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Prestorage and Poststorage Starch Levels in Chemically and Hand-defoliated 'Delicious' Apple Nursery Stock[1]

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Additional index words. carbohydrates, *Malus domestica*, leaf abscission

Abstract. **To investigate the effects of chemical and hand-defoliation on starch levels in apple nursery stock, 1-year-old commercially graded whips of 'Delicious' apple (*Malus domestica* Borkh.) were planted in April 1977 and 1978, headed at 30 cm, and later trained to a single vigorous shoot. Plots were hand-defoliated on October 1, 15, or 30. Additional plots were treated with 1, 2, or 3 applications at 5-day intervals, starting October 5, of 1.5% Dupont WK surfactant (principle functioning agent, trimethylnonylpolyethoxyethanol) alone or plus 20 ppm (2-chloroethyl) phosphonic acid (ethephon). All trees were dug Nov. 15 in both years. Starch levels increased as hand-defoliation was delayed and usually decreased with multiple as compared to single chemical applications. These effects were evident both prestorage and poststorage, with starch levels decreasing during storage in roots and stems but changing little in buds. The amount of shoot growth produced on the trees during the summer following storage and replanting displayed a pattern somewhat like that of the levels of starch in the trees. Delaying hand-defoliation until October 30 produced the highest starch levels (hand- or chemically treated) both years at April planting time.**

Because deciduous tree fruit nursery stock is usually heavily fertilized and irrigated, natural defoliation is often late, causing concern when cold weather approaches. Since nurserymen may not wish to risk tree losses from cold damage by waiting for natural leaf fall and since trees do not store well with leaves attached, considerable effort has been directed toward finding chemical treatments to speed defoliation and replace the usual practice of hand-stripping of leaves.

Dupont WK surfactant (DWK) alone or in combination with ethephon is commercially important for apple nursery-stock defoliation (5). However, poststorage condition and postplanting performance of commercially treated stock is sometimes substandard. Since starch is the main storage carbohydrate in apple (1, 4, 6, 9), reduced levels in treated stock could result in reduced storability and poor postplant performance. To help explain the occasional substandard performance of treated stock, pre- and poststorage levels of starch in 'Delicious' apple nursery stock were measured and compared to levels in untreated stock and in stock that had been hand-defoliated.

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Materials and Methods

One-year-old commercially graded whips of 'Delicious' apple nursery stock were planted in 1 × 3m rows in April 1977 and 1978 at the Washington State University experimental farm in Pullman. Trees were headed back to 30 cm from the ground after planting and later trained to 1 vigorous shoot. The trees were fertilized and irrigated uniformly to produce vigorous growth throughout the summer.

Plots were hand-defoliated on Oct. 1, 15, or 30 during both years. Chemical treatments were applied on Oct. 5, Oct. 5 and 10, or Oct. 5, 10, and 15. The chemicals used were 1.5% DWK alone or in combination with 200 ppm ethephon, typical commercial treatments. Plots consisted of 9 trees each and were replicated 4 times. Chemicals were applied to runoff with a hand-sprayer. Control trees were not treated. The degree of defoliation was visually estimated (Table 1) and trees were dug on Nov. 15 each year. Six trees from each plot were stored at 3°C with roots in moist sawdust. Three trees from each plot were washed, placed in plastic bags, and frozen at −20° for later analysis. In April, half of the trees that had been stored at 3° was washed and frozen at −20° for analysis while the other half was planted for observation and measurement of shoot growth.

Frozen trees were divided into buds, stems, and roots and then weighed. Tissue samples were lyophilized, ground, and stored in air-tight vials in a desiccator with anhydrous $CaSO_4$. A weighed quantity of tissue was extracted with 80% ethanol. The ethanolic extract residue was dried in a vacuum oven at 60°C, weighed, and kept in air-tight vials in a desiccator for later starch analysis.

Table 1. Mean percentage of defoliation induced by chemicals on 'Delicious' apple nursery stock.[z]

Treatment[y]	Oct. date	Defoliation (%) 1977	1978
Control	5	21	14
DWK (1.5%)	5	68	70
	5,10	100	100
	5,10,15	100	100
DWK (1.5%) + ethephon (200 ppm)	5	81	79
	5,10	100	100
	5,10,15	100	100

[z]Values are the average of 4 replications of 9 trees each. The percentage of defoliation was determined visually on Nov. 14.
[y]SE = 1.16 (1977) and 1.02 (1978). DWK = Dupont WK surfactant.

For starch hydrolysis, a freshly prepared stock solution consisting of 0.1 ml pancreatic α-amylase (Sigma, type I-A) in 100 ml of 20 mM potassium phosphate, pH 6.9, and 6 mM NaCl was used. Fifty mg of ethanol-extracted tissue plus 2 ml of stock solution were treated as described by Nevins et al. (8). Soluble starch from Mallinckrodt Chemical Co. was used as a standard and was treated the same as experimental samples. After incubation the samples were washed and centrifuged 3 times for 10 min at 1000× *g*, and the clear supernatants were combined and used for starch determination as described by Hudge and Hofreiter (3).

