Effect of Water Percolation on Physiological Activity of Rice Root

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Introduction

It has been believed that water percolation through paddy field soil during growing period of rice crop may exert a favorable influence on growth and yield. There are many practical experiences indicating an importance of an adequate water percolation in increasing yield. However, it can be said that the experimental researches on this problem hitherto have been conducted are rather few. Irrigation implies not only an adequate and controlled water supply, but also efficient drainage of excess water whenever desirable. By drainage of surface water, the water is not stagnant, but flows gently. By subsoil drainage percolation of water takes place.

The aim of this experiment is to make clear the direct effect of water percolation on physiological activity of root, and furthermore, growth and yield as affected by the root activity. In order to separate the direct effect of percolation from the effect of surface water drainage which apt to lower moisture content of soil, the experimental plants were grown under continuous submerged irrigation without any surface drainage, and under this condition percolation was given by the use of a specially devised facility.

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1. Materials and Methods

1) Experimental paddy field

Experimental paddy field was prepared by using fifteen concrete pots, each of which is of an area 1m×1m and of 60.6 cm depth (inside dimension), as shown in fig. 1 and 2. Each pot is provided with a drainage tube (B) at the bottom. Rate of water percolation can be controlled by a stop bulb fitted to the drainage tube. Tube A is for irrigating the pot.

Three different types of soil were used in the experiment.

(1) Konosu-soil : Paddy field soil of Konos, diluvial, relatively ill-drained.
(2) Matsuo-soil : Paddy field soil of Matsuo-town, Chiba Prefecture, typical ill-drained soil containing a large amount of organic matter.
(3) Maebashi-soil : Paddy field soil of the Gunma Prefectural Agr. Station located at Maebashi-City, well drained, productive soil.

Each pot was first charged with a 15 cm layer of coarse sands and a 9 cm layer of fine sands. Above them, a layer of sub-soil and top-soil was placed. Five pots were used for each kind of soil.

2) Experimental plant

Seedlings of a variety, Norin-29, were transplanted in all pots on 1, July 1958 with the density of 36 hills per 1 m² and three seedlings per hill. Fertilizers applied per pot were 37.5 g of ammonium sulfate, 37.5 g of superphosphate and 15 g of potassium sulfate as basal dressing and 10 g of

Fig. 1 Facility of experimental paddy field

Fig. 2 A view of the experimental paddy field and drainage facility

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ammonium sulfate as top dressing (on 20, Aug.)

(3) Percolation treatment

From transplanting to 3, Aug. all pots were under the continuous submerged irrigation without either surface or subsoil drainage. From 4, Aug. afterward two pots for each soil were subjected to percolation treatment and another two pots were not treated (control plot). The remaining one pot was served to determine plant growth and root activity at the start of the treatment. Drained water, the quantity of which was controlled to be 30 l. per day (=a loss of surface water by 3cm depth per day) was collected in a vessel and returned to the pot once a day. By this re-use of drained water, loss of nutrients, if there was, could be minimised.

The percolation treatment was continued up to 5, Sept. As the heading date was 1, Sept. in all plots, the treatment covered the period from ear primordia initiation to heading. It has been known that rooting activity of rice plant is very high during the early stages of growth, so that the damage of roots can be easily compensated by producing many new roots. But during the later period of growth, rooting activity is lowered and consequently the nutrition of plant has to be supported mainly by the activity of aged roots. The purpose of this treatment is to know the effect of percolation on roots at the later stages of growth.

(4) Determination of root activity

The roots sampled were classified into several groups according to their age and morphological characteristics and then subjected to the determination of respiratory rate, oxidation of α-Naphthylamine, reduction of Triphenyl-tetrazolium chloride (abbreviate as TTC later on) and oxidation of ferrous iron by roots.

Plants sampled were killed and dried, and then subjected to the chemical analysis of nitrogen, phosphorus, potassium and silica in order to know the absorption of these elements by roots.

2. Results and Discussion

(1) Growth of plant and yield

Plant height and number of tillers are given in fig. 3. It is shown that the percolation treatment caused an increased percentage of fertile tillers to total number of tillers with all kinds of soil, resulting in an increased number of panicles per plant. Plant dry matter production is shown in fig. 4. Among the control plots, Maebashi plot showed the greatest dry weight up to middle of August, but later it was overcome by Konosu plot, which subsequently attained to the highest dry weight. Matsuo plot was the lowest in dry weight. Dry matter production was found increased by the percolation treatment, especially the later period expression of Matsuo plot was considerably recovered.

