EFFECT OF METHYL JASMONATE, SALICYLIC ACID, HEADLINE™ AND STADIUM™ ON 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, is unknown.

Research was initiated in 2014 to investigate 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. Headline is a commonly used fungicide for control of Cercospora leaf spot (causal agent *Cercospora beticola*) and may interact with MeJA or SA treatments due to 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 2015 and 2016 the MeJA/SA/Headline field experiment was repeated. Additionally, the experiment was expanded to determine the effect of postharvest Stadium™ treatments, with or without Headline treatment, on root storage properties. Stadium is a commercial product comprised of the fungicides fludioxonil, azoxystrobin, and difenoconazole. It is currently marketed for the postharvest protection of potato.

MATERIALS AND METHODS

Field studies were conducted in 2015 and 2016 in Fargo, ND using a randomized complete block design with 4 replicates. Plots were planted with Crystal ACH 819. 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. Planting, treatment, and harvest dates for the two field studies are presented in Table 1. MeJA, SA, and Headline were applied at rates of 0.01 µM, 10 µM, and 9 oz/acre, respectively. MeJA and SA solutions contained 10 ppm (v/v) Tween 20 and were applied as foliar sprays. Roots were mechanically defoliated, hand harvested, washed and stored at 5°C (41°F) and 95% relative humidity for up to 90 days. Postharvest Stadium treatments were applied at a rate of 1.6% (v/v) to untreated and Headline-treated roots after harvest.

Table 1. Planting, treatment, and harvest dates for the 2015 and 2016 field studies. Methyl jasmonate was applied as an early season or late season treatment. Salicylic acid was applied as an early season treatment.

Production parameters	2015	2016
Planting date	29 Apr	4 May
Early season treatments		
date	10 July	29 June
days after sowing	72	56
Headline & late season treatments		
date	20 Aug	26 Aug
days before harvest	32	33
Harvest date	21 Sept	28 Sept

Respiration rate, sucrose content, loss to molasses, recoverable sugar yield, and invert sugar concentration were determined using established protocols (Campbell et al., 2012). Root firmness was measured at the widest portion of the root using a Wagner model FT40 penetrometer (Greenwich, CT, USA) with a 6 mm diameter probe.

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 AND DISCUSSION

In 2015, a late season *Cercospora* infection developed and symptoms of leaf spot were evident in treatments that did not include Headline. Not surprisingly, all Headline-containing treatments had greater root yield than treatments that did not include Headline (Table 2). All Headline-containing treatments were statistically similar. However, relative to the untreated control, root yield was significantly greater in the Headline only treatment and the early SA + Headline treatment. Previously, SA was found to protect against *C. beticola* (Bargabus et al.,

Table 2. Harvest data from 2015 field experiment. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with $\alpha = 0.05$. Treatment means that are significantly different from the control are highlighted in red.

Treatment	yield		root weight		sucrose		loss to molasses		Recoverable sugar per ton		Recoverable sugar per acre	
	(tons/acre)		(g/root)		(%)		(%)		(lbs/ton)		(lbs/acre)	
control--untreated	25.2	cde	865	a	15.0	b	2.39	abc	252	b	6343	b
early MeJA	24.8	de	690	a	15.6	ab	2.34	abc	265	ab	6577	b
late MeJA	24.8	de	773	a	15.5	ab	2.60	ab	258	b	6391	b
early SA	25.4	bcde	746	a	16.6	ab	2.10	bc	290	ab	7407	ab
late Headline	26.7	ab	860	a	15.1	b	2.73	a	247	b	6571	b
early MeJA + Headline	26.1	abcd	778	a	16.2	ab	2.17	bc	281	ab	7317	ab
late MeJA + Headline	26.4	abc	874	a	15.0	b	2.50	ab	249	b	6521	b
early SA + Headline	27.0	a	855	a	15.9	ab	2.08	bc	277	ab	7465	ab

2002), and the high root yield of the SA + Headline treatment may reflect the efficacy of these two compounds against this fungus.

In 2015, roots from plants that received the early MeJA + Headline treatment had improved storage traits. These roots respired at a rate that was 15% lower than the control treatment at 30 days after harvest (Table 3), had 22 to 23% less sucrose loss to molasses at 30 and 90 days after harvest (Table 4), and had an additional 33 lbs recoverable sugar per ton after 30 days in storage than control roots (Table 4).

Beneficial effects from the postharvest treatment of roots with Stadium were also observed, although statistically significant improvements occurred only when Stadium was combined with Headline. Roots that received both Stadium and Headline treatments had respiration rates that were 16% lower than controls at 90 days after harvest (Table 3) and had 28% less sucrose loss to molasses after 90 days storage, relative to controls (Table 4).

