Effects of Drainage on the Growth of Rice Plants in Ill-drained Paddy Fields

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Autumn-decline of rice plant growth which often occurs in ill-drained paddy fields is considered to be due to reduction of the soil as a result of continuous flooding of the fields. To take measures to meet this situation, the author layed stress on drainage effects to the conditions of water and nitrogen in the soil, and intended to make clear the effects of drainage on the growth of rice plants by examining relations of the absorption of water and nitrogen with the photosynthesis and respiration in them.

There have been many studies on the drainage before now, however, most of them were carried out by pot culture or in well-drained paddy fields. The author's studies are significant in the point that the experiments were carried out in an ill-drained paddy field of the Hokuriku Agricultural Experiment Station, Ministry of Agriculture and Forestry (Takada City, Niigata Prefecture) where are arrangements to regulate irrigation and drainage at will.

The drainage in this paper means to exclude the surface water and to stop irrigation. The experimental plots provided were three in number as shown in Fig. 1, that is, a continuously flooded plot (control), an earlier drained (a month from the end of the valid tillering time to the panicle primordium differentiation time) plot and a later drained (a month from the panicle primordium differentiation time to the heading time) plot.

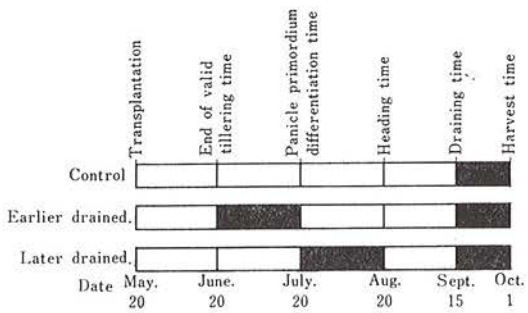

Fig. 1. Time of draining.
Note: ■ shows draining period.

Effects of drainage on the yield

According to the results of the 5 years' examinations since 1957, it was shown that an increase in yield was 7% in the earlier drained plot and 6% in the later drained one over the control. The dry matter of the plants above the ground was also larger in weight in both drained plots than in the control. Those results show that the increase in yield by drainage has relation to the increase in weight of dry matter. The author, therefore, aimed at studying the effects of drainage in respect of the dry matter production.

The effect of drainage on the absorption of water and nitrogen by the rice plant is described firstly in this paper, because the photosynthesis which is a foundation of the dry matter production has relation to the absorption of them in this plant.

Effect of drainage on the absorption of water

The water content of the leaf-blade is lower as a rule in the drained plots than in the control as shown in Table 1. The degree of decrease in water content of the leaf-blade during the drained period and after reirrigation was different between the two drained plots, although both the water content of the soil and level of ground water in the draining period were almost equal between the two plots.

Table 1. Effects of drainage on the water content of the leaf (Miyasaka unpublished)

Plot / Date	Control	Earlier drained	Later drained
July 5	78.6	73.8	—
July 15	72.5	70.9	—
July 30	71.1	70.3	70.7
Aug. 10	68.2	67.2	67.7
Aug. 20	66.9	66.0	66.4
Aug. 30	65.4	65.2	65.2
Sept. 10	62.6	62.4	62.4
Sept. 20	62.0	61.7	61.6
Sept. 30	61.2	61.0	61.1

Note 1: ~~~ shows measurements in the drained condition.

Note 2: In each plot 4 moderately grown plants were selected to take 5 moderate stems from every one of them, and all the living leaves of the 20 stems in total were used as materials.

More decrease in water content of leaf was recognized in the earlier drained plot, especially in its first half of the draining period where the working depth of roots is not deep yet, than in the later drained plot.

It was clarified that suberization of the root endodermis was promoted by drainage treatment, especially by the earlier one, and this suberization is possively related to decrease in water permeability of root.

This explanation accords also with the facts that the guttation sap and the bleeding sap, not only in the draining period but also after reirrigation, stood in the order: control plot> later drained plot>earlier drained plot.

