Topics in Subtropics Newsletter

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News from the Subtropical Tree Crop Farm Advisors in California

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Topics in Subtropics

ESTIMATING NITROGEN CREDITS FROM ORGANIC MATTER SOURCES IN ORCHARDS

ABSTRACT

Addressing N availability from organic matter sources in orchards, and in turn estimating appropriate N credits used in nutrient budgets remains a challenge. Soil health practices like cover crops and organic matter amendments add organic matter (OM) to soil in order to improve water holding capacity and maintain N in orchard top soil, thereby reducing the potential for nitrate leaching. Organic matter added to the soil contains N, however the rate at which that N becomes plant available varies dramatically depending upon on the organic matter source. We reviewed twelve extension publications across the U.S. and extracted 90 data points estimating N availability coefficients for total N inputs from different organic matter sources at one or two years after application. Year one coefficients varied for different organic matter sources including compost from -8 to 28%, beef or dairy manure solids from 16 to 40%, poultry manure solids from 24 to 52% and cover crops from 8% to 48% of total N inputs. Less data was available for year two coefficients including one data point for compost at 5%, beef or dairy from 8 to 24% and poultry from 8 to 16%. Additional parameters need to be considered when estimating N credits from organic matter sources in orchards including 1) application in tree row or alleyway; 2) application postharvest before winter rains or in springtime; 3) proportion of orchard soil wetted by irrigation water and; 4) no-till practices or use of incorporation to manage organic matter. Different N sources offer growers options to balance nutrition for orchard crops. In combination with the right rate, timing and placement, the right N sources optimize productivity and minimize N losses.

INTRODUCTION

In California, orchard crops like almond, walnut, stone fruits, olive, citrus, and avocado are planted on nearly 2 million acres and rely heavily on fertilizer and irrigation water for high productivity. These trees can effectively utilize different N sources to meet the high annual N demand for fruit and tree growth. Different fertilizer formulations like urea ammonium nitrate are widely and effectively used, and readily available for uptake. Yet, addressing N availability from organic matter sources in orchards, and in turn estimating appropriate N credits used in nutrient budgets remains a challenge. Soil health practices like cover crops and organic matter amendments add organic matter (OM) to soil in order to improve water-holding capacity and maintain N in orchard top soil. Organic matter added to the soil contains N, however the rate at which that N becomes plant available varies dramatically depending upon on the organic matter source. Furthermore, a greater understanding of how N availability changes from one year to the next is needed. This is particularly true in this era when Regional Water Quality Control Boards are requiring growers to account for their nitrogen usage.

Additional factors may need to be considered when estimating N availability from organic matter sources in orchards. These include use in the tree row or alleyway; the proportion of orchard soil wetted by irrigation water, and use of no-till or tillage of OM. The aim of the following is: 1) to outline the finding of N availability coefficients available in research and extension literature and 2) to provide recommendations for grower reporting requirements.

METHODS

We reviewed twelve extension publications across multiple land grant institutions in the United States (See references below) and extracted 90 data points estimating N availability coefficients defined as the percent of N available as ammonium or nitrate out of total N inputs from organic matter sources at one and more than one year after application. Additional data parameters collected when available included percentage of dry matter, carbon-to-nitrogen ratio (C:N), total N (TN) and the proportion of ammonium (NH4) to TN. Notes were made for examples that included incorporation with tillage or management of organic matter sources as no-till mulch. Results are reported independent of management practices employed. The N availability coefficients reported herein are designed to be unit less values to be multiplied by the total N contents of each organic matter source in dry mass per unit area.

RESULTS AND DISCUSSION

Year one coefficients varied for different organic matter sources including compost from -8 to 28%, beef or dairy manure solids from 16 to 40%, poultry manure solids from 24 to 52% and cover crops from 8 to 48% of total N inputs (Figure 1). Less data was available for year two coefficients including one data point for compost of 5%, beef or dairy manure solids from 8 to 24% and poultry from 8 to 16% (Figure 2). Studies specific to orchards are lacking, however Khalsa et al. report a range of -6 to 8% from composted sources in an almond orchard depending on the initial C:N.

Nitrogen losses via ammonia volatilization from surface application of manure is a primary finding to consider for orchards. Multiple extension publications report 100% of ammonium loss from manure when surface applied with no-till. The proportion of ammonium out of total N ranged from 0.0 to 6.7% for compost, 5.6 to 55% for beef and dairy, and 17 to 67% for poultry. No-till use of compost in orchards does not appear to be a significant path of ammonia loss. However, if growers opt to use manure, a factor of days until incorporation should be included.

Figure 1. Box plots of nitrogen (N) availability coefficients defined as the percent of N available as ammonium or nitrate out of total N inputs for year one after application for organic matter sources including compost, beef and dairy, poultry and cover crops.

Figure 2. Box plots of nitrogen (N) availability coefficients defined as the percent of N available as ammonium or nitrate out of total N inputs for year two after application for organic matter sources including compost, beef and dairy, poultry and cover crop.

The following are the most accurate quantification of N credits assuming all input parameters are available to the user for estimating the N contribution to the crop from organic matter sources.

The following are examples that demonstrate parameters to collect for each organic matter source and ask the question, "What would be the N credit for the subsequent growing season?"

Manure
Application rate in lbs/ac (AR)
Moisture in % (H2O)
Total N in % (TN)
Ammonium in % (NH4)
Tillage factor (tf)

- 1.00 = Incorporation 0 days after application
- 0.65 = Incorporation 1 day after application
- 0.50 = Incorporation 2 days after application
- 0.40 = Incorporation 3 days after application
- 0.30 = Incorporation 4 days after application
- 0.20 = Incorporation 5 days after application
- 0.10 = Incorporation 6 days after application
- 0.00 = Incorporation 7 days after application

N Credit = AR * (1-H2O) * [([TN-NH4] * 0.25) + (NH4 * [tf])]
Example – In November, a grower applies 4 tons per acre of dairy manure at 30% moisture, 2.5% Nitrogen (0.5% ammonium) and incorporates the manure into the orchard alleyway 2 days after application.

8,000 lb/ac * (0.70 dry matter) * [([0.025 – 0.005] * (0.25)) + (0.005 * 0.50))] = 42 lb N/ac

Note – This approach may be used for all manure. The higher N coefficients reported above for poultry assume no losses from rapid incorporation (Fig. 1). If the ammonium concentration and tillage factors are available, the same coefficient 0.25 may be considered for all manure sources.

Compost
Application rate in lbs/ac (AR)
Moisture in % (H2O)
Total N in % (TN)

N Credit = AR * (1-H2O) * (TN) * (0.10)

Example – In November, a grower applies 4 tons per acre of compost with a C:N between 11 to 13 at 30% moisture, 2.0% Nitrogen (0.0% ammonium) on the tree berm without tillage.

