Repeated Foliar Sprays of Abscisic Acid to Strawberry Plants Influence Plant Growth and Yield

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Introduction

Ayub et al. (2016) injected abscisic acid (ABA) into field-grown strawberry fruit at green, white, pink and red stages of development to determine the effects on gene expression and fruit quality. ABA increased soluble solids content in all stages after 24 h, but had little effect on anthocyanin content. Chen et al. (2011) found that strawberry fruit dipped in ABA solution had enhanced FaASR gene expression and concluded that the treatment might contribute to acceleration of strawberry fruit ripening. Weekly sprays of ABA from anthesis until harvest increased soluble sugar content in tomato fruit (Barickman et al., 2017).

The objective of this project was to determine if repeated ABA sprays influenced strawberry plant growth, yield and fruit soluble solid content.

Materials and Methods

Experiment 1: In an initial trial, 'Albion' day-neutral strawberry plug plants were transplanted on 30 January 2015 into 3.79 L pots containing 3:1 mixture of perlite and peat moss. The plants were grown in a greenhouse with fertigation of calcium nitrate and Chem-gro 8-12-32 supplying 80 mg/L of nitrogen after the third week. The plants were treated weekly starting 15 April 2015 with 250 mg·L^{-1} ABA foliar spray (until runoff); container drenches of 50 or 250 mg·L^{-1} ABA; or left untreated. Treatments were applied to plants in a Randomized Complete Block (RDB) design with ten replications and two plants per replication. Plants receiving the foliar ABA spray had the media shielded from ABA to reduce root contact. The plants had runners and blossoms removed until first treatment. Fruit were counted and weighed at each harvest.

Experiment 2: We thought that foliar sprays might be easier for a farmer to apply, thus we decided to evaluate concentrations of foliar applied ABA. 'Sweet Ann' plug plants were planted on 2 October 2015 and grown as described in experiment 1. First flowering occurred on 19 January 2016. The plants were sprayed with 0, 25, 50, 100, 150, 200, or 250 mg·L^{-1} ABA on 7 and 26 January; 9 and 25 February; and 8 and 23 March. Treatments were arranged in a RCB design with eight replications and four plants per replication. Plants were harvested approximately twice a week from 15 February until 24 May. Fruit were graded into commercial (>10 g) and non-commercial (<10 g and deformed fruit) and weighed and counted at each harvest. The above media surface of the plants were partitioned into crowns, leaves, and fruit. Dry weights of fruit were not taken.

Experiment 3: 'San Andreas' and 'Seascape' day-neutral frigo strawberry plants were planted on 9 June, 2016 in 3.8 L pots and grown in a greenhouse as described above. Plants were sprayed with 0, 5, 10, 15, 25, 50 or 100 mg·L^{-1} of ABA biweekly from 25 August, 2016 through 22 March, 2017. Treatments were randomized in a split plot design with four replications of two cultivars, seven ABA treatments and four plants per replication. Leaf phytotoxicity was rated on 7, 15 and 26 September, 2016 using the scale: 1 = no damage, 2 = slight damage, 3 = slight to medium damage, 4 = medium damage, 5 = severe damage. We removed leaves showing yellowing before the next spraying. Runners were counted and removed weekly from 30 August, 2016 until 7 February, 2017. We observed damage on blossoms and counted damaged and non-damaged flowers on four plants/plot on 3, 10, and 29 March and removed damaged flowers after each count. Plants were harvested approximately twice per week from 30 September 2016 until 31 March, 2017. Red fruit were sampled from each plot in January and late March and soluble solid content of composite samples (> 45 g) of each time period was measured with a hand-held refractometer.

