

EFFECT OF ROOTSTOCKS AND INTERSTEMS ON MINERAL
ELEMENT CONTENT OF 'DELICIOUS' APPLE LEAVES

by

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LITERATURE REVIEW

LITERATURE REVIEW

The increased use of clonal rootstocks and interstems in the apple industry makes it essential to study their nutritional effects on the scion cultivar.

Leaf analysis can be used to estimate the nutritional effect of rootstock systems on their scions (1, 2, 11, 20, 21, 22, 23, 25).

Tukey et al. (22) showed that the number of component parts grafted together (rootstock, interstem, bodystock and scion) must be taken into consideration when apple leaf analyses are used as a diagnostic aid for deciding fertilizer application to the orchard tree. Leaf samples from bearing apple trees were analysed for N, P, K, Ca and Mg. All components of the tree influenced the 5 major elements. Nutrient levels varied according to soil locations, years and the number of grafted component parts.

The effect of clonal rootstocks Malling 1 (M1), M2, M5, M7, M8 and M16 and scion cultivars on leaf composition of 'Northern Spy', 'Red Delicious', 'Jonathan' and 'McIntosh' apple trees was examined by Awad & Kenworthy (1). Rootstocks affected K, P, Ca and Mg but not N. Scion cultivars affected all elements except P.

In a pot experiment with four apple nursery rootstocks, leaf analysis showed that M4 absorbed more B and K but less Ca & Mg than M7, M9 or M11 (13).

Koksai (14) found that trees of all cultivars on M7 rootstocks had higher N, P, K and lower Ca and Mg leaf contents than those on M11. Trees on M9 had higher K and Ca and lower Mg than M11. Malling 9 as an interstem reduced leaf N and Mg considerably compared to trees without an interstem. Although interstems did not directly influence 'Cox's Peppin Orange', leaf K and Ca, the amounts of these two elements were decreased by M9 as an interstem. Interstems lowered the Ca and Mg content in 'Red Boskoop'. Scion cultivars influenced leaf mineral composition more than rootstocks or interstocks.

Boyce & Hopp (3) conducted foliar analyses of 'McIntosh', 'Cortland', 'Delicious' and 'Northern Spy' apples grafted on either M7 or Robin interstems with M7, M1 or Robusta 5 rootstocks in all possible combinations. Generally, cultivars grafted on M7 interstems had higher N level than similar cultivars on Robin interstems. The same was found for Ca in early but not the later years of the study. Generally, no differences were shown for P, K and Mg.

Whitfield (24) determined the N, P, K, Ca and Mg amounts in leaves from trees of 'Cox's Peppin Orange' and 'Jonathan' on M9, M7, M2 or M16 rootstocks. Jonathan leaves generally had lower amounts of P and K but higher Ca than 'Cox's Peppin Orange'. Trees on M9 had higher amounts of Ca and Mg than those on M7 and trees on M2 had higher amounts of

P, Ca and Mg than those on M16. Malling 7 caused a considerable reduction of Mg. Generally, no interaction was found between cultivar and rootstock.

Sistrunk & Campbell (21) analysed leaves from 'Winesap', 'Rome' and 'Jonathan' apples on French crab or Hiberna rootstocks for Ca content before and after soil lime and foliar Ca $(\text{NO}_3)_2$ and Ca acetate applications. Leaves from the three cultivars grown on Hiberna rootstocks had higher levels of Ca than those on French crab rootstocks. Leaves of all cultivars on Hiberna rootstocks had increased Ca content after all Ca applications while those on French crab showed no response.

Apple trees on their own stem, dwarf interstem and dwarf interstem bridged stem combinations were used by Dana et al. (8) to determine N translocation. Trees on their own stem grown with lower N levels accumulated leaf N more rapidly than dwarf interstem trees. Graft union was not responsible for stock effect as self-interstem trees accumulated N more rapidly than dwarf interstem trees.

Molcanov (17) showed that apple leaf CaO and MgO ratios were either reduced or increased by rootstock compared with own grafted trees and a rootstock/scion interaction was observed with respect to nutrient uptake.

