A Method for Maximizing Rice Yield on the Basis of V-shaped Rice Cultivation Theory (I)

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The key subject in maximizing rice yield

The yield of rice is mostly determined by the product of the number of spikelets per unit area and the percentage of ripened grains[1], and in actual investigations, therefore, the product of two components is always strongly correlated with the yield in any cases, if only there is not a big difference in the weight of 1,000 grains among varieties used.

Since the yield is determined by the product of these two components, it is quite sure that the yield can easily be increased if only these two components can be increased. Here exists, however, a lamentable fact between these two components, namely there is a strong negative correlation between these two components[1].

Therefore, if the number of spikelets is increased for increasing yield, the percentage of ripened grains will be decreased, and as a result, in not a few cases the product of these two components will rather be smaller than that in case of the number of spikelets not being increased. For the reason, in general, the yield of rice per unit area can not simply be increased, and this is the most difficult point in increasing the yield of rice.

For maximizing yield the number of spikelets per unit area must firstly be increased at any cost. If the number of spikelets has been increased, however, the percentage of ripened grains will be decreased in many cases on account of the above mentioned reason, resulting in a decrease in yield. Therefore, the key subject in maximizing yield comes to be focussed on how to keep away a decrease in the percentage of ripened grains in the case of the number of spikelets per unit area being much increased.

Most critical period in decreasing the percentage of ripened grains by heavy top-dressing with nitrogen[2]

Then, the author examined, under field conditions, the effect of an extraordinarily heavy dressing with ammonium sulphate (750 kg/ha) on the percentage of ripened grains as well as grain yield at intervals of 5 days at successive growth stages during three whole seasons[2]. As a result, he obtained the results shown in Fig. 1. According to Fig. 1, the curve for the percentage of ripened grains, as well as grain yield, is showing a V-shaped line, attaining a minimum at the top-dressing at the necknode differentiation stage, which corresponds to Treatment No. 7 and 33 days before heading. From this V-shaped line the name of the V-shaped rice cultivation has been born.

Therefore, the author examined the reason why the top-dressing at the neck-node differentiation stage showed a maximum decrease in the percentage of ripened grains. As a result, he found that the following factors to some extent are related:

1) A large number of spikelets per unit area are born.
2) Non-fertilized grains are liable to be produced.

