**FINAL REPORT**
**WTFRC PROJECT#: PH-02-245 ORGANIZATION PROJECT #5350-43000-003-17T**

**Project title:** Use of bioregulators to enhance apple fruit quality and maintain fruit condition

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**OBJECTIVE:** Develop and test uses of bioregulators, aminoethoxyvinylglycine (AVG), Ethephon (ETH) and 1-methylcyclopropene (1-MCP) to enhance apple fruit quality and consumer acceptance without loss of long-term storage potential.

**SIGNIFICANT FINDINGS:**

1. **AVG**
Reduced splitting
Reduced drop
Reduced firmness loss
Reduced color development ('Delicious' only)
Reduced soluble solids
Reduced watercore
Reduced ethylene production
Reduced sensory quality whole apples 2 of 3 years and juice 3 of 3 years (compared to control fruit, AVG treated marginally acceptable).

2. **ETH**
Increased splitting
Increased drop
Enhanced firmness loss
Enhanced color
Enhanced soluble solids
Enhanced sensory quality (whole and juice) before storage. After storage sensory texture and flavor reduced texture unacceptable.

3. **AVG + ETH**

Good storage, firmness retarded
Good color
Increased total carbohydrates
Enhanced sensory quality (whole and juice)

4. **1-MCP**
Firmness maintained, before and after ripening
Reduced sensory flavor quality whole apples: 1 of 2 years (Note: starch level 2.0 first year and <3.0 second year) and juice 2 of 2 years. (Acceptable due to excellent texture)
Enhanced sensory texture (whole)
Reduced sensory flavor quality juice: 2 years, both 'Delicious' and 'Gala'

5. **1-MCP + ETH**
Good firmness
Good color
Enhanced soluble solids
Enhanced sensory quality (whole and Juice)

**RESULTS AND DISCUSSION**

Treatment used on 'Delicious' ('Scarletspur') and 'Gala' ('Gale'). Bioregulator applications: AVG at 125 ppm, Ethephon at 300 ppm alone, and AVG + ethephon. 1-MCP at 1 ppm applied to all treatment combinations a day following harvest. Evaluations (2003-04): 'Delicious' evaluations at harvest (17 Sept and 30 Sept), after 60 days RA, 120 and 180 CA (2.0% $O_2$ & <2.0 % $CO_2$). 'Gala' at harvest (26 Aug and 9 Sept), after 60 days RA and 120 days CA (2.0% $O_2$ & <2.0 % $CO_2$).

Use of bioregulators can and does have a major impact on apple quality at harvest and after either RA or CA storage. AVG or ethephon, used alone can significantly reduce quality when compared to non-treated fruit. A combination of AVG and ethephon enhances fruit quality by maintaining texture with enhanced soluble solids and color. 1-MCP used alone maintains fruit firmness but can reduce sensory quality when compared to non-treated fruit. A combination of 1-MCP and ethephon produces fruit, after long-term storage, with good firmness and color, and better sensory acceptance than 1-MCP used alone. Proper use of bioregulators produces fruit with good quality (firmness, color and sensory acceptance) after storage with good shelf-life.

**METHODS (2003)**
**'**Delicious' ('Scarletspur') and 'Gala' ('Gale'). Bioregulator applications: AVG (125 ppm), Ethephon (300 ppm) alone, and ethephon treatment (300 ppm) of previously AVG-treated (125 ppm) fruit. MCP to be applied to all treatment combinations the next day following harvest. Eight treatments (Control, AVG, Ethephon, AVG+Ethephon and Control, AVG, Ethephon, AVG+Ethephon with MCP). Fruit will be evaluated after the second harvest and after both 60 days RA and 120 days CA storage.

**BUDGET:**

**TITLE:** Use of bioregulators to enhance apple fruit quality and maintain fruit condition

**PRINCIPAL INVESTIGATORS:**
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**PROJECT DURATION:** 2002-2004

**PROJECT TOTAL: $30,060**

| Year | Year 1 (2002) | Year 2 (2003) | Year 3 (2004) |
|---|---|---|---|
| **Total** | $14,080 | $15,980 | $0 |

**PUBLICATIONS:**

Drake, M.A., S.R. Drake, D.C. Eflving and T.A. Eisele. 2002. Influence of bioregulators on apple fruit quality. Proceedings of the Institute of Food Technologist, Anaheim, CA. pp. 109.

