Topics in Subtropics Newsletter

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News from the Subtropical Tree Crop Farm Advisors in California

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Mycorrhizae: An Underground Support Network for Trees

Philippe Rolshausen, Professor of Cooperative Extension, UC Riverside

Mycorrhizae means fungus (myco) root (rhizae). These root-associated fungi predate the evolution of terrestrial plants, and the partnership with mycorrhizal fungi facilitated the establishment of plant on earth. Mycorrhizae form symbiotic associations with more than 70% of land plants across a broad range of terrestrial ecosystems. Plants supplies mycorrhizae with photo-assimilated carbon in exchange for nutrients and water. This is the definition of a perfect relationship whereby the two sides support each other and have a personal interest at maintaining their counterpart well-being for survival. Once mycorrhizae colonize the host plant, its mycelium can grow over large distances to neighboring plants connecting them together by a common network. This extension of the root network allows plants to acquire water and nutrients (especially nitrogen and phosphorus) far beyond its root zone, rendering plants more resilient to drought and nutrient deficiency. The ability of mycorrhizae to form this underground web also enables the connected plant to communicate with each other through chemical signals and exchange water and nutrients. For example, in forest ecosystems, saplings rely on nutrients and carbon supply from older trees sent through the mycorrhizal network. This underground mycorrhizal web has also great physical properties because they improve the soil structure by forming stable soil aggregates thereby limiting erosion and leaching of nutrients.

Several studies have highlighted the instrumental role of these beneficial fungi in several cropping systems, including tree crops. In citrus for instance, they have been shown to delay diseases caused by soilborne pathogens such as *Fusarium* and *Phytophthora*. We also think that these fungi play a key role in the citrus Huanglongbing (HLB) pathosystem by protecting trees from suffering root loss. Results from our recent survey in Florida showed that healthy trees were more frequently associated with a biodiverse mycorrhizal population whereas declining trees rarely formed a symbiotic association with mycorrhizae and were frequently infected with *Phytophthora* and *Fusarium*. We think that tree decline is due not just to HLB infection in the aerial portions of the tree but also to large sectors of the root community shifting toward microbes that engage in pathogenic and saprophytic relationships with the host.

If you are a grower, how do you ensure that trees in your orchard have mycorrhizae? Well, this is where the challenge resides because the intricate relationship between the fungus and its host is not easy to replicate on command in the field. Several commercial products are available to use but it is unclear how efficient exogenous applications of mycorrhiza inocula are. Nurseries have increasingly used commercial inoculum, and data showed that it is a great way to improve productivity for some annual plants (see figure). But science is still lacking to evaluate if the symbiotic relationship can last for trees after planting and how it translates to the orchard life with respect to tree performance and longevity. An efficient way to foster relationship between plants and mycorrhizae is to adopt mycorrhizae-friendly practices. In general, low input agriculture systems that rely on soil fertility and microbial activity are conducive to mycorrhizae. One of our recent studies compared organic and conventional farming practices in California citrus orchards and showed that the former has much higher mycorrhizae biodiversity and more frequent association with trees than the later. Mycorrhizae are sensitive to conventional agrochemicals. Foliar fungicide application runoffs and glyphosate treatments have been shown to negatively affect these fungi. Similarly, high input of inorganic nitrogen and phosphorous are detrimental to mycorrhizae. In general, practices that increase organic matter in soils (compost, manure), planting of cover crops, low to moderate dose of N and P organic fertilizers and avoidance of soil disturbance (tillage) favor mycorrhizae establishment and biodiversity. Yet, a lot more needs to be accomplished before we can fully exploit this powerful underground resource.

Plant root system with and without mycorrhizae

Source: https://www.nurserymag.com/article/mycorrhizal-applications-brand-spotlight/

Notes on Applying Gibberellic Acid (GA3) to Navel Orange and other Citrus in the San Joaquin Valley of California

Craig Kallsen, Citrus and Pistachio Farm Advisor, Kern County

Typically, the price of navel oranges drops during the peak of the navel harvest season. When the peak harvest is over, prices often increase for navels that are harvested later. There is no mystery here. The price curve is merely following the law of supply and demand. When supplies are plentiful for most commodities, prices fall. Products containing gibberellic acid (GA3) are registered and available to citrus growers. For many decades growers have been extending the harvest season of navel oranges by application of plant growth regulators (PGRs) such as gibberellic acid to retard navel orange rind maturity in combination with the isopropyl ester of 2,4-D to prevent pre-harvest fruit drop. Citrus fruits, generally, store on the tree much better than in refrigerated facilities. Growers also have the option of replanting mid-season maturing orange orchards with late-maturing navels (and have been doing so). Generally, the late navels do not require application of PGRs such as GA3. However, for those that do not have the luxury of having late-maturing navels in the orchard, PGRs provide an opportunity to take advantage of higher prices that may come with a later harvest. The following "notes" may help the grower in successfully timing and applying PGRs to navel oranges. Always read and follow label directions of any chemical product carefully before using.

