Physiological Studies on the Growth of the Paddy Rice Plant in Peat Culture, with Special Reference to the Peat Conditions and the Nitrogen Source.

By

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(With 9 Text-figures)

The term "peat" is commonly used to designate a layer of the earth's crust which is largely organic in nature possessing biological, chemical and physical properties utterly differ from those of soil. Poor development[1] of higher plants in peat-bog may occur as a result of the unfavorable nature of peat, which is brought about through imperfect drainage, poor physical structure, high acidity and pathogenic microorganisms. Furthermore, substances of an organic nature, directly injurious to plant growth, may be present in peat. Peat is highly acid[2] in reaction, which may be partially attributed to the presence of colloidal humus substances of various chemical natures, and partly to the various organic acids. HISSINK (1928–1929) and others[3] are of the opinion that intimate relations exist between the plant growth and humic acid.

HILITZER (1932) and WIELER (1932) do not attach importance to the action of hydrogen ion concentration of peat, but the former recognizes rather a special action of humic acid or auximone on the plant growth. Though it is naturally obvious that various factors together have bearing upon the plant growth in peat, we can not deny the important influence of hydrogen ion concentration, either

1) MONTFORT (1922), WAKSMAN (1936).

2) ARND (1924), KEPPELER und HOFFMANN (1925), STOKLASA (1925), ARRHENIUS (1924, 1926), MEVIUS (1927), WAKSMAN and STEVENS (1928), TACKE und ARND (1928), KAPPEN (1929), MCCOLL (1932, a), RUSSEL (1932), WAKSMAN (1936).

3) TACKE und ARND (1928), NIESCHLAG (1929), ASLANDER (1930, 1932), ROBINSON (1930), HICKS (1932), MCCOLL (1932, b).

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direct or indirect. In previous papers (1929, 1935) the writer has pointed out that the bad plant growth in the culture solution containing urea in high concentration may be partly attributed to an extreme decrease of the hydrogen ion concentration, which occurs on account of rapid decomposition of urea into ammonia in a comparatively short time. Highly favourable plant growth occurs, however, if harmony between the acid reaction of peat and the application of such a physiological basic manure as urea in proper amount is secured.

The buffer action of soil is an important factor for its reaction change, and it varies in accordance with its kind. Therefore, the difference of composition and buffer action of soil may affect the plant growth variously, and the mixing of different soils would be worth practicing in view of these facts. Soil mulching is now widely practiced for the purpose of improvement of unproductive soils, though sufficient theoretical and experimental studies on this procedure have not been made.

Field cultures, which would be carried out in order to investigate this problem, do not permit the securing of satisfactory results, because the conditions in such a case are very complex. The experiments in the present investigation were carried out mostly by the pot culture in the net house, the acid reaction of peat, the kind of soils, the nitrogen sources and the plant growth being taken into consideration. In the present paper, the results of the soil culture with paddy rice plant, dealing with the problems mentioned above, will be reported. This may show how important the improvement of peat is for the culture of paddy rice plants and how important the proper application of soil mulching as well as of manures is for this purpose.

Experimental Method

1. Method of culture and kind of soil.

The experiments were carried out in soil culture in the green house communicating with an open net house, using peat, clayey loam, coarse sand, and their mixtures, sometimes in water culture. The porcelain culture vessels were of cylindrical form. Seeds of paddy rice were supplied by the Agricultural Experimental Station, Hokkaido Government, for which the writer wishes to express here his hearty thanks.

2. Determination of the hydrogen ion concentration of soil.

The hydrogen ion concentration of soil was determined by using the antimony electrode, hydrogen electrode or BIJLMANN's quinhydrone electrode, and often by the colorimetric method of CLARK and LUBS, among which the antimony electrode was most suitable. The use of the antimony electrode has great advantage for the quick determination of C_H in a wide range; for soil it has been used by SNYDER (1928), BARNES and SIMON (1932) with satisfactory results. ITANO (1926, 1929), ITANO and ARAKAWA (1930, a. b.) made comparative studies on the efficiency of the antimony electrode and of the quinhydrone electrode for the determination of pH-value of soil, and came to the conclusion that the former can be used for this purpose with greater satisfaction; especially in the case of soil containing sulfurous substances, where the quinhydrone electrode fails.

The relation between the pH-value and electromotive force of solution with known C_H was graphically indicated, and by the aid of this graph the pH-value of a sample solution was determined from the measured electromotive force. The antimony electrode was prepared as follows: powdered antimony of KAHLBAUM was melted in a hard glass tube, it was put into water in an instant, the glass tube was broken, and an antimony rod was secured. For the preparation of an electrode the antimony rod was inserted into the end of a glass tube and sealed with DEKHOTINSKY cement. The pH-values of soil in certain culture pots somewhat differed from each other in accordance with the depth of soil and method of preparation of soil suspension. As such differences of the measured pH-values cannot be overlooked for the purpose of the present work, the following experiment was carried out in order to obtain the most proper method for the preparation of soil suspension.

Preparation of Soil Suspension and its Hydrogen Ion Concentration.

Experiment I.

Sample was taken from three parts in one pot, namely; 1. at the soil surface; 2. at 6 cm. depth; 3. at 12 cm. depth. A non-alkaline glass tube of 1 cm. diameter, which was covered with a doubled gauze at its lower end, was inserted into soil 6 and 12 cm. deep. The other end of the glass tube was exposed in the air for about 1 cm. and covered with cotton. Water which entered into the glass tube from the lower end through the doubled gauze was taken with a pipette and thrown away. After a while water entered again; it was used for the determination of the hydrogen ion concentration. Soils of the following kinds were used:

1. peat
2. mixed peat (2) and clayey loam (1)
3. mixed peat (1) and clayey loam (2)
4. clayey loam.

The composition of the culture solution was made up as follows:

(A)	KH_2PO_4	0.250 gm.
	$MgSO_47H_2O$	0.250 gm.
	KCl	0.120 gm.
	$CaCl_22H_2O$	0.090 gm.
	$FeCl_3$(2%)	5 cc.
	tap water	1000 cc.
(B)	nitrogen source	
	1. $(NH_4)_2SO_4$	0.805 gm.
or	2. $CO(NH_2)_2$	0.366 gm.
	tap water	1000 cc.

Part A and one of the nitrogen sources (B) were added together to each pot. After manuring, seedlings of paddy rice plant were planted in the pot, and the initial pH-value of soil from different parts was determined on a certain day (Table I).

As the subsequent determinations which were made on Dec. 28, 1931, Jan. 22 and 26, and March 14, 1932, were nearly the same as those of Dec. 8–16, 1931 shown in Table I, the description of the results is omitted here. From Table I, it will be seen that the pH-value varies in different parts of the culture pot. Such local difference of the pH-value in a peat pot was smaller than that in the cultures of other soil kinds, for instance, clayey loam or mixed soil of peat and clayey loam. The pH-value of the surface water in the peat culture was larger than that of water taken at the 6 or 12 cm. depth, but the pH-values of the latter two samples were nearly equal. Also the pH-values of every kind of soil varied in accordance with the depth, or at least, such a tendency of the local difference of pH-value was generally recognized, no matter what the kind of soil, nitrogen source or manuring method. The following may be regarded as the responsible factor for such a local difference of pH-value:

Experimental Data

Table I

Exp. I. Dec. 8–16, 1931

Soil	N-source	Manuring	pH of soil water		
			Surface	6 cm. deep	12 cm. deep
Peat	Amm. sulphate	Once	4.4	3.9	4.0
	Urea	Once	4.9	4.4	4.2
	{ Amm. sulphate (2) Urea (1)	Once	4.3	4.1	4.2
	{ Amm. sulphate (1) Urea (2)	Once	4.3	4.1	4.1
	Urea	Twice	3.9	4.0	4.2
	Urea	Thrice	3.9	4.1	4.2
Peat (2) Clayey loam (1)	Amm. sulphate	Once	4.2	4.7	4.1
	Urea	Once	6.0	5.8	6.3
	{ Amm. sulphate (2) Urea (1)	Once	4.3	5.0	5.6
	{ Amm. sulphate (1) Urea (2)	Once	4.4	5.9	6.1
	Urea	Twice	4.4	4.9	5.0
	Urea	Thrice	4.4	5.1	5.2
Peat (1) Clayey loam (2)	Amm. sulphate	Once	4.5	5.8	5.4
	Urea	Once	4.9	5.8	7.0
	{ Amm. sulphate (2) Urea (1)	Once	4.7	5.8	6.4
	{ Amm. sulphate (1) Urea (2)	Once	4.8	5.9	6.2
	Urea	Twice	4.7	5.9	6.0
	Urea	Thrice	4.7	6.2	5.8
Clayey loam	Amm. sulphate	Once	4.7	5.9	5.6
	Urea	Once	5.6	6.6	6.7
	{ Amm. sulphate (2) Urea (1)	Once	4.9	6.1	6.7
	{ Amm. sulphate (1) Urea (2)	Once	5.1	6.1	6.1
	Urea	Twice	5.2	6.1	6.1
	Urea	Thrice	5.2	6.1	5.8

physical properties of soil, especially the size of soil particles, pore space, chemical and colloidal properties. For instance, the nature of peat is irregular in shape or composition and it does not pack closely, so that large pore spaces appear in it. This facilitates the movement of water and substances in pot, which can not be seen in clayey loam. In the present experiment, the root of paddy rice plant closely occupied the 6–12 cm. depth. As already stated, the hydrogen ion concentration in the 6 cm. depth is nearly equal to that in the 12 cm. depth, and the root developed nearly always in these depths. Accordingly the soil water in the 6 cm. depth was used as the most reasonable and suitable material for the determination of the pH-value.

Hydrogen Ion Concentration of Peat and Other Soils

Clayey loam was got from the non-manured section of the experimental field of The First Farm of our university and coarse sand was obtained from the Toyohira river. Peat was secured from Shinkawa, Kotoni village in the vicinity of Sapporo. Clayey loam and peat were crushed with a wood mallet, and the soil particles were separated into three groups, using metallic sieves of less than 1.0 mm., 0.8 cm., and 1.5 cm. mesh. The mixed soils were prepared by adding clayey loam or coarse sand to peat. The hydrogen ion concentration of these soils was determined, using the aqueous suspension or soil extract, by means of the antimony electrode.

Experiment II.

The results were as follows:

Peat.	Aqueous suspension, fine grain, of which the diameter was less than 1 mm.	pH 4.2
Clayey loam.	Same as the former.	pH 5.6
Mixed soil (peat (2) plus clayey loam (1)).	Same as the former.	pH 4.2
Mixed soil (peat (1) plus clayey loam (2)).	Same as the former.	pH 4.9
Peat.	Extracted solution, diameter of grain less than 1 mm.	pH 3.5
Peat.	Aqueous suspension, diameter of grain less than 1.5 cm.	pH 3.5
Peat.	Aqueous suspension, diameter of grain less than 0.8 cm.	pH 4.4
Clayey loam.	Aqueous suspension, diameter of grain less than 0.8 cm.	pH 5.4
Mixed soil (peat (1) plus clayey loam (2)).	Aqueous suspension, diameter of grain less than 0.8 cm.	pH 4.8
Mixed soil (peat (2) plus clayey loam (1)).	Aqueous suspension, diameter of grain less than 0.8 cm.	pH 4.5

Coarse sand Aqueous suspension. pH 6.5
Mixed soil (peat (1) plus coarse sand (1)).
Aqueous suspens'on, diameter of grain less than 0.8 cm. pH 4.4
Mixed soil (peat (1) plus coarse sand (1)).
Aqueous suspension, diameter of grain less than 1.5 cm. pH 4.4

These results show that the peat has a distinctly more acidic reaction (pH 3.4–4.2) than the reactions of coarse sand and clayey loam (pH 5.4–6.5), and the pH-value of aqueous suspension of peat is larger than that of its extract. This difference of pH-value may be attributed to the procedure of filtration and the quality of filter paper, because it is a well known fact that filter paper causes a reaction change of distilled water or salt solution.[1]

Buffer Action of Soil.

Loo (1927b) and YAMAGUCHI (1935) pointed out that the initial pH-value of the culture medium and the buffer capacity of the solution have very remarkable bearing upon the plant growth, and that if the initial pH-value is not suitable for the growth, the solution with strong buffer action is rather injurious to the plants. So far as intimate relationship exists between the growth of paddy rice plant and the reaction change of soil, attention should be paid to the buffer action of soil. In the peat or soil-culture, for which urea was used as a nitrogen source, the hydrogen ion concentration of these media decreased in accordance with the degree of the decomposition of urea. In such a case, the reaction change of soil depended on the amount of ammonia which was produced by the decomposition of urea and the buffer action of soil. In order to learn the influences of the buffer action upon the plant growth, the following experiment was carried out.

Experiment III.

The buffer capacity of soil was determined by the method of ARRHENIUS (1922), and shown by the titration curve using 0.1 N HCl, 0.1 N NH_4OH, 0.1 N NaOH and 0.1 N $Ba(OH)_2$ solutions. The pH-value was determined with an antimony electrode.

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1) ATKINS (1924), GUSTAFSON (1928), TAMIYA und ISHIUCHI (1926), WIEGNER und GESSNER (1926).

The soils used were as follows:

A. (soil grains of comparatively large size, smaller than 1.5 cm. in diameter)
   1. peat
   2. coarse sand
   3. mixed soil, peat (1) and coarse sand (1)
   4. clayey loam
   5. mixed soil, peat (1) and clayey loam (2)
   6. mixed soil, peat (2) and clayey loam (1)

B. (soil grain of middle size, smaller than 0.8 cm. in diameter)
   1. peat (soil grains smaller than 0.8 cm. in diameter)
   2. coarse sand (soil grain smaller than 0.5 cm. in diameter)
   3. clayey loam
   4. mixed soil, peat (1) and clayey loam (2)
   5. mixed soil, peat (2) and clayey loam (1)

C. (soil grain of fine size, smaller than 1 mm. in diameter)
   1. peat (soil grain smaller than 1 mm. in diameter)
   2. clayey loam (soil grain smaller than 1 mm. in diameter)
   3. mixed soil, peat (1) and clayey loam (2)
   4. mixed soil, peat (2) and clayey loam (1)

From the titration curves (Figs. 1–7), it may be concluded that peat has the greatest buffer capacity, clayey loam comes next, and coarse sand has the smallest, when it was titrated with alkali. But in the case of the addition of acid the buffer capacity of clayey loam is the greatest, peat comes next, and coarse sand is the smallest. The results obtained by many other authors[1] agree in the general principle with those of the writer: peat has the greatest buffer capacity either in the case of titration with alkali or with acid. Next the buffer capacity of the extract of peat, was determined: To ten grams of dry peat 30 cc. of distilled water was added, and allowed to stand for four days, being shaken at intervals, and then filtered. The titration curves (Figs. 8 and 9) were secured by additions of regulated amounts of 0.1 N $NaOH$, 0.1 N $Ba(OH)_2$ and 0.1 N NH_4OH. From Figs. 8 and 9 it may be seen that the buffer capacity of extract of peat is very weak in the case of the addition of alkali and its strongest buffer action is noticed when NH_4OH is added. The peat extract no more shows a buffer action strong enough for measurement, when $Ba(OH)_2$ or $NaOH$ are added, and it has almost no

1) TARR (1925), HISSINK und SPEK (1926), KAPPEN (1926), WIEGNER und GESSNER (1926), BERMANN (1928), ARND (1931).

buffer capacity in the practical meaning. From this point it may be said that the buffer action of peat depends mostly upon the physical as well as chemical natures of the peat-bog itself, but scarcely upon those characters of its solution.

