Increasing Fertilizer Efficiency by Mechanical Deep Placement of Paste-like Fertilizer in Wetland Rice

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Rice commonly recovers only 30–40% of fertilizer N applied by traditional (broadcast) methods[1]. This poor efficiency is generally attributed to the susceptibility of N to leaching, ammonia volatilization, denitrification, and surface runoff, particularly in the early growing season. Denitrification is thought to be most important commonly, although the other N losses are also reported under some special soil conditions. This N losses can be reduced by placing the fertilizer below the soil surface[1-3] or by using controlled-release fertilizers[4,5].

Interest in improving fertilizer efficiency by adopting proper application methods and suitable fertilizer forms has increased by the recent energy shortage and concern about a fertilizer-N shortage. A typical example is the International Network on Fertilizer Efficiency in Rice (INFER) program[6,7], which was initiated by national research agencies aided by IRRI and IFDC. The results of this program indicate that placement of fertilizer N as urea supergranule (1–2 g) or urea briquettes in the reduced zone (deep placement between hills) increases the fertilizer N efficiency, and that use of slow-release N fertilizer such as sulfur-coated urea appears promising in a number of rice-growing countries. A single basal application of sulfur-coated fertilizer gave yield of rice similar to or higher than a split application of conventional N fertilizers.

In Japan, considerable information about the transformation of various controlled-release fertilizers including IBDU, guanylurea oxamide and various coated fertilizers, the factors affecting the release rate of nutrients in soils, and the crop response to these fertilizers[5] has already been obtained in laboratories, greenhouses and field situations. In comparison with conventional fertilizers used under ideal N management conditions, most of the controlled-release fertilizers are slightly superior or equal in yield-increasing effect on wetland rice. Relative grain yields obtained with the controlled-release fertilizers fall most frequently around 100–104% of the check plots. N topdressing at the tillering stage can be eliminated in most cases, but N split application at the panicle initiation stage should be essential to gain higher yields, even if controlled-release fertilizers are used as a basal dressing. Under less ideal N management conditions where N losses occur to a large extent, controlled-release fertilizers can give superior performance. Current price of controlled-release fertilizers can be said to be so high that their wide use for rice cultivation has not progressed even in Japan where the price of rice is supported at a high level by the Government.

On the other hand, research has been continued to develop fertilizer materials to be used for mechanical application with deep placement in wetland rice. Mitsui[8], reviewing results related to machines and materials for deep placement to minimize denitrification, emphsized that deep placement showed remarkable advantages for increasing N efficiency for rice. Further efforts have recently led to a new type of fertilizer, "paste-like fertilizer" for mechanical deep or root-zone placement.

In the present paper, the outline of paste-like fertilizer, its application, and the results of field trials will be described with related discussions.

It is hoped that this information could be valuable for developing better way of increasing N efficiency in wetland rice.

Characteristic of paste-like fretilizer[9)]

A product containing N, P and K was prepared by suspending and/or dissolving fertilizer salts in organic liquid, a waste from alcholic fermentation or paper pulp plants. The product of a typical grade contains 12% N, 10–12% P_2O_5 and 12% K_2O. Viscocities of this product are so high (more than 10,000 centipoise) that troublesome problem of sludge and large crystal formation can be minimized during storage and it is easy to handle, pump and apply to deep soil layer. Fine pulverized K and P materials are also used to prevent this problem.

Applicator for paste-like fertilizer[9)]

Along with the development of physical properties of paste-like fertilizer for mechanical deep placement, improvement of its appli-

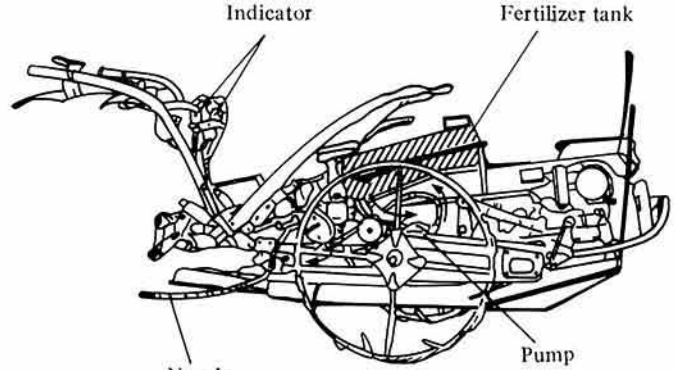

Fig. 1. Rice seedling transplanter equipped with an applicator for simultaneous application of paste-like fertilizer

