# Some Rootstock and Interstock Influences in the Olive (*Olea europaea* L.) cv. Sevillano[1,2]

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*Abstract.* An olive rootstock planting was established in Tulare County, California in 1954 using 10 different rootstocks with 'Sevillano' as the scion variety. Verticillium wilt, a major problem in California olive production, became strongly established in this planting, affecting trees on the different rootstocks to a markedly different degree. All trees on 2 of the rootstocks, *Olea ferruginea* Royle and *Forestiera neo-mexicana* Gray were killed. No trees on a clonal rootstock, *Olea europaea,* 'Oblonga' were affected, while trees on the 7 other rootstocks showed intermediate survival percentages. Over a 15-year period, tree size and yields were influenced by the rootstock. 'Sevillano' trees, on their own roots, were the smallest as measured by trunk cross section area. There was no pronounced effect of rootstock on fruit size.

In another olive planting in Tulare County, California, the effect of various interstocks, inserted during a top-working operation, on the behavior of the scion cultivar was determined. No Verticillium wilt was apparent in any of the trees in this experiment. Each of 3 genetically dwarfed clonal stocks caused a significant dwarfing influence on the scion cultivar and a reduction in yields, in comparison with the scion cultivar itself used as an interstock. No influence on fruit size occurred. Similar results were noted with *Olea chrysophylla* Lamk. as an interstock but with severe constriction of the interstock tissue.

Olive trees can be propagated either as rooted cuttings or by grafting on seedlings or clonal rootstocks. Easily rooted cultivars are usually propagated by the former method, but those difficult to root, as 'Sevillano' are almost always grafted. In California, the large-fruited 'Sevillano' is also widely used in top-working old trees of the less popular small-fruited 'Mission', or other unprofitable olive oil cultivars.

It was found previously (1) that some cultivars, e.g., 'Mission' and 'Manzanillo', when propagated as rooted cuttings developed into larger trees with considerably higher yields than trees propagated by grafting on any of the seedling or clonal rootstocks used. This was not true with 'Sevillano', however, of the rootstocks tested, some produced larger trees with higher yields than own-rooted trees, although others produced more dwarfed trees. It was noted, too, that considerable variation in tree size and production occurred from the use of *Olea europaea* seedlings as rootstocks; less variability appeared when clonal rootstocks were used.

Objectives in the present study were: (a) to test further in a commercial olive producing district of California the behavior of 'Sevillano' on certain rootstocks which had shown promise in earlier trials (1), and (b) to determine if certain interstocks could be used when top-working older trees to influence tree vigor, fruit production, and fruit size.

## Materials and Methods

*Rootstock Experiment, Wakefield Orchard, Lindsay.* Nursery trees that had been especially propagated for this planting were set out in February, 1954, at the Wakefield Orchard southeast of Lindsay, in Tulare County, California, in a relatively fertile, uniform Exeter loam (stony phase) soil. The Lindsay area is centrally located in the largest olive producing district of California. 'Sevillano' was the scion cultivar used and the rootstocks included are listed in Table 1. There were 10 replicate trees for each scion-rootstock combination which were planted in a randomized arrangement. The plot occupied about 2 acres and the trees received the usual cultural care given to olives in that area for irrigation, fertilization, pruning and herbicidal weed control.

Four species related to the cultivated olive—*Olea chrysophylla, O. sylvestris* L., *O. ferruginea* and *O. verrucosa* Link were used as rootstocks, the first 2 as rooted cuttings taken from a single parent tree and the latter 2 as seedlings. The original source of *Olea sylvestris* was obtained from Greece and has many characteristics of *O. europaea.* (It may be that *O. sylvestris* is an escape from the cultivated olive and is not a distinctly different species.) Seedlings of 'Mission' and 'Redding Picholine' were included, as these are commonly used commercially in California as rootstocks for 'Sevillano'. Two clonal rootstocks, propagated by cuttings, were included—'Armstrong A-12' and 'Oblonga'. 'Armstrong A-12' is an especially vigorous seedling selection developed by Armstrong Nurseries, Ontario, California, as a possible olive rootstock. 'Oblonga' originated about 1940 as a volun-

