Studies on the Soils in Rice-field.

IV. Relation of ammonification, nitrification and denitrification power of the soils to the yield of rice crop.

By

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This paper deals with the relation of ammonification, nitrification and denitrification to the yield of rice crop.

Since the rice plants have the peculiar physiological behavior toward the nitrogen as well as the reaction of soil and other factors, it is very interesting to investigate such correlation. For instance, the rice plants assimilate ammonia nitrogen rather than the nitrate form and prefer acid reaction. Consequently the ammonification process which is known to have little significance in this respect with other crops in Europe and America, may have close connection in case of the rice plants.

Experimental.

Description of the soil samples and the ecological factors together with the experimental data are presented as follows :

I. Fertilizers used.

The fertilizers used in this experiment are similar to those which have been employed previously as noted below :

(Table I see next page.)

The fertilizers were applied on June 30th and the rice plants (Ehime Shinriki) were planted on July 2nd, and no more fertilizer was applied. The management of the plots was carried out as usual according to the common practice in this vicinity.

Table I.

C:N Ratio and Quantity of Fertilizers applied to each Plot.

No. of plot.	Kind of fertilizers.*	Amount (Kg) of fertilizers applied per Tan.**	C:N Ratio.
1.	No fertilizer.	—	—
2.	Compost.	1,125.00	
	Soybean cake.	56.20	
	Cotton seed meal.	37.50	6.0
	Night soil.	375 00	
	Superphosphate.	26.20	
	Wood ash.	45.00	
3.	Rice straw.	1,125.00	57.0
5.	Ammonia sulfate.	63.80	
	Superphosphate.	28.10	
	Potassium sulfate.	6.75	
7.	Compost.	1,125.00	12.0
10.	Green manure.	1,125.00	11.0
11.	No fertilizer.	—	—

Notes. * Plot 1 did not receive any fertilizer nor crop was raised. Besides the fertilizers noted, 93.8 Kg. of lime was applied to each plot.

** One Tan = 993 sq. meters.

II. Rainfall.

The record of rainfall was obtained by the usual method at the weather bureau, at this Institute and is shown below:

Table II.

Record of Monthly Rainfall.

Month.	June.	July.	August.	September.	October.	November.
Rainfall in mm.	189.0	65.0	172.7	118.3	49.9	31.0

III. Temperature.

The temperature was recorded at different intervals for air, soil surface and irrigation water as shown in Table III.

Table III.

Temperature of Air, Soil surface and Irrigation water.*

Date.	Weather.	Air.	Soil surface.	Irrigation water.
		°C	°C	°C
June 25.	fine.	22.5	27.0	31.0
July 4.	fine.	25.4	27.5	32.0
〃 13.	cloudy.	28.5	28.5	30.0
〃 23.	cloudy.	26.3	27.0	27.1
August 7.	fine.	30.0	27.0	—
〃 20.	cloudy.	26.2	26.2	27.2
September 4.	fine.	30.5	29.5	30.0
〃 20.	fine.	27.5	27.0	30.5
October 4.	cloudy.	22.5	20.5	—
〃 19.	fine.	22.5	16.0	—
November 2.	fine.	19.0	15.0	—
〃 17.	fine.	11.8	12.2	—

* These records were taken in Plot 2.

IV. Moisture contents of the soil.

The moisture content was determined by the usual method and noted in Table IV.

Table IV.

Moisture Contents of Soils.

