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Topics in Subtropics Newsletter

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News from the Subtropical Tree Crop Farm Advisors in California

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Did a Newly Introduced Fukumoto Navel Budline from Spain Perform Better than the California Budline in the San Joaquin Valley?

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INTRODUCTION AND PREVIOUS RESEARCH

Buyers like the fruit of Fukumoto navel, with some asking for it by name. The fruit is early, attractive in shape and color and has good size. However, since its introduction from Japan in the late 1980s (Variety Index-VI 430), many Fukumoto navel trees in the San Joaquin Valley have grown poorly, declined or died. Fukumoto has exhibited what appears to be either a disease, physiological disorder, or greater attraction for ants and associated damage than other navel varieties. One of the most obvious early manifestation of affected trees (although not always present) is the production of a yeasty, frothy foam on the trunk and young branches during hot weather when the tree is two to three years old (Adesemoye et al., 2011). This disorder of Fukumoto navel, foamy bark rot, was named based on this gumming symptom. As the tree ages, whether or not it exhibited earlier symptoms of foamy bark rot, further problems that may develop include: stunted growth of the tree with excessive suckering at or above the graft union. As a result the tree may produce multiple weak scaffolds coming directly from the graft union in addition to delayed fruit maturity, over-growth of the scion and rootstock and in some instances decline and death of the tree. The orchards exhibiting the poorest growth are on trifoliate rootstocks and its hybrids such as citranges. Based on our observations an appropriate name for this group of symptoms would be Fukumoto navel decline (FND) and this is the name that this disorder will be referred to in the remainder of this article.

Declining Fukumoto trees are most obvious and common as the trees reach maturity. Surveys of grower's fields in 2003 and 2004 suggested that decline was not associated with trees coming from a particular nursery or budline source. Although not directly part of this project, affected Fukumoto trees have been tested for various citrus diseases, including citrus tatter leaf virus and citrus leaf blotch virus (associated with citrus graft union disorders on citrange rootstocks) and other viruses, viroids and Spiroplasma citri (stubborn disease), with mostly negative results and without finding any particular common organism among FND trees. Early field observations suggested that irrigation, freeze events and soil pH might be negatively influencing the health of Fukumoto trees. However, experimental work conducted by Craig Kallsen and Neil O'Connell from 2004 through 2009 appeared to exclude irrigation and alkaline soil as causes of FND (Kallsen and O'Connell, 2010). Although the various irrigation and soil alkalinity treatments conducted during the course of this experiment did not produce a differential response in the health and growth of citrus varieties examined, many individual Fukumoto trees in the study demonstrated symptoms of FND.

Poorly performing Fukumoto trees were present in both the irrigation experiment conducted at the U.C. Lindcove Research and Extension Center (LREC) and the alkalinity experiment conducted at the U.C.C.E office in Bakersfield (UCCE Kern). However, affected trees appeared randomly across all irrigation treatments and in pots with both neutral and basic soil pH. Fukumoto trees on citrange rootstocks (i.e. Carrizo and C-35) were more likely to be stunted as reflected in their smaller scion diameters (Figure 1) than Washington navel on these same rootstocks. Fukumoto trees were also more likely to produce large numbers of suckers (i.e. sprouts produced below the graft union) and water sprouts (i.e. scion sprouts produced between the graft union and four inches above the graft union) compared to Washington navel at LREC (Fig. 2) and UCCE Kern (Fig. 3). Production of large number of suckers and water sprouts in many tree crops has been considered a sign of incompatibility of the scion with the rootstock, but may be caused by other factors as well. This excessive sprout production is characteristic of many trees in most Fukumoto orchards. At LREC in 2009, Fukumoto on C-35 rootstock, generally, demonstrated more sprout production than did Carrizo (Fig. 2).