Relation between the Growth of Paddy Rice Plant in Peat, Soil Cultures and the Nitrogen Source

The results of the foregoing experiments show that the reaction of peat shows acidic and that it has great buffer capacity against the addition of alkali. The following four experiments were carried out in order to ascertain the relation between the growth of paddy rice plant and the reaction change of peat, which depends upon the kind of nitrogen source and of soil. The clayey loam and peat used in this experiment were the same as those in Experiment III. The materials were crushed with a wood mallet and soil grains of several sizes separated using a metal sieve of 1 mm. square mesh. Rice seedlings (Bôzu No. 6) were grown in the germinating vessel in the green house, and uniformly grown materials were planted in cylindrical culture pots of porcelain. Both the depth and diameter of the pots were about 14.2 cm. Each pot was sufficiently filled with the soils, and then the nutrient salt solutions added. The kind and amount of soils used in each pot were as follows:

Fig. 1

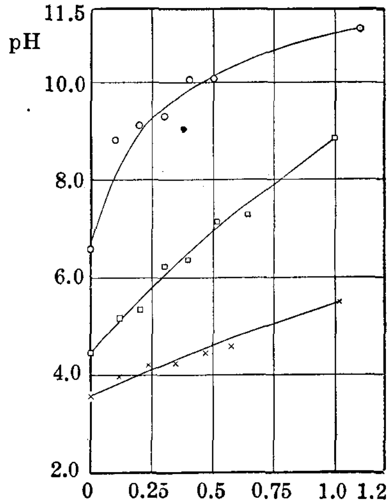

Fig. 1. Titration curves of peat, coarse sand and a mixed soil, peat and coarse sand. Titrated with 0.1 N NaOH (soil grains of large size).
○ coarse sand.
□ peat (1) plus coarse sand (1).
× peat.

Volume of soil (cc.)

Kind of soil	I	II	III	IV
Peat	1800	1200	600	0
Clayey loam	0	600	1200	1000

Fig. 2

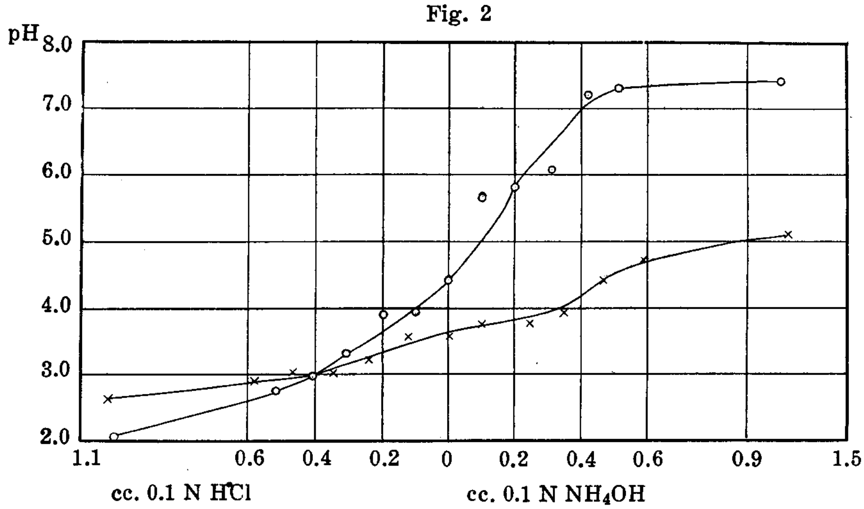

Fig. 2. Titration curves of peat and a mixed soil, of coarse sand and peat. Titrated with 0.1 N HCl and 0.1 N NH_4OH (soil grains of large size).

○ peat (1) plus coarse sand (1). × peat.

Fig. 3

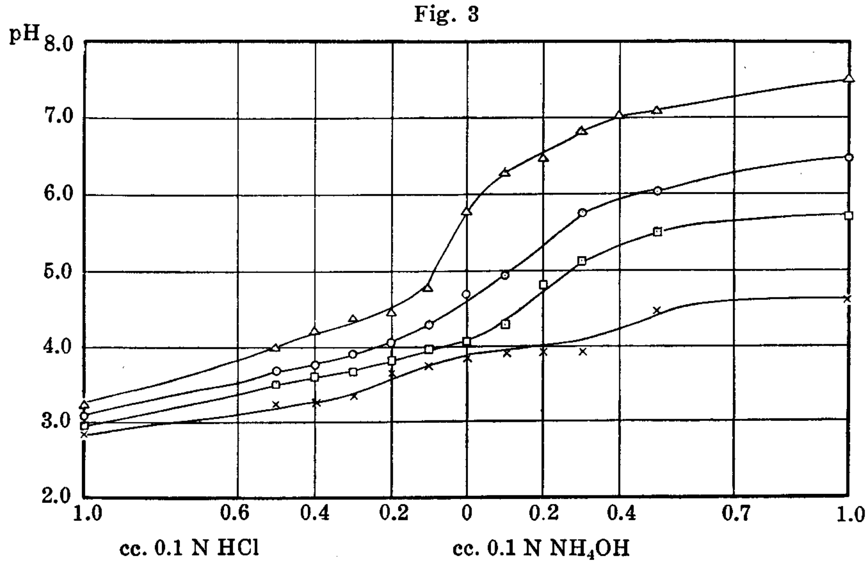

Fig. 3. Titration curves of clayey loam, peat and two mixed soils, clayey loam and peat. Titrated with 0.1 N HCl and 0.1 N NH_4OH (soil grains of large size).

△ clayey loam. ○ clayey loam (2) plus peat (1).
□ clayey loam (1) plus peat (2). × peat.

Fig. 4

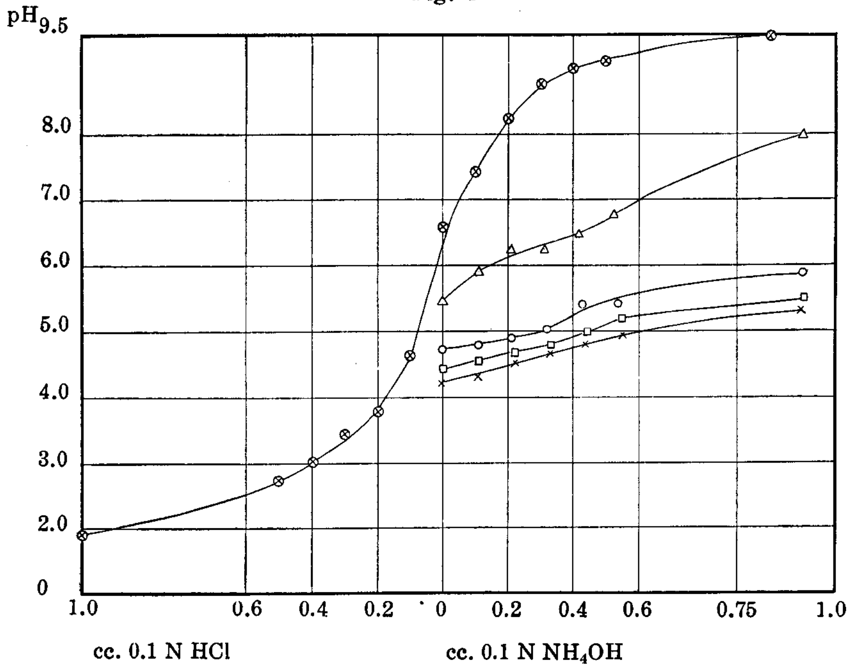

Fig. 4. Titration curves of clayey loam, coarse sand and two mixed soils. Titrated with 0.1 N HCl and 0.1 N NH_4OH (soil grains of middle size)

⊗ coarse sand.
○ peat (1) plus clayey loam (2). △ clayey loam.
□ peat (2) plus clayey loam (1). × peat.

The amount of nutrient salts given per pot was as follows:

(A)	KH_2PO_4	0.500 gm.
	$MgSO_47H_2O$	0.500 gm.
	$CaCl_22H_2O$	0.179 gm.
	KCl	0.240 gm.
	$FeCl_3$(1%)	2 cc.
(B)	(nitrogen source)	
	1. $(NH_4)_2SO_4$	1.610 gm.
or	2. $CO(NH_2)_2$	0.723 gm.

Part A was given to each pot, but the manuring of nitrogen source (B) was carried out in the following five ways.