8,000 lb/ac * (0.70 dry matter) * (0.02) * (0.10) = 11 lb N/ac

Note – This example assumes compost C:N from 10 to 15, values higher than 15 may result in lower coefficients less than 0.10, equal to 0.0 or even negative leading to immobilization.

Cover crops
Biomass production in lbs/ac (AR)
Moisture in % (H2O)
Total N in % (TN)
Quality factor (CN)

- 0.50 = Cover crop with TN equal to 4.0%
- 0.46 = Cover crop with TN equal to 3.5%
- 0.42 = Cover crop with TN equal to 3.0%
- 0.38 = Cover crop with TN equal to 2.5%
- 0.26 = Cover crop with TN equal to 2.0%
- \- 0.12 = Cover crop with TN equal to 1.5%

N Credit = AR * (1-H2O) * (TN) * (CN)

Example – In March, a grower estimates a cereal rye cover crop stand of 6 tons per acre at 75% moisture, 2.0% Nitrogen.

12,000 lb/ac * (0.25 dry matter) * (0.02) * (0.26) = 16 lb N/ac

Note –A cover crop stand will depend greatly on winter rainfall. Furthermore, the quality factor for a cover crop will be affected by the developmental stage and termination date of the cover crop.

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TIMING ETHYLENE APPLICATIONS AS A FUNCTION OF HEAT UNIT ACCUMULATION

INTRODUCTION

Side by side trunk shaking 'Manzanillo' table olive harvester efficiency could be improved with an effective, reliable abscission compound that did not also produce excessive leaf loss. In the past 12 years we have investigated all the recent developments in Ethephon research. We tried buffering the ethephon with monopotassiumphosphate (MPK), marketed as HarvestVant ®, (Birger et al 2008; Burns et. al. 2008). We tried the Goldental-Cohen et. al (2016) method of adding 0.3% ascorbic acid or 100 mM butyric acid to the standard 1500 PPM ethephon in 2016 and 2017. In all cases, the effects on fruit removal force were erratic; the ethylene sprays either had no effect or decreased fruit detachment force and excessive leaf loss. As our years of spray trials have not yielded reliable results we are now proposing a different approach.

All fruit growth is a function of heat. And all fruits have a specific "accumulated heat unit requirement to mature; Growing Degree Days; GDD. We proposed characterizing fruit development, primarily by measuring volume growth and dry weight, as it matures while simultaneously tracking the heat unit accumulation; this is called developing a phenology model. The value of a phenology model is that once a fruit's growth as a function of heat has been determined; growth and maturity can be predicted by knowing how many more heat units need to be accumulated to achieve maturity. Hopefully, by using accumulated heat units to determine when an olive fruit is approaching maturity, and theoretically receptive to ethylene, we can better target when to apply ethephon. We have developed a fruit phenology model for pistachios that predicts kernel growth and hull split in six different cultivars. This model is now used to determine when to start and stop midseason deficit irrigation and to determine when to start end stage monitoring for optimum harvest time.

In 2021 monitored temperature accumulation above 15*C of (59* F) and olive fruit growth in two locations, and, as maturity approached, started testing fruit removal force. When the fruit removal force began to decline we applied whole tree ethephon spray and continued testing fruit removal force until the fruit was judged ready for harvest. At that time the treated and control trees were mechanically harvested with a trunk shaker, the mechanically harvested fruit submitted for grading at the receiving station and the remaining fruit gleaned to determine harvester efficiency of the ethephon treated and untreated mechanically harvested trees.

This experiment was done incooperation with two mechanically harvested orchards; Nickels Soils Laboratory and Burreson Orchards; both Manzanillo orchards with Sevillano pollinizers. In both locations a side by side trunk shaking pistachio harvesters, but different models, were used for harvesting. The experimental objectives and materials and methods are detailed below.

2021 Objectives: (April 1st – October 31st 2021)

Evaluate olive fruit growth as a function of accumulated degree days (DD) after full bloom above 59*F (15*C) to determine:

1. At what accumulated GDD fruit removal force starts to decline:
    a. We are assuming this is when the abscission zone is starting to form.
2. At what GDD accumulation applying ethephon is most effective.
3. Demonstrating ethephon applied based on GDD accumulation increases trunk shaking harvester efficiency.

2021 Experimental Procedures:

Orchards

Two moderate density orchards pruned for trunk shaker and canopy contact harvesting were secured:

1. Nickels Soils Laboratory moderate density (20 years old; 202 tree/acre) orchard in Colusa County:
    a. Four replications, three rows wide, 3 trees each for treated and control.
        i. Total 36 treated and 36 controls: 72 trees total.
2. Glenn County Orchard, moderate density (~30 years old, 180 trees per acre) trained for trunk shaking harvesting:
    a. Three replications repeated in three row wide, 3 trees each for treatment and control.
        i. 54 trees total, 9 trees at each treatment timing.

Temperature Logging and Growing Degree Day (GDD) Accumulation Calculation

Local data loggers that measured temperature accumulation were used for Growing Degree Day (GDD) accumulation in *F and *C.

At full bloom the loggers started logging daily temperatures used to calculate **G**rowing **D**egree **D**ay (GDD) accumulation as follows: (15*C, 59*F as Tbase)

GDD = (Tmax + Tmin)/2 – Tbase

When olives were ~ 1 cm in length, 3 sets of 100 olives/row were collected weekly:

- Average size by volume was determined by water displacement and caliper measurement

Fruit Removal Force (FRF) Measurements;

When olive fruit volume growth started to slow fruit removal force (FRF) was tested on 100 olives/row:

Ethephon Treatment

When fruit removal force started declining, and/or fruit showed color, treatments were started:

3 rows x 3 trees = 9 trees per treatment and control each, were sprayed to drip @ 100 GPA rate

1. 1500 PPM Ethephon + 0.25% surfactant*
2. Water control + 0.25% surfactant

Nickels Soils Laboratory

1. *The ethylene was sprayed on*
   a. *September 10th, 13th and 16th at 2128, 2186 and 2233 GDD total.*

Burreson Ranch:

1. *1. The ethylene was sprayed on*
   a. *September 19th, 13th and 16th: we do not have the GDD calculated yet.*

Harvest Efficiency:

At harvest, the mechanically harvested weight of each 3 tree set was combined, weighed and combined into one sample for receiving station grading.

Trees were hand gleaned after harvest and fruit weighed but not graded

Harvester efficiency of ethephon sprayed versus control trees was be calculated as:

$$Efficiency = \frac{Mechanically\ harvested\ (lb)}{Manually\ harvested\ (lb) +\ Mechanically\ harvested\ (lb)} \times 100$$

Statistical Analysis:

An Analysis of Variance with and LSD means separation test compared:

Harvester efficiency for treated versus control trees for:

- among the sequential spray dates to determine at which GDD accumulation the ethephon spray was more effective.