Note 1: Dr. Coggins, a former professor at the University of California in Riverside, spent many years researching the use of foliar-applied GA3 to prolong storage of navel oranges on the tree (for more info see: https://www2.ipm.ucanr.edu/agriculture/citrus/Delaying-Fruit-Senescence-with-Gibberellic-Acid-GA3/). The late September to mid- October application window, was found to be best time to apply GA3 to navels in the San Joaquin Valley for reducing puff and crease, rind staining, and, generally, for maintaining a more juvenile rind longer. Applying the gibberellic acid two-weeks before the fruit begins to change color from green to orange (called "color break") remains a handy rule-of-thumb. Color break in mid-season navels (like Washington, Frost Nucellar, Atwood and others) usually occurs about two weeks after color break in the early navels (like Beck and Fukumoto). Dr. Coggin's research showed the GA3 was significantly more effective when a nonionic silicon-based surfactant was included with the spray as an adjuvant. Note that the addition of an effective surfactant can increase the chance and/or severity of significant leaf drop. Always follow the surfactant's label carefully and make note of any cautionary statements regarding phytotoxicity.

Note 2: Treating with an auxin (an isopropyl ester of 2,4-D is registered for this purpose) in November or early December is necessary if fruit is treated with GA3. The auxin prevents fruit from dropping too early. There is no point in delaying the maturation of the rind with GA3 into April or May if the navel is going to drop from the tree in February.

Note 3: Uptake of GA3 by the peel is improved if the spray solution is acidic. A pH of the spray solution of about 4 to 5 is recommended and several acidifying agents and products are available to accomplish this. Zinc sulfate, applied at a rate of 1 lb. of zinc sulfate/100 gallons of spray solution, has been used as an acidifying agent with gibberellic acid, which, also, helps correct zinc deficiency. Obviously, many other acidifying and buffering agents are available. In general, tank mixing other pesticides or nutrient solutions with GA3 should be avoided.

Note 4: Growers have obtained good results with GA3 applications using the labeled rates of GA3 on a weight-of-product-per-acre basis using dilute or concentrated sprays. Whichever option is selected, good spray coverage of the fruit is essential, and all else being equal, better coverage is more likely with higher spray volumes. Most of the beneficial results of GA3 are obtained with about 25 grams (active ingredient) of gibberellic acid per acre.

Note 5: Not uncommonly, a navel grower in Kern County will report a significant drop of fruit and leaves as a result of a GA3 spray. Usually in these cases, GA3 was sprayed within a week or two of a narrow-range oil spray. There appears to be a connection here, but GA3 and oil have been sprayed a few days apart with no observed phytotoxic effects. However, erring on the side of caution suggests avoiding spraying petroleum oils and GA3 within a few weeks of each other. Make sure when applying either GA3 or oil that the trees are not under water stress and that GA3 or oil are not applied to trees that show phytotoxic affects from either a previous oil or other chemical spray. The addition of a spreader adjuvant may increase the risk of leaf drop with gibberellic acid. Monitor soil-water carefully in the fall before gibberellic acid or oil is applied. The temptation is to reduce irrigation too much in response to the first light rains of fall. Often these rains, especially in the southern San Joaquin Valley, will not meet the evapotranspiration requirements of citrus, especially on the hilltops where soils are thin, leaving the trees more susceptible to damage from chemical spray applications.

Note 6: Gibberellic acid works best on blocks of fruit that normally hold well on the tree. Past harvest records can play an important role here. A good strategy is to harvest blocks that are prone to early rind breakdown first and to treat only blocks where the fruit naturally holds longer with GA3. Applying GA3 to an orchard with poor fruit-holding qualities may extend the life of the fruit a few weeks, while applying it to fruit of a good-holding block may give the grower an additional six to eight weeks of tree storage.

Note 7: Sometime fruit does not grow as quickly as a grower would like, and a block that was scheduled for an early or mid-season harvest may be rescheduled for a late season harvest. Gibberellic acid applications can still delay harvest (although not for as long a period of time) if treated later than October. Do not apply GA3 to fruit that is in the process of changing color. A permanently two-tone fruit may result. If fruit is in the process of changing color, wait until the fruit has turned completely orange and then apply the gibberellic acid. Check the label for application timing. Gibberellic acid can negatively affect next year's crop if applied too late.

