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Performance of a Clementine Mandarin with Cachexia-Xyloporosis on Eleven Rootstocks*

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The Clementine mandarin industry in Italy comprises 8,000 hectares and about 100,000 tons of production. Almost all trees are grafted on sour orange rootsock. The Comune variety is the most important, and yields seedless fruit of excellent quality. Unfortunately, this variety produces a high percentage of small fruit and, in many areas, fruit set is poor. Physiological stress, such as that caused by unfavorable temperatures and inadequate moisture, induces a drop of the weak parthenocarpic fruiting. Productivity is increased by interplanting Avana (Willowleaf) mandarin as a polinizer, which induces seedy fruits, by girdling, or by gibberellic acid sprays. The problems connected with the above practices are well known (Damigella *et al*, 1970).

Since rootstocks also influence parthenocarpic fruiting (Krezdorn and Phillips, 1970), in 1968, we started a field trial to evaluate a clone of Clementine on 11 rootstocks. Some years later, the clone was found to be affected by cachexia-xyloporosis, and the effects of the disease on the trees were also evaluated. Preliminary reports have been published (Tribulato, 1976; Catara *et al.*, 1976).

MATERIALS AND METHODS

The trial was carried out in eastern Sicily where the productivity of Comune clementine is low. The area is far from the coast, on a low hill, and has low humidity. From 1969 to 1978, the annual rainfall averaged 530 mm and the net heat accumulation was about 2080°C. The soil is sandy clay with over 50 per cent lime and about 11 per cent free lime.

The rootstocks were planted in 1968, on a 4.5 x 4.5-m spacing, and were grafted 1 year later with Comune clementine. Buds were from 10-year-old trees grafted on trifoliate orange, with no symptoms of exocortis, psorosis A, concave gum-blind pocket, cristacortis, or cachexia-xyloporosis. Subsequent indexing confirmed the visual diagnosis except for the last disease. The rootstocks were: sour orange, alemow, Volkamer lemon, rough lemon, Cleopatra mandarin, Avana mandarin, *C. taiwanica, C. amblycarpa,* Troyer and Carrizo citranges, and citrumelo C.E.S. 1452. Each stionic combination was replicated 18 times in three randomized blocks.

From 1973 to 1978, canopy volumes, circumferences of stock and scion, yields, and fruit quality were evaluated. Data for trees on alemow are from only three plants, free of decline. Symptoms of iron chlorosis and virus diseases on leaves, fruits, stems, and trunks were recorded. Bark patches were removed across the bud union to check for xylem and/or phloem alterations. Randomly selected trees were tested for exocortis, psorosis A, concave gum-blind pocket, and cachexia-xyloporosis on Madam Vinous sweet orange and sour orange seedlings, and on Parsons Special mandarin and Etrog citron grafted on Volkamer lemon.

RESULTS AND DISCUSSION

Tree performance was greatly influenced by the rootstocks (table 1). Volkamer lemon and *C. amblycarpa* produced large trees, whereas, Carrizo and Troyer citranges, which are sensitive to lime, produced small trees. Sour orange produced smaller plants than other stionic combinations.

Trees on citranges have shown a neck at the bud union (Tribulato, 1976), as

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indicated by more than 27 per cent difference between the average circumference of the stock and the scion.

Trees on Volkamer lemon showed a rapid increase in canopy size until 1975, and a slow increase thereafter. Other rootstocks induced a more uniform rate of increase (fig. 1).

Table 1 shows the cumulative yield 10 years after grafting. The first yield was obtained in 1973. Yields were highest from the trees grafted on alemow, Volkamer lemon and rough lemon, in that order. The poor capacity of sour orange to produce high yields of Comune clementine was confirmed by yields only one-third of those produced on Volkamer lemon. Citranges gave poor results in contrast to those obtained in Corsica (Blondel, 1973; 1974).

