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INTEGRATING SOIL MOISTURE, PLANT MONITORING, AND IMAGERY FOR SITE-SPECIFIC ZONE IRRIGATION MANAGEMENT IN WALNUTS

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Objectives

1. Evaluate the ability of Zone Irrigation Management (ZIM) to reduce spatial variability in yield, nut quality, and water use efficiency thereby improving yields of low-producing areas.

2. Develop a method for implementing site-specific irrigation scheduling based on integrated monitoring of soil water, plant water status (using stem water potential sensors and comparing to pressure chamber), and imagery from satellites or unmanned aerial vehicles.

3. Disseminate findings through the University of California Cooperative Extension network, private consultants, and publications in scientific journals.

Background

This project addresses the priority of improved accuracy of irrigation scheduling. The California Walnut Board (CWB) has identified a specific need for developing technologies that integrate midday stem water potential (MSWP) (from stem water potential sensors or pressure chamber) and soil-based moisture measurements for managing irrigation frequency and duration.

Another problem addressed by this proposal is spatial variability in production caused by underlying soil variability. Walnut acreage is forecasted to increase as consumer demand expands. However, deep well-drained soils have become scarce and expensive, so the production of walnuts has expanded into areas with more marginal soils such as the west side of the Sacramento Valley. These marginal soils tend to have more spatial variability in texture and structure, which influences available water holding capacity, fertility, and sometimes sodicity and salinity in the root zone. This translates to greater orchard variability in both canopy growth and yield. Growers are interested in management practices that can turn this variability from a liability into an opportunity by increasing crop production on the lesser-quality soils and improving water, energy, fertilizer, and other production efficiencies.

This project is focused on developing management practices and tools that integrate soil- and plant-based monitoring systems to support the implementation of Zone Irrigation Management (ZIM). ZIM involves taking relatively simple, low-cost steps to retrofit an existing sprinkler or microirrigation systems in established or young walnut orchards to better match the soil or orchard canopy variability with the goal of improving production.

We have completed two seasons, 2019 and 2020; during the 2021 walnut season, we plan to continue evaluating the ability of ZIM to reduce spatial variability in yield and nut quality, and evaluate stem water potential (SWP) osmometer sensors against the pressure chamber.

Results & Discussion

In 2020, dry in-shell walnut yield was measured using a weigh wagon retrofitted with load cells and an Insero AgHippo GPS system (https://aghippo.com/about) for georeferencing the location of field weights. This new yield measurement method shows potential to accomplish orchard yield mapping but requires further research and development. In 2020, the dry in-shell yield was monitored in areas ranging from about 0.3 to 1.1 acres, whereas in 2019 yields were measured manually from areas of 0.04 acre. The average percent difference between a grower and experimental yields was 17 and 11% in 2019 and 2020 respectively. In 2019, in-shell nut yields averaged 5,527 lbs/ac but ranged from 2,792 to 7,523 lbs/ac, while in 2020 yields averaged 4,568 lbs/ac but ranged from 3,170 to 6,013 lbs/ac, indicating that ZIM might be slowly reducing the variability in yield. We also observed a wide range in canopy light interception (PAR) in both years ranging from 52 to 87 and 44 to 81% in 2019 and 2020 respectively. Similarly, cumulative crop biomass production derived from satellite imagery ranged from 17,419 to 27,564 lbs/ac and was closely correlated to yield.

Nut quality measured by Blue Diamond revealed several insights including 1) nearly 3X difference in kernel shrivel across the 14 different monitoring locations, 2) a 4.8% difference in edible yield from a high of 46.6 to a low of 41.8%, and 3) a relative value range of 0.86 to 0.76 representing a 10% relative difference. This variability in quality implies that, e.g., in a year like 2020 where walnut prices were low at about $0.60/lb, this translated to a price of $0.60/lb vs $0.54/lb. So, at a 2020 yield average of 4,500 lbs/ac, this translated to gross revenues of about $2,700/acre vs $2,400/acre in the good vs weak areas in the orchard. For a higher yield year like 2019 with better prices of about $0.90/lb and yields on the order of 5,500 lbs/ac, the economic difference equates to $0.90/lb vs $0.81/lb and differences in gross revenues of $4,950/acre vs $4,450/acre. All of this begins to quantify the potential economic opportunity to be gained if the ZIM approach effectively raised yield and quality in the weakest areas of the orchards.

In 2020, we observed that on average yields from the heavy soil irrigation zones were higher than yields from the light soil irrigation zones and that the layered soil irrigation zones had the lowest yields. Water use efficiency was also highest in heavy irrigation zones and lowest in the layered soil irrigation zones. Production was clearly lower where PAR was less than 60%, especially if the soils in the root zone of these production areas have low root zone water holding capacity. Increasing seasonal actual ET increased yield, especially below 40 inches. The relationship between irrigation and yield was not consistent and needs more research. We also observed that SWP levels below baseline were strongly correlated with yield. We discovered that seasonal cumulative crop biomass estimated through remote sensing as daily photosynthetic CO_2 assimilation was strongly correlated with in-shell nut yield.

We compared the performance of osmometer-based stem water potential sensors to stem water potential measured using the pressure chamber and found that the agreement was not consistent probably due to poor contact between the tree xylem and the sensor's semipermeable membrane. This was somewhat expected because the suppliers of these sensors previously communicated challenges with their sensors specifically in young walnut trees. More work is still needed to improve contact between the sensor osmotic membrane and tree xylem. At the moment we are not yet ready to recommend management advice regarding the use of osmometer-based stem water potential sensors for irrigation scheduling in walnuts. We will continue to evaluate improved versions of the osmometer sensor in the coming 2021 season. We will also continue to evaluate smart irrigation scheduling tools, e.g., satellite-derived actual ET and wireless soil moisture sensing.

Overall, we recommend that growers use a combination of stem water potential (to determine when), soil water (to manage soil water depletion), and ET (to determine how much water to apply) to schedule irrigation in each management zone.