Nitrogen Nutrition of Rice Plant

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Importance of nitrogen fertilization in rice cultivation

The acre-yield of rice in Japan has nearly been doubled since 1870. It is a well-known fact that the rice plant requires more nutrients to produce more yield, and that the Japanese farmers use large quantity of fertilizers as illustrated in Table 1. However, heavy application of fertilizer does not always give higher yield. Especially, in case of nitrogen, much use of fertilizers presents various problems. Excessive application of this nutrient tends to cause yield reduction through the plant lodging, heavy mutual shading of leaves, or the damage by insect pests. Accordingly, research on the rational method of nitrogen application is of great importance in the fertilization of rice plants. It can be said that the high yield standard of rice cultivation in present Japan has been attained mainly by the proper practices of nitrogen application based on the fundamental studies of nitrogen nutrition for this crop plant.

Table 1. Average dosage of chemical fertilizers and the mean yield of brown rice in Japan in 1966 (Kg/ha).

N	P_2O_5	K_2O	Yield
91.8	82.8	78.3	4,000

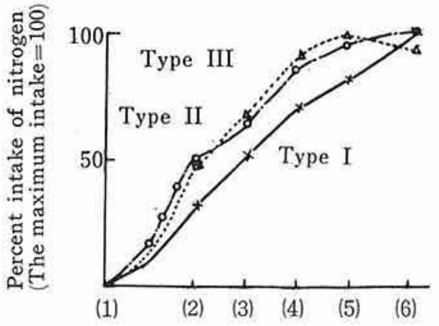
In this paper are presented some of the research results on nitrogen nutrition and the recent trends of fertilizer application methods developed in Japan.

Many investigations and the improvements of techniques, of course, had been made before the Japanese rice culture reached the present level of high yield under heavy application of fertilizer. One must keep in mind that the increased rate of fertilizer application has been developed under the progress of these cultivation tequniques. Rice plants are grown under diverse environmental conditions in the world. Naturally, the application method of nitrogen established in Japan can not always be applicable directly to other countries that have different environments. But the knowledge concerning basic problems of nitrogen nutrition must be of value regardless of the environmental differences.

Intake of nitrogen at successive stages of plant development.

J. Takahashi and M. Yanagisawa[4] made analysis of rice plants for chemical composition at each developmental stage, the plant samples being gathered from various locations in Japan, ranging from the northern island of Hokkaido down to the south of Kyushu. They found that the intake curves of nitrogen could be classified into three types as illustrated in Fig. 1.

In the case of type I, there is suppressed intake of nitrogen at the early stage of plant growth, followed by promoted absorption from the middle stage to maturity. In type II and type III, a comparatively large amount of nitrogen is taken up at the initial stage, but there is little absorption from heading to harvest time. Especially, the type III rice plant shows almost no signs of nitrogen absorption after heading stage. These differences in nitrogen intake may be caused by various factors, such as climatic conditions and the nitrogen supply available



(1) Transplanting
(2) Most vigorous tillering
(3) Ear primordia forming
(4) Heading
(5) Middle stage during the ripening
(6) Harvest

Fig. 1 Cumulative curves of nitrogen intake by rice plants during the whole stages of development.

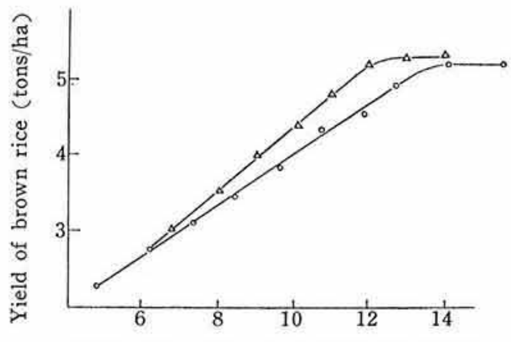


Fig. 2 Relationships between dry matter production and the yield of brown rice. -○-: The whole dosage of nitrogen was applied as basal dressing (Experiments in 15 prefectures). -△-: Split application of nitrogen (Experiments in 18 prefectures).

from the soil. It is generally noted that the rice plants belonging to type I nitrogen absorption are found on fertile soils, tending to give higher yields, but those of type III are seen on soils of low fertility and give low yields. Rice plants of type II are intermediate. Such a course of nitrogen intake as mentioned above also well corresponds with that of increase in dry matter, which is also classified into three types.

Basal dressing of fertilizers guarantees the supply of nutrients for the earlier stages of plant growth, and the top-dressing for the later stages. If one wants to make the rice plant follow the type 1 course of nitrogen intake by application of fertilizers, he must attach great importance to the top-dressing of nitrogen fertilizer.

Figure 2 illustrates the relationships between total dry matter production and the yield of brown rice as affected by the rate and method of nitrogen application; that is non-split and split application. The data are based on the experiments conducted in various locations in Japan. A high degree of linear correlation can be seen between the dry matter production and the grain yield. If compared on the same level of dry matter production, the rice plants to which nitrogen is split-applied give higher yields of brown rice than those of non-split, to which the whole dosage of nitrogen is given as basal dressing. Namely, the total dry matter production is increased by raising the dosage of fertilizer, but the efficiency for grain yield can be enhanced by the split application of nitrogen.

