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TECHNICAL BULLETIN No. 11

OCTOBER, 1916

NOTES ON
THE PRESENCE OF NITRATES
IN ORCHARD SOILS

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NOTES ON
THE PRESENCE OF NITRATES
IN ORCHARD SOILS

BY

J. H. GOURLEY AND V. D. SHUNK

NEW HAMPSHIRE COLLEGE
OF
AGRICULTURE AND THE MECHANIC ARTS
DURHAM, N. H.

NOTES ON THE PRESENCE OF NITRATES IN ORCHARD SOILS.

BY J. H. GOURLEY AND V. D. SHUNK.

Much has been written on the various cultural systems used in apple orchards and considerable data have been presented to show the effect of each of the systems on the growth and yield of the trees. Some general recommendations are now considered standard and are in common use, *e. g.*, most authorities agree that to grow trees in sod is usually not a good practice but that the grass mulch system is a perfectly practical method of culture especially when accompanied by the use of fertilizers. There is also general agreement that tillage in the orchard is quite beneficial and will stimulate growth and increase production, and when the use of cover crops accompanies it the value is enhanced. Some information is also at hand to show the effects of these systems on the soil but all mooted questions in this regard do not appear to be satisfactorily answered.

It is the purpose of this paper to present some additional data showing the effect of sod and tillage on the presence of nitrates in the soil, and to partially correlate these with the behavior of the trees as regards yield and growth. Primarily the writers are interested in determining some of the reasons why trees behave differently under different cultural treatments and why fruit buds are formed with abundance when grown under a good system of culture and greatly reduced when grown in sod land without fertilizers or tillage. The observations here reported are made as a corollary of such a study.

In Technical Bulletin No. 9, N. H. Experiment Station, the senior author makes the statement that the formation of nitrates is greatly reduced in a sod orchard. But the evidence presented at that time showed only that less nitrates were recovered in our soil samples during the growing season under sod than where tillage was practiced, and therefore would not show conclusively that nitrification was not active under sod, but rather raise the question whether the grass and trees together did not use up

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such an excessive amount of nitrates that little accumulated as an excess or as a residual in the soil.

At the outset it is well to state that the assumption is not herein made that the presence or absence of large amounts of nitrates is the sole cause of vigorous growth or the reverse, for without question other factors are of great importance. Aëration in itself has doubtless a beneficial effect other than increasing nitrification, for the oxidation processes may make available other forms of plant food materials and also encourage a beneficial soil flora. Just how much these various cultural treatments furnish additional nutritive material and how much they may be of a "sanitary" value cannot be fully stated.

THE ORCHARD.

The work here reported has been conducted in a mature Baldwin apple orchard of nine acres which was acquired for the purpose of experimentation in 1908. Prior to that time the orchard was in grass and the hay cut and removed each year until it was in a weakened and unproductive state. Ten plots were laid out with a division row between each so that the influence of one plot would not extend over to an adjoining one. The orchard is quite level and the soil fairly uniform but the plots are somewhat lighter on one end than on the other.

CHARACTER OF THE SOIL.

Of the ten plots in the orchard we are interested at this time in three only, Nos. 1, 4 and 5, none of which have been fertilized. The soil of these plots is practically identical and is therefore well suited to a study of the comparative amounts of nitrates and moisture present under the different systems of culture. Later in the paper, however, mention is made of Plots 11 and 12 in connection with liming. The soil of those plots is somewhat heavier and they have also been fertilized as described below.

A composite sample was taken from the first series of plots mentioned and a mechanical analysis made. The following table gives this analysis:

TABLE NO. 1.
Mechanical Analysis of Soil.

	Surface soil 0-7 in.	Subsoil 7 in.-3 ft.
Fine gravel, 2 to 1 mm.	3.9	6.7
Coarse sand, 1 to 0.5 mm.	11.4	19.0
Medium sand, 0.5 to 0.25 mm.	13.1	21.1
Fine sand, 0.25 to 0.1 mm.	16.4	27.6
Very fine sand, 0.1 to 0.05 mm.	11.9	6.9
Silt, 0.05 to 0.005 mm.	33.4	14.6
Clay, 0.005 to 0 mm.	9.5	4.9

Lyon, Fippin and Buckman* give the average analysis of six fruit soils, and it is here cited for comparison with the soil in question:

Fine gravel	1.0
Coarse sand	6.8
Fine sand	42.0
Silt	23.3
Fine silt	7.3
Clay	10.9

From these analyses it will be seen that the soil under question is of a distinctly light nature, especially is the subsoil very sandy and therefore such a soil as we would expect to suffer a rapid loss of nitrates after a heavy rain, which has proven to be the case throughout.

