Evaluating Ethylene for Seed Tuber Accumulation

Report on 2019 Research Activities

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Project Overview:

Starting in 2018, the Prince Edward Island Potato Board and Agriculture & Agri-Food Canada started a project under the Agronomy Initiative for Marketable yield (AIM) to evaluate the use of ethylene gas for increasing tuber numbers in several potato cultivars grown in Prince Edward Island. Use of ethylene gas for both sprout inhibition and tuber accumulation has become routinely used in Western Europe. The interest from our Seed Working Group relates to the ability of ethylene to increase the number of tubers per plant and decrease average tuber size as part of a seed production management program. Increasing average tuber number may also be of interest for commercial production of certain cultivars that normally have a small number of tubers per plant.

Five cultivars were evaluated at two sites while three cultivars were evaluated just at one site. From the 2018 results, there were multiple cultivars that showed a significant increase on tuber number, with the Russet Burbank variety showing the largest degree of effect. Results were encouraging enough to repeat the trial in 2019.

Materials and Methods:

An ethylene generator was procured from the Restrain Company for the second year in a row. This generator had an internal tank for the liquid ethanol to be converted to ethylene as well as sensors to detect the ethylene concentration in the air of the storage room and to measure temperature, relative humidity, and carbon dioxide concentration.

Seed potatoes of ten varieties were procured from certified seed producers in mid-February. The Restrain ethylene generator was started on February 22nd in a small refrigerated storage room at the AAFC Harrington Research Farm, and half of each seed lot was placed into this room. The remaining seed potatoes were placed into a separate refrigerated storage room in a separate building, held at a constant temperature of 4 degrees C.

The ethylene treated storage room was held at 7.5 degrees C until April 8th to encourage sprouting of the majority of eyes to 2 mm in length. On April 8th, the temperature in the treated storage room was lowered to 4 degrees C.

The ethylene generator was turned off on May 23rd. The temperature in both storages was increased to 10 degrees C on May 24th to allow the seed to warm up before planting. Planting was performed at the AAFC Harrington site (6 processing cultivars) on May 29th. Planting was performed at the Atlantic Agri-Tech (AAT) site (6 processing cultivars plus 4 privately controlled varieties) on June 4th. At AAFC Harrington, paired rows of treated and non-treated cultivars were planted with four replicates in a randomized complete block design. At AAT, 7.6 m rows were planted in a randomized split block design.

Special care was taken to ensure that average seed piece size was the same between the ethylene treated rows and the control rows, as well as minimizing the variation in seed piece size within each row. Table 1 contains the within-row seed spacing and fertility rates for each cultivar. Spacing and fertility rates were the same at both research sites.

Table 1. Within-row seed spacing and fertilizer rates for cultivars in ethylene study.

Cultivar	Within-row Seed Spacing (in)	N rate (lbs/ac)
Russet Burbank	11	120
Ranger Russet	9	120
Mountain Gem	9	120
Clearwater Russet	11	120
Payette Russet	9	120
Dakota Russet	9	105
Creamer 1	4	105
Creamer 2	4	150
Chip Variety 1	10	160
Long White 1	10	150

Fertilizer was applied as a 15-15-15 mix banded at planting at 700 lbs/acre, in addition to 0-0-60 potassium which was banded at 125 lbs/acre. Additional nitrogen was applied as a top-dress at hilling using calcium ammonium nitrate (CAN). Each trial field had moderate to high fertility levels for all nutrients in advance of planting.

Emergence was monitored for each plot two or three times per week until full emergence was achieved. Stem counts were performed on July 10th at AAT and after desiccation at AAFF Harrington. Desiccation with diquat was performed on September 6th at Harrington and September 10th at AAT. Harvest was performed on September 30th at Harrington and October 7th at AAT.

Emergence:

Table 2. Emergence data from AAFC Harrington Site.

