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Akif Eskalen
Editor of this issue

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The State of Dothiorella Canker on Avocado in California

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Branch and trunk canker on avocado was formerly attributed to *Dothiorella gregaria*, hence the name Dothiorella canker. So far *Botryosphaeria dothidea* (anamorph: *Fusicoccum aesculi*) is the only known species causing Dothiorella canker on avocado in California. Symptoms observed on avocado with Dothiorella canker include shoot blight and dieback, leaf scorch, fruit rot, and cankers on branches and bark (Fig. 1, 2, 3).



Fig. 1. Dothiorella branch dieback and canker symptoms on Hass cv. avocado tree.

However, recent studies based on DNA analyses suggest greater species diversity of this pathogen group than based on morphological characteristics alone. Thus far, multiple species of *Botryosphaeriaceae* have been found to cause the typical Dothiorella canker (Fig. 3) and stem-end rot (Fig. 5) on avocado in California. Percent recovery of *Botryosphaeria* spp. based on morphological characters ranged from 40-100% in Riverside county, 42-53% in Ventura county, 33% in Santa

Barbara county, 60% in San Diego county and 32-60% in San Luis Obispo county.



Fig. 2. Dothiorella branch and shoot dieback symptoms on Hass cv. avocado tree.

According to preliminary results from a continuing survey throughout avocado growing areas of California, multiple species of *Botryosphaeria* (*Neofusicoccum australe*, *B. dothidea*, *N. luteum*, and *N. parvum*) were found.



Fig. 3. Dothiorella perennial canker on branch

Pycnidia (overwintering structure) of *Botryosphaeriaceae* species were also observed on old diseased avocado tree branches. Sequenced rDNA fragments (ITS1, 5.8S rDNA, ITS2,

amplified with ITS4 and ITS5 primers) were compared with sequences deposited in GenBank.



Fig. 4. *Dothiorella* perennial canker on trunk

Pathogenicity tests were conducted in the greenhouse on 1-year-old avocado seedlings, Hass cv., with one randomly chosen isolate from each of the *Botryosphaeriaceae* species noted above. Four replicate seedlings were stem-wound inoculated with a mycelial plug and covered with Parafilm. Sterile PDA plugs were applied to four seedlings as a control. Over a period of 6 months, seedlings were assessed for disease symptoms that included browning of leaf edges and shoot dieback. Mean vascular lesion lengths on stems were 64, 66, 64, and 18 mm for *B. dothidea*, *N. parvum*, *N. luteum*, and *N. australe*, respectively. Each fungal isolate was consistently re-isolate from inoculated seedlings, thus completing the pathogenicity test. To our knowledge, this is the first report of *N. australe*, *N. luteum*, and *N. parvum* recovered from branch cankers on avocado in California.



Fig. 4. Leaf scorch symptoms of *Dothiorella* canker

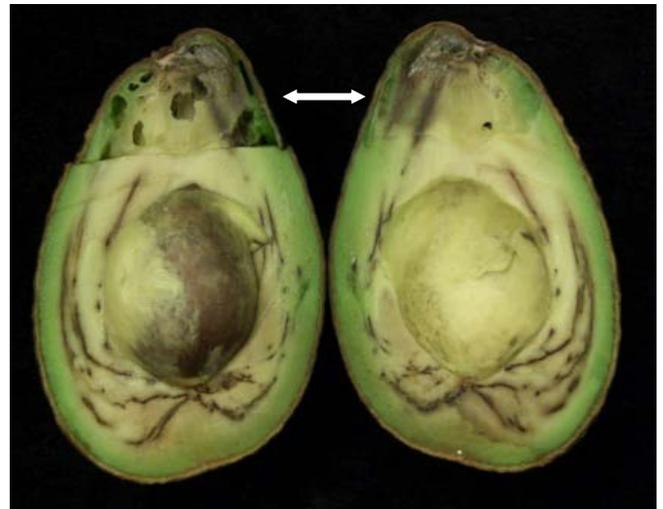


Fig. 5. Stem end rot symptom of *Dothiorella* pathogens

These results are significant because *Botryosphaeriaceae* canker pathogens are known to enter the host plant through fresh wounds (pruning, frost, and mechanical). With high-density planting becoming more common, which requires intensive pruning, the transmission rate of these pathogens could increase in California avocado groves. The Eskalen laboratory is currently investigating control measures for dothiorella canker and stem-end rot pathogens.

