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Equations for Calculating N-Fertilizer Rates for Khaw Dauk Mali-105 Rice from Soil Analysis

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ABSTRACT

Comparisons were made to assess the reliability of 10 chemical methods for evaluating the availability of N in soils to Khaw Dauk Mali-105 rice and for calculating rates of N-fertilizer for rice. The methods studied were: (1) measuring soil organic matter by Walkley and Black's method, (2) measuring total soil N by Kjeldahl's method, (3) extracting soil N with acidified $K_2Cr_2O_7$ solution, (4) extracting soil N with basified $KMnO_4$ solution, (5) extracting soil N with acidified $KMnO_4$ solution, (6) extracting soil N with solution of $CaCl_2$ and K_2SO_4, (7) extracting soil nitrate according to Keeney and Nelson (1982) and then measuring the extracted nitrate by Kjeldahl distillation, (8) extracting mineral N in soils with 2*N* KCl followed by distillation of NH_3 with MgO and Devarda alloy, (9) measuring NH_4-N production from incubation of soils under waterlogged conditions for 7 days, and (10) measuring NH_4-N production from incubation of soils under waterlogged conditions for 14 days. The study was made with field-plot experiments at 18 sites inside and outside the Khaw Dauk Mali-105 producing areas.

Only the indices from the methods (9) and (10) gave significant relationships (at 95% confidence level) with the relative paddy yields, with Method (10) showing slight superiority over the method (9). None of the chemical methods gave significant relationships among the index and the relative dry matter and amount of N in plants. The equations for calculating rates of N fertilizer required for desired paddy yields were: (a) $\log (100 - y) = 2 - 0.0226b - 0.0374x$ for method (9) and (b) $\log (100-y) = 2 - 0.00533b - 0.0584x$ for method (10); where y is the desired grain yield (as % of maximum yield), b availability index value for soil N (in ppm N), and x rate of fertilizer N required (as kg N/rai, 6.25 rais = 1 ha). Both of the two equations gave highly significant correlation between the actual paddy yields and the predicted paddy yields. However, method (10) was more recommended than method (9) for it was more reliable than method (9) in prediction of the yield.

Key words : aromatic rice, estimation, N fertilizer, rate, soil analysis

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INTRODUCTION

Nitrogen status of soils at different sites may vary widely depending on soil-forming factors and land use. Among soils with similar genetic factors, land use may immensely affect the N status. For example, a soil may be so high in N status that it gives high crop yields without fertilization while another soil of the same series may be so low in N status that cropping depends solely on fertilization. Accordingly, fertilizer recommendation based on soil genetic characteristics, for example soil series or soil texture, may suffer from low reliability and, as a result, a recommended N fertilizer rate may be too low for some soils but too high for some other soils. Accordingly, the yield will be too low in the former case while, in the latter case, not only low response to the fertilizer will be obtained but the excessive fertilizer may also render detrimental environmental effects by excessive leaching of nitrate. Moreover, in the latter case, low quality grains of aromatic rice will be inevitably obtained, as it has been reported that quality of grains of Khaw Dauk Mali-105 rice decreases with increasing N fertilizer rates which are higher than the rate that produce paddy at 80% of the maximum (Suwanarit *et al*., 1996). Evaluation of N status of soils is the most appropriate measure to overcome these problems and chemical test is the most appropriate method for evaluating nutrient status of soils.

Numerous chemical methods have been proposed for evaluating N status of soils (Bremner and Mulvaney, 1982) and different methods have been reported most reliable for paddy soils by different authors (Kawaguchi and Kyuma, 1969; Sahrawat, 1980, 1982; Dolomat *et al*., 1980). However, there has been no study on reliability of different chemical methods and their relationships with performance of Khaw Dauk Mali-105 rice under field conditions in Thailand. The present study was therefore conducted to (1) compare different chemical methods reported to be most reliable by different authors so that most appropriate method may be used for evaluating availability of N in soils for Khaw Dauk Mali-105 rice production in Thailand and (2) to provide equations for calculating the amount of fertilizer N needed for the rice from chemical soil analysis.

