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An Analysis of Mineral Uptake in Apple Rootstock Seedlings

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Summary. Eight families from biparental crosses of apple rootstocks and 12 families from open pollinated *Malus* spp. were analysed in 2 years for N, P, K, Ca and Mg content of the foliage. Highly significant differences were found between the families for all elements. There were no significant differences between the means of the biparental group and the open pollinated group. Ca and K content were significantly more variable in the open pollinated families compared with the biparental families. It is suggested that this increased variation could prove useful in breeding for efficiency of mineral uptake by apple rootstocks.

Key words: *Malus* spp. – Apple rootstocks – Breeding – Selection – Mineral uptake

Introduction

The development of physiological disorders of apples during storage has been shown to be related to the mineral balance within the fruit (De Long 1936; Bangerth 1973; Shear 1975; Sharples 1980). The availability of nutrients to the scion variety can be greatly influenced by the rootstock (Kidd and West 1933; Tukey et al. 1962; Hansen 1965; Blasco 1976; O'Loughlin and Jotic 1978).

The potential for success in breeding improved genotypes depends on the presence of adequate genetic variation in the breeding population. Significant genetic variation for mineral uptake, particularly calcium and potassium, has been demonstrated in apple rootstocks (Kennedy et al. 1980). However, the response to selection in one generation is proportional to the phenotypic standard deviation of the genotypes selected as parents (Falconer 1960). The purpose of this paper, therefore, is to investigate the likely effect on variation for mineral uptake in apple rootstocks by introducing unselected *Malus* species into the breeding programme. While an increased phenotypic variation may be beneficial in increasing the response to selection, this response is measured relative to the population mean value. It must, therefore, also be established that the introduction of diverse, wild material does not depress the population mean to such a degree as to cancel the expected improvement from increased variation.

Materials and Methods

Twenty families were used in the investigation; the parentage, origin and size of the families are shown in Table 1. The biparental families were taken from the East Malling breeding programme. The pollen parent is unknown for the open pollinated families and could be from different *Malus* species or cultivated apple. *M hupehensis, M. sikkimensis* and *M. sieboldii* are known to produce some apomictic seed (Sax 1949; Dermen 1949; Luckwill and Campbell 1954; Olden 1953; Hjelmqvist 1957; Sampson 1969).

The experimental area was divided into 4 blocks and seedlings of each family were divided equally among the blocks. The plants were individually randomised. The trees were 2 years old when transplanted into this experiment and were hard pruned in February 1977. Samples of 8 leaves, without petioles, were taken from the middle of new extension shoots in mid-August 1977 and 1978 when the trees were 3 and 4 years old. The samples were oven dried and analysed for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) content by standard chemical procedures.

The open pollinated families were compared with the biparental rootstock families by the analysis of variance.

Results and Discussion

Table 2 shows the expected mean squares for the analysis of variance given in Table 3. The years were not combined for this analysis because yearly measurements were not independent since they were made on

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Table 1. The parentage, origin and size of families analysed

Family	Biparental Rootstock Crosses	Origin	No. of Seedlings
1	M.27 × MM.106	East Malling Res. Station	8
2	M.27 × M.20	East Malling Res. Station	4
3	M.20 × M.7	East Malling Res. Station	4
4	M.13 × M.27	East Malling Res. Station	8
5	M.25 × M.27	East Malling Res. Station	28
6	M.25 × M.9 A	East Malling Res. Station	36
7	M.25 × M.7	East Malling Res. Station	48
8	M.25 × MM.106	East Malling Res. Station	12
	Open pollinated Families of *Malus* species		
9	(*M. sublobata* × M.9)	Dr. J. N. Cummins, Geneva, New York (USA)	16
10	*M. hupehensis*	Royal Botanic Gardens, Kew (UK)	8
11	*M. sikkimensis*	Royal Botanic Gardens, Kew (UK)	8
12	*M. trilobata*	Royal Botanic Gardens, Kew (UK)	12
13	*M. baccata*	Hort. Expt. Station (Korea)	8
14	*M. sieboldii*	Hort. Expt. Station (Korea)	16
15	*M. coronaria*	Vavilov Institute, Leningrad (USSR)	20
16	*M. sylvestris*	Vavilov Institute, Leningrad (USSR)	16
17	*M. niedzwetzkyana*	Vavilov Institute, Leningrad (USSR)	12
18	*M. orientalis*	Vavilov Institute, Leningrad (USSR)	20
19	*M. sieversii*	Vavilov Institute, Leningrad (USSR)	16
20	*M. sieboldii*	Vavilov Institute, Leningrad (USSR)	12

