white-flowered field, in that centrally located plots averaged only slightly less in percent outcrosses as compared with border plots (based on the stem length test. It is doubtful that testing samples from each plot throughout the entire Ranger field would have appreciably changed this result. Flowering alfalfa might have been a more effective deterrent to outcrossing in larger fields than methods used in these experiments.

Field size and distance

Field size appeared to be a definite factor affecting outcrossing in these experiments, as both 30 by 30 ft blocks of white-flowered alfalfa exhibited at least three times more contamination than did the 3-acre white-flowered field (see table). This occurred even though honeybees were adjacent to the large plots and 665 and 800 ft from the small plots. Bare ground, or crops other than alfalfa, comprised the balance of the area between the large and small blocks.

An increased amount of contamination occurred in the white-flowered field in 1966—possibly because it was reduced (in size) from 3 acres to 0.6 acres.

Evidence that distance from bees and contaminant pollen also influences outcrossing was shown by comparing the two small plots of white-flowered alfalfa. In 1965 the plot nearest the bees and large alfalfa fields contained 31.6% outcrossing whereas the plot at a more distant location averaged 23.3%.

Wind effects

Although the effects of wind or endemic pollinators were not evaluated, the results in these experiments indicate that size and distance may be factors of great importance in larger alfalfa seed fields. Size probably contributes more toward minimizing contamination.

Some of these data indicate that flowering alfalfa can minimize outcrossing, but its contribution needs further substantiation. Sampling, followed by greenhouse-testing areas in larger fields (25, 50, and 100 acres), which lie at various distances from other alfalfa fields, could pinpoint the relative importance, along with field size and distance, as isolation barriers.

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OBLONGA

HUDSON HARTMANN • W. C. SCHNATHORST • JOHN WHISLER

Response of young olive plants to inoculations with strains of Verticillium albo-atrum. Top: Manzanillo after inoculation with severe (T-1) strain (left) and mild (SS-4) strain (right). Bottom: Oblonga after inoculation with severe (T-1) strain (left) and mild strain (right).

. . . a clonal olive rootstock resistant to Verticillium wilt

A field planting in Tulare county of Sevillano olives grafted on various rootstocks provided opportunity for observations on susceptibility to verticillium wilt. In this 16-year test period, trees growing on the Oblonga clonal rootstock remained free of symptoms while 20 to 100 percent of the trees grafted on other olive species and varieties were killed by verticillium. None of the trees with the highly susceptible Sevillano as the scion variety on the Oblonga root showed symptoms of verticillium wilt—suggesting that the pathogen is not transmitted through the graft. Several trials with two major strains of Verticillium albo-atrum **taken from cotton and olives in Tulare county, using controlled inoculation techniques and greenhouse conditions at Davis, confirmed the resistance of Oblonga to verticillium wilt. Sevillano, Ascolano, and Mission develop to normal sized trees on Oblonga roots. However, in studies at Winters this rootstock exerted some dwarfing influence on Manzanillo. No evidence of graft incompatibility or a weak graft union has appeared in any of these combinations.**

VERTICILLIUM WILT, caused by the soil fungus *Verticillium albo-atrum* (microsclerotial form) is the most serious cultural problem now facing olive growers in the San Joaquin Valley. The disease appeared in olives in this region about 1945 and today it is difficult to find an olive orchard in Tulare county without trees dead or dying from verticillium. Hundreds of olive trees—both young and old trees—die each spring. Typical symptoms are the sudden collapse of large branches or entire trees, particularly in the spring with the onset of hot weather. Leaves turn brown but remain attached to the dead limbs on into the summer.

It has been suggested that *V. albo-atrum* spreads from nearby verticillium-infected cotton and accounts for the increased incidence and severity in olive groves in recent years. Studies are in progress to determine whether cotton plantings are involved, or whether certain cultural practices in the olive groves account for the increase in the disease.

No satisfactory chemical treatment applied to the soil has been developed to control this fungus in existing orchards. Resistant rootstocks are believed to be the most satisfactory long-term solution to the problem.