MATERIALS AND METHODS

Field experiments

Field experiments were conducted, using Khaw Dauk Mali-105 rice, at 18 sites which were in and outside the production areas of this rice cultivar. The soils had organic matter contents of 0.63 - 3.06 % and pH 4.0 - 7.5. Information for each experimental site are shown in Table 1. The field experiments were done during the growing seasons, August-November, of the years 1994 - 1996.

Randomized complete block designs with 6 treatments and 6 replications were employed for experiments at all sites. Plot for each treatment measured 5.0 m x 3.0 m. Dikes made of soil from outside the plots were put up around each plot to prevent cross contamination among the neighboring plots. Prior to puddling, the soil was submerged for at least 5 days. The treatments were 6 rates of nitrogen fertilizer, namely, 0, 5, 10, 15, 25 and 45 kg N/rai (6.25 rais = 1 ha) as ammonium sulfate. The nitrogen fertilizer was applied by equally splitting at puddling and at primordial initiation stage (PI) of the plants. Application of the N fertilizer at puddling of the soil was done by broadcasting in the entire plot followed by incorporating into the soil by hoeing. Application of the N fertilizer at PI was done by broadcasting on the soil surface of the entire plot after lowering water in the plot where possible. Basal application of P and K fertilizers were 20 kg available P_2O_5/rai as triple superphosphate and 20 kg K_2O/rai as KCl applied at puddling by the same method as that for the N fertilizer.

Except site no.'s 9 and 10, planting was done by transplanting 25 - 30 days old seedlings within three days after puddling. Plant spacing were 25 cm both between rows and between hills of 3 - 5 seedlings per hill. In the case of site no.'s 9 and 10, planting was done by sowing pre-germinated seeds at the rate of 15 kg/rai. The latter case was introduced in order that effects of planting method on the fertilizer requirement might be observed.

Measurements of N status of soils and N in plants

The soil samples used for the evaluation of N status were composite samples of subsamples from the 0-15 cm layer of each plot collected shortly before puddling and subsequently air dried and crushed to pass a 2-mm sieve.

The following ten chemical methods were used for evaluating N status of the soils: Method 1, measuring soil organic matter by Walkley and Black (1934)'s method; Method 2, measuring total soil N by Kjeldahl's method (Bremner, 1965a); Method 3, extracting soil N with acidified $K_2Cr_2O_7$ solution (Sahrawat, 1983); Method 4, extracting soil N with basified $KMnO_4$ solution (Sahrawat and Burford, 1982); Method 5, extracting soil N with acidified $KMnO_4$ solution (Standford and Smith, 1978); Method 6, extraction soil N with solution of $CaCl_2$ and K_2SO_4 (Fox and Pickielek, 1978); Method 7, extracting soil nitrate according to Keeney and Nelson (1982) and then measuring the extracted nitrate by Kjeldahl distillation; Method 8, extracting mineral N (ammonium + nitrate + nitrite) with 2*N* KCl followed by distillation with MgO and Devarda alloy according to Bremner (1965b); Method 9, measuring NH_4-N production under waterlogged conditions at 40^0C as described by Keeney (1982) in which the incubation was done for 7 days; and Method 10, same as Method 9 but the incubation was done for 14 days.

The amounts of N in paddy and stubble were measured with a semi-micro Kjeldahl method (Bremner, 1965a).

Calculation of relative values

Relative grain yields, relative dry matter and relative N yields were calculated by calculating maximum values for grain yields, dry matter and N yields from the obtained data using the following second degree polynomial regression model.

$$y = a + b_1x + b_2x^2,$$

where, x = independent variable, y = dependent variable, a = the intercept on the y-axis, and b_1 and b_2 = regression coefficients. The obtained data were then calculated as percentages of their corresponding maxima.

Calculation of relationships between the availability indices and the relative values from plants

Relationships among availability indices for N of different soils measured by the ten chemical methods and relative grain yields, relative dry matter and relative N yields were measured by regression coefficients calculated with double log curvilinear regression model as follows.

$$\text{Log } y = a + b \log x,$$

where, x = the obtained index value, y = the relative values from plants, a = the intercept on y-axis, and b = slope of the line.