Grain yield is shown in table 1. Konosu plot gave the highest yield, and Matsuo the lowest. Percolation was found effective to increase yield with all kinds of soil, but percentage increase and factors which brought about yield increase are different with soils. In Matsuo plot,
17% increase of yield over the control was derived from the increase in panicle number, seed-setting percentage as well as 1,000 grain weight. In Konosu plot, panicle number and 1,000 grain weight were increased, but seed-setting percentage was not increased. In Maebashi plot, only panicle number was increased, but other factors were rather decreased by the treatment.

(2) Changes of roots

Basing on the fact that distribution of rootlets and color of roots vary with the aging of roots, the roots can be classified into several classes. Before the start of treatment, the roots of Konosu and Maebashi plot were divided into five groups according to their age. In Matsuo plot, however, another group of roots, showing a peculiar shape similar to lion-tail was observed and referred to lion-tail root (L in fig. 5).

Roots sampled at 18, Aug. and 1, Sept. were shown in fig. 5. At this stage of growth, a new type of root was observed. It was characterized by (a) slender and relatively short shape, covered very densely with many long and branched rootlets, (b) forming a mat-like network layer just beneath the soil surface, and (c) being produced merely on the upper nodes of stem (upper than the 10th node counted from the lowermost basal node), so that never observed by this stage. This root may certainly be what was called superficial root or root-mat by ALBERDA (1953). In fig. 5 the superficial roots are shown by dotted block. Numerical figures indicate the age of root: 1 for the youngest group and the greater number for the older roots.

The effects of percolation treatment on roots are observed as follows.

(a) Root color and rootlets: In Konosu and Maebashi plot, the treatment made the roots more fresh and white in color than roots of control plot, which were blackened by FeS. On the contrary, in Matsuo plot the treatment caused the more blackening of roots. Detailed observation proved that the blackening occurred mainly on rootlets and not on roots. In the control plot almost all rootlets were already destroyed and disappeared except the superficial roots which have developed in the most recent stage, whereas in the treated plot rootlets are still alive on the older roots and exposed to the blackening. Roots showing fresh color and no falling off of rootlets might be in the best condition, but the roots on which the rootlets are still alive although they were blackened may be in better condition than the roots which have no longer rootlets and therefore can not be blackened.

![Fig. 5 Number and dry weight of roots per hill.](image)

**Fig. 5** Number and dry weight of roots per hill. C=Control plot, T=treated plot. Numerical figures in columns indicate the grouping of roots. Dotted columns indicate superficial roots.

![Fig. 6 Respiratory rate of roots as affected by percolation treatment.](image)

**Fig. 6** Respiratory rate of roots as affected by percolation treatment.

Numerical figures below the abscissa indicate the root-groups. Root-groups from 1 to 4 in this figure correspond to the root-groups of fig. 5 as follows.

In Konosu plot: 1 and 2, 3, 4, 5.
Matsuo plot: 3, 4, 6, 7.
Maebashi plot: 1, 3, 4, 5, 6. 
(b) Superficial roots: Percolation treatment caused an increase in number and length of the superficial roots with the exception of Maebashi plot. As shown below, the superficial roots are very active in physiological functions, such as respiratory rate, oxidation of α-Naphthylamine and reduction of TTC, as compared with the other older roots. During the later period of growth, the nutrition of plants must be supported mainly by the physiological activity of the superficial roots. That the percolation treatment benefited the development of the superficial roots is shown in fig. 5. The beneficial effects is very remarkable with Matsuo plot, while it is not clear with Maebashi plot. Mori (1958) pointed out an importance of new roots developed during later growing period and occupying upper layer of soil (up to 10 cm depth) in productivity of rice. Ūeda (1958) also reported an increase of roots developing near soil surface (0 ~ 20 cm depth) and an increase in panicle number and 1,000 grain weight by percolation treatment. All these results support the result of this experiment.

(3) Physiological activity of roots

Effect of percolation on physiological activity of roots is given in fig. 6 and 7. By the treatment the respiratory rate was promoted with all groups of roots in Matsuo plot. However, in Konosu soil promotion was recognized only with superficial roots, and in Maebashi soil root respiration was retarded. This difference in response of root respiration is in harmony with the yield response to the treatment, i.e., big yield increase was resulted by percolation in Matsuo soil where the big promotion in root respiration was observed, while in other plots where the increase in respiration was only few or even a decrease took place the yield increase was few or insignificant. In Maebashi plot, the decrease in root respiration reflected the poor ripening process as expressed by a decrease in seed-setting percentage and 1,000 grain weight.

Activity of root to oxidize α-Naphthylamine and ferrous iron was approximately in parallel with the respiratory rate, showing an increase by percolation. But reduction of TTC alone behaved in quite different way, showing retardation by percolation.

