CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE
FERTILIZER RESEARCH AND EDUCATION PROGRAM (FREP)

A. FINAL REPORT

01/01/03 to 012/31/03

A. Project Title:
Seasonal Patterns of Nutrient Uptake and Partitioning as a Function of Crop Load of the 'Hass' Avocado

Project Location:
Somis, CA

Project Duration : Three years

Project Leader (s): (Name, Title, Affiliation, Mailing Address, Telephone #, FAX #).

Richard Rosecrance
Assistant Professor
Dept.of Biology
California State University
Chico, CA 95926
Phone: (530) 898-5699
FAX: (530) 898-5845
E-mail: <rrosecrance@csuchico.edu>

Carol J. Lovatt
Professor of Plant Physiology
Dept. of Botany and Plant
Sciences University of California
Riverside, CA 92521-0124
Phone: (909) 787-4663
FAX: (909) 787-4437
E-mail: <carol.lovatt@ucr.edu>

Cooperator(s): (Name, Title, Affiliation, Mailing Address, Telephone #) Do not include names of organizations or individuals unless a letter of support is included with the proposal at the time of submission. See guidelines for details.

Don Reeder and Scott Savard
Somis Pacific
P.O Box 136
Somis, CA 93066
Phone : (805) 484-1779
FAX: (805) 523-8072

Ben Faber
UC Farm Advisor
Coop. Ext. Ventura County 669
County Square Drive, #100
Ventura CA, 93003-5401
Phone: (805) 645-1451

B. Statement of Objectives :

Briefly specify the problem being addressed by the project.
The project objectives should be restated and consistent with the objective(s) of the original proposal.

The overall objective is to quantify the seasonal pattern of nutrient uptake and partitioning in `Hass' avocado trees on heavily-bearing (on) and lightly-bearing (off) crops.

The specific objectives are:

(i) to determine the period(s) of high nutrient demand in the phenology of the `Hass' avocado tree;

(ii) to quantify the effect of crop load on nutrient uptake and partitioning.

C. Executive Summary:

Briefly describe and summarize the project tasks, milestones and products delivered.

The objectives of this study was to quantify the seasonal pattern of nutrient uptake and partitioning in 'Hass' avocado trees on heavily-bearing (on) and lightly-bearing (off) trees. In order to improve yields, nutrient use efficiency, and decrease environmental pollution we determined period(s) of high nutrient demand in the phenology of the 'Hass' avocado tree and quantified the effect of crop load on nutrient uptake and partitioning. Over a two year period, two mature avocado trees (one on- and one off -year tree) were excavated monthly, dried, weighed, and nutrient content determined. In mid August and mid November, ^{15}N ammonium sulfate was applied to the soil and trees excavated three months later to quantify tree ^{15}N recovery.

Accumulation of N, P and K in fruits and in the whole tree (ie. roots plus shoots) occurred during mid-to-late summer and in spring before harvest. Little accumulation occurred during the winter months. Labeled ^{15}N recovery percentages were high when applied in mid-summer (August), with on- and off-year tree recovering 59% and 35% of the ^{15}N applied, respectively. However, when ^{15}N was applied during the winter months, 15N recovery rates were significantly lower. The percent recovery rates of 15N applied to trees in November and excavated in March were 11 % and 27% for on- and off-year trees, respectively. Over the alternate bearing cycle, on-year trees took up 125 lbs of N, 171 lbs of K, and 19 lbs of P per acre, and fruits comprised 40%, 59% and 38% of the total N, K, and P uptake, respectively. In contrast, only 95 lbs of N and 48 lbs of K, and 14 lbs of P per acre were taken up in off-year trees. Thus, to improve yields, N, K, and P use efficiency, and decrease environmental pollution: 1) apply nutrients in mid-to-late summer and in spring before harvest, 2) avoid nutrient applications during the winter months, and 3) match fertilizer applications with orchard crop load, applying more nutrients during heavy vs. light cropping years.

D. Work **Description**: Work description should be identified by task and subtask numbers as they appear in your contract and include a descriptive title.

