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BEHAVIOR OF NITROGENOUS FERTILIZERS IN ALKALINE CALCAREOUS SOILS: II. FIELD EXPERIMENTS WITH ORGANIC AND INORGANIC NITROGENOUS COMPOUNDS

By

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BEHAVIOR OF NITROGENOUS FERTILIZERS IN ALKALINE CALCAREOUS SOILS: II. FIELD EXPERIMENTS WITH ORGANIC AND INORGANIC NITROGENOUS COMPOUNDS

BY W. H. FULLER, W. P. MARTIN,* AND W. T. MCGEORGE

INTRODUCTION

Semiarid soils are characteristically low in organic matter and, therefore, in reserve nitrogen. Under continuous cropping these lands are showing increasing response to nitrogen fertilization. Since the crops grown on these lands vary in their seasonal and over-all need for nitrogen, availability of various nitrogenous materials has assumed importance. This is illustrated particularly by the nitrogen control experiments with citrus at the Yuma Mesa Citrus farm (5). In order to study the behavior of various nitrogenous materials including green manures, under field conditions, some experiments were set up on the Yuma Mesa and in the Salt River Valley.

The field experiments relate to one main process, nitrification, and a number of others, such as tie-up of nitrates by decomposing organic materials (subsequent ammonification and nitrification), and loss of nitrates by leaching. Nitrates are transitory in the soil. If they are not utilized by plants or microorganisms when formed under irrigated soil conditions, they may leach below the root zone. It is important that nitrates are continuously available during the period when the plant needs the nitrogen. Since nitrogen is an important economic factor in our fertilizer program, it is advantageous in some cases to hold onto as much of it as possible and remove it from its sphere of activity by sagacious use of cover crop, mature crop residues, and manures.

FIELD EXPERIMENTS ON MOHAVE SANDY LOAM AND JOKAKE CLAY LOAM

EXPERIMENTAL PROCEDURES

Two typical soils, Mohave sandy loam and Jokake clay loam, from the Salt River Valley planted to citrus were collected to a uniform depth of 1 foot, hauled to the University date farm, dried, sieved, and mixed thoroughly with various nitrogenous fertilizers according to Table I for 250 pounds of soil giving a nitrogen equivalent of 250 ppm of soil.

Except for ammonia, which was added in solution, each fertilizer was added to the soil dry and mixed thoroughly with it in a cement mixer. The soil-fertilizer mix was then placed in a board enclosed plot 8 feet by 8 inches by 12 inches. Irrigations were made as usual for citrus. Samples for pH, ammonium-, nitrite-, and

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TABLE 1.—SOURCE OF MATERIALS AND NITROGEN CONTENT

Plot	Treatment	Nitrogen-percentage
1	Untreated	0
2	3 lb. cattle manure	2.0-2.5
3	3 lb. goat manure	2.0-2.5
4	0 261 lb commercial fertilizer (urea with manure filler)	25.0
5	0.421 lb. calcium nitrate	15.5
6	1.6 lb. activated sewage	3.0-5 0
7	0.15 lb. urea	42.0
8	0.3 lb. calcium cyanamid	21.0
9	0.3 lb ammonium sulfate	20.7
10	35 grams ammonia (liquid)	82.0

nitrate-nitrogen determinations were taken from each plot after various periods of incubation.

The rate of nitrification of the fertilizers in the Bartlet-Heard (Mohave sandy loam) and Baldwin orchard soil (Jokake clay loam) is shown in Figures 1 and 2, respectively. The organic materials high in carbon were plotted separately from those having no carbon or only small amounts for convenience.

NITRATE FORMATION

For the most part the untreated Mohave sandy loam was found to liberate between 1 to 10 ppm nitrate-nitrogen throughout the year. The untreated Baldwin orchard soil or Jokake clay loam varied between a range of 1 to 10 ppm nitrate-nitrogen the first 130 days and between 10 and 20 ppm the remaining 230 days. In general, however, the nitrification of the fertilizers was very similar in both soils.

The steer manure appeared to liberate nitrogen as nitrate to a slightly greater extent than goat manure. In fact the greatest amount of nitrate-nitrogen, 26 ppm, in the goat manure was found in the soil-manure mixture at the beginning of the experiment; in two days the amount had dropped to 0 and did not increase above 22 ppm during the entire 360 days of the experiment. The commercial fertilizer mix of urea, manure and calcium nitrate and urea alone yielded nitrate-nitrogen in almost identical amounts to that of goat manure. Activated sewage appears to be a very desirable nitrogen fertilizer. Nitrate-nitrogen was liberated rather slowly the first week but increased very rapidly to about 85 ppm within three weeks and never fell below 50 ppm for the remainder of the year.

Calcium cyanamid maintained a much higher nitrate-nitrogen content in the Jokake clay loam than in the Mohave sandy loam. The heavier Jokake soil is more highly buffered against a change in pH than the light sandy Mohave soil. The pH of the cyanamid-treated Mohave was above that of the Jokake soil at the beginning of the experiment and remained higher during the early days of the investigation. Such differences in the pH, particularly in this critical range, could well influence nitrification. The nitrification of the cyanamid in both soils was notably higher than for the manures, however. The presence of a large amount of carbonaceous materials in the manures undoubtedly was an important factor in keeping the nitrogen immobilized. The ratio of carbon to nitrogen is much wider in the manures than in the cyanamid. Calcium cyanamid applied at the rate of 250 pounds of nitrogen per acre appears to be an acceptable fertilizer and has the advantage of supplying nitrates steadily over a long period of time.

Nitrates of calcium nitrate were leached quickly from the sampling depth of the soils. Urea also appeared to exhibit this same characteristic, only the leaching was more delayed. Only about 10 to 20 ppm nitrates were found in the calcium nitrate-treated Mohave sandy loam shortly after the initial application. Slightly more appeared in the Jokake clay loam.

Ammonium sulfate yields rather large amounts of nitrate over a long period of time in both soils. About 13 ppm nitrate-nitrogen was found in the soils in two weeks, 83 to 106 in four weeks and never less than 60 ppm for the remainder of the experiment. As much as 156 ppm nitrate-nitrogen was recorded in the Jokake clay loam on the 130th day after the treatment began.

Aqueous ammonia treatments yielded data similar to those from ammonium sulfate except that nitrification was delayed about two weeks when compared with the ammonium sulfate but after the initial lag period the supply of nitrate was steady.

In summary of these data it appears that all the materials tested provide a desirable source of nitrate-nitrogen. A greater supply of nitrate-nitrogen was available from ammonium sulfate, anhydrous liquid ammonia, and activated sewage for the duration of the experiment than from the other fertilizers. Slightly more nitrates accumulated in the heavy Jokake clay loam than the Mohave sandy loam. This is due to the favorable buffering and absorbing properties of the clay colloid, which was dominant in the Jokake clay loam.

AMMONIUM ION ACCUMULATION

Data plotted in Figures 3 and 4 show that ammonia-nitrogen was most abundant in soils treated with ammonium sulfate, ammonium liquid and activated sewage. The ammonia-nitrogen was rather high in the soils treated with the ammonium sulfate and ammonia liquid for a period of ninety days after which the values dropped to a level of the untreated soil. Less spectacular amounts of ammonia-nitrogen were found in the soils treated with activated sewage, though moderate amounts, about 45 to 50 ppm, were maintained during the first forty days of the experiment. Calcium cyanamid yielded different results in the two soils. Between 20 to 40 ppm ammonia-nitrogen was found in the cyanamid-treated Mohave sandy loam throughout the first seventy-five days before the values dropped to a level near that of the untreated soil, whereas the cyanamid-treated Jokake clay loam yielded data similar to the untreated soils at all times. The amount of ammonia-nitrogen found in soils treated with urea, calcium

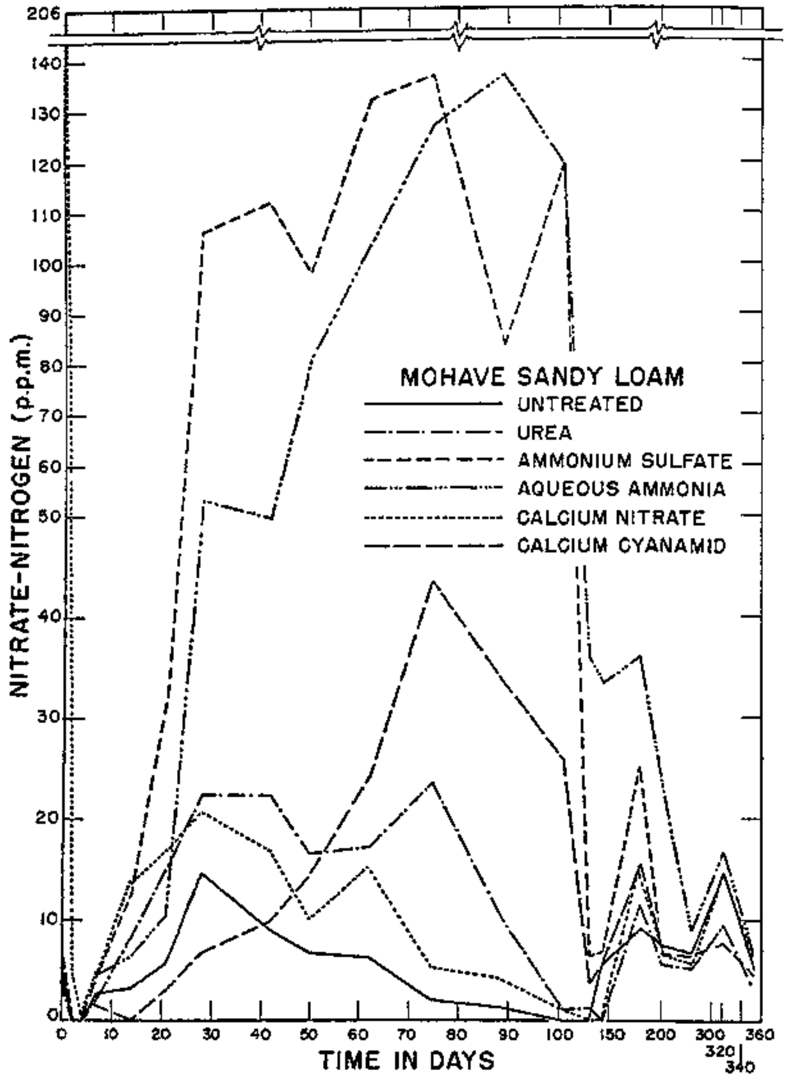

Figure 1, *A*.—Change with time of nitrate-nitrogen in Mohave sandy loam treated with various nitrogen fertilizers.

