

burst declined with longer chilling periods in the present experiments with 'Delicious' is not clear. Additional research is needed to determine if this is reproducible.

The promoting effect of chilling temperatures on shoot elongation of the bud explants is reminiscent of the effect of chilling on physiologic dwarfs of apples and many other woody species. Such dwarfs, obtained from embryos excised from non-stratified seeds of species that require stratification for normal growth, typically form a rosette of leaves with virtually no internode elongation, and may remain dwarfed for years (7). The dwarfed condition may be alleviated by chilling or by supplying gibberellic acid continuously (2, 3, 7). Thus, chilling the axillary buds either before or after excision may stimulate shoot growth by providing gibberellins.

The fact that 2 weeks chilling of explants from 'Antonovka' seedlings did not promote additional bud burst should not be interpreted to mean that excised apple buds do not respond to chilling. Intact apple trees normally require 8 or more weeks of chilling for bud burst. Longer chilling periods for the explants must be tested to clarify this point.

Although 2 weeks of chilling did not promote bud burst, it promoted shoot elongation in some instances. This suggests that bud burst and shoot elongation either have different threshold requirements for gibberellin, or they are controlled by different hormones. The latter seems more likely. Cytokinins appear to activate axillary bud growth in *Psium* whereas gibberellin promotes shoot elongation (12). Cytokinins also promote bud break of apple (4, 9, 11, 16).

Our results indicate that the bud explant technique is a useful method for studying bud dormancy and growth in apple. It eliminates correlative effects in a system that is easy to manipulate and to control environmentally.

#### Literature Cited

1. Altman, A. and R. Goren. 1974. Growth and dormancy cycles in *Citrus* bud cultures and their hormonal control. *Physiol. Plant.* 30:240-245.
2. Barton, Lela V. 1956. Growth response of physiologic dwarfs of

- Malus arnoldiana* Sarg. to gibberellic acid. *Contr. Boyce Thompson Inst.* 18:311-317.
3. Blommaert, K. L. J. and N. Hurter. 1959. Growth response of physiologic dwarf seedlings of peach, apricot and plum to gibberellic acid. *S. African J. Agr. Soc.* 2:409-411.
  4. Broome, Olivia C. and R. H. Zimmerman. 1976. Breaking bud dormancy in tea crabapple [*Malus hupenhensis* (Pamp.) Redh.] with cytokinins. *J. Amer. Soc. Hort. Sci.* 101:28-30.
  5. Denny, F. E. and E. N. Stanton. 1928. Localization of response of woody tissues to chemical treatments that break the rest period. *Amer. J. Bot.* 15:337-344.
  6. Dutcher, R. D. and L. E. Powell. 1972. Culture of apple shoots from buds *in vitro*. *J. Amer. Soc. Hort. Sci.* 97:511-514.
  7. Flemion, Florence. 1959. Effect of temperature, light and gibberellic acid on stem elongation and leaf development in physiologically dwarfed seedlings of peach and *Rhodotypos*. *Contr. Boyce Thompson Inst.* 20:57-70.
  8. Hatch, A. N. and D. R. Walker. 1969. Rest intensity of dormant peach and apricot leaf buds as influenced by temperature, cold hardiness and respiration. *J. Amer. Soc. Hort. Sci.* 94:304-307.
  9. Kender, W. J. and S. Carpenter. 1972. Stimulation of lateral bud growth of apple trees by 6-benzylaminopurine. *J. Amer. Soc. Hort. Sci.* 97:377-380.
  10. Nichols, D. C., D. L. Jones, and W. K. Thompson. 1974. Effects of autumn on the induction of dormancy in apple and peach seedlings and their subsequent regrowth in spring. *Austral. J. Agr. Res.* 25: 899-907.
  11. Pieniazek, Janina. 1964. Kinetin induced breaking of dormancy in 8-month-old apple seedlings of 'Antonovka' variety. *Acta Agrobotanica* 16:157-169.
  12. Sachs, T. and K. V. Thimann. 1967. The role of auxins and cytokinins in the release of buds from dominance. *Amer. J. Bot.* 54: 136-144.
  13. Schneider, E. F. 1970. The rest period of *Rhododendron* flower buds. *J. Expt. Bot.* 21:799-807.
  14. Thompson, W. K., D. L. Jones, and D. G. Nichols. 1975. Effects of dormancy factors on the growth of vegetative buds of young apple trees. *Austr. J. Agr. Res.* 26:989-996.
  15. Wareing, P. F. and I. D. J. Phillips. 1973. p. 221-231. *In* The control of growth and differentiation in plants. Pergamon Press, Oxford.
  16. Williams, M. W. and E. A. Stahly. 1968. Effect of cytokinins on apple shoot development from axillary buds. *HortScience* 3:68-69.

