Productive Efficiency of Fertilizers in Recent Rice Culture in Japan

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Heavy application of chemical fertilizers and high-yield of rice in Japan are well known. About a hundred years ago the average yield of brown rice was only about 1.9 tons/ha, while it has attained to about 4.5 tons/ha recently.

Such increase in yield is closely related to increased fertilizer applications based on the improvement of application techniques. Especially after World War II, rice yield was remarkably increased by the heavy use of chemical fertilizers.

The author reported previously[1] that dispite such increased application of fertilizers, productive efficiency of fertilizers remained almost unvaried. However, the tendency since 1965 has been advanced toward more heavy application. In the light of the law of diminishing returns there is a problem whether or not the increased application of fertilizers in recent years has caused any decrease in the efficiency of rice production.

Low cost of fertilizers in contrast to high price of rice in Japan resulted in the easy practice of rice culture with heavy application of fertilizers. But needless to say, low efficiency of fertilization is not desirable from an economical point of view.

The author has studied yearly trend of productive efficiency of three major elements of fertilizer (N, P_2O_5, K_2O) in relation to more enhanced tendency toward heavy application of fertiilzers in recent years[2].

Average yields of brown rice and nitrogen applied

Fig. 1 shows yearly trend of average yields of brown rice and of nitrogen applied in Japan since 1956*.

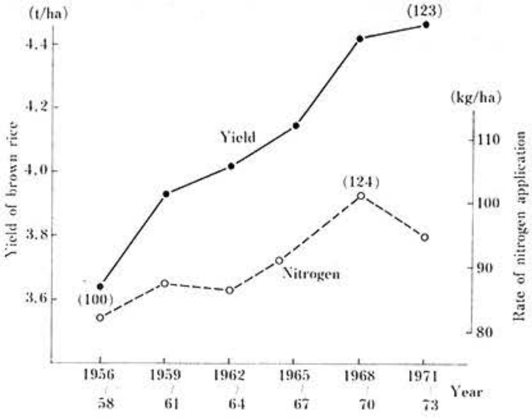

Fig. 1. Average yield of brown rice and nitrogen applied by chemical fertilizers

Taking the average yield (3.64 tons/ha) for 1956 to 1958 as 100, that of 1971 to 1973 (4.46 tons/ha) is 123. Similarly, application of fertilizer nitrogen increased during this period from 100 to 124.

Rice yield showed a rapid increase from 1956 to 1960, followed by a slow increase from 1960 to 1966, and again a remarkable increase

* Three-year-averages were presented based on data taken from "Crop Statistics" of Japanese Government.

Table 1. Amount of nitrogen applied in different forms

(kg/ha)

Form of applied N	Years					
	1956–58	1959–61	1962–64	1965–67	1968–70	1971–72
Chemical fertilizer	81.8	87.1	86.4	91.1	101.3	95.0
Manure	30.3	31.6	28.3	25.9	24.4	18.9
Straw	0.6	0.6	1.2	2.6	3.4	2.9
Total	112.7	119.3	115.9	119.6	129.1	116.8
%	100	106	103	106	115	104

since 1967.

The trend of fertilizer nitrogen application showed nearly the same trend as that of average yields but a slight decline was recognized after 1971.

A very high positive correltaion is found between the yields and the amount of fertilizer nitrogen application over a period of 18 years, as shown in Fig. 2.

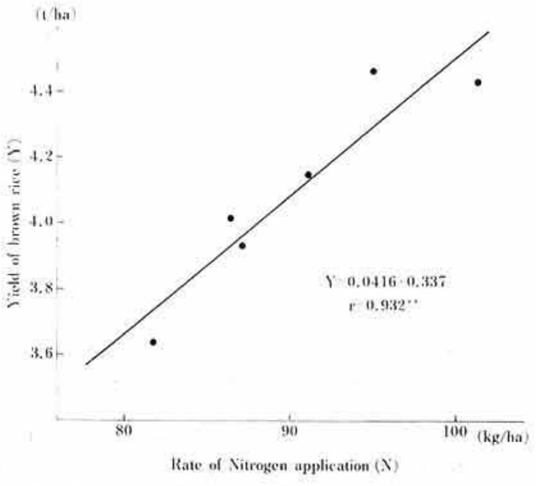

Fig. 2. Relationship between yield of brown rice and amount of nitrogen applied by chemical fertilizers

In the period from 1960 to 1966, rice production in Japan was not self-sufficient and rice was imported. But afterward, the self-sufficiency of rice was achieved and finally area cropped to rice was curtailed.

