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DEVELOPMENT OF NITROGEN FERTILIZER PROGRAMS FOR CALIFORNIA AVOCADOS

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Nitrogen is the fertilizer element most likely to be limiting for production of the avocado. Prior to about 1942, nitrogen fertilization of the avocado generally followed practices used for citrus. Subsequent observations indicated that avocados needed only about half as much nitrogen as recommended for citrus prior to 1942 (7, 8). (It is now known that the early recommendations for most citrus cultivars were too high.)

Studies evaluating nitrogen yield responses by avocado are difficult because tree by tree yield variability of uniformly treated trees is considerably higher for avocado than for citrus and most other tree crops (9). To adequately evaluate yield results more replication is needed for avocado experiments than for citrus.

In 1951 a program was initiated to establish sound nitrogen programs and leaf analysis standards for avocado. It was found that varieties do not respond uniformly to a given nitrogen program. For example the authors observed an orchard that was alternately planted to Fuerte and Mac-Arthur. Both varieties were treated the same. The Fuerte was too high and the MacArthur too low in nitrogen for maximum production. In an experiment in which MacArthur and Fuerte were alternately planted, withholding nitrogen for two years resulted in nitrogen deficiency in the MacArthur while the Fuerte was still adequately supplied with nitrogen (6).

Fuerte

A 1943 report on an unreplicated experiment with the Fuerte variety indicated that production was maintained with two pounds of nitrogen per tree annually and that withholding nitrogen resulted in a loss in yield (10.).

Initial detailed studies with the Fuerte showed that yields could be limited with two low or too high a level of nitrogen in the tree. The most productive range was found to be between 1.6 and 2.0 per cent nitrogen in dried leaves. These leaves were sampled in the mid-August to mid-October period and were the youngest fully-expanded and matured leaves from shoots, from four quadrants of the trees, that were not fruiting or flushing. Normally, under California conditions, these are spring-cycle leaves (3). The nitrogen application rates associated with leaf levels in the most productive range have varied considerably from orchard to orchard, depending upon such factors as prior fertilizer history, soil type and depth, absence or presence and amount of sod, amount of nitrogen in irrigation water, etc.

Hass

Experiments have shown that the Hass variety is not as responsive as the Fuerte to varying nitrogen rates. A 1968 report (4) indicated: (a) a high level of nitrogen will not reduce yields but may increase them and (b) the nitrogen level in Hass leaves should be maintained slightly higher than in the Fuerte, possibly not less than 2.0 per cent.

Previously unpublished results from a Hass experiment conducted in Temescal Canyon near Corona are shown in Tables 1 and 2. The experiment consisted of four rates of nitrogen in factorial combination with four times of application, replicated eight times. Thus the internal replication for nitrogen rate and for timing was thirty-two. The trees were six years old when the experiment was initiated. There was an undetermined amount of nitrogen supplied in the irrigation water. However, relatively low nitrogen leaf values did develop in the trees receiving the low rates of nitrogen. The varying rates of nitrogen had no significant effect on yield (Table 1) even though rather wide differences in leaf nitrogen levels were obtained (Table 2). This experiment does not indicate that high rates of nitrogen or leaf levels above 2.0 per cent are needed to maintain high production, but suggest that the leaf standards used for Fuerte would be adequate for the Hass. The latter experimental results are in accord with the previous indication that the Hass variety is rather insensitive to nitrogen rates and variations in nitrogen levels in the trees. Applying the four rates of nitrogen in February, July, November or a split application in July and November had no significant effect on yield. Therefore, the data are not presented.

TABLE 1. EFFECTS OF NITROGEN RATE ON YIELD. HASS AVOCADO, TEMESCAL CANYON.[1]

Pounds N per tree annually		*Yield in pounds per tree*								*Mean*
1960-65	*1966-68*	*1961*	*1962*	*1963*	*1964*	*1965*	*1966*	*1967*	*1968*	*1961-68*
0.25	0.25	31	94[2]	72	88	65	110	95	63	77
0.50	1.00	30	116	61	101	64	161	70	91	87
1.00	2.00	21	93	86	90	58	148	92	57	80
2.00	4.00	16	84	67	75	81	137	119	55	79
Significance[3]		NS	*	NS	NS	NS	NS	NS	NS	NS
CV%[4]		133	50	84	81	118	88	109	110	

[1] This experiment was conducted in cooperation with Marvin Miller, Farm Advisor, University of California Agricultural Extension Service, Riverside. Appreciation is expressed to Theodore J. Todd for permitting this experiment to be conducted in his orchard and for his cooperation.