TASK I & 2: Quantify seasonal pattern of nutrient uptake and partitioning as a function of crop load of the `Hass' avocado and rate of fertilization

Month of initiation: 01/02 Month of completion 3/03

Subtask 2.1: Quantify seasonal pattern of nutrient uptake and partitioning as a function crop load of the `Hass' avocado

`Hass' avocado trees bearing on-year and off-year crops were excavated monthly between January and December 2002. Trees were dissected into 12 components and the total biomass (fresh weight) of each component was weighed. Subsamples were taken from the 12 tree components and the fresh biomass of each subsample determined. These subsamples were then oven dried at 60 °C and their dry weight determined. Five individual fruit per tree were weighed and dissected into peel, flesh and seed, each of which were weighed. Each component was dried, reweighed and ground. All samples were ground in a Wiley mill to pass through a 40-mess screen (0.635-mm), and three representative samples from each subsample of the 12 tree components and 3 fruit components were sent to Albion Labs for macro- and micro-nutrient analysis. This task has been completed as of March 2003.

Subtask 2.2: Analyze data

Leaf Nutrient Concentrations.
Alternate bearing had no significant effect on leaf nutrient concentrations and therefore data were combined between on- and off-year trees (Figure 1). Leaf N, P, and K concentrations were highest in young leaves and declined with leaf age. The rate of decline accelerated during flowering when the leaves were about 10 months old. Leaf Ca and Mg gradually increased over time. Leaf nutrient concentrations were all within the sufficient commercial range for that nutrient; none were found to be either nutrient deficient or nutrient excessive. Interestingly, at leaf fall, only N and S were remobilized and exported from senescing leaves; trees resorbed little or no P, K, Ca, and Mg. The high nutrient status of these trees may have contributed to the lack of nutrient resorption.

Fruit Dry Weight and Nutrient Content

Fruit growth followed a three stage growth pattern typical of many deciduous fruits (Figure 2). Approximately half of the total fruit dry weight occurred during the summer and fall (July through November) and half during the following spring and summer. Little or no fruit growth occurred during the winter months. The flesh comprised between 50 and 70% of total fruit dry weight and the seed at maturity contained approximately 25% of the total fruit dry weight.

Fruit nutrient accumulation patterns in general mirrored dry weight accumulation (Figure 3). Following anthesis, nutrients accumulated rapidly in fruits, remained constant during the winter, and increased in spring and summer. Much of the potassium and phosphorous accumulation occurred during the last three months of growth. Potassium plays a role in sugar transport and studies have shown that K additions can increase fruit size of `Hass' avocado (Lahav, personal communication). In contrast, fruit calcium did not increase after the first three months of growth, indicating that the calcium requirement was met early in the growth of the fruit.

Total Tree Nutrient Accumulation

The total mineral distribution in 20 year-old 'Hass' avocado trees is shown in Table 1. The leaves and branches were the primary reservoirs for the macronutrients (N, P, K, Mg, Ca, and S), though the leaves had consistently higher nutrient concentrations. The leaves and twigs comprised 12% of total dry weight, yet contained close to 30% of the macronutrients (N, P, K, Mg, Ca, and S). In contrast, branches (stems greater than 2.5 cm in diameter) composed 50% of total tree dry mater, but less than 40% of tree N, P, K, and S. The roots contained 19, 21, 15, and 15% of the N, P, K and Ca, respectively. High Fe, Al and Na levels in roots likely resulted from soil contamination adhering to the roots. The fruit were extremely low in Ca and Mg.

Nutrient accumulation in whole trees increased during the summer months (Figure 4). The fruit and branches were the primary organs where nutrients accumulated. Nutrient levels in roots remained relatively constant over the year.

Tree N K, and P Uptake over the Alternate Bearing Cycle

An estimate of total tree N, K, and P 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 5). Over the alternate bearing cycle, on-year trees took up 125 lbs of N, 171 lbs of K, and 19 lbs of P per acre, and fruits comprised 40%, 59%, and 38% of the total N, K, and P uptake, respectively. In contrast, only 95 lbs of N, 48 lbs of K, and 14 lbs of P 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.

Subtask 2.3: Quantify seasonal pattern of nitrogen uptake and partitioning using labeled nitrogen fertilizer (15N).

