Computational method for appropriate nitrogen level by soil diagnostics in Andosols of Japan

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Abstract
In farm production, it is important to reduce the cost of production and increase yield. It is necessary that countries like Japan that depend on import for resources reduce the quantity of the chemical fertilizer consumed in the cost of production. In this study, it was aimed to develop the soil diagnosis formula that was able to decide the appropriate amount of chemical fertilizer nitrogen. The evaluation method of available nitrogen of the soil was examined in the beginning. As a result, the phosphate buffer extractable N (PB-N) that used an oven dry (160 ˚C, 2 hour) soil sample was adopted for available nitrogen. Next, the amount of the chemical fertilizer nitrogen absorbed by Chinese cabbage, corn, and carrot was measured using ^{15}N labelled ammonium sulphate. The multiple linear regression analysis was calculated using as dependent variable the absorbed chemical fertilizer nitrogen and explanatory variable that was the total amount of nitrogen absorption of crops, inorganic nitrogen, and available nitrogen. This multiple regression equation was adopted as a soil diagnosis formula. As a result, the amount of chemical fertilizer nitrogen was able to be reduced, while maintaining yield.

Key Words
Nitrogen excess, nitrogen cycle, nutrient management tool.

Introduction
A lot of studies report on soil fertility deterioration (Hartemink 1997). On the other hand, there is a region where the production conditions have deteriorated, along with soil eutrophication due to excessive fertilizer, use. Understanding available nitrogen (N) is important for optimizing N fertilizer recommendations (Matsumoto *et. al.* 2000). To estimate N fertility, a 4 week incubation method measuring the amount of inorganic N released during incubation at 30 ˚C under field moisture conditions has been commonly used. However, there is little research from which an accurate amount of applied nutrient is calculated using available N. One of the problems is the time taken for the 4 week incubation method of analysis. In Japan, because this method and the correlations were high, a simple expedient method, 1/15M phosphate buffer at pH 7.0 extraction, was used (Saito 1988). Higuchi (1981) reported that 1/15M phosphate buffer (pH 7.0) extracted the Protein-like N compounds in soil. In fact, the 4 week incubation method evaluates the inorganic N, and 1/15M phosphate buffer at pH 7.0 extraction method is a method of evaluating the organic N. However, this simple analysis method had not been used for the soil diagnostics in Japan. It is because the accuracy of this simple method is low. The purpose of this study is to examine the analysis method to solve such a problem, and to develop a method of diagnosing the soil to calculate an appropriate amount of the chemical fertilizer N. The reduction in the energy cost and the decrease of the negative environmental impact can be expected by advising the appropriate amount of the chemical fertilizer N, while maintaining or improving agricultural production.

Methods and Materials
The soil samples used in all the analyses are Andosols from Japan. All samples were air dried once and a part of the samples were oven dried for 160 ˚C, 2 hour in a glass bottle. For the 4 week incubation N (4w-N), 10 g of air and oven dry soil samples in a 100 mL plastic bottle was moistened at 60 % of maximum water-holding capacity. These bottles were covered with polyethylene, and the soils were incubated at 30 ˚C for 28 days. After incubation, the inorganic N in a soil was extracted with 10 % KCl and determined by FIA (flow-injection analyser). A 10 g air and oven dry soil samples with 40 mL of 1/15 M phosphate buffer (pH 7.0) consisting of Na_2HPO_4-$12H_2O$ (14.6 g/L) and KH_2PO_4 (3.5 g/L) was shaken for 1 hour to extract the organic N (PB-N).The soil extracts were passed through No. 6 filter paper (Advantec), and the organic N was measured by the steam distillation method. The concentration of protein in the soil extract with phosphate buffer was measured by a protein assay kit (Bio-Rad), which applied the Bradford method using g-globulin as a standard. Inorganic N was filtered after it was extracted by using 50 mL of 10 % KCl solution and soil

10g, and measured with FIA. The cultivation experiment followed using Chinese cabbage, corn and carrot. The field where the diagnosis formula was developed and the cultivation examination field were at different locations.

Results and Discussion

Development of the index of available N by simple analysis

As compared with air dry soil samples, oven dry soil samples showed the higher values for phosphate buffer extractable N (PB-N) and 4 week incubation N (4w-N) (Figure 1). By heating (160 ˚C, 2 hour), the correlation coefficient of PB-N and 4w-N increased (Figure 1). By heating, some of the soil microbes die out. As for the increase in amount of 4w-N, the mineralization of dead bodies of these soil microbes was considered to be the cause. However, this process alone cannot explain the increase in PB-N. It is because N of soil microbe origin is contained in PB-N. It is difficult to think that microbes increase by heating at high temperature and for short time. By heating, the amount of total N in the soil samples did not decrease (Figure 2). On the other hand, Protein N in Phosphate buffer extraction sample tends to increase a little with PB-N by heating (Figure 2). These results show that PB-N of oven dry samples contains easily decomposable organic matter. When carrying out soil diagnosis, it is desirable that the spread and dispersion of measured values become small. Therefore, it was thought that PB-N was suitable as an index of available N.

