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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) [7]. 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 NH_4OAc (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. Recommended dose of phosphorus and potassium @ 40 and 30 kg/ha were given as basal through SSP and MOP. Twenty five old seedling of rice *var*. CAU R-1 was transplanted in each pot. Each treatment was replicated thrice in completely randomized design. Normal water management practices for lowland rice were followed. The plants from each pot were harvested at 45 days after transplanting and washed in acidified solution, rinsed with deionized water, dried at 65 ^{0}C 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-Kjeldahl method (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) [3]. 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 ^{0}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/100g. 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) [5]. 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	Soil separates			Soil texture
		Sand (%)	Silt (%)	Clay (%)	
1	Potsangbam Awang Khullel	36.00	22.70	41.30	Clay
2	Leimakhong	9.29	33.50	57.21	Clay
3	Khurkhul	17.33	37.00	45.67	Clay
4	Ngeirangbam	19.50	17.70	62.80	Clay
5	Heibongpokpi	25.20	30.40	44.40	Clay
6	Kiyam	13.70	28.50	57.80	Clay
7	Sagoltongba	8.69	26.90	64.41	Clay
8	Moidangpok	3.70	32.80	63.50	Clay
9	Meitram	19.70	25.90	54.40	Clay
10	Irom 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	Sangaithel Thuizang	28.00	19.20	52.80	Clay
15	Kadangband Part 1	27.70	26.70	45.60	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 Ingkhol	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 Maning Leikai	28.32	31.60	40.08	Clay
25	Heikrujam	2.36	34.20	63.44	Clay
Mean		17.27	28.33	54.41	

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

Soil sample no.	Name of the villages	pH	EC (dSm^{-1})	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	Khurkhul	4.83	0.10	2.38	20.20
4	Ngeirangbam	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	Sagoltongba	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	1.87	13.50
14	Sangaithel Thuizang	4.30	0.08	1.80	18.07
15	Kadangband Part 1	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 Ingkhol	5.01	0.08	1.85	15.20
22	Kameng	5.11	0.10	2.31	19.80
23	Yarou Bamdiar	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

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 with 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 per cent with an average of 1.05 per cent. 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 per cent yield varied from 65.63-97.80 per cent with a mean value of 63.74 per cent.

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 levels (kg /ha) 0	30	60	80	Mean	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	12.83	13.26	12.08	1.12	112.98	78.63
2	Leimakhong	268.34	12.13	13.12	13.63	13.71	13.15	1.03	124.93	88.99
3	Khurkhul	293.42	10.42	12.56	14.22	14.18	12.85	1.20	125.04	73.28
4	Ngeirangbam	318.51	10.62	13.08	13.68	13.71	12.77	1.08	114.70	77.63
5	Heibongpokpi	230.70	11.16	12.31	13.56	13.85	12.72	0.92	102.64	82.27
6	Kiyam	293.42	10.46	12.94	13.36	13.26	12.51	1.05	109.83	78.29
7	Sagoltongba	243.25	12.56	14.31	14.68	15.23	14.20	1.01	126.82	85.52
8	Moidangpok	230.70	11.07	11.83	13.68	12.72	12.32	1.00	110.66	80.90
9	Meitram	243.25	10.24	12.12	12.71	13.04	12.03	1.16	118.78	80.57
10	Irom Meijrao	331.06	14.74	15.17	15.73	16.10	15.43	1.18	173.89	93.69
11	Uchiwa	243.25	11.25	12.52	12.84	12.82	12.36	0.92	103.51	87.63
12	Lamdeng Makha Leikai	243.25	10.28	11.88	13.83	13.74	12.43	1.02	104.86	74.33
13	Salam Keikhu	268.34	10.32	12.08	15.50	15.56	13.36	1.03	106.30	66.59
14	Sangaithel Thuizang	305.97	11.52	12.19	13.26	12.54	12.38	1.24	142.86	86.88
15	Kadangband Part 1	243.25	10.24	11.83	14.52	13.46	12.51	1.20	122.88	70.52
16	Koutruk	198.82	9.16	10.86	12.52	12.92	11.36	0.84	76.94	73.16
17	Senjam Chirang	268.34	9.87	11.19	11.50	11.86	11.10	1.01	99.64	85.79
18	Loitang Sandhum	268.34	10.32	11.67	12.96	12.68	11.91	1.06	109.39	79.63
19	Tendongyan	255.79	10.23	12.21	13.72	13.68	12.46	1.08	110.48	74.56
20	Kanglatombi Awang Leikai	255.79	12.18	13.04	14.16	14.05	13.36	0.94	114.48	85.99
21	Mana Ingkhol	305.97	10.32	11.94	13.26	13.23	12.19	1.00	103.20	77.83
22	Kameng	318.51	13.24	14.18	15.26	14.98	14.42	1.07	141.70	86.78
23	Yarou Bamdiar	293.42	12.48	12.73	13.15	13.18	12.89	1.05	131.04	94.90