Differential sucker and water sprout production between Fukumoto and Washington navel did not begin to occur at LREC until the third year of the trial (Figures 2 and 4). Citrus trees growing in the 20-gallon pots of the UCCE Kern experiment were usually under considerably more transient water and salt stress than those growing in the ground because of a poorer soil water storage reservoir and poorer drainage. In UCCE Kern, unlike the trial at the LREC, differential sucker and water sprout production between Fukumoto and Washington navel was observed during the first year of the trial (Fig. 3). The average values shown in the tables and figures tend to minimize the actual differences seen in the experimental plots or pots between the best and poorest performing Fukumoto navels for all measured growth characteristics. For example, the number of suckers produced by a given Fukumoto tree varied considerably (Fig. 4). Note, also, that trees that produced excessive sprouts at an early age continued producing high numbers of sprouts as they grew older even though the trunks were shaded by the leaf canopy. Variable performance of individual Fukumoto trees within a grower’s field is commonly observed in commercial orchards as well. Why some Fukumoto trees perform similarly to Washington navel on the citrange rootstocks and other perform poorly remains unknown.

Fire ants were present in the LREC test plot in 2006 and their presence was associated with tree trunk gumming. In some Fukumoto trees, the gum was frothy, with small branches breaking at their attachments to the larger scaffolds as occurs with foamy bark rot. Twenty-four percent (24%) of Fukumoto navel trees were exuding gum, compared to only 9 and 1 % of Washington navel and Clemenules mandarin, respectively, suggesting Fukumoto navels produce more gum and so are more attractive to ants. Observationally, the gumming in Fukumoto not only occurred under the tree wrap as in the other two varieties, but commonly higher on the scaffolds and in the leaf canopy.

Even though tests for graft-transmissible pathogens of citrus have been repeatedly performed in the past by the Citrus Clonal Protection Program (CCPP) with negative results the persistence of the FND problem in California and the absence of FND reports from other citrus producing areas of the world led to the hypothesis that a peculiar disease organism or, perhaps, some physiological problem (e.g. bud sport or spontaneous mutation) may have existed or developed in the original 1980s California budline of Fukumoto navel (i.e. VI 430).

Figure 1

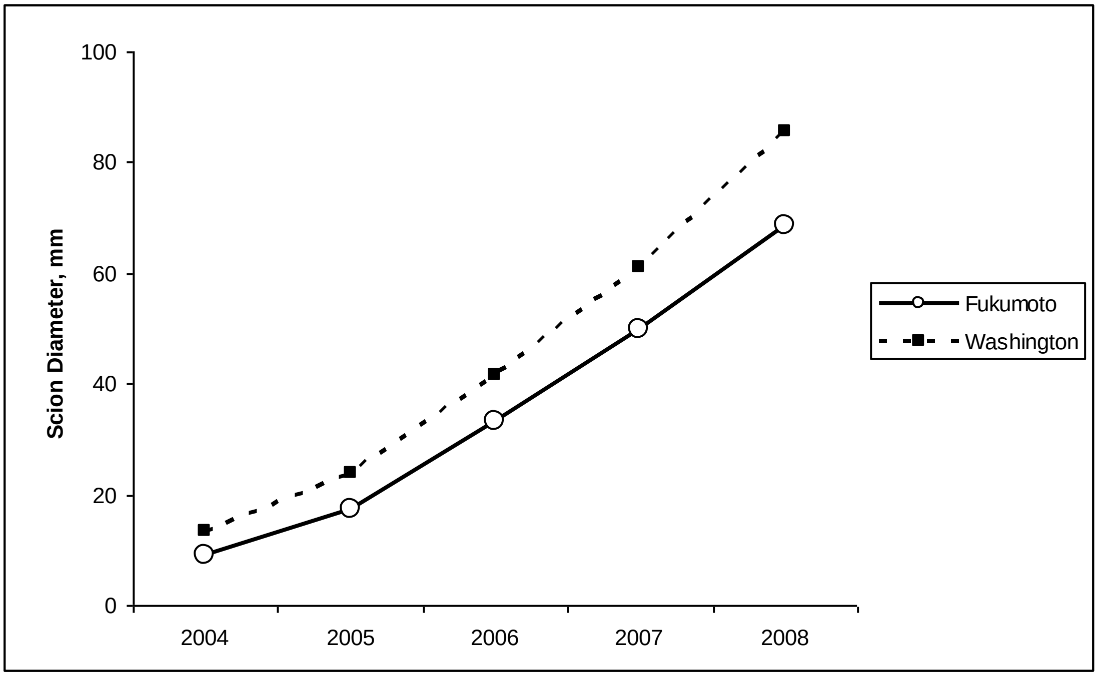

Figure 1. Differences in scion diameter with time between Washington and Fukumoto navel (VI 430) in trees grown on Carrizo and C-35 rootstocks in the highest irrigation treatment at LREC, 2008.