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## Effect of Rootstock on Mineral Composition of Apple Leaves<sup>1</sup>

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Additional index words. *Malus domestica*

**Abstract.** Significant differences were evident in levels of Mg, Ca, Fe, Mn, and Na in leaves of 'McIntosh' apple (*Malus domestica* Borkh.) scions grafted on 16 different rootstocks when sampled over a 4-year period. Trees on Malling-Merton (MM) 106 rootstock were among the highest in leaf Mg and Ca, while those on Malling (M) 4 were among the lowest in leaf Mg, Ca, Na, and Al.

Foliar analysis can be used to determine nutrient status of fruit trees and to estimate the differential effects of rootstock, interstock, and scion components (1, 2, 5, 6, 7, 8, 9, 11). Trees on M 2 and M 5 are susceptible to K deficiency (10), trees on M 4 need increased levels of Mg (4), and leaves of trees on MM 106 reportedly contain higher levels of Mg and Ca than do those of trees on MM 104 and MM 111 (2).

Scion cultivars may differ in their influence on levels of leaf N, K, Ca and Mg (1, 7, 9, 11). However, few significant interactions between rootstock and scion cultivar have been reported (7, 11), indicating that stock and scion act independently.

The purpose of this study was to identify clonal rootstocks which induce relatively high or low nutrient levels in the 'McIntosh' scion cultivar. The present paper is based on 4 years of leaf mineral analyses (1973-1976) using graft combinations of known origin.

#### Materials and Methods

A commercial orchard (Sodoma Bros.) located in Western New York was used in this study. The trees were planted at a

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4.57 × 9.14 m spacing on Alton gravelly loam soil in 1958 and grown under sod culture. The treatments were 'McIntosh' scions on M 2, M 4, M 7, M 9, M 25, M 26, MM 102, MM 104, MM 106, MM 109, MM 111, M 9/MM 106, M 9/seedling, seedling, Alnarp 2, and Robusta 5. Treatments were replicated 6 times in a completely randomized design as single tree plots. Each tree received 0.25 kg of N in 1975, and 2.25 kg of sulfate of potash-magnesia in 1976.

Only vigorous, bearing trees were selected for sampling over the 4-year period. Twenty healthy leaves with petioles attached were collected in mid-August, from the midsection of the current season shoots at about shoulder height around each tree. The leaf samples were dried in a forced air drying oven at 72°C and ground in an intermediate Wiley Mill to pass a 20-mesh screen. Sub-samples were analyzed for P, K, Ca, Mg, Mn, Fe, Cu, Na, B, Al, and Zn by an Applied Research Laboratories 1.5 m emission spectrometer. Total N was determined by a modified Kjeldahl method (3). Leaf composition data were subjected to analyses of variance; differences between means were delineated by Duncan's multiple-range test.

### Results

**Calcium.** The M 9/MM 106 trees induced significantly higher levels of leaf Ca than did MM 104, M 2, MM 102, Robusta 5, Alnarp 2, seedling, M 25, M 26 or M 4; values for MM 106 were higher than for M 26, M 25 and M 4; and those for M 9/seedling higher than for M 4. The M 9, M 7 and MM 111 understocks' influence on Ca accumulation was not significantly different from those of all other rootstocks (Table 1).

