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 K₂Cr₂O₇ solution, (4) extracting soil N with basified KMnO₄ solution, (5) extracting soil N with acidified KMnO₄ solution, (6) extracting soil N with solution of CaCl₂ and K₂SO₄, (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 2N KCl followed by distillation of NH₃ with MgO and Devarda alloy, (9) measuring NH₄-N production from incubation of soils under waterlogged conditions for 7 days, and (10) measuring NH₄-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 P₂O₅/rai as triple superphosphate and 20 kg K₂O/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 K₂Cr₂O₇
solution (Sahrawat, 1983); Method 4, extracting
soil N with basified KMnO₄ solution (Sahrawat
and Burford, 1982); Method 5, extracting soil N
with acidified KMnO₄ solution (Standford and
Smith, 1978); Method 6, extracting soil N with
solution of CaCl₂ and K₂SO₄ (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 2N KCl followed by distillation with
MgO and Devarda alloy according to Bremner
(1965b); Method 9, measuring NH₄-N production
under waterlogged conditions at 40°C 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.

\[ y = a + b_1 x + b_2 x^2, \]

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.

\[ \log y = a + b \log x, \]

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).

\[ \log (A - y) = \log A - c_1 b - c x, \]

where, \( A \) = the maximum grain yield (given as
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.

<table>
<thead>
<tr>
<th>Site no.</th>
<th>Location(^1/)</th>
<th>Year</th>
<th>Soil series</th>
<th>% OM</th>
<th>pH</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>KRES</td>
<td>1994</td>
<td>c.n.</td>
<td>1.09</td>
<td>5.6</td>
<td>Clay loam</td>
</tr>
<tr>
<td>2</td>
<td>KRES</td>
<td>1994</td>
<td>c.n.</td>
<td>0.64</td>
<td>6.8</td>
<td>Sandy clay loam</td>
</tr>
<tr>
<td>3</td>
<td>KRES</td>
<td>1994</td>
<td>c.n.</td>
<td>0.94</td>
<td>6.7</td>
<td>Loam</td>
</tr>
<tr>
<td>4</td>
<td>KRES</td>
<td>1994</td>
<td>c.n.</td>
<td>0.63</td>
<td>5.0</td>
<td>Loam</td>
</tr>
<tr>
<td>5</td>
<td>PMRES</td>
<td>1994</td>
<td>Phimai</td>
<td>1.17</td>
<td>5.0</td>
<td>Clay loam</td>
</tr>
<tr>
<td>6</td>
<td>PMRES</td>
<td>1994</td>
<td>Phimai</td>
<td>1.45</td>
<td>4.6</td>
<td>Loam</td>
</tr>
<tr>
<td>7</td>
<td>SRRES</td>
<td>1994</td>
<td>Roi Et</td>
<td>0.68</td>
<td>4.0</td>
<td>Loam</td>
</tr>
<tr>
<td>8</td>
<td>SRRES</td>
<td>1994</td>
<td>Roi Et</td>
<td>0.63</td>
<td>4.1</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>9</td>
<td>KSKU</td>
<td>1995</td>
<td>Kamphaeng Saen</td>
<td>2.66</td>
<td>6.7</td>
<td>Loam</td>
</tr>
<tr>
<td>10</td>
<td>KSKU</td>
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<td>Kamphaeng Saen</td>
<td>2.48</td>
<td>6.8</td>
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</tr>
<tr>
<td>11</td>
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<td>1995</td>
<td>Phimai</td>
<td>1.19</td>
<td>5.6</td>
<td>Clay loam</td>
</tr>
<tr>
<td>12</td>
<td>PMRES</td>
<td>1995</td>
<td>Phimai</td>
<td>1.22</td>
<td>5.4</td>
<td>Clay</td>
</tr>
<tr>
<td>13</td>
<td>SRRES</td>
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<td>Roi Et</td>
<td>0.66</td>
<td>4.5</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>14</td>
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<td>16</td>
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<tr>
<td>17</td>
<td>PTRRC</td>
<td>1996</td>
<td>Rangsit</td>
<td>3.06</td>
<td>4.9</td>
<td>Clay</td>
</tr>
<tr>
<td>18</td>
<td>FRF</td>
<td>1996</td>
<td>c.n.</td>
<td>1.17</td>
<td>4.8</td>
<td>Clay</td>
</tr>
</tbody>
</table>

\(^1/\) 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
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>9</td>
<td>$\log (100 - y) = 2 - 0.0226b - 0.0374x$</td>
</tr>
<tr>
<td>10</td>
<td>$\log (100 - y) = 2 - 0.00533b - 0.0584x$</td>
</tr>
</tbody>
</table>

$y =$ 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.
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.

ACKNOWLEDGEMENT

The authors express their sincere thanks to the Kasetsart University Research and Development Institute for financial support to this work.

LITERATURE CITED


Received date : 10/05/98
Accepted date : 4/11/98