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

Continuing Project; Year 5 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 (56-168 $kg \cdot ha^{-1}$) 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 168 $kg \cdot ha^{-1}$ (168 trees/ha) in six small doses of N at 28 $kg \cdot ha^{-1}$ 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 28 $kg \cdot ha^{-1}$ was applied at each time for total annual N of 196 $kg \cdot ha^{-1}$. Two phenological stages were identified for which N application at 56 $kg \cdot ha^{-1}$ in a single application (double dose of N) significantly increased the 4-year cumulative yield (kilograms 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 (178-325 g/fruit). 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 kilograms 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 early-stage 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 (196 $kg \cdot ha^{-1}$), time of application was the more important factor. You may receive a copy of this paper by e-mailing your request to me at <carol.lovatt@ucr.edu>.

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. 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, the growth of each shoot type 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:

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, California. 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 or length of 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

The results of the first harvest (1997-98) clearly demonstrated that the time of N fertilizer application is more important than the amount of N that was applied (Table 1). However, the rates of N applied that year were incorrect (Table 1). The error was corrected starting in January 1999. Henceforth, all treatments received 125 lbs. N/acre. Yields for the subsequent 1998-99 and 1999-2000 harvests were compromised by the freeze of December 1998. Time of N application had a significant effect on yield for the harvest of 2000-01 (Table 2). The better treatments were all due to extra N applied to the soil in November or April. These results are consistent with the results of our earlier research conducted in Temecula. Foliar application of urea in April was not effective. Harvest data for additional years is needed to confirm the results in 2001. N treatments had a significant effect on the number of inflorescences produced on sylleptic shoots tagged January 2001 (Table 2). The relationship between the number of inflorescences produced by sylleptic shoots and yield will be determined with harvest 2002.

Additional Research

Our prior research clearly showed that extra nitrogen provided at key times in the phenology of the tree significantly increased cumulative yield. However, we do not know whether using double or triple 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 the extra N. We received a grant from CDFA FREP to test this hypothesis. We are using buried resin (strong anion and cation) bags to quantify the amount of nitrate and ammonia leaching past the root zone for the different N fertilization strategies and the controls listed above. 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. In press.

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. A freeze occurred in December 1998. The N 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	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 2001 and on the number of inflorescences per sylleptic shoot in spring 2001. The N applications were made for an "on" year.[z]

Treatment	2000-2001 lbs. fruit/ tree	Average number of inflorescences per shoot
2x N in August (all years)	179 ab	2.20 c
Grower fertilization practice	181 ab	4.36 abc
2x N in November (prior to "on" years) and April ("off" years)	201 a	4.68 abc
2x N in November (all years)	202 a	3.16 bc
Control	169 ab	3.85 abc
2x N in April and November (no N in February and June) (all years)	178 ab	4.50 abc
2x N in April ("off" years) and 3x N ("on" years)	199 a	5.25 ab
2x N in April (all years)	209 a	3.65 abc
2x N in April ("off years) and 3x N ("on" years) applied foliarly	150 b	6.15 a
P-value	0.10	0.06

[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.