scheduled to be delivered in January 2024.

Activity 1: Reviewing Alternative Options for Flume Repurposing

Milestone Deliverable 1: Literature Review

- Overview of key findings identified in the literature, with references to the primary information sources
- Interpretation and relevant commentary on published methodologies and results
- List of opportunities and challenges related to the potential re-use of flume, accounting for current regulatory frameworks and market opportunities

Process

In July 2023, Vineland initiated a comprehensive review of existing academic and technical literature to identify resources that could be used to inform the reuse of flume derived through vegetable processing for horticultural applications in agricultural and horticultural production environments. Vineland focused the literature search on resources published between 1995 and present. The literature review surveyed peer-reviewed, scientific literature obtained using academic resource databases, as well as technical articles such as theses and trials that are not peer reviewed. The search was conducted by identifying and inputting key phrases and sorting the resulting resources by relevance until no new relevant articles emerged.

Keywords used for the search are outlined below:
Keyword List:

- "Flume"
- "Tomato washwater"
- "Fruit and Vegetable"
- "Washing sediment"
- "Agricultural waste"
- "Mud Waste"

AND

- "Reuse"
- "Repurposing"
- "Processing"
- "Management"
- "Regulations"

Project Timeline

June 2023	Finalized the coding structure for the literature review to generate a template with instructions including available resource libraries, keywords, and the appropriate date range of publications.
July 2023	Due to the lack of research on the reuse of flume sediment from tomato processing two related fields were identified as applicable to the current review, namely **(i) fruit and vegetable washwater quality** and **(ii) sediment reuse in agriculture.**

August 2023	Collected a range of academic and technical literature to formulate an evidence-based database.
September-October 2023	Reviewed literature to identify key findings resources integral to effectively evaluating opportunities related to the reuse and application of flume sediment in agricultural and horticultural production.

Key Findings

1. **Requirements for field application of agricultural washwater.**
Wash-water from fruit and vegetable processing is regulated by the Ontario Ministry of the Environment, Conversation and Parks (MECP) as it has the same degree of impact on the environment as industrial wastewater. This is due to the high content of soil, organic matter, and pathogens in washwaters that can negatively impact aquatic ecosystems, wildlife, and humans when released into water bodies untreated. A common example of these impacts is eutrophication of water bodies, where algae grows in the water due to the excessive concentrations of nitrogen and phosphorus. In addition, washwaters with high levels of organic loads can consume oxygen from water bodies, negatively affecting the aquatic ecosystem and its fish species. To mitigate these effects, washwaters must be treated to meet regulatory standards before being released into the environment. The direct field-application of tomato washwater will require an Environmental Compliance Approval (ECA) from the MECP or a Non- Agricultural Source Material Plan (NASM) from Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA). To meet these standards water quality parameters should be monitored for environmental and food safety purposes including water clarity, nutrient content, organic matter, dissolved oxygen, pH and microbiological levels.

2. **Baseline properties of fruit and vegetables washwater.**
Samples of raw sewage were collected from two facilities located in the Podlasie province. One facility processed fruit and vegetables, producing mainly juice of fruit and vegetable purée, and the other processed dairy products,mainly hard cheese, yogurt and cottage cheese. The properties of the wastewater samples were characterized and compared to municipal wastewater. It was determined that fruit and vegetable waste had higher values of BOD5 and CODCr and comparable levels of nitrogen and phosphorus.

Table 1. The average monthly values for raw sewage (Puchlik & Struk-Sokolowska, 2017).

Parameter	Unit	Raw wastewater					
		Fruits and vegetables processing			Dairy		
		V	VI	VII	V	VI	VII
BOD	mgO_2/dm^3	860	2 200	3 200	1 220	2 800	3 900
COD	mgO_2/dm^3	919	3 350	3 700	1 680	3 300	5 420
$N_{tot.}$	mgN/dm^3	40.0	48.0	60.0	76.0	69.0	87.0
$P_{tot.}$	mgP/dm^3	9.4	14.8	16.0	12.6	16.0	22.0
TSS	mg/dm^3	249	356	420	200	245	286
pH	-	5.5-7.2	4.3-7.1	4.6-7.9	6.1-9.3	6.6-9.0	6.8-9.4

Puchlik, M., & Struk-Sokołowska, J. (2017). Comparison of the composition of wastewater from fruit and vegetables as well as dairy industry. *E3S Web of Conferences*, *17*, 77-. https://doi.org/10.1051/e3sconf/20171700077

Potential applications of fruit and vegetable washwater.
There are multiple opportunities identified within the literature for washing sediment re-use in agriculture, forestry, and horticulture. One opportunity identified to have high potential is the use of this sediment in the production of manufactured topsoil and plant-growing media for application in nurseries, landscaping, parks, sport pitches, wetland construction, brownfield redevelopment, and restoration of mining sites. More specifically, the reuse of washwater as a fertilizer or soil amendment has had increasing interest as it can improve the fertility of soils under conventional farming practices and in the recycling of nutrients in crop production.

