Fruit Pigmentation of Four Green Apple Cultivars Responds to Urea Sprays but not to Nitrogen Fertilization

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Abstract. Four green apple (*Malus domestica* Borkh.) cultivars, ‘Granny Smith’, ‘Mutsu’, ‘Newtown’, and ‘Shamrock’, were subjected to a factorial experiment of two rates of nitrogen fertilization and three concentrations of foliar urea sprays for 4 years. The higher rate of N (160 kg N/ha) had no effect on ground color or fruit quality relative to the lower rate of 80 kg N/ha. Urea sprays enhanced green pigmentation in ‘Granny Smith’ and ‘Newtown’ at harvest and retarded yellowing of fruit in all cultivars during air storage at 0°C. Response was similar for urea at 0.5% and 1%, and urea sprays did not adversely affect quality. Urea sprays increased fruit N by 23% and 47% for the 0.5% and 1% concentrations, respectively.

Green apples, like ‘Newtown’, have a tendency to turn yellow as they mature. Because market appeal of green apples depends on a pronounced green pigmentation, growers appreciate cultural practices that enhance greenness. High rates of N fertilization promote greenness in apples (Bould and Jarret, 1962; Fallahi et al., 1985; Neilsen et al., 1984; Richardson, 1986; Ruiz et al., 1986; Vang-Petersen et al., 1977; Ystaas and Froynes, 1991) but can lower firmness (Higgs and Perring, 1989; Mason, 1968; Neilsen et al., 1984; Richardson, 1986) and increase the incidence of postharvest disorders (Raese, 1990). Meheriuk (1990) noted that fruit were greener when ‘Newtown’ trees were treated with foliar sprays of 1% urea in the late summer. This paper compares the effect of rate of N fertilization and foliar urea sprays on ‘Granny Smith’, ‘Mutsu’, ‘Newtown’, and ‘Shamrock’ apples over 4 years. Skin color and fruit quality were evaluated at harvest and after 120 days’ storage in 0°C air.

Materials and Methods

‘Granny Smith’, ‘Mutsu’, ‘Newtown’, and ‘Shamrock’ apple on M.26 rootstock were planted in 1986 in a randomized block design (n = 10 blocks) at a spacing of 3 m between trees and 4 m between rows, except for ‘Shamrock’, which was spaced at 2 m between trees. Each block contained single three-tree plots of ‘Granny Smith’, ‘Newtown’, and ‘Mutsu’ and a four-tree plot of ‘Shamrock’. The first three

cultivars were trained to a central leader system and ‘Shamrock’ was trained to a spindle. Tree density and training were based on recommendations of staff at the research center. Single rows of ‘Sumac’ apple on either side of the planting served as pollinators. Vegetation within the rows was controlled by two applications of N-(phosphono-methyl) glycine (glyphosphate), one in the spring and one in midsummer. Alleyways were mowed as required and irrigation was provided by an under-tree microjet system.

Treatments from 1990 to 1993 consisted of two levels of N (80 and 160 kg N/ha as NH_4NO_3), broadcast annually within the tree row in late April or early May, and three concentrations of urea. Five blocks chosen randomly received the low-N treatment and the remaining five blocks the high-N treatment. Urea was applied by pressurized gun to the point of drip in late summer at weekly intervals over 4 weeks, the last spray taking place 1 week to 10 days before harvest. The urea sprays were randomized among the three trees in each plot in all blocks and each tree received 0, 0.5% or 1% urea. The fourth tree in the ‘Shamrock’ plots was not used. Harvest dates varied from 10–15 Sept. for ‘Shamrock’, 20–25 Sept. for ‘Mutsu’, 5–10 Oct. for ‘Newtown’, and 10–20 Oct. for ‘Granny Smith’.

A box of fruit (≈ 60 to 80 apples) was picked annually from each treatment tree in all blocks. A 15-fruit sample from each box was evaluated for average fruit weight, skin color, firmness, titratable acidity (TA), soluble solids concentration (SSC), and incidence of solar injury. The remaining apples were stored at 0°C for 120 days. Another 15-fruit sample from each box was evaluated immediately after storage for skin color, firmness, TA, and SSC. The remainder of the fruit in each box from storage was ripened at 20°C for 7 days and then assessed for incidence of disorders.

Skin color was read with a Minolta CR 200 chroma meter (Minolta Canada, Mississauga, Ont). Color was reported as hue angle as suggested by McGuire (1992). Firmness was obtained with a Magness-Taylor (Lake City Technical Products, Kelowna, B.C.) penetrometer (11.1 mm tip). Titratable acidity and SSC in the juice were determined by titration (pH 8.1) and refractometry, respectively.

A composite of a longitudinal slice from each apple (seeds excluded) in the 15-fruit sample at harvest was lyophilized in a freeze drier and ground into a powder (0.42-mm mesh screen). Magnesium, Ca, K, P, and N concentrations in the powder were determined by atomic absorption and spectrophotometric methods (Neilsen et al., 1993).

Composite leaf samples of 30 leaves each were taken in 1990–92 from the mid-third portion of extension shoots for each cultivar and rate of N fertilization (five blocks per rate of N). Leaves were always sampled before application of the urea sprays. The cumulative effect of urea on leaf N was assessed in ‘Shamrock’ trees in 1992. All leaf samples were oven-dried, ground to a powder, and analyzed for N, K, Mg, Ca, P, Zn, Fe, Mn, and Cu by atomic absorption and spectrophotometry (Neilsen et al., 1993).

Statistical evaluation of the data was done with SAS’s GLM procedure (version 6.07, SAS Inc., Cary, N.C.). Data from each year and cultivar were analyzed separately. The design was a split plot with main plots of three trees receiving one of the two N treatments and split plots of single trees within the main plots receiving one of the three urea treatments. Proportions were converted to arcsin values for the statistical evaluation.

