species in this study differed in their response to \( \text{NO}_2 \), \( \text{SO}_2 \), and \( \text{O}_3 \), singly and in mixture, indicates the need for continued research on the effects of \( \text{NO}_2 \), \( \text{SO}_2 \), and \( \text{O}_3 \) in mixture on a wide range of species. This study would also support the need for more biochemical studies to determine why interactions of \( \text{NO}_2 \), \( \text{SO}_2 \), and \( \text{O}_3 \) are common in some species but not in others.

**Literature Cited**


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**Effect of Rootstocks and Interstems on Composition of ‘Delicious’ Apple Leaves**

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*Additional index words.* rootstock, interstem, *Malus domestica*, foliar analysis

**Abstract.** Leaf nutrient composition \((\text{N}, \text{P}, \text{K}, \text{Ca}, \text{Mg}, \text{Mn}, \text{Fe}, \text{Zn}, \text{and Cu})\) was determined for 10-year-old 'Delicious' apple trees \((Malus domestica\ Borkh.)\) grown on 21 rootstock and interstem combinations classified according to vigor \((\text{standard, semi-standard, semi-dwarf, dwarf}).\) Significant differences in leaf \( \text{P}, \text{K}, \text{and Mn} \) were observed between the 4 vigor classifications. \( \text{P} \) and \( \text{K} \) were higher in leaves of standard than in leaves of dwarf trees, but leaves of dwarf trees had higher \( \text{Mn} \) than those of the other size classifications had. "Delicious''/Malling (M)/Alanarp (A) 2 (dwarf) and 'Delicious'/M7/Robusta (R) 5 (semidwarf) contained high \( \text{K} \) and low \( \text{Mg} \) levels. High \( \text{Mg} \) and low \( \text{K} \) were found in dwarf trees on M 2 and M 26 rootstocks. Calcium was higher in leaves of trees on Malling Merton (MM) 106 rootstock than in those on M 7/MM 104. Trees on M 26 had high \( \text{Mn} \). Fruit yield was correlated negatively to tree size and leaf \( \text{K} \) and positively to leaf \( \text{Mg} \) and \( \text{Mn} \). Other elements were unaffected by the rootstock systems tested, which suggested that the rootstock and interstem combinations had only a minor effect on nutritional status of scion leaves.

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Leaf analysis can be used to measure the nutritional status of trees and to determine the effect of rootstock systems on the nutrition of scion cultivars (1, 2, 13).

Each graft component on a grafted apple tree can influence the 5 major elements \((\text{N}, \text{P}, \text{K}, \text{Ca}, \text{and Mg})\) in the tree (16).

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Apple trees on M 9 rootstocks, for example, had higher foliar \( \text{Ca} \) and \( \text{Mg} \) levels than did those on M 7; trees on M 2 had higher foliar \( \text{P}, \text{Ca}, \text{and Mg} \) levels than did those on M 7; trees on M 2 had higher foliar \( \text{P}, \text{Ca}, \text{and Mg} \) levels than did those on M 16; M 7 rootstocks considerably reduced foliar \( \text{Mg} \). MM 106 rootstock caused higher foliar \( \text{Ca} \) than did MM 111 (10, 14); and trees on M 26 had significantly higher leaf \( \text{Mn} \) than did those on M 9/MM 106, M 2, or MM 109 (12). Transport rate of \( ^4\text{Ca} \) and \( ^32\text{P} \) to roots and scion is known to be related to the vigor class of the tree (4). Jones (7) found that xylem sap from above the interstem had a lower concentration of \( \text{N}, \text{P}, \text{K}, \text{Ca}, \text{and Mg} \) than that from below the interstem, and that difference increased with the dwarfing effect of the interstem.

Our evaluation of rootstock systems was concerned with the
nutritional status of their scions and a further understanding of the effect of rootstock systems on the nutrition of the apple tree.