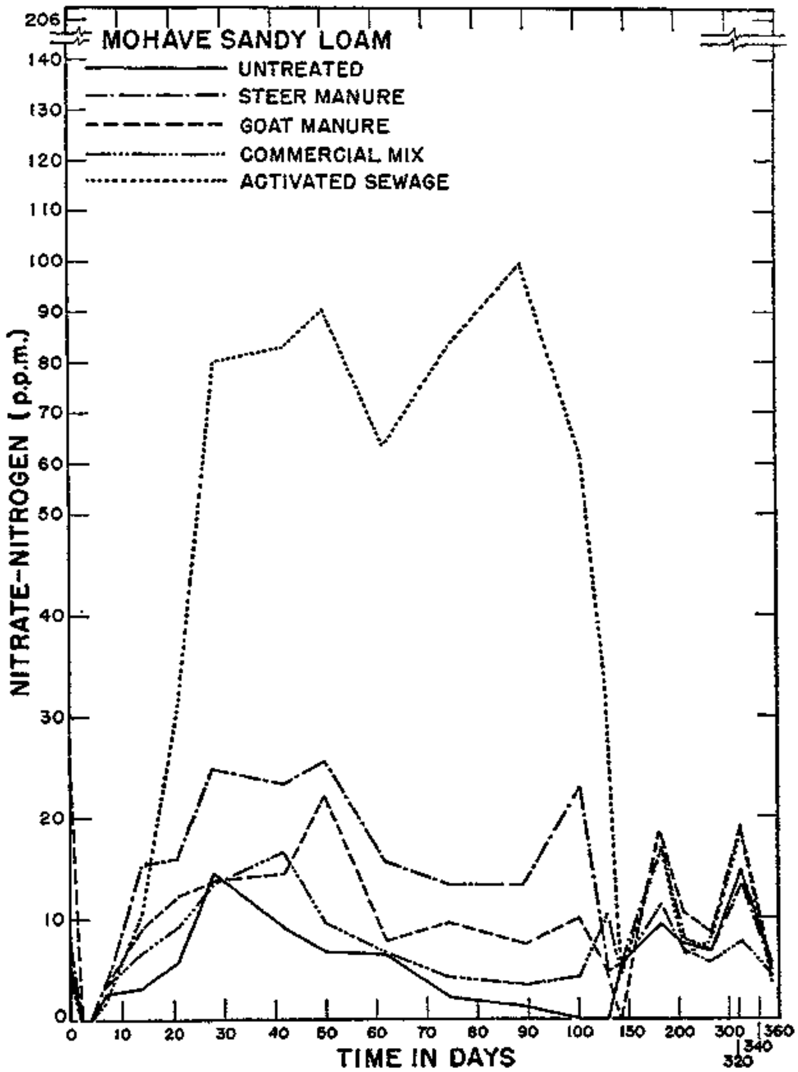

Figure 1, B.—Change with time of nitrate-nitrogen in Mohave sandy loam treated with various nitrogen fertilizers.

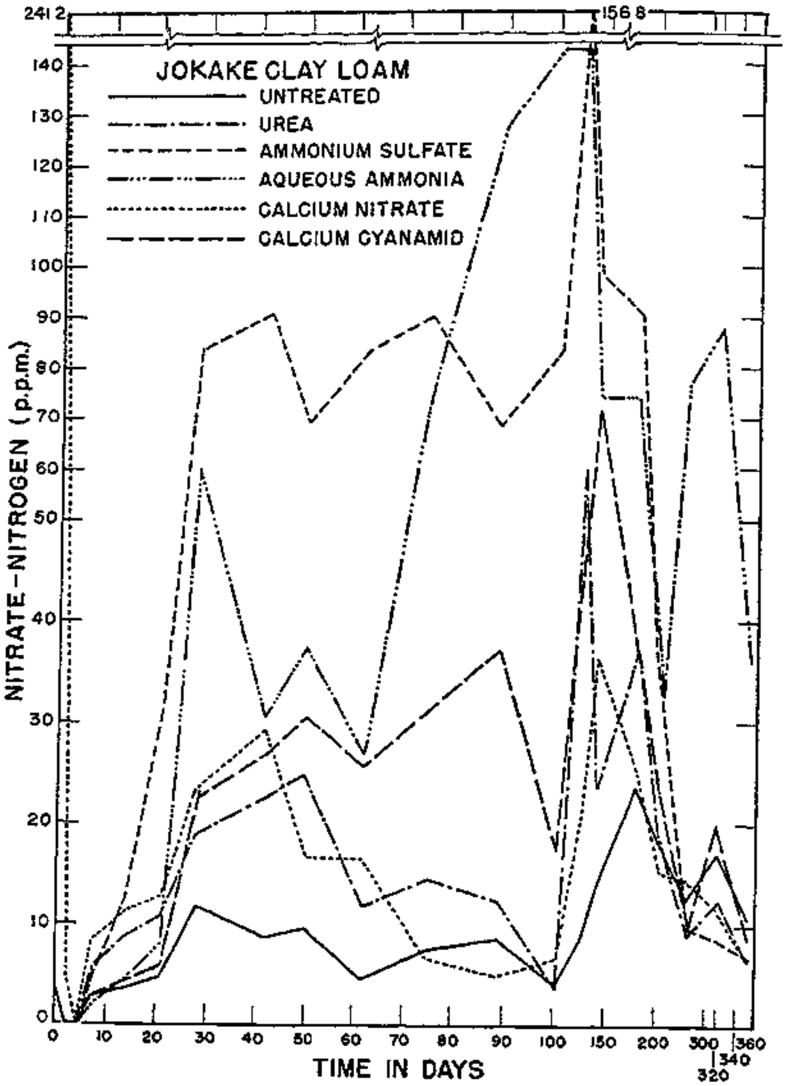

Figure 2, *A*.—Changes with time of nitrate-nitrogen in Jokake clay loam treated with various nitrogen fertilizers.

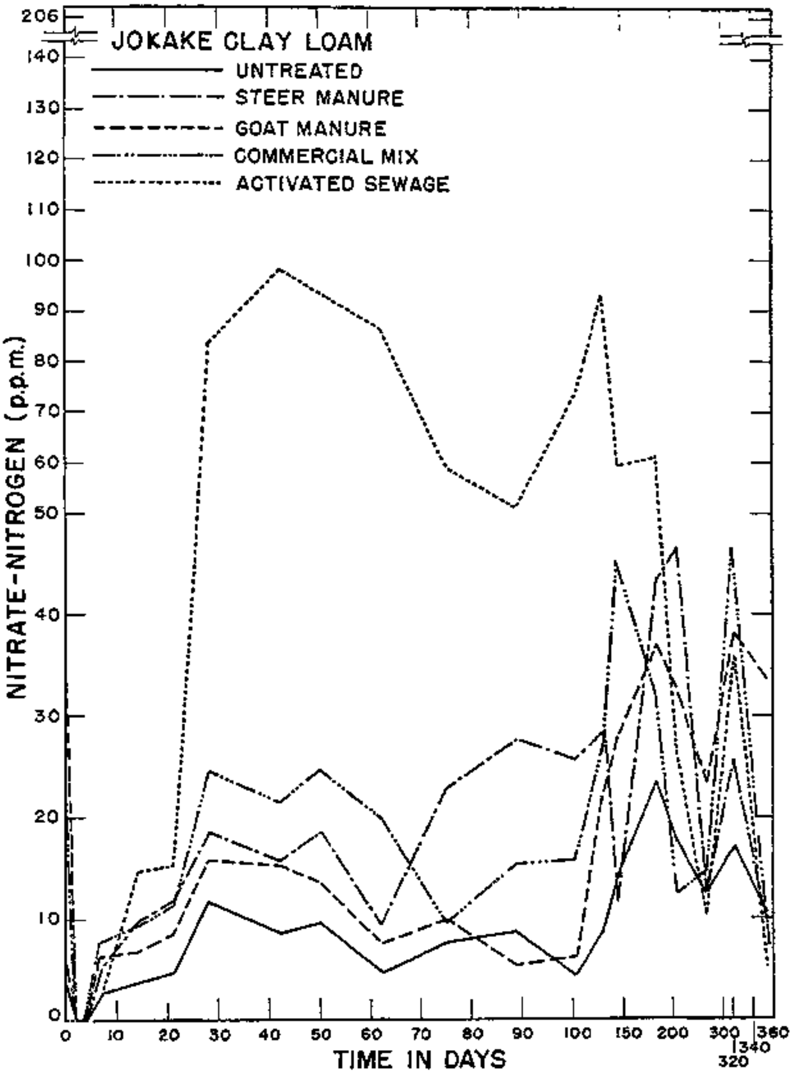

Figure 2, *B*.—Changes with time of nitrate-nitrogen in Jokake clay loam treated with various nitrogen fertilizers.

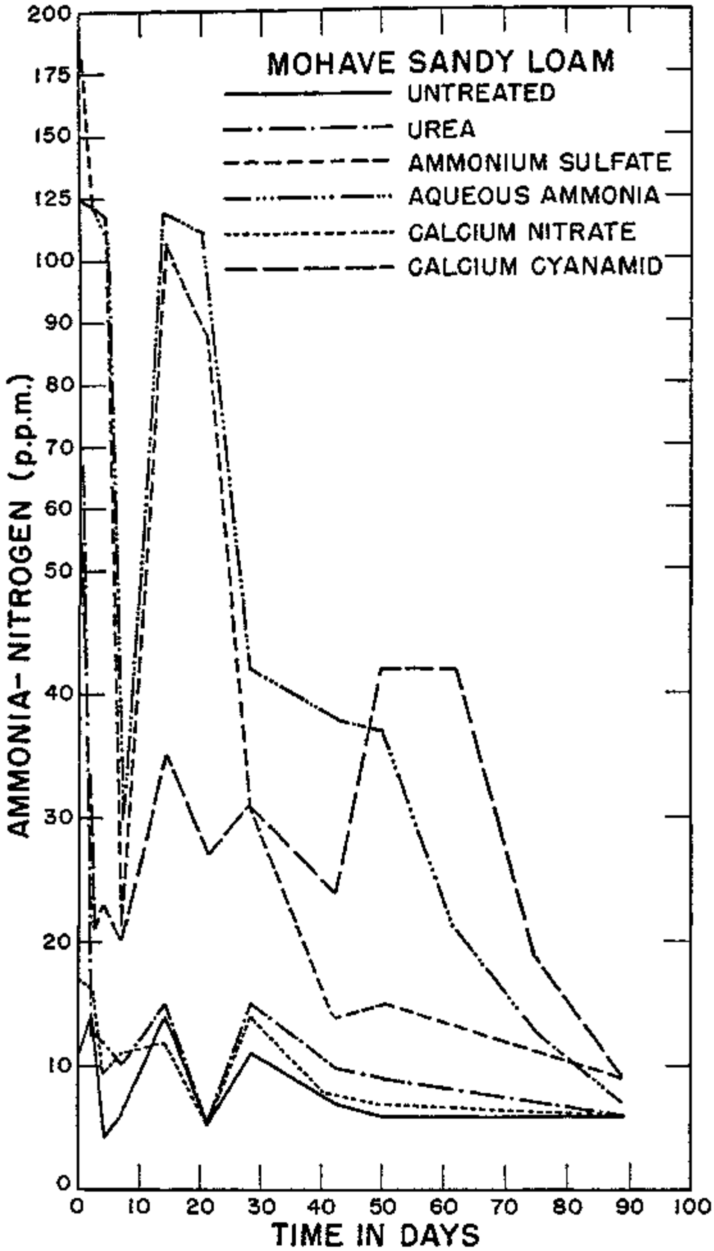

Figure 3, *A*.—Change with time of ammonia-nitrogen in Mohave sandy loam treated with various nitrogen fertilizers.

