Manuring Management Practices of the Paddy Field Highly Utilized with Introduced Vegetables

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Under the present agricultural status of Japan where it is becoming more difficult year by year to enlarge the agricultural scale owing to the rapid increase of land price, it is an important subject, especially for paddy field, to establish a high yield system getting rid of the conventional agriculture to which too much importance of rice cropping had been attached.

As one of the countermeasures for such necessity, a high utilization system of paddy field combined with many kinds of vegetables as the preceding and succeeding crop is becoming an important cropping system in the farming area of the urban and industrial suburbs.

When the high utilization system of paddy field introduced with vegetables is regarded as a compound cultivation system which consists of different cropping, that is, when the rice crop preceded or succeeded by vegetables is regarded as an unit of cultivation, there will remain many problems which cannot be easily solved by a simple combination of old knowledges of rice and vegetable.

Under this cropping system, the production of vegetables is unstable because of heavy manuring intensive culture, and rice output is apt to be badly affected by the residual activity of the fertilizer applied to vegetables and by the plowing-in of the residue of harvested crop[1].

Therefore, it is important to establish technical countermeasures of manuring management. From such point of view, three examinations were held on phosphorus and nitrogen which are especially essential for the production of crop plant. The results are described hereunder.

Optimum amount of phosphorus applied to the paddy field to which vegetables were introduced

1) *Difference between rice plant and vegetables in respect of phosphorus requirement*

For the compound rotation system of rice and vegetables, it is necessary to establish a reasonable application method of fertilizer to increase the production of crops avoiding the excessive accumulation of phosphorus. Consequently, since it is desirable to examine the relation between the nutrient supply of soil and the nutrient demand of crop, the phosphorus demand of each crop was investigated at first.

Fig. 1 shows the relation between the dry matter production of vegetable and rice and the amount of available phosphorus in soil on the 40th day after sowing.

As the result, it was shown that the amount of available phosphorus, which brings about the maximum yield of crops, namely "marginal amount of available phosphorus" is about 70 mg per dried soil of 100 g. This is a high value compared to the amount of less than 20 mg in the paddy field under submerged cultivation with the same soil.

Moreover as to the comparison of final yield,

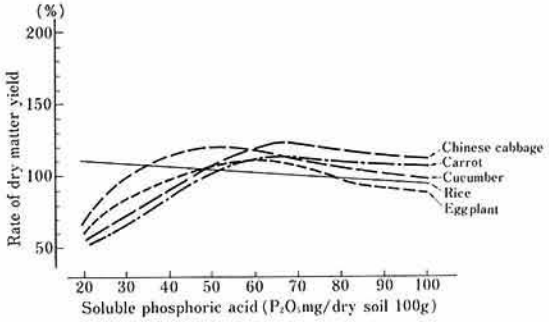

Fig. 1. Relation between the amount of available phosphorus and dry matter yield (40 days after germination)

80 mg are needed for tomato and less than 20 mg for rice plant. Thus, a great difference of phosphorus requirement was recognized between vegetables and rice plant.

2) Relation between A-value and the amount of the available phosphorus measured by chemical method

It is necessary to determine the method of the available phosphorus measurement by which the growth of crop plants can be evaluated correctly for the calculation of the optimum amount of fertilizer in consideration of the marginal amount of available phosphorus of each crop. Since the biological measuring method is most reliable to meet this demand, the A-value method of Fried Dean[2] was applied for the examination.

Table 1 shows the A-value of cucumber, cabbage and rice determined with the soil of 14 soil samples of the paddy field introduced with vegetables. In this table, the A-value of vegetables is very low compared to that of rice, and the variability of the value is great by the difference of soil and the amount of available phosphorus soil is different even between the rice crop and vegetable cultivated on the same soil.

Table 1. A-value of some crop plants
(N=14)

Crop plant	Mean value	Minimum—maximum
Rice (water logging)	71.9	31～108
Cucumber (upland)	47.7	17～ 97
Cabbage (upland)	42.2	10～ 88

A-value can be regarded as the maximum value of the phosphorus in soil which is available for the crop plant during cultivation with the availability as well as the phosphorus of the used fertilizer.