*Table 1.* Effect of rootstock on size of Sevillano olive trees and resistance to *Verticillium albo-atrum* after 15 years. Ten trees on each rootstock initially planted.

| Rootstock | Trunk cross-section area Sq. in.[x] | Percent of trees killed by verticillium |
|---|---|---|
| Armstrong A-12 | 64.8 a | 30 |
| Mission seedlings | 73.0 ab | 30 |
| Redding Picholine seedlings | 73.0 ab | 60 |
| Sevillano (own root) | 62.7 a | 20 |
| Oblonga | 79.8 b | 0 |
| *Olea sylvestris* | 98.2 c | 20 |
| *Olea verrucosa* | 75.7 ab | 80 |
| *Olea chrysophylla* | 91.5 c | 30 |
| *Olea ferruginea* | — | 100 |
| *Forestiera neo-mexicana* | — | 100 |

[x]Numbers not followed by same letter are significantly different at the 5% level.

[1]Received for publication January 20, 1970. Department of Pomology.
[2]The cooperation of Early California Foods, Visalia, California, A. R. Wakefield and Vernon Noell, Lindsay, California, on whose property these tests were conducted is gratefully acknowledged.

teer seedling in the Malott orchard near Corning, California. The tree was noted for its rapid growth and large size and 'Sevillano' grafted onto this as a rootstock was found to develop into large, heavy producing trees. 'Sevillano' on its own roots, propagated by cuttings, was included in the present study for comparison with grafted trees. Finally, seedlings of *Forestiera neo-mexicana,* in the family *Oleaceae,* were used as one of the rootstocks. This had been used in a previous study (1) and seemed to have potential value as a very dwarfing rootstock for 'Sevillano'.

Fruit yields per tree were obtained for all trees each year (except 1967) from 1960 to 1969, inclusive. In 1964 and 1965 commercial size grades of the fruits were determined as well as the percent shot-berries (undersized parthenocarpic fruits), split-pits (normal sized fruits having a separation of the endocarp), and soft-nose (an undesirable softening and darkening of the mesocarp at the distal end of the fruit). In addition, in both of these years any effect of rootstock on fruit maturity was determined by counts of fruit numbers showing red or black color at harvest (olive fruits are normally harvested at a straw-green color stage). At the conclusion of the experiment in 1969, trunk cross section area was determined for each tree as a measure of rootstock effect on tree size.

Shortly after this plot was established in 1954, widespread branch wilt, dieback, and killing of olive trees by *Verticillium albo-atrum,* presumably originating from microsclerotia disseminated from nearby cotton plantings, became a major problem in olive production in the San Joaquin Valley of California (3). The orchard in which this planting was located was heavily damaged by Verticillium and, in fact, by the end of the experiment almost 50% of the trees in this test had been killed. The experimental planting thus became in effect a test of the rootstocks used for their relative resistance to Verticillium; counts of trees killed by Verticillium were made during the course of this study.

Foliar analysis is often used in California to determine the mineral fertilizer requirements of olive trees but little information has been available concerning possible rootstock influence on the mineral levels in olive leaves. In 1956 and 1957 analyses were made of leaves taken from trees grafted on the 9 different rootstocks as well as from own-rooted trees.

*Interstock Experiment. Early California Orchard, Exeter.* Top-working of olive trees in California is a common practice, especially during recent years in the San Joaquin Valley where many orchards of 'Mission' trees have been grafted to the more profitable 'Manzanillo' and 'Sevillano'. In this connection it seemed desirable to determine whether, by the use of a dwarfing interstock, a useful reduction in tree size and a possible increase in fruitfulness could be obtained.

During a top-working operation in April, 1955, in a 'Mission' orchard at Exeter, California belonging to Early California Foods, Inc., a ½ acre block was set aside for an interstock trial. 'Sevillano' was the scion cultivar for all trees in this test and 4 replicates of each interstock combination were used, set in a randomized arrangement. The interstocks included are listed in Table 4. *Olea chrysophylla* was known from previous work (1) to be the most compatible with *Olea europaea* of several *Olea* species tested. Stocks 'A', 'D', 'H', and 'I' are selected genetic dwarfs from *Olea europaea* seedlings grown at Winters, California, which after 6 years had remained as small bushes of various sizes rather than developing into full sized trees. 'Barouni' was included as an interstock since it is known to be a consistently heavy bearing clone. 'Sevillano' was used to include trees with 2 graft unions, but with an interstock the same as the scion cultivar. Interstock pieces were about 12 inches long and were inserted by 2 grafting operations, the scion being grafted to the interstock about a year after the interstock was grafted to the rootstock.