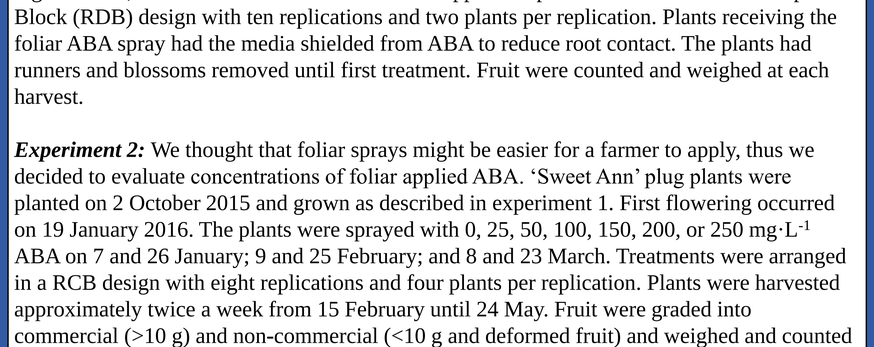

Figure 2. (A) Untreated strawberry plant and (B) plant sprayed with ABA and developing yellow basal leaves. (C) More advanced yellowing of plant sprayed with ABA.

Literature Cited

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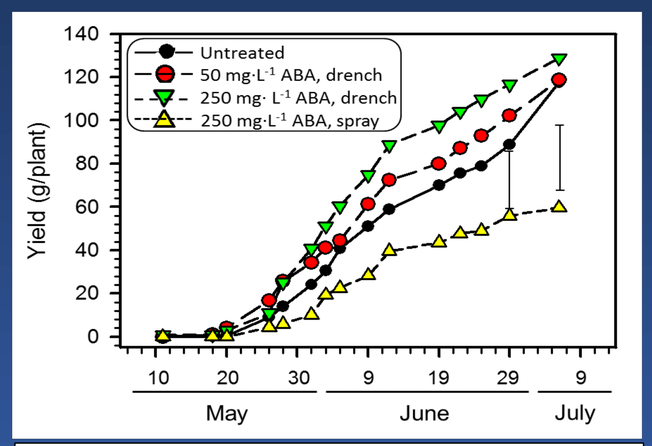

Figure 1. Accumulated yield in 2015 of 'Albion' plants treated weekly with foliar sprays of 250 mg·L^{-1} ABA; container drenches of 50 or 250 mg·L^{-1} ABA; or untreated.

Table 1. Fruit yield and quality in 2016 of 'Sweet Anne' strawberry plants sprayed biweekly with ABA

ABA[Z] (mg·L^{-1})	Yield (g/plant)[Y] Commercial[W]	Small[V]	Total	Berries (no. /plant)	Berries (g/berry)	SSC [X] (%)
0	432.7 a[U]	66.7 a	499.4 a	35.3 a	15.6 a	7.6
25	371.8 b	69.0 a	440.8 b	33.8 a	14.1 abc	7.9
50	341.9 b	48.1 bc	390.0 c	27.8 b	15.5 a	6.5
100	282.9 c	51.2 b	334.1 d	25.3 b	14.9 ab	7.1
150	196.1 d	46.0 bc	242.0 e	19.5 c	13.1 cd	6.5
200	165.4 d	34.4 c	199.8 e	16.2 cd	13.4 bcd	6.8
250	117.9 e	32.9 c	150.9 f	13.1 d	11.9 d	7.1
P-value[T]	***	***	***	***	***	NS
Linear	***	***	***	***	***	NS

[Z]Foliar sprays applied biweekly from 7 January until 23 March 2016.
[Y]Yield from 18 February until 24 May.
[X]Soluble Solids Content of fruit from measurements in March and May, > 45 g of blended fruit/sample.
[W]Fruit larger than 10 g and of commercial quality.
[V]Fruit smaller than 10 g and a few cull fruit.
[U]Means of within a column followed by the same letter are not significantly different according to Fisher's protected least significant difference ($P \leq 0.05$).
[T]NS, *** Nonsignificant or significant at $P \leq 0.001$, respectively. The significance values in the *P*-value row obtained from GLM/mean separation and the Linear row from GLM/linear regression. No quadratic regressions showed significant differences at $P \leq 0.05$.