Highlighted Resources

1. Bertoldi, B., Bardsley, C. A., Baker, C. A., Pabst, C. R., Gutierrez, A., De, J., Luo, Y., & Schneider, K. R. (2021). Determining Bacterial Load and Water Quality Parameters of Chlorinated Tomato Flume Tanks in Florida Packinghouses. *Journal of Food Protection*, *84*(10), 1784–1792. https://doi.org/10.4315/JFP-21-100

- Flume tank water samples were collected from three packing houses in Florida and analyzed for pH, total dissolved solids (TDS), free chlorine, chemical oxygen demand (COD), oxidation-reduction potential, and turbidity.
- Additional flume water samples were collected and analyzed for total aerobic plate count (APC), total coliforms (TC), and *Escherichia coli*.

- Fresh tomatoes were collected before and after washing and tested for total aerobic plate count (APC), total coliforms (TC), and *Escherichia coli*.

2. Rushing, J. W. (Clemson U., Cook, W. P., & Spell, L. (1995). Accumulation of pesticides in tomato packinghouse wastewater and the influence of integrated pest management on reducing residues. *HortTechnology (Alexandria, Va.)*, *5*(3), 243–247. https://doi.org/10.21273/horttech.5.3.243

- The analysis of water from six commercial tomato packinghouse dump tanks in South Carolina identified that metal and pesticide residues accumulate in the dump-tank water during daily operation.
- The amount of metal and pesticide residues varied: Asana (esfenvalerate), 0.3 to 13.8 ppb; Bravo (chlorothalonil), 0.1 to 2.7 ppm; copper, 2.0 to 7.3 ppm; and manganese, 0.1 to 2.5 ppm.
- Contamination decreased when growers implemented integrated pest management (IPM) in their production practices.

3. Lucia, C., Pampinella, D., Palazzolo, E., Badalucco, L., & Laudicina, V. A. (2023). From Waste to Resources: Sewage Sludges from the Citrus Processing Industry to Improve Soil Fertility and Performance of Lettuce (Lactuca sativa L.). *Agriculture (Basel)*, *13*(4), 913-. https://doi.org/10.3390/agriculture13040913

- To assess the effect of Citrus Sewage Sludge (CSS) applied at different concentrations (2.5, 5, 10 t ha−1) on soil fertility and lettuce performance.
- The CSS amendment improved soil fertility by increasing total organic C, and, at the highest dose, P availability and microbial biomass C.
- The resulting increase in soil fertility and soil microorganisms, lead to an increase in lettuce biomass.

4. Vidal-Beaudet, L., Charpentier, S., & Rossignol, J. P. (2009). Physical and mechanical properties of washed sediment mixed with organic matter. *Soil Use and Management*, *25*(2), 141–151. https://doi.org/10.1111/j.1475-2743.2009.00209.

- The physical and mechanical properties of the non-structured washed soil and the effectiveness of organic matter amendments (peat and green waste compost) were evaluated.
- When compressed, large pores (radius >1500 lm) disappeared in the washed soil mixtures but were still observed in the control and were maintained by aggregate stability.
- The additions of organic matter improved all the washed soil properties by increasing structural porosity and vertical stress resistance.

5. Kiani, M., Raave, H., Simojoki, A., Tammeorg, O., & Tammeorg, P. (2021). Recycling lake sediment to agriculture: Effects on plant growth, nutrient availability, and leaching. *The Science of the Total Environment*, *753*,

141984–141984. https://doi.org/10.1016/j.scitotenv.2020.141984

- Plant growth conditions were improved from the addition of lake sediment as treatments had nearly double the phosphorus uptake of ryegrass compared to the control soil.
- To improve plant yield and soil nutrient status without increasing phosphorus and nitrogen leaching from the soil a 75-cm thick layer of sediments was applied on the agricultural sandy loam soils surrounding the lake.
- In addition, a 2-cm layer of biochar between the sediment and soil reduced P and N leaching by 50%.

