Nitrogen Fertilizers on Olive

response to nitrogen applications apparently influenced by variable factors found in different olive growing districts

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Most commercial olive growers in California apply nitrogen to their orchards annually, although the response of the trees seems to be different in the various olive districts, probably because of the influence of such factors as soil type, topography, and amount of rainfall.

In well-maintained orchards in the Tulare County districts no immediate response to variations in nitrogen application is ordinarily observed. For example, in a previously well-fertilized Manzanillo orchard on Madera loam soil, trees with no nitrogen fertilizer applications for three years dropped in leaf nitrogen content from 1.61% to 1.32%, a level still considered within the normal range for olives. Similar trees in the same orchard fertilized with 1½ pounds of actual nitrogen per tree annually for three years showed a change in leaf nitrogen from 1.56% to 1.43%. The final difference in leaf nitrogen under these two treatments was not significant.

Under the different soil, topography, and rainfall conditions of the Butte County foothills, the reaction of the trees is completely different. For example, in a well-cared-for orchard near Palermo, in the spring of 1952, 30″ of rain fell after the orchard had been fertilized with one pound of actual nitrogen per tree. By June, leaves on most of the trees in the orchard—and in similar adjoining orchards—were either yellow or a pale yellowish-green in contrast to the normal dark-green. Leaf analyses showed a nitrogen content of 0.58% for the yellow leaves and 1.08% for the yellowish-green leaves. The low nitrogen content was undoubtedly due to leaching of soil nitrogen by the high rainfall. Analysis of several other elements which could possibly be deficient showed them all to be within the normal range. Olive leaves will ordinarily abscise when their nitrogen content drops below 0.9%.

Some trees in this orchard had been top-grafted but with a nurse branch retained on each. It was significant that the leaves on the nurse branches had retained their deep green color and had a nitrogen leaf content of 1.60%. The reduced top-root ratio of the grafted trees probably permitted the root system to absorb sufficient nitrogen for the single nurse branch, whereas the roots were unable to absorb adequate nitrogen for the intact, ungrafted trees. Subsequent fruit set—the same year—on the ungrafted trees with the yellow leaves and low nitrogen was negligible, but on the nurse branches of the grafted trees with the higher nitrogen content, fruit set was heavy.

Experiment 1

To study the effect of different levels of nitrogen fertilizer on leaf nitrogen and fruit set, a series of five plots of two trees each of the Mission variety on a Redding gravelly, sandy loam was established in June, 1952, in the Palermo orchard. All trees in this and the other two experiments were maintained under irrigation.

Ammonium nitrate was applied to the soil under the trees annually for five years at the rate of 0, 1, 2, 3, and 4 pounds of actual nitrogen per tree. The 3 and 4 pound rates are excessive and would not be used commercially. In 1954, 1955, and 1956 leaf samples from each tree were analyzed for nitrogen. Fruit-set determinations—expressed as the number of fruits per 100 inflorescences—were made on three replicate branches per tree.

In this experiment other data were obtained. In 1953, the effect of the different levels of nitrogen on the rate of fruit maturity was expressed as the percentage of colored fruit at time of harvest. In 1953 and 1954, oil analyses were made on fruit samples taken from each plot. In 1954, the percentage of perfect flowers—the olive produces two flower types: perfect and staminate—on four sample branches per tree was determined for each plot. In 1956 the number of inflorescences produced per 100 centimeters of fruiting wood, the average inflorescence length, and the average number of flowers per inflorescence were determined on four sample branches per tree in each plot.

During the 3-year period under study, significant correlations were found between leaf nitrogen and fruit set, increased nitrogen being associated with a greater fruit set. Correlation coefficients were 0.873 in 1954, 0.835 in 1955, and 0.944 in 1956. However, inflorescence production, inflorescence length, number of flowers per inflorescence, and the percentage of perfect flowers was not associated with the nitrogen level of the trees.

As observed in other fruit crops, increased amounts of nitrogen were associated with delayed fruit maturity in the olive. In 1953, unfertilized trees had 68% of the fruit showing color at harvest, while trees fertilized with one pound of nitrogen had 54% of the fruit showing color; with two pounds, 12%; with three pounds, 16%; and with four pounds, only 7% of the fruit showed color. This may have been an indirect effect, however, resulting from the differences in the amount of fruit on the trees.

Oil content of the fruit was unaffected by the level of nitrogen. In 1953 the fruit from unfertilized trees had 23% oil, while the fruit from trees receiving four pounds of nitrogen had 22%. In 1954 the oil content was 19% for unfertilized trees and 17% for those receiving four pounds of nitrogen.

