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Maximizing Canopy Light Interception Increases Yield in Prune Orchards

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The productivity of an orchard is related to the ability of the crop to utilize the sun's energy to fix carbon. Maximizing the quantity of light intercepted by the orchard canopy will maximize yield potential. Although tree training and pruning techniques are the most obvious factors directly affecting canopy light interception, cultural and environmental conditions, plant genetics, soil fertility, and pressure from pests and diseases may impact tree vigor and indirectly influence canopy light interception.

New technology for assessing canopy light interception

A mobile platform for measuring midday canopy interception of photosynthetically active radiation (PAR)* was developed by Bruce Lampinen, Extension Specialist, UC Davis, and colleagues. The device consists of a series of light sensors mounted on bars extending on either side of a Mule (Figure 1). This system offers numerous advantages, not the least of which is the speed at which one can collect data from both sides of rows and cover an entire orchard within one hour of solar noon. The light bar-equipped Mule can accommodate orchards with row spacings between 10 and 32 ft, and the use of a GPS receiver allows for routes of the platform to be overlayed with Google Earth images.

Figure 1. Mobile platform for measuring midday canopy interception of PAR.

Application in nut crops

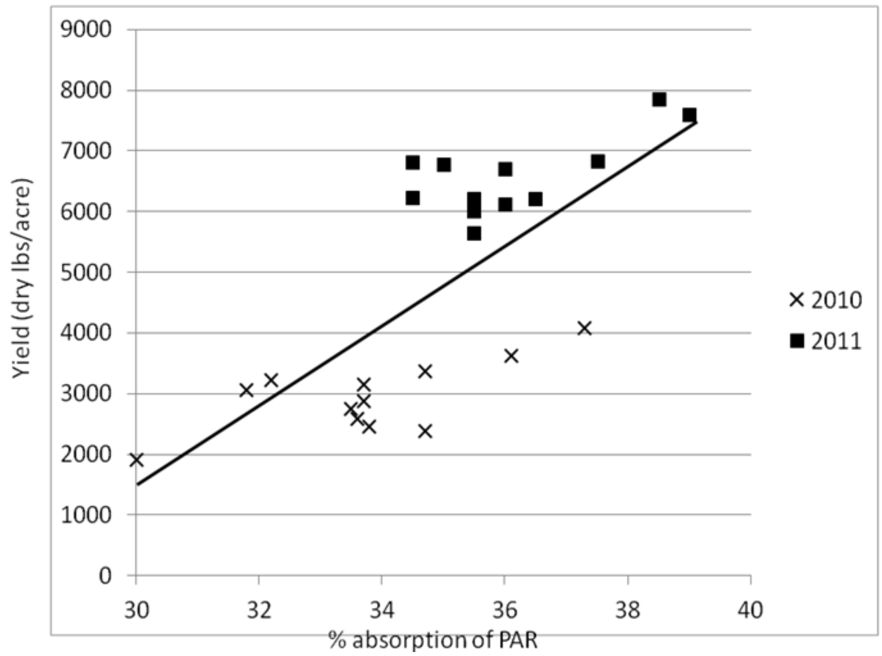
Lampinen's group has utilized the light bar-equipped Mule extensively in nut crops; however, the technology can be applied to most orchard systems. Lampinen's group has employed this technology to assist in determining the productivity potential of walnut and almond cultivars. Maximum light interception in almond orchards was achieved when orchards reached approximately 12 years old, whereas walnut orchards reached maximum light interception at approximately 15 years old.

Application to prunes

In 2010 and 2011, a mechanical pruning trial on 'French' prune on Mariana rootstock was conducted in Tulare County. One objective of the study was to determine whether the pruning treatments influenced canopy light interception and consequent yield. In two consecutive years, the pruning treatment had no influence on canopy light interception. In this experimental block, however, it was possible to elucidate the relationship between canopy light interception and yield—a topic not well documented in prune.

Canopy light interception in the prune block was dramatically higher in 2011 than in 2010 -- a change that was also reflected in yield (Figure 2). In 2010, canopy light interception ranged from approximately 30-37% of PAR; whereas in 2011, canopy light interception ranged from 35-38% of PAR. Similarly, yields for each test row were generally below 4,000 dry lbs/acre in 2010 and above 5,000 dry lbs/acre in 2011.

