4. SOIL CHARACTERISTICS CONCERNING WITH THE BENEFICIAL EFFECT OF WATER MANEGEMENT IN RICE CULTIVATION

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Flooding and water management are a part of the most fundamental works of rice cultivation. The merit of flooding is to make favorable soil condition for the growth of rice plants. Some new techniques have recently been introduced with expectation of an increased yield of paddy cropping, that is, the water management with active practice of surface drainage during the growing stage of rice plants. The Nakaboshi drainage (midsummer drainage) or intermittent drainage has been accepted as one of the high-yielding techniques from the results of the Rice competition in Japan. On the other hand, from the viewpoint of general cultivation techniques of farmers, some problems are still remained whether the surface drainage in mid course of the flooding stage is a technique directly related to the constant high yield of paddy crop or not. Several experiments on water management were conducted in the scientific fields of soil and fertilizer for ten odd years to clarify such a problem, nevertheless it remained still obscure. The results of the experiments in Japan may be abstracted as follows: although water management has influences for the growth and yield of rice plants, the changes in soil fertility of the plow layer, and the soil tilth and trafficability after the surface drainage in autumn, it is not always effective to increase the yield, and furthermore water management results in the leaching of bases in top soil and the decline of soil nitrogenous fertility. A constant effect of water management is the increase of trafficability in the paddy fields after the surface drainage in autumn.

1. Effect of water management on the oxydation-reduction status of top soil in paddy cropping season

The most distinctive characteristic of paddy soils in the irrigation season is the soil reduction accelerated by the vigorous action of microbes in the soil isolated from the atmosphere by flooding under high temperature in summer. The redox status of top soil is related to the transformation of nitrogen, phosphorus, iron, manganese and sulfur. As a result, it will be closely related to the rise and fall of toxic substances and nutrients supply. The progress and degree of soil reduction in plow layer is fundamentally determined by the interrelationship between the contents of easily decomposable organic matter and the oxidizing ability which can be expressed by the contents of oxygen, nitric acid, easily reducible manganese and extractable iron oxides,[1] but, in the paddy field of higher soil nitrogenous fertility, the soil after flooding is apt to be "extreme reducing condition". In such case, therefore, the soil must be improved to be "adequate reducing condition" accompanied with a satisfactory balance between availability of nutrients and concentration of toxic substances (Table 1). Adequate reducing condition is helpful state of soil reduction for rice growth. It seems that drainage is the most effective means of avoiding the state of extreme reducing condition.[2] The effect of water management can be divided in two ways; one is the effect of drainage and the other is percolation; (1) introduction of atmospheric oxygen into

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Table 1. Characterization of waterlogged soil

State of reduction	Eh (volt)	Characteristics of waterlogged soil
Oxidizing conditions	>0.3	Oxidizing ability of soil is relatively high. N and P are less available. N liable to be lost.
Adequate reducing conditions	0.3–−0.05	Organic matter is decomposed by semi-anaerobic and anaerobic metabolism of bacteria. Stage of iron reduction. The beneficial condition of the waterlogged environment. N and P are much available.
Extreme reducing conditions	<−0.05	Organic matter is decomposed by anaerobic metabolism of bacteria. Stage of sulfate reduction. The concentration of reduced substances in soil solution liable to become too great for the rice roots.

top soil by means of Nakaboshi (midsummer drainage) and/or intermittent drainage during irrigation season makes general improvement of reduced condition of soil; (2) percolation can eliminate or dilute organic acids such as acetic acid and butyric acid and toxic inorganic compound produced in the course of progress of soil reduction.

These effects of water management are much more expectable under the condition of developed soil structure of top soil and subsoil (plow sole and B-horizon). In the transplanting culture accompanied with puddling, the top soil easily changes to the minimum permeable layer with muddy structure of soil.[3] Many cracks are formed on top soil after surface drainage. However, in muddy top soil, as the extent of oxidized part is limited on soil surface and crack surface, the reduced condition in clod cannot be improved (Fig. 1).[4] In the soil of granular structure, oxygen easily penetrates into clod from soil surface and crack surface, and, as a result, reduced condition is improvable (Fig. 2).[4] These facts show that the effect of drainage on the improveemnt of reduced condition cannot be expected unless the structure of top soil is kept in good condition.