Rootstocks did not influence the time of color break, but some induced changes in fruit quality (table 2). Trees on Cleopatra mandarin bore the smallest fruit, as observed for Orlando tangelo on the same rootstock (Krezdorn and Phillips, 1970). Citric acid was lower in fruit from trees on Volkamer lemon, and the lowest total soluble solids were produced on trees on rough lemon and alemow. Volkamer lemon did not differ from other rootstocks in this respect.

The intensity of iron chlorosis in the leaves indicated the susceptibility of rootstocks to lime. No symptoms were observed on alemow, Volkamer lemon, and *C. amblycarpa*; slight symptoms on a few trees on rough lemon and Cleopatra mandarin; slight symptoms on many trees on sour orange, *C. taiwanica* and Avana mandarin; mild symptoms on trees on citrumelo; and severe symptoms on trees on Troyer and Carrizo citranges.

Trees on alemow began to decline 6 years after planting, with typical symptoms of xyloporosis. In 1975, sour orange, Cleopatra mandarin, rough lemon, *C. amblycarpa* and *C. taiwanica* had no symptoms; *C. volkameriana* had a few plants with mild, indefinite reactions, mostly pitting and pegging; citrumelo, Troyer and Carrizo citranges had bark indentations and gum deposits at the bud union; Avana mandarin and alemow had typical tiny pits in the wood, pegs and gum formation in the bark near the bud union.

The final number of trees showing symptoms is reported in table 3. All but three of the trees on *C. macrophylla* showed severe pitting and pegging, poor growth, and decline (fig. 2). Two began to show wood pitting in 1978 and the other is still symptomless. Some trees on *C. volkameriana* had mild symptoms.

The scion reaction varied with the stock and was present on trees grafted on some symptomless rootstocks (fig. 3).

Indexing gave a positive reaction only on Parsons Special mandarin, indicating cachexia-xyloporosis infection.

CONCLUSIONS

Rootstocks of the lemon group (Volkamer lemon, alemow and rough lemon) behaved differently from others and produced greater yields, as observed in Florida for Orlando tangelo (Krezdorn, 1977) and in Corsica for Comune Clementine (Blondel, 1973; 1974). These rootstocks may have a better capacity to overcome nutritional and water stresses like those after an abundant bloom. These rootstocks may possibly play a specific role in the metabolism of the scion which induces greater parthenocarpic fruiting.

Trees on Volkamer lemon gave an annual yield of 26 tons/hectare in 1977 and 1978, whereas those on sour orange bore 10.7 tons. Yields of trees on rough lemon and alemow were 18 and 24 tons, respectively. The yield for alemow is, of course, only an indication, because it refers only to those plants not declining. Under our conditions, alemow and rough lemon, though lower in total soluble solids, did not affect the fruit quality badly.

The different rate of canopy increase of trees on Volkamer lemon appears related to the onset of fruiting. This rootstock appears to effectively overcome the low productivity of Clementine. From a phytopathological point of view, it is tolerant of concave gum-blind pocket, exocortis, scaly bark, tristeza, and probably to stubborn (no acorn fruit or seed abortion in affected trees), but is intolerant of woody gall, cristacortis, *Phytophthora* spp., and *Phoma tracheiphila* Kanc. et Ghik., the cause of mal secco disease. Further observations are needed to evaluate the long-term reaction to cachexia-xyloporosis.

Though results on alemow are not conclusive, because of the decline caused by cachexia-xyloporosis, this rootstock appears to be promising for Clementine and could be useful in those areas where Volkamer lemon cannot be used.

In our experience, rough lemon and Cleopatra mandarin appear tolerant of cachexia-xyloporosis, whereas in California and Brazil, they have shown a variable degree of susceptibility (Calavan and Christiansen, 1965; Moreira, 1968). Sour orange, *C. amblycarpa*, Avana mandarin, Cleopatra mandarin, and *C. taiwanica* behaved in agreement with the literature.