Therefore, if a chemical measuring method, which possesses a high correlation with the A-value in equivalent value, can be found, it may be possible to indicate easily the amount of available phosphorus in field cultivation as the amount of the phosphorus fertilizer.

Table 2 shows the correlation between the A-value and the amounts of soluble phosphorus determined by eight chemical measuring methods on the substances extracted by dilute acids, acid buffer solutions and NH_4F containing liquid which have been used all over the world.

Table 2. Relation between A-value and several available phosphorus amounts

Crop plant	A-value (mg/100 g)	Amount of available phosphorus (mg/dry soil 100 g)		Regression equation	Correlation coefficient
Cucumber	45.8	BRAY P_1 method	25.6	$Y = 27.53+0.714X$	0.741**
〃	〃	BRAY P_2 method	46.0	$Y = 5.65+0.873X$	0.810**
〃	〃	Double lactate method	17.8	$Y = 22.31+1.320X$	0.679**
〃	〃	OLSEN method	4.3	$Y = 17.00+6.700X$	0.717**
〃	〃	2.5% acetic acid method	42.6	$Y = 11.13+0.814X$	0.755**
〃	〃	TRUOG method	21.1	$Y = 20.91+1.180X$	0.892**
〃	〃	1% citric acid method	126	$Y = -19.33+0.517X$	0.892**
〃	〃	0.2 NHCl method	122	$Y = 3.25+0.348X$	0.712**

Note: ** Significant at 1% level

In the results of any measuring method, a high coefficient of correlation more than r=0.700 at the level of 1% was obtained on the vegetables. Among these eight methods, the Bray P_2 method may be the most suitable one for the evaluation of the amount of available phosphorus soil for the cultivation of vegetables because the result of this method is equivalent to the A-value and the determination can be achieved very easily and rapidly.

3) Manuring management of phosphorus upon the paddy field introduced with vegetables

In the rotation cropping of vegetables and rice plant which is very different in their requirement for phosphorus element, the amount of applied phosphorus fertilizer is determined on the basis of the marginal amount of available phosphorus of the vegetable of which phosphorus requirement is the highest among cultivated vegetables.

And when the amount of the available phosphorus of the cropping soil is less than the marginal amount of phosphorus required by the introduced crop plant, the difference between these two amounts should be the optimum amount of phosphorus fertilizer.

Under such management, a sufficient amount of phosphorus is well reserved to be supplied to the succeeding paddy crop because this amount is always maintained in the soil and therefore no additional application of phosphorus may be needed.

If the manuring management of phosphorus is carried out with such idea on the paddy field highly introduced with vegetables, the nutritional condition of soil can always be kept at an adequate level without not only an excessive phosphorus residue in the soil but also any apprehension of a surplus accumulation of phosphorus in the future.

Behavior of nitrogen in the paddy field introduced with vegetables and the influence of nitrogen on the growth of crop plant

1) Residual effect of nitrogen applied on the preceding vegetable crop to the suceeding paddy crop

Heavy nitrogen was used in the experiment to clarify the behavior of the nitrogen in soil which was reserved excessively in the paddy field preceded by vegetable crop and had the most important relation on production, and to clarify the pattern of absorption and utilization of nitrogen by rice plant.

In this experiment, the mineralization of nitrogen due to residual effect of applied nitrogen was pursued with the difference of the availability of the available nitrogen in soil between the paddy field preceded by vegetables and that preceded by fallow.

The residual nitrogen reveals more availability at the young panicle formation stage and heading time in the paddy field preceded vegetables as shown in Fig. 2, though this

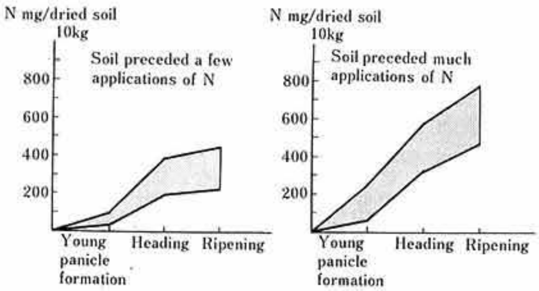

Fig. 2. Growth stages and the process in which residual N becomes available

availability is maintained throughout the long growing period up to the ripening stage.