Date. \ Plots.	1.	2.	3.	5.	7.	10.	11.
	%	%	%	%	%	%	%
June 25.	34.04	37.28	34.58	32.30	35.10	34.60	32.12
July 4.	37.14	40.43	40.09	36.78	38.60	40.95	34.11
〃 13.	32.82	40.58	35.49	37.27	40.42	35.72	34.82
〃 23.	34.72	39.43	36.57	34.39	38.43	34.82	31.07
August 7.	34.08	34.46	34.28	36.15	36.73	32.66	29.96
〃 20.	37.05	45.25	37.80	43.00	44.08	39.22	32.78
September 4.	34.68	44.47	39.50	42.22	41.25	43.30	34.72
〃 20.	38.85	45.59	43.46	42.17	43.10	42.35	40.44
October 4.	29.71	36.14	33.88	33.24	32.35	32.98	28.28
〃 19.	31.19	34.51	31.34	31.69	31.28	34.51	28.44
November 2.	30.06	34.70	29.25	30.43	31.00	31.99	25.74
〃 17.	30.26	33.83	30.32	32.08	30.34	29.69	27.14
Average.	33.71	38.81	35.55	35.98	36.89	36.10	31.64

Table IV indicates that the moisture content was greatest during one month up to August 20th and decreased thereafter owing to the absence of irrigation water. Plot 2 (control) was the greatest which is followed by Plots, 7 (compost),

10 (green manured), 5 (mineral fertilizers), 3 (rice straw), 1 (no fertilizer and no crop) in oder and 11 (no fertilizer but cropped) contained least which is 7% less than that of the control plot.

V. Hydrogen ion concentration of the soil.

The determination of hydrogen ion concentration was made by the quinhydrone method taking the water extract of the air dried sample (1 : 1). The results are noted in Table V:

Table V.

Hydrogen Ion Concentration of Soils.

Date. \ Plots.	1.	2.	3.	5.	7.	10.	11.
	P_H	P_H	P_H	P_H	P_H	P_H	P_H
June 25.	7.58	7.53	7.56	7.62	7.65	7.63	7.56
July 4.	7.56	7.75	7.62	7.13	7.79	7.70	7.62
" 13.	7.60	7.70	7.56	7.44	7.79	7.74	7.44
" 23.	7.44	7.67	7.58	7.15	7.62	7.55	7.58
August 7.	7.41	7.43	7.27	7.13	7.51	7.27	7.32
" 20.	7.34	7.30	7.20	6.96	7.63	7.41	7.30
September 4.	7.34	7.30	7.20	7.03	7.44	7.39	7.49
" 20.	7.41	7.41	7.25	7.27	7.41	7.32	7.48
October 4.	7.30	7.20	7.18	7.04	7.27	7.36	7.41
" 20.	6.92	6.87	6.97	6.87	7.04	7.03	7.18
November 2.	6.84	6.70	6.78	6.68	6.99	6.92	6.99
" 17.	6.78	6.78	6.89	6.63	6.97	6.87	6.91
Average.	7.29	7.30	7.26	7.08	7.43	7.35	7.36
Initial P_H—final P_H.	+0.80	+0.75	+0.77	+0.99	+0.68	+0.76	+0.65

Table V indicates that the reaction remained alkaline until three weeks after the application of fertilizer and gradually became acid after that. However in Plot 1 where no fertilizer is applied, the P_H value decreased gradually and steadily without rising above the initial P_H value. On the average, Plot 7 became most alkaline and the rest of plots were in the following order: Plots 11, 10, 2, 1 and 3 while Plot 5 was the smallest. The difference between the initial and the average P_H lied somewhere +0.7 to +0.8 for all the plots except Plot 5 which showed +1.0.

VI. Bacteriological analysis of the soils used.

The soil samples were taken as described previously but the irrigation water was not investigated since the significance was not marked.

1. Ammonifying power of the soils.

The method employed for the determination of ammonifying power was that of WAKSMAN which was described in detail in our previous report. However the sample used for inoculation was 10 cc of 10% soil suspension, shaken for five minutes, corresponding to 1 g. of the original soil. The results are given in Table VI in which the data are noted on the dry basis:

Table VI.

Ammonification power of Soils.