Month of initiation: 11/02 Month of completion 11/03

Ten percent ^{15}N enriched ammonium sulfate was applied on two dates (August, 15, 2002 and November 14, 2002) and whole tree were excavated three months after application and analyze 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 ^{15}N in the off-year tree (Figure 6). 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 6). 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 6). 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

Subtrask 2.3: Outreach

Some of the results from this project were presented at the UC Davis Pomology Extension Continuing Conference on Friday March 21, 2003. in talked given by Richard Rosecrance entitled, "N Calculators Nutritional Model, Background, and Development". There were approximately 35 people in attendance.

This project was presented to 30-40 avocado growers in July 10, 2003 at a meeting of the Production Research Committee of the California Avocado Commission. The meeting was held in Room `B', UCR Extension, 1200 University Dr in Riverside. The 25 minute talk was entitled, "Patterns of Nutrient Uptake and Partitioning of the `Hass' Avocado."

I gave a presentation at CDFA's Eleventh Annual Fertilizer Research & Education Program Conference on November 20, 2003 in Tulare, CA. The title of the talk was, "Seasonal patterns of nutrient uptake and partitioning as a function of crop load on the `Hass' avocado." Approximately 40 people were in attendance.

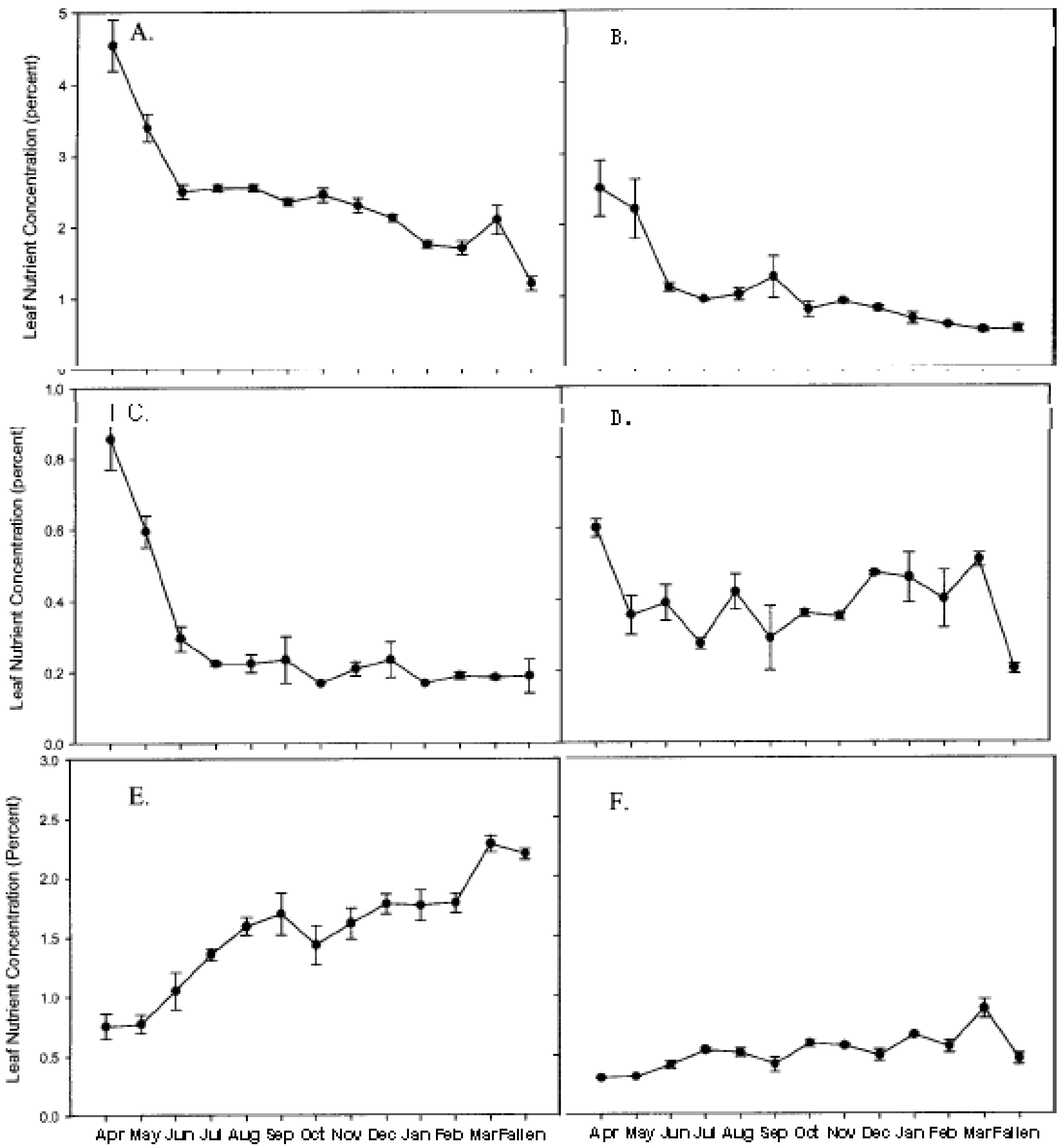

Figure 1. Leaf nitrogen (A), potassium (B), phosphorus(C), and sulfur (D), calcium (E), and magnesium (F) concentration in mature 'Hass' avocado trees. Each point is the mean of two tree replicates, with standard error bars.

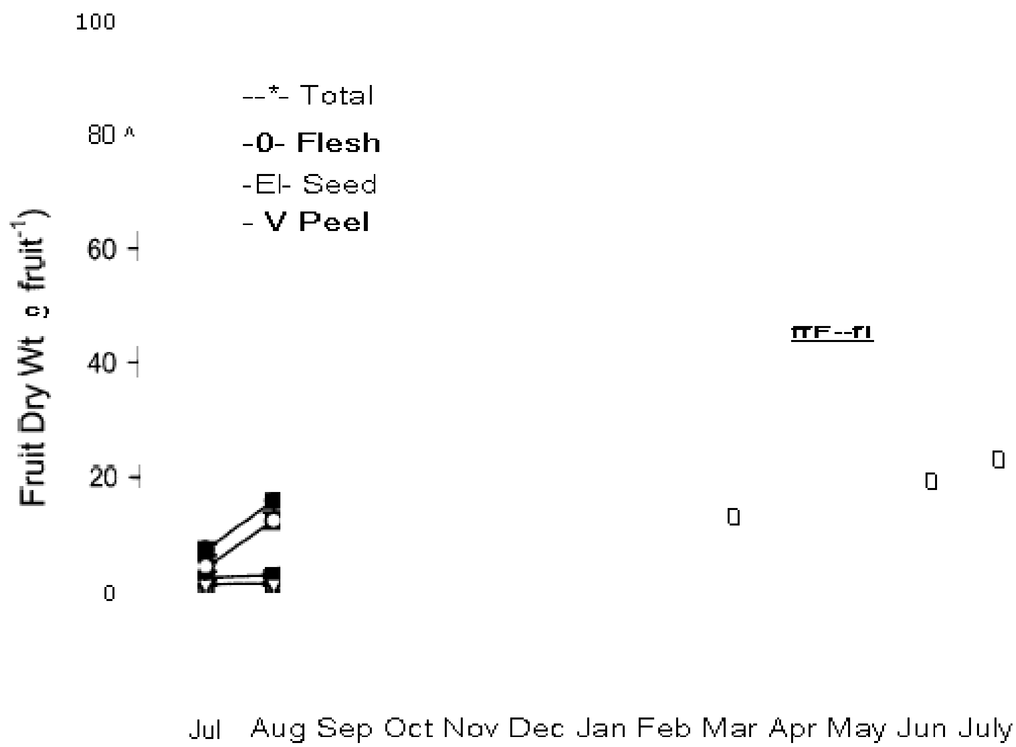

Figure 2. Fruit dry weight over the season in the total fruit, flesh, seed, and peel. Each point is the mean of between 5 and 12 fruit, with standard error bars.