Effects of drainage on the absorption of nitrogen

The author's result shows that the absorption of nitrogen is larger in the latter half of the draining period and after the heading time in the earlier drained plot and in and after the latter half of the draining period in the later drained plot (Fig. 2), though many researchers (Murojima 1950, etc.) have reported an inhibition of nitrogen absorption by drainage. A little decrease of nitrogen absorption was recognized only in the first half of the draining period and for ten days immediately after reirrigation in earlier drained plot. On the other hand, available nitrogen is fairly smaller in amount in the cropless soil of both drained plots than in that of the control. Therefore, the fact that the absorption of nitrogen is a little smaller or occasionally larger in amount in the drained plots than in the control can not be explained by the amount of available nitrogen in them.

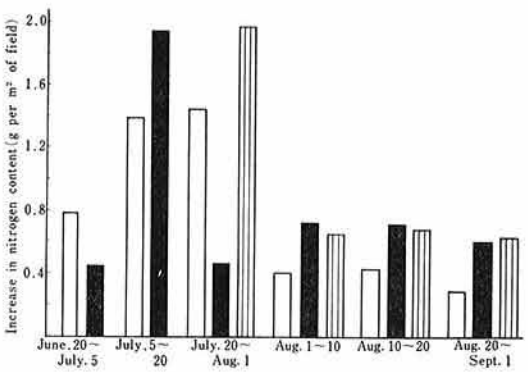

Fig. 2. Effects of drainage on the increase in nitrogen content of the rice plant (Miyasaka unpublished).

Note: □: Control ■: Earlier ▥: Later darined

To clear up the cause, the author examined the number and activity of roots and the oxidation-reduction potential of the soil, obtaining the results that the primary roots were smaller in number in the drained plots than in the control, and the oxidation-reduction potential lowered sharply in the control after about July 10 (that is, from the latter half of the draining period of the earlier drained plot), while it was kept on a higher level not only during the draining period but also after the reirrigation in the both drained plots. With correspondence to oxidation-reduction potential the activity of roots was higher in the latter half of the draining period in both drained plots than in the control, though it was about the same in the earlier half of the draining period in the earlier drained plot as in the control (Fig. 3). Accordingly, the

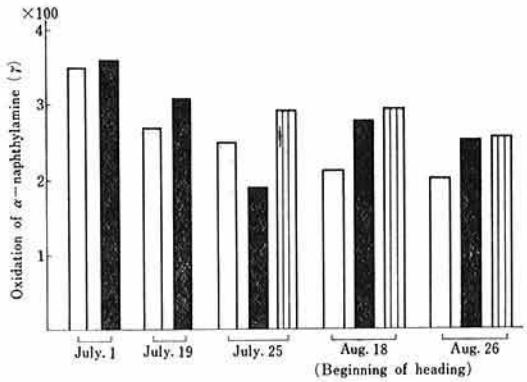

Fig. 3. Effects of drainage on the oxidation of α-naphthylamine by the root (Miyasaka unpublished).

Note: □: Control ■: Ealier drained [II]: Later drained

fact that the nitrogen absorption by rice plants is larger in amount in both drained plots for the amount of available nitrogen in the soil is due to the higher activity of roots in them. Drainage has an effect on the activity of roots through the oxidation-reduction potential of the soil, and is related to the absorption of nitrogen.

Effects of drainage on the photosynthesis

The amount of photosynthesis was measured in population obtaining the results as shown in Fig. 4. The relation between the photosynthesis and the absorption of water and nitrogen changes seasonally as follows.

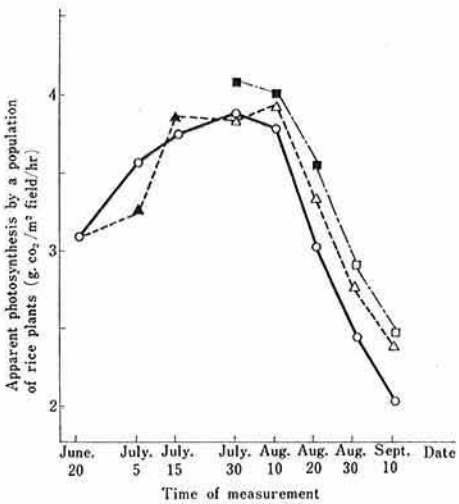

Fig. 4. Effects of drainage on the apparent photosynthesis of rice plants in population. (Miyasaka unpublished)

Note 1: Measurements were carried out at 10–11 a.m.

