COLOR ENHANCEMENT IN CRANBERRY FRUIT BY USING ENVIRONMENTALLY SAFE NATURAL PRODUCTS

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1. Introduction

The commercial value of the cranberry crop is related to the amount of color (anthocyanin) in the fruit. The production of color at the time of fruit ripening appears to be in response to low temperature and light. Thus the fruits exposed on the top of plant canopy change color first and the fruits underneath the plant canopy remain white or blush until quite late in the fall. In order to get good color growers usually try to delay harvest. However, the problems and risks associated with frosts discourage growers to delay harvest.

Research has been conducted to devise chemical means to accelerate and increase color production in the cranberry fruit. Ethephon is an approved chemical for use on cranberries in Wisconsin for increasing anthocyanin content. However, its application has yielded inconsistent results from season to season (Shawa, 1979). Several years ago we initiated research to find environmentally safe chemical means for early color enhancement in cranberry fruit. A summary of this research and progress to date is given below.

2. Cranberry Fruit Cuticle (surface) is Essentially Impermeable to Ethrel.

By microscopic examination of live cross-sections of cranberry fruit we were able to demonstrate that the color in the fruit is limited to outer two cell layers (Palta and Stang, 1983). We were also able to show that cranberry has relatively thick cuticle. Later examination of the fruit surface with scanning and transmission electron microscopic showed that fruit cuticle was embedded with waxes (Farag, et al., 1985; Farag and Palta, 1987b). This cuticle contained no pores. We hypothesized that cranberry fruit cuticle was essentially impermeable to Ethrel. This was later confirmed by measuring transport of Ethrcl across isolated fruit cuticle (Farag and Palta, 1987a; Farag et al., 1985).

3. Overcoming the Permeation Barrier by Modifying the Ethrel Solution

The transport of Ethrel across enzymatically isolated fruit cuticle was studied. For this purpose a transport chamber was designed and fabricated. This chamber allowed the study of transport of Ethrel across the fruit cuticle. Ethrel permeation across the cranberry fruit cuticle was very slow and in most cases the cuticle was essentially impermeable to Ethrel. We then systematically modified the Ethrel solution by adding transport enhancers. These enhancers increased the permeation of Ethrel across the fruit cuticle by over 100-fold. All the enhancers studied were natural products. These enhancers were effective because of one or more of the following properties (Farag and Palta, 1987C):

(i) Some enhancers were molecules that are constituents of the cranberry cuticle such as ursolic acid. These molecules are able to recognize the cuticle surface, stick to it, and thus allow the cuticle to become permeable to Ethrel.

(ii) Some enhancers were organic solvents such as ethanol (alcohol). These molecules stick to the waxy surface thus temporarily changing its property. In their presence cuticle became permeable to Ethrel.

(iii) Some enhancers were highly lipophyllic (fat loving) molecules. These molecules are able to get into the waxy surface and take along the Ethrel across the cuticles. Example of these molecules are lysophosphatidylethanolamine and urea.

These transport enhancers were field tested and were demonstrated to be effective in color enhancement. With some of these mixtures we were able to increase anthocyanin content by 50% over the untreated controls in 10-15 days after application.

4. Development and Large Scale Field Testing of an Ethrel Formulation which is Consistently Effective in Cranberry Fruit Color Enhancement.

Based on several field trials we selected the cheapest and one of the most effective formulations of Ethrel for further field testing. This formulation consisted of a mixture of Ethrel, ethanol (ordinary alcohol), urea and a spreader (detergent). This formulation has been tested on a large scale in Searls and Stevens cranberries. The results show that we are able to consistently increase the anthocyanin content from 40 to 100% over the untreated controls in about two weeks (Tables 1, 2, 4). These results are based on the last four years of field experiments. Results from last two seasons are shown in Tables 1, 2 and 4. In addition to a dramatic increase in average anthocyanin content all the fruits were improved in color (Tables 3 and 5) which means the fruits underneath the canopy (white and blush stages) were also improved in color. For example, in 'Stevens' no white fruits were present in the treated area.