Note 8: Gibberellic acid and an isopropyl ester of 2,4-D can also be applied to some other citrus fruit with useful results. Read and follow the labels carefully before applying the commercially available PGRs. Label directions include crop registrations, uses, timings, rates, cautions and other necessary information that will vary with citrus variety. Puff and crease and rind staining of Minneola tangelo, lemons, and some mandarins may be reduced and fruit storage on the tree may be extended by the use of these growth regulators. The timing of application is similar to that of navels in most cases.

Note 9: Late harvested navel varieties have been readily available to citrus growers in California now for over four decades. Late maturing navels are not as likely to require the addition of gibberellic acid and 2,4-D to produce high-quality fruit late in the season. Growers wishing to compete in the late-navel market are encouraged to plant one of the many late navel varieties.

Saline Waters - A Growing Problem

Ben Faber, Subtropical Horticulture, Ventura/Santa Barbara County

Irrigated agriculture must always contend with salts, but two years without rain and a dry winter forecast, salt is an even more important issue. We rely on winter rainfall to leach the salts from root zones that have accumulated from previous irrigations. Salinity affects plant growth and understanding what it is and how it is measured and evaluated need to be understood.

All waters, even rainwater, have some salts dissolved in them, so all waters could be called saline. The term saline is restricted to waters with concentrations that could cause harm to plants or people. Seawater is highly saline, many wells are moderately saline. But unlike humans that excrete salts, plants are often affected by salt levels that have very little health impact on humans. Well waters used for irrigation can often exceed standards for plants that are fit for human consumption. However, with proper management many waters can be used on plants, depending on the plant species. Domestic water supplies from cities typically have better quality than some well waters because they are monitored and often blended to meet human consumption. Most domestic water supplies have low concentrations of salts and are not considered to be saline. However, using even domestic water in growing subtropicals does not mean that we should not be concerned about salinity.

Before going any further it is worth remembering that salt is not just the sodium chloride that's on the table. Salts are combinations of electrically charged ions. These ions separate from one another when a salt dissolves in water. Water with dissolved sodium chloride and potassium nitrate contains sodium, potassium, chloride and nitrate ions. The most common ions in natural waters are: sodium (Na+), chloride (Cl-), sulfate (SO42-), calcium (Ca+), boron (H3BO3), magnesium (Mg+), and bicarbonate (HCO3-). Different waters can have very different proportions of these ions and these proportions can change with time. Some typical analyses of City of San Buenaventura water can be seen in the following chart (2005 Annual Report of the City of San Buenaventura).

Ionic composition of some wells in Ventura

Sample	Na^+	Ca^+	Mg^+	Cl^-	SO_4^{2-}	TDS	EC
	(mg/l)						(umhos/cm)
1	200	259	70	92	839	1668	1990
2	45	92	191	44	210	645	874
3	28	59	21	20	140	316	580

Total dissolved solids (TDS) and electrical conductivity (EC) are two different ways of measuring the total amount of salts in water. The old way of taking a specified volume (l for liter) of water and boiling it down to the residue which is weighed (mg for milligram) gives TDS. The more modern technique is to measure the electrical current a water will carry (umhos/cm or micromhos/cm), which is in proportion to the number of ions in the water.

Natural waters also contain low concentrations of many other elements. For most, the amounts are too low to be either harmful or beneficial to plants. The main exception is boron which can be a problem for sensitive plants, such as citrus and avocado and probably for cherimoya as well, when in excess of 1 mg/l. Many well waters in Santa Barbara and Ventura Counties contain potentially harmful levels of boron for plants. This is not as common a problem in San Diego County.

In addition to the ions mentioned, there are also those that come from fertilizers and the soil. The main extra ions are potassium, ammonium, nitrate and phosphate. The concentrations of these will depend on the type of soil and the amounts and kinds of fertilizers applied, minus the amounts taken out by plants, held by the soil and lost by leaching or erosion.In evaluating a water for its potential to harm plants, it is necessary to look at total salinity, as well as the specific ions. Waters with a TDS in excess of 1000 mg/l or an EC greater than 1500 umhos/cm might pose problems for sensitive subtropical plants, and none at all to tolerant plants like figs, apricots or pomegrantes. Waters with an excess of sodium and/or chloride (more than 100 mg/l) can induce symptoms that are similar to high levels of salinity. In most cases, plants respond by initially having their leaf margins turn yellow and die. This happens first on older leaves because they have had the longest time to accumulate the ions. Annual plants are often less affected than perennials, since they do not grow long enough to accumulate sufficient ions to cause damage. As trees remove water from the soil, the concentration of salts in the remaining soil water increases. Plants adapt to moderate increases, but if the plant is sensitive (and most subtropicals are), it will slow growth in response. If the salt increase is small, the growth reduction will be small and acceptable. But if the level of fertilizer use is high, the water quality poor, or the soil has not been properly leached, the increased soil salinity could reduce growth seriously.

