Nitrogen Fertilization Strategies to Increase Yield of The 'Hass' Avocado

Continuing Project: Year 6 of 6

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Benefit to the Industry

This project meets the industry priority on "fertilization of avocado trees, including optimal formulations, timing, application techniques and rates and efficacy based on soil type and consideration of grove location." This project integrates an understanding of avocado tree phenology to enhance fertilization management strategies with the aim of increasing productivity (cumulative yield) and minimizing alternate bearing.

To protect the groundwater from potential nitrate pollution, 'Hass' avocado growers in California divide the total annual amount of nitrogen (50-150 lbs./acre) into six small soil applications made during the period from late January to early November. The lack of research data raised the question of whether 'Hass' avocado yield was being compromised by this fertilization practice. In a previous study, Lovatt (2001) addressed the question of whether yield of 'Hass' avocado could be increased by doubling the amount of N currently applied during specific stages of tree phenology. The control in this experiment was the practice of annually applying N as NH_4NO_3 at 150 lbs./acre in six small doses of N at 25 lbs./acre in January, February, April, June, July, and November. From these six application times, five were selected on the basis of tree phenology and additional N as NH_4NO_3 at 25 lbs./acre was applied at each time for total annual N of 175 lbs./acre. Two phenological stages were identified for which N application at 50 lbs./acre in a single application (double dose of N) significantly increased the 4-year cumulative yield (lbs. fruit per tree) 30% and 39%, respectively, compared to control trees ($P \leq 0.01$). In each case, more than 70% of the net increase in yield was commercially valuable large size fruit (packing carton sizes 60-40). The two phenological stages were: when shoot apical buds have four or more secondary axis inflorescence meristems present (mid-November); anthesis-early fruit set and initiation of the vegetative shoot flush at the apex of indeterminate floral shoots (approx. mid-April). When the double dose of N was applied at either of these two stages, the lbs. and number of large size fruit averaged across the 4 years of the study was significantly greater than the control trees ($P \leq 0.01$). Averaged across the 4 years of the study, only the November treatment increased yield compared to the control trees ($P \leq 0.05$). Application of the double dose of N at flower initiation (January), during an early-stage of gynoecium development (February), or during June drop had no significant effect on average or cumulative yield or fruit size compared to control trees. Application of the double dose of N in April significantly reduced the severity of alternate bearing ($P \leq 0.05$). Yield was not significantly correlated with leaf N concentration. Time and rate of N application are factors that can be optimized to increase yield, fruit size, and annual cropping of 'Hass' avocado. When the amounts of N applied were equal (175 lbs./acre), time of application was the more important factor.

To determine whether the results obtained in the previous study, which was conducted in Temecula, could also be obtained with a different soil type and location, this research, including objectives not covered in the first experiment, is being repeated in a new orchard in Somis, representing the soils and climate of the northern avocado growing area. The new study also includes additional application times based on the discovery by my lab. that avocado trees transition from vegetative to reproductive growth at the end of July-beginning of August (Salazar-Garcia et al., 1998). The research also integrates the results of a 2-year long study we undertook with funding from the CDFA FREP program (no CAC funds were used). The results of the CDFA project provided evidence that foliar N fertilization was successful in increasing yield when urea was applied at the time the leaves of the new flush were 66% to 100% fully expanded but not hardened. So our current project includes both irrigation and foliar applied nitrogen applications. Foliar applications are made to simulate helicopter application. We are also testing different nitrogen fertilization strategies that are designed specifically for "on" and "off" years to even out alternate bearing and increase cumulative yield. With funding from the CDFA, we are also quantifying the effect that supplying extra N at key stages in the phenology of the 'Hass' avocado tree has on the amount of N leaching past the root zone and thus, on the potential for nitrate pollution of the groundwater. To understand the mechanism by which nitrogen fertilization influences alternate bearing, we are quantifying the effect of the nitrogen treatments on the quantity of sylleptic and proleptic shoots produced and the productivity of each shoot type. Basic information about the relative productivity of sylleptic vs. proleptic shoots is not only important for optimizing fertilization but is also fundamental to pruning practices. Our prior research was the first to consider tree phenology and crop load in the fertilization of the 'Hass' avocado and our current project is the first to use nitrogen fertilization as a tool to control alternate bearing.