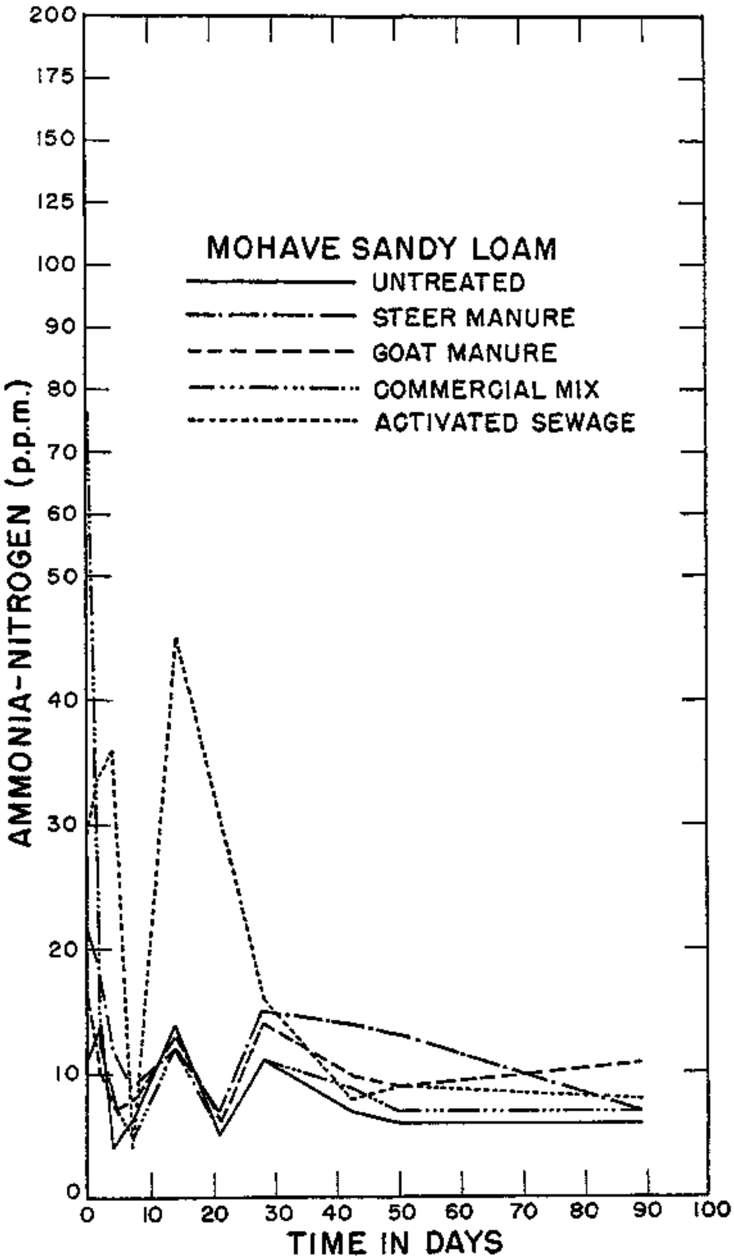

Figure 3,B.—Change with time of ammonia-nitrogen in Mohave sandy loam treated with various nitrogen fertilizers.

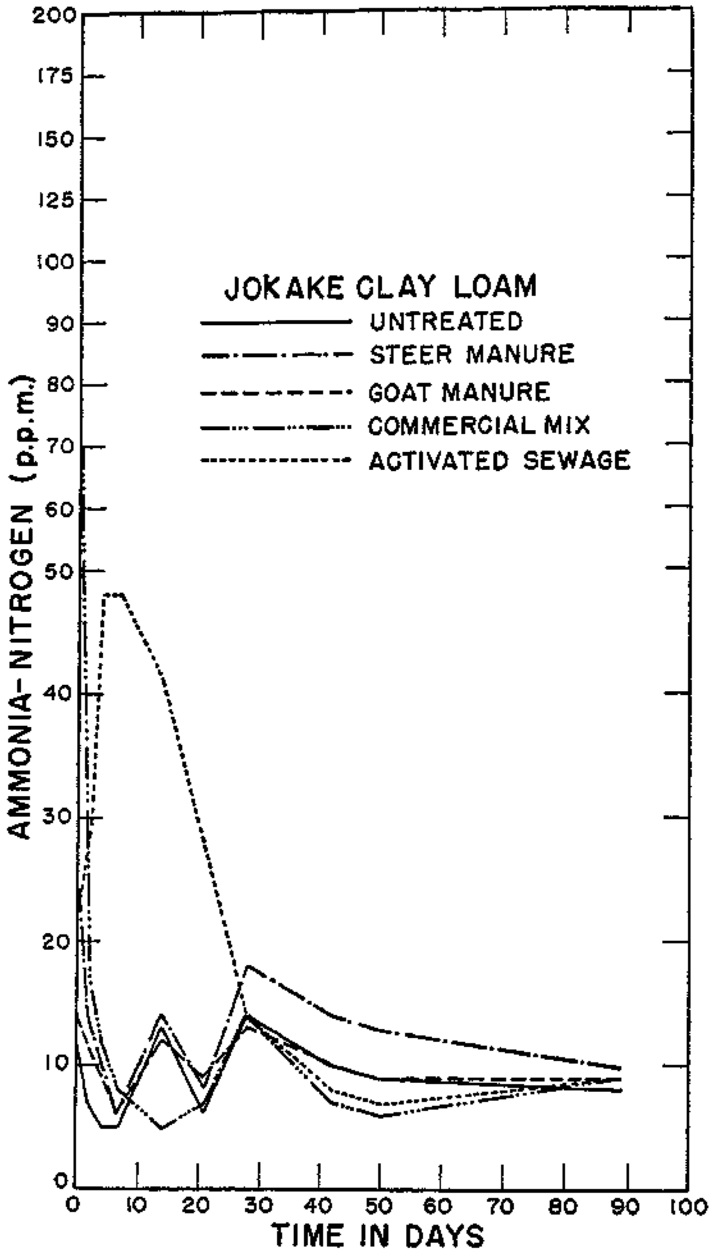

Figure 4, *A*.—Change with time of ammonia-nitrogen in Jokake clay loam treated with various nitrogen fertilizers.

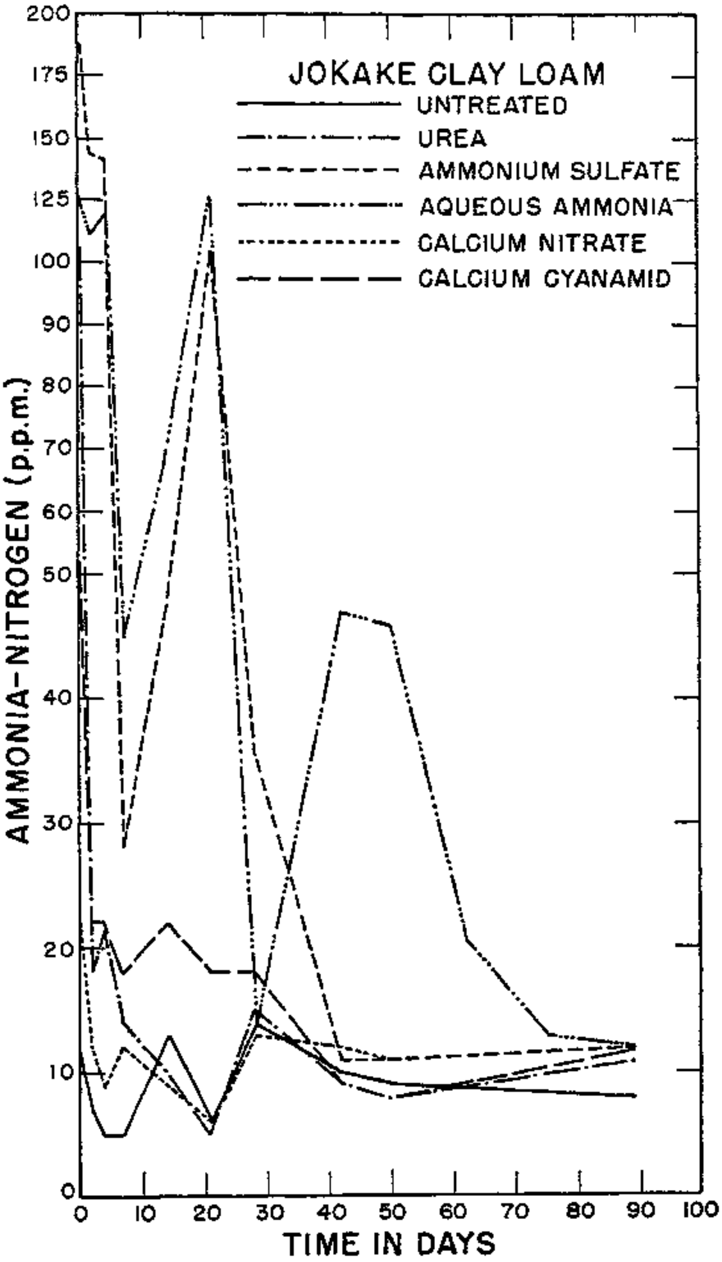

Figure 4, *B*.—Change with time of ammonia-nitrogen in Jokake clay loam treated with various nitrogen fertilizers.

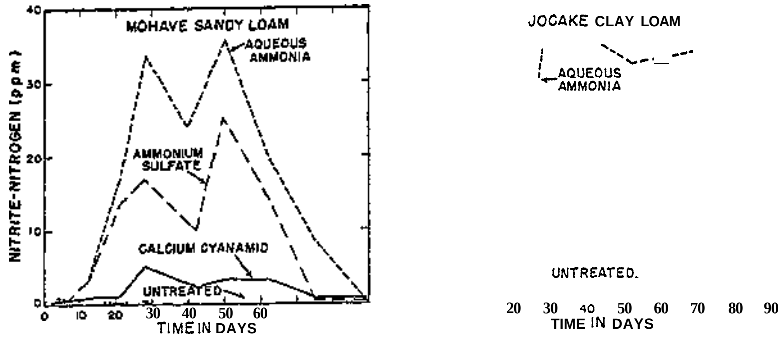

Figure 5.—Change with time of nitrite-nitrogen in Mohave sandy loam and Jokake clay loam treated with various fertilizers.

nitrate, steer and goat manure, and the commercial mix was about the same over the ninety-day period of study as that of the untreated soil. Urea apparently washed out of the soils quickly. Neither ammonia nor nitrates accumulated to any extent with this fertilizer.