Note 2: Marks

	Flooded condition	Drained condition
Control	○	
Earlier drain.	△	▲
Later drain.	□	■

a) The photosynthetic activity in population is lower in the earlier half of the draining period in the earlier drained plot than in the control. This is the result of a decreased photosynthetic rate, an increased respiration rate, and a decreased LAI (leaf area index) due to drainage. And those changes are caused by a decrease in water content of

leaves.

b) The photosynthetic activity in population is higher in the latter half of the draining period in the earlier drained plot and through the draining period in the later drained plot than in the control, resulting in an increase of the dry matter of plants above the ground. This change has relation to an increase of photosynthetic rate, a decrease in respiration rate and also to an increase of LAI. The increase in photosynthetic rate due to drainage has relation to an increase in nitrogen content of leaves.

And the increase in LAI is connected with an increase in length of the leaf-blades which grow in this period and with an increase in number of stems, accordingly with the total number of leaves. Those changes are also the result of an increase in nitrogen absorption due to drainage.

The decrease in respiration rate by drainage seems to have relation to inhibited reduction in the soil. And, taking the report of Baba et al. (1960) into consideration, this effect is possibly due to a decrease in amount of ferrous iron in the soil.

c) In the earlier drained plot, the photosynthetic rate decreases and the respiration rate increases temporarily (for about 15 days) after the reirrigation. And the leaves are grown smaller in length, number of stems and nitrogen content of leaves decrease in this period. Accordingly, the photosynthetic activity in population of this drained plot lowers to such a level as there is observed little difference between the control. However, such an inhibition is only temporary. The photosynthetic rate becomes higher than in the control before long, the respiration rate gets lower and the receiving condition for sun-light which is represented by the extinction coefficient is improved, resulting in higher photosynthetic activity in population though the LAI (leaf area index) is smaller than in the control.

d) In the later drained plot, the photosynthetic activity in population is higher through the draining period and after the reirrigation than in the other plots. The main factors of this result seem to be an increased absorption of nitrogen and a larger LAI.

e) The photosynthetic activity in population during the ripening period is maintained to be higher in both drained plots than in the control. The factors which seem to have relation to this result in the drained plots are as follows.

(i) The photosynthetic rate is highe and the leaves are more vertical, being smaller in the angle of inclination. Those two characters are related to an increase in thickness of the leaves (leaf dry matter index).

(ii) The ratio of photosynthetic rate/respiration rate is higher (Fig. 5).

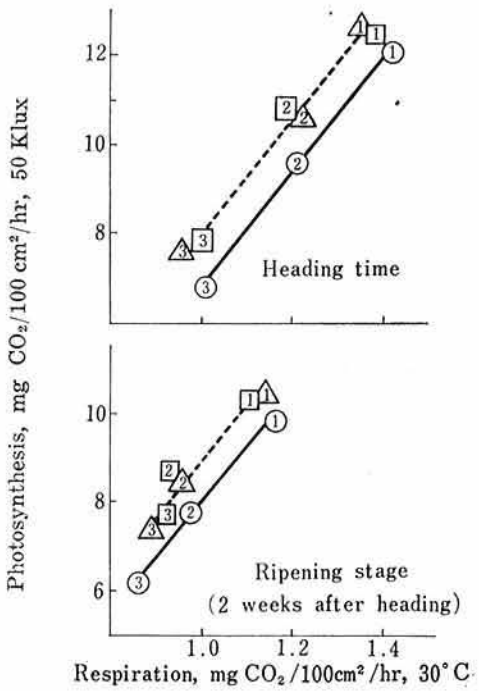

Fig. 5. Relation between photosynthesis and respiration of rice plant.

	Top leaf (flag)	1st leaf from Top	2nd leaf from Top
Control	①	②	③
Earlier drain	△1	△2	△3
Later drain	[1]	[2]	[3]

(iii) The living green leaves per stem is larger in number. This is related to the increase in nitrogen absorption during the ripening period. And lesser decrease in weight of roots and higher activity of roots in this period are mentioned as the causes of this increase in nitrogen absorption.