5. Our Recommendations.

Based on our large scale field testing we recommend the following:

1 gallon Ethrel/acre
l-2 gallon Alcohol (ethanol)/acre
1 pint detergent (Tergitol)/acre
6 lbs. urea/acre

These chemicals are dissolved and applied as spray at the rate of 200 gallons of solution per acre. This amount of spray solution ensures that the chemical reaches the uncolored berries underneath the plant canopy.

6. Development of a Procedure for Effectively Delivering the New Ethrel Formulation on the Cranberry Plants.

In 1989 we devised a simple procedure for precise application of the new formulation on the bed. In this procedure the chemicals are directly injected into an individual irrigation line on the field (figure 1). This approach consisted of mixing the chemicals in a 5 gallon soda tank. By attaching this tank to a pressurized carbon dioxide cylinders we were able to inject the chemicals right into an individual irrigation line in the bed. By adjusting the pressure, it was possible to vary the speed of injection. Total amount of water applied was about 200 gallons/acre.

7. Use of New Ethrel Formulations for Color Enhancement in Cranberry Fruit: Future Perspectives

Ethrel is currently marketed by Rhone-Pulenc in USA. This company is not interested in maintaining the Ethrel label for cranberries. However, it is possible to obtain third party label of Ethrel for cranberries with the permission of Rhone-Pulenc. We have had discussions worth Mr. Jere Downing of Ocean Spray Inc. and with Dr. John Pickles of the Hopkins Chemical Co. (UAP). There seems to be interest in pursuing this option for Ethrel use in cranberries.

8. Alternative to Ethrel: Potential use of new (environmentally safe) Natural Lipids for Improvement of Cranberry Fruit Color and Improvement of Keeping Quality of Fruit During Storage.

In the last two years we have investigated the use of natural lipids such as lysophosphatidylethanolamine (LPE) for improvement of fruit color in cranberries (Farag and Palta, 1989). This lipid is known to be present in all biological systems and is currently purified from egg yolk.

We have found that LPE is able to promote natural production of ethylene in fruit which in turn stimulates color production. We do not know at present the exact mechanism by which these natural lipids stimulate fruit ripening. The most interesting property of these lipids is that they are able to improve color as well as keeping quality of the fruit. During 15 weeks of cold storage after harvest the cranberry fruits sprayed with lipids had much less soft and rotted fruits compared with controls. We plan to conduct further research on the USC of these lipids for fruit color enhancement and for improving fruit storability.

9. Conclusions

(i) Cranberry fruit surface (cuticle) is essentially impermeable to Ethrel.

(ii) In the presence of transport enhancers the Ethrel is able to permeate across the fruit cuticle. These enhancers are environmentally safe natural products.

(iii) A new formulation of Ethrel containing ethrel, urea and spreader (detergent) has proved to be consistently effective in improving fruit color.

(iv) A simple system utilizing 5 gallon soda-tanks and pressurized carbon dioxide has been devised to deliver new formulation effectively in the cranberry field.

(v) Some natural lipids show potential for improving fruit color and fruit storability. The use of the chemicals as an alternative to Ethrel is currently being investigated.

10. **Acknowledgements--** We would like to acknowledge Whittlesey and Dubay Cranberries for providing facilities for this work and Brian Bowan, Assistant Superintendent Hancock Experiment Station, for help with field application by chemigation.

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Table 1. The effect of field applications of new ethephon formulation on the anthocyanin content of Searles cranberry fruit. Chemicals were applied by chemigation method on Sept.18, 1989 and harvested on Oct.6, 1989..

Treatments	Fruit Anthocyanin Content (mg/100 g fr.wt) at 8 Locations							
	1	2	3	4	5	6	7	8
Water	20.10*	11.44	15.71	9.53	12.56	14.76	12.36	14.43
	20.08	11.73	15.72	9.04	12.48	14.94	12.20	14.40
	12.40	15.23	13.52	12.13	13.26	15.11	11.75	14.79
	13.34	14.30	13.83	13.18	13.60	15.11	10.67	14.16
	13.63	13.47	16.69	9.64	12.70	15.64	13.59	14.08
	13.11	14.31	16.13	10.09	12.84	15.86	14.65	13.97
Mean	15.44	13.41	15.27	10.60	12.91	15.23	12.55	14.31
Overall Mean 13.72±0.60**								
	20.91*	24.76	29.11	25.04	26.41	30.15	33.37	20.04
	20.65	25.21	30.41	25.17	28.78	30.88	33.56	19.75
Ethephon+	17.21	31.85	25.78	24.41	31.72	29.39	36.48	21.93
Tergitol+Urea+	17.71	31.57	24.07	23.97	30.48	30.63	38.45	21.57
Ethanol	22.35	25.19	35.11	25.47	28.83	34.09	35.64	20.53
	20.82	26.00	35.57	26.37	29.90	34.26	46.25	20.52
Mean	19.92	27.43	30.01	25.07	29.35	31.57	37.29	20.72
Overall Mean 27.67±2.02**								

