EFFECT OF METHYL JASMONATE, SALICYLIC ACID, HEADLINE™ AND STADIUM™ ON ROOT YIELD, SUCROSE YIELD, AND STORAGE PROPERTIES

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INTRODUCTION

Methyl jasmonate (MeJA) and salicylic acid (SA) are increasingly being investigated for their ability to enhance yield and protect crop plants and products from environmental stress and disease (Rohwer and Erwin, 2008; Hayat et al., 2010). For a number of crop species and plant products, the application of these compounds improves resistance against a range of pathogens and insect pests and provides protection against environmental stresses including cold temperature, drought, and high soil salinity. MeJA and SA can also affect plant development, growth, and metabolism, and increases in biomass (Pelacho and Mingo-Caster, 1991; Khan et al., 2003; Loutfy et al., 2012), alterations in carbohydrate partitioning (Khodary, 2004; Wang and Zheng, 2005), and improvements in water and nitrogen use efficiency (Kumar et al., 2000; Singh et al., 2010) have been attributed to their use. Previous research established that sugarbeet roots respond to these compounds and documented the ability of postharvest MeJA treatments to reduce rot from three storage pathogens (Fugate et al., 2012; 2013). The effect of preharvest MeJA and SA treatments on sugarbeet production and storage properties, however, has not previously been examined.

Research was initiated in 2014 to determine the effects of an early season MeJA treatment, a late season MeJA treatment, or an early season SA treatment on sugarbeet root yield, sucrose content, and storage properties. A late season SA treatment was not included since preliminary studies indicated a detrimental effect of this treatment on storage properties. All treatments were applied singly or in combination with a late season Headline treatment. At the time these experiments were initiated, Headline was a commonly used fungicide for control of Cercospora leaf spot (causal agent *Cercospora beticola*) and was used by some for possible plant health benefits. Headline treatments were included in this study because of its potential to interact with MeJA or SA treatments due to its purported hormone-like attributes (Köhle et al., 2003).

In 2014, significant increases in root yield and recoverable sugar per acre were observed for plants that received an early MeJA treatment + a late Headline treatment (Fugate et al., 2016). Plants that received the early MeJA + Headline treatment yielded 3.5 tons acre^{-1} more than untreated controls. Recoverable sugar per acre (RSA) for the early MeJA + Headline treatment was 1856 lbs acre^{-1} greater than the RSA of controls. No statistically significant effects on storage traits including root respiration rate, sucrose loss in storage, invert sugar accumulation, or root firmness were observed due to early MeJA + Headline treatment.

In a 2015 repetition of this experiment, MeJA had no beneficial effects on root yield, sucrose content, or sucrose yield at time of harvest. The experiment, however, was compromised by a late season Cercospora infection, and Headline-containing treatments outperformed treatments without Headline. An early season MeJA + Headline treatment, however, affected storage traits, and roots that received this treatment had reduced respiration rates after 30 days in storage, reduced loss to molasses after 30 and 90 days in storage, and improved recoverable sugar per ton after 30 days in storage (Fugate et al., 2017). Postharvest Stadium™ treatments, with or without Headline treatment, were also included in the 2015 experiment. Stadium is a commercial mixture of three fungicides (fludioxonil, azoxystrobin, and difenoconazole) that is marketed for the postharvest protection of potato and other tuber and corm products. Beneficial effects due to Stadium were only observed with roots that received both Stadium and Headline treatments. Roots receiving this treatment had lower respiration rates and reduced sucrose loss to molasses after 90 days in storage, relative to controls (Fugate et al., 2017).

In 2016, the MeJA/SA/Headline field and storage experiments were repeated a third time and results of these experiments are reported here. Field and storage experiments were also carried out in 2017. For 2017 experiments, the early MeJA treatments, with or without Headline, were expanded to include two application times and two rates. SA treatments were eliminated since beneficial effects for these treatments were not found in the previous three years.