Percolation has little effect on the redox potential of submerged soil compared with drainage, but is helpful in the removal of toxic substances from reduced soils. However, the effect of percolation may also decrease in the muddy condition of top soil. Because the quantity of percolation is not much in the field of which top soil is muddy condition before Nakaboshi drainage. After reirrigation, the quantity of percolation increases

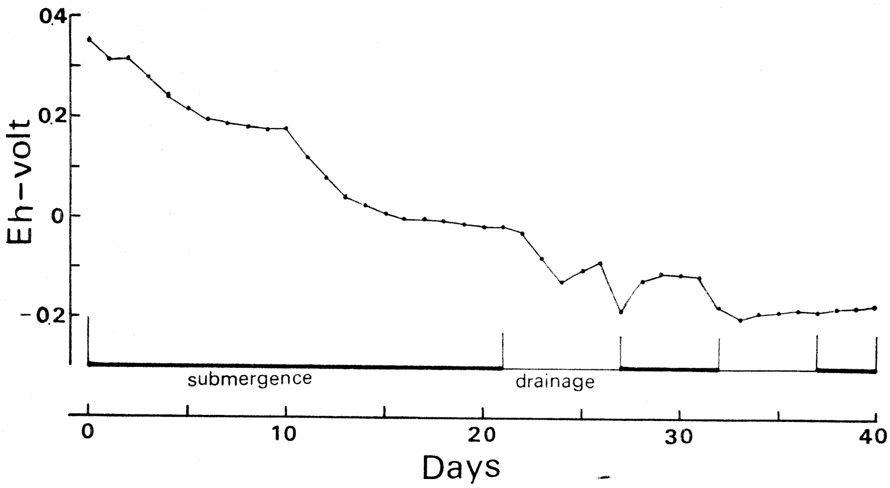

Fig. 1. Changes of Eh in muddy structure of soil (Aomine · Shiga, 1959)

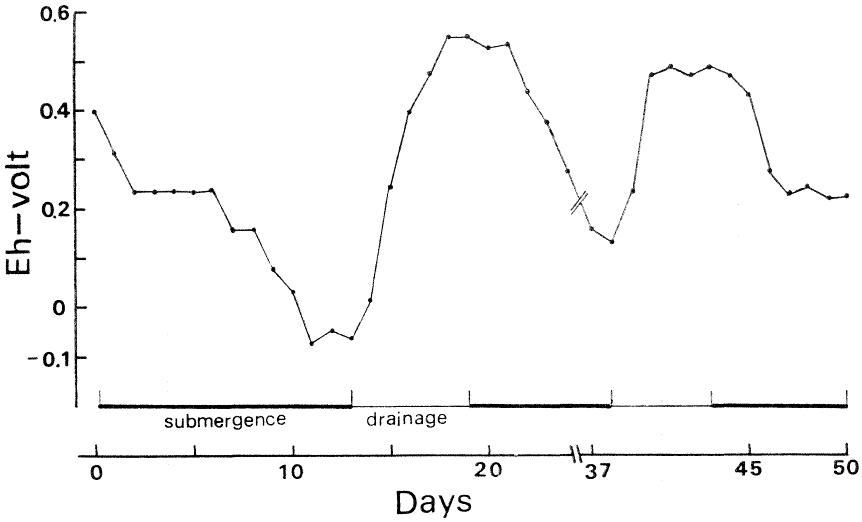

Fig. 2. Changes of Eh in granular structure of soil (Aomine・Shiga, 1959)

owing to the formation of cracks by drainage, but the effect to leach out toxic substances from clods may be insufficient because most of the water pass through cracks.

2. Effect of water management on the behavior of nitrogen in submerged soil

It is very important to clarify the change in behavior of soil nutrient, especially of nitrogen, for the study on the relationship between soil, water management and the growth of rice plants. The production of NH_4-N derived from soil organic nirtogen (ammonification) becomes active owing to the action of semianaerobic and anaerobic bacteria according to the progress of soil reduction after flooding. Water management is one of the effective factors for the ammonification after flooding as same as the quality and quantity of easily decomposable soil organic nitrogen, soil pretreatment before flooding (drying, freezing, adjustment of soil reaction, mechanical crushing of soil, deflocculation of humus) and soil temperature.

The production of NH_4N increases sometime and decreases other time in the soil incubation test accompanied with percolation compared to the production of NH_4-N in the test without percolation as shown in Fig. 3.

Such effect of percolation on the variation of ammonification is closely related to the contents of easily decomposable soil organic nitrogen in soil used. In the course of the active decomposition of organic matter by microbes under abundant existence of easily decomposable soil organic nitrogen, percolation acts to fall the Eh in soil and to promote ammonification. On the contrary, percolation rises Eh and limits ammonification under the condition containing less of easily decomposable soil organic nitrogen. In other words, the action of microbes becomes high and the production of NH_4-N increases in the former cases owing to the leaching action by percolation which decreases the concentration of toxic substances, while in the latter case, the production of NH_4-N is restrained by the oxidative condition of soil caused by the oxygen introduced by percolation.