A two-acre olive rootstock planting set out in 1954 in the A. R. Wakefield orchard southeast of Lindsay, Tulare county, by the U.C. Department of Pomology consisted of trees grafted on nine different rootstocks, as well as self-rooted trees. Sevillano was the scion variety and, in the initial planting, each scion-rootstock combination was replicated 10 times, with a randomized planting arrangement. The rootstocks used are listed in table 1.

Four species related to the cultivated olive: *Olea chrysophylla, O. sylvestris, O. ferruginea* and *O. verrucosa,* were used as rootstocks as well as seedlings of Mission and Redding Picholine, commonly used commercially in California as rootstocks for Sevillano. In addition, two clonal rootstocks, propagated by cuttings, were included: Armstrong A-12 and Oblonga; Armstrong A-12 originated as an especially vigorous seedling selected by Armstrong Nurseries, Ontario, California, as a possible olive rootstock. Oblonga originated about 1940 as a volunteer seedling in the Earl Malott orchard near Corning in Tehama county. Sevillano on its own roots, propagated by cuttings, was included in the Lindsay planting for comparison with the grafted trees. Finally, seedlings of *Forestiera neo-mexicana,* the California "wild olive" in the family *Oleaceae,* were included as one of the rootstocks. It had been used in a previous rootstock planting at Winters, California and seemed to have potential value as a very dwarfing rootstock for Sevillano.

Fruit yields

Fruit yields were obtained for each tree every year (except 1967) from 1960 to 1969, inclusive. In 1964 and 1965 commercial size grades of the fruits were determined as well as the percentage of 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 both of these years any effect of rootstock on fruit maturity was determined by counts of fruit numbers showing red or black color when harvested as table olives. 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 injury to olive trees from verticillium wilt appeared in the San Joaquin Valley. The orchard in which this planting was located had been heavily damaged by verticillium and by 1970 about half of the test trees were dead. This experimental planting thus became, in effect, a test of the relative resistance of the rootstocks to verticillium wilt. Counts of trees killed by

Dwarfing influence on Manzanillo trees due to Oblonga rootstock. Left: Manzanillo, own-rooted. Right: Manzanillo on Oblonga roots. Both trees are 22 years old. Winters, California.

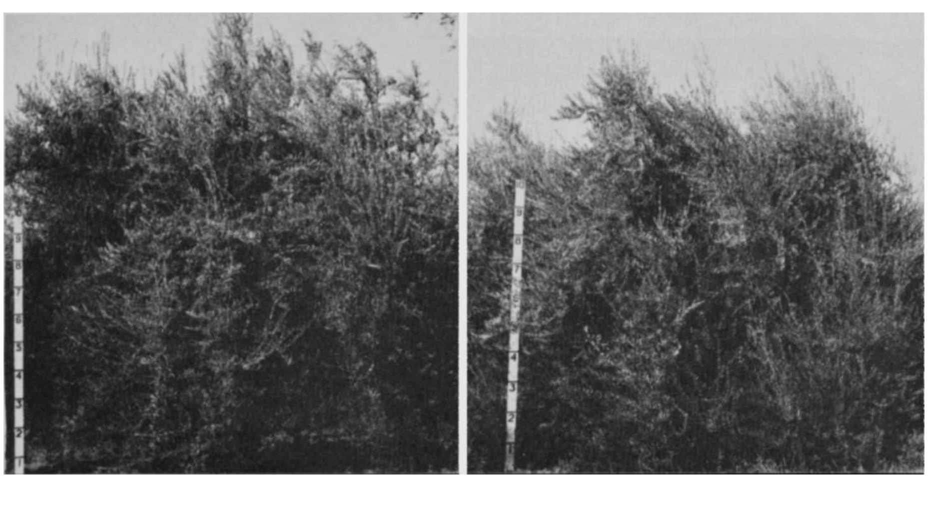

TABLE 1. EFFECT OF ROOTSTOCK ON SIZE OF SEVILLANO OLIVE TREES AND RESISTANCE TO VERTICILLIUM ALBO-ATRUM AFTER 15 YEARS. TEN TREES ON EACH ROOTSTOCK WERE INITIALLY PLANTED IN 1954, LINDSAY.