Experiment 2

In another section of the same orchard, an additional nitrogen fertilizer plot was established in 1954 and continued for four years. The primary purpose of this additional plot was to study the effects of different levels of soil nitrogen on yields and fruit sizes.

Fertilizer treatments were: *1*, control, no nitrogen; *2*, one pound of actual nitrogen per tree annually, half in February and half in June; *3*, one pound of actual nitrogen per tree annually in February; and *4*, three pounds of actual nitrogen per tree annually in February. Treatment No. *2* was to study the effect of a split application, part of the total applied early in the season to stimulate fruit setting and part in early summer to stimulate vegetative growth for fruiting wood for the following season.

The crop was harvested each year in early November, and leaf samples for analysis were taken in late winter or early spring.

Fruit size grades were obtained with a commercial grader. The size index was calculated by multiplying the percentage of fruit in each grade by an arbitrary factor and adding the results. Factors used were: mammoth, 0.05; extra large, 0.04; large, 0.03; medium, 0.02; standard, 0.01; substandard, 0.00.

At the 1956 and 1957 harvests representative fruit samples were taken from each plot and measurements were made of fruit weight, flesh-pit ratio, length-width ratio, and the percentage of fruit showing evidence of color change from green to red.

Leaf size was obviously much smaller on the unfertilized trees and in 1957, measurements were taken of the leaf area of sample leaves from trees in each plot.

Leaf nitrogen and yields under the Butte County foothill soil conditions increased, in general, as the amount of nitrogen applied in February was increased. The trend was consistent for each of the three years records were taken, yield differences being especially pronounced in 1956, a heavy crop year. The differences in yields between the controls and the fertilized trees were significant, but those between the different levels of nitrogen were not.

In all three years, fruit size was inversely proportional to the amount of nitrogen applied; unfertilized trees produced the largest fruit and those receiving the maximum amount of nitrogen, the smallest. Measurements taken in 1957 showed that decreased flesh-pit ratios occurred with increased amounts of nitrogen, which is typical for large crops of small fruits when compared with small crops of large fruits. Rate of fruit maturity was retarded with increasing amounts of nitrogen but again this may have been a reflection of the amount of fruit on the tree. Size of leaves from unfertilized trees was far below that of leaves from trees receiving nitrogen.

Effect of Nitrogen Fertilizer Applications on Yields per Tree, Fruit Size, and Leaf Nitrogen

Experiment 2. Mission olives. Palermo orchard.

Treatment. Nitrogen per tree	Pounds of fruit per tree, size index, and percent leaf nitrogen								
	1955			1956			1957		
	lbs.	size index	%N	lbs.	size index	%N	lbs.	size index	%N
Control	1.3	2.96	1.23	48.8	2.50	1.23	60.8	2.84	1.06
½ lb. in Feb. ½ lb. in June	9.3	2.82	1.52	171.6	1.84	1.42	98.4	2.70	1.49
1 lb. in Feb.	21.2	2.46	1.43	196.2	0.93	1.62	106.2	2.28	1.53
3 lbs. in Feb.	19.5	2.32	1.48	225.7	0.57	1.60	105.4	2.00	1.71
Diff. required for significance									
at 5% level	13.8			54.5			30.5		
at 1% level	18.5			72.9			40.9		

Effect of Nitrogen Fertilizer on Fruit Size, Flesh-pit Ratio, Length-width Ratio, Rate of Fruit Maturity, and Leaf Size

Experiment 2. Mission olives. Palermo orchard.

Treatment. Nitrogen per tree	Weight per fruit grams		Flesh-pit ratio	Length-width ratio		Colored fruit at harvest %		Leaf size sq. cm.
	1956	1957	1957	1956	1957	1956	1957	1957
Control	4.02	4.01	6.86:1	1.23:1	1.21:1	98	99	5.65
½ lb. in Feb. ½ lb. in June	3.43	3.99	6.82:1	1.26:1	1.24:1	84	94	8.13
1 lb. in Feb.	3.04	3.54	6.37:1	1.26:1	1.21:1	82	91	8.70
3 lbs. in Feb.	2.42	3.42	6.43:1	1.24:1	1.24:1	47	63	8.21
Diff. required for significance								
at 5% level	0.13	0.54	....	....	....	9	29	0.21
at 1% level	0.19	0.81	....	....	....	14	45	0.29