NITRITE ACCUMULATION

Nitrite-nitrogen was found only in quantities of less than 1 ppm for soils treated with fertilizers other than liquid ammonia, ammonium sulfate, and calcium cyanamid according to data in Figure 5, though only in the Mohave sandy loam was the nitrite nitrogen of the cyanamid treated soil appreciably higher than the untreated soil. Accumulation of nitrites from the ammonium-treated soils took place only for a period of about forty days, at a time, corresponding to the most intense activity of the microbial transformation of ammonia to nitrate.

pH VALUES

Ammonium sulfate, aqueous ammonia, and activated sewage lowered the pH value of the soil as much as 0.75 unit during the period of active nitrate formation, see Figures 6 and 7. Steer manure lowered the pH value about 0.25 unit in both soils, whereas all other materials except calcium cyanamid lowered the pH only slightly below that of the untreated soil. The pH of the calcium cyanamid treatment was 9.2, the highest of all treatments, at the beginning of the experiment in the Mohave sandy loam and 8.75 in the Jokake clay loam. In the Mohave sandy loam the pH decreased sharply to a low of 7.85 in sixty days and a low of 8,2 in twenty-eight days in the Jokake clay loam. The pH values of all treatments were lowest at the time of greatest nitrate formation, whereas the highest pH values, at the start of the experiment, were associated with an early formation of ammonia from the fertilizers.

The most significant feature of the pH data is the formation of nitrates at pH values above the threshold of 7.7 ± 1. The pH was determined on these field-collected samples in saturated soil pastes with a glass electrode. Values obtained by this method should be no different from those obtained on soil at a moisture content of 70 per cent of its water-holding capacity as suggested by Caster, Martin and Buehrer (1) and should be directly comparable to those of the laboratory experiments of the first bulletin of this series (3). Various reasons may be postulated for the apparent discrepancy between nitrate formation in the laboratory and the field samples. *Firstly,* the laboratory experiments are designed to demonstrate mechanisms and are not considered to be directly applicable to field conditions without qualifications. *Secondly,* the small scale laboratory experiments with intimately mixed ingredients are not wholly characteristic of field conditions where micells, or small areas of the soil may vary considerably in pH from the surrounding material. These small zones may be either entirely unfavorable for nitrate formation or be a haven for intense nitrate formation. In the event of the latter, as water carries ammonium and nitrite ions through such points, nitrates are readily formed despite the over-all pH of the soil as determined on a paste by stirring the soil with water to obtain a uniform consistency. *Thirdly,* the presence of organic residues in small pockets and minute areas under natural field conditions provide highly buffered areas ideal for microbial activity. Such pockets could provide a suitable pH and nutritional condition for active nitrate formation even for added fertilizers.

Regardless of the reason for the discrepancy, nitrates are formed in soils under natural conditions above a pH value of 7.7 $\pm$ 1. Under natural conditions nitrates are derived from biological transformation of the nitrogen of plant residues and other organic sources. Organic residues no doubt provide a microhabitat, favorable for intense biological activity including the nitrogen transformations, in which the pH may be much lower than the soil mass as a whole.

FIELD EXPERIMENTS ON VIRGIN AND SILTED SUPERSTITION SAND

At the Yuma Mesa Farm an attempt was made to evaluate the influence of cover crops on the soil nitrogen economy. Such questions, for example, as: do cover crops use nitrogen in competition with the citrus tree, do cover crops immobilize additional nitrogen when plowed under, and what rate of release of nitrogen can be expected from organic residues incorporated in soils?, require answering before a program of nitrogen fertilization can be made for growing citrus on the Yuma Mesa. The peculiar climatic conditions of the Yuma Mesa and soil conditions, such as low organic matter and soil colloid, high pH value, low moisture-holding capacity, and year-round favorable temperature for microbial activity make it difficult to answer such questions without field data. Moreover, silting has taken place in some of the mesa sand by flooding with muddy water. The addition of this colloidal material to the sand undoubtedly will effect microbial transforma-

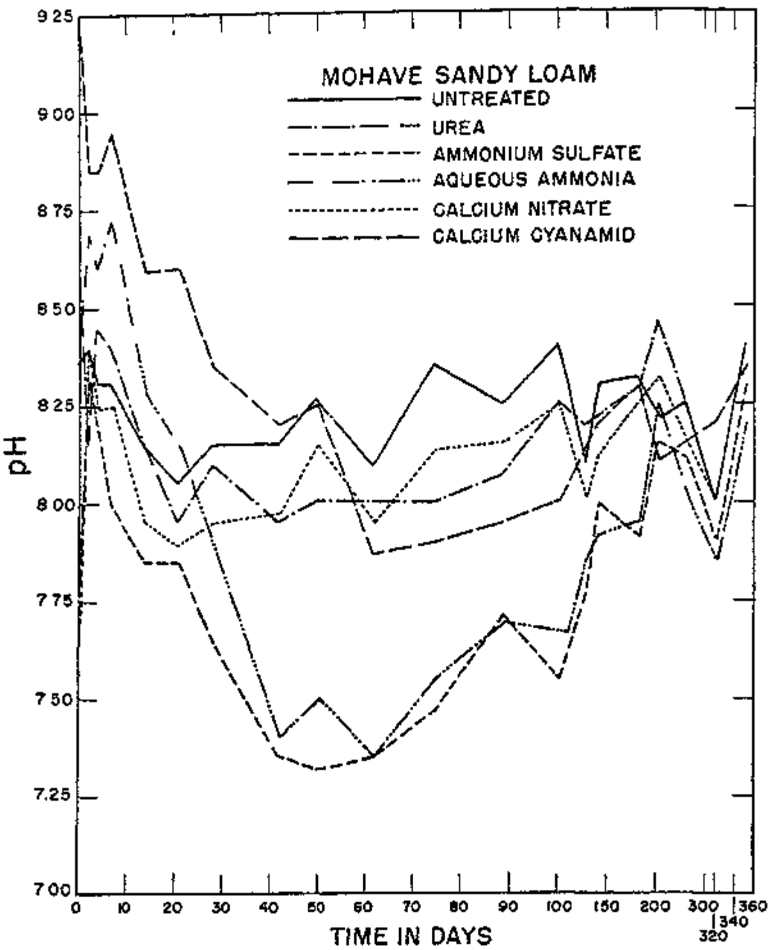

Figure 6, *A*.—Change with time of pH values in Mohave sandy loam treated with various nitrogenous fertilizers.

tions of nitrogenous and carbonaceous materials, and the leaching of materials from the root zone.

EXPERIMENTAL PROCEDURE

The influence of manure, Sudan grass, alfalfa, ammonium sulfate and urea upon the accumulation of ammonium-, and nitrate-nitrogen in silted and non-silted Superstition sand of the Yuma Mesa was determined by analyzing soil samples at predetermined intervals for the ion desired. Changes in pH and organic carbon were also followed at various intervals over a period of a year.

Duplicate blocks of silted and virgin sand were set up to contain six plots 8 feet by 8 inches by 8 inches. The plot treatment

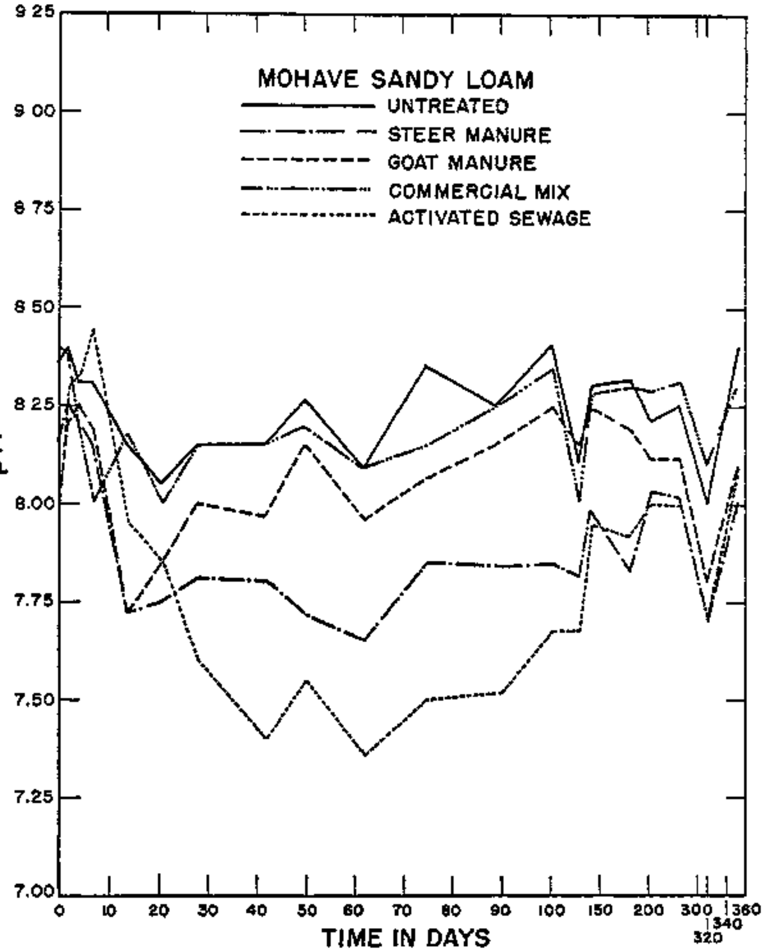

Figure 6, *B*.—Change with time of pH values in Mohave sandy loam treated with various nitrogenous fertilizers.

was as follows:

Plot	Treatment
1	Untreated
2	Alfalfa (5 per cent wet weight)
3	Sudan grass (5 per cent wet weight)
4	Ammonium sulfate (1 lb./400 lb. soil)
5	Manure (1 per cent air-dry weight)
6	Urea (¼ lb./400 lb. soil)

This experiment was begun September 13, 1940, and completed one year later.

NITROGEN TRANSFORMATIONS

Rather unusual conditions have been brought about in the fertility of the raw Yuma Mesa sand as a result of cultivating and irrigating the soil with the muddy waters of the Colorado River.

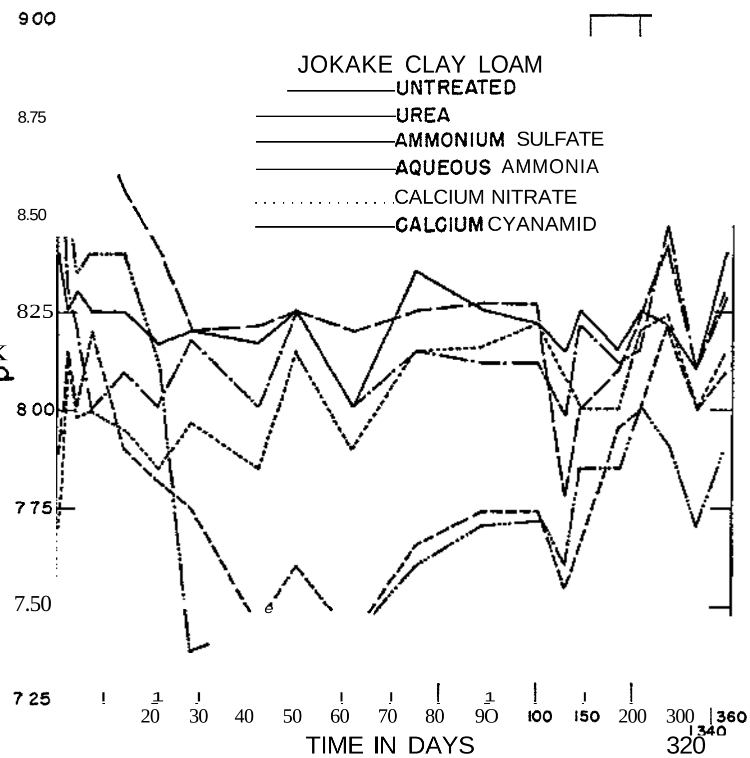

Figure 7, *A*.—Change with time of *p*H values in Jokake clay loam treated with various nitrogenous fertilizers.