Figure 2. Canopy light interception was positively correlated with yield in a Tulare County orchard over two consecutive years.



Future Studies

In 2012 we plan to further document the relationship between canopy light interception and yield in ‘French’ prune. Documenting this relationship in prune may have several advantages to growers. First, it allows for conceptualization of maximum productivity of an orchard. Second, it allows the evaluation of the impacts of pruning treatments on the light interception/yield relationship. Additionally, it provides a metric for assessing the productivity of new cultivars and rootstocks being developed by breeders. Finally, it may offer a method of estimating property value of orchards based on potential productivity.

*Photosynthetically Active Radiation (PAR): The amount of light available for photosynthesis, which is light between 400 and 700 nanometer wavelength.

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Lime-Induced Iron Chlorosis: A Problem in Prunes and Other Fruit and Nut Crops

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Although iron (Fe) is the fourth most abundant element in the lithosphere, Fe deficiency is among the most common plant micronutrient deficiencies. Fe deficiency in plants is common in calcareous soils, waterlogged soils, sandy soils low in total Fe, and in peat and muck soils where organic matter chelates Fe, rendering Fe unavailable for plant uptake. In California, lime-induced Fe deficiency is observed in soils and irrigation water containing free lime, and is exacerbated by conditions that impede soil drainage (ie. compaction, high clay content), resulting in reductive conditions. Given that over 30% of the world's soils are calcareous, lime-induced Fe deficiency is a challenge in numerous perennial cropping systems including: grapes, pears, apple, citrus, avocado, pecans, and stone fruit (prune, almond, apricot, peach, nectarine, cherry).

In most soils, Fe oxides are the common source of Fe for plant nutrition. Solubility of Fe oxides is pH dependant; as pH increases, the free ionic forms of the micronutrient are changed to the hydroxy ions, and finally to the insoluble hydroxides or oxides. In calcareous soils, the bicarbonate ion inhibits mobilization of accumulated Fe from roots to foliage and directly affects availability of Fe in soil by buffering pH. When irrigation water is also high in bicarbonate, probability of Fe deficiency is enhanced because bicarbonate is continuously supplied to the soil, and more importantly, the roots may become crusted with lime as water evaporates, thus inhibiting root growth and function. Inside the plant, bicarbonate inhibits nutrient translocation from roots to interveinal leaf regions, thus inhibiting photosynthesis. The adverse effects of high bicarbonate levels are exacerbated in very saturated, very dry, or compact soils, where bicarbonate levels increase concurrent with diminished root growth and nutrient uptake.

Symptoms of Fe deficiency in plants

Fe is immobile in plants; therefore, symptoms appear in young leaves. Interveinal chlorosis (Figure 1) is the main symptom associated with Fe deficiency, followed by reduced shoot and root growth, complete foliar chlorosis, defoliation, shoot dieback, and under severe conditions may result in tree mortality. Overall productivity (yield) is reduced, mainly from a reduced number of fruiting points.

Figure 1. Interveinal chlorosis on 'French' prune in Tulare County, CA

Plant Adaptation

Plant species and cultivars vary in their sensitivity to Fe deficiency, and are categorized as either "Fe-efficient" or "Fe-inefficient." Fe-efficient plants have Fe uptake systems that are switched on under conditions of Fe deficiency. Fe-inefficient plants are unable to respond to Fe deficient conditions. All Fe-efficient plants, except grasses, utilize a Fe-uptake mechanism known as Strategy 1. Strategy 1 plants decrease rhizosphere pH by release of protons, thus increasing Fe solubility. Some plants may excrete organic compounds in the rhizosphere that reduce ferric iron (Fe^{3+}) to the more soluble ferrous (Fe^{2+}) forms or form soluble complexes that maintain Fe in solution. Additionally, roots of Strategy 1 plants have specialized mechanisms for reduction, uptake, and transfer of Fe within the plant. Strategy 2 plants (grasses) produce low molecular weight compounds called phytosiderophores which chelate Fe and take up the chelated Fe with a specific transport system.