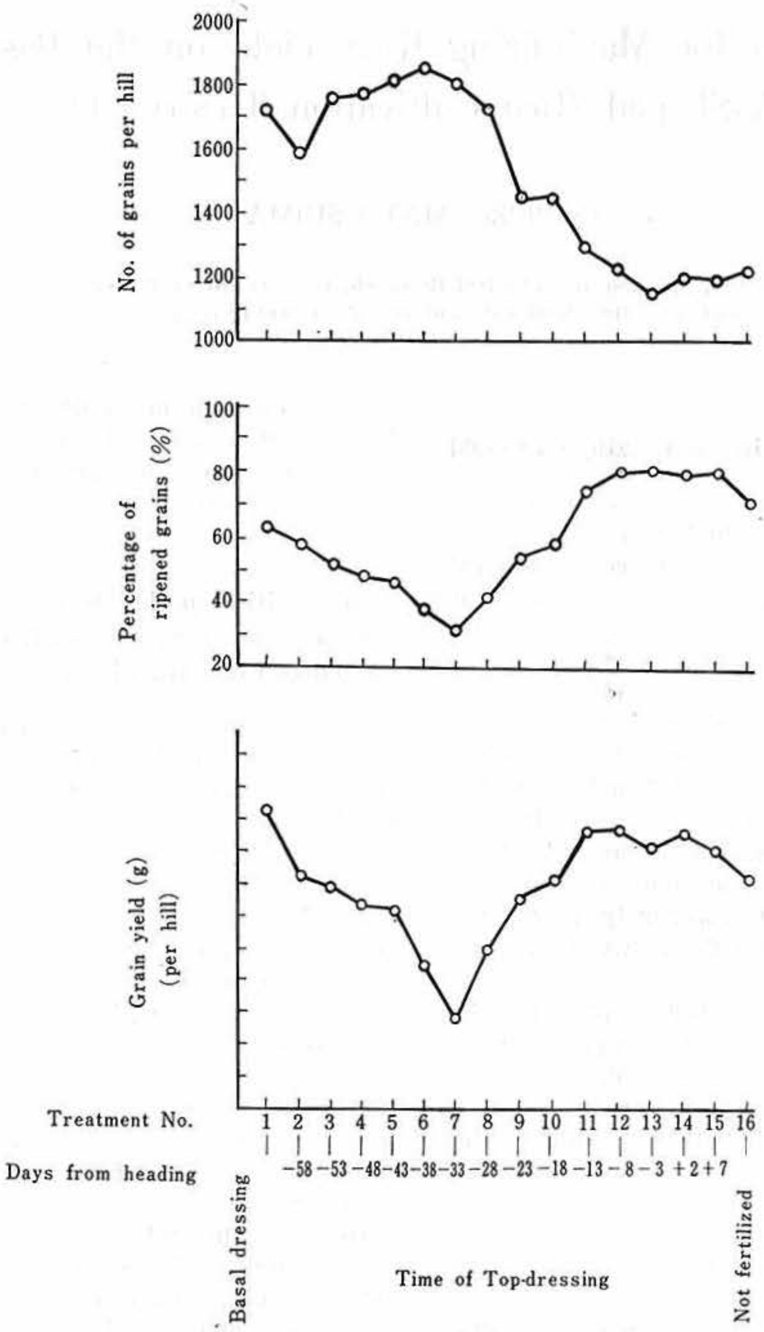

Fig. 1. Effects of an extraordinary heavy dressing with nitrogen on the percentage of ripened grains as well as grain yield at successive growth stages.

3) Rice plants are liable to lodge.
4) The accumulation of carbohydrates in the plant before heading is much decreased.

The most influential factor, however, is considered to be the "plant type" after heading, as shown in Fig. 2. The author found that the plant height, the uppermost leaf-blade and the second uppermost leaf-blade are longest

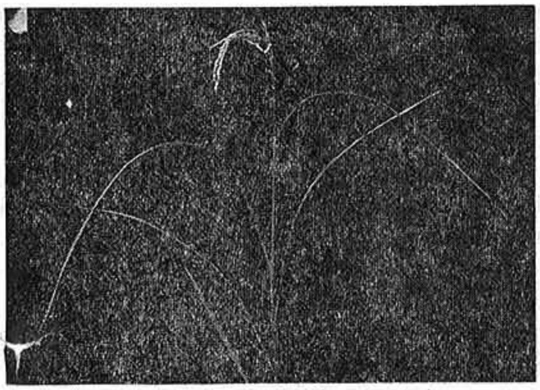

Fig. 2. An undesirable plant type (Treatment No. 7).

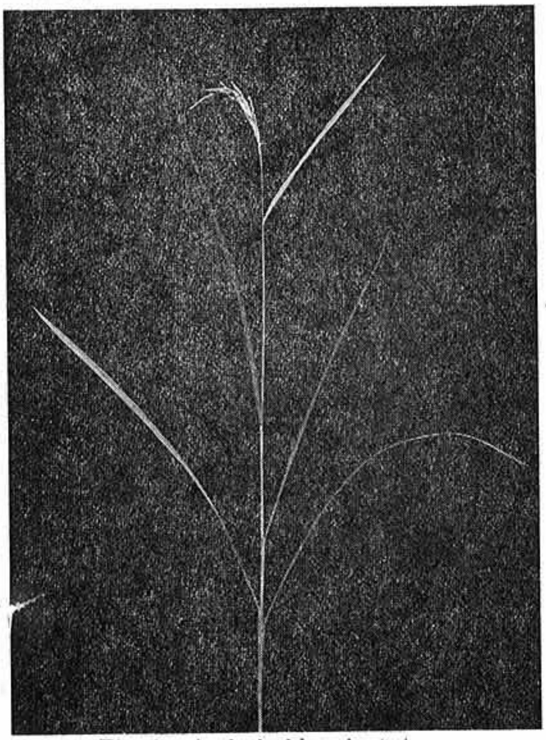

Fig. 3. A desirable plant type

at Treatment No. 7. Moreover, these leaf-blades droop as shown in Fig. 2, not being erect as in Fig. 3.

