Study on the Irrigation in Rice Cultivation

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The rice plant is considered to be semiaquatic crop, although the plant is grown in moisture condition ranging from the submergence to the upland. The rice cultivation generally is conducted with the continuously submerged irrigation during the period from the early tillering stage to the ripening stage and the rice production has been stabilized by such irrigation. This is for the following reasons.

1. Natural supply of nutrient to the crop is more in the submerged condition than in the upland condition, because the irrigation water contains nitrogen, phosphorus, potassium and other inorganic nutrients as well as useful soil colloid.
2. Emergence of weed is reduced markedly with the increase in depth of submerged water, particularly barnyardgrass, competing strikingly with rice, is controled by the submerged water depth of 15 cm or more.
3. Submergence may enhance the fixation of nitrogen by the blue-green algae and other organisms, and increase the availaility of both the native phosphorus and the applied fertilizer.
4. Submergence makes the decomposition of organic matter in soil slower and controls the waste of soil fertility,
5. As water has high specific heat, the submerged irrigation in cool region may protect the rice plant from cold damage and stabilizes the production.

On the other hands, the submerged irrigation reduces the gaseous exchange between the atmosphere and the soil, and consequently allows the accumulation of products of anaerobic decomposition such as methane, organic acids and hydrogen sulfides. Some of these products may retard the physiological function of rice root, reduce the nutrient absorption and, in some cases, cause those physiological diseases as straight head and bronzing resulting in the decreased yield.

Rice has a tissue which transfer oxygen from leaves to roots and secretes the tranfered oxygen into the soil to cope with the reductive condition. However, the root rot occurs in the severe soil reduction which overruv the oxidative activity of rice root.

In submerged condition, the supplies of oxygen to the soil system are conducted through the diffusion and the percolation of oxygen dissolved in the surface water. In paddy field the amount of percolated water usually ranges from several mm to several cm a day in decreasing water depth. It is shown in Table 1 that more than 95% of oxygen supplied are consumed by the micro-organisms in the layer less than 2cm deep from the surface. This implies that it is hardly possible to increase the root activity and to accelerate the decomposition of organic matter by the only oxygen amount in the percolated water. Thus, the aeration by the drainage of underground water is necessary for the rice growth.

It is shown in Table 2 that the effects of submergence on rice yield differ with the amounts and the kinds of fertilizer. In the case of less fertilization, rice yields in the drained plot, which kept under wet condition (no standing water) from one week after transplanting to harvesting time, are 12% less than those in the continuously submerged plot, while, in the case of much fertiliza-

Table 1. Change of oxygen dissolved in underground by water percolation

plot	Date	Aug. 19	Aug. 20	Aug. 21	Aug. 21	Aug. 31	Sept. 7	Sept. 13
	Time	13	14	6	13.30	13	13	13
Control	Surface water	9.4mg/l	9.0mg/l	3.0mg/l	9.1mg/l	6.4mg/l	14.1mg/l	13.1mg/l
	underground water (2 cm)	0.4	0.4	0.4	0.2	0.3	0.4	0.6
	underkround water (12cm)	0.4	0.7	0.6	0.5	0.3	0.5	0.4
Percola-tion	surface water	11.4	12.2	4.4	12.2	9.0	13.3	10.3
	underground water (2 cm)	0.3	0.6	0.5	0.5	0.4	0.3	0.3
	underground water (12cm)	0.3	0.6	0.6	0.7	0.3	0.2	0.3

Notes: Percolated period: Aug. 20～Sept. 8.
Percolated amount: 5 cm per day in decreasing water depth.

Table 2. Interaction of irrigation × fertilizer on rice yield

Plot			Brown rice wt.	Straw wt.
			kg/are	kg/are
Much fertilization	Powdery chemical	Submerged	46.4	64.8
		Humid	44.2	58.1
	Granular chemical	Submerged	44.7	63.7
		Humid	47.3	64.0
	Soybean cake	Submerged	45.3	61.7
		Humid	43.6	55.3
Less Fertilization	Powdery chemical	Submerged	47.0	56.5
		Humid	41.0	49.8
	Granular chemical	Submerged	47.6	57.8
		Humid	42.0	50.7
	Soybean cake	Submerged	43.6	55.3
		Humid	39.8	46.9

tion, there are no significant differences in rice yield between the submerged and the drained plots. It is also found that the rice yields in the drained plot, as compared with those in the submerged plot, are 8 to 9% less in the case of such quick-responsive fertilizers as powdery chemical and soybean cake, while 3% less in the slow-responsive fertilizer like granular chemical. From this experiment, it is suggested that the continuously submerged irrigation is not always necessary for the rice growth in the field where a great quantity of nitrogen, phosphorus and potassium are applied. Some nutrients in irrigation water and nitrogen fixation by algae may be important factors in regions where soil fertility limits the rice production, but these may be replaced by fertilizer, compost and soil dressing. The other effect of submerged irrigation on weed control is also of importance as a cultural practice. If the weeds are controled by such appropriate method as herbicide and mechanical weeding, the improved irrigation management in rice cultivation in warm region are to save the irrigation water and to regulate the nutrient uptakes by the plant as far as possible.