Symptoms on trifoliate hybrids have not been reported for cachexia-xyloporosis. In 1976, the original mother trees had gumming at the bud union and wood pitting on the trifoliate orange rootstocks, with no scaly butt. These symptoms appear similar to those described for gum pocket (Schwarz, 1975) or gummy pitting (Fraser *et al.*, 1975). On the basis of other rootstock reactions, we believe that a strain of cachexia-xyloporosis might be responsible for the observed symptoms on the trifoliate hybrids, but we cannot exclude the possibility that a second transmissible entity was present. This also could be responsible for the heavy gumming at the bud union observed on other rootstocks like Volkamer lemon.

The results show the insufficiency of visual checks for cachexia-xyloporosis detection, even on a susceptible species such as Clementine. Since many factors influence symptom expression, careful indexing must be done when a susceptible rootstock is to be used.

TABLE 1
INFLUENCE OF ROOTSTOCK ON CUMULATIVE YIELD (1973-78) AND TREE GROWTH.

Rootstock	Cumulative yield (kg/tree)	Canopy volume* (m^3)	Circumference of stock* (cm)	Difference of scion and stock† (%)
Volkamer lemon	187 a‡	14.8 a	43.4 a	- 9.2c
Rough lemon	112 b	12.4 b	39.7 b	- 8.3 c
Sour orange	63 c	8.1 d	33.6 e	- 4.1 b
Citrus amblycarpa	42 d	14.5 a	42.5 a	-10.5 d
Citrumelo C.E.S. 1452	40 d	10.2 c	42.8 a	-13.0 e
Avana mandarin	23 e	12.3 b	34.5 de	+ 1.9 a
Cleopatra mandarin	15 g	10.5 c	34.6 d	- 8.3 c
C. taiwanica	14 fg	10.7 c	37.7 c	-14.5 f
Troyer citrange	11 g	8.5 d	43.2 a	-27.7 g
Carrizo citrange	2 h	4.7 e	33.7 de	-27.2 g
Alemow§	185	10.0	32.0	- 6.2

* Data on canopy volume and trunk circumference refer to the 9th growing year (1978).

† Calculated as: $\frac{\text{scion circumf. - stock circumf.}}{\text{stock circum.}} \times 100$.

‡ Mean values followed by unlike letters differ at the 0.05 level of significance.

§ Mean values of the only three trees not showing decline at the 9th growing year. Data not subjected to statistical analyses.

TABLE 2
INFLUENCE OF ROOTSTOCK ON FRUIT QUALITY. MEAN VALUES FOR 6 FRUITING YEARS.

Rootstock	Weight per fruit (g)	Juice (%)	Citric acid (g/100 ml)	TSS* (%)	TSS/acid (ratio)
Volkamer lemon	58 c†	46.4 a	0.94 b	10.2 bc	10.9 a
Rough lemon	63 ab	46.0 a	0.99 ab	9.7 c	9.8 cd
Sour orange	59 bc	46.4 a	0.99 ab	10.3 b	10.4 ab
Citrus amblycarpa	59 bc	47.0 a	1.05 a	10.9 a	10.4 ab
Citrumelo C.E.S. 1452	62 abc	46.7 a	1.10 a	10.2 bc	9.3 d
Avana mandarin	59 bc	46.1 a	1.05 a	10.5 ab	10.0 bc
Cleopatra mandarin	52 d	44.0 a	1.05 a	10.4 ab	9.9 bc
C. taiwanica	64 a	45.5 a	1.02 ab	10.3 b	10.1 bc
Troyer citrange	60 abc	47.6 a	1.08 a	10.6 ab	9.8 cd
Carrizo citrange	60 abc	45.9 a	0.99 ab	10.7 ab	10.8 a
Alemow‡	57	48.3	1.00	9.9	9.9

* TSS = total soluble solids.

† Mean values followed by unlike letters differ at the 0.05 level of significance.

‡ Mean values of the only three trees not showing decline at the 9th growing year (1978). Data not subjected to statistical analyses.

