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Seasonal Patterns of Nutrient Uptake and Partitioning as a Function of Crop Load of the 'Hass' Avocado

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Introduction

For the 'Hass' avocado (*Persea americana* L.) industry of California, optimal rates and times for soil fertilization of nitrogen, phosphorus and potassium have not been adequately determined. Fertilization rates and optimal leaf nutrient ranges have been borrowed from citrus. Competition from Mexico and Chile requires the California avocado industry to increase production per acre to remain profitable. Optimizing fertilization is essential to achieve this goal.

The seasonal pattern of nutrient uptake is a key component of fertilizer management. Matching fertilizer application times and rates with periods of high nutrient demand not only maximizes yield, but also increases nutrient-use efficiency and, thus, reduces the potential for groundwater pollution. Experiments on nutrient uptake and allocation are routinely done to develop best management practices for commercial annual crops. However, determining nutrient uptake in mature trees is considerably more difficult, requiring repeated tree excavations at important phenological periods over the season. Thus, few best management practices have been developed for perennial tree crops.

The goal of this project is to determine the seasonal pattern of nutrient uptake and partitioning in alternate-bearing 'Hass' avocado trees. The research will quantify the amount of each nutrient partitioned into vegetative or reproductive growth and storage pools. The research will identify the periods of high nutrient use from bloom to harvest as a function of crop load, and thus identify the amount of each nutrient required, and when it is required, to produce an on-crop and good return crop the following year. The results will enable us to provide guidelines for fertilization based on maximum nutrient-use efficiency and eliminate applications made during ineffective periods of uptake to thus protect the groundwater and increase profitability for California's 6,000 avocado growers.

Project Objectives

1 To quantify the seasonal pattern of N, P, K, B, Ca, and Zn uptake and partitioning in bearing 'Hass' avocado trees;
2. To quantify the effects of different crop loads on these seasonal patterns of nutrient uptake, partitioning into vegetative and reproductive growth, and storage;

3. To determine the seasonal patterns of nutrient uptake in alternate bearing avocado trees and to develop best management fertilizer practices for the ‘Hass’ avocado tree.

Project Description

The research was conducted in a commercially bearing avocado orchard in Somis, CA. In June 2001, 60 trees were selected for inclusion in the project based on their trunk diameter, height, canopy size, and fruiting potential. Thirty of these trees were subsequently defruited to establish both lightly fruiting and heavy fruiting trees. The experiment was set up as a completely randomized design, with factors: 1) cropping status (heavily cropping—On and lightly cropping—Off trees) and 2) time of excavation. Two trees (an on- and an off-year tree) were excavated monthly between November 2001 and December 2002 for a total of 13 excavation dates. The entire tree (roots and shoots) was excavated every third month (4 dates), and the aboveground dry matter was harvested for the other nine dates. Trees were dissected into the following components, and the total weight of each component determined: leaves, new shoots, inflorescences or fruit (separated into seed and flesh), small branches (£ 2.5 cm), mid-size branches (2.5-5.0 cm) scaffolding branches, scion trunk, rootstock trunk, scaffolding roots, small roots, and new roots. Sub-samples were dried, ground, and analyzed for carbon, nitrogen, nitrate-nitrogen, phosphorus, potassium, calcium, iron, magnesium, manganese, zinc, boron, sulfur, copper, sodium, chloride, and aluminum.

Ten percent ^{15}N enriched ammonium sulfate was applied on three dates (August, 15, 2002; November 14, 2002; June 15, 2003) and whole trees were excavated three months after application and analyzed for percent ^{15}N recovery. ^{15}N analyses from the June 15 tree excavation are currently being conducted and these data will be reported at a later time. These data will be used to determine periods of high N uptake capacity in avocado trees and evaluate the effects of alternate bearing on N uptake and recovery. Such data are required to develop best management N fertilizer practices.

Data analysis.
The results obtained were used to calculate gram nutrient per tree by the following equation using nitrogen as the example:

g N/g dry wt tissue X g dry wt tissue/g fr wt tissue X total fr wt tissue/tree = total g N/tree

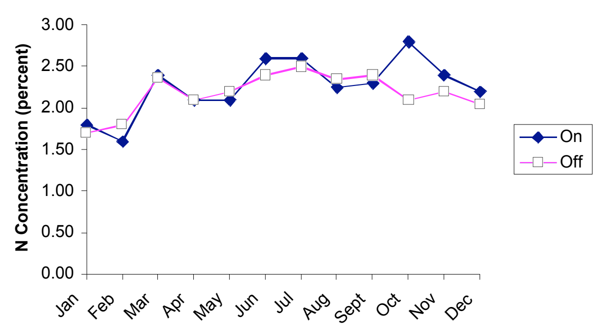
Nutrient uptake was determined as the difference in total tree nutrient contents from sequential tree excavations and from ^{15}N recovery in the various tree parts.

Results

Quantify seasonal pattern of nutrient uptake and partitioning as a function crop load of the ‘Hass’ avocado.