Table 3. Respiration rate, root firmness, and invert sugar concentration 30 and 90 days after harvest (DAH) for the 2015 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)				firmness (kg/cm^2)				inverts (mg/g fresh wt)			
	30 DAH		90 DAH		30 DAH		90 DAH		30 DAH		90 DAH	
control--untreated	5.29	ab	5.02	ab	60.9	a	60.0	a	1.71	ab	2.48	a
early MeJA	5.07	abc	5.24	a	60.3	a	59.8	a	1.59	ab	2.88	a
late MeJA	4.85	abc	4.75	abc	60.8	a	58.0	a	2.20	ab	3.42	a
early SA	5.26	ab	4.89	ab	59.9	a	57.9	a	1.67	ab	2.72	a
late Headline	4.80	abc	5.37	a	61.5	a	59.9	a	1.17	b	2.10	a
early MeJA + Headline	4.48	c	4.55	bc	60.2	a	59.4	a	1.79	ab	1.56	a
late MeJA + Headline	4.94	abc	4.78	abc	61.3	a	58.6	a	2.10	ab	1.58	a
early SA + Headline	4.93	abc	4.85	abc	61.2	a	59.2	a	2.29	a	3.27	a
Stadium	5.45	a	4.44	bc	60.3	a	57.9	a	2.24	a	3.14	a
Stadium + Headline	4.77	bc	4.22	c	61.7	a	60.4	a	2.31	a	1.95	a

Table 4. Sucrose content, loss to molasses and recoverable sugar per ton 30 and 90 days after harvest (DAH) for the 2015 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		90 DAH		30 DAH		90 DAH		30 DAH		90 DAH	
control--untreated	16.4	abcd	17.7	ab	2.87	a	3.77	a	271	bc	278	ab
early MeJA	16.2	bcd	16.4	b	2.80	ab	3.30	abc	267	bc	262	b
late MeJA	17.3	abc	16.6	b	2.72	ab	3.60	ab	291	ab	259	b
early SA	17.5	a	17.1	ab	2.66	ab	3.45	abc	297	ab	273	ab
late Headline	16.1	cd	16.4	b	2.78	ab	3.35	abc	267	bc	260	b
early MeJA + Headline	17.5	a	17.4	ab	2.25	b	2.92	bc	304	a	290	ab
late MeJA + Headline	17.0	abcd	16.6	b	2.89	a	3.61	ab	282	abc	260	b
early SA + Headline	16.0	d	16.6	b	3.05	a	3.52	abc	259	c	262	b
Stadium	17.3	abc	17.4	ab	2.77	ab	3.58	ab	291	ab	276	ab
Stadium + Headline	17.4	ab	18.0	a	2.56	ab	2.73	c	296	ab	304	a

In 2016, *Cercospora* disease pressure was extremely high, and treatments that included Headline tended to give the highest yields (Table 5). However, no treatment differed significantly from the untreated control. Similarly, all treatments had statistically similar sucrose content at harvest. The evaluation of storage properties for the 2016 field experiment is in progress. At the time of writing, only determinations of respiration rate at 30 and 60 days after harvest and sucrose content 30 days after harvest are available. For these three storage parameters, no significant alterations were observed for any treatment relative to the untreated controls.

Table 5. Harvest and storage data for the 2016 field experiment. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with α = 0.05. Experiment is ongoing; table presents the data available at the time of writing.

Treatment	yield		root wt		sucrose content (%)				respiration (mg CO_2/kg/h)			
	(tons/acre)		(g/root)		0 DAH		30 DAH		30 DAH		60 DAH	
control--untreated	17.4	ab	609.0	a	16.8	ab	17.4	a	3.67	a	3.45	abc
early MeJA	17.5	ab	711.9	a	16.7	ab	17.0	a	3.49	a	3.75	a
late MeJA	20.1	a	667.1	a	16.6	ab	17.6	a	3.90	a	3.20	c
early SA	18.0	ab	701.3	a	16.1	b	17.0	a	3.71	a	3.78	a
late Headline	19.5	ab	690.0	a	17.2	ab	17.6	a	3.60	a	3.67	abc
early MeJA + Headline	18.1	ab	784.1	a	17.0	ab	17.5	a	3.75	a	3.39	abc
late MeJA + Headline	18.1	ab	618.7	a	17.6	a	18.1	a	4.01	a	3.69	abc
early SA + Headline	18.7	ab	667.3	a	16.5	ab	17.2	a	3.66	a	3.22	bc
Stadium	16.9	b	627.4	a	16.7	ab	16.8	a	3.85	a	3.73	ab
Stadium + Headline	20.1	a	651.5	a	16.5	ab	17.0	a	3.59	a	3.60	abc

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