Fig. 4 shows a remarkable influence of the drainage on the ammonification in submerged soil.[6] A large amount of NH_4-N is produced as a result of continuous submergence. Ammonification is rapid at first, but practically stops after about three

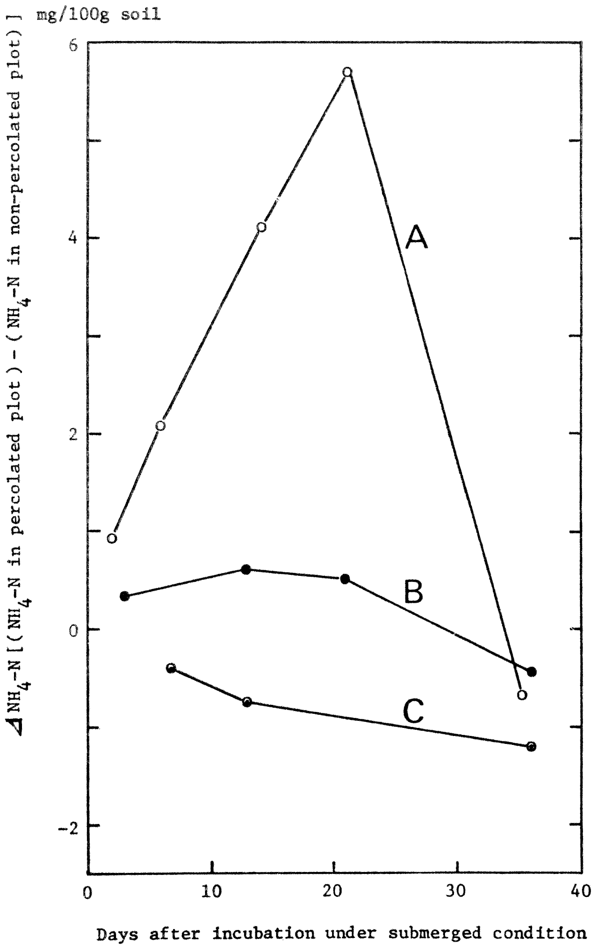

Fig. 3. Influence of percolation on ammonification (Lab. of Soil, Tokyo Univ.; 1968) Percent of T-N; A 0.53, B 0.157, C 0.094

months. In the case of discontinuous submergence, the concentration of NH_4-N rises sharply during the initial submergence. During the three weeks drained period following this submergence, about one-half of this NH_4-N disappeares, presumably having been nitrified. After three submerged and drained cycles, only a trace amount of NH_4-N is present, owing to the consumption of easily decomposable soil organic nitrogen. The NO_3-N disappeares by leaching or denitrification.

The fertilizer nitrogen balance is also affected by drainage. Table 2 shows the distribution pattern of applied nitrogen at the ends of the first and second month after flooding in a pot test with ^{15}N. The percentage of the nitrogen absorbed by rice plants becomes lower and that of unknown nitrogen which might be caused chiefly by denitrification becomes higher in the intermittent drainage plot compared to the continuous submergence plot. It seems that intermittent drainage promotes the denitrification of applied nitrogen. As to the percolation, its influence is not so much, and the percentage of the immobilization of applied nitrogen is slightly high and that of the unknown

