California Avocado Association 1933 Yearbook 18: 39-49

Fertilizing Avocado Groves

(With especial reference to the use of and the supplementing of manure)

L. D. Batchelor
University of California, Citrus Experiment Station

Paper read at Avocado Growers' Institute, San Diego, April 12, 1933.

I have been persuaded by your Chairman to address you on the subject of "Fertilizing avocado groves." I must confess to you at once that I am doing this with considerable hesitation, as my consideration of fertility problems has been concerned primarily with citrus culture. I have attempted to select for my discussion a general consideration of the use of certain fertilizer materials which I believe are applicable to avocado and other tree crops. The responses to fertilizer materials by the several tree crops grown in this country have been remarkably similar. Fertilizer trials throughout the length and breadth of this country with such crops as citrus, apples, and peaches, and conducted on many soil types, have led us to believe that these crops have many problems in common.

The general subject of orchard fertilization has many ramifications. These are concerned with the materials to use, methods of application, season of application, most economic sources available, and most economic amounts to use. It will not be possible within the time allocated to me to discuss all these aspects of the problem at any great length.

Fertilizing an avocado grove is an investment. It has not been reduced to an exact science. At best a farmer is merely acting upon a probability when he fertilizes a grove. This is true of many orchard operations; money is spent for fumigation, spraying, and other pest control measures,, based on the probability that if control measures were omitted damage to the trees and crop would result in a loss in excess of the money expended. The farmer spends money for fertilizer materials upon the probability that their use will return the expended money and show an additional return. The particular materials which are purchased should be those which experience has shown are most likely to return the greatest profit per dollar expended. The greatest return for the money spent in fertilization may not mean the greatest profit per acre, as the relative profitableness follows the "law of diminishing returns."

The chemical elements which are essential for plant growth are from eleven to fourteen or more in number. Their ultimate origin under natural conditions is as follows:

(a) Those derived from the solid portions of soil are calcium, magnesium, potassium, phosphorous, iron, sulfur, boron, manganese, and traces of three or more others.

(b) Those derived directly or indirectly from air are carbon, hydrogen, oxygen, and nitrogen.

Eight of these are among the group of elements which form 99.88 per cent of the earth's crust.

Fertilizer is used merely to supplement the fertility of the soil in such a way that the elements may be supplied which are in some measure deficient. It must be clear to every one who seriously considers this matter that fertilizing plants to supplement soil deficiencies is in no sense comparable to feeding a balanced ration to livestock.

It is impossible by the application of fertilizers to establish or maintain any preconceived notion of a balanced soil nutritional condition. The reaction of the components of fertilizers with soils will vary greatly according to the soil types and previous fertilizer treatments.

Furthermore, if it were possible to maintain a definite balanced nutrient solution in the soil, providing one could be safely prescribed, there is no evidence to show that such a condition is essential. In summarizing studies on this subject Hoagland[1] (1919, p. 113) writes as follows:

"From a consideration of previous experiments it is concluded that there is no sufficient evidence to prove that the plant requires for optimum yield any very specific ratio of ions or elements within wide limits provided the total supply and concentration of essential elements are adequate."

It is fortunate indeed for the farmer that fertilization does not include the necessity for adding all the elements needed by the plant. The majority occur in agricultural soils in adequate amounts. Fertilizers are essential merely to supplement the supply already present so that crops may grow with sufficient vigor and abundance to be profitable.

As a general rule in supplying- soil deficiencies one should purchase the fertilizer materials which contain the most of the desired fertilizer units for the money expended. This can not be followed literally in all cases, however, and there is no uniform fertilizer treatment which can be prescribed for the entire area of California. Differences in soil conditions, previous treatments of the orchards, impurities in the irrigation water, climatic conditions, and the economics of each problem must all be considered. Some of these factors will be considered later in more detail.

Before proceeding to more specific problems concerning the use of fertilizers we may properly consider the general differences between soils of the humid regions with those of the arid southwest,, and southern California in particular.