Cultivar	Treatment	20 June % emergence	8 July % emergence
Russet Burbank	Control	**17.2 a**	100.0
Russet Burbank	Ethylene Treated	**46.6 b**	100.0
Ranger Russet	Control	**12.9 a**	100.0
Ranger Russet	Ethylene Treated	**52.9 b**	100.0
Mountain Gem	Control	50.0	100.0
Mountain Gem	Ethylene Treated	57.8	99.2
Clearwater Russet	Control	3.4	100.0
Clearwater Russet	Ethylene Treated	6.9	100.0
Payette Russet	Control	0.7	**90.9 a**
Payette Russet	Ethylene Treated	2.1	**98.5 b**
Dakota Russet	Control	**25.0 a**	97.7
Dakota Russet	Ethylene Treated	**49.3 b**	100.0

Emergence was measured at each location but with different dates after planting.

Twenty-two days after planting, there is was a noticeable different in emergence rate between the ethylene treated seed and the control treatment for the Russet Burbank, Ranger Russet and Dakota Russet cultivars. There was no significant difference observed for the Mountain Gem cultivar. The other two cultivars (Clearwater Russet and Payette Russet) were slower to emerge in this trial and also did not show a difference after twenty-two days after planting.

Forty days after planting, there is only one cultivar that showed a statistical difference in final emergence (Payette Russet). Payette Russet was notably slow in emerging in all plots. This appears to be a limitation of the cultivar. At the time of this report, emergence data for multiple dates after planting was not available; however, it was observed in the field that for most varieties the ethylene treated plots generally emerged faster than the control plots. This is consistent with results from 2018.

Table 3. Emergence data from Atlantic Agri-Tech Site:

Cultivar	**Treatment**	**28 June % emergence**	**5 July % emergence**
Russet Burbank	Control	85.2	99.1
Russet Burbank	Ethylene Treated	96.3	100.0
Ranger Russet	Control	81.1	100.0
Ranger Russet	Ethylene Treated	90.2	100.0
Mountain Gem	Control	98.5	100.0
Mountain Gem	Ethylene Treated	100.0	100.0
Clearwater Russet	Control	14.8	100.0
Clearwater Russet	Ethylene Treated	35.2	100.0
Payette Russet	Control	0.8	93.9
Payette Russet	Ethylene Treated	5.3	96.2
Dakota Russet	Control	62.9	96.2
Dakota Russet	Ethylene Treated	62.9	95.5
Creamer 1	Control	**36.7 a**	97.4
Creamer 1	Ethylene Treated	**71.4 b**	100.0
Creamer 2	Control	70.7	98.0
Creamer 2	Ethylene Treated	81.0	97.7
Long White 1	Control	**71.7 a**	100.0
Long White 1	Ethylene Treated	**95.0 b**	100.0
Chip Variety 1	Control	16.7	95.0
Chip Variety 1	Ethylene Treated	14.2	94.2

At the Atlantic Agri-Tech site, only the Creamer 1 and Long White 1 cultivars showed a significant difference ($p<0.05$) at 24 days after planting, both in favour of the ethylene treatment. Most varieties achieved 100% emergence or very close to it by 31 days after planting. Clearwater Russet, Payette Russet, and Chip Variety 1 were noticeably slower getting to full emergence than the other cultivars, but there was not a pronounced difference between the treatment and control.

Yield and Size Distribution of Processing Cultivars:

Table 4. Stem Number and Tuber Counts by size category for processing cultivars.

Cultivar/Treatment	Stems/ Plant	Total Tubers/m^2	# Tubers 30-45 mm/m^2	# Tubers 45-55 mm/m^2	# Tubers 55-85 mm/m^2	# Tubers > 85 mm/ m^2
Clearwater Control	4.77	45.8	18.9	19.2	5.9	0
Clearwater Ethylene	4.61	46.3	20.0	20.6	4.8	0
Dakota Control	2.17	28.7	5.3	**10.7 a**	12.0	0.2
Dakota Ethylene	2.24	32.7	7.2	**14.7 b**	9.8	0.2
Mountain G Control	4.03	41.3	7.7	14.4	18.1	0.2
Mountain G Ethyl	4.07	43.9	9.7	14.3	18.7	0.1
Payette R Control	**3.88 a**	**39.0 a**	13.5	14.3	9.5	0.1
Payette R Ethylene	**4.32 b**	**44.7 b**	16.5	15.4	10.9	0.1
R Burbank Control	**2.55 a**	**37.0 a**	9.9	**12.3 a**	13.0	0.3
R Burbank Ethylene	**3.53 b**	**45.6 b**	13.7	**19.7 b**	10.8	0.3
Ranger R Control	2.97	37.4	12.2	15.2	8.8	0.1
Ranger R Ethylene	3.05	39.8	13.0	15.9	9.5	0.0

Means in bold type and with “a” and “b” after the mean indicate statistical significance at p=0.05.