The accumulation of nitrates as a result of transformation of inorganic and organic nitrogenous materials in two soils as shown in Figures 8, 9, and 10, for example, is remarkably different. No nitrate-nitrogen was found in the untreated virgin sand, whereas the silted sand had 1 to 10 ppm throughout the course of the experiment of one year. Again no nitrates accumulated in the virgin sand treated with Sudan grass, whereas Sudan grass-treated silted sand began accumulating nitrates in about 150 days (middle of February) and yielded about 20 ppm nitrate-nitrogen at the end of the experiment in September. Urea-treated virgin sand was also devoid of nitrates during the 365-day experiment (see Figure 8). In silted and cultivated sand urea produced as many nitrates as did ammonium sulfate (Figure 9). The quantity was very high for both fertilizers. Probably urea washed below the 8-inch sampling depth in the raw sand before it could be detected. Manure shows no nitrate accumulation in raw sand, whereas in silted sand more nitrates were present in the manure than the untreated soil after December 1, and gradually increased in the treated soil up to 30 ppm at the time the experiment was terminated.

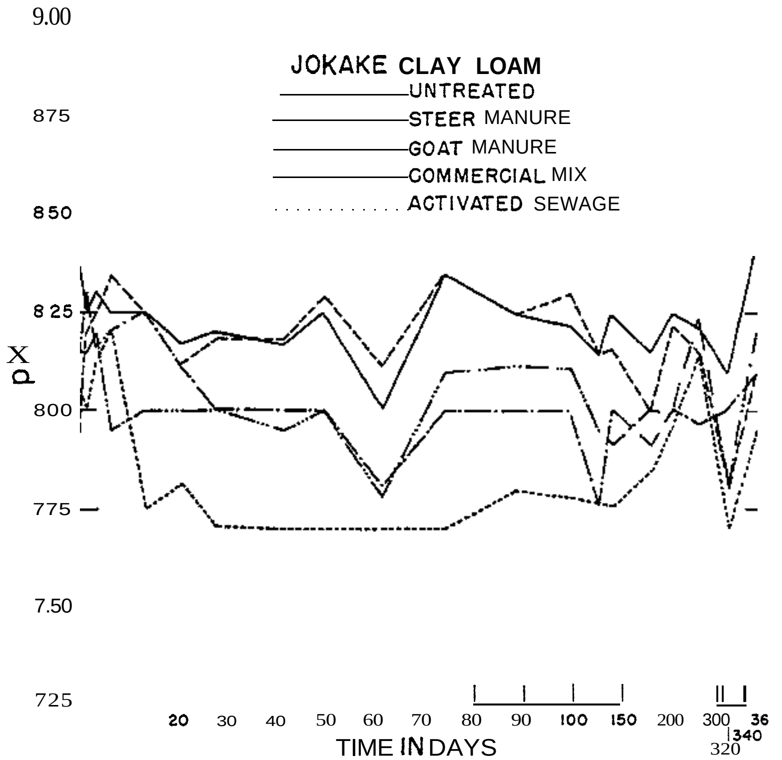

Figure 7, *B*.—Change with time of *p*H values in Jokoke clay loam treated with various nitrogen fertilizers.

The only treatments that brought about an accumulation of nitrate-nitrogen in the virgin sand were those of alfalfa and ammonium sulfate. According to Figure 8 the two materials nitrified at about identical rates during the early part of the experiment. Alfalfa, however, appeared to produce small amounts sporadically the remainder of the year, whereas ammonium sulfate treatment failed to show nitrates after the forty-fifth day. Results with silted soil seen in Figure 10 indicate that alfalfa yielded nitrates in rather large amounts over a period of a year; as much as 84 ppm was reported on the 127th day and about 75 ppm on the 246th and 365th day.

The trend of ammonium-nitrogen is very similar to that of nitrate-nitrogen in the two soils according to data plotted in Figure 11, though the ammonium ion either added to the two soils or formed from the ammonification of organic materials appeared in the soil only for a few days at the beginning of the experiment. No ammonia was found from any of the materials after the twenty-ninth day in either soil.

In general the nitrogenous fertilizers had a greater influence on the *p*H values of the virgin Yuma sand than the silted sand,

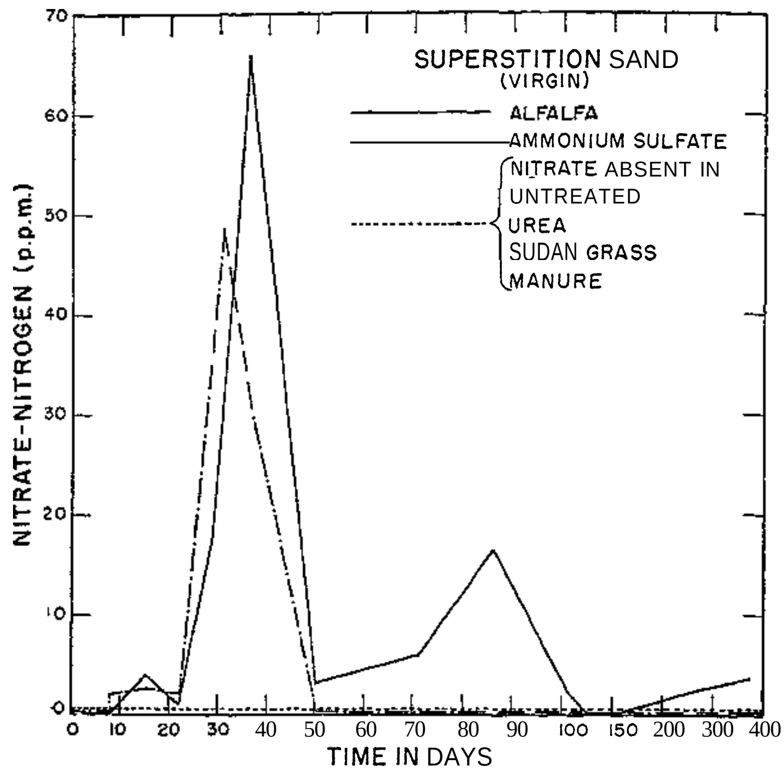

Figure 8.—Change with time of nitrate-nitrogen in virgin Superstition sand treated with various nitrogen fertilizers and manures.

indicating the latter is better buffered as a result of the presence of the colloidal residue from the Colorado River water (see Figure 12). Urea and manure had no effect on the pH values of the virgin sand. On the other hand, urea lowered the pH of the silted sand almost as much as ammonium sulfate. These data are further evidence indicating urea is quickly washed from the virgin sand. Ammonium sulfate and alfalfa have lowering effect, about 0.7 to 0.9 pH units, in both soils. The influence of alfalfa on the pH values are longer lasting than the fertilizers.

Again the pH of the soils of the field experiments were above the threshold pH value and nitrates were formed. Except for two or three occasions in the alfalfa- and Sudan grass-treated raw sand the pH was above 7.8. Above threshold pH values are reported for the silted soil throughout the year in the untreated, manure, and Sudan grass plots and near the pH value of 7.7 ± 0.1 in the urea, ammonium sulfate, and alfalfa treated plots. The absence of nitrite-nitrogen accumulation would appear to indicate that the pH was not unfavorable for nitratification in soils having a pH value above 7.7 ± 01.

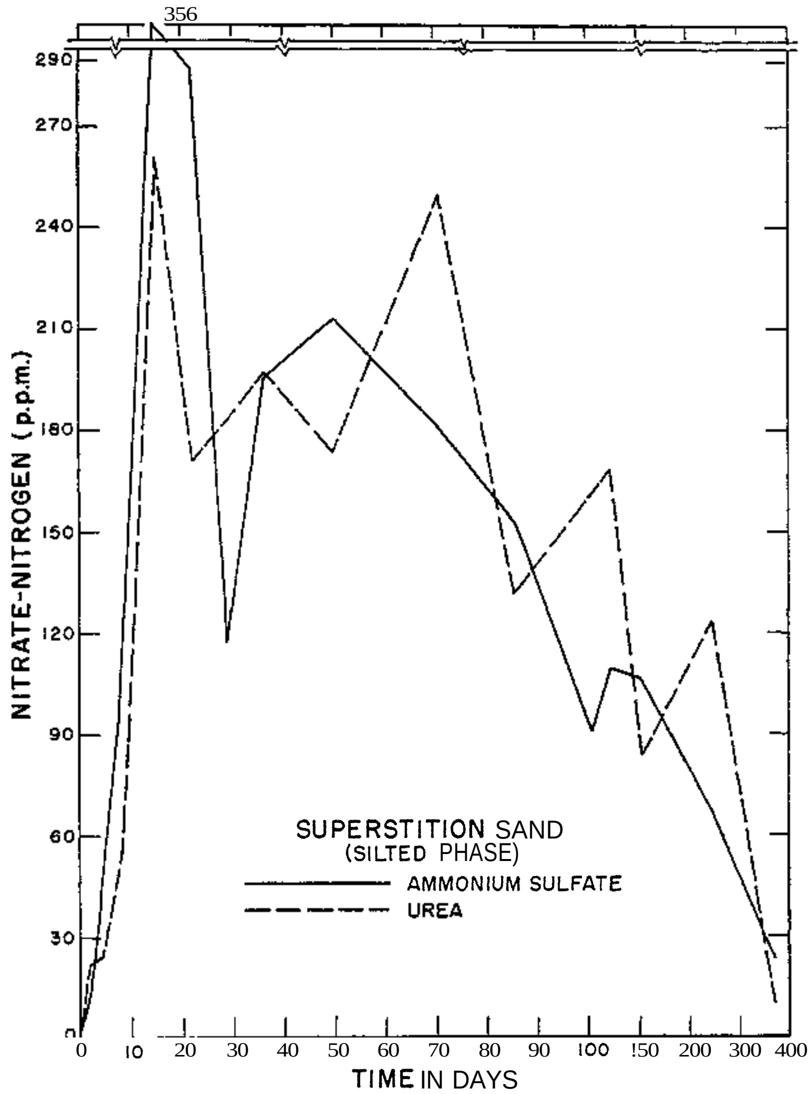

Figure 9.—Change with time of nitrate-nitrogen in silted Superstition sand treated with urea and ammonium sulfate.

