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Characteristics of Microorganisms in Paddyfield Soils

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Distribution of Microorganisms in Various Horizons of Paddyfield Soils.

The oxidation-reduction reaction of soils goes on in paddyfields not in the same way as in upland fields, because soils are, being covered by irrigation water, not aerated during summer in the former, while they are aerated year-round in the latter. It is natural that microflora grown in these soils are distinct from each other. In order to assess this difference, the microflora in paddyfields was compared with that in upland fields under the same moisturecontent of soil; test materials were drawn from paddyfields in autumn when irrigation water was drained. In this way nearly the same moisture content was assured in both fields.

Following this idea, Ishizawa and Toyoda[4] carried out a paddy-versus upland field comparative study across the country, Hokkaido through Kyushu. The results are shown in Table 1. In the first horizon, i.e. plow layer paddyfields showed a greater number of bacteria and anaerobic bacteria, while a smaller number of actinomycetes and fungi than upland fields respectively. On the other hand, Ishizawa et al.[3] studied effects of moisture content of soils on various types of microorganisms, and found that actinomycetes and fungi were predominant in low moisture and dry condition of soils, and the greater the moisture content of soil was, the more bacteria were found. Takai et al.[8] reported that bacteria were prevailing among microorganisms in water-logged paddy soils. Therefore results shown by Ishizawa et al. were to be interpreted that a water-logged condition of paddy soils which are contrary to that in upland soils did not cease to exist after irrigation water was drained.

In observing horizontal-wise, paddyfields produced a greater number of bacteria in the second and the third horizons, while much less fungi in both horizons than upland field respectively.

Table 1 shows a horizontal distribution of sulfate reducer, an obligate anaerobe; denitrifier which is deemed to be facultative anaerobe; and nitrifier which is an obligate aerobe. In the first horizon of plow layer paddy soil contained pretty much amount of sulfate reducers, more denitrifiersand less nitrifiers than upland soil respectively. The evidences fully illustrate the types of bacteria grown in soils under the unaerated condition of water-logged paddyfield.

It must be noted that considerable amounts of sulfate reducers and denitrifiers are found even in the lower horizons of paddy soil, II and III. This is the feature which distinguishes paddy soil from upland soil. Supplies of irrigation water amount to 900 cubic meter per 10 ares during summer, and water permeated thereout leach bacteria and their basic food, i.e. organic matters, with the result that these are deposited in the lower horizons. Takai *et al.*[7] observed organic carbon, iron and bacteria in their leached state in the permeated water which

Table 1. Abundance of Microorganisms of Paddy and Upland Soil in Japan
(Numbers of microorganisms per 1 g of dry soil)

Kinds of Microorganisms	Paddy Soil*			Upland Soil**		
	1 st. Horizon	2 nd. Horizon	3 rd. Horizon	1 st. Horizon	2 nd. Horizon	3 rd. Horizon
Aerobic and Facultative Anaerobic Bacteria	30, 000, 000	13, 100, 000	8, 370, 000	21, 850, 000	6, 280, 000	1, 640, 000
Actinomycetes	2, 200, 000	880, 000	380, 000	4, 770, 000	1, 720, 000	350, 000
Fungi	85, 000	16, 000	6, 000	231, 000	43, 000	11 '000
Anaerobic Bacteria	2, 320, 000	1, 120, 000	220, 000	1, 470, 000	570, 000	160, 000
Sulfate Reducer	79, 000	16, 000	4, 000	980	610	3
Denitrifier	297, 000	164, 000	122, 000	42, 000	27, 000	—
Nitrifier	11, 300	—	—	70, 470	53, 020	520

* Average of 18 samples.
** Average of 26 samples.

is periodically released from plow layer. In this experiment plow layer is contained in permeation tube saturated with water, and kept at constant temperature 26.5°C. The results show that, following the leaching of organic matters and iron out of water-logged plow layer much bacteria and sulfate reducer are also leached. Therefore the evidence quite agreed with Ishizawa and Toyoda's study on horizontal distribution of microorganisms in which bacteria, denitrifier and sulfate reducer are abundant in the lower horizons.