Data was analyzed using ANOVA with an LSD means separation.

Desired Result:

The 1500 ppm ethephon treatment will decrease fruit removal force, increase harvesting efficiency to at least 90% without producing leaf loss over 25%.

Results Summary:

2. The ethylene, while demonstrating a trend which paralleled the normal decrease in fruit removal force, did not significantly lower the fruit removal force at any of the three application times: T1, T2 or T3 in either orchard location; Nickels Soils Laboratory in Colusa County and Burreson Ranch in Orland County.
3. The trunk shaking harvester harvested olives with approximately 50-60% efficiency at Nickels Soils laboratory with an ENE pistachio trunk shaker and 65-80% efficiency in Burreson Ranch with a Coe pistachio trunk shaker.
4. There were no statistically significant differences in crop value, which ranged from $1320 – 1340 at Nickels Soils Laboratory and averaged $1200.00 per ton for Burreson Orchards, among the three ethylene timing treatments.

While this trial detected no difference in harvester efficiency with ethylene treatments it did demonstrate 75 – 80% harvest efficiency with a trunk harvesting shaker. This is the best efficiency we have been able to demonstrate with a trunk shaking harvester thus far. Visual evaluation during harvest suggest the differences in final harvester efficiency suggest this was due to harvester shaking strength and duration.

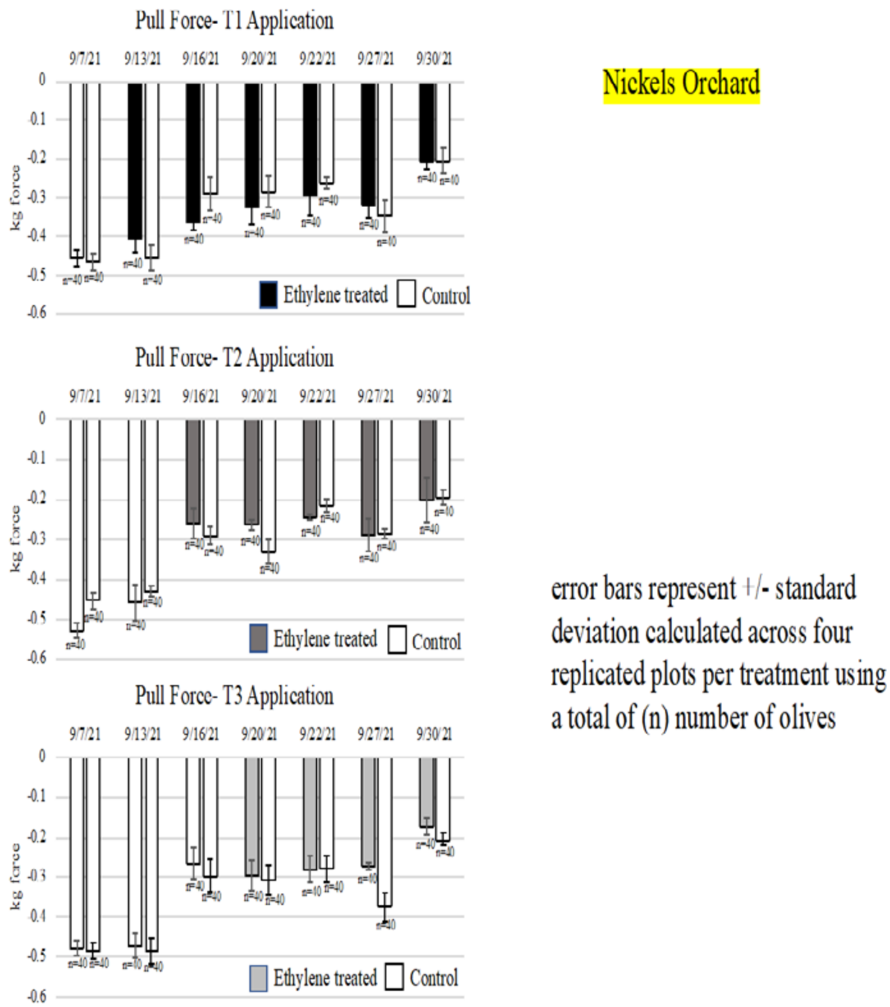
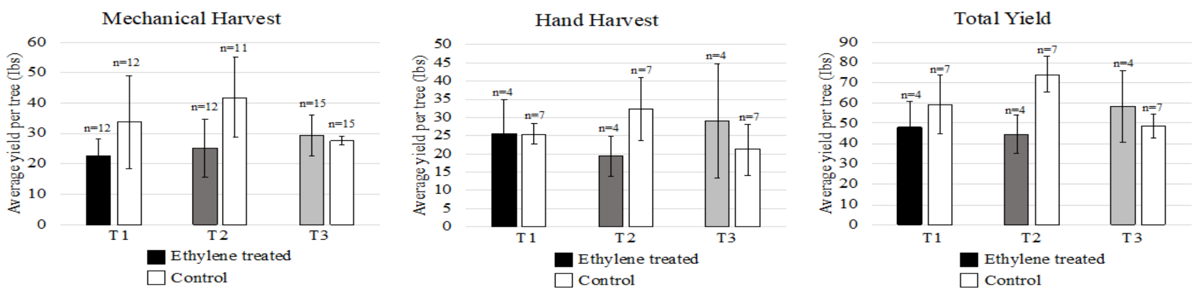


Figure 1. This figure shows the decrease in pull force overtime at three different spray times; T1, T2 and T3. A can be seen in the three timings above the pull forced in both the untreated and ethylene treated trees decreased from approximately half a kilo (1.10 pounds) to approximately 0.20 kilo (0.44 pound) from September 7th to September 30th. There were no consistently statistically significant differences in the decrease in pull force over-time in trees treated with ethylene versus untreated controls.

Nickels Orchard



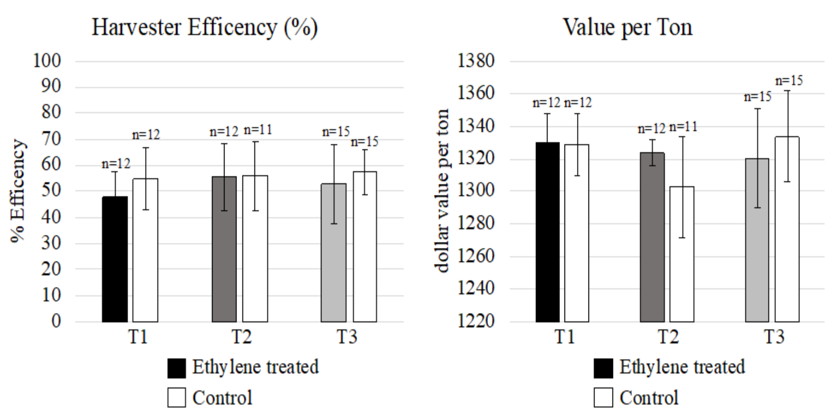
error bars represent +/- standard deviation calculated across four replicated plots per treatment using a total of (n) number of trees

error bars represent +/- standard deviation calculated across four replicated plots per treatment using a total of (n) number of trees

error bars represent +/- standard deviation calculated across four replicated plots per treatment using a total of (n) number of trees

Figure 2. This figure demonstrates there were no statistically significantly differences among the ethylene treatment timings in the weight of olives harvested by hand or mechanically, or the total yields per treatment, versus untreated control trees.