Relation between morphological characteristics and the rate of carbon assimilation in rice plant[2]

Bringing together all the results of the author's experiments on the relation between morphological characteristics and the photosynthetic efficiency, he concluded that it is desirable for the rice plants in community conditions for increasing the percentage of ripened grains, in particular under luxurious growth conditions, that the uppermost two or three leaf-blades should be short and erect, so that the sunlight may be spread evenly over all the leaf-blades.

Relation between morphological characteristics in receiving light and the percentage of ripened grains under luxurious growth conditions[2]

Under field conditions the author investigated the relation between the morphological characteristics and the percentage of ripened grains with the following results:

Under luxurious growth conditions, the percentage of ripened grains is negatively and strongly correlated with the sum of lengths of the uppermost three leaf-blades, the sum of curvedness of the uppermost three leaf-blades and the sum of the angle of stem to the uppermost leaf-blade and that to the second leaf-blade.

From the results of the present experiments, it is noted that under luxurious growth conditions the uppermost two or three leaf-blades should be short, erect and straight to obtain a high percentage of ripened grains.

Characteristics of an "ideal plant" for maximizing yield

Referring to the results mentioned above, as well as other research worker's data which studied growth analysis and lodging of rice plants, the author established the idea of an "ideal plant" for maximizing yield.

The characteristics of an "ideal plant" for maximizing yield are proposed as follows:

a) The plant should have the necessary and sufficient number of spikelets per unit area to obtain the target yield.

b) It should be short in culm height as well as in panicle length and should have many culms to protect against lodging and to increase the percentage of ripened grains.

c) Its upper three leaves should be short, thick and erect to increase the light utilizing efficiency and consequently the percentage of ripened grains.

d) It should keep absorbing nitrogen even in the period after heading to increase the percentage of ripened grains.

e) It should have as many green leaves per culm as possible (the number can be considered as an index of healthiness).

f) Its heads should emerge in early August (in Japan) so that it may be exposed to at least 25 sunny days continuously after heading to increase the amount of photosynthetic products at the ripening stage.

A method to create the "ideal plant type"[1),2),3)]

The most important morphological characteristics of the "ideal plant type" are that the uppermost three leaf-blades should be short, thick, erect and straight and the culm height should be short in particular lower three internodes should be short for protecting the plant from lodging.

From the results of the various experiments, it has been found that the restriction of nitrogen absorption during the period from 69 to 93 in the "leaf-number index"[1)] can be said to be a key to establishing the "ideal plant type". (The critical period, from 69 to 93 in the "leaf-number index", is roughly corresponding to nearly 43 days to 18 days before heading.) As to the method for controlling the length of each leaf-blade, sheath and internode, refer to the author's book "Crop Science in Rice" (p. 253).

Methods for increasing the rate of carbon assimilation per unit leaf-area after heading

After heading, the nitrogen in leaf-blades is translocated to panicles day by day, so the nitrogen content in leaf-blades decreases progressively with the advance in ripening[2)]. If the rice plant is top-dressed with nitrogenous fertilizers at heading time, the nitrogen content in its leaf-blades is always much higher than that in the no-top-dressed plant during ripening period[2)]. On the other hand, there is found a definite positive correlation in leaf-blades between the rate of carbon assimilation and the nitrogen content[2)].

Furthermore, many other field experiments, in which the rice plants were top-dressed with nitrogenous fertilizers at heading time, confirmed that the top-dressing made the rice plant increase the rate of carbon assimilation and consequently it served to increase the percentage of ripened grains in many cases.

Moreover, as many research workers pointed out, there is a definite relationship between root-activity and the rate of carbon assimilation, so that keeping the roots of rice plants healthy after heading is also an important way of increasing the photosynthetic activity per unit leaf-area.

Maximizing grain yield through "ideal plant" by water culture under community conditions[2)]

Therefore, the author tried to maximize the grain yield by raising ideal rice plants by water-culture under community conditions. Using water-culture, one can easily control the growth of rice plants at any growth stage by decreasing the concentration of nitrogen in the solution. In this way the author controlled the growth of rice plants during the period from nearly 43 days to 20 days before heading, making the plants short in the length of upper three leaf-blades as well as lower three internodes and also increasing the thickness of leaf-blades. The plants were planted at the spacing of 29 hills per square meter, and each hill consisted of 3 seedlings. Each plot was 10 square meter in area. As a result, the following results were obtained.