N-source and manuring		Amount of N-source (gm)	
		H_2SO_4	Urea
Ammonia,[1)	once	1.610	0
Urea,	once	0	0.732
{ Ammonia Urea,	once, both together	0.805	0.366
Urea,	twice	0	0.366 (in each manuring)
Urea,	thrice	0	0.244 (,,)

Fig. 5

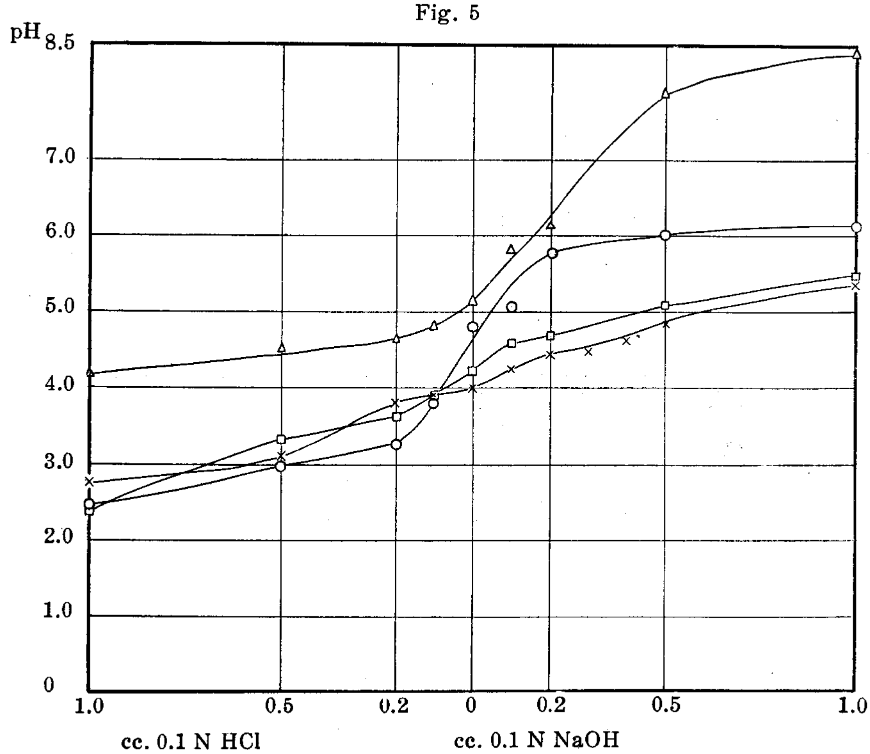

Fig. 5. Titration curves of peat, coarse sand and two mixed soils. Titrated with 0.1 N HCl and 0.1 N NaOH (soil grains of fine size).

△ clayey loam. ○ clayey loam (2) plus peat (1).
□ clayey loam (1) plus peat (2). × peat.

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1) In the form of ammonium sulphate. The same thing applies in the following.

Fig. 6

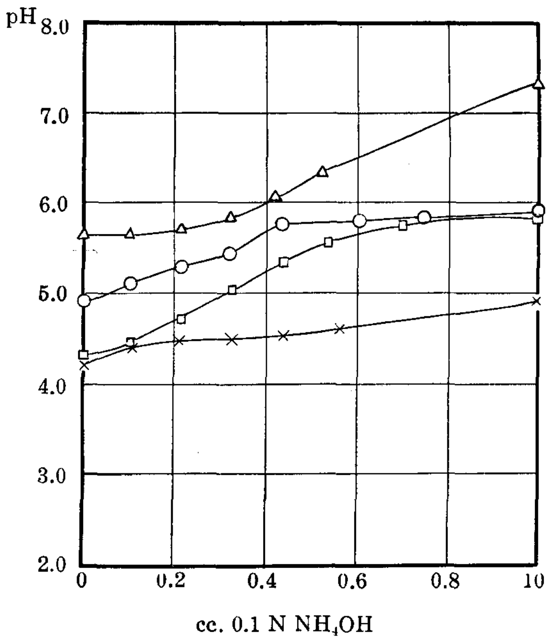

Fig. 6. Titration curves of peat, coarse sand and two mixed soils. Titrated with 0.1 N NH_4OH (soil grains of fine size).

△ clayey loam. ○ clayey loam (2) plus peat (1).
□ clayey loam (1) plus peat (2). × peat.

Fig. 7

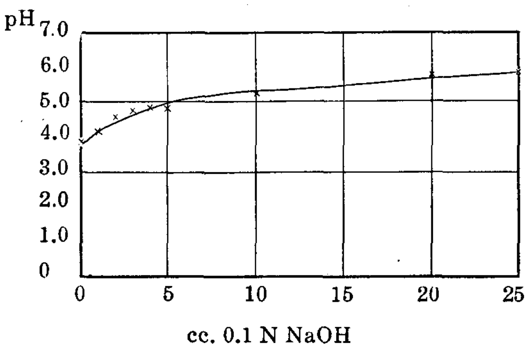

Fig. 7. Titration curve of peat. Titrated with 0.1 N NaOH (peat grains of middle size).

Experiment IV.

Four rice seedlings (shoot ca 23.0 cm. and root ca 11.0 cm. long) were planted in each pot at the beginning of the experiment[1]. Two of them were selected out after a week. Temp.: 17°–34°C (April), 15°–34°C (May), 15°–37°C (June). April 14–June 26, 1932, Peat (fine), Table II.

Fig. 8

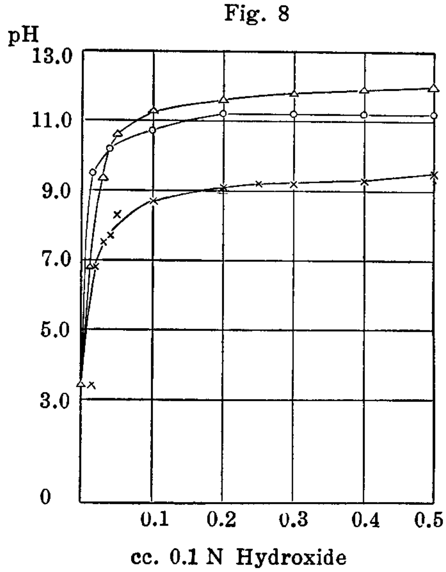

Fig. 8. Titration curves of extracted solution of peat. Titrated with 0.1 N NaOH, 0.1 N $Ba(OH)_2$ and 0.1 N NH_4OH. △ NaOH. ○ $Ba(OH)_2$. × NH_4OH.

Fig. 9

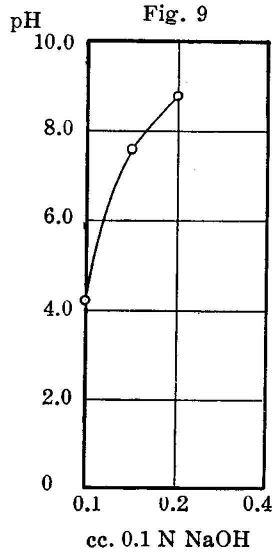

Fig. 9. Titration curve of extracted solution of peat (peat grains of middle size). Titrated with 0.1 N NaOH. extracted solution (60 cc.) plus water (40 cc.)

The growth of seedlings and the tillering were best when the plants were manured with urea one time. The use of ammonium sulphate only caused the worst growth, and the combined application of both urea and ammonium sulphate or repeated manuring with urea two or three times resulted in intermediate growth (Table II). The initial pH-value of peat provided with ammonium sulphate only was nearly 4.6–5.3, and it became less acidic during the culture (pH 4.4–6.5). The degree of the reaction change of peat, manured

1) The same procedures as to material and temperature were applied to Exps. V, VI and VII, too.

with urea or in the case of combined application of ammonium sulphate and urea, varied only slightly according to the manuring method. But the pH-value of peat manured with urea was always larger than that manured with ammonium sulphate, independently of the manuring procedure. Such a reaction change of the culture solution during the course of culture depends certainly upon the nature of the physiological alkalinity and acidity of urea and am-

Table II

Exp. IV.

N-source	pH				Length of shoot (cm)				Green weight of shoot (gm)	Number of tillers per seedling
	14/IV (initial)	30/ IV	7/ V	14/ V	30/ IV	11/ V	24/ V	26/ VI		
Ammonia,[1] once	4.6	4.7	—	5.3	24.7	35.0	45.0	50.0	6.0	5.5
Urea, once	4.7	5.7	—	6.1	33.5	38.0	45.0	75.0	13.5	11
{Ammonia, Urea, once	4.5	4.7	—	6.3	33.0	41.5	60.0	75.0	16.0	8.5
Urea, twice	4.4	5.6	5.6	6.0	28.0	39.0	60.0	72.0	13.0	9
Urea, thrice	4.4	5.6	6.4	6.5	23.5	32.0	40.0	70.0	8.0	7.5
Not given	4.2	5.0	—	5.4	26.0	31.0	40.0	60.0	7.0	5

monium sulphate respectively. Under natural conditions and in the ordinary soil culture urea is decomposed into ammonia and carbonic acid by the action of bacteria or with aid of urease contained in the plant bodies, and the ammonia thus formed plays a rôle in the reaction change of the culture solution. This is naturally influenced by many factors, especially by the manner of manuring and amount of urea.