The foliar N, P, K, Ca and Mg were determined over a 4-year period in young apple trees by Lockard (15). The

trees were grown on Malling Merton 111 (MM 111), MM106 or M9 rootstocks; Red Delicious, MM106 and M9 interstems of 2.5, 7.5, 12.5 and 18 cm length. Calcium was lower in foliage of trees on MM111 than in those on MM106 or M9 and K was lower in trees with M9 than MM106 or 'Red Delicious' interstems. Only M9 length differentially affected the level of P but inconsistently. Rootstock differentially affected N and Ca levels over the 4-year period.

'Golden Delicious', 'Delicious', 'McIntosh' and 'Spartan' were used as scions and interstems in 16 combinations on M9 rootstock by Eaton & Robinson (9). Foliar N, P, K and Ca and fruit Ca, Mg and K were determined over 4 years.

'Delicious' accumulated P in leaves and K and Ca in fruit more than other cultivars. Leaf levels of Ca and Mg were greatest in 'Golden Delicious' while leaf K and N differed slightly among cultivars. Leaf and fruit nutrition did not depend upon the interstem.

The effect of spacing, cultivar and 4 rootstocks (M7, MM106, MM111 and seedling) on yield, fruit and tree size and mineral composition of leaves, was studied by Schneider et al. (20). The scion cultivar had the greatest effect on mineral composition. Malling Merton 106 trees had both yields and foliage mineral contents among the highest in each nutrient measured; M7 trees the highest N and P and the lowest Ca leaf content; MM106 trees were higher in Ca than

MM111 trees; MM111 trees were lowest in P and seedling rootstocks were highest in P and lowest in N. Rootstocks did not affect foliar Mg although trees on M7 were low in Mg. Scion/rootstock interaction was significant only in case of Ca.

Mineral uptake and translocation of 'McIntosh' trees on 16 rootstocks was tested by Oberly & Poling (18). Other cultivars were tested on 7 clonal rootstocks. No significant cultivar/rootstock interaction was observed thus rootstock and scion acted independent of each other. Seedling and MM106 rootstock trees had higher levels of Mg than Robusta 5, Alnarp 2, M4, MM102 trees. The M9/MM106 interstem combination trees had higher levels of Ca than MM104, MM102, R5, A2, seedling, M25, M26 and M4 trees. Trees on M26 and MM102 had significantly higher leaf Mn than those on M9/MM106, M2 and MM109.

Trees on M1, M4 and M7 rootstocks had more Mg deficiencies than trees on M9, M2, M5 and M12 (11).

Leaves of 'Starking Delicious' trees grown on MM104, MM106, M25, A2 or M9 rootstocks were analysed for N, P, K, Ca and Mg contents by Vukmirovic (23). Leaf N, Ca and Mg contents were highest on M9 and lowest on MM104 and A2 rootstocks. Leaf P was highest on MM104 and lowest on MM106 trees while K was highest on A2 and lowest on M9.

Significantly different levels of Mg and Ca were reported by Poling & Oberly (19) in the leaves of 'McIntosh' apple grafted on 16 rootstocks when sampled over a 4-year period. Trees on MM106 were among the highest in leaf Mg and Ca content while those on M4 were among the lowest.

The effect of N fertilizer applied at different rates and times of the year was assessed on the growth, yield and leaf N content of apple trees of various scion/rootstock combinations by Fiedler & Schuricht (10). The leaf N content was not a reliable indicator of the level of N fertilization and was strongly influenced by the scion/rootstock combination.

Damigella (7) found N leaf composition was affected by both variety and rootstock and in general, leaf N was directly related to tree vigor.

'McIntosh' trees with different rootstocks grown in solution cultures showed that the transport rate of ^{32}P to the roots and scion and of ^{45}Ca to the scion was closely related to the vigor observed in those plants under field conditions. Transport of ^{32}P in rooted layers ranked M16>M7>M9 (4).