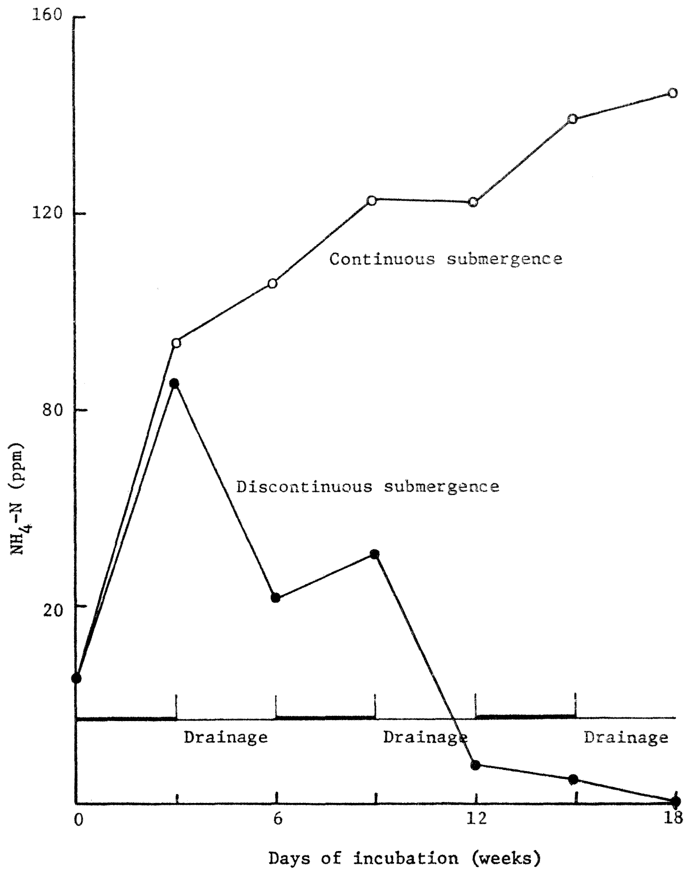

Fig. 4. Ammonium nitrogen content of soil as affected by moisture treatment (Patrick, Wyatt; 1964)

Table 2. Distribution of ^{15}N-fertilizer supplied

(%)

Management	Months after fertilizer application	Remained NH_4-N	Immobilization	Uptake by plant	Leaching	Unknown (denitrification)
Continuous submergence	1	1.3	15.3	54.5	—	28.9
	2	tr.	18.2	51.2	—	30.6
Intermittent drainage	1	0.8	18.6	40.3	tr.	40.3
	2	tr.	22.3	40.0	tr.	37.7
Percolation	1	2.0	19.8	54.6	0.3	23.3
	2	tr.	19.7	50.3	0.3	29.7

(Maeda·Onikura; 1975)

part tends to be a little low compared to those in the plot of continuous submergence. The applied nitrogen leached out is only a small amount during the submerged period. However, under drained condition after harvest, the tagged NO_3-N derived from immobilized organic nitrogen leached out continuously until next summer, presumably having been nitrified.

Although the accumulation of easily decomposable soil organic nitrogen in ill-drained paddy field is greater than that in well-drained paddy field, the control of ammonification and the adjustment of the reducing condition of soil after flooding cannot be achieved completely because of the difficulty in water management. Therefore, the negative effect caused by injurious factors is apt to be greater for the growth of rice plants in ill-drained paddy fields. On the contrary, as to well-drained paddy fields, the easily decomposable soil organic nirtogen can be accumulated artificially by means of the application of organic materials and soil dressing, and the sufficient supply of nutrients is practicable owing to water management and adequate application of fertilizer, avoiding the "extreme reducing condition" of soil.

In general, it may be said that the effect of water management tends to be greater in the more fertile paddy fields and water management is necessary for such fields.

3. Rice yield in cultivation tests with the management of water

Water management is regarded, through experience, as one of the high yielding techniques to get a yield of more than 7.5 t/ha by brown rice, though it has various aspects being composed of the control in depth of flooding water, Nakaboshi (midsummer drainage), intermittent drainage and their combination. However, from the results of many cultivation tests of which yield was about or less than 6 t/ha, water management seems not always effective to increase the yield.

In the comparison of soil conditions between normal paddy fields and high yielding ones in which the effectiveness of water management has been accepted in Tohoku district (north-east regions of Japan), following characteristics are always recognized in high yielding paddy fields; (1) Soils belong to the type of well-drained paddy soils with fine texture derived from ill-drained paddy soils, being situated in the lay of the land of comparatively good natural drainage; (2) accomplished under drain, and well developed blocky structure of subsoil in many cases; (3) top soil which is rich in easily decomposable soil organic matter owing to soil dressing and abundant application of compost and high degree of water stable aggregation in soil. The effect of management, therefore, may be expectable in the paddy fields of similar characteristics.

Fig. 5 and Table 3 show a part of the results of experiments conducted for three years from 1957 to 1959 at the Central Agricultural Experiment Station.[8] In the paddy fields used for these experiments, Nakaboshi (midsummer drainage) was practiced for five to seven days just before the maximum tiller number stage and then the water level of the open channel (drain) was lowered to the bottom (60 cm in depth) in order to make percolation.

As shown in Fig. 5, no effect of water manageemnt appeares on the nitrogen absorption of rice plants when the amount of applied compost was 18.75 t/ha. But the effect of water management became apparent and the nitrogen absorption by the rice plants in the water management plot became high when the amount of applied compost was 56.25 t/ha, especially, under the heavy application of nitrogenous fertilizer.