On the other hand, the rates of absorption of the residual nitrogen by rice plant are high at the heading and ripening stage as shown in Fig. 3. This trend corresponds to the appearing process of the availability of the residual nitrogen in soil.

It is a specific point of the rice cropping

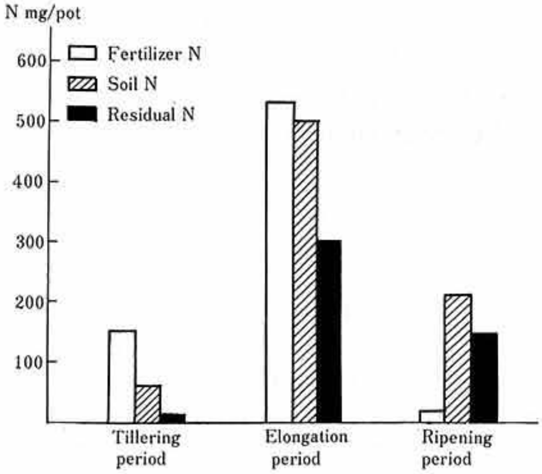

Fig. 3. Growth periods and the amounts of N absorbed from various sources

after the culture of vegetables that the excessive nitrogen derived from the residual availability of the fertilizer applied to the preceding crop is supplied to rice at the later half stage of growth, and consequently delay of the growth and reduction of ripening of rice plant were induced under these conditions.

2) Nitrogen attributed to the residue of harvested vegetables

The behavior of nitrogen in the soil and the absorption of nitrogen by rice plant under water logging condition of the field added with the outside leaves of the cabbages labelled with ^{15}N were studied.

Fig. 4 shows the rise and fall of the inorganic nitrogen derived from the nitrogen of cabbage residue in the water logging soil.

Fifty per cent of the nitrogen contained in the cabbage residue were convereted into inorganic nitrogen during 30 days after plowing-in, while about 20 per cent of the nitrogen in ammonium sulphate, which were added to the soil at the same time, were converted into organic nitrogen on the 30th day.

Both inorganic and organic parts in this case are nondistillable acid-soluble N (principally composed of amino acids and amino sugar); therefore, these nitrogen fractions may play an important role on the behavior of nitrogen in the soil.

The amount of inorganic nitrogen originated in the organic substances of the soil to which the cabbage residue was added is larger than that of the soil without residue. This means

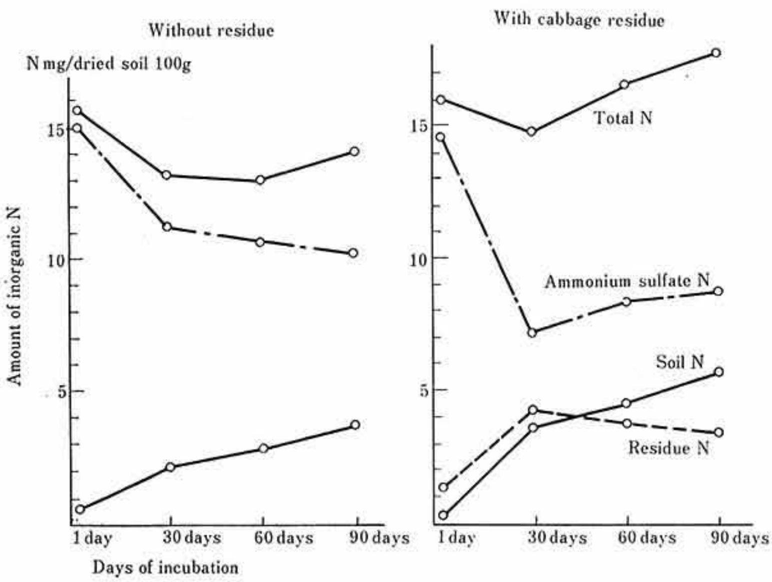

Fig. 4. Rise and fall of the inorganized N from various sources in flooded soil and their origins