Activity 2: Material Testing and Evaluation

Milestone Deliverables 2: Soil Health Reports, Recommendations for Use and Application of Flume, Environmental Compliance Approval (ECA) Application Guidelines for Flume Repurposing, Non-agricultural Source Materials (NASM) Application Guidelines for Flume Repurposing

- Two comprehensive Soil Health Reports detailing physical, chemical, biological and hydrological properties of flume sediment provided by Conagra and Highbury Canco
- Recommendations for the prospective use and application of flume based on its observed properties
- Comprehensive guideline outlining the various steps required to complete an ECA or NASM applications to permit the use of flume in agricultural/horticultural applications

Experimental Design

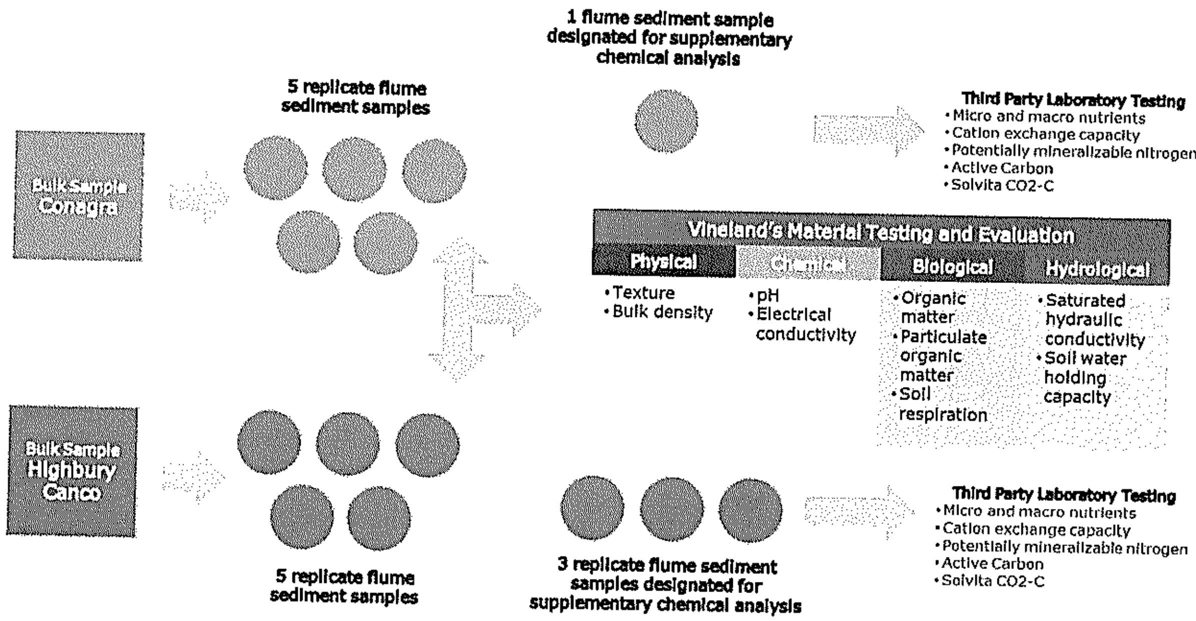


Figure 2. Overview of experimental design used for material testing and evaluation of flume sediment

- 5 replicate samples of material provided by both Conagra and Highbury Canco were used to evaluate the physical, chemical, biological and hydrological properties of flume sediment derived from vegetable processing
- 3 replicate samples of the material provided by Highbury Canco were used to evaluate the supplementary chemical properties of the flume sediment, including Solvita CO2-C, potentially mineralizable nitrogen, active carbon and macro and micro nutrient content. Only 1 sample of the material provided by Conagra was submitted for supplementary chemical analysis, where

- The data and information derived through the characterization of physical, chemical, biological, hydrological and supplementary chemical properties will be used to inform the prospective use and application of flume sediment, allowing Vineland to provide detailed recommendations for the transfer and management of material as it relates to its use in horticultural and landscape applications
- With an understanding of the inherent properties of flume sediment and its recommended use and application, Vineland will develop a step by step guideline outlining the information required to complete either an ECA or NASM application to permit the use of fume according to its intended reuse application.

