Growth Type of Rice Plants under Heavy Application of Fertilizers

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Rapid increases in fertilizer use for field crops in recent years seem to be a world-wide trend. Especially, the rate of fertilization to paddy fields in Japan is extremely high. This is a result of the effort of Japanese farmers, who own small farmland, to increase land productivity.

Increased rate of nitrogen application has promoted the development of split application technique, because it is often difficult to apply full amout fertilizer at one time. Process of the development was reported in detail by Kawata[2], who made a wide review on nitrogen application techniques in Japan. His understanding is that the top dressing is a technique to compensate defects of soil environment, and he showed with many examples that high yields can be obtained without top dressing of nitrogen on ideal soils. However, such ideal soils are quite rare, and difficult to obtain widely by land improvement. Therefore, it is realistic to grip the issue of heavy fertilization as related to problems of both basal dressing and top dressing. On the other hand, Dei[1] suggested that top dressing is a technique complemental to the manifestation of nitrogenous soil fertility. Paying attention to this point, the following discussion will be made.

The present authors and their cooperators have found out some problems related to plant growth type under heavy fertilization, by comparing growth of rice plants in a field where no fertilizer was applied for many years to that in a heavily fertilized field. Plant growth in the no-fertilized field depends on only soil fertility of a wide sense, including nutrient supply from irrigation water, so that the growth pattern there can be regarded as a reflection of the pattern of soil fertility manifestation, which makes the comparison to the latter easy.

On the other hand, ratio of quantity between basal and top dressing, and timing of top dressing are generally regarded important in split application. In addition, Tanaka[7] pointed out the importance of placement (depth of application) of nitrogenous fertilizers. The authors[4] also found out that the absorption and effectiveness of nitrogen applied as top dressing are greatly influenced by the amount of basal dressing of nitrogen and the placement of top dressing.

In the present paper, some basic problems related to growth type of rice plants under heavy fertilization will be presented, by analyzing research results so far obtained.

Defects in dry matter production in a heavily fertilized field[6]

1) Experimental method

Seedlings of 3 varieties differing in growth duration were raised without fertilizer and planted to a field where no fertilizer was applied since 1951 (located in Ritto, Shiga Pref.) and an adjacent fertilized field (120 kg/ha each for 3 elements). The plot size was 3×3 m for each variety. Sampling was made 5 or 6 times during the growth period to determine dry weight of tops and roots.

2) Results

Although slight varietal differences in dry weight increase were observed, they are not

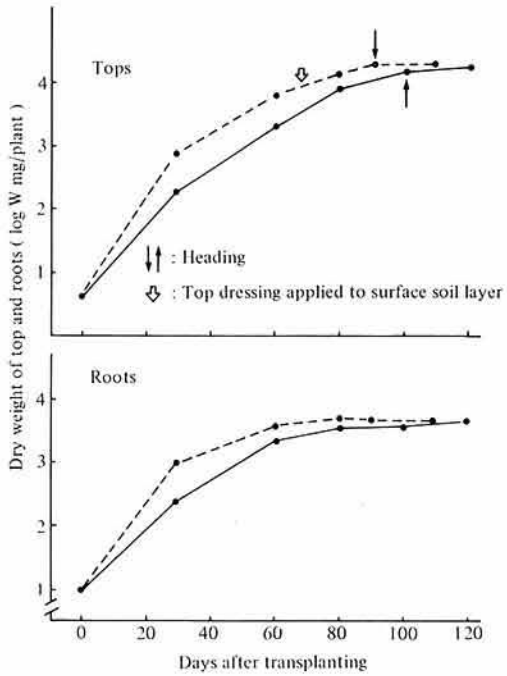

Fig. 1. Dry weight of plants grown in no-fertilized field and in heavily fertilized field
Variety: Nakateshinsenbon (planted on May, 11, 1977)
Solid line: no-fertilized
Broken line: heavily fertilized

recognized as different types of dry weight increase. Therefore, the result of a medium maturing variety, Nakate-Shinsenbon, was shown in Fig. 1, as a representative of 3 varieties. Difference in dry weight increase was observed exclusively during about 1 month period after planting, but after that the increases in both fields were almost parallel. Top dressing made in the heavily fertilized field did not cause any change to the type of dry weight increase.