Yield records were obtained from each tree in this plot every year from 1960 to 1968, inclusive. Fruit size measurements were determined in 1964 and 1965 and a size index calculated as explained in Table 1. At the conclusion of this experiment in 1969, cross-sectional area measurements were made of the scion cultivar just above the upper graft union.

## Results

*Rootstock Experiment. Wakefield Orchard, Lindsay.* As shown in Table 1, pronounced variability in resistance to *Verticillium albo-atrum* was exhibited by the several rootstocks used. All trees on *Forestiera neo-mexicana* were killed by Verticillium after 3 to 4 years. Trees on *Olea ferruginea* were the next most susceptible; all had died after about 10 years. No trees on the clonal rootstock, 'Oblonga', were killed throughout the 15-year period of this test. The other rootstocks used showed varying degrees of resistance to Verticillium.

As shown in Table 1, after 15 years certain rootstocks used in this study had imparted some degree of invigoration to 'Sevillano', trees of this clone on its own roots being the smallest. Figure 1 and Table 2 show rootstock influence on yields. Differences were not great and were significantly changed only in the case of trees on *O. verrucosa* which had reduced yields resulting, no doubt, from their susceptibility to Verticillium. Fruit size was not strongly affected by the rootstock used, the greatest difference being a size increase of fruits on *O. verrucosa* roots, probably resulting from the reduced yields. Shotberry production was about the same with all rootstocks except *O. verrucosa,* where a pronounced increase oc-

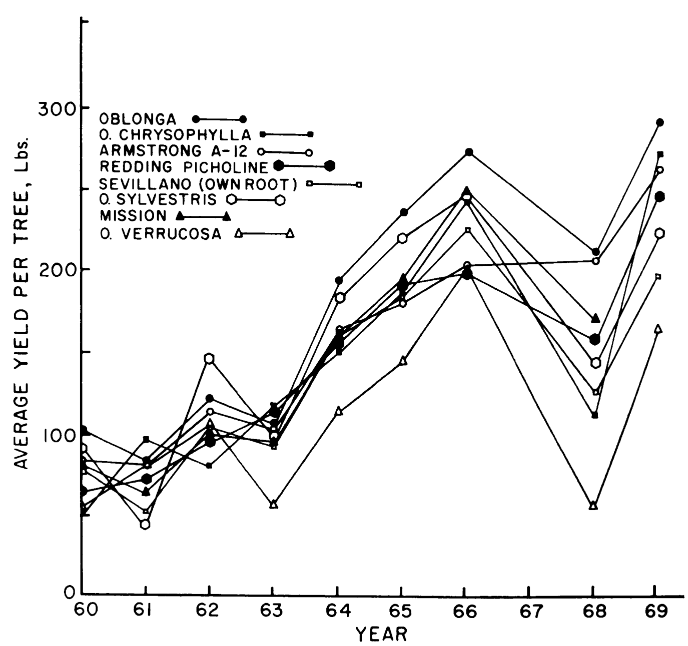


*Fig. 1.* Trends and annual fluctuations in yields of Sevillano olives as influenced by the rootstock used, in comparison with own-rooted trees.