Drake, S.R., D.C. Elfving, T.A. Eisele, M.A. Drake, S.L. Drake and D.B. Visser. 2003. Effects of ethephon and aminoethoxyvinylglycine on the carbohydrate and acid contents of ‘Scarletspur Delicious’ apples (Malus domestica Borkh.). Proceedings of the Institute of Food Technologist, Chicago, IL pp. 115.

Drake, S.R., M.A. Drake, S.L. Drake, D.C. Elfving and T.A. Eisele. 2004. The influence of bioregulators on the instrumental and sensory quality of apples and apple juice. Proceeding of the Institute of Food Technologist, Las Vegas, NV. (In press)

Drake, S.R., D.C. Elfving, M.A. Drake, T.A. Eisele and S.L. Drake. Bioregulators, aminoethoxyvinylglycine and ethephon and their influence on carbohydrates, acids and mineral content of 'Scarletspur' Delicious apple Juice. Journal Agriculture and Food Chemistry. (In review).

Drake, S.R., D.C. Elfving, M.A. Drake, T.A. Eisele and S.L. Drake. Aminoethoxyvinylglycine and ethephon, bioregulators that influence objective and subjective quality of apples and apple products. HortTechnology (In review).

Sensory evaluation, at harvest, of 'Delicious' apple juice as influenced by the bioregulators AVG and ETH, or a combination of AVG + ETH, 2002.

| | Harvest I | | | Harvest II | | |
|---|---|---|---|---|---|---|
| Control/Bioregulator | Preference %[z] | Intensity[y] | Like | Preference % | Intensity | Like |
| Control | | 4.3a | 6.7a | | 4.9a | 7.3a |
| 125 ppm AVG | C | 3.9b | 6.4a | C | 4.0b | 6.3b |
| 150 ppm ETH | T | 4.6a | 7.0a | N | 5.0a | 7.3a |
| AVG + 150 ppm ETH | T | 4.4a | 6.9a | C | 4.5b | 6.9a |

[z]Significantly preferred ($P \leq 0.05$) as the preference: T=treatment, N=neither control or treatment, C=control

[y]Intensity and like on a scale of 1 to 9 (1=too weak, or dislike extremely; 5= just right, or neither like nor dislike; 9= too strong, or like extremely).

[x]Means in a column not followed by a common letter are significantly different ($P \leq 0.05$).

N=50.

Sensory evaluation of 'Delicious' apple juice as influenced by the bioregulators ethephon (ETH) aminoethoxyvinylglycine (AVG) and 1-methylcyclopropene (1-MCP), after 120 days CA storage, 2003.

| Bioregulator | MCP | Preference %[z] | Intensity[y] | Like |
|---|---|---|---|---|
| Control | No | | 4.7a[x] | 7.4a |
| 150 ppm ETH | No | N | 5.0a | 7.4a |
| AVG + ETH | No | N | 4.6a | 7.4a |
| | | | | |
| 1-MCP | Yes | C | 4.0c | 6.5c |
| 150 ppm ETH | Yes | N | 4.7a | 6.8b |
| AVG + ETH | Yes | N | 4.0c | 7.2a |

[z]Significantly preferred (P≤).05) as the preference: T=treatment, N=neither control or treatment, C=control
[y]Intensity and like on a scale of 1 to 9 (1=too weak, or dislike extremely; 5= just right, or neither like nor dislike; 9= too strong, or like extremely).
[x]Means in a column not followed by a common letter are significantly different (P≤0.05).
N= 50