The second difference was observed in the root dry weight in the later growth period: root dry weight increase in the fertilized plot showed a declining tendency while that in the no-fertilized plot continued until end of the growth period. Therefore, difference in relative growth rate (RGR) of top dry matter was greater in the early growth stage, but it decreased in the middle growth stage. In the later stage, RGR decreased in both fields but the dcrease was less in the no-fertilized field, where RGR exceeded that of fertilized field in case of a variety. Thus, T/R ratio increased markedly in the middle stage in the fertilized field, and the difference from the no-fertilized field continued to enlarge.

Nitrogen absorption of rice plants as effected by methods of basal dressing and top dressing[5)]

1) Experimental method

Experimental plots, shown in Table 1, were designed, using a variety, Nihonbare. Two plants were grown in a pot (1/2000 are). Each plct was consisted of two subplots differing in placement of top dressing: soil surface layer (S) and deep layer (D). Ammonium sulfate labelled with ^{15}N was used in order to make it possible to distinguish 3 fractions of

Table 1. Experimental plots

Experimental plot	Quantity of nitrogen applied		Subplots*	Three elements applied by basal dressing (g/pot)			Nitrogen applied by top dressing (g/pot)
	Basal dressing	Top dressing		N	P	K	
A	large	small	S and D	0.6	1.0	1.0	0.3
B	small	large	S and D	0.3	1.0	1.0	0.6
C	large	large	S and D	0.6	1.0	1.0	0.6
D	small	small	S and D	0.3	1.0	1.0	0.3

* S : Shallow placement (in surface soil layer) of top dressing (July 27)
D : Deep placement (in deep soil layer) of top dressing (July 16)

nitrogen derived from basal dressing, top dressing, or from soil nitrogen. Plant samples were taken 5 or 6 times in the growth period from 2 pots each for all subplots and nitrogen contents of tops and roots were determined by Kjeldahl method. The three fractions of nitrogen were calculated from the result of emission spectrographic measurements.

2) Results

Results obtained from the A plot (large amount of basal dressing followed by small amount of top dressing) and B plot (small amount of basal dressing followed by large amount of top dressing) will be discussed here. In both plots, top dry weight was greater in D subplot than in S subplot, and the difference between A-D subplot and B-S subplot was small. On the other hand in both plots, top dressing to soil surface layer caused a rapid decrease of root dry weight immediately before heading, resulting in a far less root quantiny in S subplot than D subplot (Fig. 2).

Nitrogen content of tops at the tillering stage was greatly influenced by the quantity of basal dressing, but after the application of top dressing it increased very much in the B plot, while not much in the A plot. In both plots, the nitrogen content after the top dressing was higher in D subplot than in S subplot, especially in B plot it reached the highest at the heading time. The three fractions of these nitrogen contents are illustrated in Fig. 3.

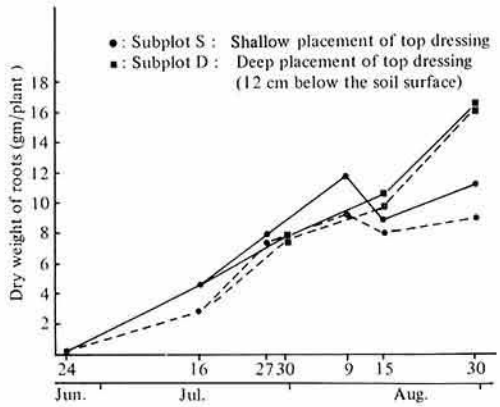

Fig. 2. Effect of different methods of nitrogen application on root dry weight
Solid line: A plot (large amount of basal dressing and small amount of top dressing)
Broken line: B plot (small amount of basal dressing and large amount of top dressing)