TREATMENT OF PLOTS.

Plot 1. Sod. This plot has remained permanently in sod and the grass is cut once during the summer and allowed to remain where it falls. No fertilizer has been applied, and no grass mulch is included in this experiment.

Plot 4. Clean cultivation. This plot is plowed every spring and cultivated every two weeks until September 1. No cover crop is sown and no fertilizer applied.

Plot 5. Cultivation and cover crop. This plot is plowed in the spring and tilled every two weeks until July 10 when a cover crop of crimson clover is sown, no fertilizer is applied.

*Soils, 1915.

Plot 11. The limed plot extends across one end of four fertilized plots and each tree has received an application of 20 pounds of lime* per tree for nine years.† The fertilizers on the four plots respectively are 2 pounds nitrate of soda, 4 pounds sulphate of potash, $8\frac{1}{2}$ pounds acid phosphate, per tree; 2 pounds nitrate of soda, 4 pounds sulphate of potash, 17 pounds acid phosphate, per tree; 6 pounds nitrate of soda, 4 pounds sulphate of potash, $8\frac{1}{2}$ pounds acid phosphate, per tree; and 2 pounds nitrate of soda, 10 pounds sulphate of potash, $8\frac{1}{2}$ pounds acid phosphate, per tree.

Plot 12. For a check on the lime treatment a similar plot of trees was selected which stands parallel to the limed plot.

YIELD AND GROWTH OF TREES.

These plots have behaved differently as regards yield and growth since they have been under the influence of the various treatments. Therefore it should be possible to trace some of the reasons for the marked and consistent variation in behavior to the effect of the treatments on the soil activities.

The following measurements were made at the end of the growingseason by taking the length of new growth of twenty twigs which so far as can be determined are typical of the growth of the tree. Each tree in a plot is thus measured and the average growth for the plot then calculated.

TABLE No. 2.
Average Annual Twig Growth Per Tree.
Inches.

Year.	Plot 1 Sod.	Plot 4 Tillage.	Plot 5 Tillage and cover crop.
1909	4.59	6.29	8.31
1910	4.15	8.79	10.19
1911	3.21	8.43	8.19
1912	4.79	8.43	8.92
1913	5.76	9.03	9.03
1914	4.70	4.90	6.90
1915	6.40	7.18	10.30
Average	4.80	7.58	8.83

*65% CaCO_3 .

†See Bulletin 168, N. H. Experiment Station.

It will here be seen that Plot 1 (the sod plot) has made an average growth of less than 5 inches a year for a period of eight years, Plot 4, $7\frac{1}{2}$ inches and Plot 5 nearly 9 inches (8.83 in.) or nearly twice the growth of the plot in sod. It will of course be understood that the trees under cultivation produce many twigs of a greater growth as well as water sprouts and excessive growth in the tops of the trees, but such growth is eliminated from the data and only the normal growth at the ends of the permanent branches is included. Plots 4 and 5 have been of special interest as the soil on these plots is quite uniform and the outstanding difference in treatment is that Plot 5 has a cover crop plowed in annually while Plot 4 has had clean cultivation throughout. In some years there was little difference in the growth on these plots but the past two years the superior treatment of Plot 5 has been showing. At this time we wish to call attention to the greater amount of nitrates found each year in Plot 5 than in Plot 4 as shown in a later table which may explain at least to some extent the difference in growth. The moisture content is slightly superior in Plot 5 but scarcely sufficient to account for the difference in growth.

TABLE NO. 3.

Average Annual Yield Per Tree.
Number of Apples.

Year.	Plot 1 Sod.	Plot 4 Tillage.	Plot 5 Tillage with cover crop.
1908	467	105	77
1909	95	106	80
1910	481	1859	2381
1911	795	549	99
1912	376	2105	2162
1913	734	371	99
1914	270	2859	2737
1915	No crop due to a freeze		
Average	459	1136	1091

As regards yield it will be noticed that Plot 1 remains the lowest as was true with growth, while Plot 4 shows a little higher yield

than Plot 5, indicating that both plots have been receiving sufficient supplies of available food materials for fruit production.

MOISTURE AND NITRATE DETERMINATIONS.

Soil samples were taken weekly during most of the growing season for four years. The surface soil is taken from 7 to 9 inches (or a little more) depending on its depth and the subsoil is taken from that point to 3 feet. Three samples are taken from each plot and after thoroughly mixing, a pint sample is taken for analysis. Moisture is determined by oven drying a 50 gram sample at close to 100° C. Nitrates are determined according to the method described in Bulletin No. 31, U. S. Dept. of Agriculture, Bureau of Soils. The following tables show the average percentage of moisture and nitrates (parts per million of dry soil) found each week during the growing season for four years under the various treatments heretofore mentioned.