Working with 6 rootstocks and 4 cultivars, Awad and Kenworthy (1) examined the effect of rootstock on Mn, Fe, Cu, B, Mo and Al. Significant differences among rootstocks were found only for Cu while scion cultivars affected Mn, B and Mo.

Lockard (15) tested the effect of three rootstocks, three interstems and three interstem lengths on the foliar Cu, Fe, Mn and Zn in young apple trees over 4 years. Rootstock had no effect on the microelements tested. Lengths of M9 affected Mn content inconsistently. Kind of interstem affected Cu level but also inconsistently.

Four cultivars, 'Golden Delicious', 'Delicious', 'McIntosh' and 'Spartan' were used as scions and interstems in 16 combinations on M9 rootstocks by Eaton and Robinson (9). Fe, Mn and Zn were analysed in leaves over 4 years. Delicious accumulated Fe while Zn differed only slightly among cultivars.

The effect of spacing, cultivar and 4 rootstocks (M7, MM106, MM111 and seedling) on yield, fruit and tree size and mineral composition was studied by Schneider et al. (20). The scion cultivar had the greatest effect on mineral composition. Malling Merton 106 trees had both yields and foliage mineral content among the highest in Mn and Fe. Malling 7 trees had the highest foliar Cu and the lowest Mn and Zn content. Trees on MM111 were highest in Mn and Zn, while seedling rootstocks were highest in Cu. Scion/rootstock interaction was significant only for Mn.

Iron, Na, Mn and Al were found significantly different in leaves of 'McIntosh' apple scions grafted on 16 rootstocks. Malling 4 rootstock was among the lowest in leaf Na and Al (19).

The nutrient concentrations in xylem sap collected from above and below M8, M9, M26 and M7 dwarfing interstems were measured by Jones (12). The sap above an interstem had lower concentrations of nutrients compared to that from the rootstock levels. These differences increased as the dwarfing effect of the interstem increased. Analyses of sap from above, mid-way along and below interstems showed that the changes in contents were produced at, or close to, the graft union between scion and interstem.

Some viruses were found to reduce the Zn content of leaf tissues by 40% or more. This appeared to be due to a general virus infection rather than to specific viruses (16).

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EFFECT OF ROOTSTOCKS AND INTERSTEMS ON MINERAL
ELEMENT CONTENT OF 'DELICIOUS' APPLE LEAVES¹

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Abstract

The foliar mineral element content of 10-year-old 'Delicious' apple trees (Malus domestica, Borkh.) as affected by 21 rootstock systems and vigor classification were determined. Rootstock systems used were Seedling and Robusta 5 (R-5) (Standard); Alnarp 2 (A-2), Kansas 14 (K-14) and Malling Merton 111 (MM111) (Semi-standard); Malling 2 (M2), MM106, M7/R-5, M7/MM104, M2/MM104, M7/MM111, M7/A-2 and M7/M2 (Semidwarf); and M26, M9/R-5, M26/R-5, M9/MM104, M26/MM104, M9/MM111, M26/A-2 and M9/A-2 (Dwarf). Leaf tissues were examined for N, P, K, Ca, Mg, Mn, Fe, Zn and Cu contents.

Significant differences among vigor classifications of trees was observed for P, K and Mn levels in the leaves of the scion. Standard trees had higher P and K contents than dwarf trees while dwarf trees had higher Mn content.

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Rootstock systems differentially affected the foliar content of K, Ca, Mg and Mn. Among dwarfs and semidwarfs, trees on M7/A-2 and M7/R-5 contained high foliar K and low foliar Mg levels. Trees on M2 and M26 rootstocks exhibited high levels of leaf Mg and low levels of leaf K, suggesting an antagonistic relationship. Higher foliar Ca levels accumulated with MM106 rootstock than with M7/MM104. Trees on M26 had a high leaf Mn content.

Since other elements in scion leaves were not affected by rootstock systems tested, these rootstock systems did not have a major effect on mineral nutritional status of scion leaves.

Leaf analysis can be used as a measure of the nutritional status of the tree and to determine the effect of rootstock systems on mineral nutrition of fruit trees (1, 2, 7, 14, 17, 19, 20, 22, 23).