For the second year in a row, Russet Burbank showed among the highest impact on the use of ethylene. Use of ethylene resulted in a statistically significant increase in stems per plant and total tuber number for both Russet Burbank (+23.2%) and Payette Russet (+14.6%). Dakota Russet also saw a numerical increase in total tuber number (+13.9%) but not statistically significant. This was similar to results for Dakota Russet in 2018. There was a significant different in the number of tubers between 45 and 55 mm for Dakota Russet (+37.4%) in favour of ethylene treatment.

Table 5. Mean yields for processing cultivars by size category.

	Yield (cwt/acre)					Mean Tuber
Cultivar/Treatment	30-45 mm	45-55 mm	55-85 mm	>85 mm	Total Yield	Weight (g)
Clearwater Control	65.0	135.1	63.2	0	265.3	65.4
Clearwater Ethylene	76.8	149.6	49.7	0	277.4	67.2
Dakota Control	23.2	**100.2 a**	164.8	6.1	300.0	**117.1 b**
Dakota Ethylene	33.4	**135.0 b**	130.8	5.1	306.2	**106.0 a**
Mountain G Control	26.7	107.6	218.8	5.0	361.3	99.2
Mountain G Ethyl	33.2	108.2	218.1	3.5	364.1	93.7
Payette R Control	45.22	96.0	98.7	3.2	**245.8 a**	75.2
Payette R Ethylene	56.3	99.3	110.0	1.8	**270.9 b**	70.6
R Burbank Control	34.5	**92.5 a**	**158.7 b**	6.4	**301.3 a**	**92.3 b**
R Burbank Ethylene	48.3	**144.4 b**	**123.2 a**	7.2	**326.4 b**	**81.8 a**
Ranger R Control	40.9	103.5	99.8	1.4	247.1	73.7
Ranger R Ethylene	43.7	106.1	101.2	1.0	254.0	72.2

Means in bold type and with “a” and “b” after the mean indicate statistical significance at p=0.05.

In 2019, both the Russet Burbank and Payette Russet cultivars saw a significant increase in yield after ethylene treatment. Total yield increases were 10.2% for Payette Russet and 8.3% for Russet Burbank. As shown above, there was also an increase in total tuber numbers for these cultivars, resulting in

smaller mean tuber weights for the ethylene treatment. There was also a statistically significant reduction in mean tuber weights for the ethylene treated Dakota Russet cultivar, as well as a significant yield increase in the 45-55 mm size category (which is the most valuable size category for seed production). The other cultivars did not see a significant difference between the ethylene treatment and control, and numerical differences were generally small, leading us to surmise that ethylene does not appear to have much of an effect on these cultivars.

Table 6. Means for tuber count and yield variables across all varieties.

Variable	**Control**	**Ethylene Treated**	**Significance Level**
Percent Emergence	98.3	99.8	ns
Stems/Plant	3.4	3.6	<0.001
Total Tubers per m^2	38.2	42.2	<0.001
Mean Tuber Weight (g)	87.1	81.9	<0.001
# of tubers 30-45 mm per m^2	11.2	13.4	<0.001
# of tubers 45-55 mm per m^2	14.4	16.8	<0.001
# of tubers 55-85 mm per m^2	11.2	10.7	ns
# of tubers >85 mm per m^2	0.1	0.1	ns
Yield (cwt/ac) of tubers 30-45 mm	39.3	48.6	<0.001
Yield (cwt/ac) of tubers 45-55 mm	105.8	123.8	<0.001
Yield (cwt/ac) of tubers 55-85 mm	134.0	122.1	0.015
Yield (cwt/ac) of tubers >85 mm	3.7	3.1	ns
Total Yield (cwt/ac)	286.8	299.8	<0.001

When pooling the results across all cultivars, there is a statistical significant between ethylene treatment and control for most cultivars, including stems per plant, total tuber number, and total yield. This is despite several cultivars having non-significant differences when examined individually.