Figure 2

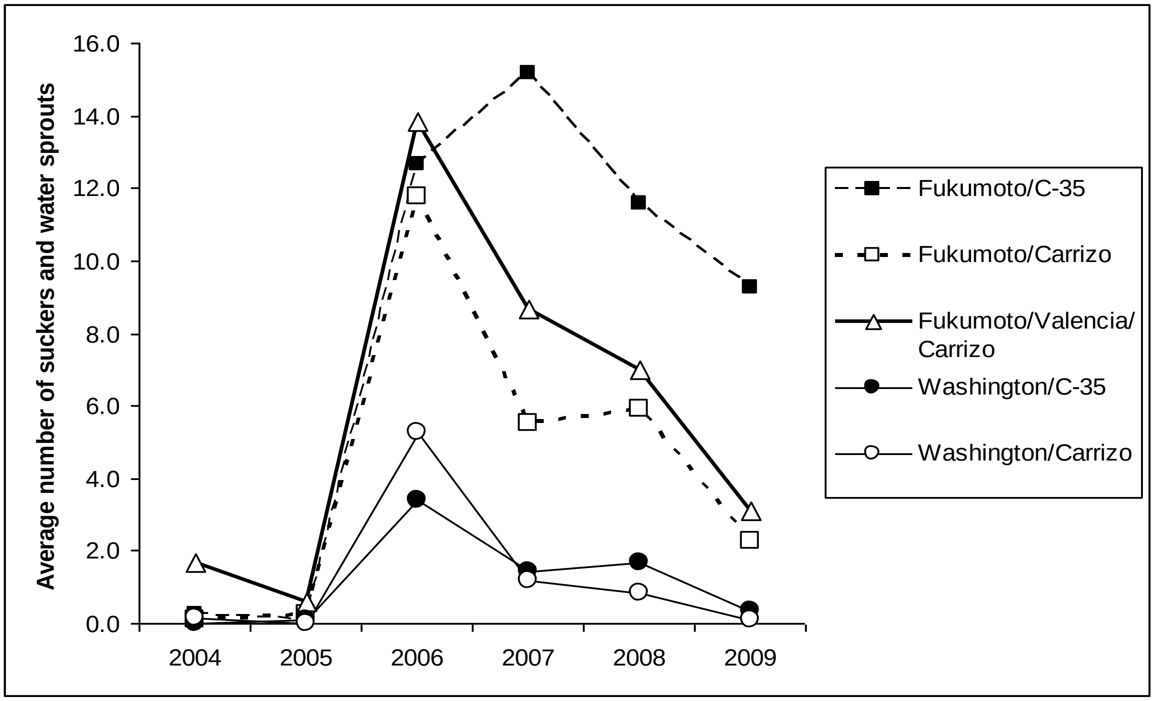

Figure 2. Average number of suckers and water sprouts per tree per year at LREC. For Year 2009, the total is as of June 11. Note that in the legend, the combination of Fukumoto/Valencia/Carrizo represents a tree having a Valencia interstock between the Fukumoto scion (VI 430) and the Carrizo rootstock.

