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 improved resistance against a range of pathogens and insect pests and provided 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 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 including root respiration rate, sucrose loss, invert sugar accumulation and root firmness. 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 and may interact with MeJA or SA treatments due to purported hormone-like attributes (Köhle et al., 2003). In 2015, research was expanded to investigate 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 postharvest potato protection.

MATERIALS AND METHODS

Field studies were conducted in 2014 and 2015 in Fargo, ND using a randomized complete block design with 4 replicates. Plots were planted with Crystal ACH 819. Treatments in 2014 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, and (8) an early season SA treatment + a late season Headline treatment. In 2015, these 8 treatments and two additional treatments of (9) a postharvest Stadium treatment, and (10) a late season Headline treatment + a postharvest Stadium treatment were used. In 2014, field plots were planted on 22 May. Early MeJA (0.01 µM) and SA (10 µM) treatments were applied 54 days after sowing (15 July 2014). A late season MeJA treatment and Headline (9 oz/acre) treatments were applied 35 days before harvest (26 August 2014). In 2015, field plots were planted on 29 April. Early MeJA and SA treatments were applied 72 days after sowing (10 July 2015), and a late season MeJA treatment and Headline treatments were applied 32 days before harvest (20 August 2015). Preharvest treatments were applied as foliar sprays. In both years, roots were mechanically defoliated, harvested by hand, washed and placed into storage at 5°C (41°F) and 95% relative humidity for up to 90 days. In 2015, postharvest Stadium treatments (1.6%, v/v) were applied to untreated and Headline-treated roots.

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 determine when differences between treatment means were significant.

RESULTS AND DISCUSSION

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 (Table 1). 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 yield or RSA gain was observed with MeJA or Headline alone. This suggests that the gain for the combined treatment was due to an interaction between MeJA and Headline.

Storage properties including root respiration rate, invert sugar accumulation, and root firmness were unaffected by the early MeJA and Headline treatment (Table 2). Storage properties were unaffected by all treatments except the early SA + Headline treatment. For this treatment, respiration rate was significantly elevated relative to control roots 30 days after harvest and root firmness was reduced 90 days after harvest.

All treatments had statistically similar sucrose concentrations at harvest (Table 1) and after 30 or 90 days storage (Table 3). No statistically significant differences in loss to molasses or recoverable sugar per ton were observed 30 or 90 days after harvest.

Table 1. Harvest data from 2014 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 controls are highlighted in red.

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	23.7	bc	962	a	14.4	a	2.40	a	240	a	5668	b
early MeJA	23.5	bc	679	c	14.7	a	2.12	ab	251	a	5927	ab
late MeJA	23.5	bc	827	abc	14.3	a	2.10	ab	243	a	5736	b
early SA	24.2	abc	798	abc	15.3	a	1.93	ab	267	a	6446	ab
late Headline	21.5	c	870	ab	14.8	a	1.77	b	260	a	5592	b
early MeJA + Headline	27.3	a	970	a	15.8	a	2.25	ab	272	a	7524	a
late MeJA + Headline	26.2	ab	752	bc	15.1	a	1.86	ab	265	a	6937	ab
early SA + Headline	25.0	ab	682	c	14.2	a	2.16	ab	242	a	6083	ab

Table 2. Respiration rate, root firmness, and invert sugar concentration 30 and 90 days after harvest (DAH) for the 2014 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 controls 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	3.96	b	4.04	ab	54.8	ab	55.8	a	2.76	ab	5.04	a
early MeJA	3.84	b	4.10	ab	57.0	ab	53.5	ab	2.71	ab	3.77	a
late MeJA	3.96	b	3.95	b	54.4	b	52.6	ab	3.25	a	4.07	a
early SA	4.00	b	4.31	ab	55.5	ab	53.0	ab	2.43	b	3.84	a
late Headline	3.94	b	4.26	ab	58.3	a	52.2	ab	2.88	ab	3.81	a
early MeJA + Headline	3.93	b	3.87	b	54.1	b	53.1	ab	3.03	ab	4.00	a
late MeJA + Headline	3.89	b	3.86	b	54.4	b	55.9	a	2.80	ab	4.03	a
early SA + Headline	4.70	a	4.88	a	56.1	ab	50.3	b	2.97	ab	4.56	a

Table 3. Sucrose content, loss to molasses and recoverable sugar per ton 30 and 90 days after harvest (DAH) for the 2014 field experiment. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with $\alpha = 0.05$.