MATERIALS AND METHODS

Field studies were conducted in Fargo, ND in 2016 and 2017 and at a location near Mooreton, ND in 2017. For Fargo experiments, seed of Crystal ACH 817 was planted using a randomized complete block design with 4 replicates. In 2016, treatments included (1) an untreated control, (2) an early season MeJA treatment, (3) a late season MeJA treatment, (4) an early season SA treatment, (5) a late season Headline treatment, (6) an early season MeJA treatment + a late season Headline treatment, (7) a late season MeJA treatment + a late season Headline treatment, (8) an early season SA treatment + a late season Headline treatment, (9) a postharvest Stadium treatment, and (10) a late season Headline treatment + a postharvest Stadium treatment. MeJA, SA, Headline, and Stadium were applied at rates of 0.01 µM, 10 µM, 9 oz/acre, and 1.6% (v/v), respectively. MeJA and SA solutions contained 10 ppm (v/v) Tween 20 and were applied as foliar sprays. For the Fargo, ND 2017 experiment, treatments included (1) an untreated control, (2) a late season Headline treatment, (3) an early season MeJA treatment of 0.01 µM, (4) an early season MeJA treatment of 1.0 µM, (5) a late season MeJA treatment of 0.01 µM, (6) a late season MeJA treatment of 1.0 µM, (7) an early season MeJA treatment of 0.01 µM + a late season Headline treatment, (8) an early season MeJA treatment of 1.0 µM + a late season Headline treatment, (9) a late season MeJA treatment of 0.01 µM + a late season Headline treatment, and (10) a postharvest Stadium treatment. Headline and Stadium were applied using the same rates as in 2016. Planting, treatment, and harvest dates for 2016 and 2017 are reported in Table 1.

The 2017 Mooreton, ND experiment was planted to two varieties, Hilleshög 4062 and Betaseed 73MN, as a split plot design with 6 replications, using varieties as the main plots. Treatments included (1) an untreated control, (2) a late season Headline treatment, (3) an early June MeJA treatment of 0.01 µM, (4) an early June MeJA treatment of 10 µM, (5) a mid-July MeJA treatment of 0.01 µM, (6) a mid-July MeJA treatment of 10 µM, (7) an early June MeJA treatment of 0.01 µM + a late season Headline treatment, (8) an early June MeJA treatment of 10 µM + a late season Headline treatment, (9) a mid-July MeJA treatment of 0.01 µM + a late season Headline treatment, and (10) a mid-July MeJA treatment of 10 µM + a late season Headline treatment. MeJA and Headline were applied as described above, and planting, treatment, and harvest dates are reported in Table 1.

Table 1. Planting, treatment, and harvest dates for the 2016 and 2017 field studies conducted in Fargo, ND and the 2017 study near Mooreton, ND. In 2016, methyl jasmonate (MeJA) was applied as an early season or late season treatment, and salicylic acid was applied as an early season treatment. In 2017, only MeJA was applied.

	2016, Fargo	2017, Fargo	2017, Mooreton
Planting date	4 May	6 June	9 May
Early season treatments			
date	29 June	13 July	8 Jun; 14 July
days after sowing	56	37	30; 66
Headline & late season treatments			
date	26 Aug	30 Aug	21 Aug
days before harvest	33	30	46
Harvest date	28 Sept	29 Sept	6 Oct

For all experiments (Fargo in 2016; Fargo and Mooreton in 2017), plants were mechanically defoliated and the roots were hand-harvested, washed, and stored at 5°C (41°F) and 95% relative humidity for up to 100 days. Respiration rate, sucrose content, loss to molasses, recoverable sugar yield, and invert sugar concentration were determined after 30 and 100 days in storage using established protocols (Campbell et al., 2012).

Data were analyzed using the GLM procedure of SAS (ver. 9.1, SAS Institute, Inc., Cary, NC) with $\alpha = 0.05$. Fisher's LSD was used to identify significant differences between treatment means.