As shown in Table 3, the yield of brown rice in undrained series continues gradual increase until the amount of applied compost reached 37.5 t/ha. The yield of brown rice decreases in the 56.25 t/ha plot compared to the 37.5 t/ha one. This tendency is especially conspicuous in the plot of increased application of nitrogenous fertilizer. On the other hand, the yield of brown rice in drained series increases gradually according

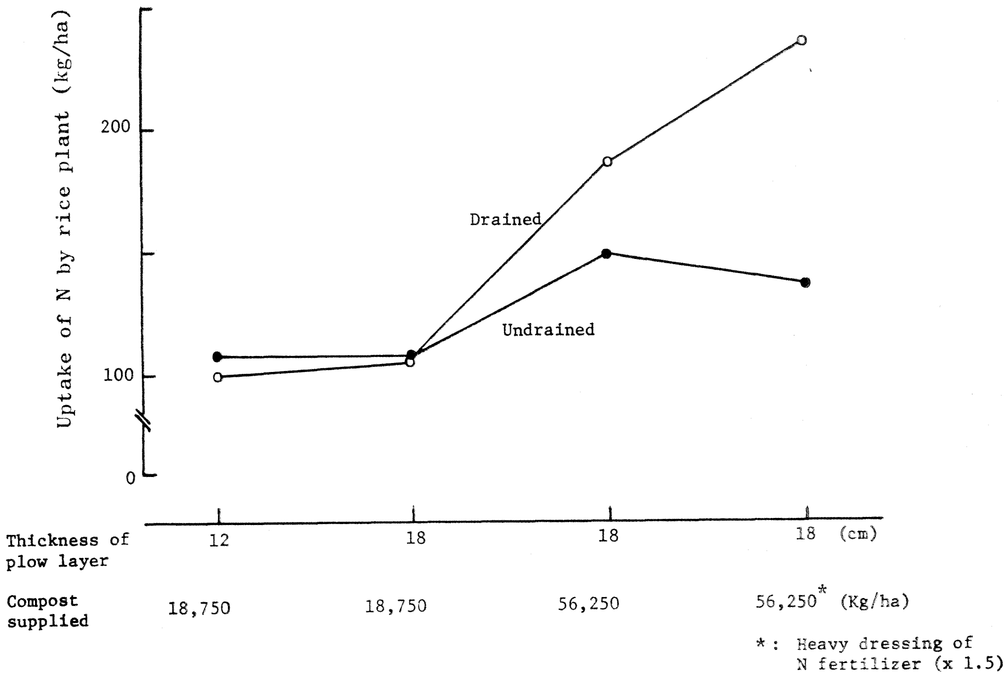

Fig. 5. Effect of drainage on nitrogen uptake by rice plant at harvest time (Shiroshita, et al.; 1962)

Table 3. Effect of drainage on paddy yield (1957-'59)
(Mean of 3 years)

Thickness of plow layer (cm)	Compost supplied (kg/ha)	Brown rice yield (kg/ha)	
		Undrained	Drained
12	0	4, 632	4, 746
12	18, 750	5, 488	5, 380
18	18, 750	5, 335	5, 233
18	37, 500	5, 733	5, 833
18	56, 250	5, 580	6, 417
*18	56, 250	4, 994	7, 893

* Heavy dressing of N fertilizer (half as many) (Shiroshita, et al.; 1962)

to the increase of applied compost. In the plot in which the application amount of nitrogenous fertilizer was additionally increased besides 56.25 t/ha of compost, a high yields of about 8 t/ha was obtained.

Furthermore, the data show that when the yield target is set at a yield of less than 6 t/ha, water management is not necessary to get the aimed yield which is obtainable only by the artificial increase of nitrogenous fertility of soil.

As mentioned above, water management decreases the concentration of toxic substances in submerged soil and at the same time accelerates the decrease in content of easily decomposable soil organic nitrogen. The yield target may be expectable, therefore, by decreasing toxic substances and controlling nitrogenous fertility of soil during the flooding stage in the paddy field of which nitrogenous fertility was highly increased artificially or in the paddy field of peat soil, while the effect of water management may be little for yield increasing in the paddy field of low nitrogenous fertility because of greater influence of nutrient loss.

4. Effect of water management on the change of soil fertility

1) Leaching of soil components by subsurface drainage

The leaching of soil components is generally increases according to the development of soil structure and the increase of permeability at the flooding stage. In an imperfectly drained paddy field in the Agricultural Experiment Station of Yamagata Prefecture, as shown in Table 4, the leached amount is different by the kind of components nearly as follows; $CaO \fallingdotseq Fe_2O_3 > SiO_2 > MgO > T\text{-}N > K_2O$.[9] The difference of leached amount by the kind of components may be derived from the different mineralogical composition of parent material.