As shown in table 2, quantity of guttation was increased by percolation with an exception of Maebashi plot, being in parallel to the change of respiration. Guttation can be considered as expressing a degree of active absorption of water, which depends upon the physiological activity of root.

(4) Nutrients absorbed by plants

Fig. 8 gives the content and total amount of nutrients absorbed by plants. Nitrogen content in straw was slightly increased by percolation in each plot. After top dressing of nitrogen applied, plants of the treated plot showed more green leaf color than the control plot of respective soil. This can be explained by the increased nitrogen content in the treated plants. Thus the percolation promoted nitrogen absorption.

As to phosphorus, it is observed that phosphorus content in the panicle was increased by percolation, but no effect is observed with straw. Kipo et al (1958) reported that the plants grown on well-drained field contained more phosphorus in their panicle than the plants grown on ill-drained field, although there was no difference in phosphorus content of straw. Potassium content shows no difference between the treated and the control plant. Silica content gave very interesting changes. Matsuo plot showed the lowest content, whereas Maebashi and Konosu plot showed about the same content.

Percolation caused a remarkable increase in silica content of plants in Matsuo plot, and to less extent in Konosu plot, but no increase in Maebashi plot. Silica absorption by root is believed to be closely linked with the aerobic respiration of root, and this is true in the case of this experiment.

Table 2. Guttation quantity* (ml/1 g Fresh Wt. leaf blade)

<table>
<thead>
<tr>
<th>Plot</th>
<th>Treatment</th>
<th>1, Aug.</th>
<th>19, Aug.</th>
<th>6, Sept.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maebashi</td>
<td>Control</td>
<td>4.86</td>
<td>3.88</td>
<td>2.97</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td></td>
<td>3.80</td>
<td>2.85</td>
</tr>
<tr>
<td>Konosu</td>
<td>Control</td>
<td>4.89</td>
<td>3.76</td>
<td>2.33</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td></td>
<td>3.85</td>
<td>2.72</td>
</tr>
<tr>
<td>Matsuo</td>
<td>Control</td>
<td>4.41</td>
<td>3.55</td>
<td>2.62</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
<td></td>
<td>3.89</td>
<td>2.62</td>
</tr>
</tbody>
</table>

* Guttation from 5 PM to 9 AM next morning
水稲根の生理的活動に及ぼす灌漑水の浸透の影響

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水稲根における灌漑水の浸透が水稲根の生理的活動に及ぼす影響を及ぼし、ひいては生育、収量にいかなる関係をもたらすかを研究する目的を以て、1960年に、第1，2区に示すところ実験の水田を設け、前橋、岡山および松尾（千葉県）の三種の土壌を用いて、稲苗をきめ細かく栽培し、8月4日～9月5日にわたり、1日3cmの滅水深に相当する浸透処理を加えた。その期間中も田面は常に滅水状態に保ち、また浸透水は集めて再浸透した。（1）三種土壌とも浸透処理により、有効窒素化合物は高まって数値が増し、また地上部乾物重も増加した。とくに松尾土壌区では生育後期に乾物增加の増幅が見られるが、処理によってそれが回復する（第3，4図）。（2）松尾土壌区では乾物の増加のほか、処理により穂実歩合、稔粒千粒重の増加が起って、17％の増収を示した。他の二区でも僅かの増収を示したが、前橋土壌区では乾物数は増加しているが穂実歩合、稔粒千粒重の低下が起つった（第1表）。（3）処理により前橋土壌区を除く二区では「うわ根」の発生が増加され、とくに松尾土壌区で顕著である（第5図）。根の呼吸率も前橋土壌区を除く二区では処理によって増加し、また根によるα-Naphthylamineおよび二酸化硫黄の浸透がの生理的活動が高まったが、とりにTTC還元能は処理によって急激に低下するが見られた。根の浸透性酸が安かって浸透液中も前橋土壌区を除いて増加した（第6，7図および第2表）。（4）処理により水稲の穂粒数はやや増加し、単粒数は変わらなかったが、無粒化は顕著に増加した。しかしここで前橋土壌区ではその増加が認められない。また無粒化は無粒化数の変動はないが穂の無粒化浸透による増加している（第8図）。（5）かくのごとく処理によって「うわ根」が増し、呼吸その他の生理的活動が高まる区では無粒が良好となり、無粒根その他の収穫も増加されているが、前橋土壌区では無粒、浸透処理の効果は土壌によって異なることが示された。

Literature Cited.
7) Yamada et al. (1958) : ibid 26 (3) : 205～211.
8) Yamada et al. (1958) : ibid 27 (2) : 155～160.