Soils from the arid regions are in general consistently higher in total soluble material; especially lime, magnesia, soda, phosphate, and potash. Soils of the humid regions have been leached for countless ages by heavy rainfall, while the rainfall of the semi-arid and arid sections penetrates only to shallow depths in the soil.

The plant foods most commonly lacking in soils are nitrogen, phosphorous, and potassium. Hence these are the elements usually applied in commercial fertilizers. Fertilizers which contain all three of these elements are spoken of as "complete" fertilizers. Actually, of course, they are very far from being complete so far as supplying all the essential elements for plant growth. Among the relatively infertile soils of the humid regions are found some which are deficient in all three of these elements. Deficiency does not always imply a low total supply in the soil but does mean that the plants growing thereon are unable to secure enough of that particular element or elements to meet their growth requirements. Hence, applications of such materials in forms which are soluble will result in increasing plant growth.

A deficiency in all three of these elements is very much more frequently noted in the humid regions than in the arid sections of this country. We very rarely find soils in the arid regions of the southwest which are considered to be deficient in all three of these elements. Some of the soils of the humid sections are also deficient in available calcium, magnesium and manganese. Many crops growing on acid soils of the humid regions are benefited by lime applications. This response to lime is due in many cases to its neutralizing effects on soil acids, in others to its ability to supply needed calcium and magnesium; and in many cases both effects are important. On the other hand, nearly all southern California soils are neutral or somewhat alkaline and, for the most part, contain abundant supplies of available calcium and magnesium. Thus there is no theoretical basis for the use of lime, and experimental evidence confirms this general conclusion.

This brief discussion of arid and humid soils is sufficient to indicate that fertilizer experiences gained in the humid sections lack in reliable applicability to arid-climate soils in southern California.

The results of several fertilizer trials with citrus in California may offer considerable guidance in the matter of fertilizer practice with avocado trees. Carefully controlled and conducted trials have been carried on from five years to, in some cases, over twenty years. These trials were located in San Diego, Orange, Riverside, San Bernardino and Tulare counties.

In all of these trials the use of nitrogen has been followed by a striking increase in the growth and productivity of the trees. In most cases, but not in all of them, the use of organic matter incorporated into the soil has been followed by equally favorable effects. In most of the trials there has not been a striking contrast, or even a probable significant difference, between the several nitrogen-carrying materials. For example, in one of the trials in Tulare County, nitrate of soda, manure, tankage, and a "complete" fertilizer gave the same results when applied using comparable amounts of nitrogen. In all cases they were used with a winter cover crop.

In the Chaffey experiments it is questionable if there are any significant differences in the fertilizing values of comparable amounts of sulfate of ammonia,, cotton seed meal, tankage, and complete fertilizer, as carriers of nitrogen. Several other trials have shown the same lack of any real choice in the effectiveness of different nitrogeneous fertilizers. This may not be true under all conditions of soil and irrigation water, however, as will be discussed later.

With regard to phosphate and potash, not one of the experiments has shown any measurable effect from the use of either one of these materials. The total absence of any effect from phosphate or potash has been observed with regard to the growth of weeds, cover crops, and trees, and fruit tonnage and quality. The results of these trials may be taken as practically certain proof that the soils in these experimental fields are naturally well supplied with readily available phosphate and potash. The soils on which the fertilizer trials were located were selected because they were expected to typify large areas of comparable soils on which citrus and avocado trees are growing.

As the use of nitrogen and organic matter has most commonly shown a beneficial effect, perhaps we should dwell somewhat at length upon the most common commodity containing both of these materials. Dairy manure has long been the most readily obtainable source of nitrogen and organic matter combined in one fertilizer material. In some districts it has also usually been one of the most economical sources as well. Inasmuch as manure is frequently purchased by the cubic foot, and by tonnage, as well as by analysis, it is easy to overlook its composition. Even when purchased on an analysis basis it is commonly paid for according to its content of nitrogen and organic matter. This practice may have helped us to overlook the other materials present, such as soda, potash, lime, magnesia, phosphorous, sulfur, and traces of several other elements. We may properly consider a more complete analysis of manure as it has a bearing,, first, on the most desirable way to purchase the material and, second, on the fertilizer materials which should be used to supplement the applications of manure.