* Anthocyanin content (mg/100 g fresh weight)
** Mean of 48 separate observations±SE.

Table 2. The effect of field application of new ethephon formulation on the anthocyanin content of Stevens cranberry fruit. Treatments were applied by chemigation method on Oct. 1st ,1989 and harvested on Oct.13, 1989.

Treatments	Fruit Anthocyanin Content (mg/100 g fr.wt) at 10 Locations									
	1	2	3	4	5	6	7	8	9	10
Control	19.83*	25.05	25.17	24.85	22.42	28.09	21.72	21.96	26.66	29.71
	22.73	23.50	25.83	25.40	22.18	27.67	22.74	21.50	27.86	29.14
	21.66	20.14	20.02	26.46	24.13	28.85	22.85	22.65	22.10	27.14
	21.21	20.76	19.79	26.56	23.64	28.55	22.44	23.18	23.60	26.85
Mean	21.36	22.36	22.70	25.82	23.09	28.29	22.44	22.32	25.06	28.21
Overall Mean24.17±0.80**										
Ethephon+	39.42	46.93	39.49	44.59		44.68	36.50	35.96	30.44	31.92
Tergitol+Urea	41.64	46.99	41.76	41.57		40.99	34.84	32.20	30.79	34.08
+Ethanol	39.26	44.81	39.10	45.20		36.79	35.22	40.61	35.80	32.04
	39.29	41.35	43.88	45.77		36.50	45.87	42.37	34.32	31.82
Mean	39.90	45.02	41.06	44.28		39.74	38.11	37.79	32.84	32.47
Overall Mean*39.02±1.46**										

* Anthocyanin content (mg/100 g fresh weight)
** Mean of 40 separate observations±SE.
*** Mean of 36 separate observations±SE.

Table 3. Percentage of degree of coloration of Searles cranberry fruit at harvest as influenced by field application of the new ethephon formulations using the chemigation method.

Treatments	Extent of Fruit Coloration (%)		
	White to 10% Blush	Medium	100%
Water			
Fruit Number	13.17	57.53	29.30
Fruit Weight	11.77	58.02	30.21
Ethephon+Tergitol +urea+ethanol			
Fruit Number	1.04	16.84	82.12
Fruit Weight	0.98	15.83	83.18

Table 4. The effect of preharvest spray of new ethephon formulation on anthocyanin content of Searles cranberry fruit. Treatment was done by injecting the chemicals into the irrigation line. Chemicals were applied on Sept. 28, 90 and fruits were harvested on Oct.7,90. Location of the experiment: Whittlesey Cranberries, Wisconsin Rapids, WI. Anthocyanin analyses were done by Ocean Spray Cranberries Inc., Babcock, WI.

Treatments	Anthocyanin Content (mg/100 g)
Water	16.4 ± 0.8
Ethrel+Tergitol+Ethanol+Urea	25.1 ± 1.5

Table 5. Distribution of fruit anthocyanin content at various locations in the field as influenced by the application of new ethephon formulation at Whittlesey Cranberries in 1990 season.

Treatments	% of the Fruits in Various Classes of Anthocyanin Content (mg/100 g)							
	13-15	16-18	19-21	22-24	25-27	28-30	31-33	34-36
Water	45.4	27.3	27.3	0	0	0	0	0
E+T+U+EtOH	0	0	36.3	0	27.3	27.3	0	9.1

Abbreviations: E, Ethrel; T, Tergitol; U, urea; EtOH, ethanol.

Figure 1.