Data were analyzed by analysis of variance and treatments were compared by linear contrasts and polynomial regression (10).

Results and Discussion

Starch (mg/g dry wt) in buds, stems, and roots of hand-defoliated plants increased as defoliation was delayed (Tables 2 and 3). There was usually a significant linear effect of defoliation time. At planting time in April of both years, trees that had been hand-defoliated on Oct. 30 had higher starch levels in roots and stems than trees from any other treatment. Multiple chemical applications frequently reduced starch levels compared with single applications. Starch in roots and shoots of chemically or hand-defoliated trees was often less than in control trees, especially in 1978 (Tables 2, 3, 4), presumably due to reduced photosynthesis. Similarly, others have reported starch reduction by insect damage (2) or early hand-defoliation (2, 11) accompanied by negative growth effects. There were few significant differences and no consistent trend in starch content between the 2 chemical treatments (Tables 2, 3, 4).

Starch levels in the buds did not change greatly during storage, while levels in stems and roots were often significantly lower after storage. This pattern supports previous work showing migration of carbohydrates from roots to buds late in the dormant period (6). Starch levels were highest in the order of roots, stems, and buds, which agrees with the previous work showing that roots are the principal starch storage organ in apple (6, 7).

The amount of shoot growth (Table 5) produced by the trees during the summer following storage and replanting displayed a pattern somewhat like that of the levels of starch in the trees. As with starch levels, shoot growth increased with a delay in hand-defoliation and with single as compared to multiple chemical applications.

Thus, although bark and bud damage caused by the chemical treatments may be partially responsible for the occasional poor performance of treated stock, chemically induced reduction of

Table 2. Mean starch levels in buds, stems, and roots of 'Delicious' apple nursery stock prestorage (Nov. 15, 1977) and poststorage (April 15, 1978), as influenced by hand-defoliation and chemical defoliation in 1977.[z]

		Mean starch levels (mg/g)					
		Bud		Stem		Root	
Treatment[y]	Oct. date	Pre-storage	Post-storage	Pre-storage	Post-storage	Pre-storage	Post-storage
Control		16*	11	76*	28	213	197
Hand-defoliation	1	6	9	31*	16	126	100
	15	12	14	50*	30	209	184
	30	15L	13L,Q	60*L	42L	222L,Q	224L
DWK (1.5%)	5	12*	8	64*	34	223*	173
	5, 10	12*	17	39*	20	224*	165
	5, 10, 15	14NS	13L,Q	48*L,Q	22L,Q	186*L	140NS
DWK (15%) +	5	14	15	64*	34	203	173
ethephon (200 ppm)	5, 10	11	14	45*	14	207*	163
	5, 10, 15	13NS	14NS	42*L,Q	16L,Q	197NS	166NS

[z]Values are means of 4 replications.
L = a response, within columns, that could be described with a linear equation (5% or greater F-test significance level).
Q = a response, within columns, that could be described with a quadratic equation (5% or greater F-test significance level).
NS = no significant linear or quadratic effect of treatment.
[y]DWK = Dupont WK surfactant.
*Starch levels within plant parts differed (LSD = 5%) between time of digging and planting.

Table 3. Mean starch levels in buds, stems, and roots of 'Delicious' apple nursery stock prestorage (Nov. 15, 1978) and poststorage (April 15, 1979), as influenced by hand-defoliation and chemical defoliation in 1978.[z]

		Mean starch level (mg/g)					
		Bud		Stem		Root	
Treatment[y]	Oct. date	Pre-storage	Post-storage	Pre-storage	Post-storage	Pre-storage	Post-storage
Control		9	8	54	20	280*	189
Hand-defoliation	1	5	9	13	16	128	105
	15	6*	10	39*	10	175	155
	30	7NS	10NS	38L,Q	43L,Q	269L	229L
DWK (1.5%)	5	10	12	45*	13	201*	156
	5, 10	6*	12	31*	12	157	157
	5, 10, 15	10Q	6NS	25*L	10NS	181NS	140NS
DWK (1.5%) +	5	9*	23	42*	8	187	197
ethephon (200 ppm)	5, 10	6*	11	25*	10	171	156
	5, 10, 15	8Q	10L,Q	26*L,Q	10NS	185NS	168NS

[z]Values are means of 4 replications.

L = a response, within columns, that could be described with a linear equation (5% or greater F-test significance level).

Q = a response, within columns, that could be described with a quadratic equation (5% or greater F-test significance level).

NS = no significant linear or quadratic effect of treatment.