Results and Discussion

The higher rate of N did not influence skin color in any of the cultivars over the four years (Table 1). Nitrogen at 80 kg-ha⁻¹ resulted in slightly greener ‘Shamrock’ in 1990; none of the other hue values differed significantly. Urea sprays significantly enhanced greenness more consistently at harvest in ‘Newtown’ and ‘Granny Smith’ than in ‘Mutsu’ or ‘Shamrock’ (Table 1). Only in two of the years was the response better with 1% urea than with 0.5% urea (1993 for Granny Smith and 1991 for Mutsu). Urea-treated apples were greener in most instances than comparable nontreated apples after a storage period of 120 days at 0°C (Table 2). Nitrogen $\times$ urea interacted for ‘Granny Smith’ in 1991 and for ‘Mutsu’ in 1990. Greenest apples developed on urea-sprayed ‘Granny Smith’ trees treated with the higher rate of N and for urea-sprayed ‘Mutsu’ trees treated with the lower rate of N in each of the years mentioned above. Average fruit weight, flesh firmness, TA, SSC, and incidence of solar injury were not or only slightly affected by the rate of N and urea foliar sprays (data not shown).

Fruit N was influenced by the urea sprays but not by rate of N fertilization. During the study, mean values across all cultivars ranged from 28 to 31 mg/100 g fresh weight for

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Table 1. Influence of nitrogen and foliar urea sprays on skin color of four green apple cultivars at commercial harvest.

Treatment	Hue(°) ^z															
	Granny Smith				Mutsu				Newtown				Shamrock			
	1990	1991	1992	1993	1990	1991	1992	1993	1990	1991	1992	1993	1990	1991	1992	1993
Rate of N (kg·ha ⁻¹)																
80	115	116	115	116	113	111	114	113	113	114	114	114	112	115	114	114
160	115	116	115	116	114	112	114	113	113	115	114	114	112	115	114	114
Foliar urea sprays (%)																
0	115 ^y	116	115	116	113	111	113	113	112	114	113	113	112	116	114	114
0.5	116	116	115	116	114	112	114	113	113	115	114	114	112	115	114	114
1.0	116	117	116	117	114	113	114	113	113	115	115	114	112	115	114	114
Significance																
N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
Urea	**	**	NS	**	NS	**	NS	NS	*	*	**	**	NS	NS	NS	*
N × urea	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

^zHue angles are derived from a system where 0° = red, 90° = yellow, 180° = green, and 270° = blue.

^yMean separation within columns by Duncan's multiple range test, $P \leq 0.05$.

NS, *, ** Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively; observations per mean were $n = 5$ for rate of N and $n = 10$ for foliar urea sprays.

Table 2. Influence of nitrogen and foliar urea sprays on skin color of four green apple cultivars after 120 days of storage at 0°C.

Treatment	Hue (°) ^z															
	Granny Smith				Mutsu				Newtown				Shamrock			
	1990	1991	1992	1993	1990	1991	1992	1993	1990	1991	1992	1993	1990 ^y	1991	1992	1993
Rate of N (kg·ha ⁻¹)																
80 (N1)	113		115	114		106	109	110	108	111	110	110	---	111	111	111
160 (N2)	113		115	114		108	110	109	109	110	110	110	---	110	110	111
Foliar urea (%)																
0	112 ^x	N1	N2	114	113	N1	N2	104	107	104	108	108	---	109	110	110
0.5	113	113	114	115	114	106	108	107	110	110	109	111	---	112	111	112
1.0	115	113	114	115	115	107	107	109	110	110	109	112	---	111	111	112
Significance																
N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	---	NS	*	NS
Urea	***	**	NS	***	*	**	*	NS	*	*	***	**	---	**	*	*
N × urea	NS	**	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	---	NS	NS	NS

^zHue angles are derived from a system where 0° = red, 90° = yellow, 180° = green, and 270° = blue.

^yNo storage samples were available in 1990.

^xMean separation within columns by Duncan's multiple range test, $P \leq 0.05$.

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively; observations per mean were $n = 5$ for rate of N and $n = 10$ for foliar urea sprays.

control fruit, from 34 to 40 mg for 0.5% urea, and from 41 to 48 mg for 1% urea. Leaf N values for 'Shamrock' in 1992 were 2.38%, 2.45%, and 2.49% with the 0, 0.5%, and 1% urea sprays. The higher rate of N reduced leaf K (across cultivars) in 1990 and 1992 but had no effect on leaf N, Ca, or Mg (data not shown).

Treatment effects on disorders were minor. Slightly more breakdown occurred in 'Granny Smith' treated with 0.5% urea in 1990 and the higher rate of N in 1992 (data not shown). The incidence of breakdown was slighter in 'Newtown' with the higher rate of N in 1990 and in 'Shamrock' treated with 1% urea relative to 0% in 1991. 'Mutsu' was unaffected by any of the treatments.

Doubling the ground application of urea from 125 to 250 kg·ha⁻¹ reduced the incidence of yellow fruit in 'Granny Smith' (Ruiz et al., 1986), but a two-fold increase from 80 to 160 kg N/ha as NH₄NO₃ had no effect in our study. A high rate of N fertilization had negligible or inconsistent effects on tree growth and fruit size of 'Cox's Orange Pippin' apples (Hipps et al., 1990), a result also noted in our study with the four green apple cultivars. The beneficial effects of urea sprays on greenness in 'Newtown' apples as reported by Meheriuk (1990) were confirmed in this study.

In summary, urea foliar sprays are more effective in promoting greenness in green apples than use of high rates of N fertilization.

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