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**The Parent Washington Navel Orange
Tree- Its First Years,
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Part-I

In January 1995, during my second consultancy visit to Thailand, I was asked to lecture to the staff of Kasetsart University located in Bangkok. The lecture was on the problems of the greening disease in their country, where trees die between 4 and 8 years and rarely reach 12 years of age. The lecture was well-attended by many young staff and scientists. During the lecture, I showed them a picture of a large citrus tree dying with the greening disease (Fig. 1). While showing this picture, almost half the audience raised their hands and one by one, said that picture of this tree could not have been taken in Thailand for they had never seen a tree of this size. In truth, the picture was taken in Thailand by Dr. E.C. Calavan who visited Thailand in 1975 and gave me this slide. In truth, all of these younger scientists assumed that citrus trees lived a short period of time and were replaced. I then showed them the picture of the Parent navel orange tree which was 120 years old at the time of my lecture, and they could not grasp that a citrus tree could live that long. Today, this historical parent navel orange tree located at the corner of Arlington and Magnolia Avenues in Riverside is 134 years old (Fig. 2). It is still bearing large beautiful fruit and is in good health. In this first of two articles, I wish to relate a little of the early history of this important tree.

The first introduction of budwood of the navel orange from Bahia, Brazil to Washington, D.C.

A little known history on the introduction of the first budwood is contained in a letter in the files of the National Archives in Washington D.C. (Moore and Moore, 1951). It was written by Richard A. Edes, U.S. Consul in Bahia, Brazil and dated January 21, 1871. The budwood was sent to Horace Capron, Commissioner of Agriculture, and reads as follows: "I have the honor to acknowledge receipt of your communication of December 15, 1870. The favorite orange of this part of Brazil, and of which this province is celebrated is named the navel orange. This orange contains no seed and for

transplanting, the cuttings of the tree must be used. Such cuttings are usually put into a basket of earth of the diameter of about 10 inches and the baskets to the number of 8 or 10 are packed in a large case with a glass top. In the summer season it can be forwarded without much risk. I shall be glad to forward whatever number of cuttings may be desired and would suggest the month of May as being the most suitable for the purpose." Capron replied to Edes on February 21, 1871 and on April 20, 1871, Edes acknowledged the letter and said that he would forward the desired navel orange cuttings.

The first successful introduction of the navel orange.

Dorsett, Shamel and Popenoe (1917) reported on the recollection of William Saunders made some 29 years after receipt of budwood of the Bahia navel from Brazil. Saunders was then Superintendent of the Gardens and Grounds of the USDA in Washington D.C. and recalled that "Some time in 1869 the then Commissioner of Agriculture, Horace Capron, brought to my office and read me a letter which he had just received from a correspondent in Bahia, Brazil. Among other matters, special mention was made of a fine seedless orange of large size and fine flavor. Thinking that it might be of value in this country, I noted the address of the writer and sent a letter asking to be the recipient of a few plants of this orange. This request brought, in course of time, a small box of orange twigs, utterly dry and useless. I immediately sent a letter requesting that someone be employed to graft a few trees on young stocks and that all expenses would be paid by the Department. Ultimately a box arrived containing 12 newly budded trees and being packed as I had suggested, were in fairly good condition." In an article by (Webber (1940), he believed that the Brazilian correspondent was the Reverend F.I.G. Schneider. It is possible that the initial letter was that of Richard Edes and the date was not in 1869, but January of 1871. The second shipment of budded trees may have been sent by the Reverend F.I.C. Schneider to William Saunders, as suggested by Webber (1940).