Table 4. Quantities of components leached out by subsurface drainage during irrigation period

(kg/ha)

Tile drain flux per hr. (m^3/ha)	N	Fe_2O_3	SiO_2	CaO	MgO	K_2O
167	1.02	2.80	2.57	3.32	1.59	0.43
69	0.46	2.11	1.44	1.88	0.95	0.18

(Means of 6 times) (Shoji, et al.; 1974)

Since drainage leaches out the base, the exchangeable Ca, Mg and K in top soil naturally decrease and the degree of base saturation diminishes resulting in acidic soil reaction.

2) Change of nitrogenous fertility caused by water management

It is important to know how does the nitrogenous fertility of top soil, which is closely related to the growth of rice plants, change by continuous water management. Some answer may be given to this question by the experimental results obtained in the Central Agricultural Experiment Station.[10] This experiment was conducted for four years to know the effect of water management (continuous submergence, Nakaboshi drainage accompanied with intermittent drainage) in combination with the structure of top soil (granular, muddy), and the nitrogenous fertility of used soil was examined after the experiment. Well-drained paddy fields were used for the experiment, but the permeability during flooding stage was merely a few mm per day, and most of its was caused by the quantity of evapo-transpiration while percolation was hardly observed. The yield of brown rice was normal ranging from 4.5 to 5 t/ha. As a whole, the effect of water manageemnt on the yield was little, and drainage was apt to decrease the yield in many cases.

The nitrogenous fertility examined after this experiment with soils of each water management plot is as follows;

As shown in Table 5, in respect of the amount of nitrogen uptake by rice plant at harvest time in the rice cultivation test under uniform design without application of nitrogenous fertilizer on each plot of fields, whole plots may be divided into two groups, i.e., the group of the continuous submergence plot and Nakaboshi drainage plot of

Table 5. Rice cultivation test* under uniform design on the fields after treatments

Record of treatment		Yield of brown rice (kg/ha)	Amount of N uptake (kg/ha)
Soil structure in plow layer	Water management		
Granular	Continuous submergence	4, 050	81
	Nakaboshi drainage	3, 940	75
	Intermittent drainage	3, 180	59
	Nakaboshi and intermittent drainage	3, 140	57
Muddy	Continuous submergence	3, 470	71
	Nakaboshi drainage	3, 700	68
	Intermittent drainage	3, 400	64
	Nakaboshi and intermittent drainage	3, 320	60

* Without N fertilizer (Lab. of Soil and Fertilizer, Central Agr. Expt. Sta.; 1974)

which drainage extent was comparatively low and the group of the intermittent drainage plot and Nakaboshi and intermittent drainage plot which were of high drainage extent. The amount of nitrogen uptake by rice plant of the latter group is comparatively lower than that of the former. This trend is observed conspicuously in the series of which soil was kept in granular structure. It can be said from this fact that the strengthened drainage during the irrigation period has promoted to decline the soil nitrogenous fertility.

The amount of nitrogen uptake by rice plant in the plot of continuous submergence and granular structure is higher than that in the plot of continuous submergence and muddy structure. It might be caused by the accelerated consumption of easily decomposable soil organic nitrogen because the mineralizatoin in the muddy structure plot was advanced by puddling. On the other hand, in the case of Nakaboshi and intermittent drainage plot of which drainage extent was the highest, the amount of nitrogen uptake by rice plant in the granular structure plot is less than that in the muddy structure plot. This might be derived from the cause that the influence of strengthened drainage is apt to become higher in the soil of granular structure where the consumption of easily decomposable soil organic nitrogen was strongly promoted when the submergence and drainage was repeated as described in (2).

Furthermore, Table 5 shows that the effect of each experimental treatment on the yield of brown rice showed similar trend as that on the amount of nitrogen uptake by rice plant.

Although these are the results of the rice cultivation test under uniform design without application of nitrogenous fertilizer, same results were obtained in a similar test accompanied with application of nitrogenous fertilizer.

Soil samples were taken from the top soil of each plot after experiment, and several qualities related to nitrogenous fertility were examined before the rice cultivation test under uniform design. As the result, the influences of water management on soil nitrogenous fertility was proved clearly.