Date. \ Plots.	1.	2.	3.	5.	7.	10.	11.
	mg.	mg.	mg.	mg.	mg.	mg.	mg.
June 25.	136.51	142.46	129.20	137.20	133.96	133.46	131.64
July 4.	140.80	165.05	158.93	147.88	144.97	152.49	129.85
〃 13.	141.43	161.06	140.97	138.37	153.22	135.04	131.58
〃 23.	115.22	134.43	136.20	139.87	143.78	130.21	116.62
August 7.	157.01	155.61	157.70	155.61	165.98	155.95	148.27
〃 20.	162.22	180.22	160.30	171.29	185.09	165.75	145.76
September 4.	142.61	169.00	161.95	155.84	156.79	170.98	139.00
〃 20.	154.02	184.51	183.06	161.67	165.67	165.77	151.18
October 4.	132.04	142.08	137.75	143.15	134.63	128.17	121.70
〃 20.	132.46	147.09	128.22	136.46	134.14	147.50	120.43
November 2.	125.79	141.59	128.25	128.44	131.50	131.08	121.26
〃 17.	133.57	137.12	145.57	131.56	141.15	129.54	139.21
Average.	139.47	155.07	147.34	145.86	149.24	145.49	133.04

Note: The data indicate the quantity of ammonia produced in 100 cc. of medium.

Table VI indicates that the strong ammonification takes place beginning from the early part of August to the middle of September regardless of manuring and the crop, although it is more marked in the manured plot. Judging from the average, the order of magnitude are Plots 2, 3, 5, 1 and 11.

Then the change of ammonia content in the soil of each plot was determined by HARPER's method which is carried out as follows: 50 g. of air dried soil is shaken with 20%·KCl for 30 minutes and one gram of magnesium oxide is added and distilled over as usual by using methyl red as an indicator.

The accuracy of method was tested and the results are given in Table VII.

Table VII.

Determination of Ammonia in Soils.

Amount of soils.	Ammonia added. $(NH_4)_2SO_4$	Ammonia recovered.	Difference.
mg.	mg.	mg.	%
50.	10.50	10.46	99.62
50.	5.25	5.24	99.81
50.	3.68	3.69	100.27
50.	2.63	2.62	99.62

Note: A definite amount of ammonium sulfate and 1 cc of toluol were added to the soil, and was left for twenty four hours before the determination was made.

As Table VII indicates, the Harper's method gives accurate result. Consequently the method was applied to the soils from each plot, and the ammonification was determined during the growth of rice. The results are given in Table VIII.

Table VIII.

Change of Ammonia Contents of Soils.

Date. \ Plots.	1.	2.	3.	5.	7.	10.	11.
	mg.	mg.	mg.	mg.	mg.	mg.	mg.
June 25.	1.451	0.810	1.293	1.132	1.454	0.808	0.807
July 4.	1.950	3.245	0.971	4.855	1.295	0.968	0.649
// 13.	1.570	2.270	2.270	3.890	2.271	1.620	0.844
// 23.	1.784	1.455	1.135	2.143	0.988	0.988	0.807
August 7.	0.324	0.325	0.	0.974	0.	0.	0.

Notes: No ammonia was detected after August 20th up to October 20th. The data indicate the amount of ammonia present in 100 grams of dried soil.

As Table VIII indicates, no ammonia was detected by the method after August 20th to October 20th.

2. Nitrification power of the soils.

The method employed for the test was phenol disulphonic method after Waksman which was described in detail in our previous publication. In this determination, the air dried soil was used without an addition of calcium carbonate but the hydrogen ion concentration of the soil was determined both before and after the test. The results of nitrification tests with average difference of P_H are given in Table IX.

Table IX.

Nitrification Power of Soils.