Tukey et al. (21) studied the effect of rootstock, bodystock and interstem on leaf nutrient content and concluded that each graft component was capable of influencing the 5 major elements in the tree. Whitfield (22) found that trees on M9 rootstocks had higher foliar Ca and Mg levels than those on M7, while trees on M2 rootstocks had higher foliar P, Ca and Mg levels than those on M16. Malling 7 rootstocks caused a considerable reduction in foliar Mg levels. Malling Merton 106 rootstock accumulated higher foliar Ca content than MM111 (14, 19). Trees on M26 had significantly higher leaf Mn than those on M9/MM106, M2 and MM109 (16). Transport rate of ^{45}Ca and ^{32}P to roots and scion was closely related to the vigor class of the tree (4).

Jones (10) showed that xylem sap from above the interstem had lower nutrient concentration than that from below the interstem. The difference increased with the dwarfing effect of the interstem.

The purpose of this study was to evaluate rootstock systems with regard to the nutritional status of their scions

and to further understand the effect of rootstock systems on the mineral nutrition of apple trees.

MATERIALS AND METHODS

Plant Material:

The ten-year-old 'Delicious' apple trees used in this study were grafted on 21 rootstock systems: Seedling and R-5 (standard); A-2, K-14 and MM111 (semistandard); MM106, M2, M7/R-5, M7/MM104, M2/MM104, M7/MM111, M7/A-2 and M7/M2 (semidwarf); and M26, M9/R-5, M26/R-5, M9/MM104, M26/MM104, M9/MM111, M26/A-2 and M9/A-2 (dwarf). The trees were planted in 1969 and replanting in the field occurred in 1970 and 1971 at the Northeast Kansas Horticulture Field near Wathena, Kansas.

The 2.27 hectare orchard was on a deep, loess silty loam soil with a 12% north slope. The level contour terraces were constructed with a 4.9m minimum spacing between terraces and apple trees were grown on top of terraces. Trees, which were grown in a bluegrass sod mulch, received no irrigation, pruned to a modified central leader system and were treated with a standard pest control program. About 0.8 Kg per tree of complete fertilizer was applied annually each spring.

Plant Analysis:

Forty healthy leaves with petioles attached were collected in July 1979 from the midsection of the current season's shoots at about shoulder height around each tree (1). Leaf samples were washed, dried at 70^o C for 48 hours and ground in a Wiley Mill to pass through a 40 mesh screen.

N and P were determined using the standard sulfuric acid digestion (13) and analysed colorimetrically using the Technicon autoanalyser.

K, Ca, Mg, Mn, Fe, Zn and Cu were determined using the standard perchloric acid/Nitric acid digestion (6) and then measured using Atomic Absorption and Flame Emission spectrophotometers¹ (8).

Soil Analysis:

Twelve soil samples were taken in August 1979 after dividing the area into 12 equal subplots with dimensions 24.4 X 25.6 m. 4 in each replication of trees. This divided the area into 3 replications and 4 columns. Each sample was a composite of one core (7-23 cm soil depth) from 8 locations within the sampling area.

Soil samples were air dried and ground finely. Exchangeable cations (Ca and Mg) were analysed using ammonium acetate extraction procedure (5) and measured with an Atomic Absorption Spectrophotometer. The cation exchange capacity (CEC) was determined by saturating the sample with Ca and removing excess salt using alcohol (5) and then measuring Ca with the Atomic Absorption Spectrophotometer. The total N was determined using a standard concentrated sulfuric acid digestion, followed by a micro Kjeldahl procedure (3).

¹Perkin Elmer (303 and 360 models) Instrument Division, Norwalk, CT 06856.

Lime requirement, pH, P, K, Zn, Fe, Cu, Mn and electric conductivity (EC) were made by the Soil Testing Laboratory, Department of Agronomy, Kansas State University, using standard procedures.