As shown in Table 6, in the continuous submergence and granular structure plot, the content of total nitrogen and the values of soil-drying effect and/or temperature rising effect which are indexes of the content of easily decomposable soil organic nitrogen, are the highest among all plots. In the granular structure series, Nakaboshi drainage plot and then intermittent drainage plot come in the order succeedingly, and the values in the Nakaboshi intermittent drainage—granular structure plot are the lowest of all. As a result, the decline in soil nitrogenous fertility becomes greater according to

Table 6. Characteristics of soils in the fields after treatments

Record of treatment		pH	T-N (%)	Nitrification* (%)	Index for quantity of easily decomposable soil organic nitrogen (NH_4-N mg/100 g)	
Soil structure in plow layer	Water management				Soil drying effect	Temp. rising effect
Granular	Continuous submergence	5. 1	0. 186	22. 5	5. 9	9. 0
	Nakaboshi drainage	5. 9	0. 183	47. 5	5. 0	5. 3
	Intermittent drainage	6. 3	0. 179	53. 0	4. 8	7. 7
	Nakagoshi and intermittent drainage	6. 4	0. 173	62. 5	4. 5	4. 4
Muddy	Continuous submergence	5. 5	0. 182	34. 0	5. 9	6. 4
	Nakaboshi drainage	5. 9	0. 175	44. 0	4. 9	6. 6
	Intermittent drainage	6. 2	0. 177	52. 0	4. 7	6. 2
	Nakaboshi and intermittent drainage	6. 3	0. 177	61. 5	4. 8	5. 9

* Percent of NO_3-N formed from 20 mg of NH_4-N added per 100 g soil after 2 weeks of incubation under 70% of moisture equivalent.

(Lab. of Soil and Fertilizer, Central Agr. Expt. Sta., 1974)

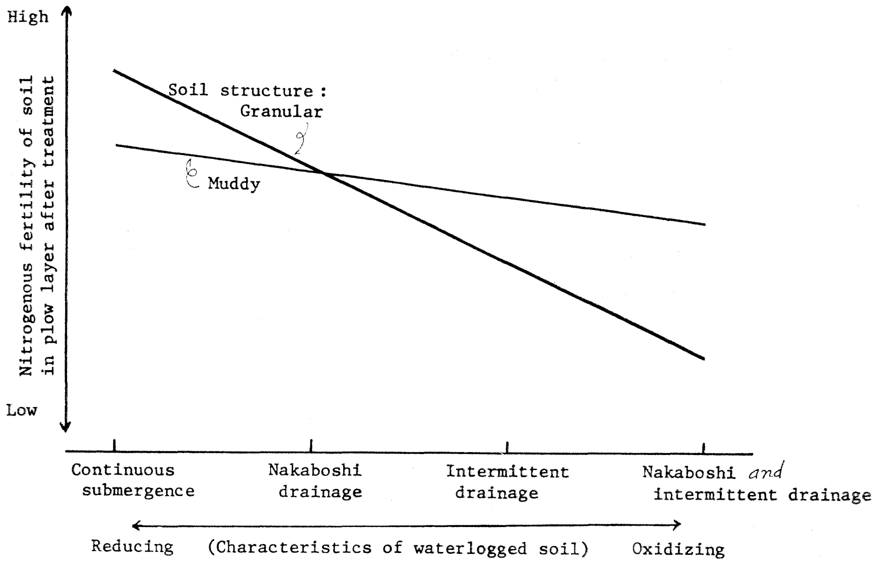

Fig. 6. Schematic presentation for the changes of soil nitrogenous fertility after water management

the increase of drainage extent in the series of granular structure. As to these values in the muddy structure series, those of the continuous submergence plot are the highest and those of the Nakaboshi—intermittent drainage plot are the lowest. But the declining trend of nitrogenous fertility which accords to drainage extent is not so conspicuous as that in the granular structure series. Such result of this chemical analysis well accords to the result of the rice cultivation test under uniform design.

The values of pH and nitrification are the lowest in the plot of continuous submergence-granular structure, and these values become higher according to the increase of drainage extent. This suggests that intensification of water management results in rised soil reaction which activates nitrifying bacteria, and therefore, the production of nitrate nitrogen advanced and the decomposition of easily decomposable soil organic nitrogen is promoted, and consequently the nitrogenous fertility of top soil becomes low. Fig. 6 shows a schematic figure of the change in the nitrogenous fertility of soil after continuous water management.

5. Change of trafficability after drainage[11]

The soil hardness at harvest time in the fields of transplanting culture increases by the drainage treatments such as Nakaboshi, intermittent drainage and early autumn drainage. The soil layer of the most declined soil hardness in the well-drained paddy fields after rice cultivation is usually limited to plow layer in the range of several tens cm in depth of soil. In this case, any drainage treated during flooding stage is effective to recover the soil hardness in plow layer after autumn drainage. It is nearly the same in the imperfectly-drained paddy field. A less intensified drainage treatment such as Nakaboshi, however, cannot easily increase the soil hardness in plow layer in the ill-drained paddy field. Therefore some intensified drainage treatments such as intermittent drainage, early drainage of residual water and water-saving culture become necessary. The drainage effect on the increase of soil hardness may appear remarkably when cultivation without puddling and drainage are used together. In general, it is clear that drainage treatment is effective to increase the soil hardness in a shallow soil layer in which hydrated soil particles are in dispersed condition.