TABLE NO. 4.

Summary of Moisture Determinations.

Average per Plot. Percentage.

Surface soil.			
Year.	Plot 1 Sod.	Plot 4 Tillage.	Plot 5 Tillage with cover crops.
1913	16.02	13.69	14.20
1914	18.87	13.39	15.03
1915	25.63	19.29	20.82
1916	20.48	16.45	21.31
Average	20.25	15.70	17.84
Subsoil.			
1913	10.98	9.06	8.93
1914	14.14	9.78	10.26
1915	14.26	14.03	13.33
1916	14.82	12.74	13.24
Average	13.55	11.40	11.44

TABLE NO. 5.

Summary of Nitrate Determinations, Water Soluble Parts per Million of Dry Soil.

Average per Plot.

Surface soil.			
Year.	Plot 1 Sod.	Plot 4 Tillage.	Plot 5 Tillage with cover crop.
1913	2.64	18.25	38.37
1914	4.41	14.01	37.27
1915	2.09	21.05	18.75
1916	3.58	16.29	41.26
Average	3.18	17.40	33.91

Subsoil.			
1913	1.55	6.90	6.87
1914	3.56	6.62	10.81
1915	1.51	10.76	6.88
1916	2.18	5.05	8.05
Average	2.20	7.33	8.15

From the above data it will be seen that the amount of nitrates recovered in the soil samples under sod is considerably reduced as compared with Plots 4 and 5. The ratio of nitrates between sod, tillage and tillage with cover crops is as 1:5.4:10.6 in the surface soil and in the subsoil as 1:3.3:3.7. At no time during the experiments have we obtained a sample under sod that showed more than 14.78 parts nitrates per million and the average for the four years is 3.18 p.p.m., while for clean tillage it has gone as high as 63 p.p.m. with an average of 17.40 p.p.m., and for tillage plus a leguminous cover crop it has shown as high as 132 p.p.m. and the average is 33.91 p.p.m. for the four years.

CHART NO. 1
 NITRATE DETERMINATIONS—1913 (Parts per million of dry soil)
Plots 1, 4 and 5.

CHART NO. 2
NITRATE DETERMINATIONS—1914 (Parts per million of dry soil)
Plots 1, 4 and 5.

CHART NO. 3
NITRATE DETERMINATIONS—1915 (Parts per million of dry soil)
Plots 1, 4 and 5.

CHART NO. 4
 NITRATE DETERMINATIONS—1916 (Parts per million of dry soil)
Plots 1, 4 and 5.

TABLE No. 6.
Nitrate Determinations—Woodman Orchard, 1913.
 Parts per Million of Dry Soil.

Date.	Surface Soil—Plots.					Subsoil—Plots.				
	1.	4.	5.	11.	12.	1.	4.	5.	11.	12.
June 4	14.78	9.378	6.313	21.94	57.14	1.048	17.93	1.723	4.627	2.602
11	1.233	17.06	10.34	36.10	24.58	1.181	3.906	1.643	4.534	4.267
18	1.932	12.18	12.69	31.01	7.515	.6290	1.308	1.350	3.428	3.264
25	3.725	13.48	28.10	43.42	3.510	1.128	4.949	12.37	1.183	4.027
July 2	1.666	11.16	44.36	104.4	49.48	.8704	2.304	2.549	3.738	11.69
9	trace	8.730	23.22	158.8	75.04	1.289	4.292	4.842	12.15	6.421
16	1.089	14.66	33.70	126.0	138.6	1.866	6.807	6.116	27.14	3.876
23	1.690	3.222	29.11	171.3	38.29	trace	4.925	2.815	10.29	6.433
30	1.676	24.31	37.20	130.8	144.3	1.867	6.448	10.06	26.67	3.355
Aug. 6	2.236	37.10	49.64	137.3	118.1	1.367	3.874	3.994	12.75	6.966
13	1.720	30.14	33.17	128.7	121.1	2.240	9.298	13.38	14.06	14.34
20	1.361	46.13	80.98	33.80	13.26	1.928	8.181	7.042	131.2	5.650
27	1.923	17.06	132.3	136.2	29.32	3.947	13.72	20.63	25.82	8.66
Sept. 3	2.312	19.82	18.89	6.830	33.45	1.91	14.21	4.68	9.27	7.88
10	2.719	12.03	30.34	32.14	8.198	.967	.5652	4.30	7.73	2.984
20	2.336	15.63	43.57	18.55		1.094	7.762	12.54	19.04	
Average	2.64	18.256	38.370	82.331	57.459	1.554	6.905	6.877	19.602	6.161

TABLE No. 7.
Per Cent Moisture—Woodman Orchard.
 Weekly Records.