Rootstock	Trunk cross-section area*	Trees killed by verticillium
	sq. in.	%
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

* Numbers not followed by same letter are significantly different at the 5% level.

verticillium during this study showed great variation in resistance to verticillium among the several rootstocks used (table 1). All trees on *F. neo-mexicana* died after three or four years. Trees on *O. ferruginea* were the next most susceptible; all had died after 10 years. No trees on the clonal rootstock, Oblonga, were killed or showed any symptoms of verticillium infection in 16 years. The other rootstocks in the plot showed varying degrees of suceptibility to verticillium.

Rootstocks and growth

After 15 years, the rootstocks used in this study, with the exception of *O. ferruginea* and *F. neo-mexicana*, imparted some degree of vigor to the Sevillano scion (table 1). Trees of Sevillano on their own roots were the smallest. The graph shows rootstock influence on yields. Differences were not great and were significantly changed only in the case of trees on *O. verrucosa* roots which had reduced yields—resulting, no doubt, from their high susceptibility to verticillium. Fruit size was not strongly affected by the rootstock. Shot-berry production was about the same with all rootstocks except *O. verrucosa*, where a pronounced increase occurred. This rootstock reacted as it had in earlier studies at Winters, causing a definite increase in shot-berry development, especially when Sevillano was the scion variety.

Production of split-pit fruits was strongly influenced by the rootstock, the influence varying significantly from a low of about 5 percent when Mission seedlings were used as the rootstock, to a high of about 30 percent 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 higher and was significantly influenced by the rootstock, reaching over 13 per cent with Mission seedling roots.

Trends and annual fluctuations in yields of Sevillano olives as influenced by the rootstock used, in comparison with own-rooted trees. Lindsay, California. Trees planted 1954.

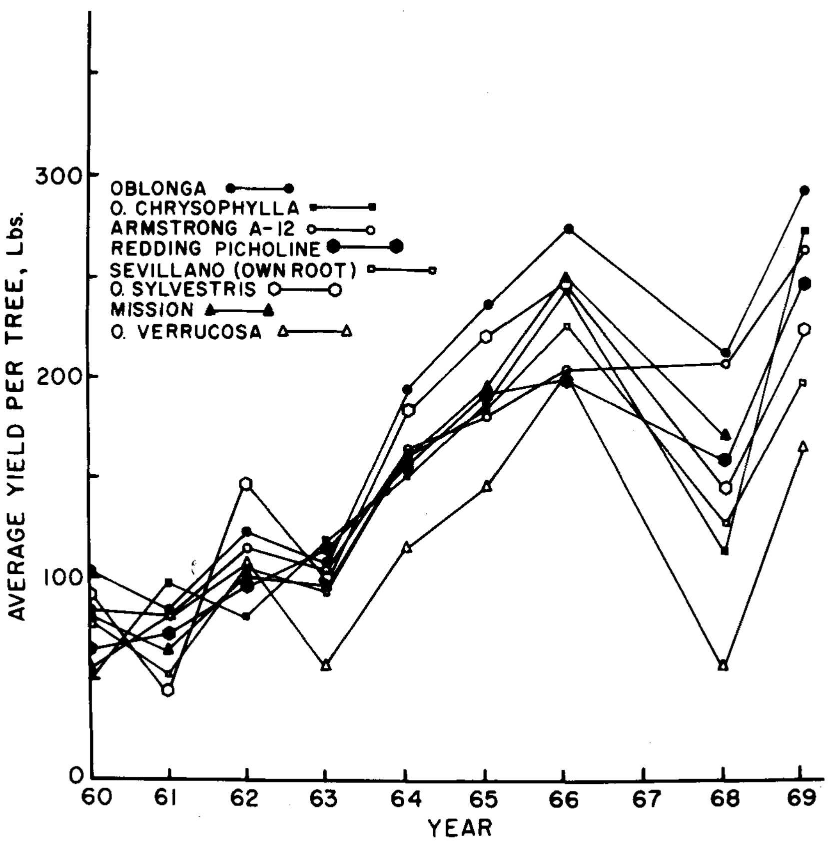

TABLE 2. REACTION OF MANZANILLO AND 'OBLONGA' OLIVE TREES TO INOCULATION WITH SS-4 AND T-1 STRAINS OF VERTICILLIUM ALBO-ATRUM IN GREENHOUSE TRIALS.*