Objectives

The objectives are to 1) increase fruit set and yield of the 'Hass' avocado without reducing fruit size or quality, and 2) test strategies of nitrogen fertilization that even out alternate bearing and increase cumulative yield. The research tests the efficacy of nitrogen fertilization strategies to increase yield over a standard practice (control) of supplying nitrogen to the soil through the irrigation in small doses spread out over five application dates at the rate of 25 lbs. nitrogen as ammonium nitrate per acre in mid-November, mid-January, mid-April, mid-July, and mid-August. The treatments are as follows with double N = 40 lbs./acre and triple N = 60 lbs./acre:
1) double nitrogen in April for all years of the study,
2) double nitrogen in November for all years of the study,
3) double nitrogen in both April and November (no nitrogen in February or June) for all years of the study,
4) double nitrogen in November going into an "on" year and April for the "off" year,
5) double nitrogen in August for all years of the study,
6) double nitrogen in April for "off" years and 3X nitrogen in "on" years,
7) double nitrogen in April for "off" years and 3X nitrogen in "on" years applied FOLIARLY,
8) control as described above, and
9) low N control, standard fertilization practice of Grether Farming Company
Please note: The total N applied in any treatment is 125 lbs.; the amount of N applied in other months is reduced to compensate for the extra N applied in the month(s) specified for the treatment.

The time of treatment applications is based on the following phenological events:

1) April – anthesis, fruit set and initiation of the spring vegetative flush
2) August – inflorescence initiation
3) November – end of the fall vegetative flush and beginning of flower initiation

Experimental Plan and Design

The experimental design is a randomized complete block with 20 individual tree replicates per treatment (9 treatments) to insure that any differences in yield observed can be evaluated as statistically significant at the 5% level. The orchard is located in Somis, Calif. The trees are 'Hass' on Duke 7 and were 17 years old at the start of the experiment in 1996-97.

To determine if the April, August or November treatments even out alternate bearing by increasing the number of sylleptic and/or proleptic shoots bearing inflorescences for the return bloom the following year relative to the control, branches with and without fruit were tagged and new growth quantified on a monthly basis for 10 replicates of each treatment. Each spring we determine the number and type of inflorescences produced by this new vegetative growth.

For nutrient analysis, 40 spring flush leaves from nonfruiting terminals are collected at chest height around each data tree in September of each year. The leaves will be immediately stored on ice, taken to UCR, washed thoroughly, oven-dried, ground, and sent to Albion Laboratories for analysis of total nitrogen.

Harvest data includes total pounds of fruit/tree and the weight of 100 randomly selected individual fruit/tree, which will be used to calculate packout/tree, evaluation of internal fruit quality, and a cost-benefit analysis of each treatment. All data is analyzed for statistical significance at $P \leq 0.05$ by analysis of variance and repeated measures analysis using SAS.

Summary

In the first year of the study, the rates of N applied were incorrect in that the trees received different amounts of N annually, which was not our original intention (Table 1). However, the results of the first harvest (1997-98) clearly demonstrated that the time of N fertilizer application was more important than the amount of N that was applied (Table 1). This was a very interesting result and we repeated the treatments in 1998-99 in order to have two years of data.

Unfortunately, yields for the subsequent 1998-99 and 1999-2000 harvests were compromised by the freeze of December 1998. Yields were low for 1998-99, averaging less than 43 lbs. fruit/tree. Yields for 1999-2000 were even lower, averaging 26 lbs. fruit/tree. Thus, there were no significant effects of any treatment on yield for the two years affected by the freeze.