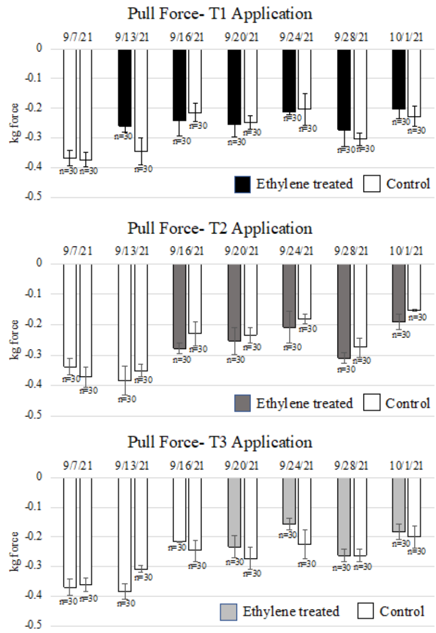
Nickels Orchard



error bars represent +/- standard deviation calculated across four replicated plots per treatment using a total of (n) number of trees

error bars represent +/- standard deviation calculated across four subsamples per treatment using a total of (n) number of trees

Figure 3. This figure demonstrates that there was no statistically significant differences in trunk shaking efficiency among the three ethylene treatments, all averaged approximately 50-60%, versus untreated control trees. The values per ton ranged from $1320-1340 per ton and were not significantly different among treatment timings.

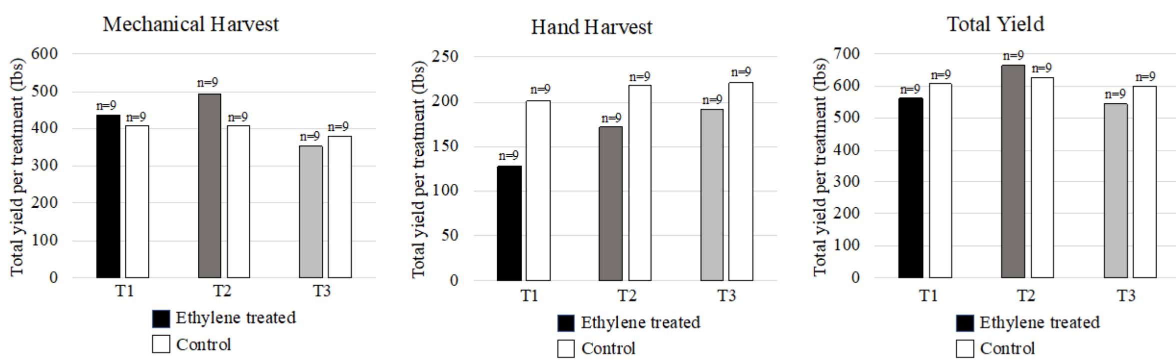


Burreson Orchard

error bars represent +/- standard deviation calculated across four replicated plots per treatment using a total of (n) number of olives

Figure 4. This figure show the decrease in pull force over-time at three different spray times; T1, T2 and T3. A can be seen in the three timings above the pull force in both the untreated and ethylene treated trees decreased from half a kilo (1.10 pounds) to approximately 0.20 kilo (0.44 pound) from September 7th to October 1st. There were no consistently statistically significant differences in the decrease in pull force over time, among treatments and versus untreated controls.

Burreson Orchard



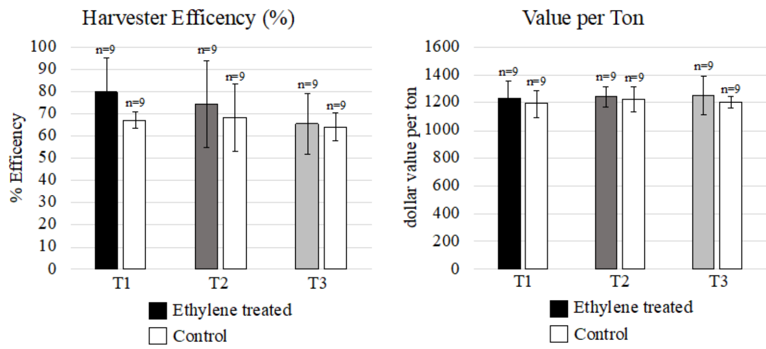
yield calculated across three replicated plots per treatment using a total of (n) number of trees

yield calculated across three replicated plots per treatment using a total of (n) number of trees

yield calculated across three replicated plots per treatment using a total of (n) number of trees

Figure 5. This figure demonstrates there was no statistically significant differences among the ethylene treatment timings, or versus controls, in the weight of olives harvested by hand or mechanically, or the total yield per treatment.

Burreson Orchard



error bars represent +/- standard deviation calculated across three replicated plots per treatment using a total of (n) number of trees

error bars represent +/- standard deviation calculated across three subsamples per treatment using a total of (n) number of trees

Figure 6. This figure demonstrates that there were no statistically significant differences in trunk shaking efficiency among the three ethylene treatment times, or versus the untreated controls, all averaged approximately 65-80 %. The values per ton averaged slightly over $1200 per ton for all ethylene treatments and untreated controls. Neither parameter was statistically significantly different among treatment timings or versus untreated controls.

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SUMMARY OF INTERNATIONAL AVOCADO IRRIGATION TRENDS

Thirteen very collaborative avocado experts from around the world kindly agreed to participate in this survey; five from California (four growers and one extension officer), two from Chile (both consultants), two from Israel (one extension officer and one consultant), one from New Zealand (a research manager), two from South Africa (both technical managers with large corporate producers), and one from Spain (a researcher). The aim was to find out trends in avocado producing countries outside of Australia in order to learn from others, identify common issues and identify where potential advances can possibly be made. This information will be shared with the Australian industry and international collaborators and will hopefully be useful to all.

A wealth of information was gathered, however the information needs to be considered in the context of the growing conditions of the region being reported. Generally, where there was more than respondent from one country, conditions were quite similar but there were differences in the environments of the two South African contributors.

Commonalities across all countries

In all countries surveyed irrigation is becoming a higher agronomic priority, reasons given are better yield and fruit size, more effective nutrition, and improved Phytophthora root rot management.The biggest challenge across the board is the shortage of water. Most countries believe that climate change is real and is generally resulting in drier and hotter conditions with more extreme weather events, especially heat waves.