Derivation of equations for calculating N-fertilizer rates for desired paddy yields

Relationships among relative paddy yields and the obtained values for different chemical indices for soil N and the amount of fertilizer N were expressed by the Mitscherlich-Bray model as follows (Tisdale and Nelson, 1975).

$$\text{Log } (A - y) = \log A - c_1b - cx,$$

where, A = the maximum grain yield (given as

100%), y = the desired grain yield, as percentage of the maximum yield, c_1 = the coefficient for the indigenous soil N, c = the coefficient for the amount of fertilizer N, and b = the obtained value of the availability index for indigenous soil N, and x = rate of fertilizer N.

The Mitscherlich-Bray equation for each selected method was derived by firstly calculating c_1 by substituting for b in the model with relative paddy yields obtained from the non-N-fertilized treatments of all of the experimental sites. The c was then calculated by substituting relative grain yields from all of the non-N-fertilized and N-fertilized treatments for b and the rates of N fertilizer for x in the model in the presence of the calculated c_1.

RESULTS AND DISCUSSION

Relationships among indices for availability of soils N and relative values from plants

Only the indices from Methods 9 and 10 gave significant relationships (at 95% confidence level) with the relative paddy yields, with Method 10 showing slight superiority over Method 9 (Figure 1). None of the chemical methods gave significant

Table 1 Locations of the experimental sites, the years in which the experiments were conducted, soil series and some properties of the soils.

Site no.	Location[1/]	Year	Soil series	% OM	pH	Texture
1	KRES	1994	c.n.	1.09	5.6	Clay loam
2	KRES	1994	c.n.	0.64	6.8	Sandy clay loam
3	KRES	1994	c.n.	0.94	6.7	Loam
4	KRES	1994	c.n.	0.63	5.0	Loam
5	PMRES	1994	Phimai	1.17	5.0	Clay loam
6	PMRES	1994	Phimai	1.45	4.6	Loam
7	SRRES	1994	Roi Et	0.68	4.0	Loam
8	SRRES	1994	Roi Et	0.63	4.1	Sandy loam
9	KSKU	1995	Kamphaeng Saen	2.66	6.7	Loam
10	KSKU	1995	Kamphaeng Saen	2.48	6.8	Clay loam
11	PMRES	1995	Phimai	1.19	5.6	Clay loam
12	PMRES	1995	Phimai	1.22	5.4	Clay
13	SRRES	1995	Roi Et	0.66	4.5	Sandy loam
14	KSKU	1996	Kamphaeng Saen	1.75	7.3	Clay loam
15	KSKU	1996	Kamphaeng Saen	2.27	7.5	Clay loam
16	KSKU	1996	Kamphaeng Saen	1.29	7.5	Loam
17	PTRRC	1996	Rangsit	3.06	4.9	Clay
18	FRF	1996	c.n.	1.17	4.8	Clay

1/ KRES = Koksamrong Rice Experimental Station, Koksamsong, Lopburi; PMRES = Phimai Rice Experimental Station, Phimai, Nakhon Ratchasima; SRRES = Surin Rice Experimental Station, Amphoe Muang, Surin; KSKU = Kamphaeng Saen Campus, Kasetsart University, Kamphaeng Saen, Nakhon Phathom; PTRRC = Pathum Thani Rice Research Center, Thanyaburi, Pathum Thani; FRF = Farmer's Rice field, Bansang, Prachinburi; c.n. = classification was not available.