Relationships between nitrogen content at the heading stage and the number of grains per unit land area.

Adequate number of grains per unit land area is a prerequisite to secure a certain target yield. Recently, Shimizu[3] found that there is a close relationship between the number of grain per unit land area and the amount of nitrogen absorbed by rice plants up to the heading time. According to Shimizu, the relation can be expressed by the equauation;

$$N = 0.039765\,m - 0.876$$

N: Nitrogen absorbed until heading stage (g/m^2)

m: Number of total grains per m^2 (Unit; 100 grains)

The equation indicates that the more nitrogen must be absorbed until heading stage to increase the number of grains, and thus to assure the higher yield.

The equation proposed by Shimizu are obtained from the experiments conducted at Fukuyama in warmer regions of Japan. The author[2] noticed that some modifications of the equation are needed in other locations as shown in Fig. 3. In northern Japan (Hokkaido), more grains can be obtained with less absorption of nitrogen, while in southern Japan (Kyushu) there is an indication that the increase in nitrogen intake does not neceessarily contribute to the increase of grain number beyond a certain limit. It has been also observed that, even at the same location, the method of fertilizer application or of cultivation influences the adaptability of the equation.

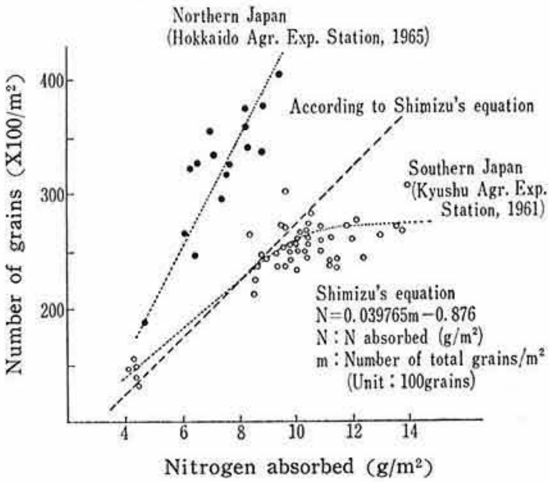


Fig. 3 Relationships between number of grains and nitrogen absorbed by rice plants until heading stage as influenced by locality.

Since the amount of nitrogen absorbed is expressed by the product of weight of straw and the percentage content of this element at the heading stage, the rice plant would be able to hold adequate amount of nitrogen with less straw weight if it has a high percentage of nitrogen. Generally, the rice plants in northern Japan have higher per-

Table 2. Productivity efficiency in number of grains per unit straw weight or unit intake of nitrogen at heading stage.

Localities and years	Treatments	Yield per m²				Nos. of grains produced per unit weight (Productivity efficiency)		
		No. of grain ×10²	Wt. of straw g	Wt. of leaves g	N absorbed g	Per g straw	Per g leaves	Per g N
Aomori 1965	Whole N as basal dressing	323	910	220	11.2	35.5	147	28.8
	Deep placing split application	413	695	188	11.2	59.5	219	36.8
	Deep plowing plus deep placing split application	490	743	192	12.8	66.0	255	38.2
Takada, Hokuriku 1966	No N applied	156	361	100	3.8	43.2	156	41.1
	Conventional fertilization	265	675	220	8.4	39.3	120	31.6
	Improved fertilization	356	776	289	11.4	45.4	122	31.3
Fukuyama, Chugoku 1965	No N applied	181	790		6.1	23.9		29.7
	Heavy application of guanyl phosphate	362	1352		17.3	26.8		20.9
	Heavy application of rice straw	308	1390		13.7	22.1		22.5

centage of nitrogen than those in southwestern Japan. This indicates that northern rice plants can hold equal number of grains with less straw weight as compared with those of southern regions.

In other words, the rice plants in the northern regions have higher efficiency of productivity with respect to grain number per unit straw weight. One of these examples is shown in Table 2, which also indicates that the efficiency mentioned above would be varied by the method of cultivation.

It is important for the increase of grain yield that the rice plant holds sufficient number of grains with less straw weight or, in other words, with smaller leaf area. Because, it would generally be inevitable that unfavorable increase of straw weight or leaf area is likely to be brought about, if the plant is so fertilized as to produce a large number of grains. Since the rice plants of great straw weight are naturally accompained with heavy mutual shading of leaves, there would be a danger of reduction in yield due to unfavorable ripening such as decreased percentage of filled grain and decreased weight per 1,000 grains, in spite of plentiful number of total grains. If the plants have adequate number of grains with as low a straw weight as possible, an unfavorable influence of heavy mutual shading can be eliminated.

Statistics in Japan show that there is a remarkable yearly increase in acre-yield of brown rice in northern areas, but a slowdown in the southern districts. Suppressed increase in the south is thought partly due to heavy mutual shading caused by luxuriant growth of leaves which is brought about by those rice plants having a large number of grains.