[2] Means were ranked at the level of significance as indicated. Differences between means are significant if there are no subscript letters in common.

[3] NS indicates not statistically significant; *-significant at the 5% level; **-significant at the 1% level.

[4] CV% is the coefficient of variability obtained by dividing the square root of the error variance by the grand mean and multiplying by 100.

[1]. See footnotes Table 1 for meaning of statistical symbols.

TABLE 2. EFFECT OF NITROGEN RATK ON THE CONCENTRATION OF NITROGEN TN 5- TO 7-MONTH OLD. SPRING-CYCLE LEAVES. HASS AVOCADO, TEMESCAL CANYON.[1]

Pounds N per tree annually		*Per cent N in dry leaves in Aug.-Oct. period*							
1960-65	*1966-68*	*1960*	*1961*	*1962*	*1963*	*1964*	*1965*	*1966*	*1967*
0.25	0.25	2.44	2.17	1.92	1.75	1.60	1.63	1.60	1.75
0.50	1.00	2.44	2.20	2.02	1.87	1.74	1.75	1.68	1.88
1.00	2.00	2.42	2.33	2.17	2.02	1.87	1.93	1.76	2.02
2.00	4.00	2.44	2.40	2.25	2.19	2.01	2.07	1.84	2.12
Significance		NS	°°	°°	°°	°°	°°	°°	°

[1]. *See footnotes Table 1 for meaning of statistical symbols.*

Mac Arthur

Of the varieties studied to date this variety is the most responsive to nitrogen rate variables. Yields were increased with application rates up to five pounds of nitrogen per tree annually. Higher rates were not studied. The highest nitrogen concentration in the leaves observed from five pounds of nitrogen applied to the soil annually was less than 2.0 per cent for five-to-seven month old, spring-cycle leaves. It is clear that high rates of nitrogen are needed for maximum production with this variety. MacArthur, like the Fuerte, responds to increasing levels of nitrogen in the leaves up to 1.8 per cent. By increasing leaf nitrogen from 1.6 to 1.8 per cent, one would expect a much greater increase in yield with the MacArthur than with the Fuerte. Experimental levels of nitrogen in MacArthur leaves above 2.0 per cent have not been obtained. Vegetative growth responses to nitrogen have been greater for the MacArthur than any other variety studied to date (6 and unpublished data).

Zutano

Only one experiment has yielded reliable data for this variety (Table 3 and 4). The Zutano trees in this experiment were interplanted with trees of the Hass variety experiment reported in Tables 1 and 2. The experimental procedures for the Zutano were the same as for the Hass. Nitrogen rates did not have any significant effect on yield for the seven-year period. Although there were significant effects on yield for each of the last two years the total yield for the two years was not different for the rates of nitrogen, because high yielding treatments were offset by low yields the following year and *vice versa.* Yields were maintained even though the nitrogen level in the leaves was around 1.5 per cent for about five years in the 0.25 pound per tree annual rate. As with the Hass variety, timing of nitrogen applications had no significant effect on yield.

TABLE 3. EFFECTS OF NITROGEN RATE ON YIELD. ZUTANO AVOCADO, TEMESCAL CANYON.[1]

Pounds N per tree annually		*Yield in pounds per tree*							*Mean*
1960-65	*1966-68*	*1961-62*	*1962-63*	*1963-64*	*1964-65*	*1965-66*	*1966-67*	*1967-68*	*1961-62 through 1967-68*
0.25	0.25	108	119	124	128	199	204	92	139
0.50	1.00	104	114	118	142	178	207	80	135
1.00	2.00	101	118	115	134	204	236	76	138
2.00	4.00	105	108	112	138	188	186	107	135
Significance		NS	NS	NS	NS	NS	*	*	NS
CV%		34	52	44	34	32	33	52	