Date. \ Plots.	1.	2.	3.	5.	7.	10.	11.
	mg.	mg.	mg.	mg.	mg.	mg.	mg.
June 25.	1.90	5.67	2.29	6.41	4.56	3.10	2.93
July 4.	3.98	16.47	11.76	5.03	8.54	5.06	0.59
// 13.	4.78	39.73	8.96	32.68	4.24	8.59	1.24
// 23.	0.67	6.57	7.63	2.40	1.32	0.89	1.47
August 7.	3.09	12.52	13.65	5.03	15.28	3.49	0.63
// 20.	8.54	7.39	5.23	8.49	11.44	10.10	4.90
September 4.	44.50	29.83	14.32	26.51	59.75	21.35	9.93
// 20.	10.02	8.55	2.82	8.49	11.88	0.79	6.62
October 4.	0.98	3.50	0.78	1.89	1.16	1.14	0.35
// 20.	22.43	31.32	17.29	12.14	29.72	12.44	11.71
November 2.	5.45	2.92	4.76	3.33	5.51	2.72	1.26
// 17.	8.11	6.67	7.66	3.55	12.80	7.65	3.15
Average.	9.54	14.26	8.10	9.66	13.85	6.44	3.73
Initial p_H—final p_H.	1.18	1.46	1.35	1.32	1.44	1.29	1.23

Table IX indicates that the nitrification was greatest from the early part of September to the middle of October in all the plots regardless of treatment except in Plots 2 and 5 where it was found to be greatest in the middle of July. Judging from the average of each plot, the order of magnitude was as follows: Plots 2, 7, 5, 1, 3, 10 and 11.

At the sametime, the transformation of nitrate nitrogen in the original soil was determined during the season, and the results are noted in Table X.

Table X.

Change of Nitrate Nitrogen in Soils.

Date. \ Plots.	1.	2.	3.	5.	7.	10.	11.
	mg.	mg.	mg.	mg.	mg.	mg.	mg.
June 25.	0.136	0.169	0.135	0.142	0.135	0.139	0.140
July 4.	0.164	3.510	0.149	4.984	0.150	0.154	0.149
// 13.	0.229	0.592	0.269	2.935	0.247	0.227	0.218
// 23.	0.433	0.911	0.392	4.118	0.357	0.357	0.292
August 7.	0.800	0.589	0.774	6.175	0.529	0.635	0.464
// 20.	0.338	0.413	0.307	0.432	0.479	0.367	0.275
September 4.	0.367	0.297	0.304	0.251	0.253	0.248	0.163
// 20.	0.317	0.308	0.266	0.307	0.233	0.288	0.308
October 4.	0.304	0.248	0.264	0.553	0.238	0.274	0.320
// 20.	0.276	0.236	0.192	0.287	0.198	0.245	0.217
November 2.	0.168	0.123	0.086	0.058	0.072	0.061	0.053
// 17.	0.150	0.154	0.162	0.150	0.143	0.115	0.065
Average.	0.307	0.629	0.275	1.699	0.253	0.259	0.222

Notes: The data indicate the amount of nitrate nitrogen in 100 grams of dried soil.

Table X shows that Plot 5 contained the greatest amount of nitrate nitrogen, and the others were in the following order, Plots 2, 1, 10, 7 and 11.

3. Denitrification power of the soils.

The detail description of method used for the determination was given in the previous publication. As the inoculum, 1 cc. of 10% soil suspension was used, and the results are given in Table XI.

Table XI.

Denitrification Power of Soils.

Date. \ Plots.	1.	2.	3.	5.	7.	10.	11.
	%	%	%	%	%	%	%
June 25.	30.3	31.9	29.0	29.5	23.1	30.6	18.4
July 4.	35.8	36.1	42.6	30.1	35.0	32.2	26.6
" 13.	24.6	39.5	27.1	17.5	33.6	24.9	26.1
" 23.	33.7	33.0	28.4	29.0	31.7	28.4	26.1
August 7.	31.0	44.7	25.7	24.6	24·1	33.7	14.9
" 20.	23.0	34.7	28.9	21.9	16.1	23.9	16.4
September 4.	31.4	27.9	29.8	6.9	17.0	25.6	3.1
" 20.	25.3	21.1	34.5	6.9	25.5	19.9	18.5
October 4.	34.1	33.7	25.7	18.7	18.5	12.7	6.3
" 20.	24.0	28.3	21.9	6.6	2.9	21.4	7.0
November 2.	27.2	32.9	17.7	10.8	7.2	5.6	11.4
" 17.	6.5	7.6	33.0	14.0	25.8	9.2	13.7
Average.	27.2	31.1	28.7	18.0	21.7	22.4	15.7

Notes: The capacity is noted on the basis of 0.1 gram of dried soil used as an inoculum.