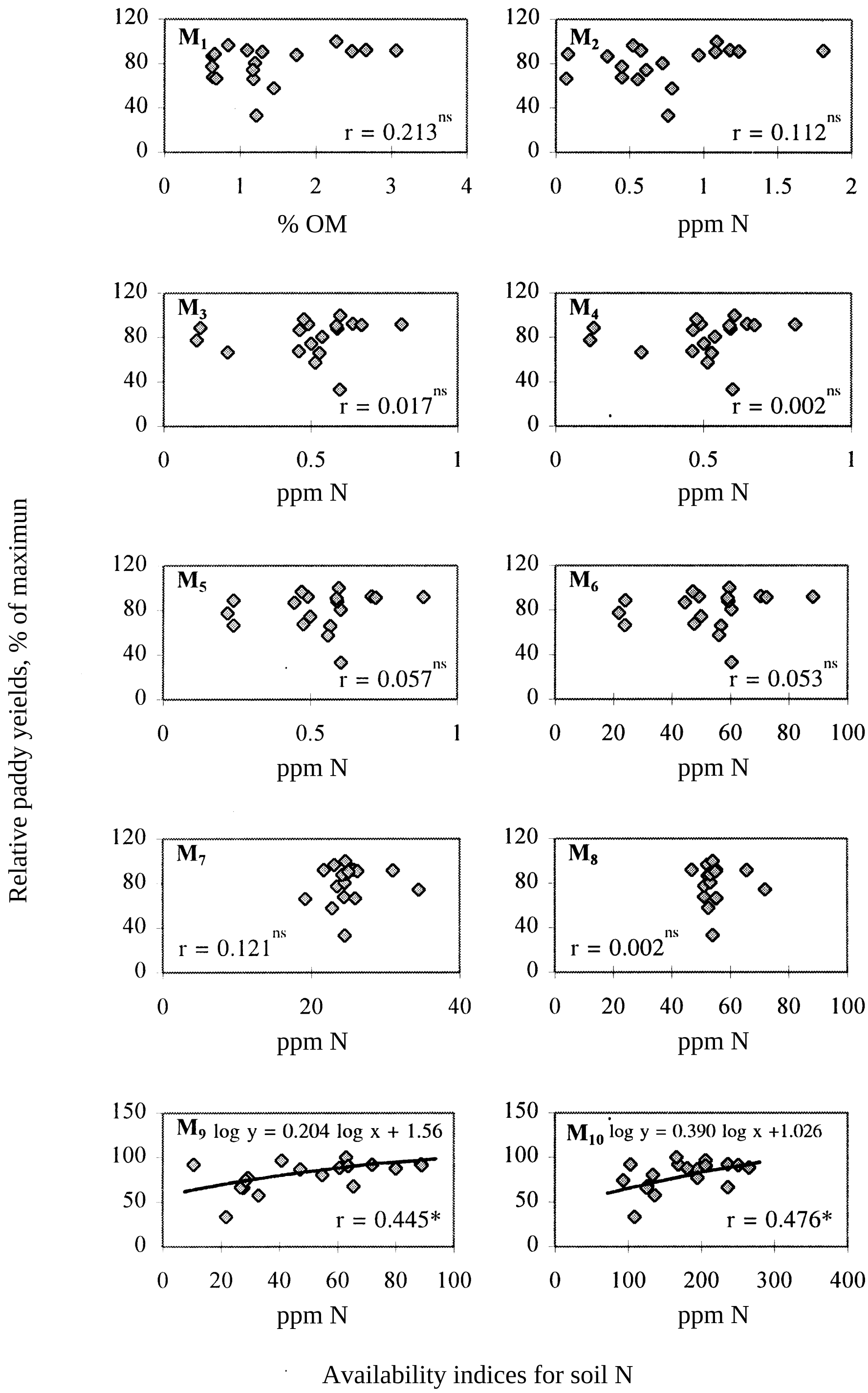

Figure 1 Relationships among the availability indices of nitrogen in soils by ten chemical methods and the relative paddy yields. M1-M10, Methods 1-10, respectively; r, regression coefficient; ns, non-significant at the 5% probability level; *, significant at the 5% probability level.

relationships among the index and the relative dry matter and amount of N in plants (Figures 2 and 3). Methods 9 and 10 were therefore selected to derive Mitscherlich-Bray equations for calculating rates of N fertilizer required for producing desired paddy yields from soil analytical data. It might be noteworthy that inclusion of data from the experimental sites no.'s 9 and 10 did not significantly affect relationship between soil analytical data and yields, suggesting that planting by sowing pre-germinated seeds gave responses to N supply that were similar to planting by transplanting.

The results of the present study on relationships among indices for soil N and the relative paddy yields, total dry matter and N uptake were not supported by the results of some other authors (Sharawat, 1980, 1982) which showed that other methods were superior to the incubation methods and the results of Kawaguchi and Kyuma (1969) which showed that soil organic matter contents, soil total-N contents and the amounts of NH_4-N released from soils by anaerobic incubation were not correlated with paddy yields. On the other hand, the results of the present study were supported by results of some other authors (e.g., Dolmat *et al.*, 1980) which showed that amounts of NH_4-N released from soils on anaerobic incubation were superior to other indices, including soil organic matter content and soil total-N content. However, results of all of the authors, except those of Kawaguchi and Kyuma (1969), showed that amounts of NH_4-N released from soils by anaerobic incubation were significantly correlated with paddy yields.