The statistical layout for plant material was a modified split plot design with 3 replications. Each main plot consisted of 4 subplots with tree spacing according to the predicted size of the tree. The spacing for standard, semi-standard, semidwarf and dwarf trees were 8.5 X 9.8m, 6.4 X 9.8m, 4.3 X 4.9m and 2.1 X 4.9m, respectively. There were 21 treatments and a pair of adjacent trees were considered as one sample.

Statistical analyses for plant samples were done by nesting treatments within the four 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 (18).

For soil samples analysis of variance procedure and Duncan's multiple range test were used to compare replications and columns.

RESULTS AND DISCUSSION

Soil Analysis:

Soil analyses mineral were as follows: N(0.063%), P(87.8 kg/ha), K(408.1 kg/ha), Ca (12.3 meq/100g), Mg(4.0 meq/100g), Mn(22.8 ppm), Fe(44.6 ppm), Zn(0.47 ppm), Cu(1.24 ppm), pH(6.2), CaCO_3 (1350.6 kg/ha), EC(0.40 m mhos/cm) and CEC(24.4 meq/100g). All elements were present in satisfactory amounts except Zn which was low (23).

Replications differed only in EC and Cu and columns differed only in Ca content. Thus soils were similar throughout the site (Appendix Tables 1 and 2).

Plant Analysis:

Replication differed only in foliar Mg and Mn levels (Appendix Table 3).

Significant differences due to tree vigor were obtained for P, K and Mn levels. Standard and semidwarf trees had significantly higher foliar P than dwarf trees while semistandards were intermediate. Standard trees contained significantly higher foliar K than semistandards and dwarf trees. Semistandard and semidwarf trees also contained more leaf K than dwarf trees. Dwarf trees had higher foliar Mn than all other classes. No difference among the other classes was shown (Table 1).

Generally, foliar P and K varied with tree vigor, the more vigorous trees had higher contents. This result was in agreement with Bukovac et al. (2) and Jones (9, 10). Dwarfs in this experiment were spaced closer than other classes. It was reported by Schneider et al. (19) that widely spaced trees had higher foliar P and K but lower Ca, Mg and Mn than closely spaced trees. The trees in this experiment were only 10 years old and, while the dwarf trees seemed to reach their full size, the standards were still spreading and had not reached their full size. So differences found here could be attributed either to spacing or to the vigor class of the tree.

Table 2 shows the effect of rootstock systems on the leaf mineral element content of the scion cultivar, 'Delicious'. None of the mineral elements were found at deficient or toxic levels in the foliage according to standards developed by Kenworthy (12). Although Cu levels were considerably lower than the standard, it was not considered deficient.

As the soil was found generally uniform and the scion cultivar was the same in all treatments, any difference in leaf mineral element content was likely due to the effect of the rootstock systems. Contents of K, Ca, Mg and Mn significantly varied with different rootstock systems. No significant differences were noted among N, P, Fe, Zn and Cu levels.

Potassium

Leaves of 'Red Delicious' trees on M7/A-2 had significantly higher K than those on M7/M2, M7/MM111, M26/A-2, M2, M9/A-2, M26/R-5, M9/MM104, M26, M26/MM104 and M9/MM111.

Also trees on M7/R-5 had significantly higher foliar K than those on M26/A-2, M2, M9/A-2, M26/R-5, M9/MM104, M26, M26/MM104 and M9/MM111 (Table 2).

Among dwarf and semidwarf trees, dwarf rootstock systems M26, M9/MM104, M26/MM104 and M9/MM111 accumulated the lowest foliar K. Although semidwarf rootstock systems had generally higher leaf K than dwarfs, the level in semidwarf rootstock system M2 was lower than other semidwarfs and was comparable to dwarf trees. The dwarf rootstock system M9/R-5 showed foliar K level comparable to that of semidwarfs.

These results were in agreement with the findings of Lockard (14) who reported that interstem M9 accumulated less foliar K than a semidwarfing interstem MM106. In this experiment rootstock systems with M9 as an interstem were found to accumulate low levels of leaf K compared to semidwarfing systems. It was also reported by Awad and Kenworthy (1) that M2 rootstocks were most susceptible to leaf scorch resulting from K deficiency. In this study, no deficiency symptoms were visible but M2 induced low levels of leaf K compared to other semidwarf rootstock systems.