M = Malling; MM = Malling-Merton

Table 2. Expected mean squares for the model used in the analysis of variance[a]

	D.F.	E.M.S.
Blocks (B)	3	$\sigma^2 + 5.72\,\sigma^2_{BF} + 78\,\sigma^2_B$
All families (F)	(19)	$\sigma^2 + 3.80\,\sigma^2_{BF} + 15.22\,\sigma^2_F$
Biparental families (Bip)	7	$\sigma^2 + 4.15\,\sigma^2_{BF} + 16.62\,\sigma^2_F$
Open pollinated families (O.P.)	11	$\sigma^2 + 3.39\,\sigma^2_{BF} + 13.55\,\sigma^2_F$
Bip vs. O.P.	1	$\sigma^2 + 5.93\,\sigma^2_{BF} + 23.73\,\sigma^2_F$
B × F	57	$\sigma^2 + 3.80\,\sigma^2_{BF}$
Residual	232	σ^2

[a] From the EMS appropriate variance ratio (F) tests may be deduced

Table 3. The analysis of variance, weighted to taken account of the unequal numbers of seedlings in each family

	D.F.	N		P		K		Ca		Mg	
		1977	1978	1977	1978	1977	1978	1977	1978	1977	1978
1 Blocks	3	0.098 ns	0.596***	0.0015**	0.0019*	0.254***	0.103*	0.113 ns	0.032 ns	0.0014 ns	0.0042 ns
2 All families	(19)	0.965***	1.031***	0.0044***	0.0076***	0.499***	0.462***	0.455***	0.334***	0.0097***	0.0045 ns
3 Biparentals	7	0.379***	0.711***	0.0018***	0.0065***	0.124***	0.093***	0.108 ns	0.078*	0.0054**	0.0034 ns
4 Open pollinated	11	1.011***	1.146***	0.0041***	0.0056***	0.606***	0.601***	0.385***	0.478***	0.0076***	0.0022 ns
5 Bip. vs. O.P.	1	4.561***	2.006***	0.0258***	0.0373***	1.946***	1.516***	3.654***	0.542***	0.0629***	0.0373***
6 Blocks × families	57	0.040 ns	0.081 ns	0.0002 ns	0.0009*	0.028 ns	0.038 ns	0.046 ns	0.034 ns	0.0012 ns	0.0016 ns
7 Within families	232	0.043	0.079	0.0003	0.0007	0.032	0.032	0.047	0.042	0.0015	0.0044
P $MS_4 > MS_5$[a]		0.05 – 0.10	> 0.10	0.10	> 0.10	0.01 – 0.05	0.005 – 0.01	0.01 – 0.05	0.005 – 0.01	> 0.10	> 0.10

[a] Probability that MS_4 is greather than MS_5; * significant at $P = 0.05$; ** significant at $P = 0.01$; *** significant at $P = 0.001$

Table 4. Mean values[a] of nutrient concentrations in leaves of biarental (Bip.) and open pollinated (O.P.) families