Figure 3

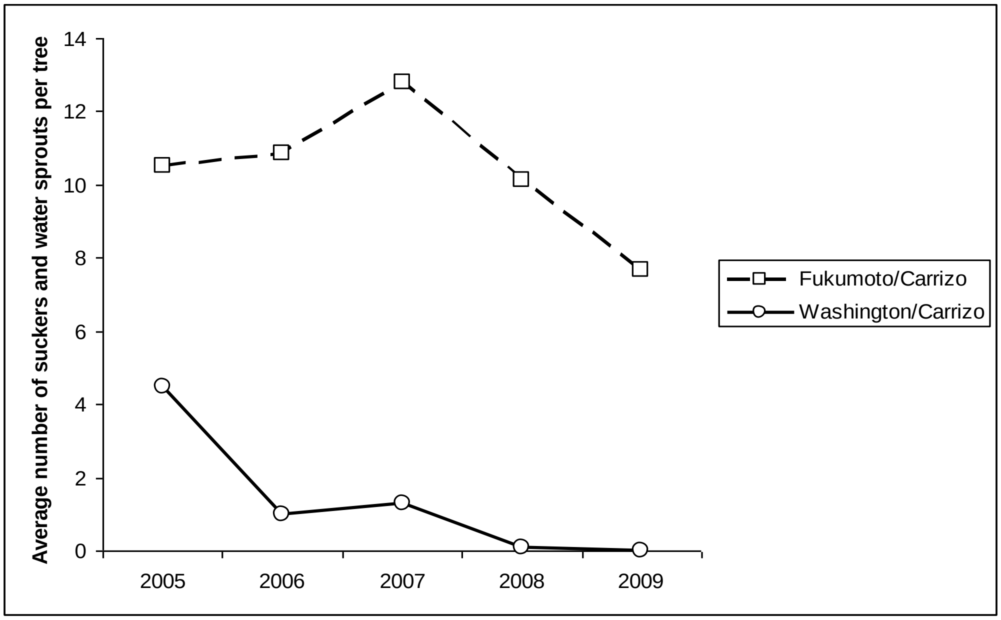

Figure 3. Average number of suckers and water sprouts per Fukumoto (VI 430) or Washington navel tree per year on Carrizo rootstock in large pots at UCCE Kern. For Year 2009, the total is as of June 18.

Figure 4

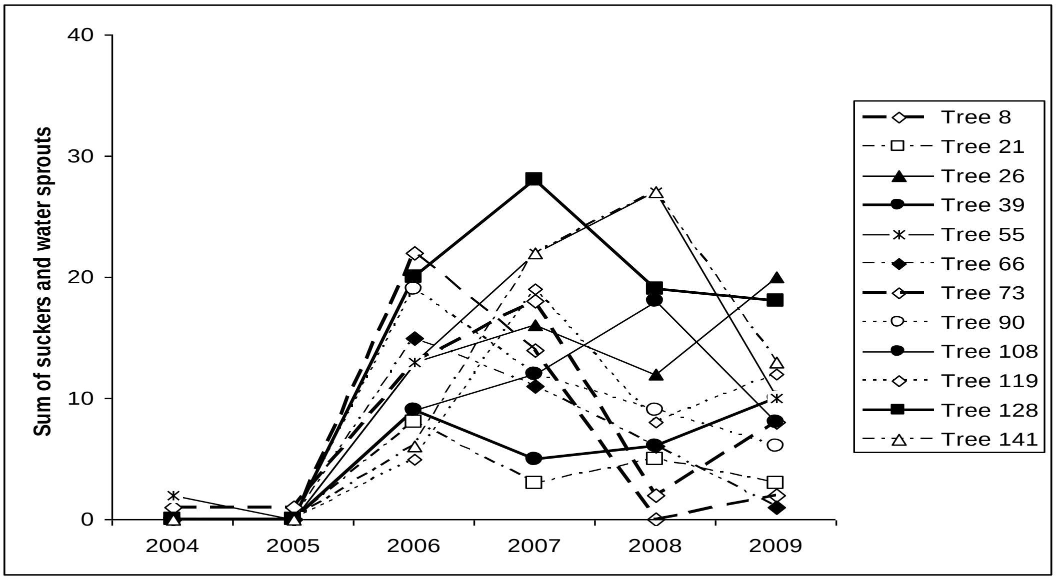

Figure 4. Annual total number of suckers and water sprouts for each Fukumoto tree (VI 430) on C-35 rootstock in the LREC trial (identified by position in the trial regardless of irrigation treatment). For Year 2009, the total number of sprouts is as of June 11.

NEW RESEARCH

During communications with Spanish citrus researchers, growers and nursery-people it was reported to us that in Spain they have not had any problems with Fukumoto on Carrizo citrange rootstock such as the FND observed by California growers even though the Spanish Fukumoto budline was introduced into Spain from California and more specifically the CCPP source of VI 430 (Luis Navarro, personal communication). This report provided the opportunity to test our hypothesis that the 1980s California Fukumoto budline (VI 430) may have acquired a peculiar disease, mutation, or other genetic disorder (i.e. compare side by side the non-FND budline from Spain vs the FND budline from California).

