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Ammonium fixation and release studies in major rice growing soil series of Karaikal region (U.T. of Puducherry)

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Abstract
To assess the ammonium fixation and release pattern in major rice growing soils of Karaikal region a study was conducted in laboratory of Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal. The soils of major rice growing soil series namely Thirunallar, Karaikal and Pattinam were taken for the study. The different series were examined after adding with different NH_4^+ rates viz. 0, 5, 10, 15, 20 and 25 ppm. The result revealed that irrespective of soil series, the ammonium fixation increased with increase in N levels. However, the per cent ammonium fixed was found to increase with increase in N levels in Karaikal and Pattinam soil series while decrease was conceded in Thirunallar soil series. Based on the scope of NH_4^+ fixation, the soil series could be arranged in the order:
Karaikal soil series > Thirunallar soil series > Pattinam soil series.
The cumulative release of NH_4^+ fits well into the Cobb-Douglass equation of the form $\hat{Y} = aX^b$. While comparing the soil series, instant release of NH_4^+ would be greater in Thirunallar soil series and followed by Karaikal and Pattinam soil series, respectively.

Keywords: Ammonium fixation, ammonium release pattern, soil series

Introduction

The slogan "Rice is Life" is most appropriate for India; as this crop plays a vital role in our country's food security and is a mean of livelihood for millions of rural households (Ajaykumar *et al.*, 2016) [1]. The rice production largely depends upon the resource availability, varietal potential and nutrient management technologies. The nutrient management is one of the most important input in agriculture. Among all plant nutrients N deserves the highest attention as the too low rates may depress the profit, too high rates may result in N losses (Mengel *et al*. 2006) [9]. According to Peltonen-Sainio and Peltonen (1994) [14] under favourable conditions N application alone in spring may be sufficient to promote plant growth, but may result in insufficient N availability during grain filling. For this reason the splitting of the nitrogen application rate is recommended for an efficient use of fertilizer-N (López-Bellido *et al*. 2012) [7]. Ammonium fixation and release can play a crucial role for the efficiency of fertilizer N (Steffens and Sparks 1999; Juang *et al*. 2001) [19, 3], as it impacts the indigenous soil N supply towards crop N uptake. Some soils are able to bind ammonium (NH_4^+) and potassium (K^+) in such a manner that these cannot be easily replaced by other cations. McBeth (1917) [8] defined the unrecovered portion of the added NH_4^+ as "fixed NH_4^+". The fixation of NH_4^+ is defined as "the adsorption or absorption of ammonium ions by the mineral or organic fraction of the soil in a manner that they are relatively unexchangeable by the usual methods of cation exchange" (Osborne 1976; SSSA 1984) [13, 18]. In soils with high NH_4^+ fixation capacity, a part of the NH_4^+ supplied through NH_4^+-forming or NH_4^+-containing fertilizers may be bounded in clay mineral interlayers. Increasing NH_4^+ fixation can be a way in building up an available N pool in soils to optimize crop recovery and minimize N losses into the environment (Liu *et al*., 2008) [6].

The farming sector are planning to perform their fertilizer recommendations based on the soil test values; but on prescribing the soil test values, there was less concern about the fixation and release pattern studies. The release and supplying power of the soil that are used synonymously is the key thing to have an idea about capacities of soil to supply nutrients to the plants all along its growth. Therefore, fixation properties, residual value of nutrients and their release patterns should be evaluated for fertilizer recommendation to have positive and practical impact on the crop grown.

Material and Methods

Selection of sites

The Karaikal region is situated in the east coast belt at the tail end of the river Cauvery. The soils of Karaikal region are alluvial deposits of river Cauvery and Coastal sand deposits. There are six soil series identified and mapped in Karaikal region (NBSS and LUP, 2008) [10]. Among them, Thirunallar, Karaikal and Pattinam series covers larger extent and are considered as a major rice growing soil series of Karaikal. The locations were identified as per the NBSS and LUP soil series map and soil samples were collected for the respective series, shade dried, and ground to pass through 2 mm sieve and used for lab analysis for their initial soil characterization (Table.1).