Magnesium:

Malling 2 rootstocks induced significantly higher levels of foliar Mg than did M7/R-5, M7/A-2 and M7/MM104. The M7 interstem was found to influence low levels of Mg in foliage. This was in agreement with the findings of Awad and Kenworthy (1), Bould and Campbell (2) and Schneider et al. (19). They investigated M7 as a rootstock but the same effect was found in this experiment when we used M7 as an interstem. Low Mg levels in M7 interstem trees did not occur when either M2 or MM111 were the rootstocks. Malling 2 as a rootstock induced high levels of Mg and may have counteracted the interstem effect. The same may have been true for MM111. In certain cases Mg deficiency can be avoided by selecting proper rootstock systems.

Trees on M26 had more foliar Mg than those on M9/R-5, M26/A-2 or M9/A-2. This was in agreement with Awad and Kenworthy (1) who reported that M26 rootstock induced high levels of foliar Mg.

Rootstocks A2 and R-5, when used with M7 interstem, induced the highest foliar K level and low levels of Mg. Trees on M2 and M26 had the highest leaf Mg and low levels of K. This suggested an antagonistic effect between K and Mg. Since the supply of K in our soil was high, the average leaf K accumulated by all trees was higher than the standard while the average Mg was lower than the standard (Table 2).

This was reported by Bould and Campbell (2) who concluded that high soil K reduced leaf Mg markedly.

Calcium:

Trees on MM106 rootstock contained greater quantities of Ca than those on M7/MM104. Malling Merton 106 rootstock was reported to be among the highest in leaf Ca by Bould and Campbell (2), Lockard (14) and Poling and Oberly (17), while M7 induced low Ca levels (19).

A number of apple disorders were related to Ca level in the fruit (Oberly and Kenworthy (15). Soil application of calcium proved ineffective, so the use of a rootstock that accumulates more Ca can be a possible solution.

Manganese:

Trees on M26 rootstocks had significantly higher foliar Mn levels than those on M26/A-2, M9/MM104, M9/R-5, A-2, K-14, MM111, M7/R-5, M2/MM104 and M7/A-2.

The high Mn content in trees on M26 rootstock was previously reported by Oberly and Poling (16). The wide range of Mn in this study (60-122) was in agreement with Poling and Oberly (17) who reported that clonal rootstocks tend to have wide range of Mn. It was suggested that this might necessitate more intensive study on the effect of different rootstock systems on foliar Mn levels.

With the exception of Mn, variations of leaf mineral content associated with rootstock systems were small; N, P, Fe, Zn and Cu were not affected significantly; and all levels of mineral nutrients in the leaves were within the adequate range established by Kenworthy (12). Thus the total effect of rootstock on mineral nutrition of these apple trees was quite restricted. Either the selection process for rootstock systems has, over time, eliminated those that ineffectively absorb nutrients or apple rootstock plays a minor role in apple tree nutrition.

Table 1. Effect of vigor class in 'Delicious' apples on leaf mineral element content.^z

Vigor class ^y	N	P	K %	Ca	Mg	Mn	Fe (ppm)			Zn	Cu
Standard	1.81	.41 ^a	1.86 ^a	1.17	.24	67 ^b	116			33	5.5
Semistandard	1.95	.31 ^{ab}	1.60 ^b	1.18	.24	69 ^b	107			31	6.2
Semidwarf	1.92	.33 ^a	1.73 ^{ab}	1.14	.25	73 ^b	108			35	5.9
Dwarf	1.99	.21 ^b	1.34 ^c	1.33	.26	94 ^a	110			36	5.8
	N.S.			N.S.	N.S.		N.S.			N.S.	N.S.

^z = Numbers in the column with a common letter are not significantly different at the 5% level of Duncan's Multiple Range Test.