Time of N application had a significant effect on yield for the harvest of 2000-01 (Table 2). Trees in all treatments received 125 lbs. N/acre starting in January 1999. Trees that received a double dose of N applied to the soil in April for all years of the study had a significantly higher yield than control trees receiving five applications of 25 lbs. N/acre despite the fact that the single doses of N were applied at key stages in 'Hass' phenology (Table 2). This result is consistent with the result of our earlier research conducted in Temecula. The treatment supplying a double dose of N to the soil in April was also significantly better than the foliar application of a triple dose of low-biuret urea in April. Trees receiving a double dose of N to the soil in April had yields that were not significantly different from trees receiving a double dose of N to the soil in August or November, a triple dose of N to the soil in April or only 40 lbs. of N to the soil in August. These last two results are interesting: (1) thus, far there is no added benefit from the extra N when a triple dose of N is applied to the soil in April and (2) 40 lbs. N/acre applied to the soil in August has been sufficient to maintain yield equal to that of trees receiving significantly more N. Additional years of harvest data are required to confirm these observations.

The harvest for 2001-02 is being conducted September 18-20, 2002. The yield for 2001-2002 will also make it possible to determine the relationship between yield and sylleptic and proleptic shoot growth. These results will be presented at the October 26, 2002 California Avocado Research Symposium at UCR.

Additional Research

Our prior research clearly showed that extra nitrogen provided at key times in the phenology of the tree significantly increased cumulative yield, increased fruit size and reduced the severity of alternate bearing. The current study has confirmed that April is a period of high N demand for 'Hass' avocado trees and that supplying extra N at that time increases yield. However, we do not know whether using double doses of soil applied N will increase the potential for nitrate groundwater pollution. It is hypothesized that supplying an avocado tree with extra N at times when demand is greater should not increase leached nitrate. Since yield increased, the interpretation is that the tree utilized some portion of the extra N. We received a grant from CDFA FREP to test this hypothesis. We used buried resin (strong anion and cation) bags to quantify the amount of N leaching past the root zone for the different N fertilization strategies and the controls listed above. The treatments were initiated in January 1999. The results for nitrate leaching past the root zone were not significantly affected by the treatments on any sampling date or in any year (Table 3). However, it is clear that dividing the total annual N into five small doses results in a numerically, but not statistically significant reduction in the amount of N leaching past the root zone, reducing the potential for nitrate pollution of the groundwater. The data have not been adjusted for the N contribution from organic matter in the soil associated with each of the data trees. The combined results of the research proposals will identify the BMP for N for the 'Hass' avocado in California.

Literature Cited

Lovatt, C.J. 2001. Properly timed soil-applied nitrogen fertilizer increases yield and fruit size of 'Hass' avocado. J. Amer. Soc. Hort. Sci. 126:555-559.

Salazar-Garcia, S., E.M. Lord, and C.J. Lovatt. 1998. Inflorescence and flower development of the 'Hass' avocado (*Persea americana* Mill.) during "on" and "off" crop years. J. Amer. Soc. Hort. Sci. 123:537-544.

Table 1. Effect of nine nitrogen fertilization strategies applied April 1997 to January 1999[y] on the yield of 'Hass' avocado harvested in 1998 and 1999. The applications were made for an "on" year.[z]

Treatment	1997-99 total lbs. N/acre	1997-98 lbs. fruit/ tree	1998-99 lbs. fruit/ tree
2x N in August (all years)	40.0	73.6 a[z]	37.8
Grower fertilization practice[y]	42.5	70.7 a	40.1
2x N in November (prior to "on" years) and April ("off" years)	40.0	68.1 a	40.5
2x N in November (all years)	40.0	62.3 ab	44.6
Control	80.0	58.8 ab	49.4
2x N in April and November (no N in February and June) (all years)	80.0	58.8 ab	32.8
2x N in April ("off" years) and 3x N ("on" years)	60.0	58.6 ab	48.5
2x N in April (all years)	40.0	56.8 ab	42.1
2x N in April ("off years) and 3x N ("on" years) applied foliarly	100.0	42.3 b	44.6
P-value		0.06	NS

[z] Values in a vertical column followed by different letters are significantly different at the specified *P* level by Duncan's Multiple Range Test.