Ammonium fixing capacity

The method described by Verma and Verma (1970) [20] was followed to identify the ammonium fixing capacity of rice soil series. Soil sample weighing 5g was taken in 100 ml shaking bottle separately and 2.5 ml of varying concentration of $(NH_4)_2SO4$ *viz*. 0, 5, 10, 15, 20 and 25 ppm was added. The entire set was incubated at room temperature for 24 hours to attain equilibrium. At the end of 24 hours, 50 ml of 2M KCl was added and shaken for 1 hour, filtered and NH4 – N was determined by steam distillation (Keeney and Bremner, 1966) [4] method. The NH4 – N fixed was calculated by using the formula:

NH4 fixed = [Original ex. NH4 + NH4 added] – [Ex. NH4 after equilibrium]

Ammonium release pattern

The method proposed by Ramanathan (1977) [16] was followed for NH4 – N release. The (NH4)2 SO4 solution were added at varying concentrations *viz*. 0, 5, 10, 15, 20 and 25 ppm @ 2.5 ml per 5 grams of soil sample and the soil was kept at room temperature for 24 hours. After 24 hours, 50 ml of 2M KCl was added, shaken for one hour and centrifuged for 10 minutes at 2000 rpm to estimate NH4 – N by Bremner method. To the same soil, another 50 ml of 2 M KCl was added and the same procedure was repeated till the released NH4 – N was constant or no further NH4 – N was released. The cumulative NH4 – N releasing power of the soil was computed by adding the values of NH4 – N extracted by successive extractions.

Results and Discussion

Ammonium fixing capacity of soils

The extent of ammonium fixation at different levels of added N and the percentage of NH_4^+ fixed to that of added N in the experimental soils are presented in Table.2. The results of the N fixation in three rice soil series revealed that the soils vary widely in their NH_4^+ fixing capacity, as they differ in the soil properties with special reference to CEC, OC, clay per cent, type of clay minerals, K saturation in the interlayer and moisture conditions. Among the soils, the NH_4^+ fixation was higher in Karaikal soil series and lower in Pattinam soil series and irrespective of soil series, the ammonium fixation increased with increase in N levels. In case of Karaikal and Pattinam soil series, the per cent fixation of NH_4-N increased with N levels and the maximum per cent *i.e.* 100 per cent fixation was encountered at highest N level of 25 ppm (Karaikal soil series) and 77 per cent at 20 ppm (Pattinam soil series). The per cent ammonium fixed was found to increase with increase in N levels in Karaikal which might be due to the reason that large portion of N being forced into inter lattice position from lattice pool as influenced by the concentration gradient (Aruna, 2001) [2]. Another study of Scherer *et al*. (2014) [17] also revealed that if NH_4^+ applied to heavy soil, a part of NH_4^+ ion may be fixed by clay minerals decreasing the release of N to plants. The higher fixation in these soils might be due to the dominant clay mineral of 2:1 smectite groups especially montmorillonite which possess high fixing capacity due to more isomorphous substitution in the tetrahedral layer. The tangible reason for lesser fixation in Pattinam series (77 per cent) might be due to the loamy sand texture with medium status of organic carbon coupled with lower CEC that would have resulted in medium buffering capacity of soil to hold nutrients. Even though the clay per cent (2.5 per cent) was low, a considerable amount of fixation would have happened in silt fraction (12.5 per cent) which would bind NH_4^+ - N in the non – exchangeable form as reported by Niederbudde and Friedrich (1984) [12].

The decrease was conceded in Thirunallar soil series, where the per cent ammonium fixed was higher in 10 ppm (81 per cent) level and the remaining levels had almost maintained the same per cent of NH_4^+ fixation (*i.e.* 64 per cent). In this soil series, the per cent fixation of NH_4 is 19 per cent lesser when compared to Karaikal soil series, even though both the soils are heavy soils with high organic carbon status and with higher CEC. The initial higher fixation and subsequent reduction with increased level of N in Thirunallar soil series might be due to the fact that the fixation is usually fast and occurs within first few hours after addition of N and then the fixation rate is controlled mainly by ion diffusion that declines as the equilibrium point is approached (Liang and MacKenzie, 1994) [5].

Based on the scope of NH_4^+ fixation, the soil series could be arranged in the order:

Karaikal soil series > Thirunallar soil series > Pattinam soil series

Ammonium release pattern

The release of fixed NH_4^+-N depends upon chemical equilibria between the amount of fixed NH_4^+, exchangeable NH_4^+ and NH_4^+ in soil solution. With decreasing concentration of NH_4^+ in soil solution, the NH_4^+ ions diffuse from clay mineral interlayers.