Materials and Methods

These 21 rootstock and interstem systems were used: French crab seedling and R 5 (standard); A 2, Kansas (K) 14, and MM 111 (semi-standard); MM 106, M 2, M 7/R-5, M 7/MM 104, M 2/MM 104, M 7/MM 111, M 7/A-2, and M 7/M 2 (semi-dwarf); and M 26, M 9/R-5, M 26/R-5, M 9/MM 104, M 26/MM 104, M 9/MM 111, M 26/A-2, and M 9/A-2 (dwarf). One hundred twenty-six 'Delicious' trees (6 trees per rootstock system) were planted in 1969 in the orchard at the Northeast Kansas Horticulture Field near Wathena, Kans. Replanting was done in 1970 and 1971 with some trees, due to the graft failures. This orchard is on a deep loess, silty-loam soil with a 12% north slope.

Grown on top of terraces in a bluegrass-sod, unirrigated, the trees were pruned to a modified central-leader system and treated with a standard pest-control program. Fertilizer (1–1–1 oxide ratio) was applied annually at the rate of 0.08 to 0.1 kg N/tree based on tree vigor.

The statistical design for plant material was a modified split-plot design with 3 replications. Each main plot consisted of 4 subplots that contained trees spaced according to predicted tree size. Spacings for standard, semi-standard, semi-dwarf, and dwarf trees were 8.5 x 9.8 m, 6.4 x 9.8 m, 4.3 x 4.9 m, and 2.1 x 4.9 m, respectively. A pair of adjacent trees was considered as one sample.

Trunk cross-sectional area of each scion was determined from trunk circumference (A = C2/4π) measured at a marked location 5–10 cm above the uppermost graft union. During the 10th leaf, fruit was harvested and weighed; yield was averaged for the 2 trees of the same rootstock system within each plot and was expressed as kg/cm2 of trunk area.

During July 1979, 40 healthy leaves with petioles attached from the mid-section of the current season’s growth were collected from each tree and prepared for analysis by standard procedures. N and P were determined on the sulfuric acid digest (9) using a Technicon colorimetric autoanalyser; K, Ca, Mg, Mn, Fe, Zn, and Cu were determined in the perchloric acid/nitric acid digest (6) with atomic absorption (Ca, Mg, Fe, Zn, and Cu) and flame emission (K) spectrophotometers (17).

Composite samples (7–23-cm depth to avoid litter on soil surface) were taken in August 1979 from 12 equal subplots, 4 in each replication of trees. Air-dried soil samples were analyzed for N, P, K, Ca, Mg, Mn, Fe, Zn, Cu, pH, CaCO3, electric conductivity (EC), and cation exchange capacity (C.E.C.) by using standard techniques (3, 5, 17).

Statistical analyses for plant samples were carried out by nestling treatments within the 4 classes of trees. Analysis of variance procedure was used within and between classes. Duncan’s multiple range test was used to compare treatments within classes, while a Bonferroni t-interval multiple comparison was used to compare treatments between classes (15).

Results and Discussion

Soil analysis. Results of soil analyses (average values) were as follows: N(0.063%), P(88 kg/ha), K(408 kg/ha), Ca(12 meq/100g), Mg(4 meq/100g), Mn(23ppm), Fe(45 ppm), Zn(0.5 ppm), Cu(1.2 ppm), pH(6.2), CaCO3(1351 kg/ha), EC(0.04m mhos/cm), and CEC(24.4 meq/100g). All elements were present in the soil in satisfactory amounts except Zn, which was low (19).

Fruit yield. In the 10th year, dwarf trees produced the highest yield, and semi-dwarf trees yielded more than did standard or dwarf trees, which had nearly equal yields (Table 1). Among standard trees, yields did not differ (Table 2). Within semi-standards, yield of ‘Delicious’ on K-14 was less than on A-2 or MM 111, which were not different in yield. Highest yields of ‘Delicious’ within semi-dwarfs were on these rootstock systems: M 2, M 7/M 2, MM 106, and M 7/MM 111; lowest yields were on M 7/R-5 and M 7/A-2. Within dwarfs, ‘Delicious’M 9/R-5 yielded the least; yields on all other rootstock systems were comparable.