PERSISTENCE OF ORGANIC CARBON

The similarity in the rate of decomposition of the organic residues and organic matter in the two Yuma soils is very striking (see Figure 13) despite the fact that the soils differ considerably in percentage of total organic carbon. The virgin sand is almost wholly devoid of organic matter, whereas the silted and cultivated soil has 1.0 to 1.1 per cent carbon: a value rather high for

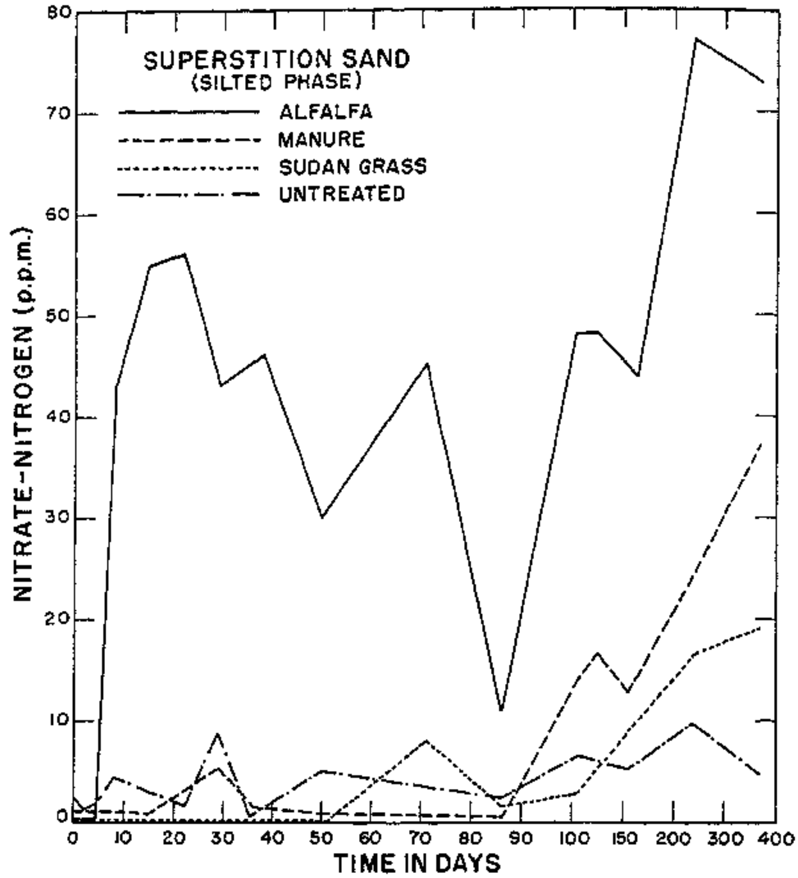

Figure 10.—Change with time of nitrate-nitrogen in silted Superstition sand treated with alfalfa, Sudan grass and manure.

arid soils. Though there were notable differences in amount of carbon added as a result of mixing alfalfa, Sudan grass, and manure with the soils on an equal weight basis, after about ten days these differences were largely eliminated and the soils maintained a rather constant level of carbon higher than that of the untreated soil throughout the remainder of the year. Manure, being higher in lignin than either alfalfa or Sudan grass, would be expected to decompose less rapidly and accumulate organic matter in the soil to a greater extent than alfalfa or Sudan grass. Allison and his co-workers (7) have shown, however, that the effect of lignin on organic matter accumulation in soil is not as dominant as once was suspected.

It is important to note further that the organic matter content of both soils was substantially increased, 0.14 and 0.18 per cent for

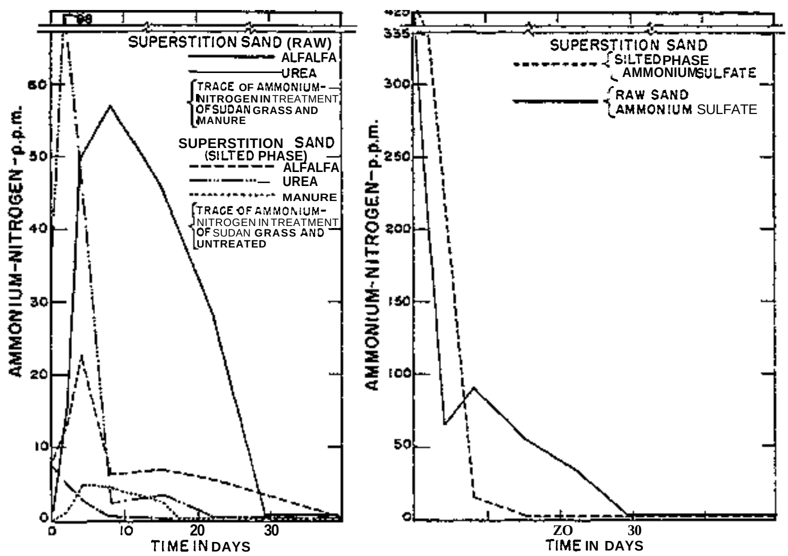

Figure 11.—Change with time in ammonium-nitrogen in silted and virgin Superstition sand treated with nitrogenous materials.

the raw and silted sand, respectively, at the end of the year as a result of the addition of the organic materials. The implication of these data is that even under the favorable conditions of year-round temperatures, moisture, and aeration, organic matter can be built up. The low content of organic matter in the original soil is an important factor in permitting this build up.

SOIL TEMPERATURES

The mean soil temperatures taken at a depth of 6 inches in Superstition sand planted to Sudan grass and clean cultivated are shown in Figure 14 beginning January 1, 1943, and continued until May 5, 1944. The data clearly show that the soil temperature under vegetation is lower than that fully exposed to the sun. Furthermore it is evident that at no time of the year was the temperature so low that nitrification could not proceed. During the last part of December and until the middle of February, however, nitrification may be somewhat retarded by the night temperatures. These data were obtained to show that the year-round temperature of the soil in the Yuma district favors continuous microbial activity without the usual winter refrigeration so characteristic of the northern agricultural areas.

FIELD EXPERIMENTS ON LAVEEN CLAY LOAM

A third experiment was set up at the Mesa Experimental Farm on Laveen clay loam to determine the rate of nitrification of various nitrogenous fertilizers in the Salt River Valley area during the cool fall and winter months. Phosphate fertilizers were

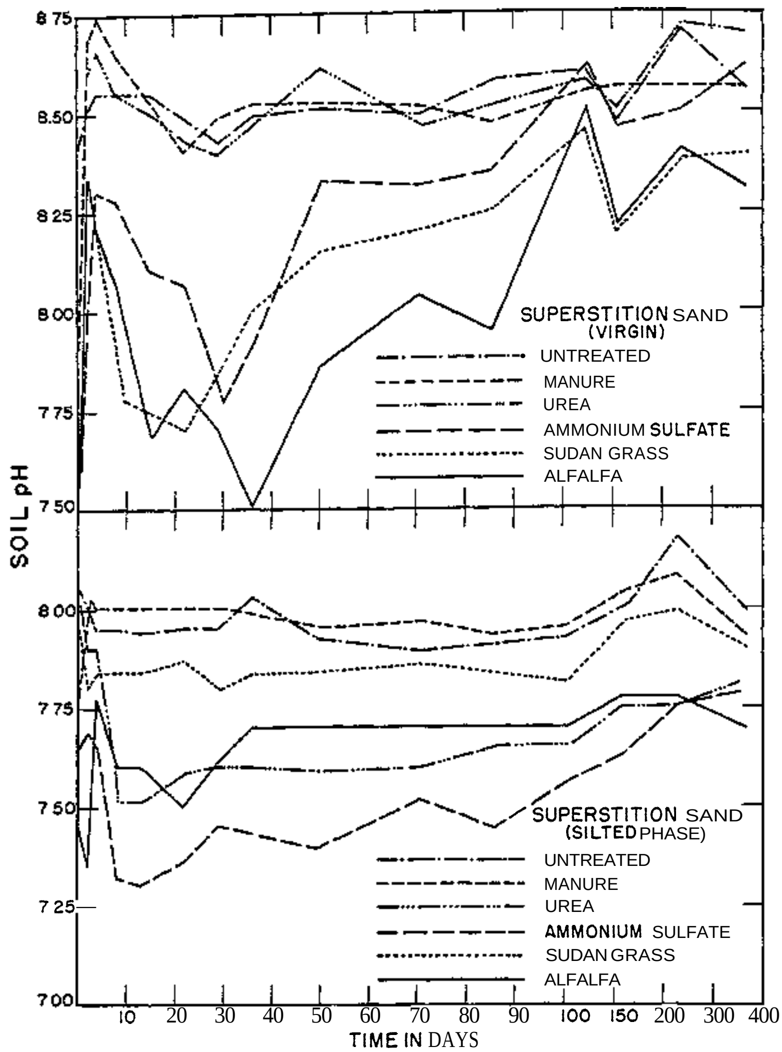

Figure 12.—Change with time in *p*H value in silted and virgin Superstition sand treated with nitrogenous materials.

also added and the changes in the amount of CO_2-soluble phosphorus followed over a period of 150 days. Since organic residues as manure are reported to have some influence on the availability of both nitrogen and phosphorus fertilizers in calcareous soils, a heavily manure-treated soil was given the same fertilizer treatment as the unmanured soil. Nitrification data from these plots may be compared directly with those data from the Date, and Yuma Mesa Experimental farms.

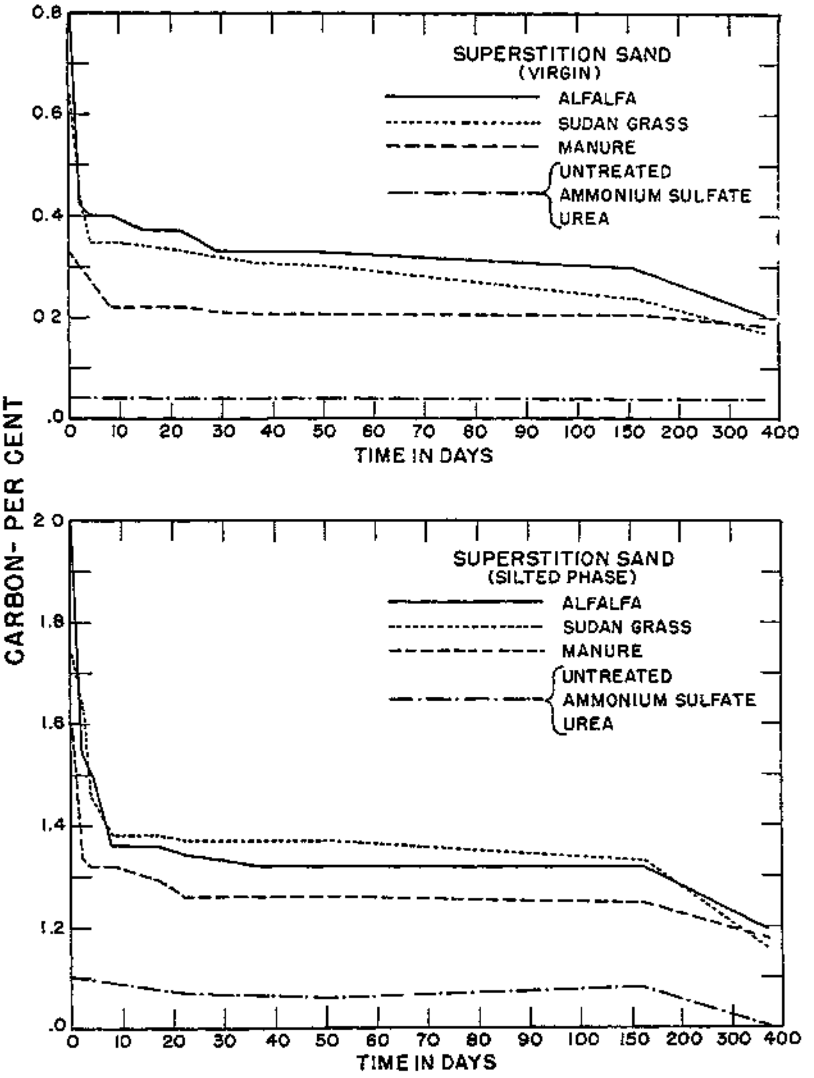

Figure 13.—Carbon content over a period of a year of silted and virgin Superstition sand treated with various organic manures.