Equations for calculating N-fertilizer rates and their reliability

The Mitscherlich-Bray equations relating indices for the indigenous soil N and the rates of fertilizer N to paddy yields for the chemical Methods 9 and 10 are shown in Table 2. In derivation of the equations, only the cases in which the maximum paddy yields were produced and those in which the paddy yields were increased by the N fertilizer were accounted for, i.e. excluding the cases in which the N fertilizer depressed the paddy yields. This was because it was found that the equations so derived were superior to those derived from all of the cases, regarding relationship between the actual yields and the predicted yields.

Table 2 Equations relating expected relative paddy yields to the availability indices for soil N and the rates of fertilizer N required for different chemical methods.

Method no.	Equations[1/]
9	$\log(100 - y) = 2 - 0.0226b - 0.0374x$
10	$\log(100 - y) = 2 - 0.00533b - 0.0584x$

1/ y = the obtained grain yield (as % of maximum yield); b = availability index value for soil N, in ppm N; x = rates of fertilizer N required (Kg N/rai).

Reliability of the equations

The obtained index values for N status of the soils were used to calculate predicted relative paddy yields, using the obtained equations. The predicted paddy yields per rai were then calculated from the predicted relative paddy yields and the actual maximum yields per rai. The relationships between the actual grain yields and the predicted paddy yields are shown in Figures 4 and 5 for Methods 9 and 10, respectively. Both Methods 9 and 10 gave highly significant relationships between the actual and the predicted yields. They gave the predicted yields comparable to the actual yields at rather high levels of N supply, i.e. the levels that produced paddy yields of around 850 kg/rai. At lower levels of N supply, the predicted yields were higher than the actual yields, the lower levels of N