The variability of different lots of dairy manure is shown in table 1 which gives a partial analysis of six different lots selected from data secured in the course of our analyses of materials applied to certain fertilizer experiments. These analyses as well as others presented in tabular form are the result of studies by my co-workers in the Citrus Experiment Station. Mr. J. G. Surr, Dr. H. D. Chapman and Dr. W. P. Kelley have made notable contributions to the analytical data which I am about to discuss.

TABLE I

Chemical Analyses (in Per Cent) of Dairy Manure, Citrus Experiment Station

Lot No.	Nitrogen	Phosphoric acid	Potash	Organic matter	Moisture	Ash	Carbon : nitrogen ratio
1	0.41	0.36	0.98	14.75	45.89	39.36*	21
4	0.66	0.56	1.84	27.62	29.34	43.04	29
5	1.23	0.74	2.32	47.06	13.72	....	22
6	1.06	0.62	2.54	40.72	33.01	26.27	22
8	1.12	0.50	2.30	41.91	20.13	37.95	22
10	1.89	0.54	1.92	63.48	22.65	14.75	20

* Estimated.

The extreme variability of such material is apparent; some of this is due to differences in feeding materials on which the animals are maintained. The greatest differences, however, are due to age, manner of storing, and the addition of impurities—mainly water, straw, litter, and dirt. Basing the value of these lots shown in table 1 upon the nitrogen and organic matter content, lot 1 was of relatively low nitrogen and organic matter content because of the content of water, as well as dirt in the ash. Lot 4 also was low in the desirable materials because it had an excessive amount of dirt in the ash. Uncontaminated material should contain only 5 to 6 per cent ash. Lot 10 was relatively valuable because of its high nitrogen and organic matter content, and very low dirt impurities in the ash. It is apparent from this table that manure should be purchased upon an analysis basis whenever practicable. Otherwise it becomes a real gamble with no way of knowing the relative value of such purchases. From table 1 it is clear that lot 10 was worth a little over four times as much as lot 1, based on the amount of organic matter and nitrogen present.

Let us turn now to the second consideration of these analyses, that is, the bearing they have upon the fertilizers which may be used to supplement dairy manure. Manure contains appreciable amounts of phosphate and potash. The use of manure will obviously reduce the amount or entirely obviate the necessity of applying these elements in the form of chemical fertilizers, providing there is a lack of these elements in the soil at the beginning. The phosphate and potash from manure are readily available as will be shown later.

Consider, for example, lot No. 5; in applying this material, for every pound of nitrogen we also applied 0.6 of a pound of phosphoric acid and 1.9 pounds of potash. This is somewhat in proportion to a 5-3-10 fertilizer.

It is of interest for example to know how much nitrogen, phosphate, and potash might be contained in ten tons of such manure (a fair application) per acre) compared with the amount removed by a good crop, say the content of 300 packed boxes of oranges. This is set forth in table 2.

TABLE II

Showing Relation of Amount of Fertilizer Applied to that Removed from Soil by Orange Crop

Element	Applied by 10 tons manure* pounds	Removed by 300 boxes oranges pounds	Ratio applied; removed
Nitrogen	246*	43	6:1
Phosphoric acid (P_2O_5)	148*	12	12:1
Potash (K_2O)	464*	49	9:1

* Lot 5 from Table 1. These figures are too high for fresh local manure with considerable dirt and water present; too low for some of the feed yard manures. For garbage fed hog manure these figures are too low by 65 per cent for nitrogen, and 200 per cent for phosphoric acid respectively, while they are 50 per cent too high for potash.

Phosphate and potash are applied by the manure in relatively larger amounts than nitrogen, in comparison with the removal of these elements by the fruit crops.

From the data in this table and the discussion of the availability of these materials to follow, there is apparently no sound reason for supplementing manure with additional amounts of phosphate and potash. I believe this statement is true if manure is used as a fertilizer for citrus or avocado trees in even moderate amounts, on soils which are low in available phosphate and potash content. On soils already relatively rich in these elements the above statement needs no supporting argument.