[y] Grower's fertilization practice is 40 lbs. N as ammonium nitrate/acre split as two applications in July and in August for all years of the experiment.

Table 2. Effect of nine nitrogen fertilization strategies initiated in January 1999[y] on the average yield of 'Hass' avocado harvested in 2000 and 2001. A freeze occurred in December 1998 which reduced bloom in spring of 1999 and yield in 2000. The applications were made for an "on" year.[z]

Treatment[y]	1999-2000 lbs. fruit/tree	2000-2001 lbs. fruit/tree
2x N in August (all years)	28.7	179 abc
Grower fertilization practice	28.7	181 abc
2x N in November (prior to "on" years) and April ("off" years)	17.6	203 ab
2x N in November (all years)	17.6	203 ab
Control	39.7	168 bc
2x N in April and November (no N in February and June) (all years)	28.7	179 abc
2x N in April ("off" years) and 3x N ("on" years)	28.7	198 ab
2x N in April (all years)	26.5	216 a
2x N in April ("off years) and 3x N ("on" years) applied foliarly	19.8	150 c
P-value	NS	0.05[x]

[z] Values in a vertical column followed by different letters are significantly different at the specified *P* level by Duncan's Multiple Range Test.

[y] Grower's fertilization practice is 40 lbs. N as ammonium nitrate/acre split as two applications in July and in August for all years of the experiment. Since January 1999 control trees received 125 lbs. N as ammonium nitrate/acre, divided into five, 25 lbs./acre applications made in mid-January, mid-April, mid-July, mid-August, and mid-November. Trees in all other treatments received 125 lbs. N/acre applied as 2N=40lbs./acre or 3N=60lbs./acre in the months indicated. The total N applied in any treatment is 125 lbs./acre; the amount of N applied in other months is reduced to compensate for the extra N applied in the month(s) specified for the treatment.

[x] Use of a statistical program to identify "outliers" resulted in the removal of one entry in the data set. This shifted the *P*-value from 0.10 reported last year to 0.05 reported here.

Table 3. Effect of application time for the double dose of N vs. control on nitrate leaching past the root zone from April through November in 2000 and 2001. The N applications were made for an "on" year.[z]

Treatment	2000				2001				2-year cumulative total
	Apr.	Aug.	Nov.	Cumulative total	Apr.	Aug.	Nov.	Cumulative total	
	---------- *µg* NO_3*/5 g resin* ----------								
2x N in August (all years)	1185	n/a	3833	5018	7339	776	544	8655	13673
2x N in November (all years)	4808	n/a	1043	5850	2051	10148	2449	14648	20498
Control[y]	1148	n/a	1508	2655	1166	1373	2040	4577	7232
2x N in April ("off" years) and 3x N ("on" years)	1789	n/a	7868	9656	2693	2899	1688	7277	16933
2x N in April (all years)	7920	n/a	619	8539	1009	1485	551	3047	11586
P-value	NS	n/a	NS	NS	NS	NS	NS	NS	NS

[z] Values in a vertical column followed by different letters are significantly different at the specified *P* level by Duncan's Multiple Range Test.

[y] Since January 1999 control trees received 125 lbs. N as ammonium nitrate/acre, divided into five, 25 lbs./acre applications made in mid-January, mid-April, mid-July, mid-August, and mid-November. Trees in all other treatments received 125 lbs. N/acre applied as 2N=40lbs./acre or 3N=60lbs./acre in the months indicated. The total N applied in any treatment is 125 lbs./acre; the amount of N applied in other months is reduced to compensate for the extra N applied in the month(s) specified for the treatment.