Journal of Applied and Natural Science
Special Issue: 14 (SI), 85 - 89 (July, 2022)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Kinetics of nitrogen in sodic soil of Kumulur village, Trichy District, Tamil Nadu under different organic and inorganic amendments

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Article Info
https://doi.org/10.31018/jans.v14iSI.3572
Received: March 10, 2022
Revised: April 19, 2022
Accepted: May 23, 2022

How to Cite
Naveenkumar, T. *et al.* (2022). Kinetics of nitrogen in sodic soil of Kumulur village, Trichy District, Tamil Nadu under different organic and inorganic amendments. *Journal of Applied and Natural Science*, 14 (SI), 85 - 89. https://doi.org/10.31018/jans.v14iSI.3572

Abstract
Currently more than 20 per cent of the world's irrigated land is salt affected. Of that about 60 per cent are sodic soils, warranting greater attention for efficient and eco-friendly environmentally amelioration techniques. Transformation and availability of several plant nutrient elements are affected by soil sodicity. Alkali/sodic soils are to be reclaimed so as tomake nutrients available to plants optimally. A laboratory incubation study was examined to analyse the impact of various amendments, either alone or in combination with nitrogen (N) @75 kg/ha, on the physico-chemical characteristics and nitrogen dynamics in sodic soil of Kumulur village Trichy District, Tamil Nadu (pH-10.4, EC-0.40 dS, m-1, ESP-31.8). The investigation was conducted at ADAC&RI in Trichy with three replications and eight treatments in a completely randomized design. The treatments used for sodic soil reclamation utilizing a standardized procedure were Gypsum (GYP) + Green manure (GM) @ 6.5 t ha-1 (T2), Distillery spent wash (DSW) @ 5 lakhs liter-1(T4), and Green leaf manure (GLM) @ 12.5 t ha-1(T3). Soil samples were taken at 15-day intervals from the 15th to the 60th day and tested for NH4-N, NO3-N, and accessible nitrogen. Using DSW, GYP + GM, and GLM, the pH of the water was decreased from 10.2 to 8.37, 8.42, and 9.21, respectively. The soil pH dropped the most in the DSW-controlled treatments. The application of nitrogen alone without any amendments (T5) recorded a higher value (135 kg ha-1) during an initial period (15 days) only and thereafter declined sharply due to various losses, *i.e.,* volatilization, denitrification or fixation. When nitrogen was applied along with amendments, a significant (CD-0.05%) buildup in available N contents was observed over the application of N alone. Available nitrogen (325 kg ha^{-1}), nitrate nitrogen (102 kg ha^{-1}) and ammonical nitrogen (205 kg ha^{-1}) were significantly increased due to the addition of amendments. However, the decline in available N with incubation period was only marginal when nitrogen was applied along with amendments. An increase in NH4-N at 30 DAI might be due to the release of nutrients. A slight increase in the nitrate-N content of the soil was observed at the end of the incubation period due to microbial oxidation of NH4-N to NO3-N. The application of amendments could save a quantity of N dose besides reclaiming the sodicity.

Keywords: Amendments, Distillery spent wash, Incubation, Nitrogen, Sodic soil

INTRODUCTION

Nearly 6.73 million hectares of land in India are damaged by salt, in which 56% is covered by sodic soil. Sodic soil covers 3,54,784 lakh hectares in Tamil Nadu alone. Due to severe degradation activities such as sodification, waterlogging, chemical damage, and desertification, a large portion of India's topsoil is amended and influenced by sodification (Sharma *et al*., 2016). A large number of farmers around the country are dealing with the problem of alkali land.

Sodic soils can be reclaimed by different amendments. Exchangeable sodium is replaced with a beneficial cation such as calcium to reclaim sodic soils. Calcium can be added to calcareous alkali soils by adding calciumcontaining amendments such as gypsum or by releasing natural calcium by adding acid formers to calcareous alkali soils (Richards, 1954). Poor physical conditions, low organic matter, total and accessible nitrogen (N), phosphorus (P), calcium (Ca) and magnesium (Mg) are all common characteristics of Sodic soils .

Green manure application is also beneficial in reclaiming sodic soils if rice is grown under submerged soil conditions (Dhane, 2011). The utilization of green manure reduces the soil pH by organic acid and carbon dioxide production during decomposition (Yang *et al*., 2009)

Distillery spent wash (DSW) is one of the byproducts of the sugar industry, which is highly acidic and contains a good amount of essential plant nutrients. The application of distillery spent wash to the nonsaline sodic soil that has been air dried, followed by two or three leaching with water could effectively reclaim sodic soil (Naorem *et al*., 2017). The nitrogen supply capacity and its transformation under sodic soil are important to attain optimum rice yields (Gupta and Sharma, 2007). Hence, the present study was carried out to study the dynamics of nitrogen in sodic soil of Kumulur under different amendments.