In short, the weather conditions during the rice growing period were favourable in 1962, but unfavourable in other three seasons. However, the author succeeded in obtaining more than 9.1 tons of brown rice per hectare in any season except 1963. The highest yield was 10.2 tons per hectare. From these results it is confirmed that if only the "ideal plant" is raised, an unusually big yield will be obtained without using any fertile soil.

Maximizing grain yield through "ideal plant" under field conditions

The most difficult point in applying this principle to an actual paddy field is to take nitrogen off the soil during the critical period. The author, therefore, made some other trails on this point.

1) By means of a circulating irrigation method.

Getting a hint from a circulating irrigation method in which identical water is repeatedly irrigated by a pump and which has long been practised economically in Toyama Prefecture, the author devised a method by which one can easily take the nitrogen off the soil at any time. The method is as follows:

Putting nitrate nitrogen into water and making water circulate by pumping up ditch water which comes out through underdrains of a paddy field, one can always supply nitrate nitrogen to the roots of rice plants without leaching of nitrogen. Since nitrate nitrogen is by no means absorbed by the soil, if this water is changed with new water, one can easily stop the supply of nitrogen to the rice plants. Setting up a paddy field with a circulating irrigation system, he tried to apply the principle of maximizing yield to this paddy field. As a result, he obtained 7.3 tons of brown rice per hectare, which has never been obtained so far by any other means in his experimental paddy field.

2) By means of using nitrate nitrogen in the paddy field in which water permeates too slowly.

Without using a circulating irrigation method, the author furthermore studied how to apply the principle to an actual paddy field.

The author therefore applied nitrate nitrogen (KNO_3) as nitrogenous fertilizers to a paddy field in which water permeates too slowly. He put 240 kg of ammonium sulphate as basal dressing and top-dressed as much as 600 kg of potassium nitrate per hectare in split application by the time of 60 days before heading and left water unchanged until 45 days before heading, and on the 45th day before heading he changed water in the paddy field with new water and kept irrigating until 20 days before heading.

In this way the author succeeded in taking nitrogen off the paddy field. And on the 20th day before heading he top-dressed 150 kg of ammonium sulphate per hectare and again top-dressed the same amount of ammonium sulphate at full heading time. Thus, he could raise considerable "ideal plants" and could obtain 6.5 tons of brown rice per hectare which has never been obtained so far in this paddy field by any other cultural methods.

3) By means of using nitrate nitrogen in the paddy field in which water permeates too rapidly

Using a paddy field which is lowest in fertility and largest in water-permeability in the Konosu Experimental Station, the author studied how to apply the principle to a paddy field in which water permeates too rapidly.

Sowing directly under an upland condition and dressing heavily with nitrate nitrogen, he grew the rice plants as large as possible, not irrigating at all until 45 days before heading, and on the 45th day before heading he irrigated for the first time so as to wash away nitrogen from the soil and kept intermittent-irrigating unil 20 days before heading. By this means he succeeded in taking nitrogen off the soil. Thereafter, he top-dressed twice with ammonium sulphate as above. In this way he obtained nearly six tons of brown rice per hectare in a paddy field which is lowest in fertility and largest in water-permeability in the Konosu Experimental Station.

4) General methods in the ordinary paddy field.

After conducting many experiments under ordinary field conditions, the author confirmed that the following methods could be used to take nitrogen off the soil during the critical period during which the "plant type" is predetermined.

a) Transplant healthy and strong seedlings in narrow spacing.

b) Transplant as early as possible.

c) Decrease the amount of nitrogenous fertilizers in basic application.

d) Give up the top-dressing, or decrease the amount of top-dressing, or advance the time of top-dressing, which is to be applied during the period from the transplanting time to the panicle initiation stage.

e) Put off the time of top-dressing, which is to be applied during the critical period, till 20 or 18 days before heading.

f) Apply nitrogenous fertilizers on the surface of top-soil, not mixing them with the whole top-soil.

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(To be continued in next number)