Key Analysis Methods

The following indicators will be used to characterize the baseline physical, chemical, biological and hydrological properties of flume sediment provided by Conagra and Highbury Canco:

Indicator		Description
Physical	Texture	Refers to the total sand, silt and clay content of soil. Measured as a percent of the total soil mass (%). Known to influence drainage, water-holding capacity, nutrient retention and availability.
	Bulk Density	Refers to the dry weight of soil, divided by its volume. Indicator of soil compaction, negatively correlated with root extension and growth.
Biological	Organic Matter	Refers to the various organic constituents of soils, including living organisms, plant residues, detritus and humus. Known to regulate soil structure, water holding capacity and nutrient content while serving as a vital food source for soil microbial and fungal communities.
	Particulate Organic Matter	Refers to active, unprocessed organic matter typically associated with soil microbial and fungal communities.
	Soil Respiration (respiration over 96 hours)	Refers to the measure of carbon dioxide (CO2) released through both the decomposition of organic matter and respiration of plant roots and other below ground biota.
	Solvita CO2-C (respiration over 24 hours)	Refers to the measure of carbon dioxide (CO2) released through the decomposition of soil organic matter and respiration of plant roots and other soil borne organisms. Measured in milligrams per gram (ppm).
	Potentially Mineralizable	Refers to the fraction of organic or unavailable nitrogen that is converted into the mineral form.

	Nitrogen	Used as an indicator the capacity of a soil's microbial community to convert nitrogen tied up in complex organic residues into the plant available form of ammonium. Measured in microgram nitrogen per gram of soil per week (μg N/ g soil/ week).
	Active Carbon	Refers to the fraction of soil carbon that is readily available to a soil's microbial community. Measured in parts per million (ppm).
Chemical	pH	Refers to the acidity or alkalinity of soil. Indicator of nutrient availability and loss.
	Electrical Conductivity	Refers to the conductivity of soil, used as an indicator of soil nutrient content.
	Macro and Micro Nutrient Content	Refers to the relative measures of vital plant nutrients including phosphorus (P), potassium (K), magnesium (Mg) and calcium (Ca), sodium (Na), sulfur (S), boron (B), copper (Cu), manganese (Mn), iron (Fe), zinc (Zn) and aluminum (Al).
	Cation Exchange Capacity	Refers to a soil's ability to hold and exchange cations. Used as an indicator of soil fertility, where higher CEC coincides with increased availability of Ca, K and Mg in soil. Measured in centimoles of positive charge per kilogram of soil (cmolc/kg).
Hydrological	Saturated Hydraulic Conductivity (KSat)	Refers to the ease with which pores of a saturated soil material transmit water. In-lab measurement is used to characterize the rate at which water moves through materials that are completely saturated. Measured in centimeters per day (cm/day).
	Soil Water Holding Capacity (HYPROP)	Refers to the tenacity with which particles of soil retain water. In-lab measurements are used to generate soil moisture release curves that estimate the total force required to extract water from soil across the entire range of soil moisture. Measured in megapascals (MPa).

Project Timeline

May 2023 Vineland identifies that approximately 20 kg of air dried flume sediment is required to support Activities 2 (Material Testing and Evaluation) and 3 (Biochemical Characterization). Vineland requests the required flume samples from project partners (Conagra and Highbury Canco)

September 21st 2023 20 kg of saturated flume sediment or 5 kg of air dried flume sediment received from Conagra

September 26th 2023 40 kg of air dried flume sediment received from Highbury Canco

September 26th - November 8th 2023 Conagra flume sediment was air dried at room temperature until constant weight was achieved (approximately 6 weeks of drying).

NOTE: The flume sediment provided by Conagra was not air dried prior to delivery. Accordingly, the 20 kg sample of saturated flume sediment was dried at Vineland, delaying Activity 2: Material Testing and Evaluation by approximately 6 weeks. The 20 kg sample of saturated flume sediment equated to approximately 7 kg of air dried material, as a result of which the experimental design has been modified to accommodate reduced sample volume. Given an insufficient amount of flume sediment, Vineland will conduct comprehensive testing using fewer replicates to characterize the properties of the flume sediment provided by Conagra.

November 8th 2023 Comprehensive testing and evaluation of the physical, chemical, biological and hydrological properties of flume sediment initiated by the Vineland Team. Sub-samples prepared and sent to a third party laboratory for supplementary chemical analysis.

December 2023 Vineland to complete comprehensive and reduced testing and evaluation of flume sediments. Vineland will use the data and information derived through Material Testing and Analysis to generate (i) soil health reports, (ii) recommendations for use and application of flume, (iii) environmental compliance approval (ECA) application guidelines for flume repurposing and (iv)non-agricultural source materials (NASM) application guidelines for flume repurposing.

January 2024 Vineland to deliver reporting for all activities to Ontario Processing Vegetable Growers, Tomato Research Institute

Key Findings

1. Preliminary handling of flume suggests that opportunities for the **reuse and application of *saturated* flume sediment as a feedstock or base material in the development and production of soil products** is limited in scope.