The greatest denitrification was observed from early part of July up to the beginning of August. The order of magnitude among the plots were as follows, Plots 2, 3, 1, 10, 7, 5 and 11.

4. Relation of the crop production to ammonification, nitrification and denitrification power of the soils.

As to the relation of crop production to ammonification, nitrification and denitrification has been investigated by Christensen[1], Fischer[2], Temple[3], Waksman[4] and others, and they did not find any definite relation among them. On the other hand, Brown[5] recognized the correlation in general while Burgess[6] found it true only when the fertility is very marked. Again it has been well recognized that a definite relation between the nitrification and crop production by Ashby[7], Löhnis[8] and others. They all agree that the change of reaction resulting from

1) Christensen, H. R., Centralbl. F. Bakt., II, 43, 1, 1915.
2) Fischer, H., Landw. Jarb., 41, 755, 1911.
3) Temple, J. C., Georgia Agr. Exp. Station, Bull. 126, 1919:
4) Waksman, S. A., Soil Science, 15, 49, 1923.
5) Brown, P. E., Jour. Agr. Research, 5, 855, 1916.
6) Burgess, P. S., Soil Science, 6, 449, 1918.
7) Ashby, S. F., Jour. Chem. Soc., 85, 1158, 1904.
8) Löhnis F., Mitteil. Landw. instit. Leipzig, 7, 1, 1905.

the nitrification or the buffer capacity of the soil has a great influence. However the relation between the denitrification and the crop production has rarely been investigated. The results of our investigation are given in Table XII and Fig. I.

Table XII.

Relation of Rice-crop to Ammonification, Nitrification and Denitrification Power of Soils.

Plots.	Crop (per Tan)		Plot 2 as 100.	Ammonification.		Nitrification.		Denitrification.	
	Grain.*	Straw.		Average.	Ratio to Plot 2.	Average.	Ratio to Plot 2.	Average.	Ratio to Plot 2.
	K.L.	Kg.		mg.		mg.		%	
1.	—	—	—	139.47	89.9	9.54	66.9	27.5	87.5
2.	0.980	1,659.5	100.0	155.07	100.0	14.26	100.0	31.1	100.0
3.	0.745	1,146.0	75.3	147.34	95.0	8.10	56 8	28.7	92.3
5.	0.920	1,428.0	80.8	145.86	94.1	9.66	67.7	18.0	57.7
7.	0 664	1,049.0	67.5	149.24	96.2	13.85	97.1	21.7	69.8
10.	0.649	916.5	67.1	145.49	93.8	6.44	45.2	22.4	72.0
11.	0.393	591.5	39.7	133.04	85.3	3.73	26.2	15.7	50.5

Note: * The rice in husk.

Figure I.

The Correlation between the Yield of Rice Crop and the bacterial Activites.