Date.	Surface Soil—Plots.						Subsoil—Plots.					
	1.	4.	5.	11.	12.	1.	4.	5.	11.	12.		
June 4	25.915	16.550	13.387	22.180	20.730	12.678	10.906	7.970	14.132	10.800		
11	24.092	13.995	17.420	21.290	19.337	12.596	9.946	8.856	11.806	13.970		
18	19.932	15.392	15.392	21.40	19.337	11.594	9.044	9.248	10.302	13.376		
25	13.612	12.830	16.49	19.64	17.50	10.388	6.878	11.302	10.078	13.812		
July 2	14.945	14.61	14.66	17.36	18.72	11.522	6.790	9.316	10.190	9.160		
9	13.07	13.45	14.66	18.38	16.54	10.038	8.754	9.282	12.240	12.328		
16	9.78	12.39	12.26	17.71	17.23	11.024	8.756	9.762	11.862	14.238		
23	15.33	14.18	17.00	20.62	18.24	9.078	9.278	9.332	11.338	9.980		
30	12.59	12.17	13.73	19.37	15.81	10.06	10.084	9.486	12.638	13.028		
Aug. 6	15.65	13.52	15.14	18.32	16.83	7.206	7.742	7.970	9.178	8.684		
13	11.47	12.09	11.07	14.41	13.14	9.676	9.330	7.500	9.418	6.964		
20	7.77	12.21	10.66	10.46	10.66	8.384	8.516	7.634	15.410	8.154		
27	11.44	11.46	10.01	13.04	11.06	10.208	10.190	9.020	10.194	12.04		
Sept. 3	18.69	13.62	14.81	18.45	18.05	12.48	10.24	8.13	11.05	12.2		
10	21.0	13.4	15.1	19.2	16.8	16.6	9.8	10.2	10.7	9.60		
20	21.02	17.24	15.54	34.45	20.59	12.16	8.87	7.99	20.28	11.219		
Average	16.020	13.694	14.208	19.143	16.749	10.981	9.066	8.935	11.922			

TABLE No. 8.
Nitrate Determinations—Woodman Orchard, 1914.
 Parts per Million of Dry Soil.

Date.	Surface Soil—Plots.						Subsoil—Plots.					
	1.	4.	5.	11.	12.		1.	4.	5.	11.	12.	
May 15	3.348	4.536	7.709	182.1	102.3		1.362	2.285	2.160	2.360	13.53	
June 4	6.134	19.22	25.98	25.57	82.43		4.8545	1.182	1.136	2.328	3.557	
11	2.906	5.823	18.12	179.3	166.2		1.115	7.769	6.911	54.38	20.32	
18	13.61	17.28	81.04	118.1	167.6		1.694	8.638	4.225	29.80	55.39	
25	5.689	11.12	34.08	80.00	44.17		2.942	7.259	1.409	24.89	8.570	
July 2	6.887	21.56	23.50	41.60	26.24		7.870	8.806	9.397	52.22	32.13	
9	5.789	14.47	18.50	20.04	19.00		9.696	14.53	18.56	9.670	3.307	
16		4.327	37.38	52.66	17.16		3.655	3.149	7.449	14.04	9.469	
23	8.478	15.30	21.64	57.28	32.63		6.474	8.962	9.313	19.70	17.73	
30	.9167	9.033	57.92	90.65	71.37		3.444	4.296	16.47	22.44	11.90	
Aug. 6	3.634	19.48	38.62	50.78	68.42		3.422	9.080	7.82	43.63	11.41	
13	5.917	22.96	95.50	53.95	38.93		5.288	8.849	28.60	43.18	20.84	
20	4.779	24.24	62.63	19.55	19.55		5.19	12.29	23.13	13.84	18.57	
27	4.230	25.31	35.70	40.61	38.93		5.451	8.853	10.16	20.96	4.614	
Sept. 3	1.096	6.895	40.61	41.78	48.29		1.482	2.358	3.710	7.381	12.59	
10	.7762	19.55	18.83	69.40	13.04		1.991	4.332	6.223	26.20	6.623	
24	.1005	5.894	31.81	11.14	6.383		.1912	6.410	28.35	5.630	8.091	
Oct. 9	.740	5.297	21.31				.806		8.455			
Average	4.41	14.016	37.271	82.464	57.091		3.563	6.626	10.813	23.431	15.214	

TABLE No. 9.
Per Cent Moisture—Woodman Orchard, 1914.
 Weekly Records.