Table No. 3

Water Soluble Phosphate (P_2O_5) and Potash (K_2O) in an orchard (Sierra Loam) Fertilized with Manure for 22 Years (1090 cu. ft. per acre each year)

Sample level (inches)	No fertilizer	Manure	No fertilizer	Manure
	Parts per million of phosphate		Parts per million of potash	
0-6	4	28	18	73
6-12	3	18	20	52
12-24	2	11	13	21
24-36	4	10	8	17
36-48	..	..	13	11

Phosph**ate and potash are much less subject to loss by leaching than nitrogen.** This is demonstrated by the increase in water-soluble phosphate and potash in a soil fertilized with manure in moderate amounts for twenty-two years, as shown in table 3. The increase in the first three feet of soil is very clear. In this zone the roots of fruit trees are usually most dense, and the movement of these materials to contact points with the major portion of the citrus roots is unquestioned. It is also of interest to note that in this soil there has been little or no movement of phosphate and potash below the lower root zone of citrus trees. This same movement and final location of phosphate has been shown in more detail by the studies of Stephenson and Chapman.[2] The authors studied this problem in connection with several fertilizer materials in addition to manure. Most of the soil types on which citrus is grown in California were investigated. As a result of their studies the authors conclude in part that:

"Water and acid extracts of soils which had received from 1 to 30 or more annual applications of a phosphate-carrying fertilizer compared with similar soils which had not received phosphate showed appreciable penetration of the phosphate below the surface foot in light to medium textured soils. Little or no penetration was found to have taken place in very heavy soils.

"Comparisons of a relative penetration of phosphate from bone meal, superphosphate, and manure disclosed several important results. After 22 annual applications there was no evidence of phosphate penetration below 12 inches in plats receiving bone meal, as compared with marked penetration in plats receiving superphosphate and manure. There are indications that the phosphorus in manure moves rapidly through the soil or else some effect of organic matter facilitates the more rapid penetration of phosphorus."

As further evidence of the absence of any notable leaching of phosphate or potash from soils, attention is called to the lack of these materials in river waters, return waters from irrigated areas, and country drainage waters in general, whereas nitrogen is frequently found in such waters in appreciable amounts.

The stability with which phosphate and potash remain in the soil has a direct bearing on any economy program which may be followed on land which has heretofore been fertilized with these materials in the concentrated chemical form, or on land which has been manured. Many groves which have been so treated no doubt have a much larger supply available than in the virgin soil, and have an ample supply of these materials for many years to come.

The adequacy of the supply in the soil of this experimental orchard as judged by analysis is further substantiated by the total lack of any beneficial effects from the application of these two materials, measured by crop growth on this soil. This soil is considered typical of many soils on which citrus is growing in this state.

Furthermore, investigations by Parker and Pierre[3] indicate that considerably less than I part per million of phosphate and 2.4 parts per million of water-soluble potash are ample providing that amount is maintained during the season of greatest need. These experiments were carried on with annual crops, which are generally considered more sensitive to a deficiency of phosphate and potash than tree crops.

Let us consider now what becomes of nitrogen and organic matter when applied to citrus orchards. Whatever form the nitrogen may be in when applied, a large portion of it will eventually occur normally in the soil in the form of nitrate. It is in this water-soluble condition that it is available for tree growth. The amount of nitrate necessary in the soil for good growth of trees has never been determined very definitely. From 2 to 10 parts per million is an amount frequently found in thrifty groves. Some students of the problem believe that citrus trees, for example, will not respond to additional applications of nitrogen if there is as much as 10 parts per million in the principal root zone of the trees. This is equal to 120 pounds of nitrate nitrogen in the first 3 feet of soil. Trees will tolerate much larger amounts than this even though it may be unnecessary.

Nitrate moves in the soil readily with movement of soil moisture. In well-drained soils it may be leached below the root zone by heavy rains and irrigation water. This is especially true if the irrigation water is applied in basins or by overhead sprinklers in such a way that the entire soil surface is wetted.