CALIFORNIA

There were five respondents from California made up of one extension officer and four growers. The climate is Mediterranean with rainfall ranging from 230 to 500mm/year, poorly distributed. Soils range from sandy loams to clay loams with depth ranging from less than 30cm to more than 100cm. Hundred percent of orchards are irrigated and 95% are fertigated. Phytophthora root rot is regarded by two respondents as a serious issue, one as a moderate issue and two as a minor issue. 5 to 33% of orchards are planted on mounds. Irrigation water is very expensive, around AUD 1,000/ML (assuming an exchange rate of AUD 1.29 to US 1).

Water quality

Water quality is an issue; chloride content varies from 40 to over 150ppm. Measures taken to manage this issue are leaching irrigations, some chemistry, keeping soils wetter than would be necessary without salts, use of Dusa® and Toro Canyon root stocks, reverse osmosis, mounds, drip irrigation, humates, calcium sources, and changes in fertilization methods and types.

Frequency of leaching is variable and ranges from every irrigation up to every fifth irrigation, monthly and six to eight times during the growing season. The frequency is determined by the calendar, evapotranspiration (ETO), weather, soil and leaf tests, water quality and quantity available, rootstock, lysimeter and convenience. One grower uses a leaf chloride over 0.25 to 0.35% as a trigger to leach, two others said that as leaf analysis is only done once per year it is not useful to determine leaching needs.

Current irrigation systems & practices

There has been a general trend towards more frequent light irrigations. Annual irrigation volumes range from 6 - 12 ML/ha. The period regarded as the most important to maintain optimum soil moisture is the entire cycle excluding autumn leaf flush and wintertime.

Mini sprinklers are the most commonly used system. Most growers use one sprinkler per tree delivering between 40 and 60 L/tree/hour; one uses 150 L/hr. Another grower uses two sprinklers per tree delivering 58 L/tree/hour. Two growers also use some drip irrigation. Configurations reported are two lines with emitters every 46 to 60 cm each delivering 1.6 or 4 L/emitter giving a total delivery rate per tree of 28 and 53 L/tree/hour respectively. Two of the five respondents reported using overhead irrigation for the purpose of cooling the canopy. The range of soil depth growers aim to keep moist varies from 20 to 100cm. Irrigation is applied during the day and night. If a heat wave is forecast all growers will pre-irrigate deeper.

Monitoring devices

Most growers don't have weather stations on the farm. Growers make irrigation decisions based on the calendar, ETO data supplied by the State or water company, physical examination of the soil using augers/spades. More recently, growers have been adopting tensiometers, capacitance probes and gypsum blocks, driven by the high cost of water. Where tensiometers are used, the trigger point to irrigate ranges from 20 to 40 cb depending on the time of year and stage of the phenological cycle.

Monitoring by devices is done remotely and automatically from continuously, to daily, to every four days. Where soil moisture is determined manually this is typically performed every two to three days.

Measures taken to make up for the fact that relatively tiny volumes of soil are measured by devices include using more than one method, physically examining the soil (with auger or spade), using the information from different areas, and observing the tree condition.

A few growers are using satellite images and a few are using Phytech dendrometers. The technology needs to be robust, easy to use and inexpensive if it is to be adopted. Between 1 and 10% of growers are using software to amalgamate information from different sources to help with irrigation decisions.

Improving efficiency of water delivery

A wide range of answers ranging from 'very few', to 50% and 'most' are reported to clean their irrigation lines, and it is reported to be done from every second month to annually. Sulphuric acid, phosphoric acid, and N-phuric (urea and sulphuric acid, used on alkaline soils) are being used for this purpose. Between 25 and 80% of growers are trying to improve the root environment and this is being done with the use of mulch, humic acid and carbon based products.

Recent changes and the future

The biggest changes seen in avocado irrigation over the past 5 to 10 years include the fact that many growers have gone out of business due to high water costs which has gone up 10% a year for 10 years, and is now about AUD 1,000/ML. This has also impinged on the frequency of leaching irrigations. Other changes include greater use of ridges in combination with drippers and shorter but more frequent irrigations. There has also been more automation and more growers applying irrigation in anticipation of heat waves.

Expected changes in the next 5 – 10 years are that many will go out of business if water prices keep going up, more adoption of monitoring and better monitoring, more low flow/low pressure (dripper) irrigation, centralization of controls and fertigation, applying less water more often, and more automation. The biggest challenge is the cost of water which is also declining in quality. Other challenges are drought and sudden heat waves.

Suggested research: can we irrigate the trees directly e.g. using an 'intra-venous' system instead of having to use the roots for water transfer? Cost efficient ways to improve water quality. Tailoring irrigation scheduling by soil type, cultivar and rootstock for each different region. One respondent said we know what to do we just need to achieve greater adoption of best practice. Information required is chemistry that helps leach salts, grove specific information, on farm visits and one-on-one evaluations.

Factors considered critical in order to irrigate effectively are ETO information, correct understanding and utilization of resources available to help schedule irrigations, timing and quantity of water, and grower education. One respondent stated that irrigation is just one of many things a grower does which include managing weeds, insects, disease, labour, regulations etc. - it has to rise to top of priorities to get attention.

CHILE

Our two respondents are both consultants.The growing area in Chile has a Mediterranean and semi-desert climate with quite cold winters. Avocados are generally grown on hill slopes (to avoid frost) in two different environments - coastal areas that have cooler but less variable temperatures (influenced by the cold Humboldt ocean current) and inland valleys which are drier and experience more extreme temperatures (hot and cold). Annual rainfall is poorly distributed and ranges from 150mm (inland valleys) to 300mm (coastal areas). The climate is reported becoming drier with up to 70% less rain. The predominant soil type is clay loam and typical soil depth is from 30 to 100cm. 90 to 100% of trees are planted on mounds. 100% of orchards are irrigated and use fertigation. Phytophthora root rot is regarded as a minor issue.

Water quality

Water quality is an issue, chloride levels range from 20 to 80ppm. Measures used to manage the poor water quality are monthly soil analysis, a leaching program, modifying irrigation frequency and using quality fertilizers. Leaching is typically conducted once per month (using three times the regular volume of irrigation) over the five months of summer. Leaching decisions are based on soil analysis (when chloride exceeds 2 meq/L), the soil moisture level and the calendar. One respondent states that using leaf analysis to trigger leaching is always too late. The other respondent uses a leaf chloride level of 0.4% to trigger flushing.

