NITROUS NITROGEN IN IRRIGATED SOILS¹

By

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The amount of nitrous nitrogen in normal soils is usually conceded to be very small, but the actual amount present in the soil under irrigated field conditions has not, so far as the authors are aware, been determined. In connection with the investigations (2, 3) which have been carried on at the Utah Experiment Station during the past twelve years on the influence of irrigation water upon the movement and production of nitric nitrogen in irrigated soils, it was thought desirable to make a study of the nitrous nitrogen content of the soil. Therefore, such determinations were made throughout four years and it is the purpose of this article to discuss the results thus obtained. Briefly stated, the outline of the work was as follows²:

The field was divided into plots of 1-26 of an acre and each plot was divided with laterals and necessary devices for distributing and measuring the water applied. The field was divided into five equal sets of plots: the first set was left fallow, the second planted to alfalfa, the third to corn, the fourth to potatoes, and the fifth to oats. Each of these sets was further divided so that one plot in each set received a maximum, one a medium, one a minimum irrigation, and one was not irrigated. The first season the plots were sampled in the spring, then before and after each irrigation during the summer, and again in the fall; while during the last three years the samples were taken in the spring, midsummer, and fall, and analyzed for nitrous nitrogen and moisture. The irrigation and sampling were so arranged that the results from the cropped irrigated plots could be compared with the non-irrigated plot of the same series and also with the fallow plots receiving a corresponding amount of irrigation.

¹ Received for publication October 2, 1916.

² For a complete description of the experimental field, together with a description of the methods employed and the results for nitric nitrogen, the reader is referred to the publications noted above.

METHOD OF ANALYSIS

The soil solution was obtained by means of the Pasteur-Chamberlain filter. For rapid work a series of 24 Pasteur-Chamberlain filters were used as shown in Plate I. A weighed quantity of soil, 50 gm., was titrated in a mortar with 250 c.c. of cold distilled water. The water contained a few drops of chloroform for the purpose of inhibiting bacterial action. The soil was titrated for two minutes, allowed to stand fifteen minutes, and then filtered through the Pasteur-Chamberlain filter. Fifty c.c. of this solution were treated with 2 c.c. of the nitrite reagent and allowed to stand for 15 minutes. This solution was compared with a standard nitrite solution containing 0.01 mg. of nitrous nitrogen treated in the same manner. The nitrite reagent was prepared by mixing equal volumes of standard solutions of a naphthalamine acetate solution and sulfanilic acid (1). Moisture determinations were made on the soil and all the results calculated to dry bases.

During the first season the samples were taken to a depth of 10 feet in the spring (before irrigation and after irrigation), and in the fall. They are of especial interest in that they show the quantity of nitrous nitrogen contained in the soil at various depths, and also the immediate effect of irrigation water upon the quantity and distribution of the nitrous nitrogen of the soil. The results are given in Table I as pounds per acre¹ of nitrous nitrogen found in the soil.

The most striking point brought out by these data is the uniformly low nitrous nitrogen content of all the soil. The nitrous nitrogen is about evenly distributed throughout the ten feet, the total quantity never exceeding 17 pounds per acre. There is, however, a slight seasonal fluctuation which is most pronounced in the case of the alfalfa-bearing soil. The application of irrigation to the alfalfa and oats decreases the nitrous nitrogen content of the surface foot of soil, while the corn and fallow plots both show an increase.

From the last results reported in the last column of Table I, it is clear that there is no uniform relationship between the nitric nitrogen content of a soil and its nitrous nitrogen content, for we find the nitrous nitrogen-nitric nitrogen ratio varying from as narrow as 1 to 3.03 to as wide as 1 to 80.

The work of the first season indicated that it was not necessary to determine the nitrous nitrogen content of the soil to a depth of more than one foot, since the nitrous nitrogen is uniformly low through the ten feet of soil. Therefore, during the years 1913, 1914, and 1915 a careful study of the nitrous nitrogen content of the first foot was made. In this work the samples were taken in spring—about the middle of April, midsummer, about the last of July, and in the fall—the last of October or the

¹ One acre-foot of soil is assumed to weigh 3,600,000 pounds.

first of November. The results, therefore, as reported in Table II represent the average of a number of determinations extending over three years and should represent very nearly the nitrous nitrogen content of

TABLE I
NITROUS NITROGEN CONTENT OF SOIL GROWING VARIOUS CROPS AS DETERMINED AT DIFFERENT SEASONS: RESULTS STATED AS NITROUS NITROGEN IN POUNDS PER ACRE