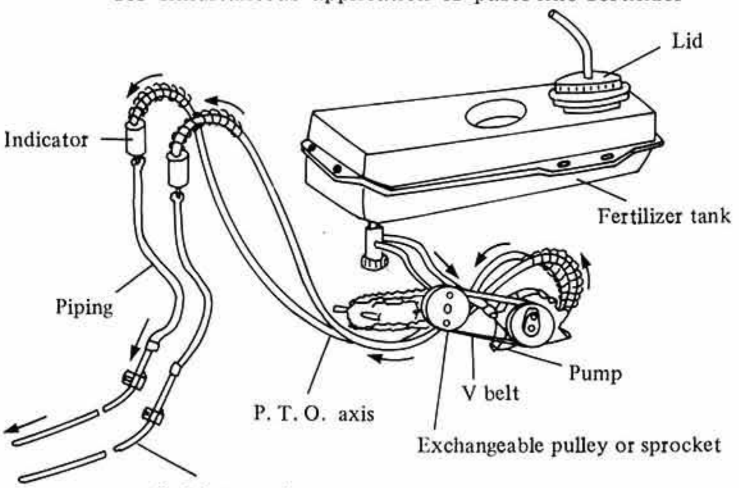

Fig. 2. Applicator for paste-like fertilizer

cator was also progressed. A developed applicator equipped to a typical transplanting machine is shown in Fig. 1, and a sketch of the applicator in Fig. 2. It uses a flex rotary pump to inject the fertilizer into soils through the stainless nozzule. A linear and localized placement of the fertilizer can be achieved by adjusting the nozzle position (between rows and at depths of 3-5 cm). Application rate is controlled by the size of exchangeable pulley or sprocket wheel and the speed of P.T.O. axis (20-70 kg N/ha).

Results of field trials[9]

Field trials on various soils throughout the country were conducted to evaluate practical performance of the applicator and effectiveness of paste-like fertilizer to wetland rice in 1975 and 1976.

Tests concerning the application rate and uniformity and placement position showed satisfactory results. In particular, this mechanical application of paste-like fertilizer appeared to be more uniform than traditional broadcast and incorporation methods.

Fig. 3 gives frequency distribution of yield index of brown rice obtained with the root-zone application (at 2 cm aside from hills and 3 cm of depth) of paste-like fertilizer. The data summarized from 76 trials conducted in the northern region in 1975 show that in 80% of the trials the root-zone application of paste-like fertilizer gave higher grain yields than the standard broadcast application and in only 7% of the trials it gave clearly lower yields (less than 95%). This indicates that if fertilizer N is applied below the soil surface, there is considerable scope for improving its efficiency. Another advantage of the root-zone placement in the northern region can be elucidated as follows.

To obtain consistently high yields in the present cultural system using mechanical transplanting of young seedlings, establishment of enough number of productive tillers during the early vegetative growth period is the most important target in fertilizer and field management. In this regard, the root-zone placement is reasonable to accelerate nutrient uptake at the earlier growth stage under low temperature conditions, resulting in the increased number of ripened panicles at the harvesting season. Analysis of yield components also indicates that the higher yields can be attributed to the increased number of panicles. However the root-zone application of paste-like fertilizer tended to cause a depression of N uptake to some extent in the later tillering and panicle intiation stage, so that proper amount and timing of N top-

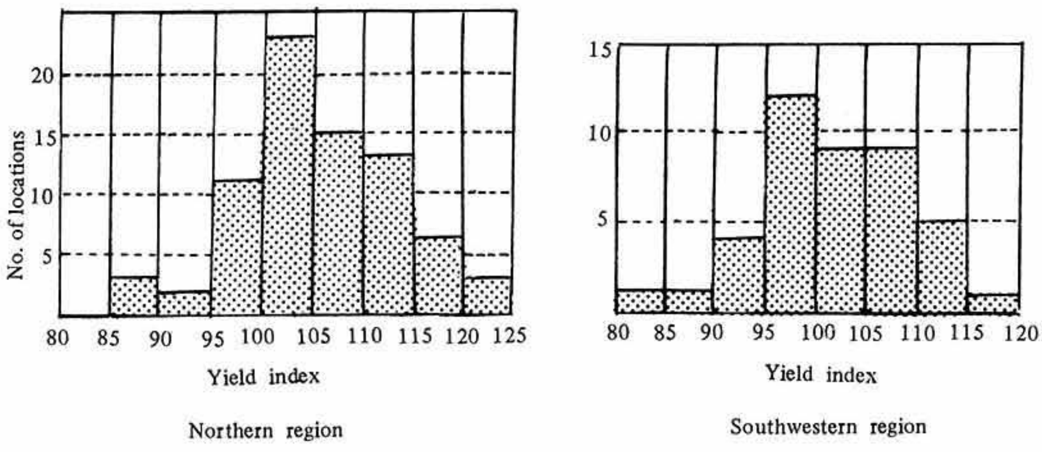

Fig. 3. Frequency distribution of yields of brown rice with root-zone placement of paste-like fertilizer.
Yield with standard broadcast application is taken as 100.

dressing are needed to maintain the favorable effect on grain yields.

On the other hand, the effectiveness of root-zone application of paste-like fertilizer was not apparent in the southwestern region (Fig. 3). The number of panicles was generally increased by that method, but the number of grains per panicle and filled grains were decreased. This suggests that the root-zone placement is not always favorable for increasing rice yields under higher temperature conditions due to excessive growth occurring during the very early growth stage. Therefore, attention must be paid in order to maintain better nutritional status during the maximum tillering and panicle intiation stage by adjusting the position of deep placement and the rate and timing of N topdressing. For example, field tests at the Chugoku Agricultural Experiment Station showed that root-zone placement plus deep placement between hills with paste-like fertilizer gave a marked increase in yield[9].