The acid reaction of peat was regulated by the addition of clayey loam and the growth of rice seedlings in such mixed soil was investigated.

1) In the form of ammonium sulphate. The same thing applies in the following tables.

Experiment V.

April 14–June 26, 1932. Peat (2) plus clayey loam (1) (both fine). Table III.

Table III

N-source	pH				Length of shoot (cm)				Green weight of shoot (gm)	Number of tillers per seedling
	14/IV (initial)	30/IV	7/V	14/V	30/IV	11/V	24/V	26/VI		
Ammonia, once	4.4	5.2	—	5.7	41.2	60.5	66.0	85.0	16.5	8
Urea, once	4.6	6.8	—	6.7	27.7	49.0	53.0	95.0	24.5	10
{Ammonia, Urea, once	4.6	5.8	—	7.3	24.0	46 5	60.0	78.0	14.5	6
Urea, twice	4.7	6.1	7.2	7.3	28.0	46.5	65.0	85.0	15.5	8
Urea, thrice	4.5	5.4	6.3	7.5	33.5	57.5	76.0	95.0	21.0	7.5
Not given	4.5	5.0	—	6.0	34.0	53.5	70.0	75.0	11.0	3

Experiment VI.

April 14–June 26, 1932. Peat (1) plus clayey loam (2) (both fine). Table IV.

Table IV

N-source	pH				Length of shoot (cm)				Green weight of shoot (gm)	Number of tillers per seedling
	14/IV (initial)	30/IV	7/V	14/V	30/IV	11/V	24/V	26/VI		
Ammonia, once	4.9	4.7	—	6.5	46.5	63.0	76.5	108.0	37.0	11
Urea, once	5.7	6.7	—	7.3	35.5	54.0	83.0	113.0	33.0	11
{Ammonia, Urea, once	5.1	5.6	—	7.4	23.0	37.5	61.0	92.0	24.0	8.5
Urea, twice	5.3	5.9	6.9	8.2	31.0	54.5	69.0	105.0	26.0	8
Urea, thrice	4.9	5.5	7.1	7.4	37.5	58.5	80.0	100.0	32.0	11
Not given	4.5	5.5	—	5.4	27.5	43.0	70.0	85.0	14.5	5

From Tables III and IV it will be seen that the pH-value of the mixed soil manured with urea became larger than that of the same soil manured with ammonium sulphate. Such a reaction change of the mixed soil depends largely upon the ratio between the amounts peat and clayey loam, and the method and time of manuring urea. The reaction change of the mixed soil which contains more peat than clayey loam was similar to that of peat itself, but that of the mixed soil which contains more clayey loam than peat was similar to that of clayey loam itself. For such a manner of reaction change, the buffer capacity of peat and clayey loam may be considered as one of the most responsible determining factors. The growth of seedlings manured with urea one time was comparatively poor. From this fact it may be concluded that urea in large amount does not serve as a favourable nitrogen source. These points will be touched upon again in the following paragraph.

Experiment VII.

April 14–June 26, 1932. Clayey loam (fine). Table V.

Table V

N-source	pH				Length of shoot (cm)				Green weight of shoot (gm)	Number of tillers per seedling
	14/IV (initial)	30/IV	7/V	14/V	30/IV	11/V	24/V	26/VI		
Ammonia, once	5.3	5.0	—	6.1	39.0	61.5	76.5	100.0	32.5	9
Urea, once	5.5	5.8	—	6.3	36.7	46.5	75.0	120.0	29.5	9.5
{Ammonia, Urea, once	6.7	6.8	—	6.8	21.5	39.5	56.0	88.0	23.5	9.5
Urea, twice	5.7	6.7	7.5	7.1	32.7	52.0	73.0	100.0	27.5	9
Urea, thrice	5.3	5.9	7.0	7.4	50.0	63.0	76.0	110.0	34.0	7
Not given	5.3	5.2	—	5.5	30.5	55.5	70.0	75.0	13.0	4.5

From Table V it may be seen that the growth of seedlings manured with ammonium sulphate or three times with urea was the best, that of the seedlings without the nitrogen-manuring was the worst, and that of the seedlings manured with urea or with urea and ammonium sulphate combined showed an intermediate growth between them. Such differences of plant growth may be attributed to the kind of nitrogen source and the method of the manuring. These factors caused the reaction change of culture conditions, which affords ill or good effects on the growth of seedlings in turn. The results of the experiments described above are in agreement with those of the writer's previous paper (1936), in which peat and clayey loam in the natural state were used. In conclusion, from the results of experiments IV, V, VI and VII it may be said that a good growth of rice plant occurs, if the unfavourable conditions of peat are improved by mulching with clayey loam, and by application of urea as nitrogen source instead of ammonium sulphate, especially when it is given many different times.

Relation between the Growth of Paddy Rice Plant in Peat, the Kind of Mulched Soil and the Nitrogen Source

In the foregoing experiments it was ascertained that the growth of rice plant in the peat culture was poorer than that in mixed soil of peat and clayey loam, and also that the nitrogen source exerted a widely various influence upon the soil reaction. The good effect of mixing of clayey loam and peat was not only on account of the buffer capacity of the soils and the added amount of various nutrients contained in the clayey loam, but also on account of the action of microorganisms. It has been shown by ARND (1926) and STOKLASA (1925) that the species and number of microorganisms depend upon the soil reaction and soil conditions, especially in the case of urobacteria[1)] in peat or acidic soils. Mixing two soils, of which the chemical and physical properties differ, such as peat and coarse sand, is very reasonable for the soil improvement.

The following experiments were carried out in order to see the relation between the sorts of mulched soil, and the plant growth in peat culture, sufficiently provided with urea, urine, ammonium sulphate or sodium nitrate as nitrogen source.

The peat, clayey loam and course sand used in this experiment were the same as those in Experiment III above. The uniformly developed rice seedlings were planted in cylindrical culture pots of porcelain in the green house. The depth and the diameter of the pots

1) GIBSON (1930), MISCHOUSTIN (1932).

were each about 14.2 cm. Each pot was filled up with soil, and the dissolved nutrient salts were added. The kinds and amounts of soil used for each pot were as follows:

1. peat
2. mixed peat (4) and coarse sand (1)
3. mixed peat (1) and coarse sand (1)
4. coarse sand
5. clayey loam
6. mixed peat (4) and clayey loam (1)
7. mixed peat (1) and clayey loam (1)

Grains of the peat were smaller than 0.8 cm. in diameter, and those of the coarse sand were smaller than 0.25 cm. in diameter. Nutrient salts given per each pot were as follows:

(A)	KH_2PO_4	0.500 gm.
	$MgSO_4 7H_2O$	0.500 gm.
	$CaCl_2 2H_2O$	0.179 gm.
	KCl	0.240 gm.
	$FeCl_3$	0.002 gm.
(B)	(nitrogen source)	
	a) $(NH_4)_2SO_4$	0.805 gm.
or	b) $CO(NH_2)_2$	0.366 gm.
or	c) Urine[1]	12 cm.
or	d) $NaNO_3$	1.036 gm.

It is a well known fact that sodium nitrate is an unfavourable nitrogen source for the culture of paddy rice plant, though the reason of its unfitness is not yet known[2]. As the reaction change of the culture solution with sodium nitrate became less acidic or more alkaline during the course of culture, this nitrogen source was used for the purpose of reduction of acidity of peat. Part A was given in all cultures, and the nitrogen sources were shown in the following table. The total number of cultures was 77. The pH-value of the soil solution in the pot was determined by the method described under Experiment I, employing the antimony electrode.

1) The amount of urea or ammonia in urine was determined by the micro-KJELDAHL method, after the hydrolysis by the aid of urease. The amount of urine-nitrogen was nearly equivalent to that of the other nitrogen source.

2) NAGAOKA (1904), DAIKUHARA and IMASEKI (1907), KELLEY (1911), WILLIS and CARRERO (1933), LOO (1927, a. b), METZGER and JANSSEN (1928), YAMAGUCHI (1935).