EXPERIMENTAL PROCEDURE

Two areas for plot experiments were selected, one having had no manure and another having had manure applied in August, 1940 at the rate of 10 tons per acre: one lettuce crop was grown on these soils following the manure addition and prior to the experiment. Treatment of nitrogen fertilizers were made at the rate of

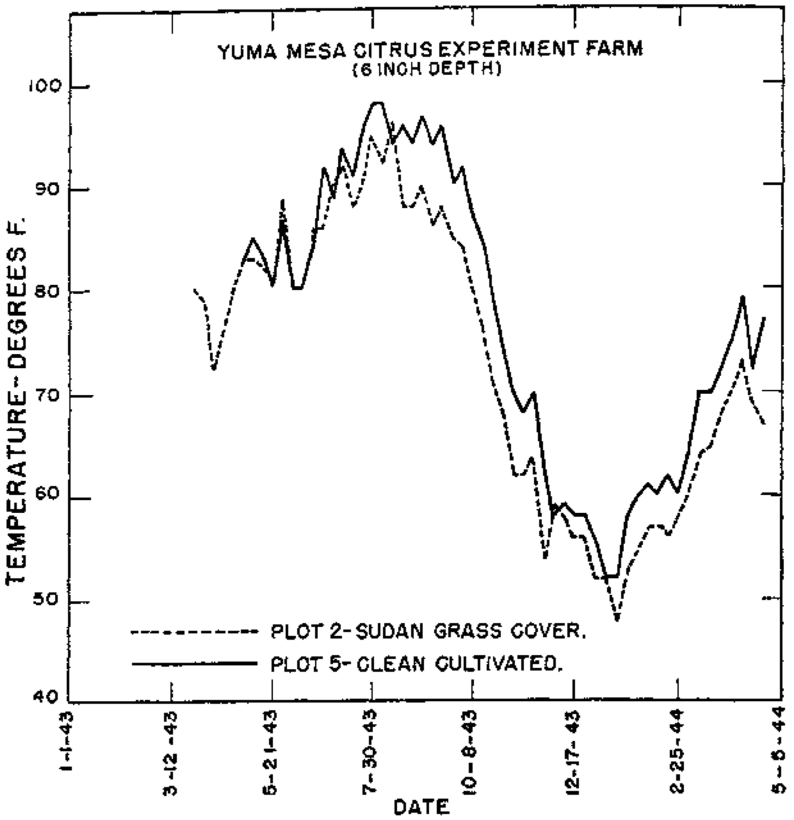

Figure 14.—Soil temperature (6-inch depth) of Superstition sand planted to Sudan grass and clean cultivated from 1-1-43 to 5-5-44.

150 ppm of nitrogen and/or 500 ppm of phosphorus in each fertilizer or combination of fertilizers added to the soil as follows:

Plot	Treatment
A	Calcium nitrate
B	Treble superphosphate
C	Ammonium phosphate (11-48)
D	Ammonium sulfate plus calcium phosphate (8-26)
E	Experimental bloodmeal mixture (7-28)
F	Experimental goat manure mixture (4-18)
G	Commercial goat manure mixture (7-30)
H	Untreated
X	Ammonium sulfate

Samples were taken from the plot beginning at the time of the treatment, September 9, 1941, and continued at regular intervals until 150 days later, February 16, 1942. Analyses for nitrate-, nitrite-, and ammonium-nitrogen, CO_2-soluble phosphorus, and pH value were made for each sample. Soil and air temperature and precipitation data were obtained for the three months, October, November, and December.

TABLE 2.—CHANGES WITH TIME IN NITRATE-NITROGEN CONTENTS OF VARIOUSLY TREATED SAMPLES OF LAVEEN CLAY LOAM FROM THE MESA EXPERIMENTAL FARM

Soil Treatment*	Date of sample collection (1941-42) and length of incubation time (days)											
	9/20	9/23	9/26	9/29	10/13	10/20	11/3	11 17	12/8	12/29	1 19	2 16
	0	3	6	9	23	30	44	58	79	100	121	149
	Manure Treatedt											
A	196	29	15	3	12	64	8	7	6	3	6	1
B	36	14	9	4	4	7	9	7	5	5	3	6
C	23	54	77	39			27	9	6	6	4	5
D	32	47	17	21	9	10	23	11	5	5	2	
E	62	35	51	32	7	7	32	8	9	5	3	1
F	50	44	7	9	15	3	12	9	6	4	3	0
G	69	34	19	15	8	9	20	10	6	5	1	4
H	33	11	0	5	6	11	11	7	5	4	2	4
X	25	30	64	42	15	70	34	11	8	3	4	3
	Untreated											
A	181	14	5	6	51	78	8	6	5	5	3	2
B	20		1	5	41	7	7	5	4	4	6	2
C	22	30	24	51	57	68	12	6	4	4	1	2
D	22	26	37	19	5	8	10	4	4	4	3	3
E	47	16	36	35	5	26	19	6	5	5	4	3
F	42	34	32	20	17	13	7	4	5	5	3	4
G	32	34	15	9	36	16	8	6	5	4	2	1
H	18	18	0	3	15	5	5	5	5	4	3	3
X	17	43	30	21	6	13	16	5	4	5	2	3

*A=Calcium nitrate; B=Treble superphosphate; C=Ammonium phosphate (11-48); D=Ammonium sulfate and calcium metaphosphate (8-26); E=Experimental blood meal mixture (7-28); F=Experimental goat manure mixture (4-18); G=Commercial goat manure mixture (7-20); H=Untreated; X=Ammonium sulfate. (150 ppm of nitrogen and/or 500 ppm of phosphorus in each fertilizer or combination of fertilizers added to soil.)

†Manure treatment made in August 1940 at rate of 10 tons/acre; one lettuce crop grown on soil following manure addition and prior to this experiment.

NITRIFICATION OF INORGANIC AND ORGANIC NITROGEN CARRIERS

The accumulation of nitrates with changes in time of variously treated plots of Laveen clay loam may be seen in Table 2. Calcium nitrate treatment shows that large amounts of nitrates were very quickly utilized by the soil microflora. Immobilization of the added nitrate was complete in six to nine days after being applied. Nitrogen, probably from microbial tissues, was again released as nitrate in amounts equivalent to % to % of that applied in about thirty days. Thereafter, as was also characteristic of the other treatments, added nitrogen did not appear in appreciable amounts as nitrates. Either it was leached from the sampling area or tied up in microbial tissues and residues, or both. This period of low nitrates corresponds to the cold months of December, January, and February. Microbial activity is expected to be at a minimum during these months.

Accumulation of nitrates was about the same in both the ammonium sulfate-treated soils. The presence of calcium metaphosphate had no effect on nitrate production. Slightly greater

TABLE 3.—CHANGES WITH TIME IN pH VALUES OF VARIOUSLY TREATED SAMPLES OF LAVEEN CLAY LOAM FROM THE MESA EXPERIMENTAL FARM

Soil Treat-ment*	Date of sample collection (1941-42) and length of incubation time (days)											
	9/20	9/23	9/26	9/29	10/13	10/20	11/3	11/17	12/8	12/29	1/19	2/16
	0	3	6	9	23	30	44	58	79	100	121	1.49
					Manure Treated†							
A	7.70	7.95	7.95	8.00	8.05	....	7.80	7.95	8.02	....	7.90	....
B	7.80	7.80	7.80	7.80	7.78		7.70	7.80	7.80	....	7.65	
C	7.50	7.55	7.45	7.50		. .	7.55	7.60	7.60	....	7.45	
	7.80	7.80	7.80	7.80	7.90		7.75	7.70	7.82	....	7.78	
E		7.72	7.68	7.55	7.70	....	7.60	7.60	7.75	....	7.75	
F	7.80	7.70	7.75	7.68	7.68	....	7.65	7.70	7.75	....	7.68	....
G	7.80	7.68	7.65	7.68	7.70	....	7.70	7.80	7.80	....	7.78	
H		8.00	....	8.00	8.10	....	8.10	8.00	8.02	....	8.00	
X	7.60	7.88	7.65	7.72	7.90	....	7.85	7.80	7.85	....	7.95	
					Unmanured							
A	7.85	8.03	7.97	8.00	8.00		8.05	8.00	8.00	....	8.12	
B	7.90	....	7.90	7.80	7.80	....	7.70	7.80	7.80	....	7.82	
C	7.60	7.70	7.60	7.60	7.50	....	7.60	7.70	7.70	....	7.85	....
D	7.95	7.85	....	7.90	7.80	....	7.65	7.80	7.92	....	7.98	
E	7.85	7.88	7.50	7.75	7.75	....	7.70	7.80	7.78	....	7.85	
F	7.80	7.80	....	7.65	7.85	....	7.70	7.63	7.65			
G	7.95	7.88	7.82	7.98	7.80	....	7.75	7.80	7.75	....	7.90	
H	8.10	8.05	8.05	8.12	8.15	....	8.05	7.90	7.90	....	8.00	
X	7.60	7.90	7.85	7.90	7.70	....	7.95	8.00	7.92	....	8.07	

*A=Calcium nitrate; B=Treble superphosphate; C=Ammonium phosphate (11-48); D= Ammonium sulfate and calcium metaphosphate (8-26); E=Experimental blood meal mixture (7-28); F=Experimental goat manure mixture (4-18); G=Commercial goat manure mixture (7-30); H=Untreated; X= Ammonium sulfate. (150 ppm of nitrogen and/or 500 ppm of phosphorus in each fertilizer or combination of fertilizers added to soil.)

†Manure treatment made in August, 1940 at rate of 10 tons/acre; one lettuce crop grown on soil following manure addition and prior to this experiment.

accumulation of nitrates took place in the ammonium phosphate-treated soil. Fraps and Sturges (2) report that phosphorus assisted nitrate formation on Texas soils. A lower pH value, according to data in Table 2, of the ammonium phosphate soil may have been responsible for this condition, though all the ammonium-treated soils registered pH value near the threshold value of 7.7 ± 0.1 throughout the experiment. In fact, the pH values of all the soils except the untreated and that receiving calcium nitrate were near the threshold. The two exceptions were only slightly above 7.7 ± 0.1.