RESULTS

In 2016, MeJA and SA treatments had little effect on root yield or sucrose yield at harvest, or storage properties at 30 or 100 days after harvest (Tables 2, 3, and 4). Relative to the untreated control, no statistical differences were noted except for an increase in root respiration rate after 30 days in storage for roots that received the early MeJA treatment (Table 3) and an increase in recoverable sugar per ton after 100 days in storage for roots that received a late MeJA treatment + Headline (Table 4). Stadium had no statistically significant effects on any storage property after 30 or 100 days storage (Tables 3 and 4).

In 2017, poor germination for the Fargo, ND field experiment required that the field be replanted. The Fargo field was replanted on 6 June and no treatments were applied until mid-July to allow plants sufficient time to become established. At harvest, no significant differences in root yield, sucrose content, recoverable sugar per ton, recoverable sugar per acre, or sucrose loss to molasses were found for any treatments (Table 5). In the 2017 Mooreton, ND experiment, all treatments had similar root yield, sucrose content, recoverable sugar per ton, and sucrose loss to molasses at time of harvest (Table 6). A significant 1149 lbs/acre increase in recoverable sugar per acre, however, was found for plants receiving a mid-June treatment of 0.01 µM MeJA + a late August Headline treatment. Storage studies for roots from both locations are ongoing.

Table 2. Harvest data from 2016 Fargo, ND field experiment. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with α = 0.05.

Treatment	yield (tons/acre)		root weight (g/root)		sucrose (%)		loss to molasses (%)		Recoverable sugar per ton (lbs/ton)		Recoverable sugar per acre (lbs/acre)	
control--untreated	17.4	a	609	a	16.8	ab	1.66	a	303	ab	5287	a
early MeJA	17.5	a	712	a	16.7	ab	1.73	a	299	ab	5212	a
late MeJA	20.1	a	667	a	16.6	ab	1.68	a	298	ab	6011	a
early SA	18.0	a	701	a	16.1	b	1.88	a	285	b	5049	a
late Headline	19.5	a	690	a	17.2	ab	1.62	a	311	ab	6082	a
early MeJA + Headline	18.1	a	784	a	17.0	ab	1.41	a	311	ab	5643	a
late MeJA + Headline	18.1	a	619	a	17.6	a	1.63	a	318	a	5723	a
early SA + Headline	18.7	a	667	a	16.5	ab	1.84	a	294	ab	5491	a

Table 3. Respiration rate and invert sugar concentration 30 and 100 days after harvest (DAH) for the 2016 Fargo, ND field experiment. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with α = 0.05. Treatment means that are significantly different from the control are highlighted in red.

Treatment	respiration ($mg\ CO_2/kg/h$) 30 DAH		respiration ($mg\ CO_2/kg/h$) 100 DAH		inverts (g/100 g sucrose) 30 DAH		inverts (g/100 g sucrose) 100 DAH	
control--untreated	3.67	a	3.88	b	0.75	ab	0.48	a
early MeJA	3.49	a	4.82	a	0.93	ab	0.55	a
late MeJA	3.90	a	3.93	ab	0.84	ab	0.53	a
early SA	3.71	a	4.25	ab	1.02	ab	0.52	a
late Headline	3.60	a	4.18	ab	0.84	ab	0.56	a
early MeJA + Headline	3.75	a	3.80	b	0.80	ab	0.43	a
late MeJA + Headline	4.01	a	4.17	ab	0.58	b	0.53	a
early SA + Headline	3.66	a	3.96	ab	0.66	ab	0.73	a
Stadium	3.85	a	4.43	ab	1.06	a	0.54	a
Stadium + Headline	3.59	a	3.94	ab	0.67	ab	0.56	a

Table 4. Sucrose content, loss to molasses and recoverable sugar per ton 30 and 100 days after harvest (DAH) for the 2016 Fargo, ND field experiment. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with α = 0.05. Treatment means that are significantly different from the control are highlighted in red.