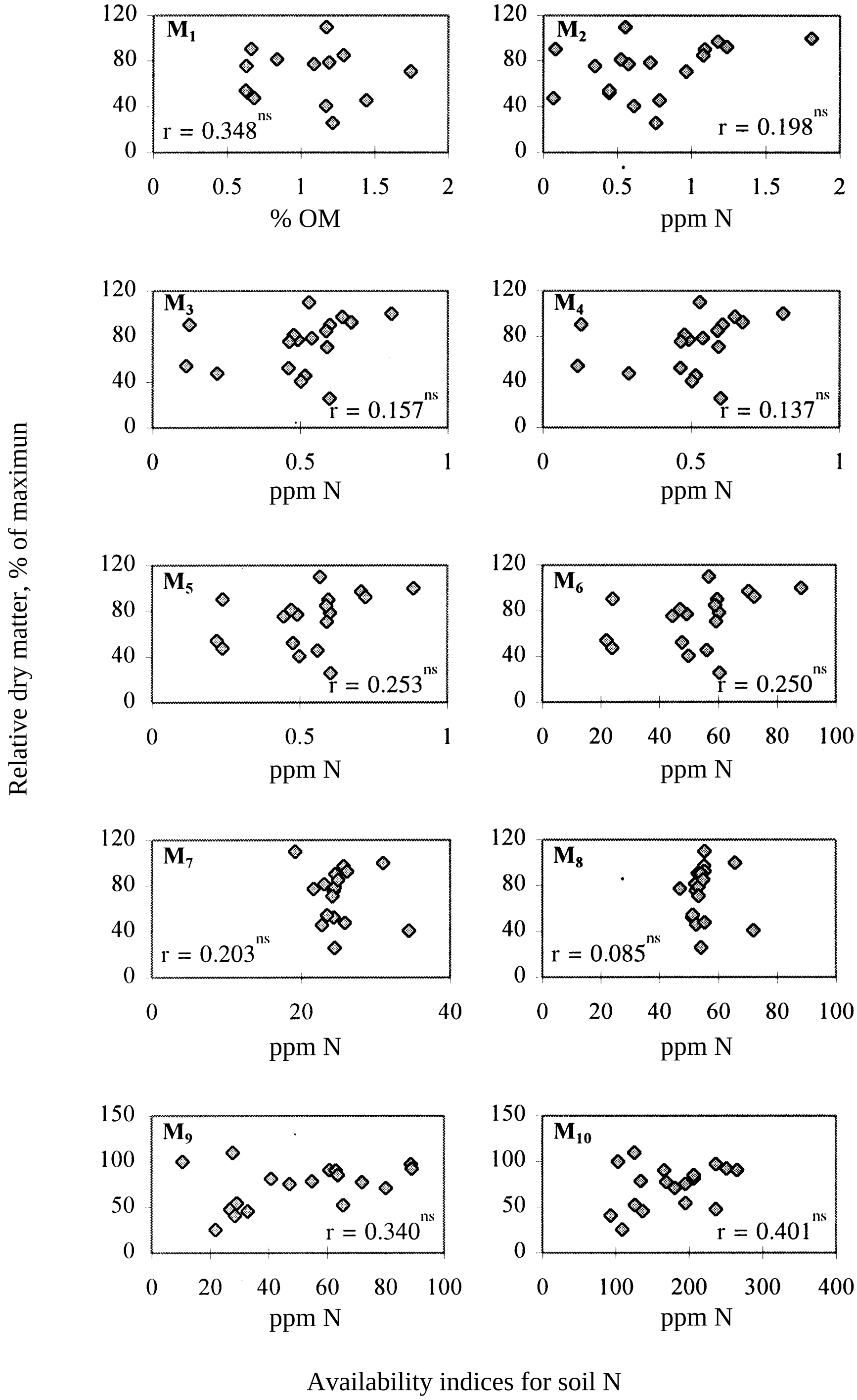

Figure 2 Relationships among the availability indices of nitrogen in soils by ten chemical methods and the relative dry matter of the above-ground parts of rice plants. Refer to Figure 1 for captions.