FALLOW SOIL												
Period	1	2	3	4	5	6	7	8	9	10	Total	Ratio of Nitrous Nitrogen to Nitric Nitrogen in 10 ft.
April	0.87	0.85	0.81	1.06	1.29	0.80	1.03	0.84	0.99	2.01	10.55	1:10.38
Bef. Irr. . .	0.84	0.49	0.20	0.38	0.32	0.37	0.62	0.17	0.38	0.21	3.98	1:20.60
Aft. Irr. . .	0.58	0.45	0.32	0.49	0.27	0.45	0.32	0.36	0.49	0.38	3.01	1:26.39
Sept.	1*	*	*	*	*	0.75	*	*	*	*		
Oct.	*	*	*	*	*	*	*	*	*	*		
ALFALFA SOIL												
Spr.	0.24	0.52	0.54	0.69	0.29	0.34	0.25	0.30	0.24	0.58	3.99	1:26.12
Bef. Irr. . .	0.86	0.87	0.43	0.42	0.49	0.41	0.37	0.48	0.37	0.68	5.38	1: 6.15
Aft. Irr. . .	0.48	0.58	0.36	0.63	0.62	0.56	0.50	0.43	0.61	0.60	5.37	1: 7.78
Sept.	*	0.28	0.13	0.17	*	*	*	0.10	0.19	0.23	1.10	1:79.18
Oct.	0.08	0.07	0.35	0.31	0.89	0.41	0.03	0.64	0.43	0.10	3.31	1:20.63
CORN SOIL												
Spr.	0.54	0.47	1.07	0.23	0.69	0.21	0.27	0.25	0.45	0.96	5.15	1:28.49
Bef. Irr. . .	0.55	1.55	0.64	0.43	0.64	0.61	0.55	0.50	0.48	0.48	6.43	1:20.90
Aft. Irr. . .	0.73	0.87	0.63	0.66	0.53	0.43	0.76	1.18	1.26	1.02	8.07	1:18.32
Sept.	0.10	0.70	0.15	1.61	0.17	0.08	0.26	0.25	0.19	0.14	3.02	1:31.22
Oct.	0.54	0.32	0.39	0.31	0.31	0.71	0.64	0.36	0.27	0.22	4.07	1:41.18
POTATO SOIL												
Spr.	1.12	1.84	0.84	0.61	1.22	0.81	0.78	0.73	0.48	0.49	8.92	1:10.42
Bef. Irr. . .	0.76	0.48	0.32	0.61	0.55	0.68	0.83	0.59	0.33	0.89	6.04	1: 9.87
Aft. Irr. . .	0.86	0.74	0.57	0.57	0.80	0.68	1.00	0.69	0.78	0.28	6.97	1:11.15
Sept.	1.78	4.73	1.33	0.45	2.34	2.02	1.69	2.59	*	*	16.93	1: 3.03
Oct.	*	*	*	*	0.44	*	*	*	*	*	0.44	1:118.3
OAT SOIL												
Spr.	0.61	0.60	0.32	0.42	0.56	0.44	0.47	0.37	0.45	0.42	4.66	1:33.30
Bef. Irr. . .	1.03	0.98	0.57	0.88	0.48	0.75	0.63	1.61	0.44	0.36	7.73	1:20.18
Aft. Irr. . .	1.15	0.87	1.24	1.48	0.49	0.56	0.99	0.72	0.73	0.57	8.80	1:22.60
Sept.	*	1.59	0.29	0.29	0.67	0.27	*	*	1.02	0.47	4.60	1:40.85
Oct.	0.64	0.32	*	1.71	*	0.07	0.32	*	0.02	1.20	4.28	1:13.25

1 "*" in this table indicates "none."

this soil when growing various crops and receiving differing quantities of water. Each result in Table II represents one determination each year for three years for each of the 5 plots, viz., alfalfa, oats, corn, potatoes, and fallow.

These results bear out the conclusions reached from the first season's work that the nitrous nitrogen content of the soil is very low and that it is higher in midsummer than in the fall. In the spring the plots receiving the greatest quantity of irrigation water are the highest in nitrous nitrogen, while in midsummer and fall, with one exception, the reverse is true, the nitrous nitrogen content being inversely proportional to the water applied. But from the results as a whole, we must conclude that the application of irrigation waters to soil varying in quantity from none to 37.5 inches per acre yearly has very little influence upon the nitrous nitrogen content of the soil.

TABLE II
NITROUS NITROGEN OF SOIL GROWING VARIOUS CROPS AND RECEIVING
VARYING AMOUNTS OF IRRIGATION WATER
Stated as Pounds per Acre

Water Applied	No. Determinations in Avge.	Seasonal Date of Sampling			Average
		Spring	Summer	Fall	
None	15	0.3762	0.5785	0.4255	0.4600
15.0 in.	18	0.7588	0.4806	0.3906	0.5433
25.0 in.	15	0.3978	0.3132	0.1937	0.3016
37.5 in.	15	1.1880	0.1847	0.2243	0.5323
Average	..	0.6802	0.3892	0.3085	

The influence of the crop upon the nitrous nitrogen content of the soil is given in Table III.