Family	N		P		K		Ca		Mg	
	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978
1	2.562	2.735	0.1412	0.1875	1.661	1.938	1.159	0.957	0.1775	0.1425
2	2.587	2.705	0.1537	0.2050	1.500	1.792	1.550	1.159	0.2212	0.1750
3	2.506	2.649	0.1462	0.2075	1.185	1.562	1.335	1.232	0.1825	0.1500
4	2.706	2.931	0.1575	0.2150	1.566	1.862	1.215	1.026	0.1831	0.1681
5	2.496	2.406	0.1470	0.1879	1.466	1.732	1.314	0.992	0.2057	0.1582
6	2.595	2.765	0.1610	0.2099	1.527	1.718	1.335	1.099	0.1958	0.1833
7	2.839	2.907	0.1695	0.2342	1.473	1.786	1.341	1.058	0.2157	0.1614
8	2.687	2.866	0.1604	0.2183	1.607	1.822	1.180	0.956	0.1642	0.1446
9	2.389	2.467	0.1437	0.1931	1.327	1.589	1.231	1.182	0.1834	0.1450
10	2.889	2.927	0.1700	0.2037	1.545	1.568	1.145	1.447	0.1581	0.1362
11	2.750	2.739	0.1587	0.1756	1.427	1.575	1.075	1.229	0.1662	0.1556
12	2.001	2.101	0.1217	0.1554	1.172	1.405	0.726	0.667	0.1183	0.1287
13	2.147	2.079	0.1231	0.1594	1.200	1.456	1.366	1.261	0.1575	0.1187
14	2.500	2.571	0.1344	0.1737	1.249	1.573	1.171	1.208	0.1828	0.1362
15	1.996	2.331	0.1107	0.1740	1.022	1.309	0.894	1.179	0.1485	0.1562
16	2.631	2.729	0.1559	0.2034	1.767	2.010	1.077	1.053	0.2059	0.1572
17	2.394	2.638	0.1383	0.2100	1.371	1.697	1.298	1.185	0.1846	0.1354
18	2.582	2.744	0.1440	0.2082	1.360	1.695	1.029	1.007	0.1900	0.1455
19	2.413	2.655	0.1572	0.2131	1.535	1.891	1.095	1.008	0.1775	0.1497
20	2.683	3.174	0.1529	0.2096	1.259	1.674	1.226	1.389	0.1567	0.1196
Grand mean	2.536	2.669	0.1496	0.2017	1.421	1.695	1.196	1.091	0.1852	0.1527
Bip. mean	2.664	2.754	0.1592	0.2132	1.504	1.769	1.310	0.927	0.2002	0.1642
O.P. mean	2.420	2.592	0.1409	0.1914	1.346	1.629	1.093	1.200	0.1716	0.1423

[a] Mean values as dry % dry weight

Table 5. The distribution of families and seedlings relative to the experimental grand means

	Relationship to grand mean		Nitrogen		Phosphorus		Potassium		Calcium		Magnesium	
			+	−	+	−	+	−	+	−	+	−
1977	Bip.	No. families	6	2	5	3	7	1	6	2	4	4
		No. Seedlings	116	32	108	40	144	4	128	20	116	32
	O.P.	No. families	5	7	5	7	4	8	4	8	2	10
		No. seedlings	64	100	60	104	48	116	48	116	36	128
1978	Bip.	No. families	6	2	6	2	7	1	3	5	5	3
		No. seedlings	116	32	112	36	144	4	44	104	124	24
	O.P.	No. families	5	7	6	6	4	8	8	4	3	9
		No. seedlings	64	100	84	80	64	100	100	64	44	120

\+ = family or seedling value > grand mean;
− = family or seedling value < grand mean;
Bip. = Biparental families;
O.P. = Open pollinated families

the same tree in the same field position on each occasion. The mean square for variation among open pollinated families is greater than that for biparental families in all cases except for P and Mg in 1978. This difference is significant ($p = 0.05$) only for Ca and K.

The mean values for each element are given in Table 4. The mean of the open pollinated families is lower than that for biparental families in all cases except for Ca (1978). The depression of the grand mean compared with the biparental mean is in no case significant when tested by Student's t-test.

These results suggest that a useful increase in variation for nutrient uptake may be obtained by the introduction of some *Malus* spp., into the apple rootstock breeding programme. This would have the most significant effect for the uptake of Ca and K. There would be no significant depression of the population mean indicated by these results. Table 5 shows the distribution of families and seedlings about the grand mean. The distributions for the two groups is similar from year to year but the groups are different from each other. The biparental families are mainly distributed above the grand mean while the open pollinated families are below this value. There are, however, a useful number of families in the open pollinated group that are above the mean. Examination of the means for each family (Table 4) would suggest that the potentially most useful species of those examined here for introduction into the breeding programme would be *M. baccata, M. hupehensis* and *M. sieboldii.*

The improvement of Ca and K uptake by apple rootstocks could have great benefits in the storage quality of fruit of scion varieties since both these elements are closely involved in the development of bitter pit when they are at low levels in the fruit.

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