Current irrigation systems & practices

There has been a trend towards more frequent, light irrigations. Annual irrigation volumes range from 8 - 12 ML/ha. The period regarded as the most important to maintain optimum soil moisture is for the entire crop cycle although one respondent does not regard winter as being quite as critical. Both mini sprinklers and drip are used. A mini-sprinkler system typically uses one sprinkler per tree delivering 20 to 35 L/hr. Drip systems typically consist of three lines, the centre one on the sunny side of the trunk but never next to it, the other two placed 40 cm on either side of the central one. Some growers are changing to drip systems and some are changing to mini sprinkler. Overhead irrigation is not used to cool the canopy. Growers aim to keep the top 45 to 80cm of soil moist and apply irrigation during the day and night.

Monitoring devices

Growers have weather stations on site to help with irrigation decisions. Growers use a combination of devices that include tensiometers, capacitance probes, excavating soil pits to examine soil moisture as well as root health and growth, use of ETO derived from weather station data and dendrometers on trees. All devices are regarded as being important. Capacitance probes are the most popular and allow continuous monitoring and the ability to evaluate water dynamics in the soil. Tensiometers are losing favour.

Monitoring is done remotely and automatically every 15 minutes to hourly. One respondent reported that dendrometers can detect trunk size changes as little as 5 to 30 microns and are used to determine plant stress levels and daily growth rates which is combined with soil monitoring data to adjust irrigation timing, the number of pulse irrigations, and avoid plant stress. The other respondent reports that trunk measurement using dendrometers was tried several years ago but was a failure.

ETO is used to forecast irrigation needs for the next week. Measures taken to make up for the fact that relatively tiny volumes of soil are measured by devices include ensuring that representative trees are used, digging soil pits, and using devices as indicators, not as 'gospel'. One respondent always uses three sensors per irrigation block. One uses satellite, the other doesn't but all information from soil, tree and weather station goes to a central dashboard. 50 to 70% of growers are using software in this way to amalgamate information from different sources to help with irrigation decisions. 70% of growers are able to remotely view data from monitoring devices and control irrigation.

Improving efficiency of water delivery

All growers clean irrigation lines, this is considered a basic requirement. It is done with citric acid, chlorine dioxide, chlorine and /or phosphoric acid. Chlorine is used fortnightly or monthly and phosphoric acid is used every 2 months. Between 10% to 80% of growers are reported to be trying to improve the root environment by using compost, mycorrhizae, humic acid and other organic matter.

Recent changes and the future

The biggest changes seen over the past 5 to 10 years have been better design of irrigation systems, better control of irrigation and soil moisture, and better maintenance of irrigation systems. Expected changes in the next 5 – 10 years include improvements to valve design to allow more pulses per day, and better satellite and/or drone tools. The biggest challenge is the shortage and quality of water. One respondent believes that better execution and extension of existing knowledge is required instead of more research. The other believes that better sensors are required to make sure all trees receive the same amount of water, and that we need more reliable drone and/or satellite tools. Good sensor readings and interpretation, a homogeneous irrigation system, and well-maintained systems with a uniformity coefficient of above 95% are considered critical in order to irrigate effectively.

ISRAEL

Two respondents, one an extension officer with the Israeli department of agriculture and the other a consultant. Israel has a Mediterranean climate (hot dry summers, cool wet winters) and experiences heat waves. Rain falls predominantly in winter, is fairly well distributed through winter and ranges from 650mm per year near the coast to 400mm in inland valleys. Both contributors feel that the climate is becoming hotter with more extreme weather events. Soils are clay loams and range from 60 to more than 100cm in depth, some trees are planted on mounds. 100% of orchards are irrigated and fertigated. Phytophthora root rot is absent or a minor issue.

Water quality

Water quality is a major issue with chloride levels over 150ppm. Measures being taken to manage this problem are the use of tolerant rootstocks and regular leaching. Leaching varies from every 2 - 4 weeks, to twice during summer and at the start of winter rains. Soil analysis & experience of the grower determines the frequency of flushing. Leaf analysis is not used for this purpose because when leaf chloride levels increase the damage is already there.

Current irrigation systems & practices

Irrigation frequency varies from 2-3 pulses per day, to daily, to every 2-3 days. It depends on soil type, ETO and other factors. Annual irrigation volumes range from 6.5 - 8.5 ML/ha in coastal areas to 8 - 12 ML/ha inland. The period regarded as the most important to maintain optimum soil moisture is the entire cycle although one respondent does not include flower initiation or winter as critical.

The main type of irrigation is drip. Typically, it consists of two lines, a dripper interval of 30-40 cm and emitter rates between 1.2 - 1.6 L/hr. This configuration delivers 26 to 32 L/tree/hr. The recent trend is towards emitter rates lower than 1 L/hr. One respondent reports the use of overhead irrigation for cooling purposes. Growers aim to keep the top 40cm of soil moist and will irrigate deeper if a heat wave is predicted. Irrigation is applied by day or night.

Monitoring devices

Growers have weather stations on site to help with irrigation decisions. The main devices used to make irrigation decisions are tensiometers, augers/spades to physically examine soil moisture, ETO calculated by the Penman equation, and dendrometers. Dendrometers are reported to be better for spring and autumn, whilst tensiometers are best for summer. One respondent gave the following irrigation trigger points for tensiometers: heavy soils 15-18 cb in summer and 30 cb in winter, light soils: 10-15 cb. The other gave the range as 25 - 35cB.

Monitoring is done remotely and automatically from hourly to daily. To make up for the fact that relatively tiny volumes of soil are measured by devices, the number of monitoring sites is increased, and to use Phytech technology. Dendrometers on tree trunks are widely used. Continual monitoring is practiced, and the ‘winning combination is the use of soil monitoring and tree monitoring together’. Dendrometers are useful for providing additional information for making decisions.

Seventy Five to 90% of growers can view soil moisture and control irrigation remotely. Seventy Fiv to 90% of growers are also adopting software systems that bring together information from several sources.

Improving efficiency of water delivery

Ninety Five to 100% of growers clean their irrigation lines. Frequency depends on the quality of the water. The majority clean once a year, some twice a year. The most common product used is phosphoric acid, although some chlorine is used. About 20% of growers are using measures including application of compost and humic acid to improve the root environment.

Recent changes and the future

The biggest changes seen over the past 5 to 10 years are better monitoring and the understanding that irrigation is the most important issue. Expected changes in the next 5 – 10 years are less fresh water available, better quality recycled water (because more desalinated water will be available), a greater number of monitoring sites, and adjustment of irrigation protocols specific for each block.

The biggest challenges (and those that need to be researched) are how to irrigate during spring, selecting the correct volumes and intervals, and the optimum emitter rates for drippers. Further development of dendrometer systems is seen as the key to making better irrigation decisions. Factors considered critical in order to irrigate effectively are close monitoring of the soil and tree, and to know how much air the root system needs in spring after the winter rains.