TABLE III
NITROUS NITROGEN CONTENT OF SOIL GROWING VARIOUS CROPS
Stated as Pounds per Acre

Crop	No. Determinations in Avge.	Season			Average
		Spring	Summer	Fall	
Alfalfa	16	1.4705	0.7354	0.3496	0.8518
Oats	16	1.3589	None	0.2877	0.8233
Corn	16	0.1760	None	0.3503	0.2632
Potatoes	16	0.1616	0.6538	0.4137	0.3430
Fallow	16	0.2347	0.5544	0.1415	0.3102

The nitrous nitrogen content of the alfalfa soil is higher in the spring than that of soils growing other crops, probably because of the compact condition of the alfalfa soil. The quantity in the alfalfa soil decreases as the season progresses until there is only one-third as much found in the soil in the fall as in the spring.

The nitrous nitrogen content of the oat soil stands next to the alfalfa, but there is this important difference between the two sets of soils, while the alfalfa soil shows a nitrous nitrogen content of 0.74 pounds per acre in the summer, the oat land contained such minute quantities that it is

here reported as none. This must be an inherent difference, and not due to accident, for it was repeated in the sixteen determinations made extending over three years, while at this season of the year the alfalfa soil invariably showed measurable quantities of nitrous nitrogen present. Otherwise, the alfalfa and oat soils are similar, both showing less in the soil in fall than in spring.

The corn and the potato land contained less nitrous nitrogen than the alfalfa and the oat land, and further differed from these in that the quantity slightly increased as the season progressed. The fallow soil differed from all of the others in that the quantity of nitrous nitrogen reached its maximum in midsummer in place of fall and spring, as was the case with the other crops. This fact would point strongly to the conclusion that the rapid removal of the nitrous nitrogen by the growing plant in midsummer stimulates the action of the nitrifying organisms with the result that the nitrous nitrogen is oxidized as fast as found. The accumulation of the nitric nitrogen in the case of the fallow soil, on the other hand, has led to an accumulation of nitrous nitrogen in the soil.

TABLE IV
NITROUS NITROGEN FOUND IN SOIL GROWING VARIOUS CROPS
Stated as Pounds per Acre

Crop	No. Determinations in Ave.	Seasonal Date of Sampling			Average
		Spring	Summer	Fall	
Sugar Beets	4	0.2376	0.7200	0.6336	0.3144
Alfalfa	5	2.7210	1.1850	0.1707	1.3589
Oats	3	0.6754	1.0080	0.3395	0.6743
Oats and Alfalfa	3	6.7540	0.4357	0.2502	2.4800

These considerations led to the conclusion that possibly a soil richer in nitric nitrogen may contain much larger quantities of nitrous nitrogen than this soil, which has been cropped for nearly thirty years without the addition of manure. The result is that the nitrogen and organic content has become very low even for a soil of the arid regions. For these reasons determinations were made of the nitrous nitrogen in soil from one of the crop rotation series which was receiving small applications of manure. The rotation was as follows:

Alfalfa	3 years
Sugar beets	2 years
Oats	1 year
Oats and alfalfa	1 year

The soil and size of plots was the same as those used in the preceding work. Weighed fresh manure at the rate of 15 tons per acre was applied to the sugar beet plot in the fall and then thoroughly disked in the next spring before planting. Each plot received 25 inches of irrigation water

applied to the soil in five equal applications. Analyses were made for nitrous nitrogen during three seasons and the summarized results as reported in Table IV represent the average of several determinations.

While direct determinations of the nitric nitrogen content and nitrifying powers of soil from these plots showed them to be much higher than the ones previously considered, they are no higher in nitrous nitrogen; they thus show that in a good arable soil the nitrous nitrogen is either transformed into nitric nitrogen practically as fast as it is formed, or is carried to lower depths by the soil water, for there is no appreciable accumulation of nitrites in the soil.

SUMMARY

The data reported in this article represent some eight hundred determinations of the nitrous nitrogen of a calcareous soil without crop, cropped to alfalfa, to oats and alfalfa, to oats, to potatoes, and to sugar beets. The water applied to the soil varied from none to 37.5 inches per acre yearly.

The nitrous nitrogen content of the soil was very low and was about evenly distributed throughout the ten feet. The total quantity found in an acre of soil to a depth of ten feet varied from a trace—too small to be determined by the method—up to 17 pounds per acre. No relationship was found to exist between the nitrous nitrogen and the nitric nitrogen content of the soil.

The application of irrigation water had no appreciable influence upon the nitrous nitrogen content of the soil.

There was a slight seasonal variation in the nitrous nitrogen content of the soil; in the alfalfa and the oat soils it was highest in the spring and decreased toward fall, while in the potato and the corn soils it was lowest in spring and increased toward fall. In the fallow the nitrous nitrogen was highest in midsummer.

The greatest quantity of nitrous nitrogen was found in the alfalfa soil during the spring, while the least was found under the oats during mid-summer.

The application of manure to the soil had no appreciable influence upon the nitrous nitrogen content of the soil.

LITERATURE CITED.

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PLATE I

Pasteur-Chamberlain Filters used in analysis.