2. **There is a need for material testing and evaluation guidelines to support the efficient and effective submission of NASM applications**
The reuse and application of flume sediment derived through vegetable processing will benefit from clear, comprehensive guidelines to support the transfer of materials from processors to field producers, who could utilize flume sediment to

supplement loss of mineral soil in field operations. Where NASM approval is required to facilitate such opportunities, Vineland will provide comprehensive guidelines outlining the various steps required to complete a NASM application to support the use of flume in agricultural/horticultural applications.

Activity 3: Biochemical Characterization

Milestone Deliverables 3: Biochemical Characterization, Additive Impact and Recommendation Report

- Detailed characterization of the baseline chemistry of flume sediments provided by Conagra and Highbury Canco using mass spectrometry (GC-MS, LC-MS)
- List of potential strategies for controlling flume odor using additives, including a detailed characterization of chemical changes that might be affected by the incorporation of various additives into flume sediment
- Recommendations as to which additives warrant further evaluation, which may include a detailed characterization of the impacts of said additives on the volatile and non-volatile biochemical components of flume sediment

Experimental Design

- Multiple technical replicates (aliquots) of the bulk samples provided by the two (2) sources were used for characterization samples/replicates
- Mass spectrometry-based chemical analyses were used to characterize similarities and differences between the flume samples from the two sources.
- Chemical components will be identified that might underlie malodorous attributes, or influence potential uses for repurposed flume.

Key Laboratory Methods

The following analytical methods were used to characterize and compare the baseline biochemical compositions of flume sediment provided by Conagra and Highbury Canco:

Gas chromatography–mass spectrometry **GC-MS**	• Odor-causing volatile chemicals emitted from flume samples were trapped and concentrated, and primary chemical components were identified by GC-MS • This provides a comprehensive analysis of organic aroma chemicals that might contribute to odor • This "volatile" chemical fingerprint contributes to understanding the source of odorant chemicals in flume, and ways to mitigate their production
Liquid chromatography–mass spectrometry **LC-MS**	• Water-soluble extracts of flume samples were analyzed using untargeted LC-MS analysis, providing a high-resolution profile of the organic chemicals present • This approach provides a comprehensive profile of thousands of flume-associated chemicals • This fingerprint of non-volatile chemical helps identify potential sources of odorant chemicals identified by GC-MS, as well as other plant-, or microbe-derived chemicals that could affect potential uses in the re-purposing of flume.

Project Timeline

September 21st 2023	20 kg of saturated flume sediment or 5 kg of air dried flume sediment received from Conagra
September 26th 2023	40 kg of air dried flume sediment received from Highbury Canco
October 2023	LC-MS and GC-MS profiling of flume sediment
October - November 2023	Data analysis and reporting of Biochemical Characterization results

Preliminary Results

Volatile profiling identifies toluene as a primary component of wet flume

- The volatile aromatic hydrocarbon toluene was the primary component (>75%) of volatile organic chemicals collected from wet flume samples provided by Source 1 (Figure 3A). Methylphenol (cresol), a microbial metabolite of toluene, was also abundant (~20%) (Figure 3A).
- Flume from Source 2, which was dry, did not release detectable levels of toluene or methylphenol (Figure 3B).