^y = Vigor class grouped by rootstock systems standard (seedling and R-5), Semistandard (A-2, K-14 and MM111), Semidwarf (M2, MM106, R-5/M7, MM104/M7, MM111/M7, A-2/M7, M2/M7) and dwarf (M26, R-5/M9, R-5/M26, MM104/M.9, MM104/M26, MM111/M9, A-2/M26, A-2/M9).

Table 2. Effect of rootstock systems on the leaf mineral content of 10 year old 'Delicious' apple trees.

Rootstock system ²	N	P	Leaf element content dry wt. bases					Cu
			K %	Ca	Mg	Mn Y	Fe (ppm)	
Standard				x				
Seedling	1.83	.35	1.68	ab 1.22	.25	74	106	5
R-5	1.79	.47	2.03	ab 1.12	.22	60	126	6
Semistandard								
A-2	1.92	.33	1.78	ab 1.22	.24	b 73	113	7
K-14	1.94	.31	1.34	ab 1.08	.24	b 62	106	6
MM111	2.00	.28	1.68	ab 1.22	.26	b 72	103	6
Semidwarfs								
MM106	1.99	.34	abc 1.79	a 1.33	x ab .25	ab 79	112	6
M.2	1.85	.32	cde 1.43	ab 1.18	a .29	ab 76	103	6
M7/R-5	1.87	.37	ab 1.98	ab 1.16	b .22	b 67	106	6
M7/MM104	1.92	.28	abc 1.77	b .92	b .23	ab 75	108	6
M2/MM104	1.91	.29	abc 1.65	ab 1.10	ab .27	b 71	107	6
M7/MM111	2.05	.27	bcd 1.51	ab 1.10	ab .27	ab 77	95	5
M7/A-2	1.82	.35	a 2.06	ab 1.19	b .23	b 64	121	6
M7/M.2	1.96	.39	bcd 1.61	ab 1.13	ab .26	ab 75	110	6

Table 2 (continued)

Rootstock system ^z	Leaf element content dry wt. bases						
	N	P	K %	Ca	Mg	Mn Y	Fe Zn Cu
							(ppm)
Dwarfs					x		
M26	2.12	.20	de 1.19	ab 1.55	a .34	a 122	136 46 7
M9/R-5	1.76	.25	abc 1.68	ab 1.22	b .23	b 83	123 44 6
M26/R-5	1.90	.18	cde 1.36	ab 1.19	ab .24	ab 96	109 33 5
M.9/MM104	2.00	.22	de 1.22	ab 1.34	ab .29	b 83	103 34 6
M26/MM104	2.11	.21	de 1.18	ab 1.54	ab .31	ab 92	107 36 6
M9/MM111	2.13	.21	e 1.16	ab 1.32	ab .25	ab 99	110 38 6
M26/A-2	2.03	.23	cde 1.50	ab 1.40	b .23	b 86	97 35 6
M9/A-2	1.84	.20	cde 1.42	ab 1.14	b .23	ab 91	93 31 6
Average	1.94	.29	1.57	1.35	.25	80	109 35 6
Standard ^w	2.15	.20	1.30	1.37	.31	101	137 42 18
	N.S.	N.S.				N.S.	N.S. N.S. N.S.

z = abbreviations used R = Robusta, A = Alnarp, K = Kansas, M = Malling and MM = Malling Merton.

y = numbers in the column with a common letter are not significantly different at the 5% of the Bonferroni T-interval multiple comparison test.

x = means separation within size classes with a common letter are not significantly different by Duncan's Multiple Range Test, 5% level.

w = standards developed by Kenworthy (1961).

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APPENDIX

Appendix Table 1. Effect of replication on the soil mineral element content.