Treatment	sucrose (%)				loss to molasses (%)				recoverable sugar per ton (lbs/ton)			
	30 DAH		100 DAH		30 DAH		100 DAH		30 DAH		100 DAH	
control--untreated	17.4	a	17.2	ab	1.73	a	1.94	a	313	a	308	b
early MeJA	17.0	a	16.7	b	1.80	a	1.77	a	305	a	303	b
late MeJA	17.6	a	17.3	ab	1.71	a	2.04	a	317	a	308	b
early SA	17.0	a	16.7	b	1.82	a	2.01	a	304	a	301	b
late Headline	17.6	a	17.2	ab	1.76	a	1.92	a	316	a	311	ab
early MeJA + Headline	17.5	a	17.2	ab	1.84	a	1.91	a	314	a	310	ab
late MeJA + Headline	18.1	a	18.3	a	1.85	a	1.92	a	325	a	331	a
early SA + Headline	17.2	a	16.7	b	1.66	a	1.87	a	312	a	301	b
Stadium	16.8	a	16.7	b	1.85	a	2.00	a	301	a	300	b
Stadium + Headline	17.0	a	17.0	b	1.78	a	1.99	a	306	a	306	b

Table 5. Harvest and storage data for the 2017 Fargo, ND field experiment. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with α = 0.05. Determination of storage properties for these roots is in progress.

Treatment	yield		recoverable sugar		recoverable sugar		loss to molasses		sucrose content 0 DAH		sucrose content 30 DAH		respiration rate 30 DAH	
	tons/acre		lbs/acre		lbs/ton		%		%				mg CO_2/kg/h	
control--untreated	16.8	abcd	5552	abc	330	a	1.42	a	17.9	a	18.7	a	4.24	ab
Headline (HDL)	16.1	bcd	5052	cd	316	a	1.90	a	17.5	a	18.8	a	3.80	b
Jul MeJA, 0.01 µM	16.7	abcd	5534	abc	331	a	1.51	a	18.1	a	18.7	a	4.31	ab
Jul MeJA, 10 µM	16.1	bcd	5150	bcd	319	a	1.65	a	17.6	a	19.3	a	4.40	ab
Jul MeJA, 0.01 µM + HDL	17.5	abc	5703	ab	326	a	1.54	a	17.8	a	19.3	a	4.16	ab
Jul MeJA, 10 µM + HDL	15.9	cd	5060	cd	318	a	1.59	a	17.5	a	19.0	a	4.38	ab

Table 6: Harvest and storage data for the 2017 Mooreton, ND field experiment. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with α = 0.05. Values that are statistically different from untreated controls are highlighted in red. Determination of storage properties for these roots is in progress.

Treatment	yield		recoverable sugar		recoverable sugar		loss to molasses		sucrose content 0 DAH		sucrose content 30 DAH		respiration rate 30 DAH	
	tons/acre		lbs/acre		lbs/ton		%		%				mg CO_2/kg/h	
control--untreated	32.4	ab	7993	bc	293	a	1.58	a	16.2	ab	16.2	abc	4.32	a
Headline (HDL)	29.9	b	7454	c	285	a	1.66	a	15.9	ab	15.9	bc	4.21	a
Jun MeJA, 0.01 µM	30.1	b	7497	c	292	a	1.62	a	16.2	ab	16.1	abc	4.14	a
Jun MeJA, 10 µM	31.4	b	7644	bc	286	a	1.49	a	15.8	b	15.9	c	4.09	a
Jul MeJA, 0.01 µM	32.4	ab	8520	ab	297	a	1.45	a	16.3	ab	16.6	a	4.03	a
Jul MeJA, 10 µM	30.8	b	7646	bc	287	a	1.53	a	15.9	b	16.1	abc	4.09	a
Jun MeJA, 0.01 µM + HDL	35.4	a	9142	a	299	a	1.18	a	16.4	a	16.5	ab	4.06	a
Jun MeJA, 10 µM + HDL	33.4	ab	8438	abc	295	a	1.43	a	16.2	ab	16.3	abc	4.02	a
Jul MeJA, 0.01 µM + HDL	31.8	ab	8045	bc	291	a	1.46	a	16.0	ab	16.3	abc	4.34	a
Jul MeJA, 10 µM + HDL	30.8	b	7678	bc	291	a	1.53	a	16.1	ab	16.3	abc	4.19	a

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