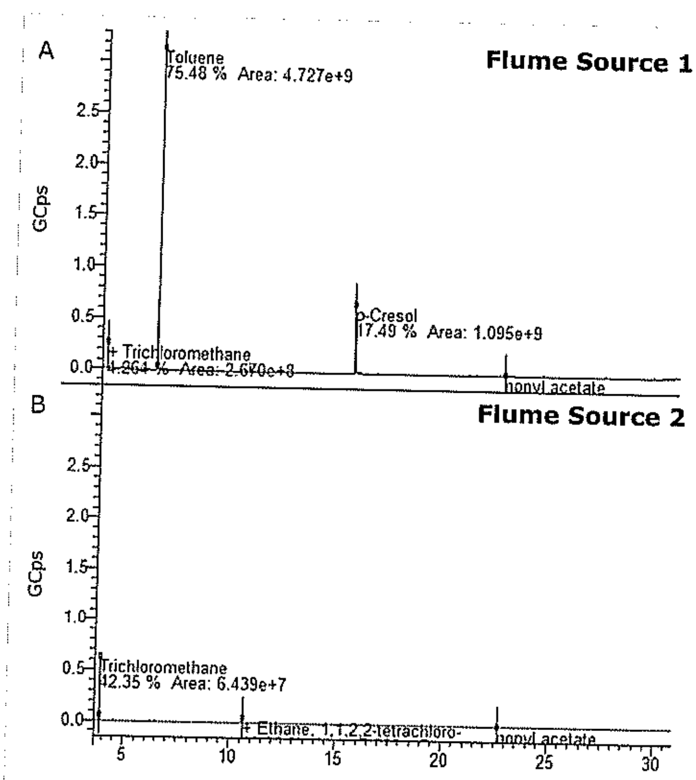


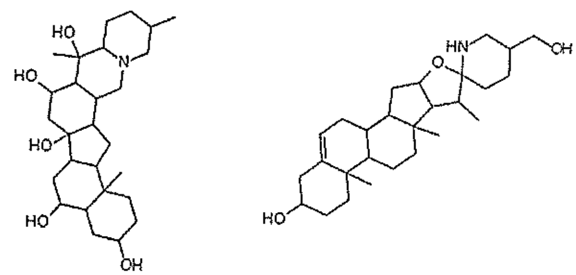
Figure 3. Volatile profiling for flume sources 1 and 2

LC-MS metabolomics reveals substantial steroidal alkaloid content in flume

- Three (3) of the most abundant chemicals detected at similar levels in flume samples from both sources belong to a class of tomato-derived defense biochemicals called steroidal alkaloids, known for their antibacterial and antifungal properties (Table 2).

Table 2. Overview of most abundant chemicals detected across both flume sediment samples

Compound	Formula	Mass Error (ppm)	Putative ID	Class
19.33_463.3293n	$C_{27}H_{45}NO_5$	-1.1	Pingpeimine A	steroidal alkaloid
22.38_429.3237n	$C_{27}H_{43}NO_3$	-1.4	Solaparnaine	steroidal alkaloid
21.13_463.3292n	$C_{27}H_{45}NO_5$	-1.2	Pingpeimine A	steroidal alkaloid



Pingpeimine A

Solaparnaine

Key Findings

1. **Toluene was the primary volatile chemical in wet flume from Source 1,** likely a product of microbe-mediated anaerobic fermentation when flume is in storage.

2. **Flume from both sources contained steroidal alkaloids as abundant components,** specialized metabolites from tomato with antibacterial and antifungal properties.

3. **Mitigation of anaerobic fermentation when flume is in storage** might reduce toluene production, and emission of its malodorous metabolites.

Tomecek Agronomy Services Inc.

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Year End Report

GRADEHUB- 2023

c/o OPVG
435 Consortium Ct.
London, ON

Nov. 14, 2023

GRADEHUB

The GradeHub system was used by the Ontario Processing Tomato Industry in 2023 for the 2nd year in a row. The platform allows Graders to easily record grading details, calculate tare values and automatically produce grading certificates which are then printed and emailed to all parties, while all data remains stored and accessible internally. From there, Processors use another version of the app to incorporate each load's weight and load value, before producing a Final Grading Certificate that is automatically emailed to growers. The app can track transfers *between* the different Processors and gives Processors the ability to generate payout statements for their growers.

The App was once again well received by Growers. They found the app easy to use and enjoyed having access to all their certificates on their mobile device while out in the field. The App gave them the ability to quickly determine what percentage of their contract they were at, and they could also see what percentage the other growers (at *their* processor) were at too. We have been told that this feature is also helpful for the Processors,as it cuts down on the number of phone calls and emails they receive from growers asking for this information.

Our team was responsible for obtaining and verifying all initial grower and contract data from the 5 Processors and AgGrade, then pre-populating/programming the App to track and calculate the following:

-Grower Names, Contracted Acreages & Tonnages, Field Names

-Details of each Processor's contracts (i.e., Price, Colour and Tare Factors)

-Staff Names and Email Addresses who will be using GradeHub

All the data input/calculated within the App is then syphoned off into back-end spreadsheets for each party (i.e., Each Processor, AgGrade, OPVG), in their ***own*** live Google Sheet document that updates in real-time as each new certificate is created and/or weight is added, and only with the data that **they** have permission to access. To help the Processors, AgGrade and the OPVG work with this large amount of data over the season, we used a program called, Looker Studios and created customized reports for each of them. Although these reports function quite well *within* the program itself, making daily viewing easy, these reports (if more than 1 page in length), do not print out nicely directly from the program. Instead, users would have to export the raw data from Looker Studios into Excel, where unfortunately it loses the parameters by which the program had originally sorted the data, so it does require some additional steps by end users who are not just "viewing the data" but wanting to save it or print.