The movement of nitrates in three citrus orchard soils is shown in table 4.

Table 4

Amount of Nitrate Nitrogen in Four Orchards Receiving Different Amounts of Fertilizer

Orchard No.	1	2	3	4	
Lowest level of sample feet	(Fertilized 5 years)	(Fertilized 16 years)	(Fertilized 5 years)	(Fertilized 8 + years)	Equivalent to nitrate of lime pounds per acre feet
	Pounds of nitrogen applied per tree each year				
	½	1-1/3	3	3-3/4 or more	
	Parts per million in air-dry soil				
½	1.4	....	2.4	....	
1	....	4.5*	1.6	19.6*	522.14
2	1.0	4.5	4.4	17.6	468.86
3	2.4	8.1	17.0	40.8	1,086.91
4	1.6	11.3	22.4	68.0	1,811.52
5	Trace	12.0	12.4	54.0	1,438.56
6	Trace	14.0	8.0	79.0	2,104.56
7	....	13.0	....	73.0	1,944.72
8	....	12.0	....	55.0	1,465.47
9	....	10.4	....	....	....
10	....	6.8	....	....	....
11	....	5.0	....	....	....
				Total......	10,842.47

*0 to 1.

It is clear from this that there has been a persistent loss below the relatively shallow root zone of citrus trees. Orchard No. 1 received only % pound of nitrogen per tree each year for 5 years; here the loss below the root zone has been negligible. Orchards 2 and 3 have received only light (1.3 pounds per tree) and medium (3 pounds per tree) applications of nitrogen respectively. Orchard No. 4 had been fertilized excessively with nitrate for several years prior to sampling. The citrus grower may properly apply only such amounts of nitrogen as are needed for crop growth. There is bound to be some loss, however, because of the occurrence of heavy rains which can not be foretold in their relationship to prior irrigation and fertilizer applications.

There is a rapid loss of organic matter from soils even though relatively large applications are made annually. Observations in this state and elsewhere have confirmed this. Table 5 illustrates this point very clearly. The first experiment mentioned here was carried on for 50 years at the Rothamsted Experiment Station in England. Heavy applications of manure have increased the organic carbon content of the soil in the first 9 inches by only one-eighth of the amount applied. The second comparison is from the Rubidoux plots of the Citrus Experiment Station. Here only one-fifth of the amount applied can be accounted for as an increase of organic carbon in the first foot. These latter data are not comparable with the first example, however, since in the latter case samples were taken 3 inches deeper, in which zone the least gain, if any, would be noted.

Table 5

Amount of Organic Carbon Remaining in Soil After Repeated Applications of Organic Matter

Duration of experiment (years)	50		23		5	
Amount applied per acre each year	15.4 tons manure	0	15 tons manure	0	4.3 tons grain straw	0
Pounds of organic carbon applied	261,800*	0	117,300*	0	20,422	0
Per cent of organic carbon in surface soil	2.230†	1.162†	0.890‡	0.334‡	0.395‡	0.380‡
Total number pounds of organic carbon in surface soil	66,900	34,860	35,600	13,360	15,800	15,200
Ratio of tonnage of organic carbon to gain over checks	8 to 1		5 to 1		34 to 1	

** Estimated using 17 per cent organic carbon as basis.*
†First 9 inches.
‡First 12 inches.

The third experiment has gone on for only 5 years. Heavy applications of grain straw have been made annually. This material is relatively low in nitrogen and high in organic carbon. The futility of attempting to build up the organic carbon of a soil without also applying comparable amounts of nitrogen is seen in this experiment. Periodical observations have shown that practically all the annual applications of organic matter in this case have disappeared six months after applying.

It is clear from this table that very little material increase in the organic carbon content of the soil can be reasonably expected even following persistent and liberal applications. The losses are also continuous, and apparently the beneficial effects must be explained by virtue of the disintegration of organic matter in the soil rather than by its accumulation.