Although such overproduction is attributable to over-all technical progress of rice culture, the effective application of abundant fertilizers that was made possible by the technical improvement might have contributed a great deal to the yield increase. Another factor causing overproduction of rice is a decrease of consumption.

Stable manures have been known to increase soil fertility, and the use of them has been recommended for a long time. Economic development in the 1960's, however, resulted in labor shortage in rural areas. At the same time, progress of agricultural mechanization caused a decrease of work animals on farm fields. Consequently, application of stable manures in paddy fields has decreased rapidly.

Table 1 shows the amount of nitrogen applied to paddy fields in various forms. It can be noted that the amount of nitrogen derived from stable manures decreased with years while nitrogen from straw application increased although fertilizer nitrogen constituted a major portion of nitrogen application (about 80%).

Productive efficiency of applied nitrogen

Yield response of fertilizers is very important in determining methods of application. In fertilizer experiments, in general, a difference in absorption by plants of a particular nutrient between two plots, with and without the application of that nutrient, is determined and expressed in percentage of the total amount of that nutrient applied. This figure is referred to "absorption rate" or "utilization rate" of that nutrient. Methods of fertilizer application giving higher absorption rate is regarded as more efficient techniques.

In this report, however, productive efficiency of fertilizer was calculated by simply dividing grain yields (Y kg/ha) by fertilizer elements applied (N, P_2O_5, K_2O kg/ha). Thus, Y/N, Y/P_2O_5 and Y/K_2O were considered to represent productive efficiency of each element, because no data was available for calculation of absorption rates.

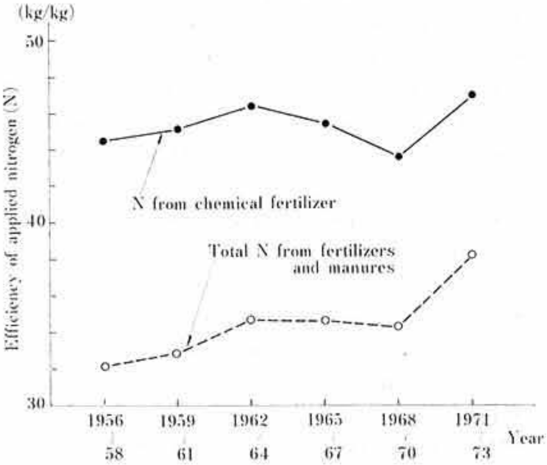

Fig. 3. Productive efficiency of nitrogen applied

Fig. 3 shows the yearly change of the efficiency of applied nitrogen. The efficiency of nitrogen of chemical fertilizers had gradually increased up to around 1964 and then declined.

Increasing application of nitrogen during the period from 1968 to 1970 resulted in a decrease of the efficiency in spite of an increase of average yields. The efficiency, however, increased again from 1971 to 1973. In this period, nitrogen applicaton became less than that of the previous period, but highly effective utilization of nitrogen did not cause any reduction in rice yields.

It can be said, therefore, that the efficiency of the nitrogen has been nearly constant or even increased in spite of a very high level of application. It means that the applied nitrogen was effectively utilized for rice production.

Productive efficiency of phosphate

The amount of phosphate applied to paddy fields in Japan was markedly increased after World War II. The increasing rate was far higher than that of nitrogen; phosphate application during the period from 1968 to 1970 was 1.8 times as much as that of a period from 1956 to 1958. Productive efficiency of phosphate calculated in the same way as that of nitrogen has declined continuously year after year. Both the amount of application and efficiency of phosphate seem to have attained an extreme in 1968–1970 as shown in Fig. 4.