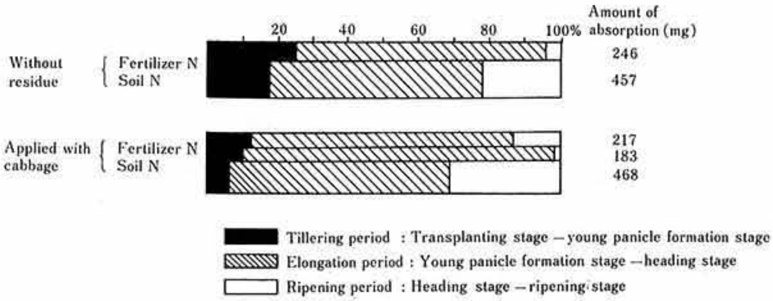

Fig. 5. Growth periods and absorption process of N (Rates when the total absorption rate was set to 100)

that there exists an action which accelerates the decomposition of the organic substances in soil, namely the priming action when some fresh organic substances were added to the soil[4].

Fig. 5 shows the process in which the nitrogen derived from various sources is absorbed by rice plant. The nitrogen derived from the residue of cabbage was utilized by the rice plant more quickly than that of ammonium sulfate and its availability was 45%. It is manifested that this value corresponds to the unorganized rate of inorganic nitrogen derived from cabbage residue in the soil.

From these points, it is presumed that the abundant supply of the vegetable residue of low C/N ratio results in the same risk as the excessive application of inorganic nitrogen fertilizer. Furthermore, the vegetable residue accelerates the decomposition of the organic substances in soil. This point is different from the usual application of organic substances.

3) Simplified measurement of available nitrogen supplied in the soil of the field preceded by vegetable crop

The relation between the incubation method, which has been one of the excellent evaluation methods of available nitrogen supply for years[5], and other chemical measuring methods was investigated.

Among the seven chemical measuring methods described in Table 3, the 1N NaOH method revealed a high correlation with the incubation method, and equivalency was recognized between their measured values. This is a very simple measuring method; that is, 1N NaOH is made to react with air-dried soil by use of Conway's micro-diffusion apparatus and then NH_4-N produced after incubation at 28°C for

Table 3. Relation between the N amount determined by several methods and the amount of NH_4-N produced by several incubation methods

Determination method	Items		
	Minimum-maximum (mg/100 g)	Mean values (mg/100 g)	Correlatition coefficient with air dried soil culture
Incubation method with dried soil	6.2～ 26.2	13.8	—
Incubation method with wet soil	0.7～ 21.5	4.3	0.212
$KMnO_4$ Oxidation	14.0～ 39.2	20.1	0.292
4.5N H_2SO_4 Hydrolysis	2.1～ 17.9	7.3	0.702**
Heated water soluble method	3.4～ 16.7	12.3	0.409
0.1N H_2SO_4 soluble method	5.0～ 22.6	12.3	0.326
1N NaOH treatment	0.1～ 23.2	11.1	0.807**
Total nitrogen	92.0～287.0	178.0	0.191

** Significant at the level of 1%

40 hours can be easily titrated.

Conclusion

It was shown that in a compound utilization system under various environments of soil such as vegetables—rice plant and upland—lowland, the soil of the paddy field of this system becomes more fertile than that of ordinary paddy field. This may be caused naturally owing to the difference of the nutrient absorption characteristics between vegetable and rice.

Therefore to utilize fertilizer more effectively, it is necessary to carry out reasonable management practices of the highly utilized paddy field on the improvement of nitrogen fertilization, which is conducted mainly for the stable production of rice, and phosphorus fertilizer application for vegetable to maintain favorable soil fertility.

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