Variety (own-rooted trees)	No. of trees inoculated	No. of trees showing symptoms
Manzanillo		
SS-4 strain	12	3
T-1 strain	11	11
Control†	5	0
Oblonga		
SS-4 strain	8	0
T-1 strain	12‡	0
Control†	5	0

* Figures are totals for 3 separate trials.
† Roots sprayed with sterile glass-distilled water.
‡ One tree died from transplant shock. Two attempts to isolate V. albo-atrum from this tree were negative.

Time of fruit maturity appeared to have no definite relation to the rootstock used.

The fact that Sevillano trees grafted on the clonally propagated Oblonga rootstock showed no evidence of verticillium wilt throughout the 16 years of this experiment indicates resistance to verticillium by Oblonga, and the likelihood that this scion-rootstock combination could be used satisfactorily for plantings in verticillium-prevalent areas. The resistance of Oblonga to verticillium wilt, as noted under field conditions, was also confirmed in greenhouse trials at Davis.

Greenhouse tests

Small plants of Oblonga and Manzanillo propagated as rooted cuttings were subjected to inoculation with *V. albo-atrum* in three separate trials. Two major strains of *V. albo-atrum* (SS-4 and T-1 from cotton and olives) that are common in the area where verticillium wilt is a problem, were grown for inoculum on potato-dextrose agar slants at 75°F in the laboratory for five to seven days. Suspensions of fungus conidia of each strain were prepared with sterile glass-distilled water, and the number of conidia adjusted to approximately 10 million per ml of suspension. The small trees were pruned to reduce leaf area in order to minimize transplant shock. They were removed from the metal pots and soil was washed from their roots. Approximately 10 ml of conidial suspension was uniformly sprayed onto each root system with an aerosol spray kit and the plants were then repotted. Control plants received similar treatment except that roots were sprayed with sterile glass-distilled water without the fungus. The trees were held in a greenhouse where temperature ranged between 73 and 78°F. Readings for disease began three weeks after inoculation and continued for several months. When external symptoms became advanced in most

Manzanillo trees, 10 tissue samples were removed from all inoculated plants, regardless of whether or not they expressed symptoms, and plated on water agar to recover the pathogen. With Oblonga, several different isolation attempts were made for each inoculated tree.

Results of the inoculation tests are presented in table 2. External symptoms in the Manzanillo variety began to appear approximately 30 days after inoculation. Manzanillo proved susceptible to both strains of *V. albo-atrum*, but was much more susceptible to T-1 than to SS-4 (see photos of young alive plants). Only three of 12 trees inoculated with SS-4 showed wilt symptoms and only one of those died. In contrast, all 11 Manzanillo trees inoculated with T-1 developed symptoms and all but two died; those that did not die were severely damaged. None of the 20 inoculated Oblonga and none of the uninoculated control trees expressed external or internal symptoms of the disease. One inoculated Oblonga tree died from transplant shock. This tree showed distress two weeks earlier than normal, even for a susceptible variety, and the internal symptoms were atypical; in addition, *V. albo-atrum* was not recovered from the tissues of this tree in two replicated attempts. An early indication of infection is the failure of shoots to elongate. This symptom occurred with Manzanillo trees but was absent in Oblonga.

The results of isolation attempts showed that the fungus was generally recovered only from plants that expressed leaf symptoms or vascular discoloration. *V. albo-atrum* was recovered from only one of 400 tissue pieces from stems of Oblonga which were symptomless in these tests. The strain recovered was T-1. These results indicate that there is a very low probability that infection in Oblonga will lead to transmission of the pathogen to a grafted susceptible scion, and are consistent with field results. To determine with more certainty that transmission of verticillium does not occur through a Manzanillo/Oblonga graft, future experiments will be conducted in the greenhouse using grafted trees and controlled inoculum and environment.