Date.	Surface Soil—Plots.					Subsoil—Plots.				
	1.	4.	5.	11.	12.	1.	4.	5.	11.	12.
May 15	18.49	12.96	16.25	17.38	19.75	11.55	10.01	9.27	12.49	13.72
June 4	24.86	16.11	17.06	15.92	20.96	14.96	13.07	10.22	8.87	14.51
11	22.89	12.06	16.07	14.03	15.40	20.87	9.03	15.27	6.75	10.33
18	15.77	11.21	13.48	13.14	14.06	13.70	5.61	9.87	7.71	8.20
25	15.98	12.73	12.30	13.97	14.06	17.10	7.89	9.55	13.98	12.09
July 2	18.24	13.97	16.03	15.65	16.98	19.51	11.91	8.58	11.79	12.99
9	24.51	16.76	19.68	20.43	22.49	16.66	11.86	9.59	9.33	12.33
16	23.18	14.98	17.02	18.28	14.47	10.83	8.57	11.87	7.95	10.19
23	22.96	15.68	19.99	16.58	17.67	12.12	10.87	8.99	9.14	10.14
30	19.06	11.52	17.12	16.32	14.61	11.63	8.90	9.14	5.97	7.29
Aug. 6	17.82	14.23	15.09	14.76	15.74	14.21	9.47	11.56	10.11	7.42
13	16.81	13.12	13.89	14.16	12.46	15.88	7.52	10.75	11.16	6.54
20	20.01	12.01	11.03	13.45	12.61	17.03	9.79	8.36	11.94	8.58
27	18.31	15.24	15.73	14.16	15.74	11.51	12.34	10.38	12.77	8.20
Sept. 3	20.95	15.13	17.23	16.96	17.32	13.38	9.51	8.64	13.10	11.59
10	16.81	12.64	14.56	13.92	14.67	12.67	12.40	13.08	11.27	13.82
24	14.55	13.03	11.55	11.62	10.99	11.0	9.14	10.04		
Oct. 9	8.41	7.75	6.51			9.67	7.24	9.59		
Average	18.87	13.39	15.03	15.42	15.99	14.14	9.78	10.26	10.28	10.50

TABLE No. 10.
Nitrate Determinations—Woodman Orchard, 1915.
 Parts per Million of Dry Soil.

Date.	Surface Soil—Plots.						Subsoil—Plots.					
	1.	4.	5.	11.	12.	1.	4.	5.	11.	12.		
May 15	2.3	33.7	13.6	20.0	17.7	2.6	14.7	8.7	10.3	8.1		
June 16	2.104	56.26	92.58	96.07	61.97	.601	19.04	13.07	32.45	12.86		
23	.96	58.42	51.53	104.10	86.70	trace	9.60	7.11	14.41	13.45		
30	1.10	63.27	60.73	65.54	22.54	.230	31.90	9.936	14.96	59.70		
July 7	.86	14.55	9.957	15.29	25.87	trace	20.66	11.99	21.45	22.34		
14	.65	14.90	4.743	17.50	15.78	trace	5.258	5.480	13.88	23.92		
21	trace	16.43	7.637	30.08	28.65	trace	4.371	3.820	26.35	18.10		
28	1.436		8.506	37.21	31.86	trace	3.956	7.062	17.99	29.56		
Aug. 4	3.011	16.68	11.99	35.48	37.05	2.642	12.72	8.964	30.44	48.99		
11	3.306	6.987	6.522	20.85	18.51	2.940	10.20	7.872	21.27	17.07		
18	4.572	11.38	16.62	26.81	28.36	2.148	9.354	7.427	7.881	23.29		
25	4.612	27.09	17.79	26.96	29.20	2.479	17.82	11.61	10.81	22.42		
Sept. 1	2.38	8.35	12.18	10.61	11.62	.64	3.05	1.04	4.32	1.45		
8	1.93	9.09	8.11	21.26	20.61	2.74	7.62	3.93	3.74	6.17		
17	1.89	12.68	3.08	11.48	2.72	1.17	11.01	2.53	2.35	3.54		
22	4.12	12.35	9.83	8.74	9.30	2.82	6.07	5.44	7.54	5.34		
29	1.45	6.34	9.76	9.40	6.05	5.86	7.04	9.84	5.54	6.12		
Oct. 6	.989	9.12	6.38	4.14	2.42	.875	6.17	1.54	4.96	1.52		
14	2.15	1.39	7.73	8.21	4.08	1.04	3.84	3.28	6.23	3.56		
Average	2.096	21.05	18.75	29.98	24.26	1.515	10.76	6.88	13.78	17.24		

TABLE No. 11.
Per Cent Moisture—Woodman Orchard, 1915.
 Weekly Records.