[y]DWK = Dupont WK surfactant.

*Starch levels within plant parts differed (LSD = 5%) between time of digging and planting.

starch reserves may also lower subsequent vigor and growth. Also, nurserymen should delay hand-defoliation as long as possible, since premature hand-defoliation reduced starch reserves.

Variable performance of defoliated stock from year to year may be due to an interaction of the defoliation treatments with cultural practices, seasonal differences in stock maturity and condition, treatment technique, and weather. Under some conditions, starch reserves may be reduced sufficiently to affect growth negatively the following year, while under other conditions the reduction caused may be relatively small.

Table 4. Contrasts of the effect of treatment types on starch concentrations in 2-year-old 'Delicious' apple nursery tree organs before and after storage at 3°C for 5 months.

	Significance[z] of comparison					
	Bud		Stem		Root	
Contrasts[y]	Pre-storage	Post-storage	Pre-storage	Post-storage	Pre-storage	Post-storage
			1977			
Control vs. Hand	**	NS	NS	NS	*	NS
vs. DWK	NS	NS	***	NS	NS	*
vs. DWK + E	NS	*	***	**	NS	NS
Hand vs. DWK	NS	NS	NS	**	**	NS
vs. DWK + E	NS	*	NS	***	NS	NS
DWK vs. DWK + E	NS	NS	NS	*	NS	NS
			1978			
Control vs. Hand	**	NS	***	*	***	NS
vs. DWK	NS	NS	***	***	***	*
vs. DWK + E	NS	***	***	***	***	NS
Hand vs. DWK	**	NS	NS	***	NS	NS
vs. DWK + E	*	***	NS	***	NS	NS
DWK vs. DWK + E	NS	***	NS	*	NS	NS

[z]Signifiance at 5% (*), 1% (**), 0.1% (***), or nonsignificant (NS).

[y]Hand = hand-defoliation. DWK = 1.5% Dupont WK surfactant. E = Ethephon (200 ppm).

Table 5. Effects of hand-defoliation and chemical defoliation in 1978 on mean shoot length per tree in 1979, after storage and replanting, of 'Delicious' apple nursery stock.[z]

Treatment[y]	Oct. date	Shoot length (cm)
Control		583
Hand-defoliation	1	284
	15	403
	30	517
DWK (1.5%)	5	573
	5, 10	539
	5, 10,15	464
DWK (1.5%) + ethephon (200 ppm)	5	472
	5, 10	478
	5, 10, 15	231

[z]Data are means from 4 replications of 3 trees/plot. 1978 data are omitted because of tree losses after planting not attributable to the experiment.
[y]SE = 64. DWK = Dupont WK surfactant.

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Initiation and Control of Sunscald Injury of Tomato Fruit[1]

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Additional index words. Lycopersicon esculentum, solar injury, radiation stress

Abstract. **Sunscald was induced by exposing fruit of tomato (*Lycopersicon esculentum* mill.) to intense solar radiation; similar injury was caused by radiation from incandescent lamps. Injurious radiation treatments caused fruit temperature to exceed 40°C and altered fruit respiration rates. High air temperatures enhanced injury, but exposure to 0 to 100% O_2 concentrations during radiation treatments had little influence on fruit response. Infrared wavelengths (>0.7 μm) were effective in inducing injury. Tissue water may serve as an important absorber of radiant energy. Overheating of the fruit appeared to be the main cause of injury, and storage at different temperatures, photoperiods, or O_2 levels did not reverse injury induced by previous irradiation.**

Sunscald is a physiological disorder of many horticultural crops grown in warm climates (1, 6). In tomato, sunscald can develop on fruits as they grow; it also arises after harvest on fruits left exposed to direct solar radiation. Susceptibility to sunscald is one limitation to achieving maximum yield of high quality tomatoes in hot, dry growing regions (2).

At the outset, it should be recognized that the term "sunscald" is also applied to a different injury that develops under freezing conditions in plants exposed to strong sunlight (9, 10). This paper, however, will focus on the superficial and internal injuries in tomato fruits induced by the combined action of high temperature and high levels of natural or artificial radiation (17). Sunscald involves a complex of visible symptoms that differ from other disorders of tomato, such as blotchy ripening, green shoulders, and greywall (11, 24), that also have been associated with solar radiation.

Our studies were done to determine the roles of irradiance, waveband, air temperature, and O_2 concentration in the initiation of fruit injury, and to assess whether conditions during subsequent storage can moderate the development of injury.

Materials and Methods

Fruit of 'vendor' tomato was harvested from plants grown in commercial greenhouses in Surrey, British Columbia. Fruit were picked at either the mature-green or red-ripe stages (26) and were taken from trusses between 1.0 and 1.5m above the ground. Following harvest, fruit were transported in conventional tomato

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