Development of soil horizons in the water-logged paddyfield and microorganisms.

Under Section (I) we confirmed that distribution of microorganims in the drained-off paddyfield is different from those in upland soil as the former soil is inevitably affected by the preceeding water-logged condition. Therefore, if a positive water-logged condition is again invited by cultivation of rice, paddy soil will certainly affect microflora yet more distinctly.

In summertime one may notice the profile of soil of water-logged paddy field tinted pale. This is plow layer: most part of it is colored bluish gray; the very surface, 1 to several mm thick, is yellowish brown. The difference in color in these two layers ascribes to the extent in which Fe is oxydized or reduced: brown color in the surface due to Fe^{3+} (ferric type) deposited there: bluish gray in the lower layer to Fe^{2+} (ferous type); the former is oxydized, while the latter reduced.

Then how are these horizons developed? They are caused by the function of microorganisms. Paddy soils, unlike marsh land soils, are exposed to air so often; from

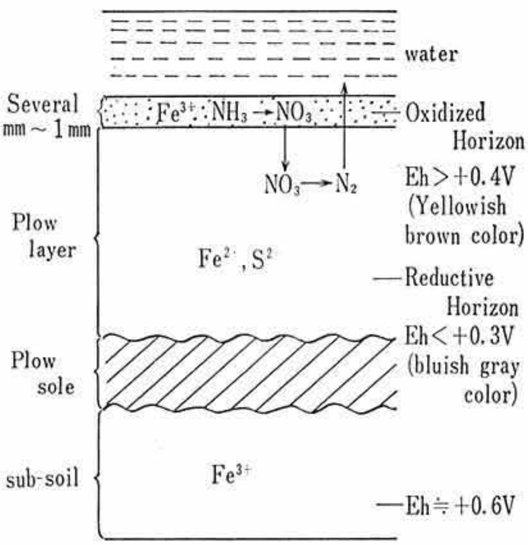

Fig. 1 Development of Soil Horizon under Water-logged Condition

autumn to next spring in the case of drained-off fields in early spring when oxydized layers of soil is broken and soil temperature become raised, in the case of year-round water-logged field, that the ecological equilibrium between microorganisms and circumferential soils is disturbed prior to irrigation water begins to permeate in between. Consequently, microorganisms may, on the arrival of irrigation water, decompose adjacent organic matters largely aerobically for the time being. In this way they consume oxygen in the soil at first, then reduce such oxydized minerals as oxydized iron, and eventually regain a new equilibrium. The supply of oxygen may be more limited in paddy field than in upland field because irrigation water disturb it. In reality, however, oxygen gas in the atmosphere is dissolved into surface water in paddyfield. Furthermore, such aquatic plants as algae and duckweeds come to grow and release oxygen through their photosyntheic action. Thus, with the permetion of diffusing water or surface water, the paddy soil is supplied with some amount of oxygen gas. This is the reason why microorganisms in paddy soil are vigorous for the time being when soil is replenished with irrigation water. Oxygen thus supplied is almost consumed by microorganisms before a new ecological equilibrium is regained and supplies of oxygen from irrigation water outweigh consumption. Consequently, the surface of plow layer of paddy soil is affected by oxygen which eventually diversify the plow layer into two horizons as shown in Fig. 2. This was the unique result demonstrated in the 1930's by late Dr. Shioiri in "Chemistry of Rice-Field Soils".[6]

Denitrification

Shioiri traced, in the above mentioned study, chemical changes of nitrogen in water-logged soil in the context of diversification of layers of soil. The chemical change of nitrogen in soil may be resulted from oxydation and reduction of soil. In the reduction condition of soil anaerobic bacteria may be active, while in the oxydized condition aerobic bacteria be active. Thus in the plow sole of paddy soil aerobic bacteria like nitrifier may not thrive because reduction prevails there; application of ammonia may be successful because ammonia are not subject to chemical change. In the uppermost layer, however, oxydation may proceed and nitrifier may be active so that ammonia may be oxydized to nitric acid. Nitric acid thus developed may diffuse itself or be transported by water into the reduction horizon. There it may be reacted by denitrifier to become nitrogen gas. The process is called denitrification. Shioiri *et al.* analyzed these phenomena and found a countermeasure to waive the inevitable denitrification by applying nitrogenous fertilizers in such a way that they are dispersed deep into lower layers of soil. This is called the 'Nitrogen application throughout plow layer.'