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	13.1 a	13.9 a	2.10 ab	2.19 a	225 a	238 a
early MeJA	13.4 a	13.2 a	1.99 ab	2.11 a	232 a	229 a
late MeJA	12.6 a	12.1 a	2.33 a	2.27 a	211 a	207 a
early SA	13.5 a	13.9 a	1.85 b	2.10 a	238 a	242 a
late Headline	13.8 a	14.2 a	1.89 ab	2.09 a	240 a	246 a
early MeJA + Headline	12.7 a	12.2 a	1.78 b	2.36 a	224 a	204 a
late MeJA + Headline	13.4 a	13.3 a	2.09 ab	2.11 a	230 a	230 a
early SA + Headline	13.1 a	13.7 a	2.08 ab	2.25 a	226 a	234 a

Table 4. Harvest and storage data for the 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 controls are highlighted in red. Experiment is ongoing; table presents the data available at the time of writing.

Treatment	yield (tons/acre)	root wt (g/root)	sucrose content (%)		respiration (mg CO_2/kg/h)		firmness (kg/cm^2)
			0 DAH	30 DAH	30 DAH	60 DAH	30 DAH
control--untreated	25.2 cde	865 a	15.0 b	16.9 b	5.29 ab	4.91 ab	60.9 a
early MeJA	24.8 de	690 a	15.6 ab	17.0 ab	5.07 abc	4.72 ab	60.3 a
late MeJA	24.8 de	773 a	15.5 ab	18.0 ab	4.85 abc	4.76 ab	60.8 a
early SA	25.4 bcde	746 a	16.6 ab	17.8 ab	5.26 ab	4.28 b	59.9 a
late Headline	26.7 ab	860 a	15.1 b	17.2 ab	4.80 abc	5.53 a	61.5 a
early MeJA + Headline	26.1 abcd	778 a	16.2 ab	18.1 a	4.48 c	4.57 b	60.2 a
late MeJA + Headline	26.4 abc	874 a	15.0 b	16.9 b	4.94 abc	4.57 b	61.3 a
early SA + Headline	27.0 a	855 a	15.9 ab	16.8 b	4.93 abc	4.68 b	61.2 a
Stadium	24.6 e	885 a	15.8 ab	17.1 ab	5.45 a	4.17 b	60.3 a
Stadium + Headline	26.3 abc	771 a	17.2 a	17.9 ab	4.77 bc	4.23 b	61.7 a

In 2015, the study was compromised by the development of a late season *Cercospora* infection. All Headline-containing treatments had greater root yield than treatments that did not include Headline, and all Headline-containing treatments were statistically similar (Table 4). However, relative to the untreated control, root yield was significantly greater in the Headline only treatment and the early SA + Headline treatment. SA has previously been shown to protect against *Cercospora* (Bargabus et al., 2002), and the high root yield of the SA + Headline treatment may reflect the efficacy of these two compounds against this fungus.

The evaluation of storage properties for the 2015 study is in progress. At the time of writing, only determinations of respiration rate, sucrose content, and firmness 30 days after harvest and respiration rate 60 days after harvest are complete. In this data, few significant differences have been observed between treatments except for a decrease in root respiration rate and an increase in sucrose content after 30 days in storage for roots from the early MeJA + Headline treatment. At 30 days in storage, no negative or positive effects due to Stadium treatment have been observed.

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