NEW ZEALAND

The region reported on was Far North of the North Island where avocado farming is relatively new and conditions are sandier, warmer and drier and therefore irrigation more necessary than the more traditional growing region of the Bay of Plenty which is wetter and cooler with richer soils. In the Far North, the average annual rainfall is 1575 mm and is well distributed with slightly more in winter. No drastic changes in climate are evident. The soil is a sand, deeper than 100cm. Half the trees are planted on mounds, almost 100% are irrigated but only 20% are fertigated. Phytophthora root rot is a moderate issue.

Water quality

Water quality is not an issue.

Current irrigation systems & practices

Mini sprinklers are the dominant irrigation system and typically consists of one sprinkler per tree delivering about 75L/tree. Generally, growers try to keep the top 30cm of soil moist. Irrigation takes place at night. There is a trend for more frequent, light irrigations. Annual application is only about 2 ML/ha/yr. The phenological stages between bud burst through to mid-fruit growth are considered the most important for maintaining optimum soil moisture.

Monitoring devices

Capacitance probes are the most popular soil moisture monitoring device. The reasons given are that they are able to monitor continuously, their data can be accessed remotely, and they require less maintenance than tensiometers. Information is usually accessed daily. Where tensiometers are used, 25 cb is the trigger point on the shallow probe to start irrigating. Only about 10% of growers control their irrigation systems remotely but the number that are adopting software to amalgamate all available data to facilitate better irrigation systems is growing, currently also about 10%.

To make up for the fact that relatively tiny volumes of soil are measured by devices is to make manual soil moisture probes of the orchards. Monitoring the tree itself is restricted to research on sap flow.

Improving efficiency of water delivery

Ninety Seven percent of growers clean their irrigation lines annually. Phosphoric or sulphuric acid is used. About 50% of growers are trying to improve the root environment by using mulch and biological soil amendments such as seaweed and humates.

Recent changes and the future

The biggest change in the past 5 – 10 years is that growers are now placing more trust in soil moisture monitoring devices. Expected changes in the next 5 – 10 years are the use of more digital sensors and the availability of online data with recommendations. Research suggested is a better understanding of negative impacts of moisture stress at different stages in the phenology.

Technology that would be useful is a platform that incorporates information from multiple sources such as weather forecasts and soil moisture devices to help with irrigation decisions. Accurate soil moisture monitoring is considered critical in order to irrigate effectively.

SOUTH AFRICA

Two respondents, one from a more benign environment near Tzaneen and the other was from a less benign environment near Nelspruit (Mbombela). Both regions have predominantly summer rainfall which ranges from 900 to 1000mm/year and is generally not well distributed through the year. Soils range from clay in the Tzaneen area to sand in the Nelspruit region. 85 to 95% of orchards are irrigated. Most trees are not fertigated. Phytophthora root rot is a moderate to serious issue.

Water quality

Water quality is not reported as becoming an issue although the orchards at Tzaneen practice longer irrigations every second week to leach salts.

Current irrigation systems & practices

Annual application is between 3 and 4 ML/ha/year. The period between budburst and early fruit growth is considered the most import period to maintain optimum soil moisture. Irrigation is applied mainly through mini sprinklers. One or two sprinklers are used per tree to deliver between 30 (wetter) to 60 (drier areas) L/tree/hour. A little drip irrigation is used in drier areas, two lines are used per row with emitters 1m apart delivering between 0.7 and 1.6 L/hr/emitter so applying between 6 and 13 L/tree/hr. There is a trend towards more drip irrigation in new plantings especially as water becomes scarcer. Growers try to keep the top 40 to 60 cm of soil moist. Irrigation is applied daily. One area irrigates deeper prior to heat waves.

Monitoring devices

Capacitance probes are the most popular devices because they are considered reliable, efficient, can be placed at different soil depths, save time and enable more precise irrigation management. Soil moisture is read remotely and automatically on a daily basis. However, tensiometers are also used because they give a clear indication of water potential in the soil ‘if stress wants to be induced or prevented’, 10 - 30cB is used as the irrigation trigger point depending on phenological stage. To make up for the fact that devices, more than one type of moisture monitoring device, monitor relatively tiny volumes of soil is used and the number of monitoring sites is increased.

One of the respondents notes that remote monitoring technology is becoming increasingly popular. Dendrometers are uncommon and are viewed by some as a research tool. They could be more effective if definite stress points within the phenology cycle could be identified. They need to be practical and easy to use for a grower, but they could provide more sensitive control during critical phenological stages. Eighty Percent of growers can view soil moisture status via a mobile device but only 5 - 20% can control the irrigation remotely.

Improving efficiency of water delivery

Only 10% of growers clean their irrigation lines. Most growers try to improve the root environment. They use mulch, especially during establishment, organic fertilisers and additives. “Sustainability” is reported as a growing trend.

Recent changes and the future

The biggest changes seen over the past 5 to 10 years are better soil moisture monitoring, use of fertigation and more efficient irrigation systems e.g. drip. Changes expected in the next 5 to 10 years include closer monitoring of soil moisture, logging data to simultaneously reduce orchard water use, more use of drip irrigation as water resources become scarcer, and automation to reduce costs.

Research suggested includes establishing crop factors suitable for different stages in phenology, and developing a drip irrigation design to suit different soil types. One respondent pointed out that we still don't know how much water avocado uses (and at different stages in the phenology). Information that would help with better irrigation decisions include comparing results of monitoring both the tree and the soil, probes at different depths to read soil moisture and EC simultaneously and instantaneously, and accurate irrigation prediction models.

Factors considered critical in order to irrigate effectively are a good understanding of soil type and tree requirements (for different canopy sizes and phenological periods), truly understanding your soil type, monitoring soil moisture as much and as often as possible, and proper soil preparation (coupled with mounding) before planting to limit the effects of compaction etc. that are often unseen.

SPAIN

Our respondent is a researcher based near Malaga. Spain has a Mediterranean climate with an annual rainfall of about 485mm that is poorly distributed. More extreme weather events are reported as occurring together with milder winters. The predominant soil type is clay loam and typical soil depth is 60 to 100cm. 50% of trees are planted on mounds. 100% of orchards are irrigated and 80% use fertigation. Phytophthora root rot is regarded as a moderate issue.

Water quality

Water quality is an issue, and the common chloride level is between 120-150ppm. More tolerant rootstocks are the main measure to deal with this.

Current irrigation systems & practices

There has been a trend towards more frequent light irrigations. Annual irrigation volume averages 6 ML/ha.The period regarded as the most important to maintain optimum soil moisture is the entire cycle except for flower initiation and winter. The main type of irrigation is drip. Typically, it consists of three lines, a dripper interval of 30 cm and emitter rates of 4 L/hr. This delivers between 160 to 213 L/tree/hr. The recent trend is towards more drip irrigation. Overhead irrigation is used for cooling purposes.

Growers aim to keep the top 40cm of soil moist and will irrigate deeper if a heat wave is predicted. The preferred time to irrigate is during the day.