[1] *This experiment was conducted in cooperation with Marvin Miller ,Farm Advisor, University of California Agricultural Extension Service, Riverside. Appreciation is expressed to Theodore J. Todd for permitting this experiment to be conducted in his orchard and for his cooperation.*

[1]. *See footnotes Table 1 for meaning of statistical symbols.*

TABLE 4. EFFECT OF NITROGEN RATE ON THE CONCENTRATION OF NITROGEN IN 5- TO 7-MONTH OLD. SPRING-CYCLE LEAVES. ZUTANO AVOCADO, TEMESCAL CANYON.[1]

Pounds N per tree annually		*Per cent N in dry leaves*						
1960-65	*1966-68*	*10/61*	*9/62*	*8/63*	*8/64*	*11/65*	*10/66*	*8/67*
0.25	0.25	2.05	1.74	1.55	1.54	1.56	1.49	1.53
0.50	1.00	2.05	1.87	1.70	1.60	1.60	1.52	1.65
1.00	2.00	2.17	1.95	1.76	1.78	1.66	1.55	1.70
2.00	4.00	2.16	2.04	1.86	1.80	1.67	1.60	1.73
Significance		*	**	**	**	**	**	**

[1]. *See footnotes Table 1 for meaning of statistical symbols.*

Based on results from this one experiment one would conclude that the Zutano variety is also rather insensitive to rates of nitrogen and to varying levels of nitrogen in the tree.

The nitrogen leaf levels in both the Hass and Zutano varieties decreased rather sharply as the trees aged from eleven to fourteen years and then leveled-off in all nitrogen-rate treatments.

Jalna

The one experiment that was conducted on mature trees of this variety showed that if the level of nitrogen dropped much below 2.0 per cent in August and September leaf samples, yields dropped off rather sharply; 1.6 per cent was definitely in the deficient range for yield. Two pounds of nitrogen per tree annually resulted in about 2.0 per cent nitrogen in the leaves and an additional two pounds raised the leaf nitrogen level only a few hundredths of a per cent (1 and unpublished data). Thus, this experiment suggests that 2.0 per cent leaf nitrogen is the desired level for this variety.

Bacon

A current experiment[2] on this variety was initiated in January. 1967 on eight year old trees near Santa Paula on what was formerly classified as Yolo silt loam (now Mocho loam). To date annual rates of nitrogen varying from one quarter to four pounds per tree have not influenced the concentration of nitrogen in the leaves at any time during the year. Leaf samples in the August-October period each year have varied between 2.0 and 2.2 per cent nitrogen. Yields have not been influenced except that in 1971 the four pound rate produced significantly less fruit than the lower rates. The cause of this reduction has not been determined, as yet, but it is not associated with levels of nitrogen in the leaves.

Prior to establishing this experiment the avocado trees received a minimal amount of nitrogen. The trees are receiving a few pounds of nitrogen per acre annually in the irrigation water. It is obvious that the trees arc drawing from reserve nitrogen supplies in the soil. It also appears that the trees in the treatment that is receiving only one quarter of a pound of nitrogen per tree annually are as high in nitrogen as can be obtained in this location. It is also obvious that there has been no need to apply nitrogen to this orchard since the experiment was established.

Alternate Bearing Effects

Alternate bearing effects complicate studies on nitrogen nutrition relations with yield. An example of this is shown in Table 5. The Fuerte orchard was planted on virgin, light-textured, well-drained soil in 1955. Prior to the establishment of the experiment in 1961 the trees had received relatively low rates of nitrogen. Data for the first experimental yield-response year, 1963, show that there was a marked response to each increment of added nitrogen. This yield response was predicted by comparing the 1962 nitrogen leaf values with the recommended leaf values for Fuerte (2). However, the nitrogen leaf values for 1963 were not greatly different from those of 1962, but the yields in 1964 were inversely related to the rates of applied nitrogen. It appears that the initial strong yield response to nitrogen in 1963 started a differential alternate bearing cycle and the alternate bearing influences were more dominant on the 1964 crop than were the nitrogen levels in the trees. The heavy cropping associated with the high rates of nitrogen in 1963 apparently depleted the energy reserves in the tree and limited yields in 1964 considerably more than nitrogen *per se.* This shows the danger of looking at only one year's data.