*Table 2.* Effect of rootstocks on yields and fruit characteristics. Sevillano olives, Lindsay, California. Ten tree replicates.[x]

| Rootstock | Mean annual yield per tree, lbs.[y] | Fruit size index[z] | | Shotberries percent | | Split-pit percent | | Soft-nose percent | | Maturity, fruit colored at harvest—percent | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1964 | 1965 | 1964 | 1965 | 1964 | 1965 | 1964 | 1965 | 1964 | 1965 |
| *Olea chrysophylla* cuttings | 146 b | 7.32 ab | 7.44 b | 4.6 ab | 4.7 a | 12.4 abc | 17.3 e | 3.3 a | 6.1 c | 15.7 ab | 17.1 ab |
| Armstrong A-12 cuttings | 142 b | 7.15 ab | 6.75 a | 1.3 a | 2.2 a | 9.8 ab | 8.2 b | 2.7 a | 8.9 d | 10.9 ab | 17.8 ab |
| Mission seedlings | 136 ab | 7.70 ab | 7.44 b | 2.0 ab | 1.9 a | 5.4 a | 5.7 a | 11.7 a | 13.3 f | 22.0 ab | 23.8 ab |
| Redding Picholine seedlings | 127 ab | 7.69 ab | 7.31 b | 2.1 ab | 2.1 a | 21.6 abc | 24.0 g | 5.8 a | 3.2 b | 16.9 ab | 16.9 ab |
| Sevillano (own root) | 126 ab | 7.74 ab | 7.78 b | 4.0 ab | 2.3 a | 29.7 c | 30.3 h | 2.2 a | 2.7 b | 9.2 a | 10.0 a |
| Oblonga cuttings | 167 b | 7.28 ab | 7.35 b | 2.7 ab | 1.8 a | 14.3 abc | 18.6 e | 7.2 a | 6.6 c | 9.8 a | 5.9 a |
| *Olea sylvestris* cuttings | 142 b | 7.74 ab | 7.53 b | 3.3 ab | 4.6 a | 16.0 abc | 12.8 c | 1.4 a | 1.3 a | 10.0 ab | 10.6 a |
| *Olea verrucosa* seedlings | 96 a | 8.45 c | 8.51 c | 12.1 c | 9.5 b | 24.7 bc | 20.9 f | 9.4 a | 12.0 e | 26.1 b | 31.2 b |

[x]Means within a column not followed by same letter are significantly different at the 5% level.
[y]From 1960 to 1968, incl. (except 1967).
[z]Arbitrary figure obtained from the summation of fruit percentages in Extra Large size grade × 0.05, Mammoth × 0.06, Giant × 0.07, Jumbo × 0.08, Colossal × 0.09, Supercolossal × 0.10, and Super Supreme × 0.11.

curred. This rootstock had also been found in earlier studies (1) to cause a definite increase in shot-berry development, especially with 'Sevillano' as the scion cultivar.

Production of split-pit fruits was strongly influenced by the rootstock, varying significantly from a low of about 5% when 'Mission' seedlings were used as the rootstock to a high of about 30% from own-rooted trees. The development of soft-nose fruits was relatively low in 1964 and was not associated with the rootstock, but in 1965 the incidence of this defect was at a higher level and was significantly influenced by the rootstock, reaching over 13% with 'Mission' seedling roots. Time of fruit maturity appeared to have no relation to the rootstock used. Although in both 1964 and 1965 fruits from trees on *O. verrucosa* roots were at an advanced maturity when harvested, this is probably a reflection of the light crops produced by these trees rather than a direct rootstock influence.

Table 3 shows the levels of several mineral elements found in leaves of 'Sevillano' olives grafted on the various rootstocks. With one exception no pronounced rootstock influence occurred, all levels being within the range usually found in olive leaves from trees in California orchards adequately fertilized and grown under irrigation (2). Trees on *Forestiera neo-mexicana* roots showed quite low amounts of K, Ca, and P in relation to those on the other rootstocks. This was probably due to poor tree growth at the time of leaf collection resulting from root damage by Verticillium. The sodium level in all samplings was the same (0.01 percent).

*Interstock Experiment. Early California Orchard, Exeter.* Dwarfs 'A', 'D', and 'H' and *Olea chrysophylla* caused significant dwarfing as well as yield reduction when inserted as interstocks between 'Mission' roots and 'Sevillano' as the scion variety in comparison with 'Sevillano' itself used as an interstock (Table 4). There was no influence on fruit size. The genetically dwarfed stocks, 'A', 'D', and 'H' produced satisfactory graft unions and seemed quite compatible with both 'Mission' and 'Sevillano'. *Olea chrysophylla* tissue, however, when used as the interstock, was severely restricted in lateral development and could become a source of mechanical weakness in the tree although at the conclusion of this test, after 14 years, no breakage had occurred.

