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 is being conducted in a commercially bearing avocado orchard in Moorpark, 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 (off-crop trees) and heavy fruiting on-crop trees. The experiment is a randomized complete block design with factors: (1) cropping status (heavily cropping—on-crop trees and lightly cropping—off-crop trees) and (2) time of excavation. Two trees (one on-crop and one-off-crop tree) are dissected at each sampling date; there are a total of 13 sampling dates. For each sampling date, the entire tree is dissected into the following components, and the total fresh and dry weight of each component determined: leaves, new shoots, inflorescences or fruit (separated into seed, flesh and peel), 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 actively growing roots. Sub-samples are dried, ground, and analyzed for carbon, nitrogen, nitrate-nitrogen, phosphorus, potassium, calcium, iron, magnesium, manganese, zinc, boron, sulfur, copper, sodium, chloride, and aluminum. These analyses will allow us to meet objective (1) to determine the period(s) of high nutrient demand in the phenology of the 'Hass' avocado tree. Having trees with varying crop loads will enable us to meet objective (2) to quantify the effect of crop load on nutrient uptake and partitioning into new vegetative and reproductive growth, and storage tissues.

The results obtained above will be used to calculate g 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 will be determined as the difference in total tree nutrient contents from sequential sampling dates. The total amount of each nutrient required by developing flowers and fruit will be plotted monthly over the course of fruit development along with the increase in individual fruit biomass. The total increase in vegetative biomass (both roots and shoots) and total nutrient content of each component will be calculated and plotted monthly. Nitrogen uptake will also be determined from ^{15}N applications to both on- and off-crop trees over the season.

Results and Conclusions

Effect of alternate bearing on 'Hass' avocado tree biomass, nutrient content and nutrient distribution within the tree

The results thus far provide evidence of the effect of crop load (i.e., on-year crop vs. off-year crop) on production of reproductive structures in spring and through early fruit set (Table 1). Trees (A) carrying an off crop (the spring 2001 fruit were removed in July 2001) produced significantly greater biomass of reproductive structures from March through June 2002 compared to trees (B) that were not defruited in July 2001. The surprising result was that even the presence of a few fruit (2 kg) was sufficient to reduce return bloom. The spring 2001 fruit were harvested in July 2002.

Nutrient concentrations varied among the tree parts as a result of alternate bearing (Table 2). Concentrations of the macronutrients N, P and K were greater in the leaves, new shoots, and small branches of off-crop trees than in the analogous structures of on-crop trees. Similarly, K levels in fine actively growing roots were greater in off-crop compared with on-crop trees. These differences likely result from a higher demand for nutrient redistribution out of these tissues and into the large number of fruit of on-crop trees.

Whole tree nutrient contents were calculated as the product of dry weight of the tree structure and the nutrient concentration of that structure (Table 3). Total tree nutrient contents were similar for both on-crop and off-crop trees, although tissues in close proximity to fruit (leaves, current wood) tended to have lower nutrient contents in on-crop vs. off-crop trees. In both tree sampling dates, heavily cropping trees accumulated nutrients primarily in their fruit, while lightly cropping trees stored nutrients in their leaves.

It will be very interesting to see how the nutrients in the tree tissues change over the season and as a result of alternate bearing. This information is critical in determining the seasonal pattern of nutrient uptake and for matching fertilizer application with periods of high nutrient demand.

Woody tissues comprised most of the tree dry weight, but contained few nutrients, whereas current season's growth made up a small fraction of the tree's dry weight, yet contained most of the tree's nutrients (Table 4). New shoot, leaves and fruit, structures that would be added to the tree each year, made up only 16% of the total biomass on a dry weight basis of the tree but contained 47% of the total N in the tree, 36% of all the P and 44% the total K (Table 4). Scaffolding branches accounted for twice as much biomass as that of new shoots, leaves and fruit combined but contained less than half as much N, P and K. The rootstock (trunk, scaffolding roots, small roots and actively growing roots) represented 28% of the total tree biomass but only 20% of the total tree N and P and only 9% of the tree's total K. It is clear that actively growing scion tissues are the major sinks for N, P and K during the year. Quantifying the monthly demand of each of these sinks for each nutrient will contribute to our goals of developing best management fertilizer practices for the ‘Hass’ avocado in California and reducing the potential for groundwater pollution.

Table 1. Biomass (dry weight) of components of mature off-crop (A) and on-crop (B) 'Hass' avocado trees sampled between January and June 2002.

A.	**Tree Biomass (kg dry wt/tree)**					
Tree Component	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***
New Shoots	0	0	0	0.36	1.80	1.38
Reproductive structures	0	0	1.52	1.88	1.44	0.49
Leaves	12.59	9.75	10.61	3.92	2.30	7.86
Green twigs <1/2"	10.64	13.73	10.89	7.89	5.34	7.52
Fruit	5.26	0.10	0.32	0.18	0.17	0.33
Small Branches >1/2-2"	17.12	23.82	13.05	14.36	6.54	7.99
Canopy Branches*	86.18	83.95	80.58	71.41	61.93	58.13
Trunk	15.88	8.29	7.09	14.21	10.14	10.78
Rootstock		28.56				12.79
Large Roots		21.89				9.83
Small roots		11.68				4.03
Total	147.66	201.79	124.06	113.94	89.67	120.86

B.	**Tree Biomass (kg dry wt/tree)**					
Tree Component	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***
New Shoots	0	0	0	0.22	1.97	1.47
Reproductive structures	0	0	0.05	0.08	0.09	0.11
Leaves	11.29	6.28	13.76	3.12	2.26	8.72
Green twigs <1/2"	10.68	8.32	14.10	7.18	6.68	10.04
Fruit	25.98	2.08	0.88	4.78	7.58	2.68
Small Branches >1/2-2"	16.72	10.62	20.04	8.64	6.70	12.32
Canopy Branches*	88.04	66.43	79.24	59.11	56.65	73.84
Trunk	13.04	12.26	9.71	17.76	11.05	10.49
Rootstock		19.56				20.69
Large Roots		7.55				11.64
Small roots		7.36				9.23
Total	165.76	140.46	138.28	100.88	92.90	160.85

*Two components comprising canopy branches were combined.