24	Kodompokpi Maning Leikai	185.00	10.12	11.78	15.42	15.46	13.20	0.86	87.03	65.63
25	Heikrujam	318.51	14.20	14.36	14.52	14.98	14.52	1.24	176.08	97.80
Mean		267.24	11.17	12.56	13.78	13.77		1.05	118.03	63.74

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.

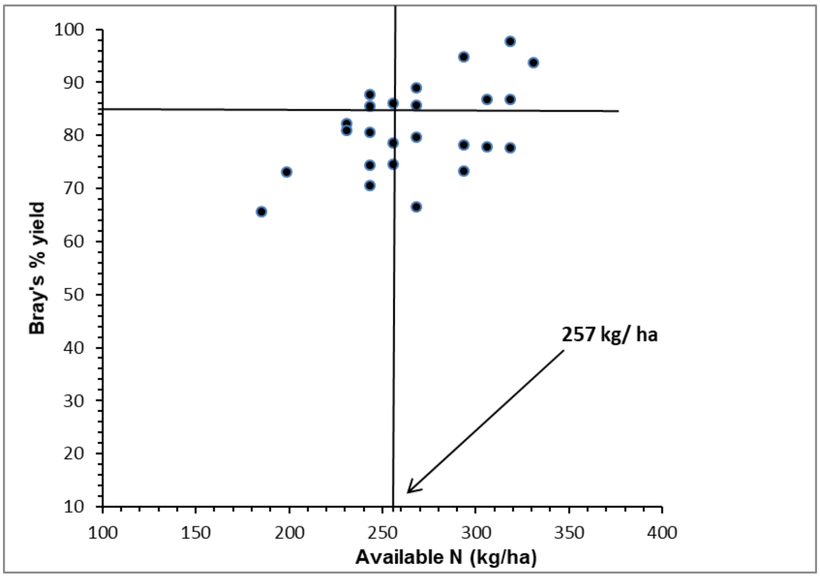

Fig 1: Critical limit of nitrogen in soil

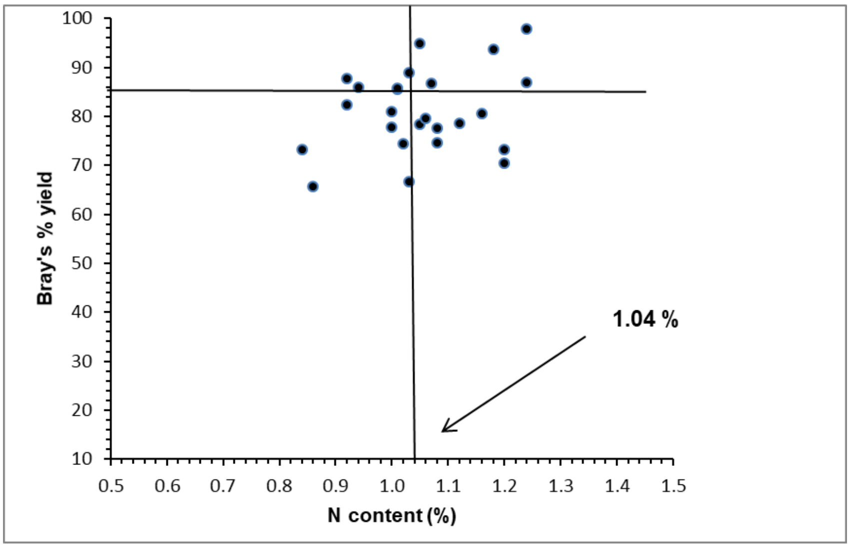

Fig 2: Critical limit of nitrogen in rice plant

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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