This was a theoretical inference deduced from the chemical analysis. Since that time a number of experiments have been tried to endorse the theory.

Ishizawa and Suzuki[2] have quantified, in their lysimeter experiment, the number of nitrifiers deposited in the surface layer (0–5mm deep) and also in the deeper layers of soil which is treated in the same condition with paddyfield. The results are shown in Fig. 2. In the water-logged period, from

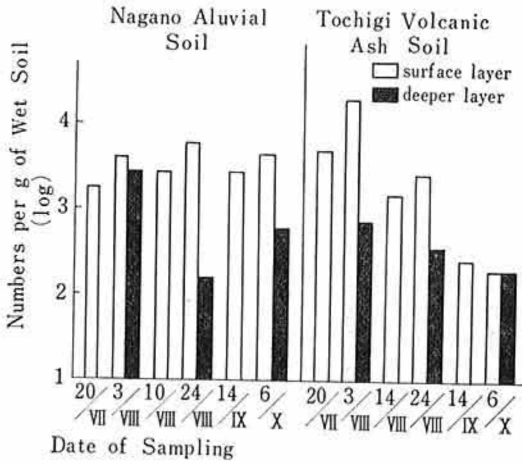

Fig. 2 Number of Nitrifier of the Soil directly Contact with Irrigation Water

late July to September, nitrifiers increased more in the surface layer than in the lower one. Chen and Chon[1] reported that denitrifiers (pseudomonus) were found side by side with nitrifiers in the paddy soil.

Very recently labor-saving methods of rice cultivation have been eagerly sought for in the wake of the agricultural improvement. A series of practices is being investigated in which transplanting may be replaced by direct sowing on dry field prior to irrigation. In this connection the effective utilization of microorganisms is also to be reconsidered. Should ammonia be left on dry field for a long time it might be oxidized to nitric acid by nitrifiers; should dry land be irrigated, nitric acid might turn to nitrogen gas through denitrification; and fertilizer effect of nitrogen would decrease considerably. In order to prevent soil from this denitrification, a certain type of nitrifier inhibitor is being developed. Thio-urea, N-serve, dicyan diamide, PCP, etc. are found effective in improving yields of rice.

Increase of Fertility in the Oxydized horizon of Paddy Soils and Microorganisms

According to denitrification theory the oxydized horizon of paddyfield may well be considered as a catchment area where nitrogens are denitrified and destined to be nullified. On the contrary, however, paddy soils are customarily believed fertile and some of them have produced more than 150 kg of rice per 10 ares in the succeeding several decades even without application of fetilizers. One of the reasons may be ascribed to minerals which are transported by irrigation water. But evidences prove that relatively small amount of nitrogen is carried in the irrigation water. Accordingly irrigation water is not necessarily be regarded as a natural supplier of nitrogen.

According to a recent study by Ishizawa, Toyoda and Tanabe[5] in the lysimeter experiment plot in Nishigahara Experiment Station, green algae and blue algae (of nitrogen-fixing nature) thrived vigorously in the surface water and in the surface soil