The effects of salinity are usually gradual on plants, unless too much fertilizer has been suddenly applied or strong, dry winds causes rapid drying. Also, with some domestic water there is variation in concentration and kinds of salts in the water with time. The 200 mg/l of sodium in water sample 1 on the chart would be a problem if this were what the homeowner continuously received. However, according to city data, this house does get 94 mg/l at times (not on the chart). The better-quality water serves to flush out the higher concentration salts. And this is how to practically deal with poorer quality water, occasionally leach the soil with a volume of water in excess of plant need. When there are no leaching rains, we need to be more aware of the potential for salt accumulation in the soil. With proper plant selection and water management even extremely saline waters can be used.

Water Terminology

The ions in water are measured as parts per million (ppm) or milligrams per liter (mg/l), terms which are interchangeable. This is like saying a percent, but instead of the ions' weight per 100 weight of water, it is the ions' weight per million weight of water. The ion concentration also can appear as milliequivalents per liter (meq/l). A milliequivalent is the ppm of that ion divided by its atomic weight per charge. Example: Ca2+ with atomic weight of 40 and a solution concentration of possibly 200 ppm. Ca2+ has two charges per atom, so it has an atomic weight of 20 per charge. 200 ppm divided by 20 = 10 meq of calcium for a liter of water.

- **Total Dissolved Solids (TDS):** measure of total salts in solution in ppm or mg/L.
- **Electrical Conductivity (EC):** similar to TDS but analyzed differently.

Units: deciSiemens/meter(dS/m) = millimhos/centimeter (mmhos/cm)= 1000 micromhos/cm (umhos/cm). Conversion TDS<->EC: 640 ppm=1 dS/m=1000 umhos/cm

- **Hardness:** measure of calcium and magnesium in water expressed as ppm CaCO3
- **pH:** measure of how acid or base the solution
- **Alkalinity:** measure of the amount of carbonate and bicarbonate controlling the pH, expressed as ppm CaCO3.
- **Sodium Adsorption Ratio (SAR):** describes the relative sodium hazard of water. SAR= (Na)/((Ca+Mg)/2)1/2, all units in meq/l. There is also an Adjusted SAR which considers the carbonate and bicarbonate present, but does not do much better in predicting plant response.

General Irrigation Quality Guidelines (U.C. Leaflet 2995, 1979)

Measurement	No Problem	Increasing	Unsuitable
Effect on Plant Growth			
EC (dS/m)	< 0.75	0.75-3	> 3
Na^+ (SAR)	< 3	3-9	> 9
Cl^- (ppm)	< 140	140-350	> 350
H_3BO_3 (ppm)	< 0.5	0.5-2	> 2
Effect on soil permeability			
EC (dS/m)*	> 0.5	< 0.5	
SAR	< 6	6-9	> 9

*1.5 feet of water with EC of 1.6 dS/m adds 10,000 # of salt per acre

35th Anniversary of the Nematode Quarantine Facility
at the University of California Riverside

J. Ole Becker and Jennifer Smith Becker, Department of Nematology, UCR

The Nematode Quarantine and Isolation Facility (NQIF) at the University of California Riverside (UCR) is one of those hidden gems that former TV personality Huell Howser would have called "part of California's Gold". Thirty-five years after its completion, its value is still unquestionable. It remains one of the few US facilities focusing on researching invasive nematode pests and their potential threat to the country's largest agricultural industry.

What are nematodes?
Nematodes are typically microscopic worms that occur everywhere on earth. They are by far the most abundant animals on our planet, accounting for about four-fifths of all animals. Most of them live in soils and sediments of oceans, rivers, and lakes. They play an essential role in the structure and function of the food web. While their activities and services occur primarily unnoticed by the general public, a few nematode species have a more notorious reputation as parasites of humans, animals, and crops. Annual crop damage caused by plant-parasitic nematodes (ppn) is estimated at 12% of world crop production or > US$ 200 billion. For California, a conservative estimate is 5% or about $1.5 billion of income lost annually.

What is the difference between introduced and invasive nematodes?
Both introduced and invasive nematode species are not native to a particular state or region. Introduced nematodes are likely to have no significant adverse effects on their new environment. In contrast, invasive species have the potential to harm the environment and/or cause economic damage. For example, the pine wilt nematode (*Bursaphelenchus xylophilus*), native to North America, is responsible for enormous pine losses in Japan, China, Portugal, and other countries.