Sensory evaluation of 'Delicious' and 'Gala' apple juice (commercial harvest) as influenced by the bioregulators ethephon (ETH), aminoethoxyvinylglycine (AVG) and 1-methylcyclopropene (1-MCP), after storage, 2004

| | | 'Delicious' 120 days CA | | | 'Gala' 60 days RA | | |
|---|---|---|---|---|---|---|---|
| Bioregulator | 1-MCP | Preference%[z] | Intensity[y] | Like | Preference % | Intensity | Like |
| Control | No | | 4.7a[x] | 7.5 a | | 5.1a | 7.6a |
| 125 ppm AVG | No | C | 4.6a | 7.0b | N | 5.4 a | 7.4a |
| 300 ppm ETH | No | N | 4.5a | 7.6 a | N | 5.1a | 7.4a |
| AVG + 300 ppm ETH | No | N | 4.9a | 6.9b | N | 4.7b | 7.5a |
| 1-MCP | Yes | C | 4.3b | 7.0b | C | 4.7b | 7.1b |
| 125 ppm AVG | Yes | C | 4.0b | 6.3c | C | 4.3b | 7.6a |
| 300 ppm ETH | Yes | C | 4.9a | 6.9b | C | 4.4b | 7.0b |
| AVG + 300 ppm ETH | Yes | C | 4.5a | 6.7b | N | 4.7b | 6.6b |

[z]Significantly preferred (P≤).05) as the preference: T=treatment, N=neither control or treatment, C=control
[y]Intensity and like on a scale of 1 to 9 (1=too weak, or dislike extremely; 5= just right, or neither like nor dislike; 9= too strong, or like extremely).
[x]Means in a column not followed by a common letter are significantly different (P≤0.05).
N=25.

Consumer sensory evaluation of 'Delicious' and 'Gala' apples as influenced by the bioregulators AVG and ETH, or a combination of AVG + ETH, at harvest, 2003.

| | 'Delicious' | | | 'Gala' | | |
|---|---|---|---|---|---|---|
| Bioregulator | Over-all Acceptability[z] | Flavor[z] | Texture[z] | Over-all Acceptability | Flavor | Texture |
| Control | 6.5a[y] | 6.5a | 6.6b | 7.1a | 7.0ab | 7.3a |
| 125 ppm AVG | 6.5a | 6.a | 6.6b | 7.0a | 6.8b | 7.3a |
| 300 ppm ETH | 6.6a | 6.5a | 6.9a | 7.3a | 7.2a | 7.4a |
| AVG + ETH | 6.5a | 6.2a | 6.9a | 7.3a | 7.2a | 7.5a |
| Harvest | | | | | | |
| I | 6.4b | 6.2b | 6.6b | 7.1a | 6.9a | 7.5a |
| II | 6.7a | 6.6a | 6.9a | 7.2a | 7.0a | 7.2b |

[E]Evaluated on a scale of 1 to 9 (1= dislike extremely, 9= like extremely.

[y]Means in a column, within bioregulator or harvest, not followed by a common letter are significantly different ($P \leq 0.05$). N=210.

Consumer sensory evaluation of 'Delicious' apples as influenced by the bioregulators ethephon (ETH), aminoethoxyvinylglycine (AVG) and 1-methylcyclopropene (MCP), after controlled atmosphere storage (180 days), 2003.

| Bioregulator | 1-MCP | Over-all Acceptability[z] | Flavor[z] | Texture[z] |
|---|---|---|---|---|
| Control | No | 6.5ab[y] | 6.5ab | 6.3b |
| 150 ppm ETH | No | 5.8c | 6.0c | 5.6c |
| AVG + 150 ppm ETH | No | 6.7a | 6.6a | 6.9a |
| | | | | |
| 1-MCP | Yes | 6.3b | 6.0c | 6.8a |
| 150 ppm ETH | Yes | 6.4ab | 6.1bc | 7.0a |
| AVG + 150 ppm ETH | Yes | 6.5ab | 6.3abc | 7.0a |

[z]Evaluated on a scale of 1 to 9 (1=dislike extremely, 9= like extremely).

[y]Means in a column not followed by a common letter are significantly different ($P \leq 0.05$).

N=210.