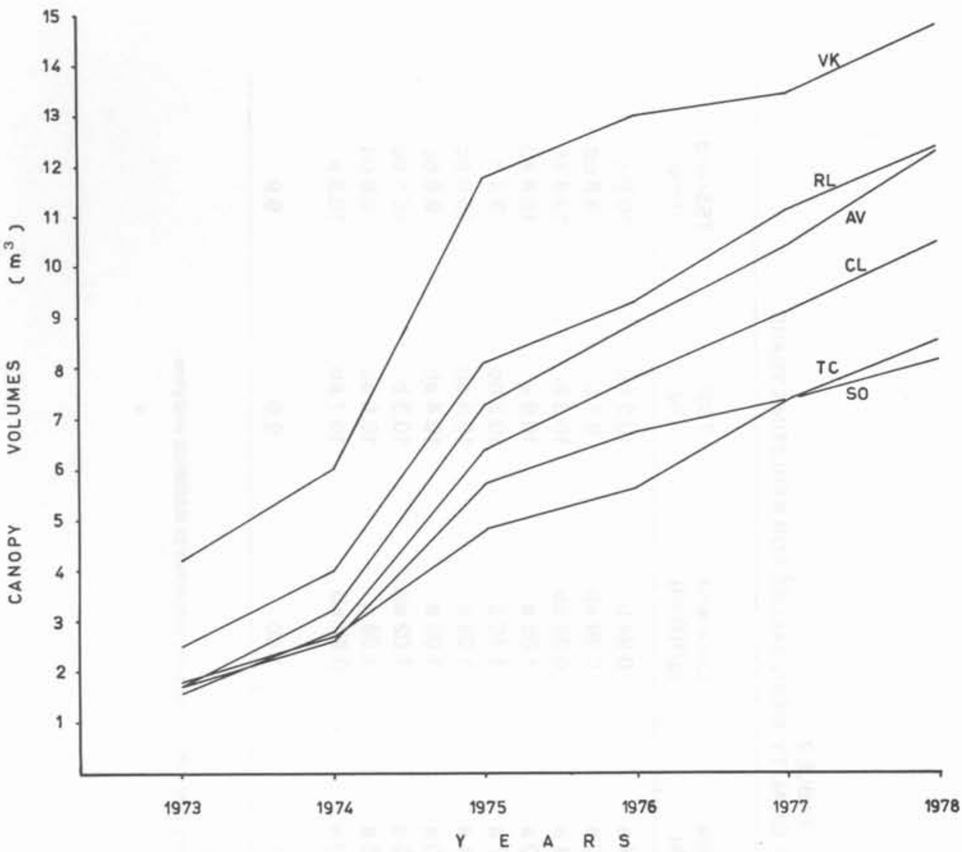

Fig. 1. Rates of increase of canopy volumes of trees on Volkamer lemon (VK), rough lemon (RL), Avana mandarin (AV), Cleopatra mandarin (CL), Troyer citrange (TC), and sour orange (SO).

Fig. 2. Severe decline in the 9th growing year of a Clementine grafted on alemow.