Amelioration of Fe chlorosis

Planting sites in calcareous soils should be well drained to provide optimal conditions for root growth and nutrient uptake. Waterlogged and compact soils contain more carbon dioxide, which reacts with lime to form even more bicarbonate. These conditions, as well as very dry soils, also inhibit microbial activity which aids in solubilization and chelation of Fe. Prior to planting, test soil and water to determine the pH, lime equivalent, and bicarbonate concentration. Bicarbonate concentrations greater than 3 meq/L in irrigation water increase the hazard of lime accumulation on and around roots. If high bicarbonate water must be used, the pH must be adjusted to 6.0-6.5 to dissolve the bicarbonate and prevent it from negating the effects of soil-based treatments. In microsprinker and drip systems, acidification of irrigation water will also reduce the risk of emitter clogging, a common problem at bicarbonate levels over 2 meq/L. The cost of reducing the pH of irrigation water will more than compensate for the savings incurred by avoiding wasted investment in failed soil- and plant-based remedies. Systems can be set up to continuously and safely inject water with acids such as sulfuric, urea-sulfuric, or phosphoric during irrigations. Specific choice and rate will depend on crop, soil type, other nutrient needs, availability, and cost. Downstream pH meters are available to continuously adjust rate of acid use. Acetic and citric acid can be utilized by organic growers.

Soil based pre-plant treatments to reduce pH include elemental sulfur (S) and acids as mentioned above. It is only necessary to treat a limited area near the root zone to ameliorate symptoms because the tree only needs to take up a small amount of Fe. Material can be shanked in or banded and incorporated in the prospective planting tree row. One ton of elemental sulfur per treated acre is needed to mitigate three tons of lime, and may need to be re-applied every 3 to 5 years after planting. The addition of organic matter such as well-composted manures will benefit poorly drained or compact soils by increasing aeration for better root growth, fostering natural nutrient ion chelation, and reducing pH (depending on source material).

If possible, choose a Fe efficient species or cultivar. In perennial systems, lime-tolerant rootstocks may be the first line of defense in combating Fe deficiency. Some rootstocks mentioned are peach-almond and Krymsk-86 for stone fruit, Gisela 5 for cherry, and *Pyrus communis* for pear. Ongoing research studies in Europe focus on screening rootstocks of grape and olive for lime tolerance.

Once soil and water quality improvements are made, post-plant management strategies may also be implemented to ameliorate lime-induced Fe chlorosis in the short term. Soil can be acidified as described above. Individual trees can be treated by digging four to six 12-24 inch holes around the drip line and burying a mixture of sulfur and Fe fertilizer. Historically, two principal methods have been utilized: 1) foliar application of inorganic Fe salts (ie. ferrous sulfate), and 2) soil or foliar application of synthetic chelates. Application of Fe salts to foliage may have mixed results due to limited penetration of Fe into leaves and inadequate mobilization within the plant. Use of Fe chelates may be of benefit; however, they are expensive and pose an environmental concern due to their mobility within the soil profile. Because Fe is not mobile within the plant, repeat application of inorganic Fe salts or Fe chelates may be necessary throughout the growing season.

Choice of nitrogen (N) fertilizer may also influence solubility of rhizosphere Fe. When N is applied in the ammonium form (NH_4^+), the root releases a proton (H^+) to maintain a charge balance, thus reducing rhizosphere pH. Alternately, fertilization with nitrate (NO_3^-) results in root release of hydroxyl ions (OH^-), resulting in an increase in rhizosphere pH. Solubility of Fe^{3+} increases 1000 fold with each one unit decrease in pH; therefore, fertility-induced rhizosphere pH changes may significantly influence Fe availability.

New methods for amelioration of Fe chlorosis are under investigation. For example, container studies have demonstrated that inter-planting sheep's fescue, a Strategy 2 plant, with a Fe-inefficient grape rootstock may ameliorate Fe chlorosis in grape. In this system, the grass produces a phytosiderophore that enhances Fe availability to the grape. Additionally, soil amendment with ($Fe_3(PO_4)_2 \bullet 8H_2O$), a synthetic iron(II)-phosphate analogous to the mineral vivianite, has been effective at preventing Fe chlorosis in lemon, pear, olive, kiwi, and peach. Vivianite has a high Fe content (~30%) and serves as a slow release source of Fe in calcareous soils.

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