Determination of Nitrogen-Supplying Capacity of Soils Using ^{15}N Tracer Technique

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Since the worldwide petroleum crisis, the demand and supply balance of fertilizer has shown a tense situation. Consequently, problems of soil fertility and effective utilization of fertilizer have come before the footlights.

It is evident that correct evaluation of nitrogen-supplying capacity of soils is indispensable for the improvement of agricultural production.

However, any satisfactory method to determine quantitatively nitrogen-supplying capacity of soils has not been found yet owing to the complexity of this problem.

The utilization of ^{15}N seems to present a new promising method for the determination of nitrogen-supplying capacity of soils. That method and related problems are described in this report.

Principle of determining nitrogen-supplying capacity of soils using ^{15}N tracer technique

It is postulated that soil is a reaction system containing nitrogen of fertilizer applied, available nitrogen originated from soil itself (soil nitrogen), and plant roots. In this system, a proportional relationship exists between the ratio of fertilizer nitrogen absorbed by plants to soil nitrogen absorbed by plants and the ratio of fertilizer nitrogen in the soil to soil nitrogen. This relationship can be detected by the use of the law of isotope dilution.

That relationship can be formulated as follows

$$N/M=S/F$$

where N: Nitrogen-supplying capacity of soils (N-value)

M: Amount of nitrogen applied

F: Fertilizer nitrogen absorbed by plants (N in plants)

S: Soil nitrogen absorbed by plants (N in plants)

Therefore, N-value is expressed as

$$N=M\times S/F$$

Variation of N-value determined by field experiments using ^{15}N tracer technique

The above equation implies that the value of N must be constant in a reaction system whatever the fertilizer level may be. That is, when the fertilizer amount is doubled, the ratio of S to F should become a half. But actually the value of N varies with different levels of fertilizer because of changes in absorption rate and of variations of the loss of nitrogen by denitrification, conversion into organic compound and runoff. As given in Table 1, N-value shows an upward trend with increased amount of fertilizer in the paddy field of high nitrogen pool (Nagano Prefecture, Japan), while it shows a downward trend in the paddy field of moderate nitrogen pool (Bangkhen, Thailand).

There is an opinion that the N-value is constant because the ratio of applied nitrogen in plants (F) and soil nitrogen in plants (S) to the amount of fertilizer applied (M) is well-balanced. More generally considered is that the N-value is constant only when the

Table 1. Relationship between nitrogen application rate (N kg/ha) and N-value

	Application rate	N-value	Authors
Nagano paddy fields (with high N. pool)	83	179	Nishigaki Shibuya Koyama
	140	182	
	175	172	
	195	204	
	215	194	
	235	192	
Bangkhen paddy fields (with moderate N. pool)	56	207	Koyama Natee
	75	155	
	94	143	
	113	155	
	131	135	

nitrogen absorbed by plants from the available soil nitrogen is scarcely affected by the fertilizer nitrogen.

It is, however, easily understood that the N-value is variable, depending on the amount of applied fertilizer because the mineralization of soil nitrogen is accelerated by the applied nitrogen (priming effect) and the recovery rate varies with fertilizer amount.

The N-value is effected also by fertilizer placement (Table 2), kind of fertilizer

Table 2. Fertilizer placement and N-value
(Merzari and Broeshart)

Soils	Placement	
	Surface layer	5 cm below
Sri Lanka	217	82
Burma	131	96
Korea	189	146
Egypt	348	219
Hungary	245	171

Table 3. Kinds of fertilizers and N-value
(Broadbent)

Soils	Kinds of fertilizers			
	$(NH_4)_2SO_4$	NH_4OH	KNO_3	Urea
Montezuma Clay	252	224	126	148
San Joaquin Loam	207	310	128	152
Yolo Fine Sandy Loam	128	174	82	98

Table 4. Plant species and N-value (Soils in Gifu Pref.)
(Nishigaki, Shibuya and Koyama)

Crop	Fertilizer amount	N-value
Rice	94	226
Onion	188	202
Wheat	94	176

Table 5. Effects of phosphorus on N-value of Soils in Klong Luang (Thailand)
(Koyama and Chittana)

P levels (P_2O_5 g/pot)	N levels (N g/pot)	N-value
0. 001	2. 0	1. 2
0. 01	2. 0	1. 1
0. 05	2. 0	0. 6
0. 5	2. 0	0. 4
2. 0	2. 0	0. 2

(Table 3) and by plant species even in a same field (Table 4). Furthermore, Table 5 shows an example indicating that other plant nutrients also affect the N-value. The N-value of the soils in Klong Luang (Thailand), deficient with phosphorus, showed a remarkable variation by phosphorus application. In addition, amount of mineral nitrogen originally presents in soils, time of sampling and cropping season also affect the N-value.