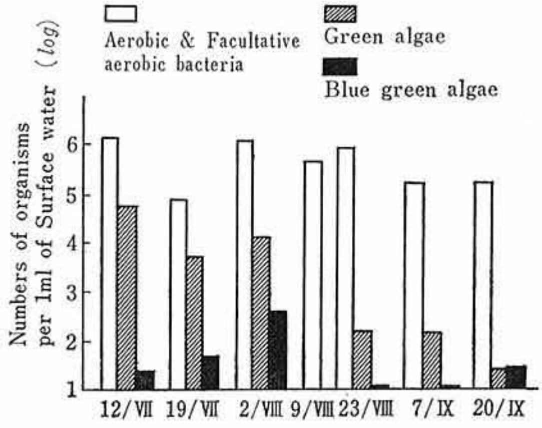

Fig. 3-1 Bacteria and Algae of Surface Water

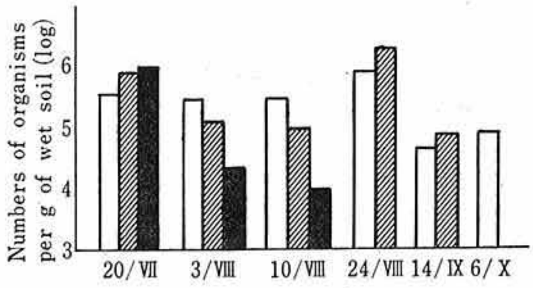

Fig. 3-2 Bacteria and Algae of the Soil directly contact with Irrigation Water

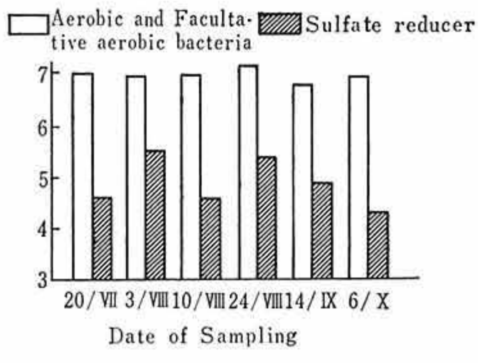

Fig. 3-3 Bacteria and Sulfate Reducer of the Soil of Inner Layer

for about 1 month after application of fertilizer on July 2. It is obvious that organic matters are produced there in great quantity and that they, in turn, are contributing to the increase of nitrogen in paddyfield.

Development of Growth-Retarding Element of Rice in the Reduced Horizon

As seen from Fig. 3-3 sulfate radical in the reduction horizon is reduced by sulfate reducer to hydrogen sulfide, and in case where a smaller amount of active iron is deposited in the soil root-rot disease develops and causes the "Akiochi" phenomenon of soil. Other growth-retarding elements of rice also develop from various fermented organic matters, i. e. mercaptan, butyric acid, acetic acid, formic acid, lactic acid, etc. Thus too much reduction is liable to cause an unhealthy growth of rice. In order to prevent such extraordinary reduction, an artificial drain of irrigation water is intermittently practiced.

Thus the diversification of oxydation and reduction horizons of paddyfield soils is caused by functions of microorganisms living there. In each horizon of soils specific flora is found to exist, and this is a characteristic of paddy field soil shown as distinct from those of upland soil. The understanding may facilitate and promote artificial control of metabolism which goes on in the paddy field soils.

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Drill Fertilizers and Their Recent Developments

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Recent tremendous changes in the socio-economic situation in Japan have provoked so serious a labor problem that the labor force is increasingly drawn out of the agriculture sector and hence agricultural productivity should inevitably be maintained through mechanization of field operations. Seeding and fertilizing practices in paddy fields, among others, have invited our attention, and various types of machines have now come to be developed. Direct sowing drills for non-irrigated fields have been invented in a wide range of size-from small to large - and is being introduced into practical use. As to direct sowing planter for submerged fields some difficulties still remain to be solved. Manual type planters, however, are now largely used in practice.

Fertilizer drill which tillage attachment

Fertilizer drill with tillage attachment is an operating unit which performs tilling and harrowing by rotary tiller and seeding and fertilizing at the same time. Design of the seeding and fertilizing part is almost the same for various types but there are two types for harrowing parts - rotary type and plow-with-harrow-type. The rotary-type fertilizer drill consiste of rotary and seeding, fertilizing device being attached to