Critical limits of nitrogen for rice in soils of Imphal West district, Manipur, India

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Abstract
The critical limit of nitrogen in soil and plant (CAU R 1) was determined through a pot culture experiment with twenty five soils of Imphal West district of Manipur, India for predicting the response of rice to nitrogen application. All the soil samples were clayey in texture and acidic in reaction with the mean pH value of 5.16, electrical conductivity ranged from 0.06 to 0.14 dSm⁻¹ with an average of 0.1 dSm⁻¹, organic carbon content from 1.06 to 2.62 % with mean value of 2.03%, cation exchange capacity of the soils from 12.20 to 20.20 meq/100g with mean value of 16.06 meq/100g. Available nitrogen content in soils varied from 185.00 to 331.06 kg N/ha with an average value of 267.24 kg N/ha. Available nitrogen in the soils was positively and significantly correlated with plant N content (r=0.653**), dry matter yield (r=0.556**), plant N uptake (r=0.726**) in control pots. There was also a positive and significant correlation between available N and bray’s per cent yield (r = 0.519**). The critical limit of available N was established at 257 kg N/ha for soil and 1.04 % for 45 days old rice plants. Soil containing N below this critical limit may respond economically to N fertilization for growing rice.

Keywords: Critical limit, nitrogen, soil, rice, bray’s per cent yield

Introduction
For optimum growth and production of rice, nutrients must be available in sufficient and balanced quantities. In general, fertilizers containing nitrogen (N), phosphorus (P), and potassium (K) as the key essential plant macronutrients are vital for productive crops (Mantovani et al., 2017) [1]. Among the essential plant nutrients, Nitrogen (N) is the most important nutrient for rice growth and metabolic processes thereby considered as one of the core factor for developing higher rice yield. However, N is the main limiting plant nutrient in the production of lowland rice (Buresh et al., 2008) [2]. N fertilizer, being the maximum consumer by rice constituted one third of the total N consumption of the world (Pandian and Perumal, 2002) [10]. The initial symptom of nitrogen deficiency in rice is a general light green to yellow colour of the plant. It is first expressed in the older leaves because nitrogen is translocated within the plant from the older leaves to the younger ones. Prolonged nitrogen deficiency causes stunted growth, reduced tillering and yield reduction. Leaves die under severe N stress (Doberman and Fairhurst, 2000) [4]. In order to have a higher efficiency of applied N, it is important to know the critical limit of N in the soil. The critical limit is therefore the soil nutrient concentration partitioning crop response into two classes: low and high. The soil nutrient concentration corresponding to the critical level was estimated from the crop response to its application. The critical limits/ levels are quite often employed for a wide variety of soils and crops, even though these critical limits may be different not only for soils, crop species but also for different varieties of a given crop.

In view the above points, the present study was taken up to determine the critical limits of nitrogen in soils and rice crop.

Material and Methods
A total of 25 bulk soil samples (0-20cm) were collected from different paddy fields of Imphal West district of Manipur, India under simple random sampling method. The soil samples were air dried in shade, ground and passed through 2 mm sieve. These samples were analysed for soil texture by hydrometer method, soil reaction (pH), electrical conductivity (EC), organic
carbon by Walkley and Black’s rapid titration method, cation exchange capacity (CEC) by leaching the soil with 1N \( \text{NH}_4\text{OAc} \) (pH 7.0) and available N by alkaline potassium permanganate method using standard procedure as described by Jackson (1973) [6].

A pot experiment was conducted during kharif season of 2017 at the net house of college of agriculture, CAU, Imphal to evaluate the critical concentration of nitrogen in soils and rice crop. Five kg of air dried soils per pot was taken in a series of pots. Different levels of N (40, 60 and 80 kg/ha) through urea were applied according to different set of treatments. Normal water management practices for lowland rice were followed. The plants from each pot were harvested at 45 days after transplanting and washed in a hot air oven for 24 hours. Dry matter yield was recorded and ground in the stainless steel blender. The dry powdered plant samples were then determined by modified macro cation exchange capacity (CEC) by leaching the soil with 1N \( \text{NH}_4\text{OAc} \) (pH 7.0) and available N by alkaline potassium permanganate method using standard procedure as described by Jackson (1973) [6].