No. of cultures	Nitrogen source	Manuring
1.	Ammonia	B, once
2.	Ammonia (1) Urea (1)	B, both together, once
3.	Urea	B, once
4.	Urea	double B, manured 75% at the beginning, 25% afterwards
5.	Urea	thrice B, manured 66% at the beginning, 33% afterwards
6.	Urea	five times B, manured 60% at the beginning, 40% afterwards
7.	Urine	double B, once
8.	Urine	four times B, once
9.	Nitrate	double B, once
10.	Nitrate	four times B, once
11.	not given	

Three seedlings (shoot ca. 20 cm. and root ca. 9.5 cm. long[1)]) were planted in each pot on the 30th June. The seedlings were cultured preliminarily from June 6–30, 1932.

Temp: 22°–34°C (June), 20°–39°C (July), 16°–39°C (August), 11°–32°C (September), 13°–27°C (October).

Experiment VIII.

June 29–Oct. 4, 1932, Peat. Table VI.

Experiment IX.

June 29–Oct. 4, 1932, Peat (4) plus coarse sand (1), Table VII.

Experiment X.

June 29–Oct. 4, 1932, Peat (1) plus coarse sand (1), Table VIII.

Experiment XI.

June 29–Oct. 4, 1932, Coarse sand, Table IX.

1) The same things concerning material and temperature were also applied to Exps. IX, X, XI, XII, XIII and XIV.

Experiment XII.

June 29–Oct. 4, 1932, Clayey loam, Table X.

Experiment XIII.

June 29–Oct. 4, 1932, Peat (1) plus clayey loam (1), Table XI.

Experiment XIV.

June 29–Oct. 4, 1932, Peat (4) plus clayey loam (1), Table XII.

The initial pH-values of the several soils—peat, clayey loam, coarse sand and the mixtures of them—varied between 4.0 and 6.6 as indicated in Tables VI–XII. But the change of hydrogen ion concentration of each soil occurred variously during the course of culture in accordance with the kind and amount of nitrogen source and manuring method. In general, when ammonium sulphate or a combination of ammonium sulphate and urea was applied, the reaction of the peat and other soils either remained unchanged or became more acidic, except in the case of peat (4) plus coarse sand (1) and clayey loam, where it became less acidic. But if the soils were fertilized with urea or urine, the reaction became alkaline or less acidic. The physiologically acidic and alkaline nitrogen sources showed always the opposite tendency to the reaction change of soils, and the degree of reaction change varied according to the kind of soil. For instance, the reaction change in the sand culture manured with urea (Table IX) extended over a wider range than in the peat culture manured with urea (Table VI). A similar phenomenon was seen in other soils (Tables VI–XII). Therefore it can be seen that the reaction change of soil depends upon the kind of soil or the ratio of amount of mixed soils, even if the same nitrogen source was used. The different properties of soil causes in the various degrees of decomposition of urea or urine and then variation of reaction change of soil in connection with the difference of the soil's buffer capacity as already stated in Experiment III. Furthermore it may be seen that not only the nature of the soil proper, but also the amount of the nitrogen source and the manner of application of manuring have to do with reaction change of soil (Tables VI–XII). The growth of rice plants in the peat culture with urea or urine, and in the clayey loam, coarse sand, and mixed soil culture with ammonium sulphate or urea was very good. The growth of plants in the several cultures with double standard doses of sodium nitrate

Table VI

Exp. VIII.

Culture	N-source	pH				Appearance of plant at time of harvest					
		28/VI (initial)	9/VII	30/VII	12/VIII	Number of tillers per seedling	Total green weight of shoot (gm)	Average length of shoot (cm)	Colour of leaf	Total weight of c ryopsis (gm)*	Total volume of caryopsis (c.c.)*
1	Ammonia	4.0	4.0	3.8	4.4	4	4.5	3.0	Gray	0.5	2.5
2	{Ammonia (1) Urea (1)	,,	4.0	3.9	4.1	11.6	37.0	5.7	Green	9.0	37.0
3	Urea	,,	4.4	4.3	4.8	10.3	40.0	6.0	Gray	10.0	48.0
4	Urea	,,	4.5	4.9	5.2	11.3	42.5	5.8	,,	7.5	50.0
5	Urea	,,	4.4	4.7	5.7	13	39.0	5.3	,,	11.0	49.0
6	Urea	,,	4.2	5.4	6.4	13.3	30.0	4.8	,,	3.0	34.0
7	Urine	,,	5.1	4.2	4.4	13.6	34.5	4.7	Green	4.5	40.0
8	Urine	,,	4.9	4.9	6.8	5.3	11.0	4.0	Brown	0.5	7.5
9	Nitrate	,,	4.0	4.3	4.5	11.3	22.5	5.3	,,	10.5	40.0
10	Nitrate	,,	4.8	4.6	4.7	0	Died	0	0	0	0
11	Not given	,,	3.8	3.6	4.7	3	11.0	4.7	Brown	3.5	10.8

Total weight and volume of caryopsis in Table VI do not harmonize with each other, because sterile grains were obtained, which resulted under the conditions of the glass house culture.

Table VII

Exp. IX.

Culture	N-source	pH 28/VI (initial)	pH 9/VII	pH 30/VII	pH 12/VIII	Appearance of plant at time of harvest: Number of tillers per seedling	Total green weight of shoot (gm)	Average length of shoot (cm)	Colour of leaf
1	Ammonia	3.8	4.2	4.6	4.6	12.3	78.0	70	Green
2	{Ammonia (1) Urea (1)	,,	3.8	4.5	4.5	14	81.5	71	,,
3	Urea	,,	4.8	4.9	4.9	12.6	80.5	72	,,
4	Urea	,,	4.7	5.3	6.3	13	55.5	70	Gray, green
5	Urea	,,	4.7	5.3	6.3	12.3	55.0	69	,,
6	Urea	,,	4.2	4.9	6.5	13	52.0	67	,,
7	Urine	,,	4.5	5.1	6.9	9	46.0	65	,,
8	Urine	,,	4.2	4.2	5.5	12	63.0	54	,,
9	Nitrate	,,	4.9	4.5	5.0	9.3	67.5	63	Yellow, gray
10	Nitrate	,,	3.8	4.3	4.3	0	0	0	0
11	Not given	,,	4.2	4.8	4.7	3	28.0	57	Yellow

Table VIII

Exp. X.

Culture	N-source	pH 28/VI (initial)	pH 9/VII	pH 30/VII	pH 12/VIII	Appearance of plant at time of harvest: Number of tillers per seedling	Total green weight of shoot (gm)	Average length of shoot (cm)	Colour of leaf
1	Ammonia	4.2	4.2	6.1	5.6	10.3	60.0	68	Green
2	{Ammonia (1) Urea (2)	,,	4.1	5.5	5.6	11.6	37.5	70	,,
3	Urea	,,	5.0	5.8	6.0	9.6	42.5	71	,,
4	Urea	,,	5.4	6.1	6.8	12	47.5	70	Gray
5	Urea	,,	5.8	5.8	6.8	14.3	55.0	69	,,
6	Urea	,,	5.0	5.9	7.0	11.6	48.0	68	,,
7	Urine	,,	4.2	5.6	7.1	12	53.0	73	,,
8	Urine	,,	5.1	5.3	7.3	12.5	46.5	72	Gray, yellow
9	Nitrate	,,	6.0	5.8	6.0	6.6	42.5	67	,,
10	Nitrate	,,	4.3	4.3	4.3	0	0	0	0
11	Not given	,,	6.0	6.0	6.0	2.6	16.5	53	Yellow

Table IX

Exp. XI.

Culture	N-source	pH 28/VI (initial)	pH 9/VII	pH 30/VII	pH 12/VIII	Appearance of plant at time of harvest: Number of tillers per seedling	Total gre n weight of shoot (gm)	Average length of shoot (cm)	Colour of leaf
1	Ammonia	6.6	4.9	5.2	6.6	11	46.5	80	Brown
2	{Ammonia (1) Urea (1)	,,	5.2	6.0	5.9	8	28.0	81	,,
3	Urea	,,	6.5	6.7	6.6	8.6	51.5	90	,,
4	Urea	,,	8.1	7.3	8.2	11.6	45.0	81	,,
5	Urea	,,	7.6	7.7	7.3	11	38.0	79	Gray
6	Urea	,,	8.0	7.3	7.9	7.6	30.0	71	,,
7	Urine	,,	7.4	7.8	7.3	10	42.0	80	Light brown
8	Urine	,,	7.5	7.2	7.1	7	34.5	67	,,
9	Nitrate	,,	8.0	8.2	7.3	3	17.0	65	,,
10	Nitrate	,,	8.1	7.5	8.1	0	0	0	0
11	Not given	,,	7.7	7.3	7.3	1	1.0	26	Light brown

Table X

Exp. XII.