Methods and Materials

In 1983 Fukumoto navel orange budline (VI 430) was introduced into California from Japan via the USDA Glenn Dale quarantine facility at the request of UC Riverside Professor Emeritus Dr. W.P. Bitters. Fukumoto was chosen by Dr. Bitters as the best appearing navel in a Japanese produce display (http://www.citrusvariety.ucr.edu/citrus/fukumoto.html). In June 1984, CCPP performed thermotherapy to the Fukumoto VI 430 budline. In thermotherapy, Fukumoto buds were grafted on to citrange seedlings and wrapped tightly with budding tape. Without pruning the citrange top the seedlings in pots were placed in the hot section of the Rubidoux quarantine greenhouse (28-40°C daytime and 25°C nighttime) for pre-conditioning. Following a one month pre-conditioning the seedlings were placed in a controlled temperature chamber set for 16 hour days at 40°C and 8 hour nights at 30°C for a period of 12 weeks. Upon removal of the plants from the temperature chamber the Fukumoto buds were unwrapped and the top of the citrange rootstock seedling was bent over such that the grafted bud became the terminal or near terminal bud. The plants were then placed in the greenhouse at 20-30^{o}C until sufficient Fukumoto growth occurred for variety indexing (VI). The Fukumoto VI 430 index took place in September 1985 and no known graft-transmissible pathogens of citrus were detected. Four Fukumoto VI 430 trees were planted in the CCPP Foundation Block at LREC in 1987 in Field 55 and two of them were registered with CDFA for budwood distribution (E114 and E115) in 1990.

In September 2007, following the proper federal and state procedures and under a USDA-APHIS-PPQ permit the CCPP introduced from Instituto Valenciano de Investigaciones Agrarias (IVIA), Spain, the Spanish Fukumoto budline (IVIA 364). The Fukumoto IVIA 364 was therapied via shoot-tip-grafting at IVIA, Spain. In shoot-tip-grafting, growing axillary buds from Fukumoto (one or two very small, visible unexpanded leaves), were removed and placed in sterile petri plates on moist, sterile filter paper disks. The extracted tips were disinfected by immersion for 5 minutes in 0.25% sodium hypochlorite and then rinsed three times with sterile distilled water. Very small shoot tips containing the apical meristem and two to three leaf primordia were excised under sterile conditions from the disinfected axillary buds tips and were grafted *in vitro* under dissecting microscope onto 12-16 day old rootstock seedlings obtained by *in vitro* seed germination. The grafted plants were grown in liquid medium in an incubator at 26-27°C and 16 hour days. *In vitro* grown shoot-tip-grafted plants were side grafted to young vigorous rootstocks and maintained under quarantine in an insect-proof greenhouse until sufficient donor material was available for disease testing. When CCPP received the Fukumoto budline (IVIA 364) verified its negative disease status by the VI 778 test in November 2008. Five Fukumoto VI 778 trees were planted in the Foundation Block Field 65G and one tree was registered with CDFA for budwood distribution (1005998) in 2010.

It is worth mentioning here that no FND symptoms were ever observed in the CCPP Foundation Block trees of VI 430 and VI 778 propagated on Carrizo and Trifoliate 16-6.

For more information on thermotherapy and shoot-tip grafting, VI and CDFA registration testing visit:

1. North American Plant Protection Organization (NAPPO, http://www.nappo.org/en/?sv=&category=Standards%20Decisions&title=Protocols)
2. Food and Agriculture Organization of the United Nations (FAO, http://www.fao.org/docrep/t0601e/t0601e00.HTM) and
3. CDFA's Citrus Nursery Stock Pest Cleanliness Program (http://www.cdfa.ca.gov/plant/pe/nsc/nursery/citrus.html)

The CCPP propagated Fukumoto trees on Carrizo citrange rootstock with the 1980s Fukumoto budline VI 430 and with the 2000s Spanish introduction Fukumoto budline VI 778. Trees were compared in a trial planted in May of 2010 on the property of a commercial citrus grower where previous plantings of Fukumoto navel had demonstrated high rates of stunting and suckering. Twenty five Fukumoto trees of the two budlines (13 VI 430 and 12 VI 778) were planted in a single row with east-west orientation in a navel oranges block located near Edison, California. The first tree on the east side of the row was a VI 430 with additional trees then planted alternately with VI 778. The trees in this trial were observed at intervals from 2010 through 2014. On June 3, 2014 tree height was measured and the number of suckers (i.e. shoots originating from below the graft union) and water sprouts (shoots originating from the graft union to point 4 inches from the graft union) were counted. Tree height was measured from the ground to the tallest point of the tree.