The organic nitrogen carriers, goat manures and blood meal, nitrified at about the same rate. The nitrification of the organic materials was almost identical to that of the ammonium sulfate treatments. Phosphate again appeared to be no factor in nitrate accumulation. Moreover, the treatment of treble superphosphate alone yielded nitrate data similar to that of untreated soil. (Table 3).

Nitrite-nitrogen accumulation, according to data in Table 4, was negligible in the variously nitrogen-treated soils since no

TABLE 4.—CHANGES WITH TIME IN NITRITE-NITROGEN COX-TENTS OF VARIOUSLY TREATED SAMPLES OF LAVEEN CLAY LOAM FROM THE MESA EXPERIMENTAL FARM.

Soil Treat-ment*	Date of sample collection (1941-42) and length of incubation time (days)											
	9/20	9/23	9/26	9/29	10/13	10/20	11/3	11/17	12/8	12 29	1/19	2/16
	0	3	6	9	23	30	44	58	79	100	121	149
	Manure Treated†											
A	0.3	0.8	0.6	0.2	0.5	1.2	0.8	0.6	0.3			
B	0.3	0.8	0.8	0.4	0.6	0.5	0.8	0.6	0.3			
C	0.5	0.9		0.9	. ..	0.3	0.6	0.9	0.7	Amount of nitrite-nitrogen approximately same as in preceding samples.		
D	0.3	1.8	6.9	1.0	0.7	0.7	2.4	0.9	0 5			
E	0.4	1.6	1.2	1.2	1.0	0.3	2.6	1.0	0.6			
F	0.3	0.8	0.4	1.0	0.9	0.6	1.0	0.9	0.4			
G	0.4	1.1	0.4	0.9	0.4	0.4	0.5	0.8	0 4			
H	0.4	0.9	0.4	0.6	0.4	0.7	0.7	0.4	0.3			
X	0.4	2.0	.	1.0	0.7	0.3	4.1	1.0	0.8			
	Unmanured											
A	0.2	0.6	0.6	0.4	1.0	0.4	0.5	0.5	0.1			
B	0.3	....	0.3	0.4	0.8	0.7	0.5	0.4	0.2			
C	0.3	0.5	1.6	0.6	1.3	0.4	3.1	0.7	0.7			
D	0.2	1.4	1.9	0.6	0.3	0.4	1.2	0.5	0.4			
E	0.2	0.5	0.6	1.0	0.3	0.7		0.6	0.5			
F	0.2	0.4	0.7	0.5	1.3	0.2	0.2	0.5	0.4			
G	0.3	1.0	0.3	0.4	0.6	0.4	0.2	0.4	0.3			
H	0.4	0.7	0.3	0.3	0.5	0.3	0.4	0.5	0.2			
X	0.2	0.7		0.4	1.5	0.5	0.9	0.6	0.5			

*A=Calcium nitrate; B=Treble superphosphate; C= Ammonium phosphate (11-48); D=Ammonium sulfate and calcium metaphosphate (8-26); E=Experimental blood meal mixture (7-28); F=Experimental goat manure mixture (4-18); G=Commercial goat manure mixture (7-30); H=Untreated; X=Ammonium sulfate. (150 ppm of nitrogen and/or 500 ppm of phosphorus in each fertilizer or combination of fertilizers added to soil.)

†Manure treatment made in August, 1940 at rate of 10 tons/acre; one lettuce crop grown on soil following manure addition and prior to this experiment.

increase in nitrate-nitrogen over that of the untreated soil was recorded.

CHANGES WITH TIME IN CO_2-SOLUBLE PHOSPHATE CONTENT

In order to study the availability of fertilizer phosphorus added to soil in the Salt Elver Valley during the fall and winter months, various organic and inorganic sources of phosphate were added to Laveen clay loam on the University Farm at Mesa, mixed into the upper 6-inch layer, and allowed to stand for 150 days. The availability of the phosphorus was followed at various intervals throughout the 150-day period by determining the quantity extracted by the CO_2-method of McGeorge (6). The data for both the manured and unmanured soil are plotted in Figure 15. For the most part, the manure application made a year before the experiment was begun, did not influence the availability of the fertilizer phosphorus, since differences between the control soil and phosphorus-treated soils were very similar. Calcium metaphosphate appeared slightly more available in the manured than the unmanured soil. The relative great difference in content of

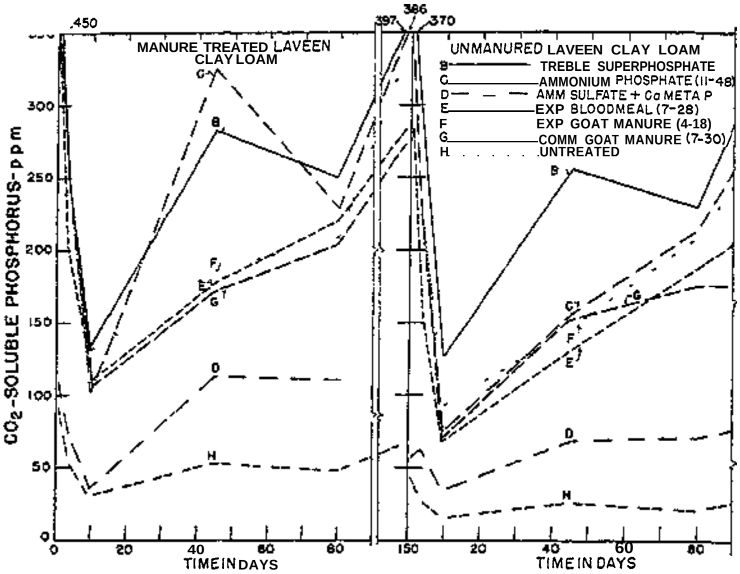

Figure 15.—Change with time of CO_2-soluble phosphorus in manured and unmanured Laveen clay loam treated with various nitrogenous and phosphate fertilizers.

CO_2-soluble phosphorus between the two soils, treated with ammonium phosphate, on the forty-fourth day is probably in error, since all other points orient themselves in the same relative positions to each other in the two graphs.

A particularly interesting feature of the phosphorus data is the characteristically rapid decrease in amount of CO_2-soluble phosphorus to about one-third of its original value in three to nine days after commencement of the experiment. In this respect it is remarkably similar to the decrease shown by nitrate-nitrogen. Within the next thirty days and until the end of the 150-day period, there was a rapid, steady increase in CO_2-soluble phosphorus.

The inorganic phosphates, treble superphosphate and ammonium phosphate appeared to be most soluble or available, whereas calcium metaphosphate was least soluble. There was little difference in amount of CO_2-soluble phosphorus found between the different organic phosphorus treatments of blood meal, experimental, and commercial goat manure in the two soils. Their position with respect to the above-mentioned phosphate is intermediate. The presence of carbon compounds as an energy source for the soil microflora along with nitrogen undoubtedly influenced the rate of release of phosphorus in the inorganic form from the organic fertilizers added to Laveen clay loam since all phosphate treatments received equivalent amounts of phosphorus, i.e. 500 ppm of soil.

Nitrogen alone also may have some influence on the availability of the phosphorus added to soils as fertilizers (2). Some evidence

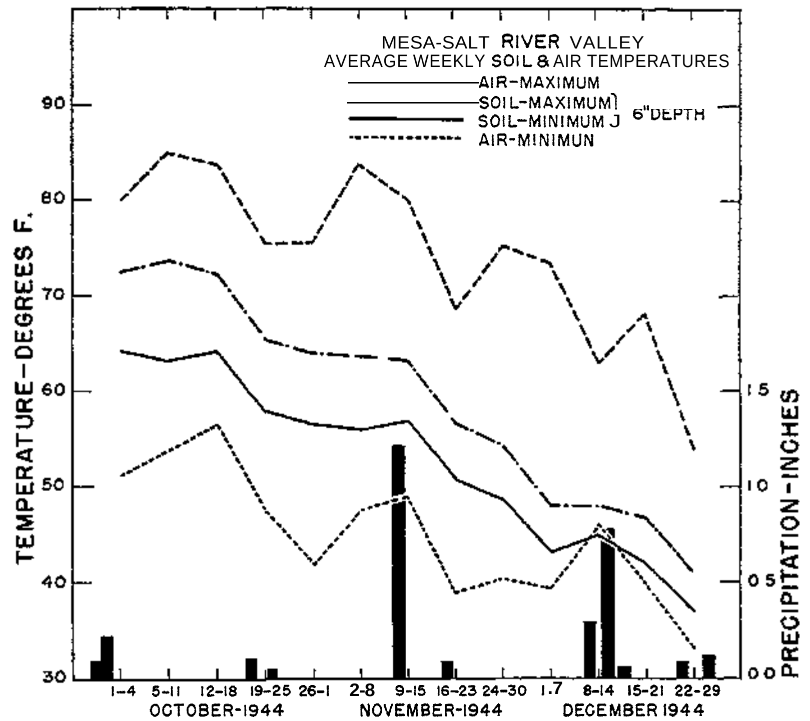

Figure 16.—Average weekly soil and air temperatures of Laveen clay loam from 10-1-40 to **12-29-40.**

of this is revealed by the small but real differences between the CO_2-soluble phosphorus of the superphosphate-treated soil and ammonium phosphate-soil. The latter was lower in CO_2-soluble phosphorus. If nitrogen were limiting in the soil and organic carbon high, nitrogen would act to increase microbial activity. Greater microbial activity as shown previously (4) is often associated with a greater demand for available phosphorus. Such a demand may result in an appreciable decrease in CO_2-soluble phosphorus.

SOIL AND AIR TEMPERATURE AND PRECIPITATION DATA

A summary of the soil and air temperature beginning October 1 and ending December 29, 1944, is shown in Figure 16. Precipitation data are also included. Soil temperatures were taken at a depth of 6 inches. Except for December, the daily average soil temperatures were about the same as the daily average air temperatures. During December the weekly average soil temperatures were lower than those of the air. Less fluctuations were observed in the soil than the air temperatures. The soil temperatures during the last part of December are low enough to retard nitrification. Compared with the soil temperatures of the Yuma Mesa orchard of

Figure 14, the Salt River Valley temperatures are much lower during the fail months. Readily available nitrogen sources are needed much more in the Salt River Valley than the Yuma Mesa for reasons of temperature alone and its influence in retardation of the nitrifying activity of the soil flora.

SUMMARY AND CONCLUSIONS

Nitrification studies were carried out under normal field conditions at two locations in the Salt River Valley and on the Yuma Mesa. Inorganic and organic fertilizers and manures were applied. Despite pH levels above the established laboratory threshold value of 7.7 ± 0.1, nitrates formed from both inorganic and organic fertilizers added at rates of 150 to 250 ppm of soil. A notable increase in the total organic carbon content of Superstition sand on the Yuma Mesa followed the applications of green manures, even after a year of decomposition. Leaching of soluble nitrogen salts is very prominent in the Yuma Mesa soil. Silt and clay brought in by muddy irrigation waters reduced such losses appreciably.

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