Culture	N-source	pH 28/VI (initial)	pH 9/VII	pH 30/VII	pH 12/VIII	Appearance of plant at time of harvest: Number of tillers per seedling	Total green weight of shoot (gm)	Average length of shoot (cm)	Colour of leaf
1	Ammonia	5.2	6.2	7.0	6.5	13	14.5	73	Gray
2	{Ammonia (1) Urea (1)	,,	6.2	6.5	8.0	13	58.5	79	Brown
3	Urea	,,	6.6	6.2	6.9	8.6	43.5	80	,,
4	Urea	,,	5.2	6.3	6.8	11.3	54.5	87	Gray, green
5	Urea	,,	5.3	5.9	8.0	15	42.5	85	Gray
6	Urea	,,	7.0	6.8	8.8	13.6	50.5	77	Gray, green
7	Urine	,,	4.9	6.0	7.6	6.3	40.5	69	Brown
8	Urine	,,	4.9	6.4	7.5	5.6	40.5	71	Light brown
9	Nitrate	,,	4.8	6.2	6.9	1.6	18.5	73	,,
10	Nitrate	,,	4.8	5.6	6.6	0	0	0	0
11	Not given	,,	5.0	6.0	7.0	7.6	45.0	69	Light brown

Table XI

Exp. XIII.

Culture	N-source	pH 28/VI (initial)	pH 9/VII	pH 30/VII	pH 12/VIII	Appearance of plant at time of harvest: Number of tillers per seedling	Total green weight of shoot (gm)	Average length of shoot (cm)	Colour of leaf
1	Ammonia	4.8	4.2	5.5	7.1	10.3	65.0	71	Brown
2	Ammonia (1) Urea (1)	,,	4.1	5.1	5.8	15	68.0	72	Brown, yellow
3	Urea	,,	5.1	6.7	7.3	11	63.0	76	,,
4	Urea	,,	5.5	6.2	8.2	11	60.5	73	,,
5	Urea	,,	4.5	5.8	8.2	13	51.5	74	,,
6	Urea	,,	5.9	6.1	9.2	13	55.5	69	Gray
7	Urine	,,	6.7	5.4	7.3	7.6	53.5	68	,,
8	Urine	,,	5.3	5.3	8.5	8.3	49.5	69	,,
9	Nitrate	,,	4.5	4.8	6.8	7.6	49.5	70	,,
10	Nitrate	,,	4.1	4.3	4.6	0	0	0	0
11	Not given	,,	4.3	5.1	5.4	2	21.5	56	Yellow

Table XII

Exp. XIV.

Culture	N-source	pH 28/VI (initial)	pH 9/VII	pH 3[illegible]/VII	pH 12/VIII	Appearance of plant at time of harvest: Number of tillers per seedling	Total green weight of shoot (gm)	Average length of shoot (cm)	Colour of leaf
1	Ammonia	4.8	4.3	4.4	5.2	12.3	65	79	Green
2	Ammonia (1) Urea (1)	,,	4.6	4.9	5.1	12.3	55	72	,,
3	Urea	,,	4.9	5.0	5.3	11.6	55	73	,,
4	Urea	,,	5.1	5.7	6.3	13	52	70	Gray
5	Urea	,,	4.9	5.2	6.1	11	46	71	Gray, white
6	Urea	,,	4.8	5.7	6.4	11	58	67	Gray
7	Urine	,,	4.9	5.5	5.9	8.3	55	67	,,
8	Urine	,,	5.1	4.7	5.6	10.6	67	69	,,
9	Nitrate	,,	4.2	4.7	5.4	7.6	48	68	,,
10	Nitrate	,,	4.2	4.3	4.3	0	0	0	0
11	Not given	,,	5.0	4.9	5.9	2.3	16	64	Yellow

was pretty good, but the colour of leaf was slightly yellowish. The development of rice plant in the peat culture with ammonium sulphate was very poor. In general, the growth of rice plants in the mixed soil cultures, peat plus clayey loam or peat plus coarse sand, was superior to that in the peat culture when urea was used as the nitrogen source. In these cases the pH-values of several soils were larger than that of the peat culture, and the growth of rice plant was very good, whereas it was very bad and in the extreme case the plant died in an early stage after planting, if manured with a large amount of sodium nitrate. This harmful effect of sodium nitrate may probably be attributable to the action of Na[1].

From the above tabulated results (Tables VI–XII) it may be clearly seen that the growth of rice plants in peat culture evidently became good by mulching with a moderate amount of coarse sand or clayey loam and by manuring physiologically alkaline manure such as urea or urine, whatever the causes of these good results may be.

The Influences of Peat Extract on the Growth of Rice Plants, with Special Reference to Hydrogen Ion Concentration of Culture Solution

It was reported in the foregoing experiments that the reaction of the medium became alkaline or less acidic during the course of the experiment in the peat culture manured with urea, and that the growth of rice plants was very good. In other cultures, the same relations were observed between the reaction change of soil and the growth of rice plants. Judging from the results described above, it seems very probable that an intimate relation exists between good plant growth and the decrease of hydrogen ion concentration of soils, the latter of which may have some direct or indirect connection with the injurious action of organic acid or other organic substances contained in peat. In order to clear such a probable relation the following experiments were carried out:

Seedlings of paddy rice (Bôzu No. 5) were cultured in quartz sand for 10 days. After this preliminary culture the seedlings were planted in porcelain pots of 400 c.c. capacity. Modified KNOP's culture solution of the following composition was used:

1) On this point further experimental results will be reported in a later paper.

KH_2PO_4	0.025 gm.
$MgSO_47H_2O$	0.025 gm.
$CaCl_22H_2O$	0.009 gm.
KCl	0.012 gm.
$FeCl_3$	0.002 gm.

Each of the above salts was dissolved in one litre of tap water or of peat extract, of various concentrations and the following three kinds of culture solution were prepared:

1. salt solution without peat extract.
2. peat extract (1) + tap water (1).
3. peat extract.

The nitrogen source was not given in order to ascertain more clearly the influences of peat extract upon the growth of rice plants. The concentration of salts in culture solution was reduced to one-tenth of the original concentration, and the amount of calcium was again decreased. Peat extract was prepared in the following manner: ten litres of tap water were added to 10 litres of peat in volume, and this was left for 10 days in the green house, and then it was filtered through cloth by the aid of hand pressure. The filtrate was again filtered through cotton. A definite amount of thus prepared extract was used for the experiment. The total free ammonia in the extract was determined by the micro-KJELDAHL method. It was 0.017 mg. per litre. This amount is equivalent to 1/10000 of the amount of nitrogen source in KNOP's solution. The pH-value of the culture solution was adjusted using sodium hydroxide (N/10–N/100). The hydrogen ion concentration of the culture solution was determined with the quinhydrone electrode.

Experiment XV.

One seedling of paddy rice plant (shoot ca 4 cm. and root 6.5 cm. long) was planted in each pot. March 9–15, 1935. Temp: 14°–29°C. Table XIII.

From Table XIII it will be seen that the best growth of rice seedling in the water culture without peat extract occurred at pH 4.0, and the plant growth became gradually worse in accordance with the diminution of hydrogen ion concentration of the culture solution (pH ca. 5.0, 6.9, 7.2). On the contrary, the growth of seedlings supplied with peat extract was very good in the less acidic region (pH 6.0, 6.6), and it was poorer on the more acidic side. But in the culture of the dilute peat extract the difference of plant growth, accompanied with the variation of the hydrogen ion concentration, was not so distinct as that in the peat or water culture. From these results it may be said that the influences of peat extract upon the plant growth of rice seedlings varied according to the difference of

Table XIII

Exp. XV.