Shipment of the navel orange to Luther and Eliza Tibbets (Fig. 3). There is much debate on the arrival of the parent navel orange trees to Riverside,

California from Washington D.C. After the trees were received from Bahia, Brazil they were budded to a rootstock by Saunders in Washington and most were sent to Florida, where they did poorly. Accounts put Eliza Tibbets in Washington, D.C. in 1873 (McClain, 1976). "She was an old friend of the Saunders and while visiting with them, Mr. Saunders showed her the young navel orange trees." McClain further stated "That no one made note of this historic event is not surprising since new varieties were constantly being brought into the area by the new settlers.

The new colony of Riverside was only 4 to 5 years old when the trees arrived. Esther Klotz, a renowned historian on the tree, in hand-written notes on the Washington navel cited evidence for the arrival of the tree on December 10, 1873 after being a month on the way (Klotz, 1972).

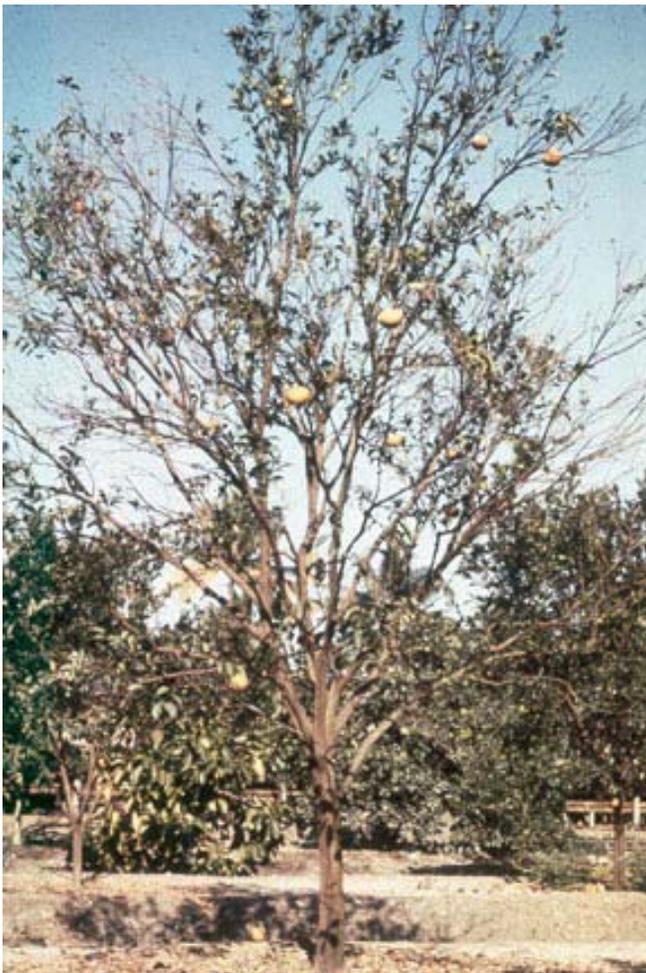


Fig. 1. This photo of a dying citrus was taken by Dr. E.C. Calavan in 1975 near Bangkok, Thailand. When this slide was shown to a group of faculty and students during a lecture in Bangkok in 1995 many in the audience objected and felt the picture could not have been taken in Thailand since, as they voiced, there were no such large citrus trees growing in the country. In truth, the picture was taken 20 years previously but since the average age that a citrus tree survives in Thailand is 8 to 12 years before dying from HLB (Grenzebach 1995), most of the people in the audience would not have seen or remembered that before HLB, trees once grew to a large size in their country.



Fig. 2. Showing the 136 year old parent Washington navel orange tree, located in Riverside, California. The tree is alive and healthy and still bearing fruit. This picture was taken in December, 2009 and the tree has to be one of the most important, if NOT the most important plant introduction ever made into the United States of America. Possibly all Washington navel orange trees throughout the world are derived from this one parent tree.