The ammonium release power of three soil series had not registered significant variation at varied levels of N. While in successive extraction except Karaikal soil series, Thirunallar and Pattinam soil series showed significant release. In case of Thirunallar soil series, decreasing release with successive extractions except for fourth and fifth extraction was observed with a maximum release occurred in the fourth extraction (26.2 ppm) which was statistically on par with fifth extraction (22.4 ppm). Other than these two extractions, the release decreased constantly and almost all the values were on par with each other. Whereas in Pattinam soil series, third extraction recorded the highest (21.8 ppm) which was on par with the fourth extraction (18.2 ppm). On the other hand, significantly lower NH_4^+ release was noticed at fourteenth extraction (9.1 ppm) but statistically on par and lower release was noticed from ninth extractions. The ammonium release was found to be significantly higher in second extraction than first extraction in control.

The cumulative release of NH_4^+ fits (Fig. 1) well into the Cobb-Douglass equation of the form $\hat{Y} = aX^b$, where, Y is the Cumulative NH_4^+ release, X is the number of extractions and a and b are constants varying with the soil indicating the instant releasing power of the soil and the slope of the curve on successive extractions, respectively.

From the Fig. 1, it could be concluded that with higher "a" value in Thirunallar ($\hat{Y} = 20.339 \times ^{0.9806}$), the instant release of NH_4^+ would be greater followed by Karaikal ($\hat{Y} = 17.609 \times ^{0.9165}$) and Pattinam ($\hat{Y} = 13.898 \times ^{1.0822}$), respectively. The higher available K (751 and 668 kg ha^{-1}, respectively) in Thirunallar and Karaikal soil series in the present study indicates that these soils have higher K saturation in the clay minerals. In the presence of solution K^+, the NH_4^+ desorption decreases as both NH_4^+ and K^+ have same mechanism for fixation and fit exactly into the ditrigonal holes in the basal oxygen of 2:1clay minerals (Nieder *et al*., 2011) [11].

Similarly, with higher power value "b" in the equation, steeper the release in successive extractions which is encountered in Pattinam followed by Thirunallar and Karaikal soil series, respectively. Therefore, factors like added N, soil organic matter, microflora, clay content and clay mineral composition will affect the concentration of NH_4^+ in soil solution and may promote either release or fixation of NH_4^+.

Table 1: Characterization of the major rice growing soil series of Karaikal

Sl. No.	Soil properties	Soil series		
		Thirunallar	Karaikal	Pattinam
I	**Textural analysis**			
1	Coarse Sand (per cent)	8.2	10.9	32.4
2	Fine Sand (per cent)	19.1	20.0	42.5
3	Silt (per cent)	27.5	18.8	12.5
4	Clay (per cent)	41.8	45.3	2.5
5	Texture class	Clay	Clay	Loamy sand
II	**Physical properties**			
6	Bulk density (Mg m^{-3})	1.250	1.052	1.176
7	PD (Mg m^{-3})	2.85	2.50	2.50
8	Pore Space (per cent)	57.89	56.25	52.94
III	**Physico-Chemical properties**			
9	Soil reaction (pH)	7.66	7.53	7.24
10	Electrical Conductivity (dS m-1)	0.62	1.18	0.12
11	Cation Exchange Capacity (c mol (p^+) kg^{-1})	38.5	41.6	24.2
12	Exchangeable Calcium (c mol (p^+) kg^{-1})	22.1	19.0	8.20
13	Exchangeable Magnesium (c mol (p^+) kg^{-1})	8.30	7.70	6.70
14	Exchangeable potassium (c mol (p^+) kg^{-1})	0.94	0.94	0.73
15	Exchangeable sodium (c mol (p^+) kg^{-1})	2.19	4.23	0.71
16	Loss on ignition	12.9	10.6	4.45
IV	**Chemical properties**			
17	Total nitrogen (per cent)	0.015	0.011	0.007
18	Total phosphorus (per cent)	0.094	0.156	0.082
19	Total potassium (per cent)	0.353	0.370	0.159
20	Organic Carbon (per cent)	1.302	0.684	0.554
21	$KMnO_4$ - N (kg ha^{-1})	387.8	380	278.6
22	Olsen - P (kg ha^{-1})	25.13	87.95	13.50
23	NH_4OAc - K (kg ha^{-1})	751	668	373

Table 2: Ammonium fixing capacity of major rice growing soil series of Karaikal region under different levels of N

(Mean of two replications)