TABLE 5. THE INFLUENCE OF ALTERNATE BEARING ON THE RELATION BETWEEN YIELD AND PERCENTAGE OF NITROGEN IN FUERTE AVOCADO LEAVES. [1]

Pounds N per tree annually		*Percent N in dry leaves Aug.-Oct.*		*Yield pounds per tree*	
1961, 1962	*1963, 1964*	*1962*	*1963*	*1963*	*1964*
0.25	0.50	1.49	1.48	76	59
0.50	1.00	1.61	1.53	107	51
1.00	2.00	1.67	1.62	121	44
2.00	4.00	1.80	1.66	140	33
Significance		**	**	**	**
CV%				53	59

[1] *There were 32 replications of nitrogen rates with single-tree plots.*

[1]. *See footnotes Table 1 for meaning of statistical symbols.*

Sources of Nitrogen

Generally, with equal amounts of nitrogen applied, one would expect no significant differences among the various inorganic and urea sources of nitrogen. However, differences due to method of culture have been observed with organic sources of nitrogen. It was found that when applied as a mulch, about two pounds of nitrogen in the form of manure was equivalent in tree response to one pound of nitrogen from ammonium nitrate. When manure was cultivated into the soil the amount of nitrogen in the manure was equivalent in tree response to an equal amount of nitrogen from ammonium nitrate (2). Presumably, when manure decomposes on top of the soil rather large amounts of nitrogen are lost to the atmosphere in the form of ammonia.

Guide to the use of leaf analysis

Leaf analysis can be used as a guide in developing nitrogen fertilizer programs. It is recommended that five-to seven-month old, spring-cycle leaves be obtained. In California such a sample is obtained in the mid-August to mid-October period. Since the concentration of nitrogen changes as the leaves age (5) it is important to obtain the proper age leaves. Sample healthy leaves. Avoid chlorotic, tipburned or otherwise injured leaves as much as possible. Sample leaves from exposed shoots that are not flushing or fruiting. It has been found that shade leaves are about .01 per cent nitrogen lower than leaves exposed to the sun.

A sampling block should be uniform in all known aspects. Sample each variety separately. Do not mix leaves from young trees with those from old trees. If one area has different yielding characteristics than another, sample each separately. Trees on the top of a hill may perform differently than those at the bottom of the hill; sample each separately. Normally, an initial sampling block consists of from five to ten acres. After several years of sampling, blocks that are similar in leaf nitrogen level and are requiring the same rates of nitrogen can be combined into larger sampling blocks.

From 50 to 100 leaves (including petioles) constitute an adequate sample from a block of trees. The sample should represent the average condition for a block. Avoid obtaining leaves from exceptionally good or exceptionally bad trees. Do not obtain leaves from the trees that are obviously diseased, girdled or otherwise injured. The leaves in the sample should equally represent each quadrant of the trees.

Leaves should be transported to the laboratory for preparation and analysis as soon as possible after picking. Avoid leaving a sample in a hot car or in the hot sun for any length of time. If necessary to keep samples overnight store them in a refrigerator.

Environmental concerns

Avocado growers should rot ignore the public concern about environmental problems. Nitrate concentrations are increasing in underground waters and agriculture is being blamed as a major contributor to this problem. Bills are being introduced in state legislatures (including California) to regulate fertilizer use. Hopefully agriculture will regulate its own fertilizer use before being forced to do so. In any event, avocado growers should not use any more nitrogen than is necessary to maintain production. Use of leaf analysis is one way to prevent overuse of nitrogen.

[1] *This experiment was conducted in cooperation with Marvin Miller, Farm Advisor. University of California Agricultural Extension Service, Riverside. Appreciation is expressed to Theodore J. Todd for permitting this experiment to be conducted in his orchard and for his cooperation. See footnotes Table 1 for meaning of statistical symbols.*

[2] *This experiment is in cooperation with B. W. Lee, Farm Advisor and County Director of Agricultural Extension, Ventura. Appreciation is expressed to Paul Leaven, Sr. and Paul Leaven, Jr. for permitting this experiment to he conducted in their orchard and for their cooperation.*

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