Fig. 3. Luther and Eliza Tibbets. Accounts put Eliza Tibbets in Washington, D.C. in 1873. She was shown the navel orange trees by Mr. Saunders who was then Superintendent of the Gardens and Grounds of the USDA in Washington D.C. and who she had befriended and known when she lived in Washington. She showed an interest in having trees shipped to her home in Riverside. It is believed that Luther Tibbets drove by horse and wagon from Riverside to Los Angeles to pick up the trees.

The two parent navel orange trees at the Tibbets' home in Riverside about 1877 (Fig. 4). McClain (1976) reported that the fact that the trees arrived safe and sound was a small miracle. The trees were shipped by rail to Gilroy via San Francisco, and then by stage coach from San Francisco to Los Angeles, taking 3 days for the stage trip. She wrote that Luther and Eliza Tibbets drove 65 miles in their buckboard wagon from Riverside to pick up the precious package. It is reported that perhaps three trees were planted, but that one had been trampled by a cow. It is widely accepted that Eliza Tibbets took care of these trees and used dishwater to keep them alive, since they were not connected up to the canal water (due to the contentious behavior of Mr. Tibbets who refused to pay for water rights).



Fig. 4. Showing the two parent navel trees at the Tibbets' home about 1877. It is reported that perhaps three trees were planted, but that one had been trampled by a cow. It is widely accepted that Eliza Tibbets took care of these trees and used dishwater to keep them alive, since they were not connected up to the canal water.

The first fruiting of the Washington navel orange. McClain (1976) reported that the first navel oranges were not produced on the trees at the Tibbets home, but rather from that of the neighbors McCoy and Cover who had budded existing seedling trees with budwood from the Tibbets' trees when they had first arrived. Commercial exposure came with the area's first citrus fair in 1879, where the seedless navel oranges won first prize over all competition. This created a demand for budwood and a fence had to be erected around the two original trees at the Tibbets' home to prevent theft. It is said that \$1.00 a bud was paid by people anxious to get buds.

On April 23, 1902 one of the two parent navel orange trees was transplanted from the Tibbets homestead to its present location in a small fenced park at the corner of Arlington Avenue and Magnolia Avenue. The remaining parent navel orange tree was transplanted on May 8th, 1903 to the courtyard of the Glenwood tavern, now known as the Mission Inn. Shown in Fig. 5 is President Theodore Roosevelt assisting in the planting ceremony.



Fig. 5. President Theodore Roosevelt assisting in the planting of one of the two Washington navel orange tree at the Mission Inn (then known as the Glenwood Tavern). The fact that a President of the United States would transplant this historic tree was testimony to its importance and significance.

The fact that a President of the United States would transplant this historic tree was testimony to its importance and significance. On December 4, 1922, the Riverside Daily Press reported that the parent Washington navel orange tree, which had been replanted to the Mission Inn patio in 1903, had been removed following its death. It was noted by local townspeople that the tree had begun to fail rapidly after the death of President Theodore Roosevelt in 1919 who had assisted in the transplanting ceremony.



Fig. 6. The parent Washington navel orange tree in its new home at the corner of Magnolia and Arlington Avenues about 1920. The tree appeared in good health as shown in this picture.

A new home. Fig. 6 shows the parent Washington navel orange tree in its new home at the corner of Magnolia and Arlington Avenues about 1920. It is in a small park dedicated as the ‘Eliza Tibbets Memorial Park’ under the care of the Riverside Parks Department. The transplanted tree appeared in good health as shown in this picture. The parent Washington navel orange tree in its small park in Riverside began to show decline about 1915-1917. In Fig. 7 we see the tree in very poor condition suffering from *Phytophthora* (gummosis) root rot. The loss of this historic tree would have been tragic, since it was one of the two original parent trees still surviving from the first shipment to California in 1873. To be continued in next issue.