N levels (ppm)	Thirunallar soil series (S_1)		Karaikal soil series (S_2)		Pattinam soil series (S_3)	
	Fixed NH_4 (ppm)	Per cent NH_4 fixed	Fixed NH_4 (ppm)	Per cent NH_4 fixed	Fixed NH_4 (ppm)	Per cent NH_4 fixed
0	16.2	-	18	-	11.6	-
5	3.2	64	1.8	36	1.0	20
10	8.1	81	8.2	82	3.6	36
15	9.6	64	13.2	88	6.8	45
20	12.8	64	18.2	91	15.4	77
25	16	64	25	100	16.8	67

(Not statistically analysed)

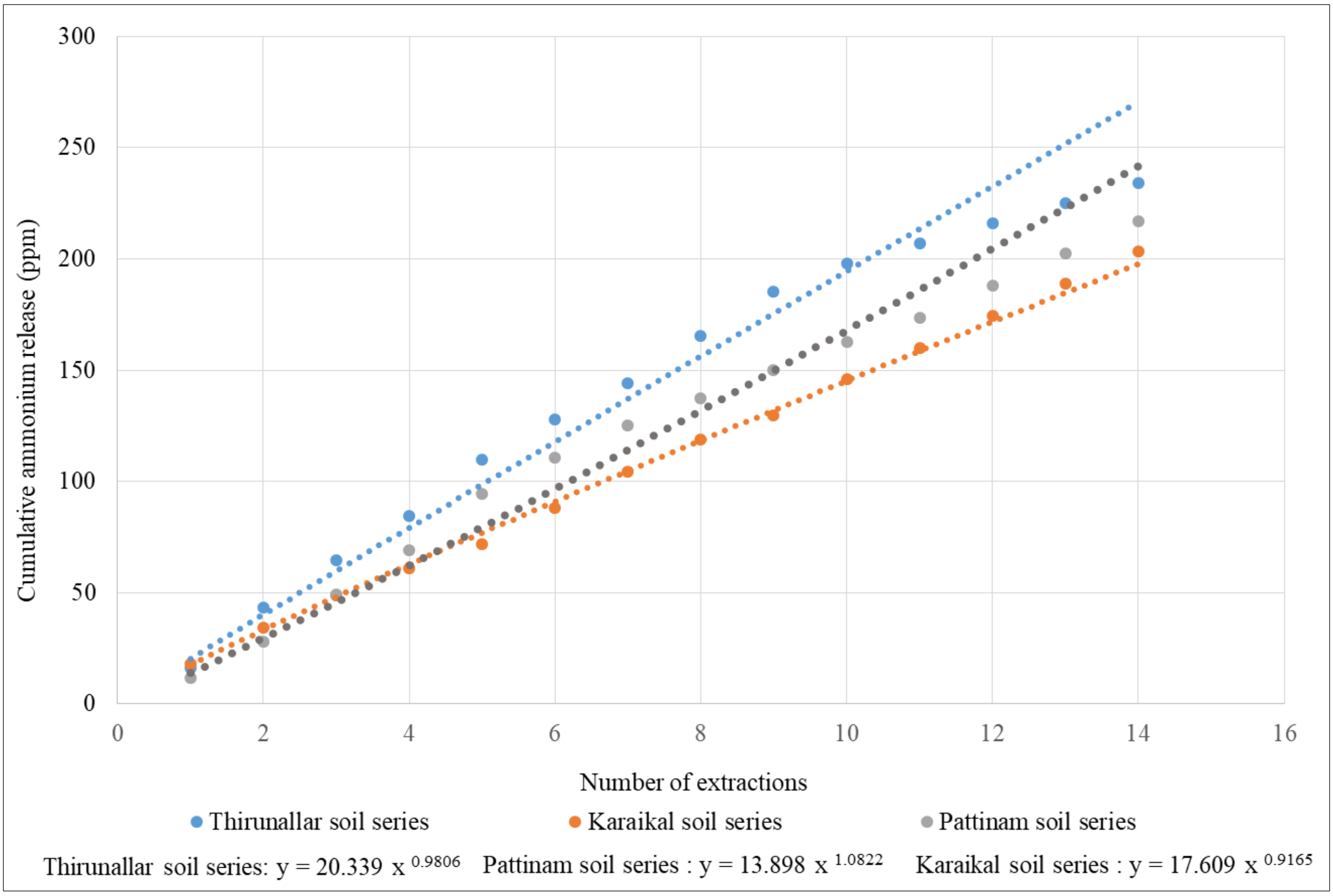

Fig 1: Cumulative ammonium release of major rice growing soil series of Karaikal region fitted with Cobb-Douglas equation

Conclusion

From the present study, it is concluded that the three soil series are varied in their fixing and releasing characters. Thirunallar soil series having a medium fixing capacity of ammonium, but the release was greater than the other two soil series. Whereas in Karaikal soil series, fixation was higher than the release of ammonium. In case of Pattinam soil series, the fixation and release are moderate. Recommendation of nitrogen fertilizer on each soil series based on their ammonium fixing and release character may increase the nitrogen use efficiency and also increase the availability of nutrient to the crop.