Table 2. 'Sweet Anne' strawberry plants partitioned in 2016 after multiple biweekly sprays of ABA

ABA[Z] (mg·L^{-1})	Plant growth (no./plant)[Y] Crowns	Leaves	Flowers	Fruit	Shoot dry weight (g/plant) Crown	Leaves	Total
0	3.25[X]	30.7 a	7.78	19.2 a	3.58 a	20.90 a	24.48 a
25	3.78	29.7 a	7.63	18.9 a	3.07 b	18.56 b	21.63 b
50	3.34	26.0 b	5.84	16.1 b	2.91 bc	17.40 bc	20.30 bc
100	3.22	23.9 b	5.50	15.8 b	2.80 bc	16.21 c	19.01 c
150	3.34	20.2 c	7.69	12.5 c	2.55 cd	13.79 d	16.34 d
200	3.25	18.8 c	6.22	11.4 c	2.33 d	12.15 d	14.47 d
250	3.50	19.4 c	6.69	11.5 c	2.16 d	11.93 d	14.09 d
P-value[V]	NS	***	NS	***	***	***	***
Linear	NS	***	NS	***	***	***	***

[Z]Foliar sprays applied biweekly from 7 January until 23 March 2016.
[Y]Plug plants planted 2 October 2015, plants partitioned 25 May 2016.
[X]Means of within a column followed by the same letter are not significantly different according to Fisher's protected least significant difference ($P \leq 0.05$).
[V]NS, *** Nonsignificant or significant at $P \leq 0.001$, respectively. The significance values in the *P*-value row were obtained from GLM/mean separation analysis and the Linear row from GLM/linear regression. No quadratic regressions showed significant differences at $P \leq 0.05$.

Results

Experiment 1 showed that compared to untreated plants (Fig. 1):
- ABA applied as a drench slightly advanced 'Albion' harvest without reducing yield.
- A foliar spray of 250 mg·L^{-1} ABA reduced yield.

Experiment 2 showed that:
- Commercial and total yield, and number of 'Sweet Anne' berries per plant were reduced linearly as foliar sprays of ABA increased from 0 to 250 mg·L^{-1} (Table 1).
- ABA did not affect fruit soluble solids content (Table 1).
- Number of leaves; and crown, leaves, and total shoot dry weights per plant were reduced linearly as ABA increased from 0 to 250 mg·L^{-1} (Table 2).

Experiment 3 showed that:
- Yellowing of 'San Andreas' and 'Seascape' strawberry basal leaves (Figure 1) increased linearly as ABA increased from 0 to 100 mg·L^{-1} (data not shown).
- Commercial and total yield, and number of berries per plant were reduced linearly as ABA increased from 0 to 100 mg·L^{-1} (Table 3).
- ABA did not affect fruit soluble solids content (Table 3).
- Number of leaves, and crown and leaves dry weights per plant of were reduced linearly as ABA increased from 0 to 100 mg·L^{-1} (Table 4).

Table 3. Fruit yield and quality of 'Seascape' and 'San Andreas' strawberry plants sprayed biweekly with ABA from 25 August 2016 until 5 April 2017

	Yield (g/plant)[Z] Commercial[X]	Small[W]	Total	Berries (no. /plant)	Berries (g/berry)	SSC[Y] (%)
Cultivar						
'San Andreas'	526.8 a	220.3 a	747.1 a	70.9 a	10.75 a	7.6 a
'Seascape'	304.3 b	348.6 b	652.9 b	88.1 b	7.47 b	8.2 b
ABA (mg·L^{-1})[V]						
0	458.6 ab[V]	368.5 a	827.1 a	98.2 a	8.58 b	8.3
5	477.5 a	316.9 a	794.4 a	89.2 ab	9.02 ab	7.6
10	477.4 a	331.7 a	809.1 a	93.0 a	8.98 ab	8.2
15	422.7 ab	326.6 a	749.3 ab	86.5 ab	9.02 ab	7.7
25	432.2 ab	237.6 b	669.7 bc	77.1 bc	8.91 ab	7.8
50	404.5 b	260.4 b	664.9 c	70.6 c	9.87 a	7.7
100	235.7 c	149.7 c	385.4 d	41.7 d	9.41 ab	8.1
P-value[U]						
Cultivar (C)	***	***	***	***	***	***
ABA	***	***	***	***	NS	NS
Linear	**	***	***	***	NS	NS
Quadratic	*	NS	***	**	NS	NS
C x ABA	0.127	NS	NS	NS	NS	NS