(iv) The LAI of the earlier drained plot which was smaller in the earlier half of the ripening period than that of the control becomes larger in the latter half period as the result of the inhibition of decrease in number of leaves. In the later drained plot the LAI is larger through the ripening period than in the others. Those facts are connected with increased nitrogen absorption in this period in both drained plots.

As mentioned above, effects of drainage on the photosynthetic activity in population and on the important factors related to this activity show seasonal changes. And according to the author's results, the photosynthesis is influenced by the inhibition of water absorption in the earlier half of the draining period of the earlier drained plot, being affected after that to nearly the time of heading through the change of nitrogen absorption in both drained plots. The photosynthesis during the ripening stage has direct relation to the thickness of leaves (leaf dry matter index), though it is also affected through the nitrogen absorption.

Distribution of dry matter

As for the effects of drainage on the distribution of dry matter to every organ in the plant, the following are noteworthy.

In the drained plots the decrease in weight of roots after the heading time is lesser, and this is one of the important factors for the increase in nitrogen absorption after that.

The nitrogen content of the rice plant before-heading time has relation to the accumulation and translocation of carbohydrates. In the earlier drained plot where the nitrogen content of the plant is lower before the heading time, both the accumulation rate of carbohydrates in the culm and leaf-sheath before the heading and the translocation rate of them to the head after the heading are higher. The relation is opposite in the later drained plot where the nitrogen content of the plant is higher before the heading time. However, there is little difference in yield between the both draines plots, because the photosynthesis is larger in amount during the ripening period in the later drained plot than in the earlier drained one.

In the earlier drained plot, spikelets decreased in number owing to the inhibition of nitrogen absorption after the reirrigation, but degenerated spikelets were small in number and the yield per 1,000 grains increased (Table 2), resulting in an increase in yield

Table 2. Effect of drainage on the number of spikelets and yield per 10000 grains

	A	B	C	D	E
Control	1703	70.0	16.8	7.6	16.6g
Earlier drain.	1667	69.5	11.6	5.4	17.7
Later drain.	1724	73.3	10.8	5.6	16.7

Note:
A : number of flowered spikelets per hill
B : number of flowered spikelets per panicle
C : degenerated number of spikelets per panicle
D : degenerated number of secondary rachis branch per panicle
E : yield per 1000 panicle

of brown rice. As compared with this, in the later drained plot the yield increased by reason that spikelets were larger in number owing to the increased nitrogen absorption during the draining period and degenerated spikelets were small in number, though there was little difference in the yield per 1,000 grains between this plot and the control plot. Accordingly, it may be said that drainage influences yield-determining factors chiefly through the nitrogen absorption.

References

1) Baba, I. and Tajima, K.: Studies on the nutrition of rice plant with reference to the occurrence of the so-called "Akagare" disease. VI. Changes in the growth, nutrients-absorption and metabolism in plant as influenced by the excessive supply of ferrous iron. Proc. Crop Sci. Soc. Japan 29, 47–50, 1960.
2) Miyasaka, A.: Effect of water management on the rice plant growth in ill-drained paddy field of Hokuriku-district. Nôgyo-Gijutsu (in Japanese) 16, 301–305, 1961.
3) Miyasaka, A.: Effect of Drainage on CO_2 Exchange and Some Characters Related to Grains Yield of Rice Plant. Proc. Crop. Sci. Soc. Japan 33, 90–93, 1964.
4) Miyasaka, A. and Ishikura, N.: Effects of some cultural conditions on the development in later growth stage of rice plant in the ill-drained paddy field. Proc. Crop. Sci. Soc. Japan 33, 107–110, 1964.
5) Miyasaka, A.: Effects of drainage on the rice plant growth in ill-drained paddy field in Hokuriku-district. Bulletin of the Hokuriku Agricultural Experiment Station. (in press).
6) Murojima, J.: Principle of fertilizing. (in Japanese), Yôkendo, 1950.