Results

Observations made on visits from 2010 through 2013 suggested that trees from the two budlines were growing slowly but similarly. On September 26, 2013 it was noted that two trees from the VI 778 line had died. The cause of death is not known. Measurements made on June 3, 2014 demonstrated that the two budlines performed similarly but sucker and water sprout production was greater in VI 778 (Table 1).

Excessive suckering and water sprout production near the graft union may suggests an increasing indication of graft union incompatibility. Both bud lines produced a relatively high number of shoots from the graft-union area, with the highest combination of rootstock suckers and water sprouts in the VI 778 budline. As was the case with the earlier study (Kallsen and

Table 1. Comparison between VI 430 and VI 778 U.C. Fukumoto bud lines for tree height, no. of suckers and water sprouts, and dead trees as measured on June 3, 2014

bud line	tree height, cm	suckers, number	water sprouts, number	Sum of suckers and water sprouts, no.	Dead trees. % of original trees
VI 430	125.0 a[1]	2.7 a	3.2 a	5.9 a	0.0
VI 778	115.9 a	3.5 a	5.5 a	9.0 b	16.7

[1] different letters in the same column denote statistical differences using one-way analysis of variance and Tukey HSD test at $P \leq 0.05$ for mean separation.

O'Connell, 2010), there was a high degree of variability in shoot production among individual trees, with one tree of VI778 having 15 shoots. The average of 9.0 shoots per tree counted in VI778 conforms to what was found in our earlier study with four-year old Fukumoto trees (Figures 2 and 3 and Photos 1 and 2) and shows no improvement over the original Fukumoto budline VI 430. Tree height in VI 778 was not greater than the VI 430 line either.

Conclusions

The cause of Fukumoto tree decline remains unknown and scion-rootstock incompatibility remains a possibility. Growth of the newly introduced VI 778 budline does not show improvement over the older VI 430 budline distributed from the LREC CCPP Foundation Block since the 1990s. Based on the results from this project the following suggestions are made for growers planting or that currently are cultivating immature blocks of Fukumoto navels:

- Always purchase trees for new plantings from reputable nurseries that use pathogen tested budwood.
- Extra effort in identifying and eradicating southern fire ant infestations is warranted.
- Growers accustomed to growing other navel cultivars, such as Washington navel, may find for similarly-aged trees under similar environmental conditions that Fukumoto navel may require less water than Washington navel as a result of a smaller canopy.
- More frequent tree inspections to remove suckers and water sprouts will be required for Fukumoto compared to other navel varieties, especially beginning in the third year after planting, and earlier, if grown under stressful conditions.
- Fukumoto on Carrizo rootstock, generally, will produce fewer suckers, water sprouts and stunted trees than on C-35, although both rootstocks have been associated with severe decline in some orchards.
- Early replacement of stunted trees that have both excessive sucker scars and small diameter scions compared to the rootstock appears advisable.

Citations

Adesemoye, A., A. Eskalen, C. Mayorquin, C. Roper, P. Wang, G. Vidalakis, C. Kallsen and N. O'Connell. 2011. Understanding 'foamy bark rot' of Fukumoto navel. Citrograph 2 (7) : 26-28.

Kallsen, C.E. and N.V. O'Connell. 2010. Scion/rootstock incompatibility as the cause of tree decline in Fukumoto navel in the San Joaquin Valley. Citrograph 1(3):20-24.

Photos 1 and 2. Four-years-old Fukumoto budlines VI 778 on left and VI 430 on right on Carrizo citrange rootstock showing typical proliferation of shoots on rootstock and scion of Fukumoto trees. Pictures taken 6/3/2014 by Craig Kallsen.