Since the N-value is determined by interactions of soil-fertilizer-crop components, as mentioned above, it is natural that the N-value varies with different situations. It may be concluded, therefore, that the N-value can hardly indicate directly the nitrogen-supplying capacity of soils during the growth period of plants.

Introduction of a concept of the maximum and minimum nitrogen-supplying capacities of soils

That the N-value varies with forms and placement of fertilizers as well as plant species is a natural consequence of the fact that the N-value is estimated basing on the availability of fertilizers applied and that the principle of isotope dilution can only be applied to a reaction system in which fertilizer and soil nitrogen are well mixed. Beside these factors, the unavailability of fertilizer nitrogen, caused by denitrification, runoff from the root-area of plants and immobilization, is a major cause which makes the N-value larger than the actual amount of plant-available nitrogen in soils that was mineralized during a cause of plant growth (leaf-fall, and nitrogen absorption capacity of plants can also be modifying factors).

Consequently, the N-value calculated with the isotope dilution method can be recognized as the maximum value for a given soil-fertilizer-crop situation because the calculation is made on an assumption that the fertilizer nitrogen was applied evenly to the roots of plants without any loss due to denitrification, runoff and immobilization.

On the other hand, the amount of nitrogen actually absorbed by plants seems to show the minimum value of the nitrogen-supplying capacity of soils on an assumption that the available soil nitrogen mineralized during the growing period of plants can completely (100%) be absorbed by plants (Fig. 1). The

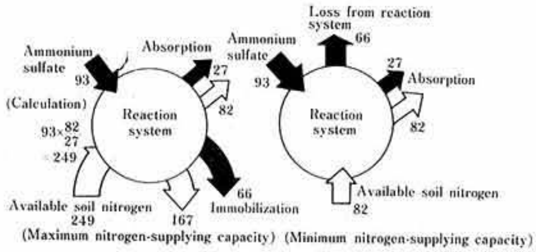

Fig. 1 Schema illustrating maximum and minimum nitrogen-supplying capacities (paddy fields in Nagano Pref.)

real value of nitrogen-supplying capacity must exist between these two values. Since it is impossible, at present, to determine the real value, the range between the maximum and the minimum value, which can be determined, should be used. (Sometimes the mean value of this maximum and minimum is considered as the surest value).

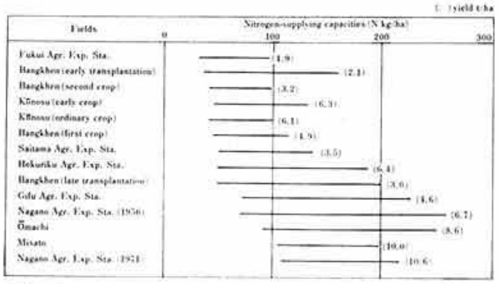

Fig. 2. Range of nitrogen-supplying capacities determined by ^{15}N method

Fig. 2 illustrates the range of nitrogen-supplying capacity of various soils, determined by ^{15}N method, and grain yields. It is recognized that high grain yield is associated with high N-value irrespective of different fertilizer application and climate.

The expression of N-value by the range from maximum to minimum has an advantage of showing a range of variability of N-value. Furthermore, an extent of runoff and immbolization of ^{15}N from the soil-fertilizer-crop system during measuring period can be checked. As an example, the condition of fertilizer in the soil during the growth period of crops can be traced. As it can be said that the narrower the range, the more is the reliability as to the total available soil nitrogen mineralized during the growing period of crops, the extent of the range itself indicates the reliability of the N-value.