## Discussion

The location of the rootstock planting on a site that proved to be heavily infected with Verticillium, provided considerable information as to relative resistance of certain olive rootstocks to this disease under orchard

*Table 4.* Interstock influence on yields, fruit size and trunk cross-section area (after 15 years), Sevillano olives. Exeter, California.[x]

| Interstock | Mean annual yield per tree, lb.[y] | Fruit size index[z] | | Trunk cross-section area, sq. in. |
|---|---|---|---|---|
| | | 1964 | 1965 | |
| *Olea chrysophylla* | 71.4 a | 7.50 a | 8.89 a | 70.4 a |
| Dwarf A | 74.7 a | 9.00 a | 8.86 a | 87.7 a |
| Dwarf D | 81.0 a | 8.87 a | 8.79 a | 93.5 a |
| Dwarf H | 81.3 a | 8.57 a | 9.19 a | 68.4 a |
| Dwarf I | 102.0 ab | 8.63 a | 8.77 a | 135.1 b |
| Barouni | 106.2 ab | 8.50 a | 8.54 a | 141.2 b |
| Sevillano | 124.6 b | 8.58 a | 8.19 a | 148.5 b |

[x]Means within a column not followed by same letter are significantly different at the 5% level.
[y]From 1960 to 1968, incl.
[z]See Table 1 for method of calculation.

*Table 3.* Mineral content of leaves. Sevillano olives. Own rooted and grafted on nine different rootstocks. Lindsay, California.

| Rootstock | Percentage dry weight[x] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | K | | Ca | | Mg | | P | | N | |
| | 1956 | 1957 | 1956 | 1957 | 1956 | 1957 | 1956 | 1957 | 1956 | 1957 |
| Armstrong A-12 cuttings | 1.15 | 0.91 | 1.01 | 1.52 | 0.12 | 0.25 | 0.173 | 0.123 | 2.14 | 1.86 |
| Mission seedlings | 1.24 | 0.97 | 1.10 | 1.52 | 0.11 | 0.20 | 0.167 | 0.131 | — | 1.74 |
| Redding Picholine seedlings | 1.23 | 0.98 | 0.84 | 1.52 | 0.10 | 0.20 | 0.169 | 0.140 | 2.00 | 1.93 |
| Sevillano (own root) | 1.31 | 0.98 | 0.85 | 1.37 | 0.09 | 0.19 | 0.163 | 0.134 | 1.83 | 1.84 |
| Oblonga cuttings | 1.33 | 1.04 | 1.01 | 1.52 | 0.10 | 0.20 | 0.186 | 0.151 | 2.00 | 1.90 |
| *Olea sylvestris* cuttings | 1.33 | 1.08 | 0.91 | 1.25 | 0.10 | 0.20 | 0.163 | 0.137 | 1.93 | 1.87 |
| *Olea verrucosa* seedlings | 1.30 | 1.02 | 0.87 | 1.34 | 0.09 | 0.20 | 0.173 | 0.148 | 1.70 | 1.96 |
| *Olea chrysophylla* cuttings | 1.16 | 0.95 | 1.17 | 1.58 | 0.12 | 0.22 | 0.184 | 0.140 | — | 1.90 |
| *Olea ferruginea* seedlings | 1.35 | 0.95 | 0.75 | 1.40 | 0.08 | 0.20 | 0.161 | 0.112 | 1.66 | 1.83 |
| *Forestiera neo-mexicana* seedlings | 0.74 | — | 0.57 | — | 0.12 | — | 0.093 | — | — | — |

[x]Leaves sampled June 15 in 1956 and October 16 in 1957.

conditions. Studies by Wilhelm and Taylor (3) have shown that genetic differences do occur in the olive in resistance to Verticillium. The fact that no 'Sevillano' trees grafted on the clonally propagated 'Oblonga' roots showed evidence of Verticillium wilt indicates the possibility that this scion-rootstock combination could be satisfactory for use in Verticillium-prevalent areas. More detailed studies have been initiated to determine the relative resistance of this clone to Verticillium under controlled conditions. Considerable information is already available concerning compatibility and stock-scion relations of 'Oblonga' as a rootstock since it had been used previously (1) in a long-term olive rootstock trial with 'Mission', 'Manzanillo' and 'Sevillano' as the scion cultivars. No compatibility problems have appeared and tree size and yields when 'Oblonga' was used as a rootstock for 'Mission' and 'Sevillano' were about average for the various rootstocks tried. As a rootstock for 'Manzanillo', however, substantial dwarfing occurred which would necessitate a higher density planting, in comparison with own-rooted trees. Such dwarfing could be highly desirable.