Fig. 7. The parent Washington navel orange tree in its small park in Riverside began to show decline about 1915-1917. We can see the tree in very poor condition suffering from *Phytophthora* (gummosis) root rot. This tree was on a sweet orange rootstock and highly susceptible to gummosis root rot.

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Mechanical Harvesting of California Table and Oil Olives

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INTRODUCTION

When and how olives are harvested are among the most important factors in both the quantity and quality, and therefore value of processed table olives and olive oil. Efficiency of harvest, the percent of fruit removed from the total crop on the tree, is the first component of total processed product value. Quality of the fruit, partially a function of maturity for table olives and oil, and size for table olives, and condition when delivered to the processing facility is the second component of total processed oil or table value. Harvesting is the final step in field production of an olive crop, but if done at the wrong time or in the wrong way it can markedly affect net return to the grower. However, within limits, depending upon the use of the harvested fruit, the two factors are ranked differently.

Efficiency of harvest removal and collection is the more important factor in developing mechanical harvesting for olives destined for olive oil. Fruit quality and condition, within limits, is secondary. Fruit quality and condition, the potential for producing an acceptable table fruit when delivered to the processing plant, is the most important factor in developing mechanical harvesting in olives destined for table fruit. Efficiency of harvest is secondary. Given the relative size of the world's olive oil and table olive industries, and the relative difficulty of developing mechanical harvesting for oil or table fruit, successful harvesting of olives for oil is being developed sooner and more easily than successful harvesting of olives for table fruit processing.

The major reason for developing mechanical olive harvesting is the high cost of hand harvesting, currently the single most expensive cost in olive production worldwide. In California's San Joaquin Valley, the 2009 average hand harvest cost per ton was approximately 50% of the gross return per ton. Other major olive producing countries report similar percentages. Further, in most olive producing countries, adequate supplies of harvest labor are less available, and the liability to meet safe working and fair employment standards is becoming more difficult.

These two factors: the potential for olive harvesting methods to affect the quantity and quality of the final processed product, and harvest costs, mean efforts to develop mechanical harvesting for olives must be dictated by both the quality of the table olives or oil produced and by the reduction in harvest costs; though as discussed above, these factors, within limits, rank differently depending upon the final use of the harvested fruit. However, reducing the cost of olive harvest is of no advantage if the harvested olives cannot be successfully processed into high quality table olives or oil.

RECENT OLIVE MECHANICAL HARVESTING RESEARCH IN CALIFORNIA

California's table olive industry is primarily based upon a single cultivar, the 'Manzanillo', processed in a style called "California black ripe". Much smaller amounts of 'Mission', 'Sevillano', and 'Ascolano' are also processed in this style. The

name is misleading as the fruit is harvested physiologically immature, therefore the abscission zone is unformed, and the fruit has a higher Fruit Removal Force (FRF) force than oil olives, which are generally harvested at physiological maturity. Immature 'Manzanillos' routinely have an FRF as high as 1 kg when harvested. When physiologically mature the FRF is less than 0.10 kg. This immaturity, combined with the traditionally large trees, 4 – 6 m tall and 3 - m ft wide, and pendulous, thick growth habit of California's irrigated 'Manzanillo' olive orchards makes mechanical harvesting difficult.

Mechanical harvesting of oil olives has developed much more rapidly because new olive oil cultivars have been bred for slow growth, planted in high to super high densities, 486 – 1800 trees per hectare, and trellised or trained in a hedgerow that is easily harvested by over-the-row grape, coffee and blueberry harvesters. The olive oil industry pursued the long term goal of tree genetics, the mid term goal of new orchard conformations with hedgerow tree training and pruning, and the short term goal of adapting existing mechanical harvesters from other crops.

Similarly, if the California table olive industry is to ultimately succeed, it must also pursue tree breeding, new orchard conformation with hedgerow training and pruning, and mechanical harvesting technology. However, there is no current table olive tree breeding program in California and only one currently active in Spain. Therefore, California's table olive industry must pursue the short and midterm goals as follows. For the short term this means developing a picking technology and tree pruning method for the current California table olive orchards. For the midterm this means developing a picking technology and new orchard conformations, with new training and pruning methods.