Table 2. Nutrient concentrations (g/100 g dry wt. tissue) in tree components of mature, heavily cropping 'on' and lightly cropping 'off' 'Hass' avocado trees, measured in August (A) and November (B) 2001.

A.

Tree Component	Heavily Cropping N	P	K	Lightly Cropping N	P	K
Scaffold Branches	0.40	0.06	0.38	0.40	0.06	0.31
Branches 2-4"	0.50	0.19	0.67	0.30	0.19	0.48
Small Branches	0.50	0.17	0.33	0.70	0.54	1.41
New shoots	0.80	0.39	1.21	0.80	0.57	1.55
Leaves	2.00	0.21	0.89	2.10	0.26	1.15
Fruit – Seed	1.50	0.24	1.12	1.30	0.27	1.27
Fruit – Flesh	2.60	0.35	2.39	1.54	0.32	1.92
Fruit – Peel	1.10	0.18	1.33	2.44	0.12	1.07
Fine Roots	1.00	0.22	0.24	0.80	0.23	0.39
Small Roots	0.40	0.09	0.21	0.70	0.11	0.21
Scaffold Roots	0.40	0.09	0.20	0.40	0.08	0.27
Rootstock	0.20	0.08	0.10	0.20	0.04	0.12
Trunk	0.30	0.04	0.27	0.20	0.04	0.12

B.[1]

Tree Component	Heavily Cropping N	P	K	Lightly Cropping N	P	K
Trunk	0.30	0.05	0.31	0.30	0.05	0.31
Scaffold Branches	0.20	0.03	0.19	0.20	0.03	0.19
Branches 2-4"	0.20	0.03	0.18	0.30	0.04	0.27
Small Branches	0.30	0.12	0.44	0.70	0.18	0.57
New shoots	0.60	0.32	0.74	0.80	0.42	1.06
Leaves	1.70	0.15	0.61	2.10	0.15	0.66
Fruit – Seed	0.75	0.16	0.89	0.80	0.20	1.03
Fruit – Flesh	1.42	0.19	1.46	1.58	0.23	1.66
Fruit – Peel	0.98	0.17	1.13	1.18	0.23	1.48

[1]Roots were not excavated in the November sampling.

Table 3. Tree dry weights (kg/tree) and nutrient content (g/tree) of mature, heavily cropping 'on' and lightly cropping 'off' 'Hass' avocado trees, excavated in August (A) and November (B) 2001.

A.

Tree Component	Heavily Cropping				Lightly Cropping			
	Dry Wt kg/tree	**N**	**P** g/tree	**K**	**Dry Wt** kg/tree	**N**	**P** g/tree	**K**
Trunk	34	103	14	93	23	46	9	27
Scaffold Branches	98	390	59	371	85	339	51	263
Branches 2-4"	25	123	47	165	49	146	93	234
Small Branches	7	37	12	24	25	178	137	359
New shoots	11	85	41	129	13	107	76	208
Leaves	22	431	45	192	29	615	76	337
Immature Fruit	5	107	15	102	9	138	25	137
Mature Fruit	11	355	55	534				
Fine Roots	13	128	28	31	17	133	38	65
Small Roots	11	44	10	23	14	97	15	29
Scaffold Roots	29	117	26	59	19	76	15	51
Rootstock	37	74	30	37	34	68	14	41
Total	302	1994	382	1758	317	1944	550	1751

B.[1]

Tree Component	Heavily Cropping				Lightly Cropping			
	Dry Wt kg/tree	**N**	**P** g/tree	**K**	**Dry Wt** kg/tree	**N**	**P** g/tree	**K**
Trunk	38	114	19	118	53	158	26	163
Scaffold Branches	94	188	28	178	79	159	24	151
Branches 2-4"	39	77	12	70	39	118	16	106

Small Branches	18	54	22	79	38	266	68	216
New shoots	26	158	84	194	29	232	122	307
Leaves	22	376	33	135	37	767	55	241
Immature Fruit	40	462	71	501	18	233	39	267
Total	277	1429	269	1276	292	1933	350	1452

[1]Roots were not excavated in the November sampling.

Table 4. Percent contributions of the various tree components to the total tree dry weight and N, P, and K contents from the August tree sampling. Data are averaged over both the heavily and lightly fruiting (on-crop and off-crop) trees.

Tree Component	Dry Wt % Total	N	P % Total	K
Trunk	9	4	3	3
Scaffold Branches	30	18	12	18
Branches 2-4"	12	7	15	11
Small Branches	5	6	14	11
New shoots	4	5	12	10
Leaves	8	27	13	15
Fruit	4	15	11	22
Fine Roots	5	7	7	3
Small Roots	4	4	3	1
Scaffold Roots	8	5	5	3
Rootstock	11	4	5	2
Total	100	100	100	100