The critical limit of N in soil and rice plant were determined by plotting the Bray’s per cent yield against the soil available N and N content in plant separately, following the graphical method of Cate and Nelson (1965) [7]. Bray’s per cent yield was calculated using the following formula:

\[
\text{Bray’s yield of rice plant} = \frac{\text{Yield without N}}{\text{Maximum yield in the treated pots}} \times 100
\]

**Result and Discussion**

**Physico- chemical properties of soils**

The studied soil samples were clayey in texture (Table 1a) and acidic in nature with the mean pH value of 5.16 (Table 1b). The acidity may be due to higher organic matter content (Nayak et al., 1996) [9]. The electrical conductivity (EC) of the soils varied from 0.06 to 0.14 dSm\(^{-1}\) with the mean value of 0.1 dSm\(^{-1}\) at 25 °C. The EC values of the studied samples were low (<1 dSm\(^{-1}\)) which might be due to leaching loss of soluble salts from soils under high rainfall conditions (Brady and Weil, 2002) [1]. On the basis of the limit suggested by Muhr et al. (1965) [8] for judging salt problem, all the soil samples were found neutral (EC < 1.0 dSm\(^{-1}\)). The organic carbon content was ranged from 1.06 to 2.62 per cent with the mean value of 2.03 per cent. Higher organic carbon content in the soils might be due to mixing of organic matter during cultivation as organic residues (Thangasamy et al., 2005) [12]. Sarkar et al. (2002) [11] also reported higher organic carbon content in top layer soils of Manipur. The cation exchange capacity (CEC) varied from 12.20 to 20.20 meq/100 g with the mean value of 16.06 meq/100 g. All the soil samples studied fall under medium range (10-25 meq100 g\(^{-1}\)). It might be due to close positive association between clay content and CEC (Ghosh et al., 2005) [3]. On the other hand, may perhaps be due to organic carbon in the surface layer. Available nitrogen content in soils varied from 185.00 to 331.06 kg N/ha with an average value of 267.24 kg N/ha.

**Table 1(a): Particle size distribution of the studied soil samples**

| Soil sample no. | Name of the villages          | Sand (%) | Silt (%) | Clay (%) | Soil texture |
|-----------------|-------------------------------|----------|----------|----------|-------------|
| 1               | Potsangbam Awang Khulliel     | 36.00    | 22.70    | 41.30    | Clay        |
| 2               | Leimakhol                     | 9.29     | 33.50    | 57.21    | Clay        |
| 3               | Khurkhol                      | 17.33    | 37.00    | 45.67    | Clay        |
| 4               | Ngairangbam                   | 19.50    | 17.70    | 62.80    | Clay        |
| 5               | Heibongpokpi                  | 25.20    | 30.40    | 44.40    | Clay        |
| 6               | Kiyma                         | 13.70    | 28.50    | 57.80    | Clay        |
| 7               | Sagotongba                    | 8.69     | 26.90    | 64.41    | Clay        |
| 8               | Moidangpok                    | 3.70     | 32.80    | 63.50    | Clay        |
| 9               | Melrim                        | 19.70    | 25.90    | 54.40    | Clay        |
| 10              | Iron Meijrao                  | 16.20    | 31.00    | 52.80    | Clay        |
| 11              | Uchiwa                        | 11.12    | 31.10    | 57.78    | Clay        |
| 12              | Lamdeng Makha Leikai          | 17.93    | 26.00    | 56.07    | Clay        |
| 13              | Salam Keikhu                  | 5.50     | 31.70    | 62.80    | Clay        |
| 14              | Sangaithe Thuizang            | 28.80    | 19.20    | 52.80    | Clay        |
| 15              | Kadangband Part I             | 27.70    | 26.70    | 46.50    | Clay        |
| 16              | Koutruk                       | 16.20    | 26.90    | 56.90    | Clay        |
| 17              | Senjam Chirang                | 13.60    | 26.30    | 60.10    | Clay        |
| 18              | Loitang Sandhum               | 22.80    | 23.80    | 53.40    | Clay        |
| 19              | Tendongyan                   | 25.50    | 27.70    | 46.80    | Clay        |
| 20              | Kanglatombi Awang Leikai      | 24.54    | 28.78    | 46.68    | Clay        |
| 21              | Mana Inginhol                 | 22.70    | 32.90    | 44.40    | Clay        |
| 22              | Kameng                        | 7.94     | 25.66    | 66.40    | Clay        |
| 23              | Yarou Bamdiar                 | 8.13     | 29.20    | 62.67    | Clay        |
| 24              | Kodompokpi Maming Leikai      | 28.32    | 31.60    | 40.08    | Clay        |
| 25              | Heikrujam                     | 2.36     | 34.20    | 63.44    | Clay        |