The value of pF in plow-layer reaches up to more than 1.5 at five to ten days after the drainage treated during an irrigation stage. As the drying of soil depends on the downward movement and evapotranspiration of water, the soil drying in plow layer becomes slow in progress when the soil is fine textured and muddy structural or some impermeable layer exists in subsoil. Cracks begin to form in the course of drying of soil at the extent from 1.3 to 1.9 in pF though it depends on the difference in quality of soil, and then after two or three rainless days dry condition of soil can easily recover even from the wet condition in which pF became zero because of rainfall.

In the drying of shallow subsoil, the pF value in the depth of 20 cm attains more than pF 1.5 two or three days later than that in the case of plow layer when the soil layer is composed of developed soil structure. In many cases, therefore, the drying of the plow sole in well-drained paddy fields is comparatively easy, and the effect of drainage usually appears even after the Nakaboshi practiced for seven to ten days. But the drying of the glay horizon just under the plow layer in ill-drained paddy fields needs more ten days than the drying of plow layer, therefore, in such cases, the effect of the Nakaboshi is not expected for soil drying and more intensive treatments of drainage become necessary.

Summary

1) Drainage was an effective method for the improvement of top soil which is in the "extreme reducing condition" during the growing period of rice plants.

The appearance of the effect, however, was closely related to the soil structure in top soil. It was geenrally difficult to introduce soils into the "adequate reducing condition" by surface drainage when the soil structure is in muddy condition.

2) The bestowing percolation on the paddy field of which top soil contained abundant easily decomposable soil organic matter resulted in the progress of ammonification, while that in the paddy field of less amount of easily decomposable soil organic matter restrained the ammonification.

In general, in the cases where oxidation and reduction were repeated consecutively by the surface drainage and reirrigation during the irrigation period, the consumption of easily decomposable soil organic nitrogen was promoted and the decline of nitrogenous fertility remained as a problem.

3) Water management was regarded as one of the high yielding techniques to get a yield of more than 7.5 t/ha by brown rice, however, when the aim was set at a yield of less than 6 t/ha in well-drained paddy field, water management was not necessary to get the aimed yield.

4) The drainage carried out during the irrigation period rendered distinct effect to the increase of soil hardness in top soil at the time of harvest.

5) In the normal standard of rice yield, the position of the balancing point between the merit of water management such as the improvement for extreme reducing condition, the control of ammonification and the increase of soil hardness and the demerit such as the decline of soil nitrogenous fertility, cannot be easily fixed because it is variable in accordance with the characteristics of soils. As a result, it is impossible to make a fixed application standard of water management.

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Question and Answer

H. K. Pande, India: Reference to Fig. 1 and Fig. 2. Please explain with reference to the soil physical condition. What will happen if clay contents are low?

Answer: The texture is silty clay, the clay mineralogical composition is montmorillonitic, and the content of humus is low. The condition of soil structure in Fig. 1 was made by strengthened puddling, and that in Fig. 2 was made without puddling.

Same tend will also appear on coarse textured soils containing less water stable aggregates.

S. I. Julian, Philippines: On page 13 of the report, Summary No. 3, I would like to have some more explanation about the paragraph.

Answer: As to well-drained paddy field, water management such as surface drainage and/or percolation is necessary to eliminate or dilute the toxic substances formed in the fertile soil rich in easily decomposable soil organic nitrogen, in which a yield of more than 7.5 t/ha will be expectable. However, other many tests show that a yield of about 6 t/ha is expectable by means of the improved application of fertilizer accompanied with the application of about 10 ton of compost without any water management. On the other hand, as to ill-drained paddy field, if the yield target is set at about 6 ton/ha, water management is necessary to get the aimed yield.

N. Yamada, Japan: Table 3 of your paper indicates effects of drainage on grain yield as influenced by soil depth and varying amounts of compost application. I would like to know whether the compost application was made only in the years of experiment or indicated amount of compost had been applied for several years before this experiment (measurement) was conducted?

Answer: Before this experiment, on this field, rice cultivation had been customarily practiced under standard fertilizer application accompanied with standard amount (7.5 t/ha) of compost. During this experimental period, the compost application of indicated amount was made every years.