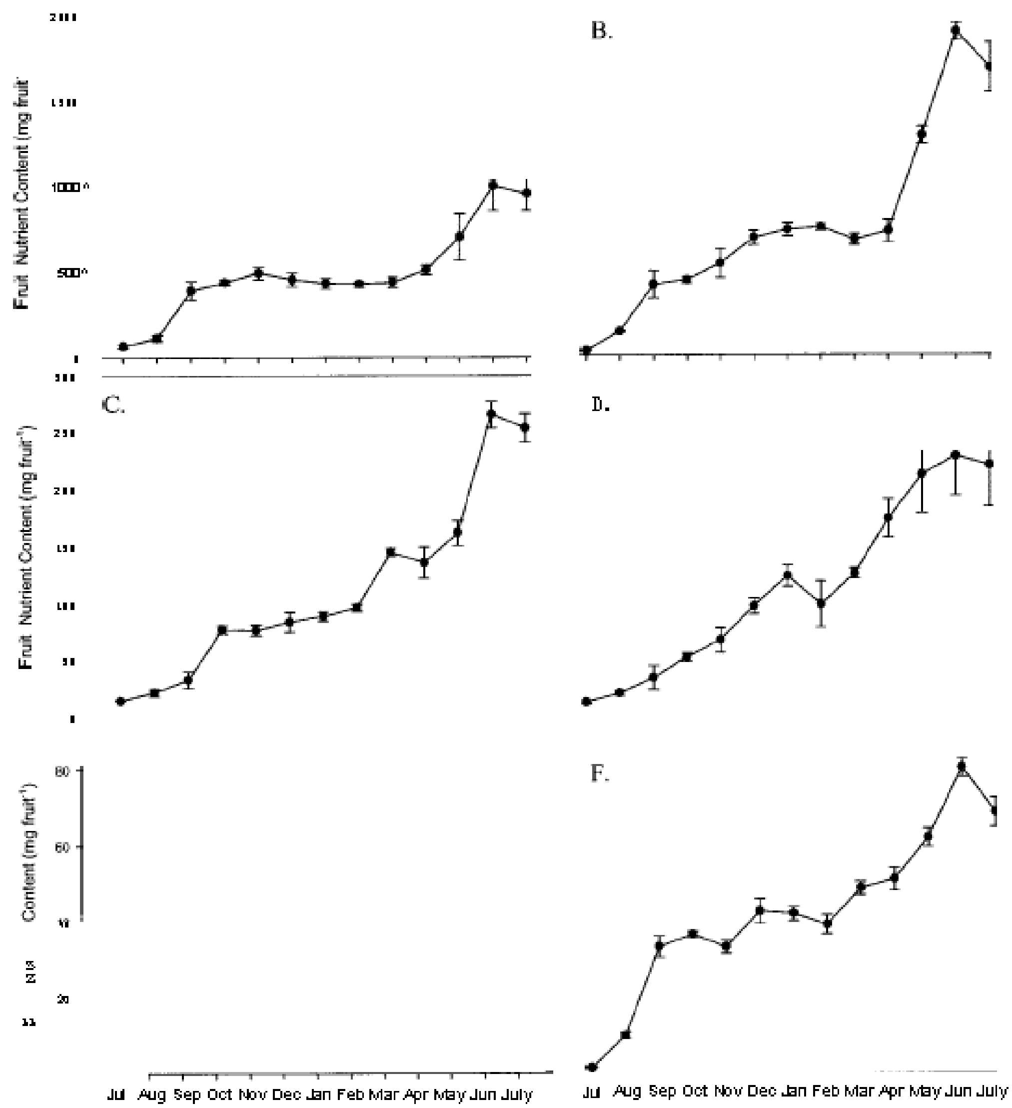

Figure 3. Fruit nitrogen (A), potassium (B), phosphorus(C), and sulfur (D), calcium (E), and magnesium (F) in mature 'Hass' avocado trees. Each point is the mean of between 5 and 12 fruit, with standard error bars.

	Mineral balance (g per tree) of 20-year-old 'Hass' avocado in California					
	Leaves & Twigs	Branches	Trunk	Roots	Fruit	Total	Proportion removed by fruit %
Dry Wt	18.2	169	24	85	170	335	5.1
N	559	657	34	293	191	1734	11.0
P	118	129	13	85	53	399	13.3
K	373	610	56	251	377	1665	22.6
Ca	575	1093	95	317	6	2086	0.3
Mg	183	471	12	61	16	742	2.2
S	101	120	14	65	45	345	13.2
Al	1.1	4.4	0.7	32.7	0.0	39	0.1
B	1.8	3.6	0.4	1.7	1.4	9	15.9
Fe	3.4	6.4	0.9	22.0	0.3	33	1.1
Mn	3.0	3.6	0.3	1.3	0.1	8	1.1
Na	9.8	23.9	9.2	85.8	1.8	131	1.4
Zn	2.1	3.9	0.8	7.6	0.5	15	3.3

Table 1. Dry weight and mineral balance (g per tree) of 20 year-old 'Hass' avocado trees.