Mean 17.27 28.33 54.41
Effect of nitrogen application on dry matter yield, N content and uptake

Application of different levels of nitrogen greatly influenced the dry matter yield of rice (Table 2). The dry matter yield in the control varied from 9.16 to 14.74 g/pot as compared to 10.86 to 15.17 g/pot, 11.50 to 15.73 g/pot and 11.86 to 16.10 g/pot, respectively in soil applied with 30, 60 and 80 kg N/ha. Dry matter yield of rice increased over control with increase in rates of nitrogen application. Higher dry matter was observed in soils treated with 60 kg N/ha with the mean value of 13.78 g/pot. It showed that the dry matter yield was mainly dependent on mineral –N status and therefore, rice crop produced a good amount of dry yield. The N concentration in rice in control pot ranged from 0.84 to 1.24 percent with an average of 1.05 percent. Comparatively higher N uptake by rice was recorded in soils treated with 60 kg N/ha (mean 184.85 mg/pot) over control (118.03 mg/pot). Bray’s percent yield varied from 65.63-97.80 percent with a mean value of 63.74 percent.

### Table 1(b): Different chemical properties of the studied soil samples

| Soil sample no. | Name of the villages | pH | EC (dS/m) | OC (%) | CEC (meq/100 g) |
|-----------------|-----------------------|----|-----------|--------|-----------------|
| 1               | Potsangbam Awang Khullel | 5.81 | 0.11 | 1.06 | 13.89 |
| 2               | Leimakhong | 4.78 | 0.12 | 2.21 | 15.00 |
| 3               | Khurkhol | 4.83 | 0.10 | 2.38 | 20.20 |
| 4               | Ngierangbam | 4.71 | 0.14 | 2.34 | 17.00 |
| 5               | Heibongpokpi | 4.30 | 0.13 | 2.24 | 18.63 |
| 6               | Kiyam | 4.07 | 0.10 | 2.46 | 12.20 |
| 7               | Sagoltsongba | 5.90 | 0.11 | 2.39 | 15.00 |
| 8               | Moidangpok | 5.73 | 0.12 | 2.26 | 16.80 |
| 9               | Meitram | 5.25 | 0.06 | 2.17 | 15.09 |
| 10              | Irom Meijrao | 5.27 | 0.10 | 2.62 | 20.05 |
| 11              | Uchiwa | 5.83 | 0.09 | 2.24 | 17.12 |
| 12              | Lamdeng Makha Leikai | 6.00 | 0.09 | 2.12 | 17.20 |
| 13              | Salam Keikhu | 5.93 | 0.09 | 2.07 | 15.50 |
| 14              | Sanghaiel Thuizang | 4.30 | 0.08 | 1.80 | 18.07 |
| 15              | Katangband Part I | 5.36 | 0.08 | 1.68 | 14.40 |
| 16              | Koutruk | 5.97 | 0.13 | 1.14 | 14.20 |
| 17              | Senjam Chirang | 5.17 | 0.07 | 1.26 | 15.80 |
| 18              | Loitang Sandhum | 4.93 | 0.08 | 2.31 | 15.20 |
| 19              | Tendongyan | 4.67 | 0.13 | 1.94 | 13.20 |
| 20              | Kanglatombi Awang Leikai | 5.01 | 0.07 | 2.31 | 15.30 |
| 21              | Mana Ingkhok | 5.01 | 0.08 | 1.85 | 15.20 |
| 22              | Kameng | 5.11 | 0.10 | 2.31 | 19.80 |
| 23              | Yarou Bamd iar | 4.74 | 0.08 | 2.12 | 15.20 |
| 24              | Kodompokpi Maning Leikai | 5.87 | 0.12 | 1.72 | 14.40 |
| 25              | Heikrujam | 4.48 | 0.12 | 2.03 | 19.00 |
| **Mean**       |                      | 5.16 | 0.10 | 2.03 | 16.06 |