These results are pooled over both sites (AAFC Harrington and AAT). There was a great deal of consistency in results between the two sites in 2019.

Yield and Size Distribution of Fresh Market Cultivars:

Table 7. Stem Number and Tuber Counts by size category for processing cultivars.

Cultivar/Treatment	**Stems/ Plant**	**Total Tubers**	**# Tubers 30-45 mm**	**# Tubers 45-55 mm**	**# Tubers 55-85 mm**	**# Tubers > 85 mm**
Creamer 1 Control	5.13	440.3	292.5	137.3	10.5	0.0
Creamer 1 Ethylene	5.75	421.0	267.3	128.5	25.3	0.0
Creamer 2 Control	5.13	**684.5 a**	526.8	143.8	14.0	0.0
Creamer 2 Ethylene	5.53	**539.3 b**	371.5	145.0	22.8	0.0
Long White 1 Control	2.85	200.5	41.5	50.3	107.0	1.3
Long White 1 Ethylene	3.20	240.0	53.8	63.5	121.0	1.8
Chip Variety 1 Control	2.40	138.0	25.0	6.8	102.0	**4.3 a**
Chip Variety 1 Ethylene	2.18	138.5	21.5	10.5	98.0	**8.5 b**

Means in bold type and with “a” and “b” after the mean indicate statistical significance at p=0.05.

This year, the two creamer cultivars did not perform as expected. The ethylene treatment actually decreased total tuber number for Creamer 2 by a large amount. Creamer 1 saw no statistical difference. In conversation with the staff at Atlantic Agri-Tech, there may have been data missing on tubers under 30 mm in size, which may have had an impact on the creamer cultivar results. There was no statistical difference in tuber numbers or stems per plant for the other two private cultivars.

Table 8. Mean yields for processing cultivars by size category.

	Yield (kg/plot)					Mean Tuber Weight (g)
Cultivar/Treatment	**30-45 mm**	**45-55 mm**	**55-85 mm**	**>85 mm**	**Total Yield**	
Creamer 1 Control	7.60	8.38	1.05	0.0	17.03	38.7
Creamer 1 Ethylene	7.58	7.88	2.35	0.0	17.80	42.3
Creamer 2 Control	11.48	7.40	1.33	0.0	20.20	29.5
Creamer 2 Ethylene	8.98	7.13	2.03	0.0	18.13	33.6
Long White 1 Control	1.30	3.28	12.80	0.35	17.83	88.9
Long White 1 Ethylene	2.10	4.23	14.00	0.48	20.80	86.7
Chip Variety 1 Control	0.90	0.45	12.68	**0.85 b**	14.88	107.8
Chip Variety 1 Ethylene	0.80	0.70	12.28	**2.15 a**	15.93	115.0

Means in bold type and with “a” and “b” after the mean indicate statistical significance at p=0.05.

There was no significant difference in total yield between treatment and control for these four cultivars, and there was no indication of difference in mean tuber yield between treatment and control, either.

All data for these four table/chip cultivars is only from the trial at Atlantic Agri-Tech.

Discussion:

In a similar result to the 2018 trial, it appears that there is a strong cultivar difference relating to the effectiveness of ethylene gas to increase tuber numbers. Cultivars with strong apical dominance and naturally lower numbers of tubers per plant appear to be less sensitive to the ethylene treatment. However, for cultivars such as Russet Burbank, Payette Russet, and to a lesser extent Dakota Russet, it appears that ethylene is effective in increasing tuber numbers without sacrificing overall yield for seed.

This trial was structured to investigate these cultivars for seed accumulation using seed production practices. It would be interesting to see how these cultivars would react to a trial aimed at commercial production practices for processing or fresh market.

In addition, the research team received feedback from representatives of the Restrain Company indicating that in Western Europe, use of ethylene allows growers to store their seed potatoes at higher storage temperatures. This allows for seed to accumulate more degree-days of physiological age while having sprout inhibition due to the presence of ethylene. Future research in North America should examine the difference in performance of seed from different storage temperatures after treatment with ethylene, particularly for apically dominant cultivars that struggle with low stem and tuber numbers per plant.

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