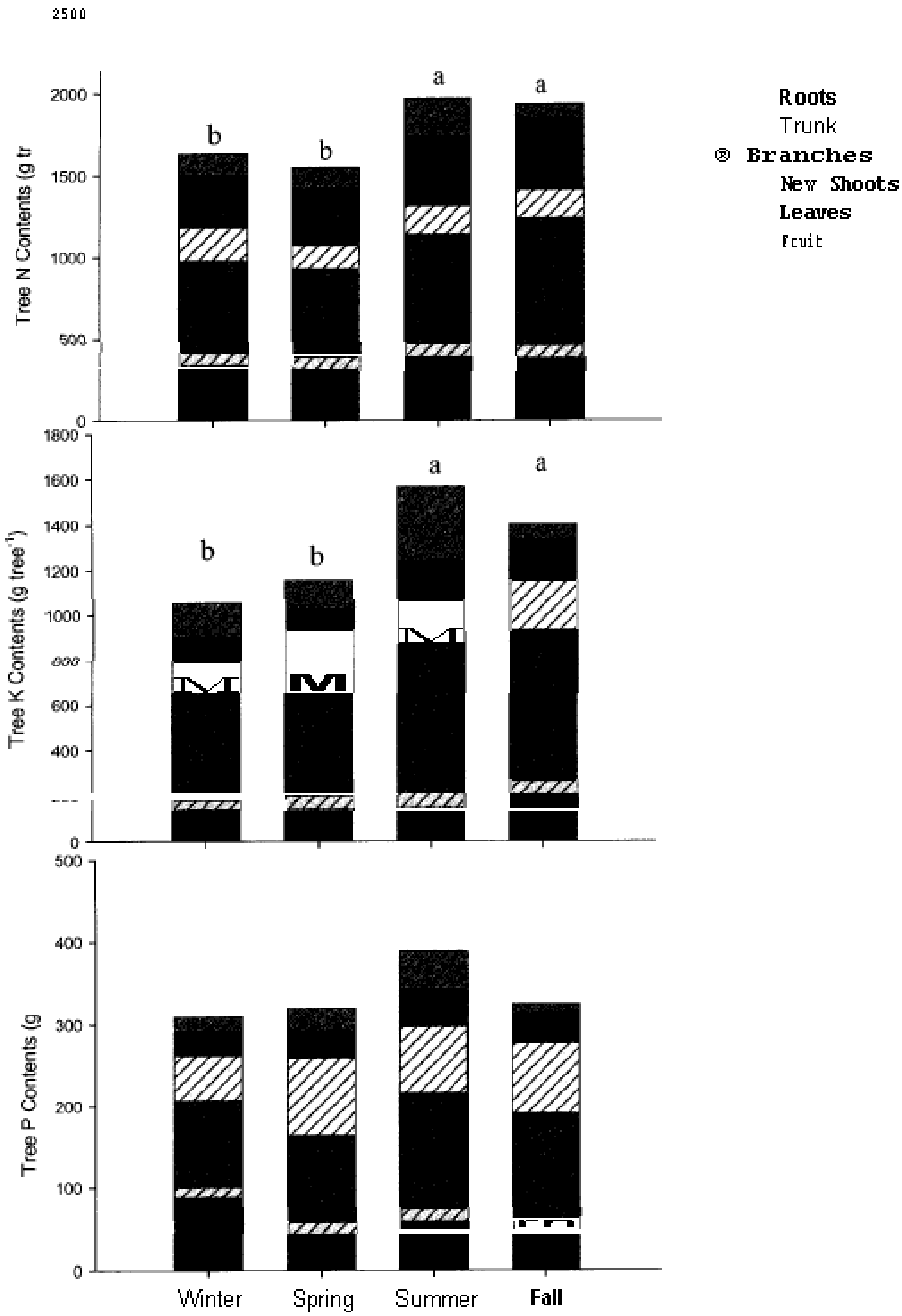

Figure 4. Nutrient accumulation in heavily cropping 20-year-old 'Hass' avocado trees over the season. Bars with different letters above them are significantly different ($p < 0.05$) based on the Tukey Krammer test.