Culture solution	pH			Growing state of plants					
				13/III		15/III			
	9/III (initial)	11/III	15/III	Leaf	Appearance of plant	Leaf	Length of shoot (cm)	Length of root (cm)	Total green weight (gm)
Salts solution	3 9	—	3.4	Green	+++	Green	16.3	11.3	0.03
	6.0	—	4.8	Slightly yellow	++	Yellow	12.0	10.5	0.02
	6.9	—	6.6	Yellow	+'	,,	10.3	7.3	0.02
	7.2	—	6.8	,,	+	,,	10.2	9.2	0.02
Peat extract (1) plus water (1)	3.9	3.9	3.8	Green	+++'	Green	17.0	12.0	0.03
	5.0	4.5	4.2	,,	+++'	,,	15.6	10.0	0.03
	5.9	4.6	3.9	,,	+++'	,,	16.1	10 3	0.03
	6.8	6.5	6.4	,,	++++	,,	17.3	10.0	0.03
Peat extract	4.0	4.0	4.0	Green	++'	Green	13.5	8.0	0.02
	5.0	4.7	4.4	,,	++'	,,	15.0	7.2	0.025
	6.0	4.9	4.5	,,	+++	,,	16.3	9.5	0.031
	6.6	5.2	4.8	,,	++++	,,	16.1	9.8	0.032

the hydrogen ion concentration. In other words, the poor growth of rice seedlings in the peat extract culture is avoidable by decreasing the hydrogen ion concentration of the culture solution. For the purpose of reduction of the hydrogen ion concentration of culture solution, sodium hydroxyde was added to it. This addition resulted in the increase of Na, though the amount of added sodium hydroxide was very small. Then the question is raised whether the good growth of rice seedling on the less acidic side may be due to the action of increased Na. In order to answer this question the following experiment was carried out using a culture solution which contains the same definite amount of Na in the form of NaCl. The procedure of preparing the culture solution and method of experiment were the same as in Experiment XV, except that the culture solution was renewed once during the course of the culture.

Table XIV

Exp. XIV.

Culture solution	pH			Growing state of plants 6/IV		
	29/III (initial)	2/IV	6/VI	Length of shoot (cm)	Length of root (cm)	Total green weight (gm)
Salts solution	4.0	4.8	5.9	16.2	14.7	0.05
	5.0	6.0	6.6	12.5	13.5	0.04
	6.0	6.4	6.8	11.8	14.0	0.04
	7.0	7.1	7.3	11.0	13.3	0.037
Peat extract (1) plus water (1)	4.4	4.0	3.2	15.5	10.8	0.053
	5.2	4.6	3.6	15.5	14.0	0.06
	5.8	5.0	4.6	17.2	11.5	0.06
	7.2	7.0	6.7	17.0	10.7	0.063
Peat extract	3.4 (without NaCl)	3.4	3.3	12.5	8.0	0.04
	3.3 (with NaCl)	3.3	3.0	14.7	8.0	0.05
	5.0 (,,)	4.0	3.3	15.8	10.3	0.067
	5.2 (,,)	4.6	4.3	17.3	11.6	0.07
	6.3 (,,)	6.3	6.3	17.3	11.8	0.067

Experiment XVI.

One seedling of rice plant (shoot ca. 4.0 and root 6.5 cm. long) was planted in each pot. March 29–April 6, 1935. Temp: 9°–28°C. Table XIV.

Table XIV shows that the best growth of rice seedlings in water culture without peat extract occurred on the acidic side and was poor on the less acidic side, while in the culture with the peat extract a contrary relation was observed, and the growth in the culture solution of water plus peat extract was nearly equal to that in the peat extract culture. That is to say, if the amount of Na was equal in each culture solution, the degree and tendency of the differences of the growth of rice seedlings at various pH-values were not different from those of Experiment XV. From these facts it may be said that the good growth of rice seedlings in the peat extract at relatively high pH-value is not caused by a slight increase of Na amount, but rather by certain other factors connected with the pH-value. Sodium acts rather harmfully at high pH-value.

The two Experiments XV and XVI clearly show that the best growth of rice seedlings appeared in the more acidic region and poor growth in the less acidic region, and that the pH-value plays a great rôle in this case. On the other hand, it may be said that peat extract acted greatly to improve the poor growth of rice seedlings, or rather to favour the plant growth in the weak acidic or alkaline region.

General Discussion

In the present work it has been ascertained that the hydrogen ion concentration of the solution in the peat culture decreases during the course of culture, if physiologically alkaline nitrogen sources are given or soil mulching is practiced, and that on the one hand, the degree of the reaction change depends upon the kind and amount of fertilizer, and on the other hand upon the initial pH-value and buffer capacity of the soil. Such tendency of reaction change in the peat culture was observed also in the writer's previous paper (1935), where cultures of various kinds were carried out.

In peat or peat extract the growth of rice plant was poor in the acidic region and very good in the less acidic region. Numerous observations have revealed the fact that peat contains a large amount of humic acid and organic or inorganic compounds, which are injurious or favorable to the growth of higher plants. The exact chemical nature of these substances and in the majority of cases, the specificity of their action are still imperfectly understood. According to WAKSMAN (1936) and others, organic or inorganic compounds in peat, which are capable of causing injury to plants, are not present in abundance in free states, but occur in combination with, or as a part of other complexes, and the favourable or unfavourable action of such compounds may become active or inactive in accordance with the change of such physical or chemical factors, as hydrogen ion concentration or kinds and amounts of various salts. Therefore, it may be probable that humic acid or organic and inorganic substances in peat or peat extract, are harmless to the growth of rice plant in the less acidic region and that no remarkable injury appears in the growing state of this plant. For the poor development of rice plant in peat culture manured with ammonium sulphate, humic acid in molecular form may be responsible. The amount of humic acid in this form depends upon the hydrogen ion concentration, because humic acid is a weak acid[1] and its dissociation may be restrained in the existence of the presence of a strong acid such as sulphuric acid. The latter acid accumulates as the result of the superior absorption of ammonia from $(NH_4)_2SO_4$.

In the above experiments sodium nitrate was used for the purpose of neutralization or reduction of the acidity of peat, because it is a physiologically alkaline fertilizer. But, when a large amount of sodium nitrate was used, it was observed that the rice plant became more or less chlorotic and then died in all cultures, especially when four times its standard amount was given. According to the writer's experiment[2], the ill effect of sodium nitrate or sodium chloride on the growth of rice plants seems to be attributable to the action of Na[3] which is accelerated by a decrease of hydrogen ion concentration. Therefore, sodium nitrate is not suitable as a nitrogen source for the cultivation of paddy rice plant, even in the case of high acidic peat culture, because the hydrogen ion concentration becomes lower during the culture.

In the water culture, the relations between the plant growth and the culture conditions may be explained rather clearly, but in many respects those in the peat or soil cultures, are more complicated. Whatever the theoretical explanation may be,-as a matter of fact, the results in the present work show that good growth of rice plants in peat culture can be obtained by soil mulching and by manuring

1) Schreiner und Shorey (1910), Odén (1916, 1919), Bottomley (1917), Stadnikoff und Korschew (1929), Waksman and Stevens (1928), Fuchs (1929).

2) Not yet published.

3) Salinas (1932).

with such a physiologically alkaline fertilizer as urea or urine, but not with sodium nitrate.

Summary

1. Studies on the growth of paddy rice plants, were carried out by the method of pot culture with peat, clayey loam, and coarse sand soils and their mixtures, using urea, urine, ammonium sulphate and sodium nitrate as the source of nitrogen. It was ascertained that the growth depends upon the change of hydrogen ion concentration of the medium and upon the buffer capacity of the soil.

2. The buffer capacities of peat, clayey loam and coarse sand were determined by means of titration curve. In the case of the alkali titration, the buffer capacity of peat was the largest, that of coarse sand was the smallest and that of clayey loam showed a degree intermediate between them. The buffer capacity of mixed soils, however, varied according to the ratio of the two parts.

3. The local difference of pH-value according to the depth in the pot, was most remarkable in clayey loam, smallest in peat, and in coarse sand it was similar to peat.

4. The hydrogen ion concentration was lowered by mulching of coarse sand or clayey loam on the one hand, and by manuring of urea, urine or sodium nitrate on the other. The reaction change in peat depends, therefore to a great degree upon the kind, amount, and method of fertilization and soil mulching. Such reaction change favours good growth of paddy rice plants, except the application of $NaNO_3$.

5. The bad growth of paddy rice plants in the higher acidic region in the peat or peat extract culture may be partly due to the harmful effects of humic acids in the molecular form or of organic substances in an active form, the amount of which depends mainly upon the hydrogen ion concentration of the culture solution.

6. As suitable methods for the improvement of peat as arable land, especially for the culture of rice plant, soil mulching with coarse sand or clayey loam, and manuring with a moderate amount of physiologically alkaline manure can be recommended.

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