Date.	Surface Soil—Plots.					Subsoil—Plots.				
	1.	4.	5.	11.	12.	1.	4.	5.	11.	12.
May 15	23.00	15.2	17.5	23.2	25.4	13.9	12.6	11.0	11.2	14.0
June 16	22.07	15.21	16.72	17.52	16.65	14.27	10.72	13.58	10.48	11.40
23	23.57	15.63	16.44	17.24	18.90	9.79	11.06	6.77	8.47	9.03
July 30	18.07	17.34	15.16	17.73	16.50	10.56	13.02	8.29	8.73	10.77
7	26.73	21.24	22.12	21.87	23.70	13.36	14.39	10.61	11.73	13.26
14	26.34	22.13	23.62	21.43	23.39	16.31	15.82	14.41	12.15	14.03
21	27.07	19.65	21.71	21.27	19.51	14.16	12.32	10.69	13.48	9.37
28	26.69	20.52	21.73	21.30	22.30	10.99	13.30	12.22	11.81	15.28
Aug. 4	28.74	21.80	21.32	22.53	23.67	14.00	12.54	10.55	11.60	12.88
11	27.81	22.92	24.85	35.77	22.62	20.65	15.79	14.12	13.77	14.92
18	27.99	22.19	21.52	22.09	23.26	14.28	14.18	15.34	12.36	12.35
25	27.06	22.79	22.55	22.47	23.71	18.10	17.03	13.36	13.70	15.01
Sept. 1	26.16	20.02	23.26	20.73	22.60	12.11	12.78	16.13	14.70	17.73
8	27.43	16.39	19.92	18.62	20.96	16.33	15.79	11.97	14.20	16.45
17	22.96	18.18	21.02	19.44	20.98	15.07	16.43	15.48	12.22	15.38
22	25.72	19.06	21.86	21.44	21.86	15.27	15.21	14.01	14.57	16.09
29	23.58	18.10	21.56	18.84	17.56	15.49	13.19	17.64	11.37	12.72
Oct. 6	27.78	20.08	20.06	20.54	22.17	14.91	16.27	19.32	13.71	15.15
14	27.32	18.04	22.68	20.64	20.42	11.40	14.17	17.84	13.99	13.44
Average	25.63	19.29	20.82	21.19	21.38	14.26	14.03	13.33	12.33	13.64

TABLE No. 12.
Nitrate Determinations—Woodman Orchard, 1916.
 Parts per Million of Dry Soil.

Date.	Surface Soil—Plots.						Subsoil—Plots.					
	1.	4.	5.	11.	12.		1.	4.	5.	11.	12.	
May 31	6.08	8.08	15.90	18.47	13.04		2.92	6.40	5.43	7.25	7.95	
June 21	3.07	4.69	7.65	28.67	12.72		3.01	2.61	1.92	2.97	2.71	
June 28	7.77	14.38	30.61	135.84	102.53		2.67	4.81	5.90	24.60	14.39	
July 5	3.86	11.34	27.75	52.20			2.10	3.00	5.36	3.34	4.61	
July 12	3.55	11.01	28.43	64.39	76.39		2.50	3.27	5.19	6.81	6.05	
July 19	2.35	15.87	52.29	127.40	82.35		1.08	3.50	5.70	9.80	7.71	
July 26	1.42	18.31	38.41	88.22	100.00		.96	3.72	8.53	10.58	11.53	
Aug. 2	1.21	14.38	40.56	56.18	77.22		.94	3.63	9.72	8.48	10.96	
Aug. 9	1.52	9.46	59.13	81.26	82.60		1.51	2.64	10.15	29.32	10.62	
Aug. 16	2.93	20.83	67.60	270.14	85.99		2.21	5.12	15.06	50.26	14.13	
Aug. 23	4.26	23.06	79.04	135.99	128.08		1.58	7.91	16.55	32.81	15.60	
Aug. 30	4.43	27.11	64.22	76.01	69.79		3.39	8.99	10.87	22.44	23.89	
Sept. 5	4.08	33.30	24.75	145.52	133.62		3.49	10.08	4.25	104.59	20.12	
Average	3.58	16.29	41.26	98.48	80.36		2.18	5.05	8.05	24.10	11.56	

TABLE No. 13.
Moisture Determinations—Woodman Orchard, 1916.
 Percentage.