This year, GradeHub calculated the tare values and produced grading certificates for over 10,300 loads at 4 of the 5 major processors. Overall, the app functioned well, there were no major technical issues or service outages and it once again proved to be a trustworthy and reliable tool for generating and storing this important industry data. Over the entire season, someone from our team was always "on-call" to answer calls/emails that came in, and helped all parties (AgGrade, Processors, Growers, OPVG) regarding accessing the app, navigating the system, and responding immediately to any issues that arose.

We implemented a new change in the 2023 season that allowed graders to correct errors on existing certificates, without having to "cancel" them and start again. For every change they made, the app would then update the "revision number" on the certificate. This saved time at the grading station and reduced the unintentional creation of so many duplicate certificates, which had been an issue in 2022. We also added a new feature to the app that helped graders identify why a certificate was coming up as "rejectable" (i.e., what specific parameter was outside its acceptable range) *before* they saved and printed it, which helped graders identify and correct unintentional data entry errors, saving time and mitigating errors at the grading station.

We received a few requests from growers last year about having more than 1 person on their operation be able to access the App and also about increasing the number of people who can receive their emailed certificates. With the OPVG's permission, each operation now have access for up to 2 unique user IDs and can get certificates sent to up to 4 email addresses We were also able to implement a grower's suggestion about adding a "comment" box and a "truck driver" box to the growers' app, so they could add notes onto each certificate/load that only they would see in their app, and also have available at the end of the season in their individual back-end spreadsheet.

In terms of any issues experienced this year and/or future considerations with respect to changes/modifications needed for the app next year, it was minimal. At the very end of the season when transfers first began from one processor to another, there was an issue with the app that would not let the graders sync their changes and print certificates. Our team worked with AgGrade and was able to get everything fixed and back up and running quickly. The main issue that AgGrade experienced throughout the season was not having a strong, reliable internet connection in the grading sheds, making it difficult for them to sync and print at times/ They are working with the respective processors to find better alternatives for next season.

The growers have mentioned that they would like the app to give them the ability to see what time their trucks leave the processor's facility. This is a bit tricky, as the processes are different at each of the different processors. Theoretically this could be achieved by having the scale house clerk enter the weights for each load directly into the App, as the truck leaves the scales, and then having us add a viewable "timestamp" onto this particular field of the app, which would give growers a pretty good idea of when their truck departed. However, the issue at this point is that not all Processors are set up to do this. Many are still printing the grading certificates and then having the scale house print the weights directly onto these certificates. The next morning, an office admin person would pick up the certificates and then enter the corresponding weights into GradeHub, so for these growers, a "time stamp" on when the weight is entered would not be useful.

This year, HCC decided not to use the GradeHub App. They had AgGrade use their internal software exclusively to generate all certificates instead of entering it into BOTH systems like was done in 2022 (i.e., HCC's and GradeHub). They were having their own App developed that would communicate the grading data from their internal software to growers. We did some preliminary work to figure out how we could import HCC's raw data into GradeHub on some regular interval throughout the season, to re-incorporate it with the rest of the industry's real-time data, so the OPVG could still have access to one industry-wide master data set with their corresponding reports. Despite reaching out on a few occasions, we never received any data from HCC. We are open to continuing to collaborate with them in the future to try and amalgamate this data.

Although this was an exceedingly difficult season for us *personally*, we are proud of the service we were still able to offer and felt that the app performed well for all parties. We have been forced to make some significant staffing changes in our business, which may affect some of our existing processes in terms of how we continue to offer this service. In the past, we were able to make changes/modifications to our apps very quickly, sometimes even mid-season. Although we still hope to provide you with the same technical capabilities and good customer service, unfortunately we will not be as nimble when it comes to implementing changes/modifications to our apps. We will require more time to be able to develop and implement changes.

Going forward, we will need to receive all requested changes/modifications for the App by December 31st of 2023. Depending on how in-depth these changes/modifications are, we would then prepare a quote (or revise our existing quote) for the added changes, and give OPTAC until February 15th to approve it, so we would have enough time to develop and implement the changes before the season begins.

Thank you for your business.

Project Title: Processing tomato breeding, 2023

Research Agency and Location: University of Guelph Ridgetown Campus; 120 Main St. E., Ridgetown, ON N0P 2C0

Lead and Key Investigators: Steve Loewen

Objectives:

1. To continue the work started in 2018 to 2020 stacking multiple disease resistance markers in breeding lines.
2. To continue the core breeding work aimed at increasing genetic diversity in regionally adapted breeding lines for release to seed company partners.
3. To develop further a novel early fruit colouring trait that may have potential use in improving consistency in tomato paste while retaining good red colour in the final product.
4. To initiate breeding work to address emerging issues as they are identified during the term of the project.