What initiated the need for the Quarantine Facility?
By the mid-1960s, the citrus race of the burrowing nematode *Radopholus similis* caused a devastating decline in citrus production in central Florida. Yield reductions reached 40-70% in typical orchards. The observations alarmed California nematologists, and the local citrus industry feared the potential introduction of the invasive nematode. As a precaution, the plan arose to study the ecology and management of the burrowing nematode and other invasive species at UCR under secure containment conditions. The imminent threat became the primary reason to plan for the construction of the NQIF. It took until 1982 and the former UCR Nematology Department Chair Seymour Van Gundy's tireless efforts to lobby for funding for the building.

What are the key features of the facility?
The building's laboratory, potting, and tissue culture rooms comprise approximately 1600 ft2; the remaining 122 ft2 are greenhouse facilities with four separate compartments. All nematode cultures, infested plants, soils, potting media, tissue cultures, contaminated tools, and containers are maintained under quarantine conditions until they are destroyed or decontaminated by heat or biocides. Physical design, restricted access, strict permitting, policy guidelines, and personnel training ensure the maintenance of secure containment. Wastewater from the laboratory sinks and greenhouse irrigation is captured in two 3600 gallon sealed concrete tanks. When one chamber is filled, the inlet valve is closed, and wastewater is diverted into the second tank. The contaminated water is heated with steam to 160˚F for at least 3 hours, then allowed to cool overnight before being released into the Campus sewer system. The facilities and procedures are annually inspected by personnel of the Pest Exclusion, Division of Plant Industry, California Department of Food and Agriculture (CDFA), and occasionally by the USDA, Animal and Plant Health Inspection Service (APHIS).

What was an important project during the past decades?
The invasive sting nematode (*Belonolaimus longicaudatus*) was discovered in golf courses of the Coachella Valley by UCR Nematologists in 1992. The CDFA initially classified the nematode as a class

"Q" rated pest suspected of economic importance but uncertain because of insufficient information. An "A" rating would have required state-enforced measures such as quarantine and eradication efforts. Years of intensive research led to various scientific publications and magazine reports. We were the first to culture the nematode on roots in transparent media. It allowed us to microscopically observe the nematode's entire life cycle and determine requirements for the completion of one generation (24 days at 82.4˚F). Genetic population analysis suggested a single introduction with sod or other plant material from the southeastern US to a private golf course in the Coachella Valley. It was likely followed by the inadvertent spread of infested soil to adjacent golf courses. Extension presentations focused on reducing the risk of dissemination of the nematodes with turfgrass equipment. Thirty years after its discovery, now a class "A" pathogen, the California sting nematode is still limited to the few golf courses around Rancho Mirage where it was first recorded.

What projects are currently ongoing?

Recently, the non-indigenous peach root-knot nematode, *Meloidogyne floridensis*, was found in two California almond orchards and a vineyard. Its wide host range includes vegetable cultivars and prunus rootstocks that are resistant to the Southern root-knot nematode *M. incognita* and related species. It is an "A" rated pest in California. Several pathogenicity trials with various fruit and nut rootstocks were conducted in two quarantine greenhouse chambers to screen for potential host resistance against the pest. Potential candidates for breeding purposes were identified.

The discovery of the Texas peanut root-knot nematode (*Meloidogyne haplanaria*) in infested American pitcher plants at Huntington Gardens added some unusual and beautiful carnivorous plants to our quarantine trials. Currently, the nematode is "Q" rated by the CDFA. Our immediate objective is to explore methods of eliminating the nematode from the infested rhizomes to save the collection at Huntington.

As part of integrated pest management studies, we investigate the efficacy of microbial biocontrol organisms against invasive cysts and other plant-parasitic nematodes. *In vitro* techniques were devised to isolate and test novel biocontrol species. The experiments will also try to pinpoint the likely mode of action for microbial antagonism or parasitism. These projects are conducted as precautionary research to respond appropriately when invasive nematodes might be introduced to California.

Future outlook

Global trade and budget constraints for border inspections of plants, roots, or produce require securing the airports, harbors, and truck routes against pest and disease introductions, a tough challenge. In California, insect researchers estimate the arrival of one new invasive species each month. Nematologists must also maintain vigilance, even though the CDFA has reported relatively few invasive nematode species during the past decades. Several economically critical plant-parasitic nematodes are real threats to California's agricultural industry. Our NQIF is a small but essential facility for investigating and mitigating potential introductions.

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