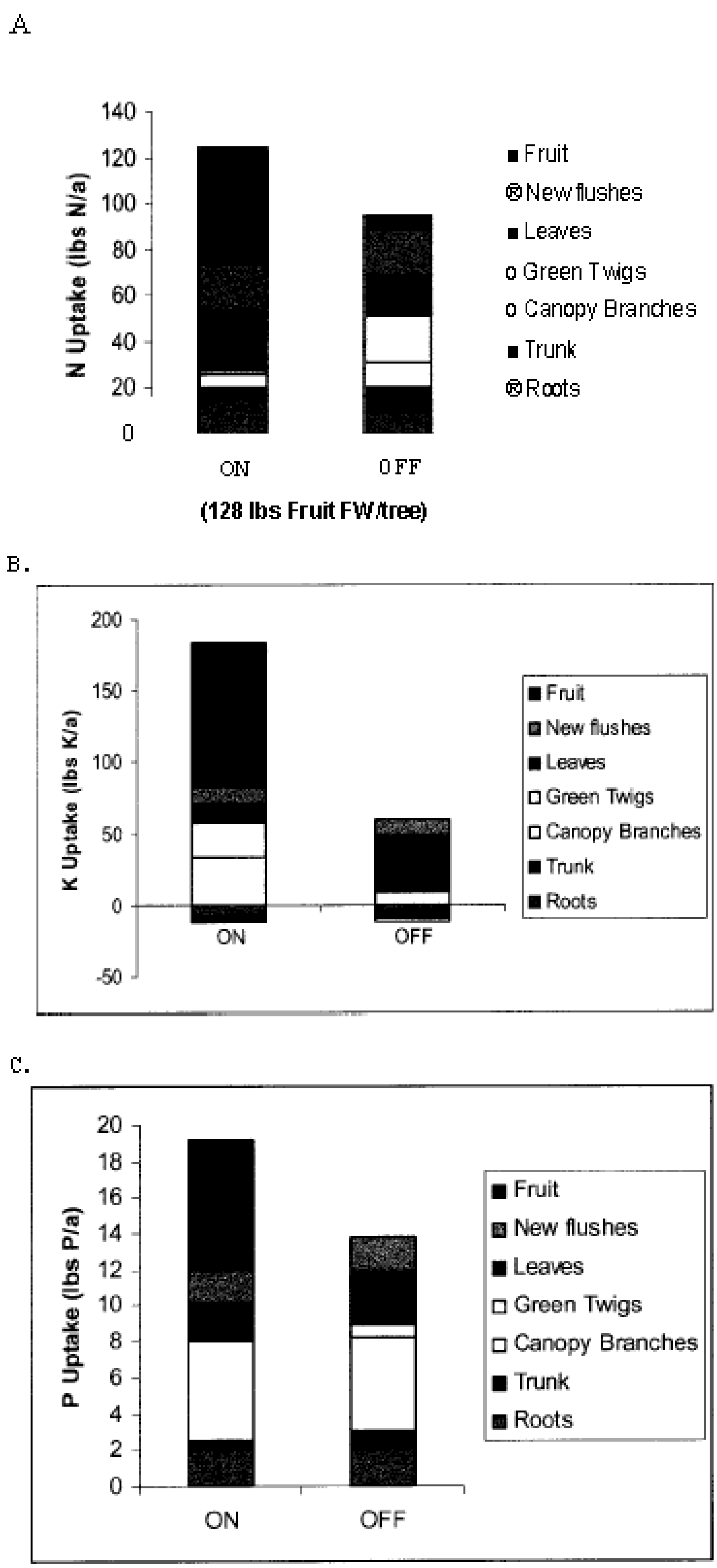

Figure 5. Uptake of N (A) K (B) and P (lbs/a) in various tree components over the alternate bearing cycle in mature 'Hass' avocado trees.