**Magnesium.** The seedling and MM 106 rootstocks induced significantly higher levels of leaf Mg than did Robusta 5, Alnarp 2, M 4 or MM 102; values for M 26, M 7, MM 104 and MM 109 were higher than for M 4, Alnarp 2 and MM 102; and those for M 9/seedling and MM 111 were greater than for MM 102 (Table 1). There were no significant differences between M 9, M 9/MM 106, M 25 and M 26 and all other stocks.

**Iron.** Trees on M 7 or Alnarp 2 were significantly higher in levels of leaf Fe than trees on M 9/seedling, MM 109, M 9/MM 106, M 9 and M 2 (Table 1). All other differences were non-significant.

**Manganese.** Relatively wide ranges in leaf Mn values were obtained. 'McIntosh' scions on M 26 were significantly higher in leaf Mn than on all other rootstocks, except MM 102 (Table 1).

**Aluminum.** Trees on M 7 were significantly higher in leaf Al than were these on other stocks except MM 104 and seedling;

the value for seedling was higher than Alnarp 2, M 9/seedling, M 9/MM 106, M 9, Robusta 5, M 25, M 4, MM 102 and Robusta 5; MM 106, MM 111 and MM 109 were higher than M 26, M 4 and MM 102; and Alnarp 2 was higher than M 26 stock (Table 1).

**Other elements.** Levels of N, P, K, B, Zn, and Cu were not significantly affected by rootstock (Table 1).

### Discussion

The apple rootstocks evaluated in this study had a statistically significant influence on the content of certain elements in 'McIntosh' scion foliage. Significant differences were obtained for Ca and Na, and highly significant effects for Mg, Fe, Mn and Al. The results concur with previous findings (1, 5) that trees on M 4 stocks tend to have low levels of leaf Mg. Our data support the findings of Awad and Kenworthy (1) that rootstocks have significant differential effects on leaf Ca and Mg, but not on leaf N and B. Trees on M 2 reportedly contain low levels of leaf K (1, 5, 10); however, in this study trees on M 2 were intermediate in leaf K content (Table 1). Bould and Campbell (2) reported higher levels of Ca and Mg in leaves of young apple trees on MM 106 than on MM 104 or MM 111, but in this experiment these rootstock influences were not statistically significant. Higher levels of leaf Mg were detected in 1976 after the application of 2.25 kg of sulfate potash-magnesia per tree; but rootstock trends remained relatively the same after the fertilizer application. Clonal rootstocks have been reported to have a relatively wide range in leaf Mn (1); large numerical differences were also found in this study for Mn, Fe, Na and Al.

Fertility level or other soil conditions may have masked certain rootstock effects. Tukey et al. (9) noted that rootstock effects on elemental composition which were significant at one location were often not evident at another location. Factors which may account for this variation are differences in soil fertility, climate, tree ages, scion cultivars, and possible cultivar × rootstock interactions. However, preliminary results (unpublished data indicate a near absence of scion/rootstock interactions between 'McIntosh', 'Golden Delicious', 'Delicious' and 'Cortland' scions on rootstocks M 9 and M 26.

The rootstock differences obtained for Ca, Mg, Fe, Mn, Na and Al do not indicate a need to modify current leaf composition values used as indices of the nutritional status of 'McIntosh' cultivar. Utilization of all the rootstocks studied appears warranted on the basis of influence on leaf nutrient levels.

Table 1. Effects of 16 apple rootstocks on mineral element composition of 'McIntosh' scion leaves. Means for 4 years, 1973-1976.