Materials and Methodology:

1. In summer 2023 there were 752 breeding lines screened for 10 different SNP markers by LGC Genomics LLC. KASP markers for Ve-1, Fus-2, Fus-3, Nematodes, TSWV and late blight (Ph-2 and Ph-3) resistance were among those screened.
2. The processing tomato breeding program uses pedigree selection, introgression and backcrossing with selection as breeding methods to achieve the breeding goals. There were 753 breeding lines from F6 to F2 generations field planted in 2023. Transplanting started on May 23 and finished on June 6. Field selection began on August 29 and was complete on September 14.
3. Breeding lines with an early fruit colouring trait have been identified as a potential way to improve paste quality.
4. There were no emerging issues identified for breeding during the 2023 season.

Results and Conclusions:

1. Results from breeding to stack multiple markers for disease resistance progressed slower than originally planned. There are three reasons for this: (a) This is partly due to the conservative counting method used for reporting where only homozygous markers were counted, (b) the program providing funding planned for covering the cost of marker screening was suspended by the sponsor, and (c) seed company cooperators cautioned that while resistance to multiple diseases is important, this tends to reduce genetic diversity along the chromosomes in the vicinity of the disease resistance genes, and the genetic diversity offered by Ridgetown breeding lines should not be compromised by requiring all lines released to necessarily contain all resistance genes.

Table 1. Number of breeding lines having stacked markers for disease resistance	
Number of breeding lines	**Number of markers stacked**
481	One marker
171	Two markers

57	Three markers
4	Four markers
This is a conservative count since only homozygous markers were counted. Heterozygous markers in segregating lines were not counted. F8 to F3 generations are represented.	

2. (a) A cohort of 15 breeding lines was released to seed company partners in February 2023 in time for 2023 field planting. These lines were chosen from selections made in Fall 2022. Breeding line AE219 had a NTSS of 6.2 and lines AE240 and AE260 had NTSS of 5.8 and 5.9 respectively (Check hybrids growing near to these lines in the field had a NTSS range of 4.4 to 5.2). Work has been proceeding for several years to incorporate nematode resistance into breeding lines and three of the lines released in this cohort (AE287, AE288 and AE301) had a molecular marker associated with Mi1.2 gene for resistance. Breeding lines AE168, AE247 and AE250 had notably healthy foliage compared to check varieties.
(b) In general, the early part of the 2023 field season was dry, with cold nights extending to late May. As the season progressed, rainfall became frequent. In July 6.3" of rain fell at the breeding plot site and August had 6.5" of rain during the last half of that month. There were 672 field selections made in Fall 2023. In addition to visual ratings of plant and fruit characteristics, data were collected on maturity and field holding ability. In Fall 2022 very strong selection pressure was imposed against fruit puffiness (which is a negative trait possibly associated with high NTSS). The results of this were evident in 2023 with very little puffiness detected in breeding lines. Decisions will be made on the 15 best advanced lines for release to partners in Winter 2024.
(c) There were 20 Harrow breeding lines, received in 2002, that were pulled from the collection and entered the breeding and development pipeline for selection and further crossing. Lines were chosen based on pedigrees to try to sample wide genetic diversity from the former AAFC breeding program. At least one selection was made from each of these lines in Fall 2023.
(d) There was one Ridgetown breeding line showing some resistance and four lines showing tolerance to ToBRFV based on work done by J. Griffiths (AAFC, Vineland). Unfortunately, due to delays from the pandemic, that project was incomplete before the funding ended. We are currently in discussions with a collaborator to carry this forward to develop molecular markers with a goal of making this germplasm available to seed company partners, and screening other breeding lines having pedigrees with a likelihood of ToBRFV resistance.
3. Breeding lines with a trait that results in early fruit colouring were grown in 2022 for field selection but were temporarily shelved for 2023 to focus efforts in other areas.
4. There were no urgent, emerging issues identified in 2023.

Acknowledgements:

The long-term support of this work by the Ontario Tomato Research Institute is gratefully acknowledged. This year has been a significant milestone. OTRI (and OPVG prior) has supported this effort for 35 consecutive years. Through that time this work has been one piece among many parts that have contributed to an increase from 20 tons/acre provincial average yield to 40 tons/acre. Looking ahead, our goal is to enable reliable achievement of 40 tons/acre. Beyond that, we want to continue collaborating with all of our industry partners to support achievement of a provincial average yield of 50 tons/acre.