Therefore, the focus of California Black table olive mechanical harvesting research for the last decade has been on dual objectives: developing successful mechanical harvesting for current and new orchards. The effort has required the simultaneous input of University of California's agricultural engineers, plant physiologists, food scientists,

agricultural economists and horticulturists, California's two major table olive processors, multiple commercial mechanical harvester fabricator/contractors, and the support of the California Olive Committee (COC). The project included research cooperators from Spain and Argentina and has been conducted in California, Argentina, and Portugal. The project has had two distinct phases and a long evolution as new harvesters have been evaluated and modified. Only the most recently summarized 2008 and 2009 research results will be given here.

a) Table Olive Mechanical Harvesting Research from 1996 through 1999.

The first phase was initiated in 1996 with a call from the olive marketing order, the California Olive Committee (COC) to harvest equipment fabricators for potential olive harvesters. AgRight of Madera, CA presented a modified wine grape harvester with a "canopy contact" head. Research trials by Ferguson et al. (1999) from 1996 through 1999 demonstrated this picking technology was very efficient if the rods of the harvester head made direct contact with the portion of the canopy bearing fruit. However, the rounded shape of a traditional olive tree rendered all but the portion of the tree canopy within the horizontal and vertical range of the picking rods, and facing the row middles, unharvestable. The harvest head could remove up to 98% of the canopy fruit facing the middle of the row, but fruit above or below the harvester head, or in the canopy between trees, was removed with less than 50% efficiency. Later versions of this machine have multiple heads that could move along a horizontal axis deeper into the canopy, slightly improving the overall harvester efficiency, (Fig. 1). Additionally, the catch frames with the early iterations of the canopy contact head harvesters were incompetent, losing 19% of the fruit removed by the picking head. This overall removal efficiency put final fruit harvester efficiency at approximately 60% or less. Additionally, the fruit was often bruised and cut, Fig. 2, and unacceptable for processing as California black ripe table olives. With the appearance of the olive fly (*Bactercera olea*) in 1999, mechanical harvesting research was discontinued.

b) Table Olive Mechanical Harvesting Research from 2006 through 2009.

Though most California table olive orchards are generally part of a diversified ranch operation, the increasing hand harvest costs and stagnant olive prices of recent years precipitated the removal of an increasing number of olive orchards. The reason was the increasing table olive hand harvest costs were eroding profitability. However, the United States is still the single largest table olive market in the world, giving California growers a marketing advantage. Recognizing this problem, and the potential opportunity, the remaining olive growers organized for the resumption of mechanical harvesting research, again supported by the COC, in late 2005.



Fig. 1. 2008 version of the canopy contact head olive harvester originally modified from wine grape harvesters in 1996. This harvester can be used as one of a pair, or as a single that does both sides of the tree. The head is mounted on a catch frame that conveys the fruit back to a field bin.

When research was resumed in 2006, there were two parallel and equal objectives. The first was to develop an efficient picking technology. Once this was defined, how to propel the harvester, catch the fruit, and convey it to a bin could be designed around the picking technology. The second objective was to identify an abscission compound that would decrease the FRF, and make the harvester more efficient.

As the following results will demonstrate, two viable picking technologies have been identified. However, development of an abscission compound remains as elusive as it has for the past 50 years. (Martin; 1994; Burns et al., 2008) As the

discussion of abscission earlier in this manuscript concluded, development of an abscission in agent, much less obtaining a registration for a crop as small as olives, remains a goal not achievable within the next decade. Both the California and international research from 2006 through 2009 have identified no new potential candidates, and confirmed the earlier results that ethylene releasing compounds are as unreliable as previously demonstrated. (Burns et al., 2008; Martin, 1994) As a result, the mechanical harvesters being developed for the California table olive industry need to achieve economic efficiency without the use of fruit loosening agents.