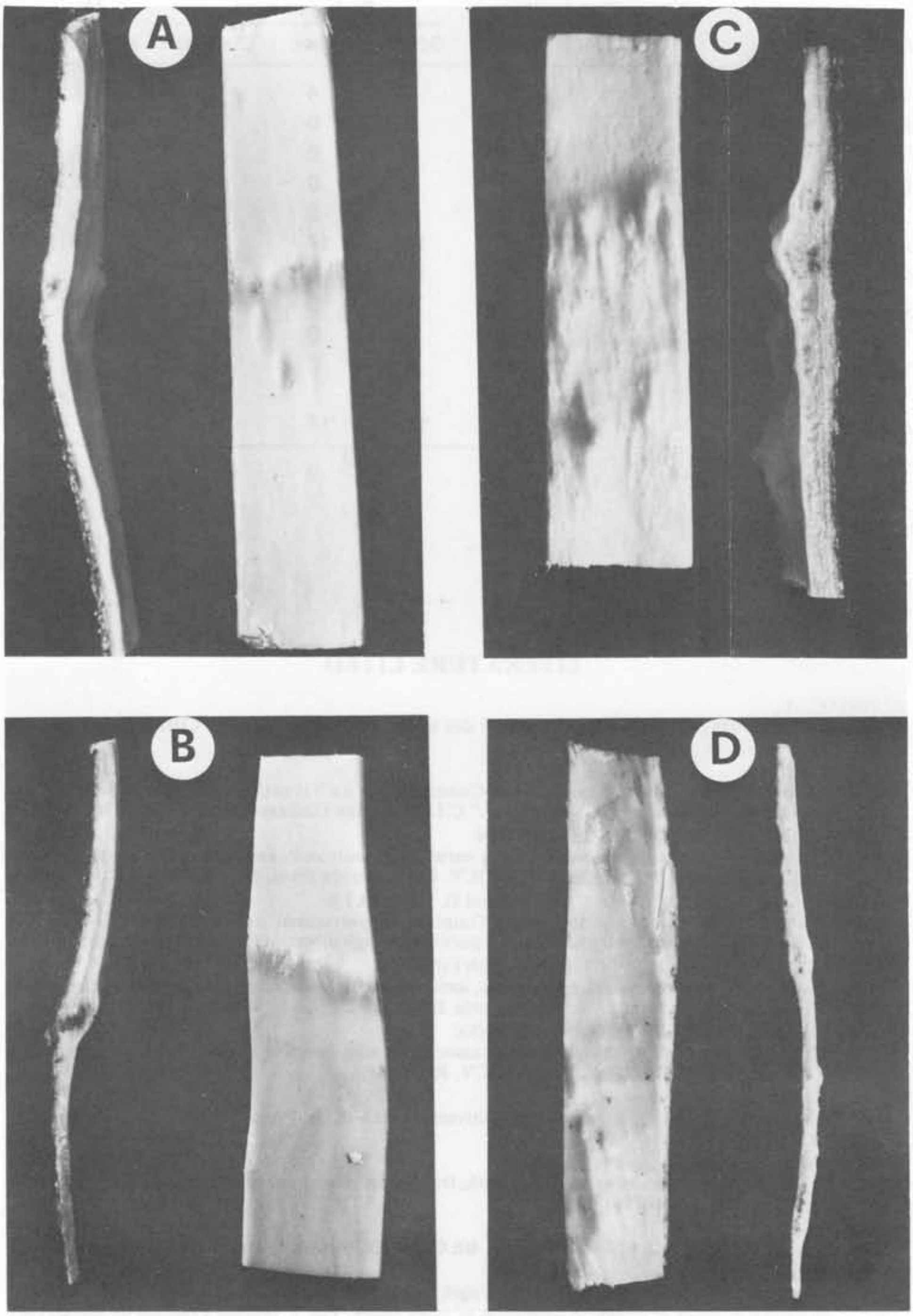

Fig. 3. Radial sections and cambial faces of bark patches taken across the bud union of trees on A) Volkamer lemon; B) Carrizo citrange; C) alemow; D) Avana mandarin. Scion portion above.

TABLE 3
NUMBER OF TREES SHOWING WOOD-PITTING AND/OR BARK-GUMMING SYMPTOMS AFTER 9 YEARS*

Rootstock	Wood-pitting		Bark-gumming			No
	Scion	Stock	Scion	Stock	Budunion	symptoms
Volkamer lemon	5	7	1	4	13	0
Rough lemon	7	0	8	0	3	8
Sour orange	0	0	0	0	2	16
Citrus amblycarpa	9	0	9	0	2	9
Citrumelo C.E.S. 1452	6	0	6	5	13	4
Avana mandarin	8	14	14	14	2	3
Cleopatra mandarin	8	0	14	0	0	4
C. taiwanica	5	0	6	0	1	8
Troyer citrange	0	3	2	0	18	0
Carrizo citrange	0	2	2	0	18	0
Alemow	17	17	17	17	17	1

* Total of 18 trees.

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