Effect of Nitrogen Fertilizer Treatments on Leaf Nitrogen, Fruit Set, Yields, Fruit Size, Flesh-pit Ratio, and Shotberry Production

Experiment 3. Sevillano olives. Corning orchard. (Initial treatments, January, 1955)

Treatment. Nitrogen per tree	Leaf nitrogen % dry weight		Fruits set/100 inflorescences	Yields per tree lbs.		Fruit size index		Weight per fruit grams		Flesh-pit ratio		Shotberry development %	
	Dec. 1956	April 1958	1955	1955	1956	1955	1956	1955	1956	1955	1956	1955	1956
Control	1.60	1.38	3.0	105	236	6.86	5.53	10.6	7.8	6.6:1	5.7:1	16.0	3.8
¾ lb. in Jan. ¾ lb. in June	1.70	1.47	6.4	133	248	6.10	4.97	10.1	7.0	6.3:1	5.1:1	13.0	1.5
1½ lb. in Jan.	1.69	1.42	4.8	121	250	6.66	5.16	10.1	7.1	6.2:1	5.3:1	12.0	1.8
3 lbs. in Jan.	1.76	1.57	6.1	151	250	6.40	5.06	9.4	7.3	6.0:1	5.5:1	9.5	2.0
Diff. required for significance													
5% level	0.12	0.12	5.9	32	62	0.78	0.94	0.9	1.0	1.5:1	0.2:1	6.9	2.3
1% level	0.18	0.18	7.8	42	83	1.12	1.36	1.3	1.4	2.1:1	0.4:1	9.9	3.3

Experiment 3

A similar experiment—near Corning—was in a Sevillano orchard of trees about 35 years old on Tehama clay loam. The trees had previously received moderately good care, including annual light amounts of nitrogen fertilizer.

The initial fertilizer applications in the experiment were made on January 27, 1955. Four treatments were given: *1*, control, no nitrogen; *2*, 1½ pounds of actual nitrogen per tree annually, three quarters pound in January and three quarters pound in June; *3*, 1½ pounds of actual nitrogen per tree annually in January; *4*, three pounds of actual nitrogen per tree annually in January. Yield records, size grades, fruit weights, flesh-pit ratios, and percentages of shotberries—undeveloped fruit—were obtained in 1955 and 1956 but not in 1957 because of the lack of a crop in the entire orchard. Fruit-set records, expressed as number of fruits per 100 inflorescences, were taken in 1955, and leaf-nitrogen analyses were made in December, 1956, and April, 1958.

Response to the differential nitrogen treatments was not definite. There was a response in leaf nitrogen to the fertilizer treatments, but the differences were not marked, and the untreated trees still had an entirely adequate nitrogen level. No marked differences in fruit set appeared in 1955, although yields of trees receiving the maximum amount of nitrogen were significantly higher than unfertilized trees. However, in 1956, no differences in yields appeared. Fruit size generally tended to be larger for unfertilized trees, indicating an indirect effect due to decreased amounts of fruit on the trees. Differences in flesh-pit ratios were inconsistent and difficult to explain. In 1955 there was an indication that increased amounts of nitrogen tended to reduce shotberry production, but this was not the case in 1956.

Nitrogen Level

The response of olive trees to nitrogen fertilizers is likely to be rapid and pronounced under any condition where the nitrogen level in the leaves of the trees is as low as 1.2%, or less.

In gravelly, shallow hillside soils, low in organic matter and subject to heavy, leaching rains—as was the case in Experiments 1 and 2—the soil nitrogen level would be low and any added nitro-

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UREA

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column the urea had penetrated, and how much had been converted to ammonium carbonate. In the first series, the columns were sectioned after all the urea had passed into the column, even though the wetting front had not quite reached the bottom. In the second series, the sections were analyzed 12 hours after the urea solution was added and in the third series the time interval was 24 hours.

In Salinas clay both the urea and ammonia showed a concentration gradient after one hour, indicating that part of the urea was retained in the upper part of the column, and that some of the urea had been hydrolyzed to ammonia even in that short interval. After 12 hours hydrolysis was essentially complete. Although the soil was uniformly wetted throughout the length of the column the distribution of added nitrogen decreased markedly with depth.

In Hanford sandy loam, urea distribution at the end of one and one quarter hours was quite uniform down to 6″ and was reflected in the uniformity of the ammonia distribution after 24 hours when most of the urea had been hydrolyzed.

A comparison of the movement of urea, ammonium sulfate, and calcium nitrate applied at the surface of Yolo loam showed that nitrate moves along with the wetting front and is concentrated at the bottom of the column, whereas urea moves downward less readily, and ammonium sulfate hardly moves downward at all.