Leaf N Concentrations
Alternate bearing had little effect on the changes in leaf N concentrations over the season (Figure 1). Leaf N concentrations tended to increase over the season, however, few differences were seen between on- and off year trees. This is surprising since avocado trees accumulated significant quantities of nitrogen in their fruit and this demand was not reflected in lower leaf N concentrations. In other alternate bearing species such as pistachios, leaf N concentrations are frequently lower in on- vs. off-year trees. This indicated that avocado leaves are highly buffered against large N demands by the fruit.

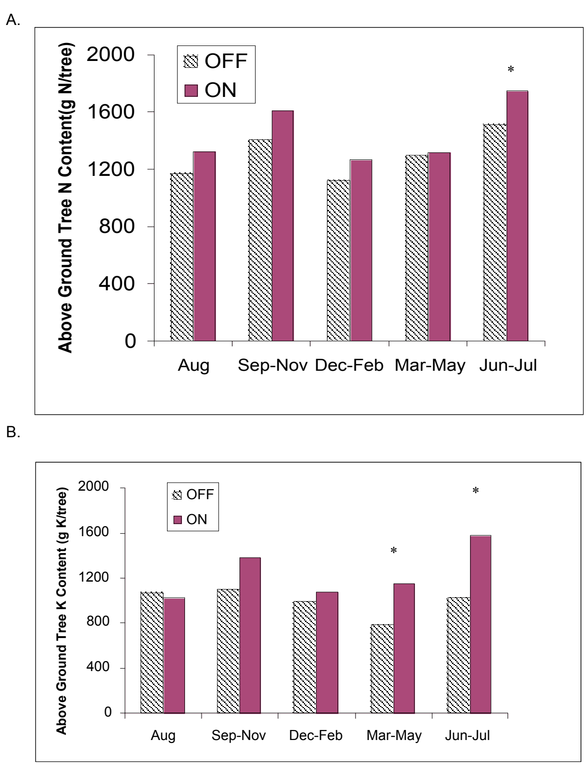
Figure 1. Effect of alternate bearing on leaf N concentration over the 2002 season.



Total Aboveground Tree N and K Accumulation
Total aboveground tree N and K contents were averaged over a three-month period in the late summer (September-November), winter (December-February), and spring (March-May), and averaged over a two-month period during fruit growth and maturation (June-July) for both on- and off-year trees (Figure 2). Tree N contents increased by almost 50% in both on- and off-year trees between the

spring and fall. Increases in leaf and fruit nitrogen (in on-year trees only) pools over the season were the primary factors in producing these increases in tree N status (data not shown). In the fall, heavy fruit loads resulted in on-year trees containing significantly more N than off-year trees. Potassium levels increased significantly in on- vs. off-year trees during fruit growth and maturation. On-year trees contained almost 60% more K than off-year trees at fruit maturity in June and July.

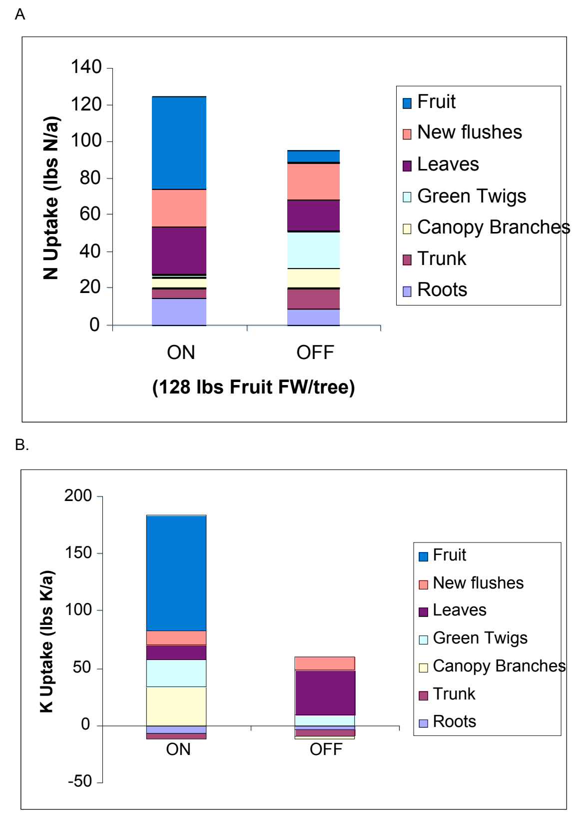
Figure 2. Aboveground tree dry nitrogen (A) and potassium contents (B) of mature avocado trees over the season. * indicate significance between on- and off-year trees at p =0.05.



Tree N and K Uptake Over the Alternate Bearing Cycle

An estimate of total tree N and K uptake was determined by the difference in tree nutrient content at bloom (February) and at fruit harvest (the following July) in both on- and off-year trees (Figure 3). Over the alternate bearing cycle, on-year trees took up 125 lbs of N and 171 lbs of K per acre, and fruits comprised 40% and 59% of the total N and K uptake, respectively. In contrast, only 95 lbs of N and 48 lbs of K per acre were taken up in off-year trees. Almost 80% of K in the tree was located in the leaves during the off year.