[Z]Yield from 30 September 2016 until 22 May 2017. Does not include fruit (mean of 19.8 g/plant) removed for plant partitioning.
[Y]Soluble Solids Content of fruit from three measurement dates in 2017.
[X]Fruit larger than 10 g and of commercial quality.
[W]Fruit smaller than 10 g and a few cull fruit.
[V]Means of within a column and category followed by the same letter are not significantly different according to Fisher's protected least significant difference ($P \leq 0.05$).
[U]NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively. The significance values of cultivar, ABA and their interaction obtained from GLM/mean separation and the Linear row from GLM/linear regression..

Table 4. Partitioning of greenhouse 'San Andreas' and 'Seascape' strawberry plants after biweekly sprays from 25 August 2016 until 5 April 2017

	Plant growth (no./plant)[Z] Crowns	Leaves	Flowers	Fruit	Plant dry weight (g/plant)[Y] Crowns	Leaves	Flowers and fruit	Total
Cultivar								
'San Andreas'	9. 2[X]	91.3	20.1	15.1 b	13.0 a	47.8 a	2.68	63.6 a
'Seascape'	9.0	87.2	22.0	23.8 a	10.7 b	36.3 b	2.77	49.7 b
ABA (mg·L^{-1})								
0	9.9	108.0 a	24.3	22.3	13.7 a	51.8 a	3.00	68.5 a
5	8.8	96.7 ab	21.0	17.6	12.7 a	46.8 ab	2.46	62.0 ab
10	9.4	92.9 ab	18.2	17.6	12.7 a	42.5 ab	2.63	57.8 ab
15	9.1	92.3 ab	22.1	20.3	12.8 a	45.5 ab	2.77	61.1 ab
25	8.4	81.5 bc	19.5	19.2	11.1 b	38.1 bc	2.72	52.0 bc
50	9.1	82.3 bc	20.6	18.8	11.0 b	39.2 bc	2.53	52.7 bc
100	8.8	70.8 c	21.4	20.7	9.2 c	30.3 c	2.98	42.5 c
P-value[V]								
Cultivar (C)	NS	NS	NS	***	NS	***	NS	***
ABA	NS	**	NS	NS	***	**	NS	**
L	NS	***	NS	NS	***	***	NS	***
C x ABA	NS	NS	NS	NS	NS	NS	NS	NS

[Z]Frigo plants grown in greenhouse from 9 June 2016 until 15 June 2017.
[Y]Plant material above media surface.
[X]Means of within a column and category followed by the same letter are not significantly different according to Fisher's protected least significant difference ($P \leq 0.05$). Means not followed by a letter are not significantly different from other means in the category ($P \leq 0.05$).
[V]NS, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively. The significance values of Cultivar, ABA and their interaction obtained from GLM/mean separation and the Linear row from GLM/linear regression. No quadratic regressions showed significant differences at $P \leq 0.05$.

Conclusions

- **Repeated foliar sprays of ABA:**
  - Reduced number and dry weights of leaves and total shoot dry weight of strawberry plants.
  - Reduced number of fruit and total yield.
  - Did not affect fruit soluble solid content.
  - Caused yellowing of basal leaves.
- **Future research**
  - Future research may show benefits from foliar ABA sprays, but these results suggest > 25 mg·L^{-1} will be too damaging on strawberry plants.
  - ABA applied as a soil application (experiment 1), such as through drip irrigation, may cause less damage to the plant and may advance harvest.