Relatively small amounts of organic matter are added to the soil mass by fertilizers or by cover crops. Fifteen tons of dairy manure would, on the average, cause an original increase of about one-quarter of one per cent organic matter to an acre foot of soil. Likewise the top portion of a cover crop of 10 tons green weight would add only between one and two-tenths of one per cent organic matter per acre foot. Such additions can hardly be expected to modify the soil mass except in a relatively small way and during only a short time.

The amount of fertilizer material which may profitably be applied to an orchard will depend on many factors. Some of these have to do with the natural conditions and the past history of the grove in question, such as, natural drainage conditions, rainfall, loss of nitrogen previously applied, amounts previously applied, location of present available amounts in the root zone, age of trees and their present condition. One of the most important factors, however, in answering this question is the probable return for the fruit one or two years hence when the effects of the current fertilizer practice will be realized.

The yields and values of different amounts of oranges produced by increasing amounts of fertilizer on six different plots at the Citrus Experiment Station are shown in table 6. These data illustrate a principle which I wish to discuss and are shown for that purpose only. These results occurred at the end of a 5-year period of consistent fertilization as noted. The trees are growing on a rather infertile soil and were in a state of gradual decadence due in some measure to the total absence of fertilizer applications for 10 years prior to the beginning of this experiment.

Table 6
Fertilizer Costs, Fruit Yields, and Value per Tree
Different Amounts of Fertilizer
(Citrus Experiment Station, 15-Year-Old Orchard)

Treatment No.	Pounds of nitrogen applied*	Fertilizer cost	Fruit yield in pounds	Fruit value†	Profit due to fertilizer purchase
1	With clean culture	.....	97	1.17c	....
6	With cover crop	.....	120	1.45	....
40	½ with cover crop	$0.088	172	2.08	$0.54
C	1, with cover crop	0.176	183	2.21	0.58
41	2, with cover crop	0.350	194	2.35	0.55
42	3, with cover crop	0.524	202	2.44	0.47

** Supplied by equal amounts from manure and urea.*
†1932 prices: 1.21c per pound, orchard run, on the trees.

The practice of incorporating a winter cover crop into the soil annually has resulted in an improvement in the vigor of the trees as well as crop production, in comparison to no fertilization. The most striking result has been the relatively large increase in productivity when only a small amount of fertilizer was applied in conjunction with a cover crop, compared to the use of a cover crop alone. Only one-half pound of nitrogen per tree increased the yield 43 per cent compared to the use of a cover crop only. This amount of nitrogen would be contained in 2 1/2 pounds of sulfate of ammonia. Increases in the amount of fertilizer applied above 1/2 pound of nitrogen per tree have caused suprisingly small increased yields. It has been shown by investigators in the past, however, that the resulting yields derived by progressively increasing the units of fertilizers applied to annual crops tend to follow a curve similar to a decreasing geometric series. The application of this principle to results of fertilizer trials has become known as the law of diminishing increment. That is, if the increase of the second unit of the fertilizer over the first is 70 per cent, then the use of a third will tend to cause an increase of only 70 percent over the second, etc. A curve drawn from data presented in table 6 shows that the increase from one unit of fertilizer is too high and following units too low to follow this law. Possibly the loss of nitrates below the root zone where large amounts are applied is the reason for this exception to general fertilizer results.

In any event it is clear in this example that the law of diminishing returns for money expended operates to reduce rapidly the profit from expending increased amounts for fertilizer. How widely applicable these data may be is not known, as it is practically impossible to obtain comparable results from commercial orchards.

It should be kept in mind, however, that orchards are fertilized to insure against a deterioration in the vitality of the trees and also to insure against unfavorable climatic seasons adversely affecting crop production. The season 1931-32 was favorable to setting a crop in the orchard in question. We believe from past experiences in fertilizer studies that greater differences in crop production between light and heavily fertilized plots, will exist during years when hot periods and other climatic factors are unfavorable to setting fruit.

The farmer can afford to insure in some measure against such periodical unfavorable seasons. The greater the prospective price of the fruit the greater the probability that the purchase of increased amounts of fertilizer will be profitable. At present prices a moderate application of nitrogen and organic matter seems amply justified. If these materials are applied there seems to be no reasonable basis for the use of additional amounts of phosphorus, potash, lime, and other soil amendments.