Date.	Surface Soil—Plots.						Subsoil—Plots.					
	1.	4.	5.	11.	12.	1.	4.	5.	11.	12.	1.	4.
May 31	12.4	11.4	16.8	22.0	24.4	9.4	10.6	13.0	12.4	14.6		
June 21	24.8	20.2	23.4	24.6	25.6	17.4	20.2	14.4	16.6	16.2		
June 28	24.4	15.4	21.0	23.0	25.4	15.2	10.8	19.0	13.2	19.2		
July 5	24.0	17.8	24.4	23.4	23.2	20.8	11.4	15.4	13.9	19.0		
July 12	23.4	13.8	23.4	23.0	25.2	17.2	12.2	13.0	15.2	17.8		
July 19	16.4	14.4	19.6	20.0	22.8	11.4	12.6	10.4	14.0	14.6		
July 26	26.0	22.4	27.0	24.6	27.8	14.0	16.6	15.4	17.8	17.4		
Aug. 2	22.0	16.8	20.0	22.6	24.0	12.6	10.0	13.4	12.8	18.6		
Aug. 9	18.0	18.8	23.2	22.8	25.0	11.8	14.4	14.8	15.6	16.4		
Aug. 16	18.6	15.8	20.0	20.4	21.2	18.4	12.0	12.8	10.6	15.4		
Aug. 23	17.4	13.6	16.6	20.8	21.5	15.1	9.8	10.0	10.4	15.4		
Sept. 30	20.1	18.2	20.0	22.7	24.8	14.9	14.2	11.5	13.9	16.9		
Sept. 5	18.7	15.2	21.6	22.2	20.8	14.4	10.8	9.0	11.9	15.9		
Average	20.48	16.45	21.31	22.47	23.98	14.82	12.74	13.24	13.72	16.72		

The summer of 1915 was very wet and as a consequence the nitrates recovered in our samples were low as compared with other years. This can be well seen on Charts 3 and 8, as the heavy rains began July 6. The curves drop down at that time and remain low throughout the rainy period without much difference between the plots. This is likely due to two things, first, nitrification was probably not so rapid when the soil was very high in moisture, and second, what nitrates were formed were readily leached out. Plot 5 here fell a little below Plot 4 with a difference in favor of the latter of about 2 p.p.m.

This evidence seemed to warrant the position that the formation of nitrates is greatly reduced in a sod orchard and from a fertility standpoint is the first limiting factor. Not only does the growth average about half as great as where a good system of culture is practiced, *i. e.*, as 4.80:8.83, but also we find a smaller size of the leaves and a poor color, denoting an insufficient amount of available nitrogen. That the lack of vigor is due to an insufficient supply of moisture cannot be advanced for it has been somewhat of a surprise throughout the entire experiment that there was a higher per cent of moisture in the sod plot than in the adjacent tilled ones.

NITRIFICATION UNDER SOD.

During the past season we have attempted to determine the approximate amount of nitrates formed under sod. In order to determine this a small plat 3 feet square was selected in Plot 1 (the sod plot) quite near to the point where the soil samples had been previously taken, and the sod carefully removed without stirring the soil beneath. Another plat of equal size was selected close to the first and after the sod was likewise removed the soil was spaded to the depth of the surface soil and cultivated with a hoe weekly. This gave three conditions within the original sod plot: (1) sod; (2) bare soil; (3) bare soil, stirred each week. While the bare plat would not represent the exact conditions under sod, yet it seems to be as near that condition as is practical to obtain in the field. While this phase of the work was not begun until the middle of summer the determinations seem to throw light on the question.

TABLE NO. 14.

Nitrates, Parts per Million of Dry Soil.

Surface Soil.

	July 24.	July 31.	Aug. 7.	Aug. 14.	Aug. 21.	Aug. 28.	Sept. 4.	Sept. 16.	Sept. 23.	Average Aug. 7 to Sept. 23.
Sod.	2.599	1.871	2.800	2.668	3.748	3.075	4.27	.568	1.464	2.656
Bare	2.575	2.615	4.717	3.330	11.112	10.755	7.856	1.923	2.380	6.010
Tilled. . . .	—	—	10.575	16.002	24.969	51.021	65.553	8.332	8.820	26.469

TABLE NO. 15.

Moisture, Percentage.

Surface Soil.