	N (%)	P (kg/ha)	K (kg/ha)	Ca meq 100g	Mg meq 100g	Mn (ppm)	Fe (ppm)	Zn (ppm)	Cu ^z (ppm)	pH	CaCO ₃ (kg/ha)	E.C. ^z m mhos/ cm	C.E.C. meq 100g
Rep 1	.07	63.0	371	13.1	4.2	21.9	38.9	.39	.98 ^b	6.3	1306	.36 ^b	26.2
Rep 2	.06	91.0	405	11.8	4.1	26.2	46.7	.43	1.25 ^{ab}	6.2	1439	.37 ^b	22.7
Rep 3	.06	109.5	447	11.9	3.7	20.2	48.1	.58	1.50 ^a	6.2	1306	.48 ^a	24.3
Avg.	.06	87.8	408	12.3	4.0	22.8	44.6	.47	1.26	6.23	1351	.40	24.4
	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.		N.S.

z = means separation within a column by Duncan's Multiple Range Test, 5% level.

Appendix Table 2. Effect of columns on the soil mineral element content.

	N (%)	P (kg/ha)	K (kg/ha)	Ca ^z meg 100g	Mg meg 100g	Mn (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	pH	CaCO ₃ (kg/ha)	E.C. m mhos/ cm	C.E.C. meg 100g
Col 1	.07	84.8	435	11.6 ^b	3.5	32.1	49.3	.48	1.14	6.10	1493	.41	23.9
Col 2	.06	78.0	387	11.6 ^b	3.9	23.7	45.1	.44	1.31	6.23	1120	.40	25.9
Col 3	.06	95.6	438	11.9 ^b	3.9	22.8	51.1	.44	1.26	6.03	1493	.42	25.2
Col 4	.06	93.0	372	14.0 ^a	4.8	12.4	32.8	.50	1.26	6.6	--	.38	22.6
	N.S.	N.S.	N.S.		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

z = means separation within a column by Duncan's Multiple Range Test, 5% level.

Appendix Table 3. Effect of replication on the foliar mineral element content of 'Delicious' apples on various rootstock systems.

Rep	N	P	K %	Ca	Mg ^z	Mn ^z	(ppm)			Zn	Cu
							Fe				
1	1.89	0.32	1.52	1.20	b 0.242	a 86.6	107.7		34.2	5.6	
2	1.91	0.29	1.63	1.16	ab 0.246	b 79.5	113.9		34.9	6.3	
3	2.03	0.25	1.56	1.30	a 0.275	b 73.1	105.7		35.4	5.6	
	N.S.	N.S.	N.S.	N.S.	--	--	N.S.		N.S.	N.S.	

z = means separation within a column by Duncan's Multiple Range Test, 5% level.

EFFECT OF ROOTSTOCKS AND INTERSTEMS ON MINERAL
ELEMENT CONTENT OF 'DELICIOUS' APPLE LEAVES

by

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ABSTRACT

The foliar mineral element content of 10-year-old 'Delicious' apple trees (Malus domestica, Borkh.) as affected by 21 rootstock systems and vigor classification were determined. Rootstock systems used were Seedling and Robusta 5 (R-5) (Standard); Alnarp 2 (A-2), Kansas 14 (K-14) and Malling Merton 111 (MM111) (Semistandard); Malling 2 (M2), MM106, M7/R-5, M7/MM104, M2/MM104, M7/MM111, M7/A-2 and M7/M2 (Semidwarf); and M26, M9/R-5, M26/R-5, M9/MM104, M26/MM104, M9/MM111, M26/A-2 and M9/A-2 (Dwarf). Leaf tissues were examined for N, P, K, Ca, Mg, Mn, Fe, Zn and Cu contents.

Significant differences among vigor classifications of trees was observed for P, K and Mn levels in the leaves of the scion. Standard trees had higher P and K contents than dwarf trees while dwarf trees had higher Mn content.

Rootstock systems differentially affected the foliar content of K, Ca, Mg and Mn. Among dwarfs and semidwarfs, trees on M7/A-2 and M7/R-5 contained high foliar K and low foliar Mg levels. Trees on M2 and M26 rootstocks exhibited high levels of leaf Mg and low levels of leaf K, suggesting an antagonistic relationship. Higher foliar Ca levels accumulated with MM106 rootstock than with M7/MM104. Trees on M26 had a high leaf Mn content.

Since other elements in scion leaves were not affected by rootstock systems tested, these rootstock systems did not have a major effect on mineral nutritional status of scion leaves.