Microbial Dynamics of Paddy Soil Under Waterlogged Condition

Yasuo Takai*

In the monsoon area of Asia, the sight of paddy field filled with water is a natural scene which adds poetic charm to the summer or rainy season.

Lowland rice may be well grown under upland moisture condition when water control is carefully operated. Nevertheless, farmers make it a custom to cultivate rice under waterlogged condition all over the world, wherever the water supply is available.

In 1972, when I studied at the International Rice Research Institute, at Los Banos in the Philippines, I learned two subjects of interest. In front of the main office, on the experimental plot without N fertilizer, rice has been successfully grown for several successive cropping seasons. At the Banaue and Bontoc areas of northern Luzon, I saw the wonderful spectacle of world-famous rice terraces, which scale the mountain wall 500-600m high. According to the Britannica, this rice terrace was constructed at 5th century B.C., about 2500 years' ago. That rice cultivation has been sustained for a long time until now, without fertilizer but with the application of wild grass.

Thus, the waterlogging provides several benefits to rice growing, as follows:
1) A plentiful natural supply of nutrients from irrigation water as well as from biological dinitrogen fixation.
2) Maintenance of organic matter in the soil.
3) Higher availability of essential nutrients such as phosphate.
4) Avoidance of soil sickness caused by continuous cropping.
5) Suppression of weed growth.
6) Moderation of sudden changes in soil temperature.

A distinguishing feature of waterlogged paddy soil lies in the creation of a reduced state in the soil due to the limiting of the oxygen supply by the flood water. Most of the above-mentioned benefits for rice growing depend on this distinctive creation of a reduced state.

According to the results of a contest for rice yield among Japanese farmers from 1949 to 1963, the rice grain yield exceeded ten tons per hectare in 1955. Those outstanding farmers applied larger amounts of organic material such as rice straw compost in general. In such farms, the ratio of applied organic nitrogen to total applied nitrogen (chemical fertilizer + organic material) exceeded on the whole 50%. By supplying a larger quantity of organic material, a fairly strong reduced condition can develop and inhibit rice root growth. Thus, such farmers conducted proper control of the oxidation-reduction condition in the soil by means of water management such as an intermittent irrigation and midsummer drainage. In order to verify those farmers' experiences, Shiroshita and others (1962) gained high yields in a rice cultivation experiment by combining deep cultivation, higher application of farmyard manure, and careful water control. The experimental result proved that the above-mentioned farmers' techniques lay within scientific rationality (1).

With such a background, my study on paddy soil commenced in the late 1940s. This lecture includes

---

* Dr. Professor of soil science, University of Tokyo
the author's previous work on microbial dynamics in waterlogged soil. There are four main subjects, as follows:

1) Reduction process and microbial metabolism.
2) The effect of water percolation on the oxidation-reduction process.
3) Oxidation process in the uppermost part of plough layer in relation to nitrification and denitrification.
4) The effect of chemical fertilizer and organic material applications on the paddy ecosystem.

**Reduction Process and Microbial Metabolism**

First, the author shows his previous research work on the reduction process of waterlogged paddy soil incubated under laboratory conditions.

Figure 1 shows that a succession took place from aerobic, anaerobic bacteria to sulfate-reducers with the drop of Eh (2).

![Figure 1. Fluctuation of bacterial numbers and Eh in paddy soil under waterlogging](image)

**Figure 2.** The process of reductive development in the submerged soil put in a syringe under laboratory conditions (Nigata yashiroata soil).

As shown in Figure 3, a bacterial cell needs energy for synthesis and for survival. It obtains this energy by biological oxidation of substrates.

**Energy metabolism**

![Energy metabolism diagram](image)

**Figure 3.** The energy flux in metabolism.