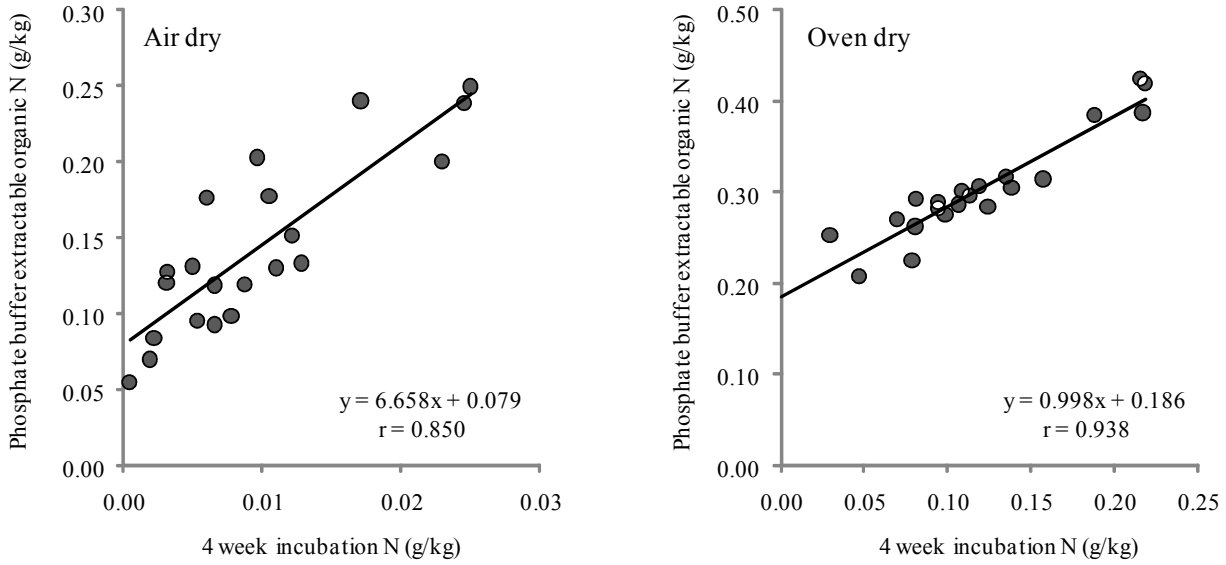

Figure 1. Relationship between phosphate buffer extractable N and 4 week incubation N for air dry (left) or oven dry (160 ˚C, 2 hour) (right) soil samples of Andosol.

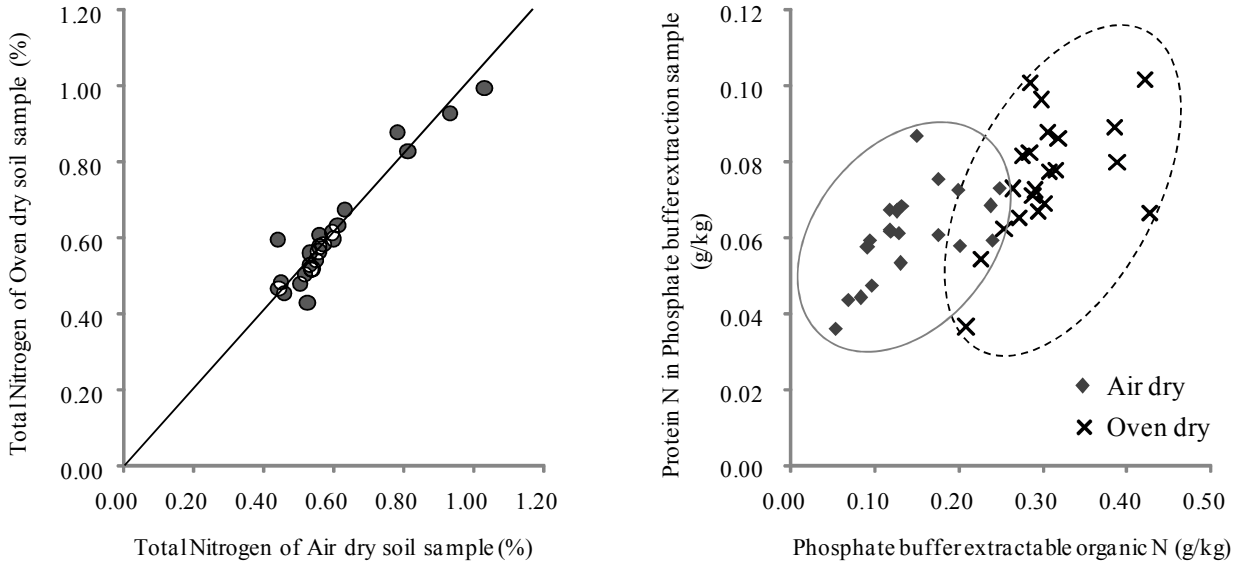

Figure 2. Relationship between oven dry (160 ˚C, 2 hour) and air dry soil samples for total N (left), and relationship of Protein N in phosphate buffer extraction samples and phosphate buffer extractable N of air dry or oven dry soil samples (right).