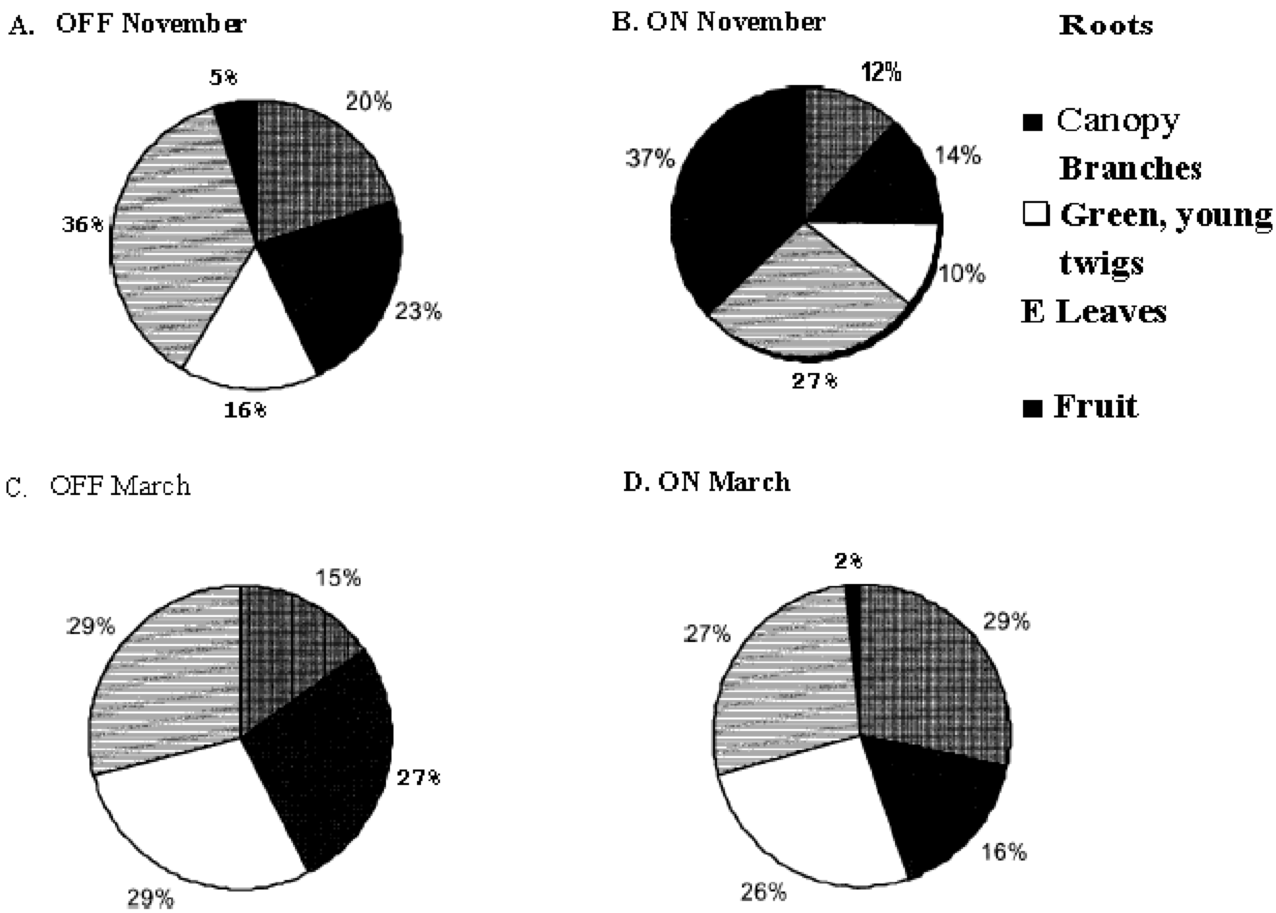

Figure 6. ^{15}N distribution in mature off- (A) and on-year (B) avocado trees, applied August, 15, 2002 and excavated on November 14, 2002 , and ^{15}N distribution in off-(C) and on-year (D) trees applied November 14, 2002, and ^{15}N distribution in off- (C) and on- year (D) trees applied November 14, 2002, and excavated on March 15, 2003.