Moisture content of soil and rice growth

Needless to say, water is required as a component of nutrients to make physiological function of rice active. It is reported by many investigators that the amount of water required to produce 1 gram of day matter of rice is 280 to 310 grams. The total irrigation water is computed by the following equation: Total irrigation water = Transpiration + Evaporation + Percolation — Precipitation. Of these factors, percolation varies considerably according to the characteristics of soil as well as the underground water level. The evapotranspiration amounts obtained in Japan range from 4 to 8mm a day in decreasing water depth. If the rice plant is irrigated with the amount of water equal to the evapotranspiration during the growing season, the submerged irrigation appears to have no beneficial physiological roles. It is shown in Figure 1 that the rice yields in the upland plots, which kept at field capacity during the growing stages, are as much as or even higher than those in both the continously submerged plots and the humid plots with the underground water levle of 5cm below the surface. The increased yield in the upland plot is attributed to the high root activity as well as to the increased mineral nitrogen resulting from the decomposition of organic matter.

However, the rice plant grown under the upland field is susceptible to the influence from the water shortage, because the roots develop in the shallow layer of soil. It is

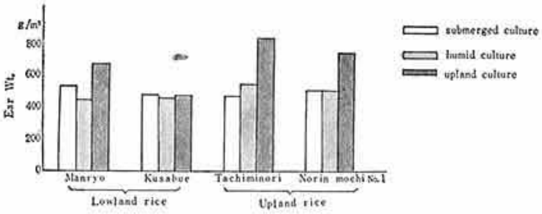

Fig. 1. Relationship between moisture condition of soil and rice yield.

obtained by many workers that the rice plants are seriously affected by the water shortage during the period from the young ear formation stage to heading time, especially at the stage of reduction division of mother cell when the plant reachs the greatest leaf area and the highest transpiration.

Therefore, the late submerged irrigation, which kept at the upland condition during the tillering stage and then switched over to the submerged condition after the young ear formation stage, may be one of the reasonable irrigation methods of saving water. It is reported by Amatatsu and Takai that the rice yield in the late submerged irrigation is higher than in the customary submerged irrigation on Akiochi soil with high concentration of toxic substance under flooded condition. The repeated submergence and drainage by the so-called intermittent irrigation system may be also effective in preventing the root rot of rice.

Relationship between irrigation method and rice yield

The decomposition of organic matter proceeds at a higher rate in well-aerated soil than in submerged soil. Much amount of nitrate is produced as the end product of mineralization in well-areated soil, but some of them are lost by leaching and denitrification due to the fluctuation of underground water and heavy rainfall. Drying a soil provides conditions for the decreased solubility of phosphorus, silica and iron etc, and sometimes retards these nutrient uptakes by the plant.

The effects of late submerged irrigation and intermittent irrigation on the rice yield are expressed in Figure 2 in the ratio to the early submerged irrigation. The irrigation treatments are:

1. In the early submerged irrigation, water was kept at 5cm in depth during the period from the tillering stage to ripening stage.
2. In the late submerged irrigation, no water was applied to the field during the tillering stage, then submerged after the young ear formation stage.
3. In the intermittent irrigation, the plants were applied 50mm of water at an interval of 7 days since the tillering stage and the field was kebt at submerged condition for 3 days followed by moist or upland condition for 4 days.

It is shown in Figure 2 that the effects of late submerged irrigation and intermittent irrigation on rice yield are affected by the level of underground water and the rainfall amount for no water period:

1. When the level of underground water was high and the rainfall was much;

The rice yields in the late submerged irrigation and the intermittent irrigation, as compared with those in the early submerged irrigation, were apparently less in the case of small amount of fertilizer. However, it is found that the rice yields in the intermittent irrigation were as much as or even higher than those in the early submerged irrigation in the case of large amount of fertilizer.

These differences in rice yield between these irrigation treatments depend primarily on the decrease of nitrogen uptakes as affected by the fluctuation of underground water and heavy rainfall for no irrigated period.

2. When the level of underground water was high and rainfall was less;

There were no significant differences in rice yield between the early submerged irrigation and the intermittent irrgation in the ceses of either much or less fertilization.

3. When the level of underground water was low and the rainfall was much;

The rice yields in the late submerged irrigation were slightly more than those in the early submerged irrigation in the less fertilization, while the former was lower than the latter in the much fertilization. Chemical analysis showed the increased nitrogen uptake by the plants in the late submerged irrigation over the early submerged irrigation.