It would be more rewarding to further investigate the detailed mineralogy and the reaction of added nutrients in the soil. Quantitative mineralogy may aid in formulating more precise fertilizer (N, P and K) recommendations for the soil series.

References

1. Ajaykumar R, Venkitaswamy R, Rajeshkumar A. Sustainable nutrient management practices to increase the productivity of transplanted low land rice. Cleanup India, TNAU, Coimbatore, 2016, 13-15.
2. Aruna L. Investigation on the nitrogen dynamics of the soil series of Cauvery delta in relation to response of rice. Ph.D thesis, TNAU, Coimbatore, 2001.
3. Juang TC, Wang MK, Chen HJ, Tan CC. Ammonium fixation by surface soils and clays. Soil Sci. 2001;166:345-352.
4. Keeney DR, Bremner JM. Comparison and evaluation of laboratory methods of obtaining an index of soil nitrogen availability. Agron. J. 1966;58:498-503.
5. Liang BC, MacKenzie AF. Fertilization rates and clay fixed ammonium in two Quebec soils. Plant Soil. 1994;163:103-109.
6. Liu YL, Zhang B, CL Li, Hu F, Velde B. Long-term fertilization influences on clay mineral composition and ammonium adsorption in rice paddy soils. Soil Sci. Soc. American J. 2008;72:1580-1590.
7. López-Bellido L, Munoz-Romero V, Benítez-Vega J, Fernández-García P, Redondo R, López-Bellido RJ. Wheat response to nitrogen splitting applied to a Vertisol in different tillage systems and cropping rotations under typical Mediterranean climatic conditions. European Journal of Agronomy. 2012;43:24-32.
8. McBeth IG. Fixation of ammoniumin soils. J Agric Res. 1917;9:141-155.
9. Mengel K, Hütsch B, Kane Y. Nitrogen fertilizer application rates on cereal crops according to available mineral and organic soil nitrogen. European Journal of Agronomy. 2006;24:343-348.
10. NBSS, LUP. Perspective land use plan, Union Territory of Puducherry. NBSS and LUP, Nagpur, 2008.
11. Nieder R, Dinesh K, Benbi, Heinrich W. Scherer. Fixation and defixation of ammonium in soils: a review Biol. Fertility Soils. 2011;47:1-14.
12. Niederbudde EA, Friedrich R. Einfluß von Gülle und Mineraldüngung auf N- und K spezifische Bodeneigenschaften einer Geschiebemergel-Braunerde. Bayer Landwirtsch Jahrb. 1984;61:781-789.
13. Osborne GJ. The extraction and definition of nonexchangeable or fixed ammonium in some soils from southern New south Wales. Australian J. Soil Res. 1976a;14:373-380.
14. Peltonen-Sainio P, Peltonen J. Progress since the 1930s

in breeding for yield, its components, and quality traits of spring wheat in Finland. Plant Breeding. 1994;113:177–186.
15. Prud'homme M. Global nitrogen fertilizer supply and demand outlook. Sci. China (Life Sci). 2005;48:818-826.
16. Ramanathan KM. Studies on dynamics of soil potassium. Ph. D. Thesis, Tamil Nadu Agricultural University, Coimbatore, 1977.
17. Scherer HW, Feils E, ans Beuters P. Ammonium fixation and release by clay minerals as influenced by potassium. Plant Soil Environ. 2014;60(7):325-331.
18. SSSA. Glossary of soil science terms. Soil Sci. Soc. American J., Madison, Wisconsin, 1984.
19. Steffens D, Sparks DL. Effect of residence time on the kinetics of nonexchangeable ammonium release from illite and vermiculite. J Plant Nutri. Soil Sci. 1999;162:599-604.
20. Verma OP, Verma GP. Potassium fixation in soils of Madhya Pradesh. Bull Indian Soc. Soil Sci. 1970;8:71-74.