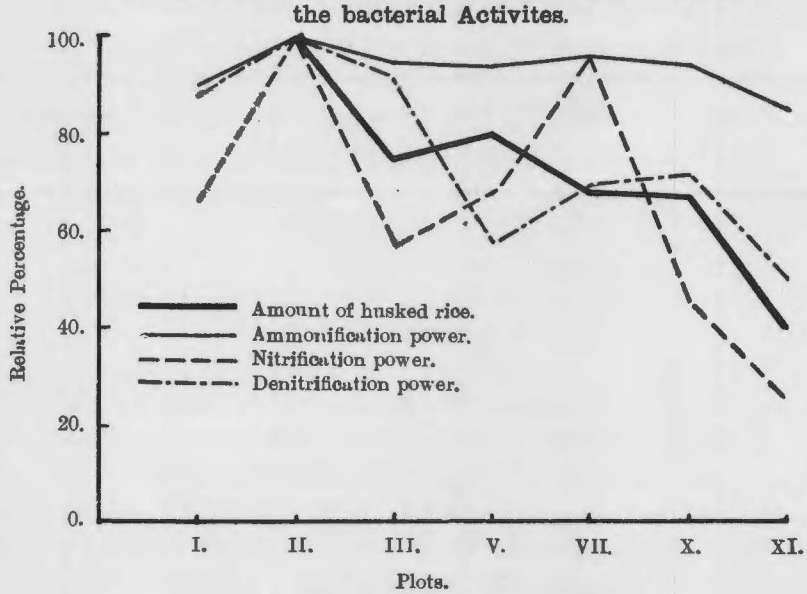

Table XIII and Fig. I indicate that there is no marked parallel relation of the crop production to ammonification, nitrification and denitrification as a whole. But in case where the crop production is very marked, somewhat a marked relation can be observed. The close relation between the crop production and nitrification has been recognized and our results substantiate the same, and also the denitrification has a similar relation while it is very doubtful in case of the ammonification.

5. Nitrification and buffer capacity of the soils.

An investigation was carried out to ascertain the relation of buffer capacity and nitrification by PIERRE's method[1] which is carried out as follows: 20 g. soil was placed in ERLENMEYER flask to which N/10 H_2SO_4 and water were added so that the ratio of soil and water becomes 1 : 5 and giving P_H 4.8. The total volume was made up to 100 cc. A wooden plug was placed in the flask and shaken occassionally. After 48 hours, P_H of the extract was determined by the quinhydrone method, and the P_H value within 0.05 of the previous determination was taken as the required value. The calculation was carried out after PIERRE, as follows:

1. Total buffer capacity toward acid = amount of cc. of standard H_2SO_4 to change the reaction of 100 g. soil to P_H 4.8.
2. Specific buffer capacity toward acid $= \frac{\text{Total buffer capacity toward acid}}{X - 4.8}$

where

X = P_H value of the original soil.

Thus the results obtained in our investigation are given in Table XIII:

Table XIII.

Relation of Buffer Capacity and Nitrification Power.

Plots.	Original P_H	Buffer capacity to reach P_H 4.8		Nitrification power of the soil.	Average, Nitrification power of soils.
		Total.	Specific.		
				mg.	mg.
1.	7.30	4.43	1.77	0.98	9.54
2.	7.20	4.43	1.85	3.50	14.26
3.	7.18	4.20	1.77	0.78	9.66
5.	7.04	4.07	1.82	1.89	8.10
7.	7.27	4.61	1.87	1.16	13.85
10.	7.36	4.61	1.80	1.14	6.44
11.	7.41	4.75	1.82	0.35	3.73

Table XIII indicates that there seems to be a parallel relation between the buffer capacity and nitrification except Plot 11 which has received no fertilizer and no crop was raised. Considering this fact in conjunction with Plot 1, the crop seems to prohibit the bacterial activity. Again in Plot 7 (compost) the bacterial activity was very marked especially the nitrification. It is interesting to note that in Plot 3 (straw), the nitrification was slightly less but the ammonification was somewhat great.

1) PIERRE, W. H., Jour. Amer. Soc. Agronomy, 19, 332, 1927.

Summary and Conclusions.

The relation of crop production to the ammonification, nitrification and denitrification of the soils from our experimental plots which have been under different fertilizer treatment as shown in Table I, was investigated and the results may be summarized as follows :

1. The ammonification was greatest from early part of August to the middle of September regardless of fertilizer and rice crop, but it is more marked in case of the Plot where the compost was applied.

2. The nitrification was most active at the beginning of September and the middle of October, and Plot 7 showed the greatest activity.

3. The denitrification was marked at the beginning of July up to an early part of August soon after the manure was applied, and it seems to be specially marked in Plot 3.

4. The parallel relation of the rice crop to the ammonification, nitrification and denitrification was not observed clearly for all the plots, but it was rather marked where the good crop was produced.

5. The parallel relation between the nitrification and the specific buffer capacity of soil was observed.