Effect of N application rate of paste-like fertilizer as basal dressing in the northern region is given in Table 1. There are small differences in yields among different application rates. Even if paste-like fertilizer is applied at the rates less than 70% of the standard application rate by conventional ap-

Table 1. Relative effectiveness of basal application of N in paste-like fertilizer for wetland rice

	N application rate (standard application rate=100)*			
	above 110	110–90	90–70	below 70
		Straw		
Locations	3	22	29	14
Average yield	119	109	106	103
C. V., %	7.1	10.7	7.3	11.4
		Brown rice		
Locations	3	24	30	19
Average yield	114	105	105	103
C. V., %	3.5	7.7	8.1	6.0

* Standard application rate in conventional fertilization.

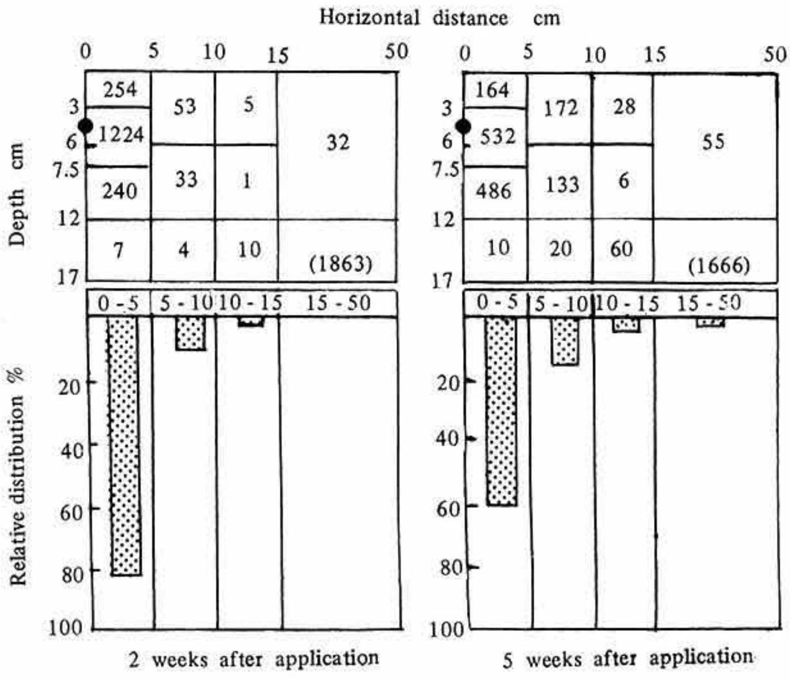

Fig. 4. Distribution pattern of ^{15}N ammonium nitrogen (mg/section) after 5 cm deep placement of paste-like fertilizer in a wetland soil
●: site of application

plication method, comparable grain yield can be expected to obtain. This finding is of great value in increasing N efficiency for rice.

Fig. 4 gives distribution of ^{15}N applied with paste fertilizer in wetland soil. Movement and/or diffusion of ^{15}N is surprisingly slow. The ^{15}N concentration was greatest near the placement site and decreased with time. Considering recovery rate of N from the soil, N losses seems to be reduced by this deep and linear placement. Nitrogen in the surface water was negligible at 24 hrs after the application of paste-like fertilizer, whereas, when granular compound fertilizer broadcated and incorporated into the soil after flooding, about 25% of applied N was present in the surface water. This placement technique is, therefore, recommended to reduce a secondary pollution of N and P derived from fertilization.

Results also indicated that quality of brown rice from a field which received pasts-like fertilizer tends to be more uniform than that of areas receiving a standard application of conventional fertilizer because of uniformity of the mechanical application resulting in the even growth of rice.

Conclusion

Based on the above results, it can be concluded that the mechanical deep or root-zone placement of paste-like fertilizer with high viscocities has several advantages for wetland rice cultivation; (1) increasing grain yields due to controlled nutrient supply achieved by adjusting the position of placement, (2) increasing N availability due to the reduction of N losses, (3) labor-saving as a result of simultaneous fertilizer application with transplanting of rice and (4) improving rice quality due to the uniform placement. This technique would help reducing possible pollution of applied fertilizer to the environment through runoff water.

Rusting of the applicator was avoided by using high polymer materials in place of metal. It is now commercially available, although not yet widely used in Japan. Limited availability of organic wastes and additional cost required to make the paste-like fertilizer, unstable driving performance of transplanters when attached with applicator and little experience of handling liquid-type fertilizer are deterrents to the extention of this technique.

Deep placement of pest ball and solid fertilizer at the panicle intiation stage as well as deep placement of prilled urea between hills subsequent to transplanting were also reported to give a favorable effect on growth and yield of rice. More research is needed to develop simple applicator for these fertilizers. Further research is also needed to precisely determine the optimum rate, position and timing of N deep placement, as affected by differences in soil, environment, and management.

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