	July 24.	July 31.	Aug. 7.	Aug. 14.	Aug. 21.	Aug. 28.	Sept. 4.	Sept. 16.	Sept. 23.	Average Aug. 7 to Sept. 23.
Sod.	27.0	26.8	25.0	25.2	22.0	24.9	21.8	27.0	26.5	24.6
Bare	26.4	27.4	24.4	24.4	21.2	25.7	22.8	27.0	26.5	24.6
Tilled	—	—	24.6	24.6	22.2	25.8	22.8	27.5	26.5	24.8

From the table it will be seen that there is practically no difference in moisture to account for variations in nitrates. It will also be seen that the amount of nitrates formed under the sod would be approximately the amount shown on the bare soil but where this same soil is stirred nitrification progresses at a much greater rate. So it would seem to indicate that nitrates are reduced under sod to a marked degree as compared with the same soil under tillage. The ratio between the three small plats is as follows:

Sod.		Bare.		Tilled.
1	:	2.2	:	10.

Later in the season another sod orchard of Baldwin trees was used to duplicate the experiment. Determinations of nitrates and moisture had been made throughout the season on two unfertilized rows under the sod and gave a weekly average for the season as follows:

CHART NO. 5
 NITRIFICATION UNDER SOB—1916 (Parts per million of dry soil)
Plots 1, 2 and 3.

Average Moisture and Nitrates in Second Orchard, 1916.

Surface Soil.

	Nitrates.	Moisture.
Row 4	3.55	22.98
Row 8	3.28	22.69

After small plats similar to the ones described in Plot 1 were made on Row 4 determinations were made which gave the following results:

TABLE No 16.

	Moisture, percentage.						Nitrates, p.p.m.					
	Aug. 21.	Aug. 28.	Sept. 4.	Sept. 16.	Sept. 23.	Av.	Aug. 21.	Aug. 28.	Sept. 4.	Sept. 16.	Sept. 23.	Av.
Sod.	22.8	26.0	24.8	28.	29.	26.12	2.980	3.838	4.606	.857	1.03	2.662
Bare	23.6	26.1	24.4	27.5	27.	25.72	9.046	6.550	6.382	.901	1.166	4.809
Tilled.	21.4	26.1	23.0	28.5	27.	25.20	11.657	13.669	29.886	3.702	3.33	12.049

No rains fell during the first few weeks of these observations and the nitrates accumulated as the weeks progressed and formed a rapidly ascending curve where the soil was stirred, but on Sept. 15, 1.42 inches and Sept. 18 1.10 inches of rain fell and the curve drops down again as the nitrates had washed out.

These results do not extend over as long a period as might be desirable but from our experience over four years in the orchard they seem to duplicate the results obtained there.

EFFECT OF LIME ON NITRIFICATION.

It has been shown a number of times that when lime is applied to soil it will increase nitrification. Four years' results on a cultivated orchard show a greater average amount of nitrates recovered in the samples where the lime was applied. However, nitrates are quite variable and seem to be readily affected by weather conditions. Especially where fertilizers have been applied do we find irregularities apparently due to obtaining some of the fertilizers in the sample occasionally. So that any par-

CHART NO. 6
 NITRATE DETERMINATIONS—1913 (Parts per million of dry soil)
Plots 11 and 12.

CHART NO. 7
NITRATE DETERMINATIONS—1914 (Parts per million of dry soil)
Plots 11 and 12.

CHART NO. 8
 NITRATE DETERMINATIONS—1915 (Parts per million of dry soil)
Plots 11 and 12.

CHART NO. 9
NITRATE DETERMINATIONS—1916 (Parts per million of dry soil)
Plots 11 and 12.

ticular determination or even the average for one season is not very satisfactory but where four consecutive years are considered, the average can be pretty well relied upon. The following tables show the nitrate and moisture determinations:

TABLE No. 17.

*Summary of Nitrate and Moisture Determinations.
Limed and Unlimed Plots.*

Nitrates.

Year.	Plot 11—Limed.		Plot 12—Unlimed.	
	Surface soil.	Subsoil.	Surface soil.	Subsoil.
1913	82.33	19.60	57.46	6.16
1914	82.46	23.43	57.09	15.21
1915	29.98	13.78	24.26	17.24
1916	98.48	24.10	80.36	11.56
Average	73.31	20.23	54.79	12.54

TABLE No. 18.

Moisture.

Year.	Plot 11—Limed.		Plot 12—Unlimed.	
	Surface soil.	Subsoil.	Surface soil.	Subsoil.
1913	19.14	11.92	16.75	11.22
1914	15.42	10.28	15.99	10.50
1915	21.19	12.33	21.38	13.64
1916	22.47	13.72	23.98	16.72
Average	19.55	12.06	19.52	13.02

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SUMMARY.

1. Nitrification proceeded slowly on the sod plots of these orchards.
2. Stirring the soil readily increased the rate of nitrification.
3. Under a good system of tillage nitrates were usually present in excess of the needs of the trees.
4. Lime consistently increased nitrification.
5. Moisture was not the limiting factor in the sod plots.

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