Monitoring devices

Growers have weather stations on site to help with irrigation decisions. The main device used to make irrigation decisions is tensiometers which are regarded as easy to manage. The irrigation trigger points are between 20 - 30cB. Tensiometers are read every three days in the field. The main measure taken to make up for the fact that relatively tiny volumes of soil are measured by devices is to increase the number of monitoring sites.

Dendrometers and sap flow meters are starting to be used but at this stage only for experimentation, monitoring the tree is regarded as being key in addition to soil monitoring. This will allow optimisation of irrigation applications specific to smaller groups of trees. It is believed that satellite imagery will become increasingly useful.

Only about 5% of growers view soil moisture and control irrigation remotely. As yet, no growers are using software to amalgamate information from different sources to help with irrigation decisions.

Improving efficiency of water delivery

Eighty percent of growers clean their irrigation lines about once a year using phosphoric acid.

About 50% of growers are trying to improve the root environment and this is being done with the use of mulch.

Recent changes and the future

The biggest changes seen over the past 5 to 10 years is the change from mini sprinklers to drip irrigation. Expected changes in the next 5 – 10 years are increasing use of drip ('low flow') irrigation and more use of satellite images. The biggest challenge is the shortage of water. Genetic research is needed to develop drought tolerant rootstocks. The availability of appropriate and easy to use sensors is needed to measure soil and tree water status.

Factors considered critical in order to irrigate effectively are greater use of weather forecasts together with data from probes.

ACKNOWLEDGEMENTS

The project team would like to sincerely thank the 13 respondents who generously gave their time to complete the survey. They were Ben Faber and four growers from California, Francisco Mena and Alejendro Palma from Chile, Iñaki Hormaza from Spain, Udi Gafni and Miki Noy from Israel, Tracey Campbell and Herbst Van Der Merwe from South Africa and Phillip West from New Zealand. The information has provided the project team and the industry valuable insights into the trends and issues amongst avocado irrigators around the world. It is expected that this information will be useful to all avocado producers.

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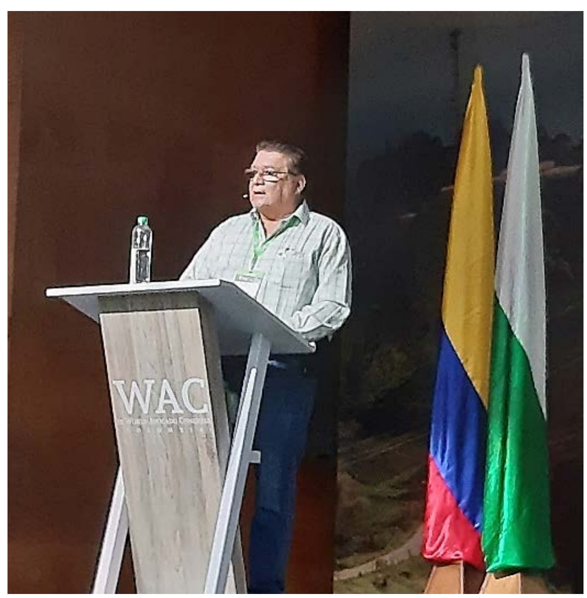
The avocado world has lost a star



Samuel Salazar-García, Ph.D.

February 12, 1956 –

August 29, 2021

Samuel Salazar-García, Ph.D., Senior Researcher at the Santiago Ixcuintla Research Station of INIFAP Instituto Nacional de Investigaciones Forestales Agricolas y Pecuarias, passed away in his home town of Tepic, Nayarit, Mexico, on August 29, 2021, due to COVID-19.

Samuel was an outstanding and tireless researcher devoted to understanding the basics of avocado tree physiology and applying that knowledge to improve avocado fruit production throughout Mexico and the Americas. Most researchers are experts in a specific area, but Samuel's expertise and hands-on experience were broad. We think it safe to say that he was one of the world's most knowledgeable avocado physiologist and horticulturalist. Samuel was *the expert* on avocado tree phenology and floral development. He created a scale illustrating key stages of avocado floral bud development that has proven extremely useful to researchers and a degree-day model of floral development that predicts anthesis. He also contributed the complete phenology of 'Hass' avocado in different climates that is of great importance to both researchers and growers. He developed the standard optimum leaf nutrient concentration ranges for avocado production in Mexico and, with the team at the Santiago Ixcuintla Research Station of INIFAP, developed a model for calculating fertilization rates for the many cultivars of avocado grown in Mexico and South America. Samuel authored two books on avocado nutrition and fertilization, as well of two chapters in two important avocado books. He contributed significantly to the success of 'Carmen Hass' avocado production in Mexico. He was also the first person to conduct research on the use of plant growth regulators in avocado production in California. Importantly, some of Samuel's data were included in the package to register the use of gibberellic acid (GA_3) at the cauliflower stage of inflorescence development to increase avocado yield and fruit size in California. Samuel conducted experiments to determine optimal pruning strategies for high density planting and investigated the best options for reducing tree height with the least impact on orchard production. He selected and field-tested salt-tolerant and root rot-resistant avocado rootstocks, starting at the end of the 70s. This year the rootstocks received Plant Breeders Rights in Mexico and will soon be available commercially and be of great value to the worldwide avocado industry.

Samuel also applied his talents to the improvement of mango production in Mexico. He and the great team with whom he worked in the Department of Fruit Crops Program, at the Santiago Ixcuintla Research Station of INIFAP, modeled the climate factors that regulated mango flowering and prescribed cultural practices to optimize bloom, fruit set and yield. Other species that he studied were nance (*Byrsonima crassifolia* L.) fruit quality indices and Tahiti lime nutrition.

For his significant efforts and enduring contributions to the success and sustainability of agriculture in Mexico, Dr. Samuel Salazar-García was awarded with the Nayarit Medal for Scientific Research in 1998, 2001, 2002 and 2005. Awarded with the Nayarit Bicentennial Medal for Scientific and Technological Research 2010. Recognized in Mexico as a Level III National Researcher in the National System of Researchers of the National Council of Science and Technology.

Samuel was a great teacher for many young agronomists in Mexico and Latin America, who thanks to his advice and teachings, have achieved a career in the avocado world. With his work, Samuel helped build a culture of avocado production with the highest levels of quality, always relying on science and his great knowledge of avocado. Samuel was always clear about where research efforts should be directed to improve avocado productivity.

He was one of the most appreciated consultants in America and considered one of the best among the avocado industry.A man of strong character and gentle appearance, he was always very demanding with the fulfillment of his research, extension and consulting tasks, but he never hesitated to team up with other colleagues and share experiences for the benefit of the avocado industry.

As the heavens gain a shiny new star, the global avocado community mourn its loss.

Our sincere condolences to Samuel's family.

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