Some of the rootstock influences noted in the present study, particularly in regard to tree size and yields, could have been altered by the presence of Verticillium. Also, records of certain scion-rootstock combinations which suffered heavily from Verticillium were necessarily obtained on a reduced number of replicate trees as tree losses occurred from time to time during the course of the experiment.

None of the distinctly different *Olea* species, *O. ferruginea, O. verrucosa,* and *O. chrysophylla,* used in this study show promise as a rootstock for the cultivated olive. This is true also for the California wild olive, *Forestiera neo-mexicana,* which together with *O. ferruginea,* is highly susceptible to Verticillium. *Olea chrysophylla* is the most likely of the related species tried to be successful when used as a rootstock for 'Sevillano' although a 30% loss of the trees to Verticillium occurred. In previous work (1) *O. chrysophylla* developed distinct incompatibility symptoms with 'Mission' and 'Manzanillo' but not with 'Sevillano'.

The interstock experiment in the Early California Orchard was in an area where none of the trees showed evidence of Verticillium infection and no tree losses occurred. Several interstocks used gave some degree of dwarfness to the scion cultivar along with a reduction in yield. Dwarfs 'A', 'D', 'H' and *Olea chrysophylla* gave definite dwarfing but the severe growth restriction of the *O. chrysophylla* interstock itself and possible breakage would probably eliminate it as a commercially useful stock.

There are many old 'Mission' orchards in California where the trees were planted much too close together to obtain optimum yields. In top-working such orchards to the 'Sevillano' variety it may be that the use of either dwarfs 'A', 'D', or 'H' as an interstock would permit the retention of all such closely-planted trees without subsequent excessive crowding.

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# Liquid Nitrogen Preservation of Spawn Stocks of the Cultivated Mushroom, *Agaricus bisporus* (Lange) Sing.[1,2]


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*Abstract.* Stock cultures of the cultivated mushroom in the form of rye grain spawn were preserved at −160 to −196 C for periods up to a year. Mycelial growth of the cultures was about the same after storage as before. A total of 285 spawn cultures derived from 66 different vials of preserved material, without exception, grew normally on rye grain and compost. Spawn performance of two strains each of White, Intermediate, and Brown mushroom varieties was evaluated after 2, 70, and 180 days storage. Results of yield tests indicated that there was no significant difference, in quality or quantity of mushrooms produced, between any preserved spawn and its check. The effect of glycerol or dimethyl sulfoxide as a protective agent during freezing was determined. Though the presence of a protective additive did not appear essential for short storage times, glycerol was added routinely in all later tests. Results to date indicate that the storage method potentially has great value for mushroom research and spawnmaking.


An estimated $5 \times 10^6$ quarts of mushroom spawn are planted annually by mushroom growers to produce the world's crop of the cultivated mushroom, *Agaricus bisporus.* Today, mushroom spawn (mycelium) is usually grown on sterilized cereal grain such as rye or millet. The spawnmaker is responsible for the maintenance and preparation of mushroom spawn capable of producing fruit of the desired quality and quantity. Until more knowledge of the genetics of *A. bisporus* becomes available, however, much of spawnmaking must necessarily remain an art. Fritsche (1, 3) studied the different means employed by spawnmakers to maintain the iden-


[1]Received for publication February 9, 1970.



[2]This report presents the results of a joint study utilizing special facilities at the American Type Culture Collection and Beltsville. We gratefully acknowledge the cooperation of Dr. C. Bitner and Mr. L. Chase, L. F. Lambert Spawn Co., Inc.; Mr. J. Bovenkerk, Grocery Store Products, Inc.; and Mr. A. Citino, Mushroom Growers Association.