Creation of a soil diagnostic formula

In the test field, where inorganic N and the amount of available N (oven dry PB-N) before cultivation differ from each other, the field experiment using Chinese cabbage, corn, and carrot was performed. Chemical fertilizer N was ^{15}N labelled ammonium sulphate (3.07 and 2.09 Atom %) for these experiments. The total amount of N absorption by plants and the amount of ^{15}N absorption by the plants were obtained as a result of the Kjeldahl method and EA-IRMS (Elemental Analysis Isotope Ratio Mass Spectrometry). Multiple linear regression analysis was performed using the following four parameters; the amount of ^{15}N absorption (Y) became the development variable; and the total amount of N absorption of crops (X1), inorganic N (X2), and available N (oven dry PB-N) (X3) became explanatory variables. Consequently, a multiple regression equation significant at the level 1% were obtained.

Chinese cabbage

$$Y = 0.836X1 - (0.339X2 + 0.064X3) \quad R = 0.971 \tag{1}$$

Corn

$$Y = 0.520X1 - (1.310X2 + 0.157X3) \quad R = 0.973 \tag{2}$$

Carrot

$$Y = 0.759X1 - (0.013X2 + 0.440X3) \quad R = 0.930 \tag{3}$$

These were considered as the soil diagnostic formulae for Chinese cabbage, corn and carrot cultivation.

Field examination of using soil diagnostics formula

The experiment was performed in the fields of eight farms. In Chinese cabbage, inorganic N was 14-115 mg/kg and available N was 65-71 mg/kg (Table 1). By using the soil diagnostics formula, the amount of N of a chemical fertilizer was reduced by 20-35 % (Table 1). The yield was 1400-1577 kg/a, and this is the same as commonly found in a farmers fields. In corn, inorganic N was 6-96 mg/kg and available N was 4-83 mg/kg (Table 1). The amount of N of a chemical fertilizer was reduced by 71-90 % by using the soil diagnostics formula (Table 1). The yield was 775-1270 kg/a, and income was reduced compared with normal expectations of a farm. This is because the amount of absorption N was greater than the actual amount of expected absorption N by 0.7-2.1 kg/a. In carrot, inorganic N was 10-26 mg/kg and available N was 54-60 mg/kg (Table 1). By using the soil diagnostics formula, the amount of fertilization N was reduced by 15-24 % (Table 1). The yield is 766-939 kg/a and increased receipts as compared with normal practices of a farm. From these results, it was shown that the amount of N of an appropriate chemical fertilizer is calculable by using a soil diagnostics formula that uses the amount of absorption N, and inorganic N and available N before cultivation.

Table 1. Component of soil diagnostics formula parameters, yield, amount of absorption N and reduction rate of fertilizer N from cultivation experiment of Chinese cabbage, corn and carrot.

	Site No.	Amount of expectation absorption N	Field before cultivation				Examination field of soil diagnosis			
			Inorganic N	Available N	Amount of conventional fertilizer N	Amount of diagnosis fertilizer N	yield	cropping index	Amount of adsorption N	Reduction rate of fertilizer N
		kg/a	mg/kg	mg/kg	kg/a	kg/a	kg/a	%	kg/a	%
Chinese cabbage (*Brassica rapa L.*)	1	2.0	115	71	2.0	1.3	1577	108	2.2	35
	2	2.0	42	79	2.0	1.5	1393	100	2.0	25
	3	2.0	14	65	2.0	1.6	1400	105	2.1	20
Corn (*Zea mays L.*)	4	1.6	96	83	2.5	0.2	1270	105	3.7	90
	5	1.6	6	4	1.8	0.5	775	79	2.3	71
Carrot (*Daucus carota L.*)	6	2.0	11	60	1.3	1.0	864	112	1.1	20
	7	2.0	26	66	1.3	1.0	766	95	1.3	24
	8	2.0	10	54	1.3	1.1	939	113	1.1	15

Conclusion

The crop management technique that decreases the amount of fertilizer used without yield decline becomes possible by using the soil diagnosis formula, that uses the total amount of N absorption of crops, soil inorganic N, and available N (oven dry PB-N). It is necessary to investigate the absorbed amount of the chemical fertilizer N of each crop to make the soil diagnosis formula. And, it is important to accurately estimate the amount of N absorbed by crops, as they will differ according to each field.

References

Hartemink AE (1997) Soil fertility decline in some Major Soil Groupings under permanent cropping in Tanga Region, Tanzania. *Geoderma* **75,** 215-229.

Higuchi M (1981) Characterization of immobilized nitrogen and organic nitrogen extracted with various buffer solution. *Journal of Soil Science and Plant Nutrition* **52,** 481-489. (in Japanese with English summary).

Matsumoto S, Ae N, Yamagata M (2000) Extraction of mineralizable organic nitrogen from soils by a neutral phosphate buffer solution. *Soil Biology and Biochemistry* **32,** 1293-1299.

Saito M (1988) Estimation of nitrogen availability indices based on UV absorption of soil extracts. *Journal of Soil Science and Plant Nutrition* **59,** 493-495. (in Japanese with English summary).