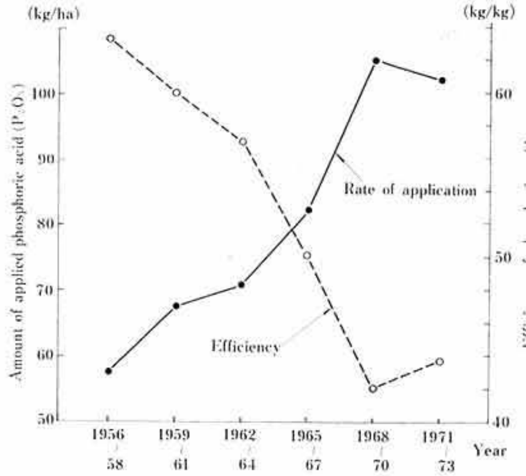

Fig. 4. Rate of application and efficiency of phosphoric acid

This result indicates that phosphatic fertilizers have not been used so effectively for the yield increase of rice in Japan. Since early days, it has been proved that phosphatic fertilizers are less effective in the alluvial paddy fields of Japan because of an abundant natural supply of phosphate. The phosphatic fertilizers, however, showed a remarkable effect in the volcanic ash soil of paddy fields newly brought into cultivation around 1970. Therefore, it is recommended to apply phosphatic fertilizers abundantly to the paddy fields derived from volcanic ash but moderately to the alluvial paddy fields.

But, recently too much phosphate is apt to be supplied to rice plants owing to the wider use of compound fertilizers which contain a large amount of phosphate.

However, an excess of the phosphate has been accumulated in soils, being fixed to soils without leaching, and which resulted in an increased phosphatic fertility of soils. Under this soil condition, rice yields are stabilized even under unfavorable climatic conditions (e.g. cool weather).

Productive efficiency of potassium

Fig. 5 shows yearly trends of application rate and productive efficiency of potassium. The trends are quite similar to those of nitrogen.

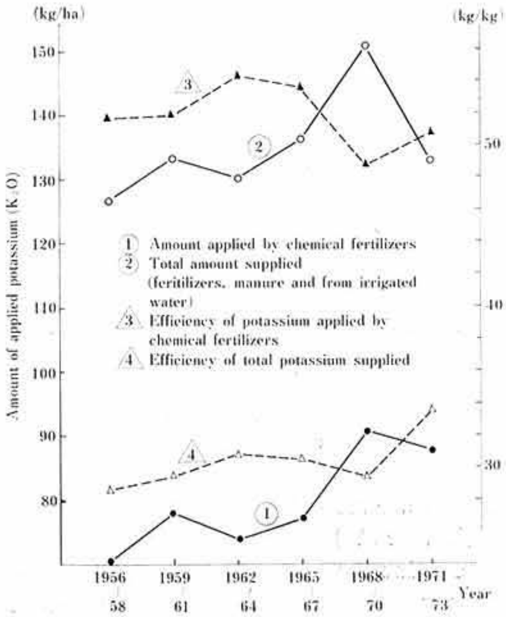

Fig. 5. Rate of application and efficiency of potassium

As potassium is closely related to nitrogen physiologically, it is recommended in Japan that potassium should be applied as much as nitrogen. This is the reason why potassium application has shown a similar trend as nitrogen.

Discussion

Although the liberal application of fertilizers and subsequent absorption by plant are required to increase grain yield, the yield increase is not always proportional to the fertilizer increase. Therefore improved application techniqeus which can prevent or minimize the reduction of fertilizer efficiency must be developed.

The present analysis indicates that the heavy use of chemical fertilizers, especially nitrogen fertilizer, has been practiced in Japan without causing a reduction of productive efficiency by adopting the split-application method, which enables rice plants to maintain a good nutritional state until the later growth stage.

The detailed description of this method was given in previous reports[1),3)]. The technique has widely been used all over Japan since around 1967–1968, and has undoubtedly made a substantial contribution to the rice yield increase by means of heavy application of fertilizers.

Rice plants require not only N, P_2O_5 and K_2O, but also several other nutrients. Particularly rice plants require and utilize a large amount of SiO_2. Therefore silicate fertilizers (slag and calcium silicate) and fused phosphate are widely used. CaO and MgO are also applied, if necessary[1)]. These elements are used not only to supply plant nutrients but also to improve physico-chemical properties of soils.

In general, the fertilizer application is a component, but not a substitute for good management. Kawada[4)] indicated that the yield increase can be obtained by an integration of good variety, good crop management (selected season, pest control, water management etc.), soil improvement (fertility and physico-chemical properties), and fertilizer application. Remarkable yield increase obtained since 1967 in Japan can be attributed to the well-balanced progress in all these components, which made it possible to utilize liberal amount of fertilizers in increasing yields without reducing productive efficiency of fertilizers.

In conclusion, the present analysis furnishes an evidence that the low of diminishing returns is not unvariable, but can be modified by the advancement of production technology.

References

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