Photo 3. Fukumoto VI 430 and VI 778 budlines test plot, near Edison, California, showing four-year-old Fukumoto trees. Picture taken 6/3/2014 by Craig Kallsen.

What values should olive growers use for estimating crop nitrogen removal at harvest?

Elizabeth J. Fichtner, Farm Advisor, UCCE Tulare County

With the implementation of the Irrigated Lands Regulatory Program, olive growers have expressed interest in gaining a more comprehensive understanding of the amount of nitrogen (N) removed by the crop at harvest. There are two components to estimating the quantity of N removed at harvest: 1) the size of the crop, and 2) the amount of N incorporated in the fruit.

Distribution of nitrogen in the olive tree. Leaves are the largest N sink of the olive tree. Approximately 44% of the tree's aboveground N is incorporated in the foliage. The twigs, secondary branches, main branches, and trunk account for approximately 33% of the N stored in the aboveground portion of the tree. Last, the fruit account for around 23% of the aboveground N, with close to 19% incorporated in the flesh. These estimates are based on research published in Scientia Horticulturae (Rodrigues, et al) (Figure 1). The published data was gathered from a dry-farmed *Olea europaea* cv. Cobrancosa orchard in north-eastern Portugal.

Interestingly, the estimated N-removal rates in fruit from the test-orchard in Portugal are similar to values estimated by Rosecrance and Kruger for three oil olive cultivars in California. An estimate of N removal from the dryland crop in Portugal is 8.23 lbs N/ton fruit; similar estimates for irrigated Arbosana, Arbequina, and Koroniki in California are 6.30, 6.81, and 7.45 lbs N/ ton fruit, respectively. The main consideration when comparing crop N removal between the dryland and irrigated systems is the anticipated yield. For example, the test-orchard in Portugal had an anticipated average annual yield of 1.11 tons/acre; both table and olive oil growers in the central valley anticipate an annual average yield of 5 tons/acre. Although anticipated N removal per ton of fruit may be similar in irrigated vs. dryland systems, the N-use efficiency (NUE) will likely vary

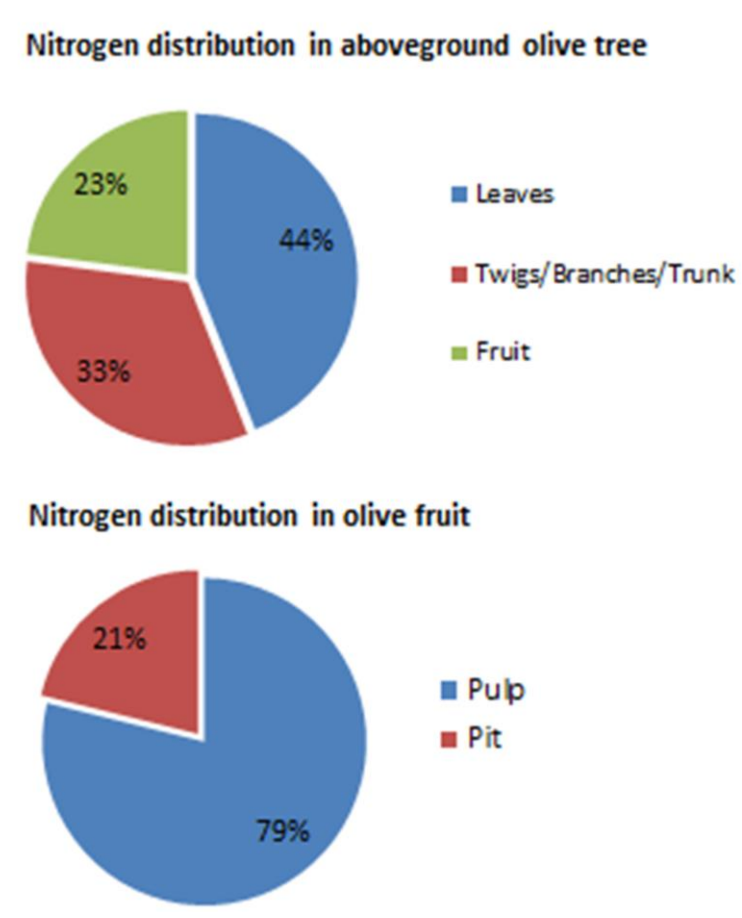

Figure 1. Pie charts illustrate estimates of distribution of nitrogen in the aboveground portion of the olive tree and the fruit. Data was gathered from Rodrigues, et al., based on studies conducted in a rainfed orchard of *Olea europaea* cv. Cobrancosa in northeast Portugal.