Plant analysis. Trees in different vigor classifications contained different amounts of foliar P, K, and Mn (Table 1). Standard and semi-dwarf scion leaves had higher P than did those of dwarf trees. K was higher in leaves on standard than on semi-standard or dwarf trees; and among all trees, dwarf-tree leaves had the lowest K and the highest Mn. No differences among other elements were observed.

Generally, foliar P and K varied with tree vigor: the more vigorous the trees, the higher the mineral contents. That agreed with the finding of Bukovac et al. (14) that widely spaced trees have higher foliar P and K, but lower Ca, Mg, and Mn than do closely spaced trees. The trees in our experiment were only 10 years old and, though dwarfed trees seemed to have reached full size, standard trees were still growing. Differences could have been related to either spacing or vigor classification.

Contents of K, Ca, Mg, and Mn varied significantly with rootstock systems (Table 2). Because no significant differences were noted among N, P, Fe, Zn, and Cu levels, they are not presented in Table 2.

Based on standards developed by Kenworthy (8), none of the elements were found to be deficient or at toxic levels in the foliage. Copper was not considered deficient, despite Cu levels lower than the standard.

Since the soil was generally uniform and the scion cultivar the same in all treatments, differences in leaf nutrient content were due to the effect of the rootstock systems.


Among dwarf and semi-dwarf trees, M 26, M 9/MM 104, M 26/R-5, M 26/A-2 and M 9/A-2, gave the highest fruit yields, showing a negative correlation between leaf K and yield (r = -0.859) (Table 2). The reason is due to the accumulation of high amounts of K in the fruit compared to other nutrients.

Table 1. Effect of vigor class in ‘Delicious’ apples on leaf mineral element content.

<table>
<thead>
<tr>
<th>Vigor class</th>
<th>Foliar concn (dry wt basis)</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P (%)</td>
<td>K (%)</td>
</tr>
<tr>
<td>Standard</td>
<td>.41a</td>
<td>1.86a</td>
</tr>
<tr>
<td>Semi-standard</td>
<td>.31ab</td>
<td>1.60b</td>
</tr>
<tr>
<td>Semi-dwarf</td>
<td>.33a</td>
<td>1.73ab</td>
</tr>
<tr>
<td>Dwarf</td>
<td>.21b</td>
<td>1.34c</td>
</tr>
</tbody>
</table>

4Mean separation within columns by Duncan’s multiple range test, 5% level.
These rootstocks gave high fruit yields resulting in low leaf K. M 26/MM 104 and M 9/MM 111 accumulated the lowest foliar K. Although ‘Delicious’ leaves from trees on semi-dwarf rootstock systems had generally higher leaf K than did those from dwarfs, M 2 was lower than on other semi-dwarfs and was comparable to that on dwarf trees. Leaf K on M 9/R-5 was comparable to that on semi-dwarfs.

‘Delicious’ leaves from trees with M 9 interstem generally had lower K than did those of semi-dwarfing systems, as also reported by Lockard (10). Awad and Kenworthy (1) reported that M 2 rootstocks were most susceptible to leaf scorch caused by K deficiency. In our study, no deficiency symptoms were visible, but the level of leaf K in M 2 foliage was low compared with that of other semi-dwarf ‘Delicious’ trees.

Leaves from trees on M 2 rootstock had higher Mg and fruit yield than did M 7/R-5, M 7/A-2, or M 7/MM 104. Among semi-dwarfs correlation between foliar Mg and fruit yield was positive \((r = 0.779)\). Trees with M 7 interstem had low foliar Mg. That agreed with others (1, 2, 14) who found the same effect with M 7 as a rootstock.

Magnesium levels in M 7 interstem trees were not lower when M 2 or MM 111 was the rootstock. M 2 as a rootstock induced high foliar levels of Mg and could have counteracted the interstem effect, as did MM 111. In certain cases, Mg deficiency could be avoided by selecting proper rootstock systems.

Trees on M 26 had higher foliar Mg concentration than did those on M 9/R-5, M 26/A-2, or M 9/A-2; there was no correlation between Mg and yield among dwarfs \((r = 0.282)\). Awad and Kenworthy (1) also reported high levels of Mg in leaves of trees with M 26 rootstocks.