### Table 2: Effect of Nitrogen application on dry matter yield and N concentration and its uptake in no Nitrogen pots

| Soil sample no. | Name of the villages | Available N (kg/ha) | Dry matter yield (g pot⁻¹) | N conc. in no N pots (%) | N uptake in no N pots (mg/pot) | Bray’s % yield |
|-----------------|-----------------------|-------------------|-----------------------------|---------------------|-----------------------------|----------------|
| 1               | Potsangbam Awang Khullel | 255.79             | 10.09                       | 12.16              | 13.26                       | 12.08           |
| 2               | Leimakhong | 268.34             | 12.13                       | 13.12              | 13.63                       | 13.71           |
| 3               | Khurkhol | 293.42             | 10.42                       | 12.56              | 14.22                       | 14.18           |
| 4               | Ngierangbam | 318.51             | 10.62                       | 13.08              | 13.68                       | 13.71           |
| 5               | Heibongpokpi | 230.70             | 11.16                       | 12.31              | 13.56                       | 13.85           |
| 6               | Kiyam | 293.42             | 10.46                       | 12.94              | 13.36                       | 13.26           |
| 7               | Sagoltsongba | 243.25             | 12.56                       | 13.41              | 14.68                       | 15.23           |
| 8               | Moidangpok | 230.70             | 10.70                       | 11.83              | 13.68                       | 12.72           |
| 9               | Meitram | 243.25             | 10.24                       | 12.12              | 12.71                       | 13.04           |
| 10              | Irom Meijrao | 331.06             | 14.74                       | 15.17              | 15.73                       | 16.10           |
| 11              | Uchiwa | 243.25             | 11.25                       | 12.52              | 12.84                       | 12.36           |
| 12              | Lamdeng Makha Leikai | 243.25             | 10.28                       | 11.88              | 13.83                       | 13.74           |
| 13              | Salam Keikhu | 268.34             | 10.32                       | 12.08              | 15.50                       | 15.56           |
| 14              | Sanghaiel Thuizang | 305.97             | 11.32                       | 12.19              | 13.26                       | 13.24           |
| 15              | Katangband Part I | 243.25             | 10.24                       | 11.83              | 14.52                       | 13.46           |
| 16              | Koutruk | 198.82             | 9.16                        | 10.86              | 12.52                       | 12.92           |
| 17              | Senjam Chirang | 268.34             | 9.87                        | 11.03              | 11.30                       | 11.86           |
| 18              | Loitang Sandhum | 268.34             | 10.32                       | 11.67              | 12.96                       | 12.68           |
| 19              | Tendongyan | 255.79             | 10.23                       | 12.21              | 13.72                       | 13.68           |
| 20              | Kanglatombi Awang Leikai | 255.79             | 12.18                       | 13.04              | 14.16                       | 14.05           |
| 21              | Mana Ingkhok | 305.97             | 10.32                       | 11.94              | 13.26                       | 13.23           |
| 22              | Kameng | 318.51             | 13.24                       | 14.18              | 15.26                       | 14.98           |
| 23              | Yarou Bamd iar | 293.42             | 12.48                       | 12.73              | 13.15                       | 13.18           |

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Relationship of available N with dry matter yield, N content and its uptake by rice plant

Simple correlation study indicated that available N was positively and significantly correlated with plant N content (r=0.653**), dry matter yield (r=0.556**), plant uptake (r=0.726**) in control pots (Table 3). There was also a positive and significant correlation between available N and Bray’s per cent yield (r = 0.519**).

Table 3: Relationship of available nitrogen with dry matter yield, plant nitrogen concentration and its uptake in no nitrogen pots and Bray’s yield

| Parameters       | Plant nitrogen concentration | dry matter yield | Plant nitrogen uptake | Bray’s yield |
|------------------|------------------------------|------------------|-----------------------|--------------|
| Soil nitrogen    | 0.653**                      | 0.556**          | 0.726**               | 0.519**      |

**Correlation is significant at the 1% level
*Correlation is significant at the 5% level

Critical limits of Nitrogen in soil and Rice plant

Using graphical procedure of Cate and Nelson (1965) [3], the plot of Bray’s per cent yield against soil available N and rice revealed that the critical limit of Nitrogen was found to be 257 kg N/ha in soil (Fig. 1) below which economic response to nitrogen application can be expected. Similarly, a plant critical limit of 1.04% (Fig. 2) was established to separate deficient plants from those having sufficient Nitrogen.

Conclusion

The results indicate that the critical limit values of available N in soils of Imphal West district, Manipur was 257 kg N/ha. The soils will likely respond to Nitrogen application effectively when it contains less than 257 kg N/ha. On the basis of the response of rice to Nitrogen, a critical level of 1.04 % N was obtained in rice plant at active tillering stage (45 days after transplanting).
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