Rootstock	Element composition (dry wt) <sup>2</sup>											
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Cu (ppm)	Na (ppm)	Al (ppm)
M 9	1.92	0.151	1.46	1.13abcd	.178ABCD	67B	74.0CD	31.7	22.9	11.6	36.8abc	101DEF
M 26	1.93	0.141	1.45	1.01cd	.191AB	76AB	138.8A	25.0	20.9	8.4	38.4abc	81F
M 9/MM 106	1.98	0.154	1.44	1.31a	.168ABCD	69B	69.3D	30.5	26.5	11.0	49.8ab	105DEF
M 9/Sdlg	1.89	0.141	1.43	1.18abc	.186ABC	71B	84.6CD	31.7	29.3	11.4	31.0c	109CDEF
M 25	2.00	0.192	1.63	1.03cd	.165ABCD	77AB	80.1CD	30.3	21.9	10.6	38.8abc	96DEF
M 7	1.98	0.153	1.51	1.17abcd	.192AB	110A	72.2CD	28.8	25.7	10.8	53.6a	152A
MM 106	1.98	0.168	1.58	1.25ab	.194A	80AB	76.6CD	32.9	25.6	12.1	41.8abc	123BCD
M 2	1.96	0.153	1.52	1.07bcd	.158ABCD	63B	68.0D	34.1	30.4	9.1	42.9abc	118BCD
M 4	1.96	0.171	1.83	0.96d	.148CD	82AB	88.0CD	29.6	23.4	11.7	31.8bc	88EF
MM 102	1.93	0.172	1.59	1.08bcd	.143D	76AB	125.0AB	30.5	25.6	10.2	28.5c	85EF
MM 111	1.90	0.139	1.71	1.16abcd	.187ABC	82AB	80.1CD	31.4	26.9	12.2	53.1a	123BCD
Alnarp 2	1.93	0.164	1.72	1.07bcd	.149CD	106A	84.8CD	29.2	24.0	10.3	35.5abc	113CDE
MM 104	1.86	0.157	1.54	1.09bcd	.189AB	85AB	73.7CD	30.8	25.3	10.4	42.7abc	135ABC
Robusta 5	1.99	0.168	1.75	1.18bcd	.152BCD	93AB	101.4BC	33.2	24.3	10.5	27.7c	98DEF
Seedling	1.85	0.145	1.43	1.05bcd	.196A	85AB	85.3CD	30.2	29.9	9.2	42.7abc	143AB
MM 109	1.85	0.155	1.59	1.22abc	.190AB	70B	60.3D	32.7	21.4	13.6	45.0abc	124BCD

<sup>2</sup>Mean separation in columns by Duncan's multiple range test, 5% level (lower case), 1% level (upper case), or nonsignificant (no letters).

In most instances, application of appropriate corrective measures can alleviate nutrient disorders that are induced by a particular stock. Rootstock effects such as tree growth control, disease resistance, winter hardiness and induction of precocity are of much greater concern and importance in selecting a rootstock for commercial purposes than is influence on leaf mineral composition. However, increasing the level of Ca in the leaves and fruit of apple by means of soil applications is generally unsuccessful. The use of rootstocks or interstocks that are good accumulators of Ca might overcome deficiencies of this element. Research to determine the influence of rootstock on the Ca content of the fruit would be appropriate, especially for fruiting cultivars subject to Ca-induced fruit disorders.