From the foregoing tables it is clear that the nitrogen and organic matter are the elusive materials in manure when used as a fertilizer. The application of additional amounts of organic matter in the form of cover crops where manure is used as a fertilizer may be justified in view of local practical considerations. The use of added nitrogen-carrying fertilizers with manure in fertilizing citrus trees is founded on sound theory and practice. The phosphate and potash have been shown to persist in the root zone of tree crops and are not lost by leaching. We believe, therefore, that their addition to manure for fertilizing is not well founded on either theory or practice, and cannot well be afforded as an extravagance at the present time.

The cost per unit of nitrogen should be the first consideration in selecting a fertilizer material which is purchased to obtain this element. The season of application in relation to rainfall, and thus the rapidity with which the material is available to the trees may be a second consideration. The nitrate fertilizers are immediately available as soon as they reach the root zone. The ammonia fertilizers require a period to nitrify. This process, which is caused by the micro-organisms in the soil, proceeds with varying rapidity depending especially upon the soil temperature and soil moisture. Whereas 100 per cent of the nitrogen in the nitrate fertilizers is available for plant growth, only a portion (from 60 to 86 per cent) is usually available from the ammonia and organic fertilizers. In this last mentioned class would be included dried blood, fish meal, cottonseed meal, manure, bean straw, and alfalfa hay. Some of the nitrogen is lost as ammonia gas and some as free nitrogen when the above mentioned materials are nitrified in the soil.

The rapidity with which they nitrify and the percentage which eventually became available as nitrate in a laboratory experiment are shown in table 7.

Percentage of Total Nitrogen which Became Available as Nitrate from Different Fertilizer Materials

TABLE 7

Material	Percentages of total nitrogen nitrified at the end of the weeks specified		
	Second week	Eighth week	Sixteenth week
Sulfate ammonia	56	72	86
Dried blood	40	56	78
Urea	56	60	78
Calcium cyanamid	3	64	74
Cottonseed meal	36	64	62

The soil moisture, temperature and air conditions were kept constantly favorable to rapid nitrification. Whereas 86 per cent of nitrogen became available as nitrate from sulfate of ammonia at the end of 16 weeks, only 62 per cent of the nitrogen became available from cottonseed meal in a like period. Additional periodical observations were made of nitrate content of samples, comparable to data presented in the table. These complete data indicate that practically the maximum nitrification had taken place by the sixteenth week period. A longer period would be required to complete the nitrification under less favorable conditions of temperature and soil moisture.

With the economies which are essential to consider at present in the fertilizer program, it is doubtful if we can justify the use of nitrogen from «organic sources which must be purchased in competition with the animal-feeding industries. It is clear from table 7 that nitrogen from such sources should actually be cheaper than the chemical salts derived from mining, synthetic processes, and by-products,, if their value is based on the percentage of the total nitrogen to become available.

The actual fertilizer prices show the converse of this to be true. There is a reasonable doubt if the avocado grower can afford at present to buy nitrogen from such sources as dried blood, cottonseed meal, tankage, and fish meal when more nitrogen for less money can be purchased from the chemical fertilizers. The organic matter applied in the before mentioned organic concentrates, which are also used for feed materials, is negligible compared with that which can be provided more economically from manure, straw, or cover crops.

At present the avocado grower can ill afford to invest money in practices which are not well founded on both theory and experience.

[1] *Hoagland, D. R. Relation of the concentration and reaction oí the nutrient medium to the growth and absorption of the plant. Jour. Agr. Res. 18:73-117. 1919.*

[2] *Phosphate penetration in field soils. R. E. Stephenson and H. D. Chapman. Jour. Agr. Agron. Vol.10. pp. 759-770, Oct. 1931.*

[3] *Parker, F. W. and Pierre, W. H. The relation between the concentration of mineral elements in a culture medium and the absorption and utilization of these elements by plants. Soil Science 25:337-343, 1928.*