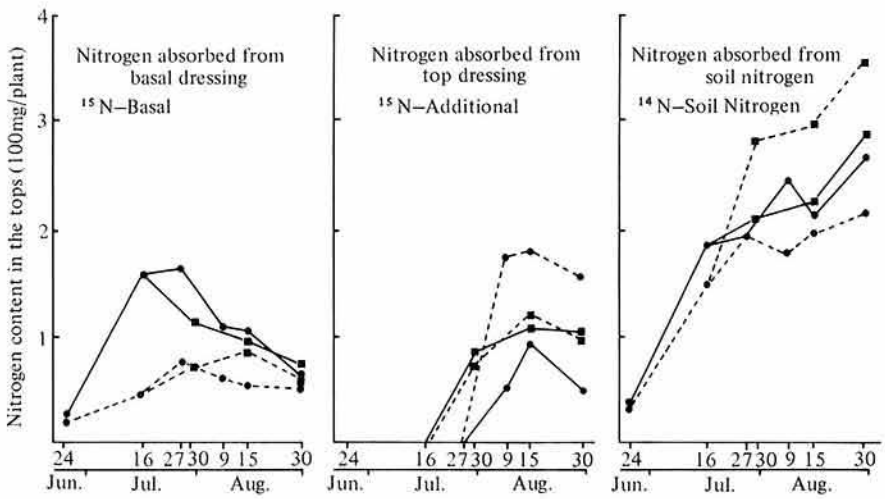

Fig. 3. Effect of nitrogen application methods on absorption of nitrogen from different sources.
Legend: same as in Fig. 2.

It shows that large amount of nitrogen applied by basal dressing was rapidly absorbed by plants at the tillering stage, but the efficiency of absorbed nitrogen for dry matter production was relatively low. Furthermore, this nitrogen was lost rapidly by decay of lower leaves and invalid tillers occurred after the application of top dressing. Application of large amount of nitrogen by basal dressing caused a relatively reduced absorption of nitrogen from top dressing as well as from soil nitrogen. On the contrary, in case when small amount of nitrogen was applied as basal dressing, plants continued to absorb nitrogen, though slowly, by the time of top dressing, and after the application of top dressing to deep soil layer the nitrogen absorption continued to increase until the heading time, although shallow placement of it induced a small loss of plant nitrogen. In addition, plants received small amount of basal dressing showed a relatively large amount of absorption from top dressing, especially more rapid absorption from top dressing applied to surface layer. Absorption of soil nitrogen was also influenced by the placement of top dressing: small amount in case of shallow placement while markedly large amount in case of deep placement.

Discussion

Based on the results of the above 2 experiments, the followings are pointed out:

1) In spite of the big difference in soil condition between no-fertilized and heavily fertilized fields, difference in growth response as expressed by dry matter production of tops was observed exclusively in a period of about 30 days after planting, and the difference was more apparent with tops than roots. In other words, the basal dressing induces growth acceleration, and the top dressing plays a role of preventing stalling of the accelerated growth. In no-fertilized field, the decrease in growth rate in the later growth period was relatively small; this must be one reason for the growth type characterized by better growth in later growth period observed in the no-fertilized field. If this growth type is regarded as a desirable normal one, remarkable decrease in growth rate occurring in heavily fertilized plants in the later growth period can be understood as the "stalling of growth". It points out an incompleteness of the current fertilizer application technology in rice culture with heavy fertilization.

2) The second problem is related to root growth. In the heavily fertilized field, root growth became stagnant in the middle and later growth stages, while in the no-fertilized field root growth continued until the later period. This can be attributed to the difference in soil environment: in the no-fertilized field, blackening of soil and roots caused by soil reduction was not observed at all, while in the heavily fertilized field the soil contained a lot of carbon sources and sulphate which promoted soil reduction and the occurrence of root rot. Thus, the new root formation might be offset by killed root. This may be the reason for poor growth in the later growth period.

3) The third problem concerns about the ratio of nitrogen quantity between basal dressing and top dressing and the depth of application of top dressing. The authors[3] recognized in other studies that the plants grown with plenty of basal dressing produced fine superficial roots after the application of small amount of basal dressing to surface layer of soil and the activity of deep roots was lowered, while in case of small amount of basal dressing followed by deep placement of large amount of top dressing, formation of deep roots (in deep soil layer) with increased activity was promoted. Thus, it is considered that the root zone expanded by the growth of active deep roots can explain the increased absorption of soil nitrogen observed in B-D plot and also the growth type characterized by better growth in the later period occurred in that plot.

Yoshino et al.[8] reported that amount of nitrogen released by soil nitrogen mineralization is expressed by accumulated effective temperature (above 15°C), so that it becomes

large in the summer season. The cultural method with small amount of basal dressing followed by large amount of top dressing seems to be an effective supplement to the shortage of released nitrogen, espcially the deep placement of top dressing serves to increase rhizosphere and absorb soil nitrogen more efficiently.

Based on the above discussions, there is a fear that if the full or majority of nitrogen is used as basal dressing in areas even in the tropics where the rate of nitrogen application is rapidly increasing, excessive top growth in the early stage and poor growth in the later stage caused by root damage may occur.

Acknowledgement

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