High K and low Mg were found in leaves of trees with M 7/ A-2 and M 7/R-5 rootstock systems, whereas leaves from trees on M 2 and M 26 had high Mg and low K, suggesting an antagonistic effect between K and Mg (Table 2). Because soil K was high, the average leaf K in all trees was high, and the average Mg was lower than the standard, which agreed with Bould and Campbell (2) who concluded that high soil K reduced leaf Mg.

Leaves from ‘Delicious’/MM 106 contained more Ca than did those from ‘Delicious’/M 7/MM 104 (Table 2). Trees on M 106 were among the highest in leaf Ca (2, 10, 13); M 7 induced low Ca levels (14). Using a rootstock that accumulates more Ca is a possible solution to apple disorders related to low fruit Ca (11). Leaf calcium content was not correlated with the yield \((r = 0.276)\).

Among the dwarf trees, those on M 26 rootstocks had significantly higher foliar Mn levels than did those on M 26/A-2, M 7/MM 104, M 9/R-5, A-2, K-14, M 2/MM 104, or M 7/A-2. Among semi-dwarfs there was positive correlation between Mn content and fruit yield \((r = 0.891)\), but no correlation was shown among dwarfs. High foliar Mn content in trees on M 26 was reported previously (12). The wide range of Mn in this study (60–122 ppm) agreed with observations by Poling and Oberly (13), who reported that clonal rootstocks tend to have a wide range of Mn and suggested the need for more intensive Mn studies related to rootstock systems.

Except for Mn, variations of leaf nutrient content associated with rootstock systems were small. N, P, Fe, Zn, and Cu were not affected significantly and all leaf nutrient levels were within the adequate range established by Kenworthy (8). The total effect of rootstock on composition of scion apple leaves was small.

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Inheritance of Early Flowering in Relation to Breeding Day-neutral Strawberries

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Abstract. Strawberry (Fragaria X ananassa Duch.) seedlings from 54 crosses between day-neutral and short-day parents were evaluated in western Washington for the proportion which flowered by September and for the earliness of such flowering when it occurred. The day-neutral progeny of ‘Aptos’, ‘Brighton’, ‘Hecker’, CN5, CN11, CN20, WSU 1714E and SHRI 7020/131, all day-neutral parents, flowered early. The day-neutral progeny of ‘Alko’, ‘Linn’, ‘Olympus’ and ‘Tioga’, all short-day parents, flowered late. Crosses producing the highest percentage of day-neutral seedlings also had the highest percentage of day-neutral seedlings which flowered early. Reciprocal crosses produced similar results relative to the proportion of day-neutral seedlings and for the proportion of such seedlings which flowered early. For date of first flowering, general combining ability was found to be more important in these crosses than specific combining ability.

Day-neutral strawberry clones (often referred to as everbearing), in contrast to short-day clones, initiate flowers under both long- and short-day length and, therefore, flower during the season of planting if growing conditions are favorable (2, 4). A major objective of the Washington State University breeding program is to originate day-neutral clones with high fruit quality and disease resistance, which produce a summer crop beginning in July and continuing into the fall.

Ourecky and Slate (5), in New York State, evaluated seedlings from crosses involving day-neutral parentage for their ability to produce fruit in late September and October. Those which fruited in this season were classified as day-neutral. They found that both day-neutral and short-day parents influenced the proportion of day-neutral seedlings and concluded that complementary genes governed the inheritance of the day-neutral trait. A number of conflicting hypotheses have been proposed for the inheritance of the day-neutral trait (6, 7).

The objectives of this study were: a) to evaluate progeny from 54 crosses for early summer-flowering and therefore early maturing fruit; b) to determine the best parents for this trait by calculating general combining ability parent values; and c) to estimate the significance of general and specific combining ability.

Materials and Methods

At the Western Washington Research and Extension Center, Puyallup, Wash., a population of 2,396 seedlings from 35 crosses (Table 1) involving day-neutral parentage was planted in June, 1977, and a second population of 1,544 seedlings from 19 crosses