#### Literature Cited

1. Awad, M. M. and A. L. Kenworthy. 1963. Clonal rootstock, scion variety, and time of sampling influences in apple leaf composition. *Proc. Amer. Soc. Hort. Sci.* 83:68-73.
2. Bould, C. and A. I. Campbell. 1970. Virus, fertilizer and rootstock effects on the nutrition of young apple trees. *J. Hort. Sci.* 45:287-294.
3. Fisher, E. G. 1953. Analysis of plant tissues for total organic and ammoniacal nitrogen by a modified Kjeldahl method. Pomology Dept., Cornell Univ. Mimeo F114-A.
4. Ford, E. M. 1964. The control of magnesium deficiency in apple rootstock stoolbeds. *J. Hort. Sci.* 39:212-223.
5. Hoblyn, T. M. 1941. Manurial-trials with apple trees at East Malling, 1920-1939. *J. Pom. & Hort. Sci.* 37:438-442.
6. Lockard, R. D. 1976. Effect of apple rootstocks and length and type of interstock on leaf nutrient levels. *J. Hort. Sci.* 51:289-296.
7. Schneider, C. G., C. E. Chaplin, and D. C. Martin. 1978. Effects of apple rootstock, tree spacing and cultivar on fruit and tree size, yield, and foliar mineral composition. *J. Amer. Soc. Hort. Sci.* 103:230-232.
8. Sistrunk, J. W. and R. W. Campbell. 1966. Calcium content differences in various apple cultivars as affected by rootstock. *Proc. Amer. Soc. Hort. Sci.* 88:38-40.
9. Tukey, R. B., R. Langston, and R. A. Cline. 1962. Influence of rootstock, bodystock and interstock on the nutrient content of apple foliage. *Proc. Amer. Soc. Hort. Sci.* 80:73-78.
10. Warne, L. C. C. and T. Wallace. 1935. The composition of the terminal shoots and fruits of two varieties of apple in relation to rootstock effects. *J. Pom.* 13:1-31.
11. Whitfield, B. A. 1964. The effect of stock and scion on the mineral composition of apple leaves. Annu. Rpt. East Malling Res. Sta. 1963. p. 107-110.

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## Ultrastructure and Chemistry of Cuticular Waxes of Developing *Citrus* Leaves and Fruits<sup>1</sup>

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*Additional index words.* epicuticular, intracuticular, orange, tangerine, lemon, navel orange, scanning electron microscopy

**Abstract.** The ultrastructure of leaf and fruit surface waxes of citrus developed similarly. The wax layers of immature leaves and fruits were initially amorphous. Small protrusions and isolated regions of upright platelets then developed. All surfaces eventually cracked and uplifted to form large flat irregular plates. Epicuticular wax concentrations ( $\mu\text{g}/\text{cm}^2$ ) of new spring flush leaves were initially high, declined rapidly in March-April, and increased to June maxima after which levels declined slightly. Fruit epicuticular wax concentration generally declined in May-June and then increased into November. Secondary alcohols dominated citrus leaf waxes in March-April but quickly decreased or were diluted to trace levels. Overall, the major citrus leaf wax fractions were primary alcohols, with paraffins 2nd in importance. Aldehydes and fatty acids were dominant in citrus fruit waxes. For each cultivar, the relative proportions of individual wax fractions changed during the year. The intracuticular waxes were mainly fatty acids. The relationships between wax ultrastructure and chemistry in developing leaves and fruits are discussed.

Plant cuticles influence foliar absorption, fungal invasion, and adaptation to water stress. *Citrus* culture depends on complex spray schedules and irrigation, therefore cuticle and cuticular wax studies are important. Studies of *Citrus* cuticular waxes (6, 17, 22) have related chemistry to the modification or con-

trol of basic physiology and surface properties of leaves and fruit. Albrigo (1, 2, 3) related ultrastructural and quantitative changes of *Citrus* epicuticular waxes to rind disorders, water loss, and deterioration of fruit quality. Studies on *Citrus* epicuticular wax development have emphasized either morphological (2, 22), chemical (6, 17, 22, 32), or quantitative changes (2, 4, 6, 22, 32). Developmental studies linking these together are required to determine cuticular changes and to more accurately predict plant response to agricultural chemicals and water stress.

This study characterizes the cuticular waxes of developing fruit and leaves of several *Citrus* cultivars and correlates epicuticular wax quantitative and chemical changes with surface ultrastructural changes.

#### Materials and Methods

**Leaf and fruit samples.** New spring flush leaf and fruit samples were collected between March and December 1977 from the same mature trees of 'Pineapple' and navel sweet

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