considerably between systems. Nitrogen use efficiency is calculated as the N taken up by the crop divided by the N applied to the orchard. In dryland systems, NUE is estimated at 50-75%; however, the N is applied near the conclusion of the winter/spring rainy season, ensuring less N loss due to leaching. I've heard grower reports of N use ranging from 50 lbs/acre to 90 lbs/acre in California olive orchards. If we assume a crop removal rate of 35 lbs N/acre (5 ton/acre x 7 lbs N/ton), then NUE's may range from around 39%-70% in irrigated, California olive systems.

Timing of fruit demand for nitrogen. Fruit is only an important N sink during the initial phase of growth. As fruit size increases, the N concentration decreases (Fernández-Escobar et al., 2011). In fact, the pulp is a higher sink for all nutrients than the pit (Rodrigues, et al).

Summary. Estimated N removal by the crop at harvest will likely range from 6.3-8.2 lbs N/ ton. To estimate the total N removed per acre, simply multiply the total tons/acre by a reasonable estimate of lbs N/ton (ie. 7.2 lbs N/ton). Alternately, oil growers in CA may prefer using the online 'Olive Calculator' tool produced by Richard Rosecrance, Professor, CSU Chico and Bill Kruger, Emeritus Farm Advisor, Glenn and Tehama Counties. The 'Olive Calculator' website can be accessed at the following URL: http://www.csuchico.edu/~rrosecrance/Model/OliveCalculator/OliveCalculator.html

The 'Olive Calculator' website additionally addresses the total suite of nutrients lost from the orchard at harvest and allows growers to access estimates from each of three cultivars: Arbosana, Koroniki, and Arbequina.

Select References:

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Irrigated Lands Regulatory Program: http://www.swrcb.ca.gov/water_issues/programs/agriculture/

Olive Calculator: http://www.csuchico.edu/~rrosecrance/Model/OliveCalculator/OliveCalculator.html

Rodrigues, M.A., Isabel Q. Ferreira, I.Q., Claro, A.M., Arrobas, M. 2012. Fertilizer recommendations for olive based upon nutrients removed in crop and pruning. Scientia Horticulturae 142:205-211.

UPCOMING COURSES

UC Davis Olive Center: UC Master Milling Certificate Course

Lead by one of the world's top olive oil experts, Leandro Ravetti, this four day course will cover the ins and outs of olive oil milling.

When: October 1 – 4, 2015

Where: Silverado Vineyards Sensory Theater, Robert Mondavi Institute for Wine and Food Science, 392 Old Davis Rd., Davis, CA 95616-8571

Course Description: Experience the best olive oil milling course in the United States at UC Davis, presented by the UC Davis Olive Center at the Robert Mondavi Institute.

The course will be led by Leandro Ravetti, among the world's top experts in olive oil processing, growing, and standards. As executive director of Australia's Boundary Bend Limited, Leandro has helped guide the company to rapid growth, high efficiency, and top awards at international olive oil competitions. The company's success is guided by innovation, data, and analysis to maximize oil production efficiency and quality.

The four-day course will be held at the Silverado Vineyard Sensory Theater at the Robert Mondavi Institute for Wine and Food Science. The course will include a field trip to three olive oil processors in Yolo County, including to Boundary Bend's new U.S. facility in nearby Woodland. Olive oil will be processed on site at UC Davis by Olive2Bottle Mobile Services.

Past attendees of the Master Milling Short Course have made immediate improvements in the quality and profitability of their oil processing operation. This course is a small investment that will pay off in more efficiency, better quality, and higher profits.

Registration

Online registration can be accessed through the UC Olive Center website: http://olivecenter.ucdavis.edu/. Registration for the 4-day course will be $1,025 until August 1, 2015, $1,225 after August 1, 2015.