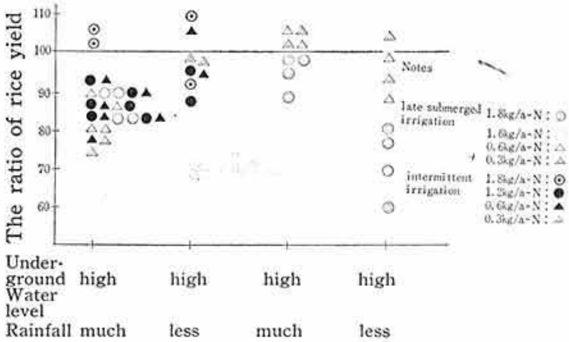

Fig. 2 Influences of late submerged irrigation and intermittent irrigation on rice yield.

4. When the level of underground water was low and the rainfall was less;

The rice yields in the late submerged irrigation were significantly lower than those in the early submerged irrigation in the much fertilization, but there were no differences in rice yields between two irrigation methods in the less fertilization.

The plants in the late submerged irrigation showed higher contents of nitrogen and lower ones of phosphorus and silica than those in the early submerged irrigation, resulting in delayed flowering, severe lodging and decreased yield.

From these observations, the continuously submerged irrigation may be not necessarily be essential for the rice growth. If the soil moisture is kept at the field capacity, it is possible to attain rice yield not less than what may be attained by submerged irrigation. There are, however, practical difficulties in supplying enough water to the rice plants grown under the upland condition during the period from young ear formation stage to heading time when the plants consume large amount of water. It is also found that the physiological disease like straight head sometimes occurs in the plant grown under unflooded condition during the booting stage on the soil rich in organic matter and the soil deficient in iron. Accordingly, a system of irrigation which is kept at the submerged condition after the young ear formation stage of rice may be favorable to stabilize the production. Controlling the root rot and regulating the fertilizer response might be practiced by the underground water drainage in the tillering stage.

For the purpose of controlloing root rot, the late-or intermittent submergence is more desirable than the continous submergence. In introducing these practices, however, climatic condition and amount of fertilizer may be important factors as shown in the above mentioned results of experiments. Major rice areas of the world are distributed in the regions with heavy rainfall and, in some cases, with the monthly rain-fall over 200mm during crop season. Furthermore, most of paddy fields distribute on the lowland where the level of underground water is in the cultivated layer. Under such condition, the relationship between the irrigation methods and rice yield may be the same as the above stated I type.

In South East Asia, India and Latin America, the rice is grown with a little or even no application of fertilizer. The late submerged or intermittent irrigation in these regions may result in the decreased yield as compared to the continuously submerged irrigation, except on the soil where much harmfull substance generate under submerged condition. It seems that an appropriate irrigation method in these regions is the submerged irrigation combined with the short period draining in the tillering stage of rice. On the contrary, the rice cultivation in Japan is conducted with heavy application of fertilizer, especially nitrogen, in order to get high yield from the limited rice field.

The rice plants grown with heavy application of fertilizer is susceptible to the influences of fluctuation of light intensity and temperature and result in severe lodging and disease and insect damage, and the decreased yield due to the excess of nitrogen uptake. It is important to regulate the nitrogen response in order to cope with the fluctuation of climatic condition. As the mineral nitrogen in soil is effectively reduced by the intermittent irrigation in which the repeated processes of oxidatian and reduction accelerate denitrification, this irrigation system may play a significant role in stabilizing the rice production. It should be emphasized that the irrigation management in rice cultivation in Japan is on regulating the fertilizer response rather than on maintaining the soil fertility.

References

1) Katsumi Amatasu, Kan Yamakawa, Fumiyoshi Hatsuku and Manabe Wada:
Research on time of irrigation in direct sowing practice of rice, Kyushu Agricultural Experiment Station Bulletin 2 (2), 1954.
2) Utaro Kawahara:
Study on water saving irrigation in rice cultivation, Nogyo oyobi Engei 19 (8), 1944.
3) Matsubayashi et al.:
Theory and Practice of Growing Rice, Ministry of Agriculture and Forestry, 1963.
4) Kazuma Nojima, Ichiro Tanaka:
Effect of water percolation on the rice growth (1st. report) Proc. Crop Sci. Soc. Japan, 29 (3), 1961.
5) Kazuma Nojima, Ichiro Tanaka and Yukimasa Uemura:
Effect of drainage on the rice growth (1st. report) Proc. Crop sci. Soc. Iapan, 30(4), 1962.
6) Ichiro Tanaka, Kazuma Nojima and Yukimasa Uemura:
Effect of drainage on the rice growth (3 rd.-report) Proc. Crop. Sci. Soc. Japan. 33(4), 1965.
7) Kinichi Yoshioka, Akira Miyake:
Staudy on irrigation in rice cultivation, Nogyo oyobi Engei, 20(4), 1945.
8) Shizuo Takai:
Research on water saving irrigation of rice, Yamaguchi Pref. Agric. Exp. Sta. Bul. 15, 1962.