Consumer sensory evaluation of 'Delicious' and 'Gala' apples as influenced by the bioregulators AVG, ETH and 1-MCP or a combination of AVG + ETH after 120 days CA storage, 2004.

| | 'Delicious' | | | 'Gala' | | |
|---|---|---|---|---|---|---|
| Bioregulator | Over-all Acceptability[z] | Flavor[z] | Texture[z] | Over-all Acceptability[z] | Flavor[z] | Texture[z] |
| Control | 6.1b[y] | 6.2b | 5.9c | 6.6a | 6.8a | 6.0b |
| 125 ppm AVG | 6.6a | 6.4ab | 7.2ab | 6.8a | 6.5a | 7.3a |
| 300 ppm ETH | 6.6a | 6.2b | 6.9b | 6.9a | 6.7a | 7.2a |
| AVG + 300 ppm ETH | 6.5a | 6.ab | 7.ab | 7.0a | 6.8a | 7.4a |
| 1-MCP | 6.7a | 6.7a | 7.3a | 6.6a | 6.5a | 7.2a |

[E]Evaluated on a scale of 1 to 9 (1= dislike extremely, 9= like extremely).
[y]Means in a column, within bioregulator not followed by a common letter are significantly different (P≤0.05).
N=190

Quality attributes of 'Delicious' apples as influenced by the bioregulators aminoethoxyvinylglycine (AVG) and ethephon (ETH), or a combination of AVG + ETH, at harvest, 2002.

| | Peel Color | | Firmness | Starch | Ethylene | Brix's | Acidity | Brix's/Acids |
|---|---|---|---|---|---|---|---|---|
| Bioregulator | L | hue | (Newtons) | (1 to 5) | (ppm) | (E) | (% malic) | (Ratio) |
| Control | 25.3a[z] | 14.1a | 72.4b | 2.5b | 16.8a | 13.1a | 0.24a | 55.9a |
| ETH (150 ppm) | 25.2a | 13.8a | 68.0c | 3.0a | 21.7a | 13.3a | 0.23a | 57.4a |
| AVG (125 ppm) | 25.1a | 12.4b | 75.1a | 2.0c | 1.7b | 12.4b | 0.24a | 51.8b |
| ETH + AVG | 25.0a | 12.6b | 75.2a | 2.4b | 2.5b | 13.1a | 0.24a | 55.6a |
| Harvest | | | | | | | | |
| I | 25.6a | 14.4a | 77.4a | 1.9b | 3.7b | 12.3b | 0.25a | 50.0b |
| II | 24.7b | 12.0b | 67.9b | 3.0a | 17.7a | 13.7a | 0.23b | 60.3a |

[z]Means in a column, within bioregulator or harvest, not followed by a common letter are significantly different (P≤0.05).
Quality attributes of 'Delicious' apples as influenced by the bioregulators aminoethoxyvinylglycine (AVG) and ethephon (ETH), or a combination of AVG + ETH, with and without 1-methylcyclopropene (1-MCP), after 180 days CA storage, 2003.

| | Peel Color | | Firmness | Ethylene | Brix's | Acidity | Brix's/Acids |
|---|---|---|---|---|---|---|---|
| **Bioregulator** | **L** | hue | (Newtons) | (ppm) | (E) | (% malic) | (Ratio) |
| Control | 24.7b[z] | 14.0ab | 62.8c | 39.8a | 13.7ab | 0.22a | 61.5a |
| ETH (150 ppm) | 24.7b | 14.8a | 60.9c | 34.8a | 13.9a | 0.22a | 62.7a |
| AVG (125 ppm) | 25.3a | 13.7b | 70.8a | 5.0b | 13.4b | 0.23a | 58.1b |
| ETH + AVG | 24.7b | 13.5b | 66.5b | 6.4b | 13.9a | 0.23a | 60.5b |
| | | | | | | | |
| Control | 24.3b | 14.2a | 57.1b | 42.4a | 13.7a | 0.22b | 61.9a |
| 1-MCP | 25.4a | 13.9a | 73.5a | 0.6b | 13.8a | 0.32a | 59.5b |

[z]Means in a column, within bioregulator, or control and 1-MCP, not followed by a common letter are significantly different (P≤0.05).