In experiments where both urea and nitrate were applied to the top of a soil column at the same time, and then water added to move the fertilizers downward, it was found that nitrate was first to appear at the bottom of the column. For example, all added nitrate was leached from a 9″ column of Salinas clay by application of 5.7″ of water, whereas 7.1″ were required to accomplish the complete removal of an equivalent amount of urea.

These experiments indicate that urea is retained by weak absorption forces in the soil, and that until hydrolysis occurs urea is intermediate between nitrate and ammonia in its susceptibility to leaching.

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The above progress report is based on Research Project No. 1681.

OLIVE

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gen would soon disappear. Under such conditions, a pronounced response of olive trees to nitrogen fertilizers—as found in these experiments—would not be expected. This would be the case, not only in the initial fertilizer applications, but year after year, as added fertilizers would tend to be lost by leaching and the low level of organic matter in the soil would not be conducive to a natural build-up of soil nitrogen.

In the heavier clay soils on flat ground—as in the Tehama County orchard—nitrogen would tend to be more stable because of the higher organic content and the reduced amount of leaching. Even with no added soil nitrogen, the nitrogen level in the trees would tend to stay for some years well within the range adequate for the needs of the tree; hence, the lack of an immediate response to a single nitrogen application, or to the withholding of a single nitrogen application, is not surprising. Under fertile soil conditions, and where a consistent annual fertilization program is carried on, it is unlikely that any one application of nitrogen could be expected to cause a marked stimulation in the immediate crop.

Maintaining olive trees at the optimum nitrogen level under the soil conditions found in the Tulare and Tehama olive districts would be relatively simple. Because soil nitrogen does not fluctuate appreciably and trees at adequate nitrogen levels do not respond immediately to a single nitrogen fertilizer application, the only problem is that of adding nitrogen to the soil at intervals to maintain the trees at an optimum nitrogen level. The frequency of these intervals can be determined best by leaf analysis, but the appearance of the trees gives a fair indication of their nitrogen status. Dark green foliage together with vigorous annual shoot growth implies ample nitrogen. Further addition of nitrogen fertilizers to trees in this condition or with a leaf nitrogen content of 1.8% to 2.0% is probably not justified because the trees are unlikely to absorb nitrogen much in excess of those values. Even at such high nitrogen levels, however, trees will gradually decrease in nitrogen content after several years and should receive added nitrogen before the leaf nitrogen content drops below 1.2% to 1.3%.

Maintaining olive trees at the proper nitrogen level under conditions such as those found in the Butte County olive district would be much more difficult and is likely to be a major problem of the olive grower. Shallow, gravelly soil with low organic matter and fertility, coupled with heavy leaching due to the rolling topography and high rainfall causes a rapid loss of soil nitrogen, necessitating frequent additions of fertilizer. For trees grown under such conditions, which tend to be continually low in nitrogen, adding the proper amount of nitrogen at the proper time is of definite importance in influencing fruit set and the consequent fruit size.

The problem of nitrogen fertilization encountered in orchards of low soil fertility is twofold. Nitrogen must be added frequently to maintain adequate conditions for growth and to induce adequate fruit setting. However, large amounts of nitrogen should not be applied, especially in the spring just preceding the fruit setting period, as excessive fruit set and, consequently, unprofitably small fruit sizes may result.

In orchards tending toward alternating bearing, heavy nitrogen fertilization in the spring of the on-year would tend to promote the development of a heavy crop, followed by the lack of a crop in the off-year. In such situations a better practice may be to delay the nitrogen application in the on-year until summer—after the fruit setting period—and to apply the nitrogen in the off-year in the spring, preceding the fruit setting period, to stimulate fruit setting.

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The above progress report is based on Research Project No. 1301.

PRODUCTION

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Kern, were the other leading counties in 1941. Then, Imperial was the major vegetable producing county.

Though the total value of the Los Angeles County farm output is now nearly twice as much as in 1941, its share in southern California agriculture has declined to 13%. Among the 12 southern counties, Los Angeles now ranks seventh in fruit and nut crops, and fifth in vegetables and in field crops. However, the value of the county's livestock output—especially dairy products—continued to expand, until recently. And, while it has lost ground as compared with other counties—its share in this group having fallen below one fourth of the total—Los Angeles remains the leading livestock county.

Tulare County was the second largest agricultural producer among the southern counties in 1941, although the value of its output was little more than half

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