So-called 'hogoe' top-dressing that is the application of nitrogen fertilizer at the time of 18 to 25 days before heading, or such a method of top-dressing as placing the fertilizer deeply into the furrow slice of the soil is found effective to increase the number of grains without luxuriant growth of straw.

Importance of nitrogen nutrition at the ripening stage

Nitrogen supply to the rice plant after heading stage had hitherto been considered to be of no significance, or even harmful for better growth. Also it had been said that nitrogen or other essential elements required by grain could be sufficiently supplied by the translocation of these nutrients from straw, and that excessive quantity of nitrogen at the ripening stage would be of danger, easily bringing about the damage by insect pests. The author[1] found that large parts of the carbohydrates in grains are built up by those which are photosynthesized during the period of ripening stage, and that the nitrogen supply at this stage is also effective under certain nutritive state of rice plants. It was made clear later that high-yielding rice plants take up larger amounts of nitrogen and other nutrients after the heading stage, and these plants have more green live leaves until the time of harvest. Nitrogen is one of the essential nutrients during the ripening stage to maintain the green leaf area as well as photosynthetic activity of leaves. It is most preferable that the nutrients required by high-yielding rice plants be naturally supplied from the soil as they are needed. In high-yielding cultivation greater considerations have been given to the fertility of soil, and one of its reasons is that the high fertility of soil assures the plants the adequate supply of nutrients until as late as after heading time.

The importance of nitrogen nutrition during the ripening stage can be pointed out also from the balance of nitrogen between grain and straw.[2] Suppose the plants hold 10g nitrogen and 30,000 grains per m^2 at the heading stage. Since the translocation of nitrogen from the straw to grain is approximately 65%, the amount of nitrogen which contributes to the development of of grain would be 6.5g per m^2 when there is no additional supply of nitrogen from the soil. Taking it into account that the nitrogen content of grain is 1.1% and the weight per 1,000 grains is 27g, the quantity of 6.5g of nitrogen could only meet with 21,800 grains, which correspond to 73% of the total number of grains.

Obviously, these rice plants need an additional supply of nitrogen from the soil in order to have an increased percentage of filled grain and higher capacity of photosynthesis so that they might give higher yields.

In the light of the foregoing, it can be infered that the more grains are borne, the more the supply of nitrogen is needed durind the period of ripening stage, provided that the plants have taken up the same amount of nitrogen until heading time. Also, such plants that may have comparatively large number of grains per unit straw weight must fill up more grains per unit leaf area during this period. The rice plants of this type should be supplied with more nitrogen for the maintenance of photosynthetic activities of leaves at higher levels until the time of maturity.

As mentioned above, the supply of nitrogen during the ripening stage would be recognized as more important in those rice plants which have higher ratios of paddy to straw and higher yield. Also it must be kept in mind that good penetration of light into plant community and healthy roots are prerequisite to the effectiveness of supplied nitrogen.

Recently in Japan, there is a trend that later application of nitrogen is important in rice cultivation. For instance, some farmers are likely to increase the rate of 'hogoe' top-dressing or to practice the top-dressing of nitrogen after heading stage, which are popularly called 'the top-dressing for grain'. These tequniques are being tried, aiming at higher yield, for the betterment of nutritional state of the last half period of plant growth, especially at the ripening stage. These methods of fertilization would make it possible to increase the dosage of application and are recognized to be favorable to increasing the grain yield. It should be noted, however, that these techniques would be effective when the following conditions are fulfilled; (1) plant types of good penetration of light, (2) introduction of rice varieties that have higher ratios of paddy to straw, (3) improvement of soil conditions so as to keep the roots in a healthy state until later stages of plant growth, (4) adequate supply of essential nutrients besides nitrogen, (5) suitable water management, and (6) control of insect pests.

References (in Japanese)

1) Murayama N. et al.: The process of carbohydrate accumulation associated with growth of rice plants. Bull. Nat. Inst. Agr. Sci., Japan. B 4: 123-166 (1955)
2) Murayama N.: Fertilizer application as related to ripening of rice plants (Mimeo). Division of Plant Nutrition, Department of Soils and Fertilizers, Nat. Inst. Agr. Sci. Japan. 1-37 (1967)
3) Shimizu T.: The yield-determining process from the view point of dry matter production of crop plants. Sakumotsu no Buttshitsu Seisan; 4: 12-26 (1967)
4) Yanagisawa M. and Takahashi J.: Studies on the factors related to the productivity of paddy soils in Japan with special reference to the nutrition of the rice plant. Bull. Nat. Inst. Agr. Sci. Japan. B 14: 41-171 (1964)

General references (in English)

The mineral nutrition of the rice plant: John Hopkins. IRRI: 1-494 (1964)

Theory and practice of growing rice: 2nd ed. Fuji (Tokyo): 1-527 (1966)

Development of paddy rice culture techniques in Japan: Association of Agricultural Relations in Asia (Tokyo): 1-284 (1966)

Matsushima S.: Crop science in rice-theory of yield determination and its application: Fuji. (Tokyo): 1-365 (1966)