Figure 3. Uptake of N (A) and K (B) (lbs/a) in various tree components over the alternate bearing cycle in mature 'Hass' avocado trees.



Quantify seasonal pattern of nitrogen uptake and partitioning using labeled nitrogen fertilizer (^{15}N).

Ten percent ^{15}N enriched ammonium sulfate was applied on two dates (August, 15, 2002 and November 14, 2002) and whole trees were excavated three months after application and analyzed for percent ^{15}N recovery. Percent ^{15}N recoveries in November were 59 and 35% for the on- and off-year tree, respectively. The on-year tree recovered almost double the amount of ^{15}N as the off-year tree (data not shown). Most of the ^{15}N recovery in the on-year tree accumulated in the fruit, whereas leaves were the main repositories for 15N in the off-year tree (Figure 3). In both the on- and off-year tree, the majority of the ^{15}N was translocated out of roots and accumulated in actively growing tissues such as fruit, leaves, and green twigs (Figure 3). These results support the hypothesis that N uptake is regulated by tree N demand.

On-year trees have a large N requirement and, therefore, more is taken up to meet that demand.

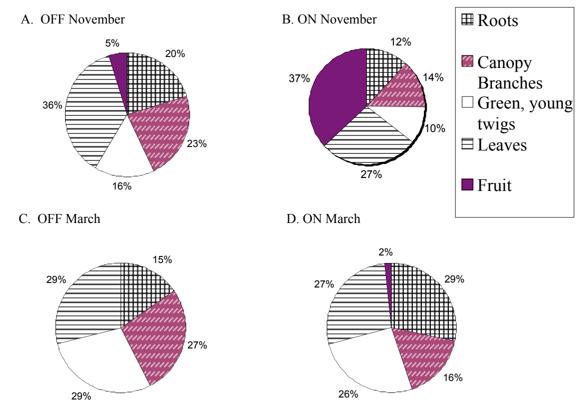
These recovery percentages in both on- and off-year avocado trees are high compared to the typical 15-30% ^{15}N recovery rates reported in the deciduous fruit crop literature. This indicates that August fertilizer N applications are efficiently taken up by roots and mobilized by the tree. Avocado trees have very dense root mats, which may have contributed to the high ^{15}N recovery rates.

The percent recovery rates of ^{15}N applied to trees in November and excavated in March were 11 and 27% for on- and off-year trees, respectively. Thus, the off-year tree recovered more than twice as much ^{15}N as the on-year tree when applied in November.

The ^{15}N accumulated equally between leaves, green twigs, and canopy branches in the off-year tree (Figure 3). In contrast, the roots accumulated the most ^{15}N in the on-year tree. This lack of ^{15}N translocation out of roots may reflect the lower N requirement for on-year trees at this time. These ^{15}N recovery results appear to contradict earlier reports that N uptake, translocation and allocation are a function of sink demand. Not so, on-year trees in November would have fewer new vegetative shoots to support than off-year trees, and since they were going into an off-year bloom in Spring 2003, they would also have fewer reproductive sinks. Fruit accumulated only two percent of the total ^{15}N recovered. In March, inflorescences were just pushing out and weighed only 1.8 kg fresh weight per tree. Growth of mature avocado fruit was just beginning to resume again in March as air and soil temperatures increased. Thus, fruit demand for N was low at this time. In contrast, trees carrying an off-year crop would have produced more vegetative shoots during the previous months and would be supporting the development of inflorescences for an on-year bloom in March 2003.

The ^{15}N recovery rates were markedly lower when applied in November compared to August. The cold and wet weather likely contributed to these lower recovery rates in two ways: 1) high rainfall events likely increased nitrogen leaching, and 2) cold weather decreased tree growth which concomitantly reduced tree N demand.

Figure 4. ^{15}N distribution in mature off- (A) and on-year (B) avocado trees, applied August, 15, 2002 and excavated on November 14, 2002, and ^{15}N distribution in off-(C) and on-year (D) trees applied November 14, 2002, and ^{15}N distribution in off-(C) and on-year (D) trees applied November 14, 2002, and excavated on March 15, 2003.



Conclusions

An understanding of seasonal tree nutrient requirements is critical in developing best-management fertilizer practices. By excavating whole trees, determining N, P, and K uptake, and analyzing for ^{15}N recovery, we have established nutrient uptake patterns over the season in on- and off-year avocado trees. Nutrient applications should be coincident with these periods of high tree demand. Careful analysis of tree growth patterns (particularly of fruits and leaves) can indicate when tree nutrient demand is high and, thus, when nutrients should be applied to maximize tree nutrient uptake and reduce environmental pollution. Nutrient leaching losses should be minimized by coordinating fertilizer applications with periods of high plant demand.