The two viable picking technologies currently being evaluated are canopy contact harvesting heads and trunk shakers. The canopy contact harvester can be successfully used in existing orchards that have been pruned to a hedgerow. It can also be used for newer, high density orchards trained to a hedgerow. The trunk shaking technology can be used in new high density orchards with straight trunks but is ineffective in older conventionally trained orchards. Interestingly, both have approximately the same final harvest efficiency, from 58% to 63%. However, the mechanism of fruit removal is different, the two machines harvest different parts of the canopy more efficiently, and the potential for tree damage is different. However, the final fruit quality as determined by grade at the receiving station of the olive processor is remarkably similar.



Fig. 2. Bruising and cutting damage produced by early version of canopy contact head mechanical olive harvester in 'Manzanillo' olives destined for California black ripe olive processing.

Improving Harvester Efficiency with Orchard Modification

The new super high density olive oil orchards being developed in Argentina, Spain, Tunisia and California among others were all developed as orchards that could be harvested with existing mechanical harvesters: wine grape, blueberry and coffee harvesters. All are straddle type harvesters with limited height and width. Fig. 3 is an example of a super high density olive orchard being harvested by an unmodified grape harvester.

Our early research suggested high density hedgerow orchards could improve the efficiency of both canopy contact and hedgerow orchards. (Ferguson et al., 1999) Efficiency would improve with canopy contact harvesters because the olives would be more accessible to the harvest head rods as shown in fig. 4. Efficiency would improve with trunk shakers because more of the olives would be closer to the axis of shaking, the main trunk, as shown in Fig. 5.

Based on this concept, a high density hedgerow orchard with three different training treatments was established in 2002. The objective was to produce a tree no more than 4 m tall, 2 m wide and skirted up to 1 m, and spaced at 3.7 m in the row and 5.5 m between rows with 490 trees/ha. The training treatments were a free-standing espalier with all the major structural branches trained within the tree row, an espalier woven vertically through three horizontal wires at 1, 2, and 3 m, shown in Fig. 9, a treatment espaliered and clipped to the trellis wires, and a conventionally trained control. The objective was to determine if these training methods decreased yields per acre.

This orchard began bearing in year 4. None of the three trellised training treatments has a significantly decreased yield relative to the conventionally pruned control. This suggests 'Manzanillo' table olive orchards can be trained and pruned for mechanical harvesting with both canopy contact and trunk shaking harvesters without significant losses in yield. However, data will be collected until the yields plateau for at least three successive years.

The next step in this ongoing research program will be to determine if the canopy contact harvesters and

trunk shaking harvesters will have higher final efficiencies in high density hedgerow orchards, or in conventional orchards that have been topped, hedged and skirted to produce a modified hedgerow. These trials will be conducted in 2010. At that time we also hope to determine the field operating parameters of ground speed, acres per hour, tons per hour and cost per ton and per hour to harvest the olives. The final project goal is an online interactive harvest calculator which will allow growers to enter their orchard parameters to determine if hand harvest or machine harvest produces a better net return.



Fig. 5. Canopy contact head harvester in hedgerow olive orchard.



Fig. 3. Typical super high density olive oil orchard and straddle harvester.



Fig. 4. Nine year old high density, 480 tree/ha, trellised 'Manzanillo' table olive hedgerow planting.

CONCLUSIONS

Interestingly, though olives are one of the world's oldest continuously produced tree crops, the technology of production has remained unchanged through even the industrial revolution, a revolution that had a greater impact on agriculture than any other sector. Now however, the changes in olive orchard development and olive harvesting technology are bringing this traditional crop into the twenty-first century. Within ten years all truly commercial table and oil olives will be mechanically harvested. The research has been an ongoing process of defining and ranking the limiting factors, while pursuing all of them simultaneously. For table olives, two picking technologies have been developed. The most limiting factor, fruit damage, has been eliminated. Now viable harvesting machines must be developed for both picking technologies, and the orchards best suited to these harvest technologies must be defined.

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