MATERIALS AND METHODS

With eight treatments and three replications, the incubation experiment was accomplished. The study was conducted in CRD, with the following treatment setup: Control (T1), GYP + GM @ 6.25 t ha^{-1} (T2), GLM @ 12.5 t ha^{-1} (T3), DSW @ 5 lakh liters ha^{-1} (T4), Nitrogen alone @ 75 kg ha^{-1} (T5), GYP + GM @ 6.25 t ha^{-1} + N @ 75 kg ha^{-1} (T6), GLM @ 12.5 (T8). As per the standard procedure, the soil was reclaimed with the above amendments, and N was applied according to the treatment schedule.

The soils were saturated for 60 days and then tested for physicochemical parameters such as pH and EC (Jackson 1973) and ESP (Richards *et al*., 1954). The incubated soils were collected at 15-day intervals (15, 30, 45, 60) and analysed for available nitrogen by Alkaline permanganate method (Subbiah and Asija, 1956), ammonial nitrogen, and nitrate nitrogen by 0.2 M KCl method (Bremner, 1965). The soil utilized in the experiment was characterized for texture by international pipette method and porosity, bulk density and particle density by Keen Raczkowski box Method (Piper, 1966). The soil belongs to Madukhur series clay loam with an apparent specific gravity of 1.2 Mg m-3, true density of 2.22 Mg m-3, and porosity of 58.60 percent. The soil collected for the experiment was acidic (pH 10.4) and had a low EC (0.4 dS m-1). Organic carbon in the soil was 0.42 percent. 6.21, 4.81, 5.12, 0.08 cmol(p+)kg-1were the exchangeable Ca, Mg, Na, K, respectively and the ESP is 31.8 percent.

RESULTS AND DISCUSSION

Physico-chemical properties

According to the observations of the incubation investigation, a decline in the pH of the soil was noticed with the application of amendments. Due to the use of DSW, GYP + GM, and GLM, the pH dropped from 10.2 to 8.37, 8.42, and 9.21, respectively. The acidic character of DSW and its capacity to solubilize free lime in soil resulted in the greatest decrease in soil pH in the DSW-applied treatments. This decline in pH could be caused by the DSW supplying Ca directly. This drop in pH could potentially be due to Ca delivered directly from the DSW. The exchangeable Na was displaced by calcium ions by the application of GYP + GM, resulting in a drop in soil pH. In the DSW-treated pots, the soluble salt content increased marginally, but the rise was found within the allowed range (< 4 desi Siemens per meter)

The soil exchangeable sodium percentage decreased noticeably upon reclamation to 13.1, 13.5, and 24.2 percent due to the usage of DSW, GYP + GM, and GLM, respectively, from an initial value of 31.8 percent, with enhanced exchangeable calcium, magnesium, and potassium and decreased exchangeable sodium. The same results were observed by Iniyalakshimi and Baskar (2017), who reported that the use of DSW solubilizes free lime releases adequate free calcium ions replacing exchangeable Na, thus reducing the ESP. The application of GM and GLM is attributed to the reduction of soil ESP through increasing exchangeable Ca and Mg ions during the breakdown of organic matter.

Available nitrogen (kg ha^{-1})

Table 1 illustrates the influence of different amendments and levels of nitrogen on the available N content of soil collected at 15-day intervals during the incubation period. At 15 days after incubation (DAI), the highest amount of available N was registered in the T_8 treatment with DSW @ 5 lakh litres ha^{-1} + N @ 75 lakh ha^{-1} (325 kg ha^{-1}), followed by T_4, T_7, T_6, T_5, T_3 and T_2. The absolute control value of 168 kg ha^{-1} was the lowest. A similar pattern can be found. At 30 DAI, the content of available N was highest (319 kg ha^{-1}) in T_8, followed by T_4, T_7, T_6, T_5, T_3, T_2, and the control (T_1) showed the lowest value (169 kg ha^{-1}). The application of various amendments and nitrogen significantly influenced the available nitrogen content 45 days after incubation.