Rootstock compatibility

Considerable information is available concerning compatibility and stock-scion relations of Oblonga as a rootstock, since it had been included as one of the stocks used in a previous long-term olive rootstock trial with Mission, Manzanillo and Sevillano as the scion varieties. This planting was established in 1949 by the Department of Pomology at the U.C. Wolfskill Experimental Orchard, Winters. Verticillium wilt has not been a problem in this planting. No incompatibility problems with Oblonga have appeared and tree size and yields (when Oblonga was used as a rootstock for Sevillano) were about average for the various rootstocks tried.

When used as a rootstock for Manzanillo, however, some tree dwarfing occurred (see photos of mature trees). Such dwarfing would indicate an increased density of tree planting would be needed to obtain the expected per-acre yields. Smaller trees could be an advantage in facilitating hand harvesting operations but would not be advantageous for trees grown in anticipation of mechanical harvesting. The effects of Oblonga as a root stock for Manzanillo and Sevillano, in comparison with other commonly used stocks—as well as own-rooted trees—on tree size, yields, and fruit characteristics are shown in table 3.

TABLE 3. COMPARISONS OF ROOTSTOCK INFLUENCES ON TREE GROWTH AND FRUITING CHARACTERISTICS OF MANZANILLO AND SEVILLANO OLIVES, WINTERS. (TREES PLANTED 1949*)

Rootstock	Trunk cross-section area after 8 yrs	Annual yields per tree 1954–1961 (5th to 12th year)	Average fruit weight	Flesh pit	Shot-berries
Manzanillo scion variety	sq. cm.	lbs	gm	ratio	%
Own-rooted trees	365a	141a	4.7a	8.3:1a	2.2a
Mission seedlings	312ab	116b	4.5ab	7.5:1b	2.3a
Redding Picholine seedlings	—	49c	4.1b	7.5:1b	3.5ab
Oblonga (rooted cuttings)	202b	60c	4.2b	8.0:1b	4.2b
Sevillano scion variety					
Own-rooted trees	285a	123a	9.8a	7.8:1a	8.9a
Mission seedlings	418a	109a	9.0b	7.5:1a	10.2a
Redding Picholine seedlings	456a	96a	8.9b	7.0:1b	9.9a
Oblonga (rooted cuttings)	376a	88a	9.2ab	7.6:1a	9.2a

* Numbers in columns for Manzanillo and for Sevillano not followed by the same letter are significantly different at the 5% level.

No dwarfing

Neither Sevillano nor Ascolano grafted on Oblonga rootstock have shown any pronounced dwarfing tendencies. Although not included in an experimental rootstock planting, a group of 10 Ascolano/Oblonga trees planted as border row trees at Davis in 1958 have developed to the usual large size expected of Ascolano.

Oblonga fruits are much smaller than any of those of the commercial California varieties and if a rootstock sucker inadvertently developed to fruiting size, it could easily be detected and removed.

Oblonga can be propagated readily by rooting small leafy cuttings in an intermittent mist propagating bed. The cutting bases are dipped in a 50% alcohol solution of the growth regulator, indolebutyric acid, at 4,000 ppm for 5 seconds, or are treated with a similar proprietary preparation, such as Hormodin 3. The young plants, when large enough for grafting or budding to the desired variety, should be grafted at least 2 ft above ground level so there is no danger of scion rooting with subsequent infection of such roots by *V. albo-atrum*, thus negating the effects of the Oblonga roots. Since none of the 10 Sevillano/Oblonga tree combinations in the Lindsay planting showed verticillium symptoms for 16 years in a heavily infested orchard, it appears that the Oblonga stock was able to prevent the movement of the fungus from the soil into the susceptible Sevillano scion top. In future greenhouse and field experiments, the possibility of transmitting *V. albo-atrum* through Oblonga roots to a susceptible scion will be thoroughly checked.

Supplies of propagating material are available from large Oblonga trees on the U.C. Davis campus and are currently being distributed to interested nurseries by the University's Foundation Plant Materials Service.

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