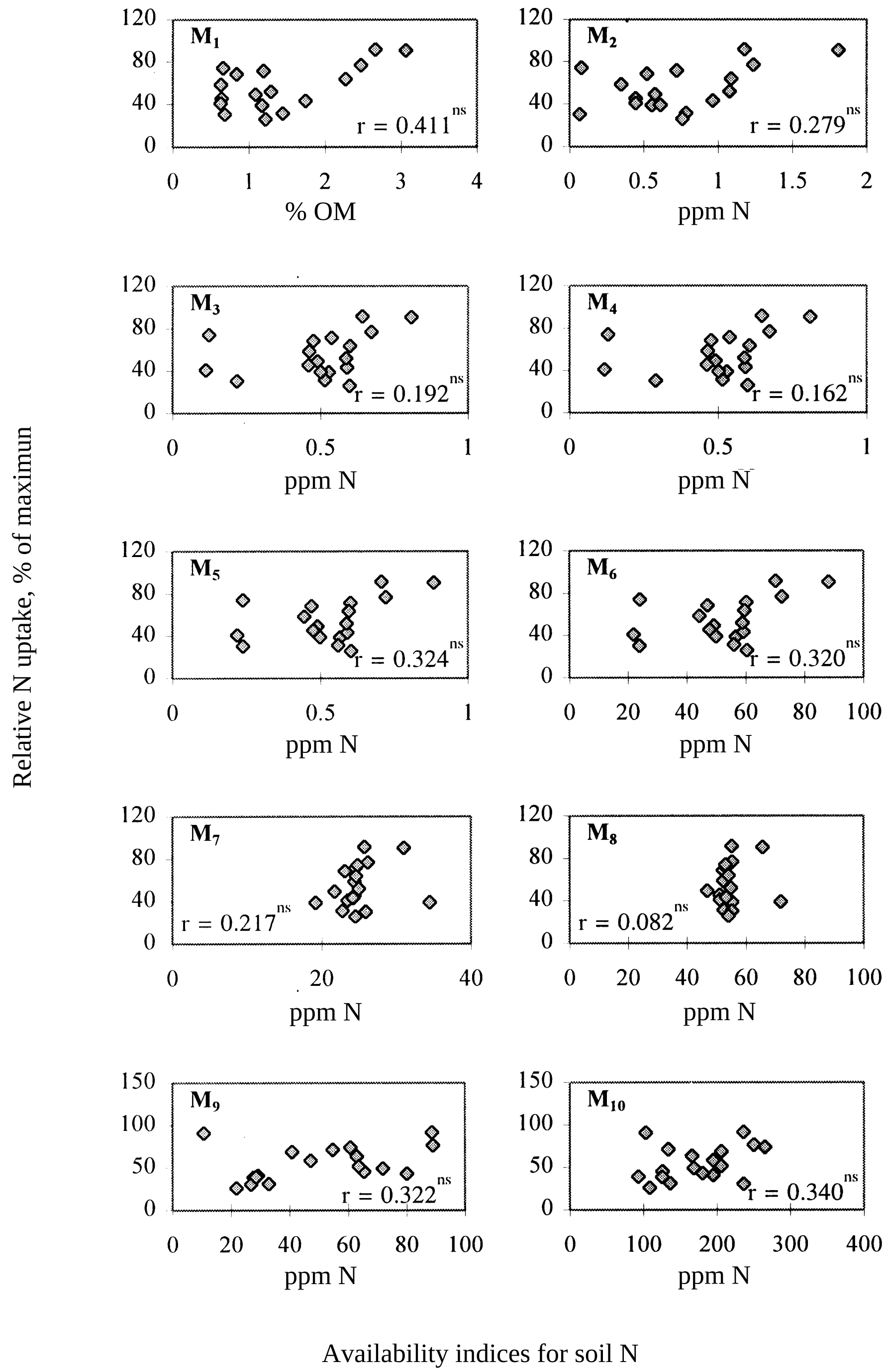

Figure 3 Relationships among the availability indices for nitrogen in soils by ten chemical methods and the relative N yields in the above-ground parts of rice. Refer to Figure 1 for captions.

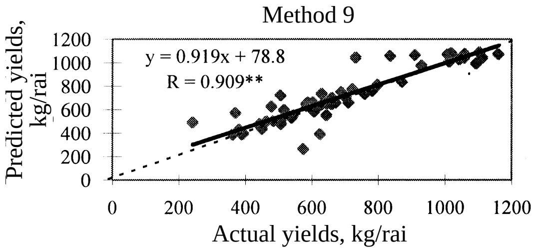

Figure 4 Correlation between the actual paddy yields and the yields predicted by the equation for Method 9 (n = 62). **, significant at the 1% probability level.

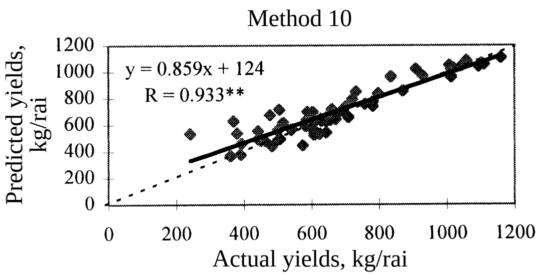

Figure 5 Correlation between the actual paddy yields and the yields predicted by the equation for Method 10 (n = 62). **, significant at the 1% probability level.

supply the larger the yield differences, but did not exceed 78.8 and 124.0 kg/rai for Methods 9 and 10, respectively. On the other hand, at higher levels of N supply, the predicted yields were lower than the actual yields; the higher levels of soil N, the lower the yield differences, hence the calculated yields were 18.4 and 45.2 kg/rai higher than the actual yields for Methods 9 and 10, respectively, when the actual yields were 1,200 kg/rai. Method 10 gave not only slightly higher correlation coefficient between the actual and the predicted yields than Method 9 but also much more regular scattering of the points than Method 9. This suggested that Method 10 was much more reliable than Method 9 in some cases. Method 10 was therefore recommended for assessment of N status of soils for Khaw Dauk Mali-105 rice.

CONCLUSIONS

1. Chemical methods that were highly reliable in evaluating N availability of soils were Methods 9 and 10.

2. The equation for calculating the amounts of N fertilizer required for desired relative paddy yields from the index values obtained with the Methods 10 was superior to that obtained with Method 9 in their predictability.

3. Method 10 was recommended for assessment of N status of soils for Khaw Dauk Mali-105 rice.

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