Treatment T_8 (DSW @ 5 lakh litres ha^{-1} + N @ 75 kg ha^{-1}) showed the highest value (308 kg ha^{-1}), followed by T_4, T_7, T_6, T_3, T_5 and T_2. The control had the lowest value (168 kg ha-1) (T1). The available N content, which ranged from 163 to 291 kg ha^{-1} at 60 DAI, is presented in Table 1. The highest (291 kg ha^{-1}) values were noted in T_8 (DSW @ 5 lakh litres ha^{-1} + N @ 75 kg ha^{-1}), followed by T_4, T_7, T_3, T_6, T_2, and T_5. The lowest value of 163 kg ha^{-1} was observed in the control (T_1). The organic form of N supplied by the application of DSW might have been slowly released into the available pool and steadily increased the available N content. This is in line with the findings of Choudary *et al*., 2017

Ammonical-nitrogen (NH_4 -N)

The effect of several amendments and nitrogen levels on the NH_4 – N content of soil at 15-day intervals during the incubation period is shown in Table 2 . At 15 DAI, the highest content of NH_4 – nitrogen (205 kg ha^{-1}) was registered in treatment $T_{8,}$ followed by T_4, T_7, T_6, T_5, T_3, and T_2, and treatment T_1 showed the minimum value of 90 kg ha^{-1}. At 30 DAI, the content of NH_4 – N was highest in the T_8 (198 kg ha^{-1}) treatment, followed by T_4, T_7, T_6, T_5, T_3, and T_2, and the control (T_1) showed the lowest value (90 kg ha^{-1}).

The application of various amendments and nitrogen significantly influenced the NH_4 – N content 45 days after incubation, as depicted in Table 2. Treatment T_8 (DSW+ N@75 kg ha^{-1}) showed a higher val-ue (185 kg ha^{-1}), which was comparable to T_4 (185 kg ha^{-1}). The lowest value was recorded with absolute control, with a value of 89 kg ha^{-1}. The NH_4 – N content, which ranged from 92 to 181 kg ha^{-}1 at 60 DAI, is presented in Table 2. The highest (182 kg ha^{-1}) was recorded in T_4 (DSW), followed by T_8, T_3, T_7, T_6, T_2 and T_5. The control recorded the least value (92 kg ha^{-1}). Kalaiselvi *et al*. (2010) reported that higher N availability in DSW applied soil could be due to the direct contribution of nitrogen as well as increased microbial activity due to the added organic matter.

Nitrate nitrogen (NO_3- N)

Table 3 explains the influence of various amendments

Table 1. Influence of amendments and nitrogen on the available nitrogen content (kg ha^{-1}) of soil at different incubation periods

T.No.	Treatments	Available nitrogen content (kg ha^{-1})			
		15th DAI	30th DAI	45th DAI	60th DAI
T_1	Control (no application of amendments)	168	169	168	163
T_2	GYP + GM @ 6.25 t ha^{-1}	179	186	192	205
T_3	GLM @ 12.5 t ha^{-1}	192	205	214	229
T_4	DSW @ 5lakh liters ha^{-1}	275	290	284	278
T_5	Nitrogen alone @ 75 kg ha^{-1}	225	211	201	175
T_6	GYP +GM @ 6.25 t ha^{-1} + N @ 75 kg ha^{-1}	245	238	232	221
T_7	GLM @12.5 t ha^{-1} + N @ 75 kg ha^{-1}	258	251	246	241
T_8	DSW @5 lakh liters ha^{-1}+ N @ 75 kg ha^{-1}	325	319	308	291
SE d		2.85	2.58	2.21	3.17
CD (0.05)		6.20	5.60	4.80	6.91

Table 2. Influence of amendments and nitrogen on the NH_4–N content (kg ha^{-1}) of soil at different incubation periods

T.No.	Treatments	NH_4–N content (kg ha^{-1})			
		15th DAI	30th DAI	45th DAI	60th DAI
T_1	Control (no application of amendments)	90	90	89	92
T_2	GYP + GM @ 6.25 t ha^{-1}	102	108	112	117
T_3	GLM @ 12.5 t ha^{-1}	118	126	131	138
T_4	DSW @ 5lakh liters ha^{-1}	182	191	155	132
T_5	Nitrogen alone @ 75 kg ha^{-1}	135	131	122	116
T_6	GYP + GM @ 6.25 t ha^{-1} + N @ 75 kg ha^{-1}	141	135	131	121
T_7	GLM @ 12.5 t ha^{-1} + N @ 75 kg ha^{-1}	148	142	138	131
T_8	DSW @ 5 lakh liters ha^{-1}+ N @ 75 kg ha^{-1}	205	198	185	181
	SE d	2.37	2.24	2.01	1.82
	CD (0.05)	5.13	4.86	4.37	3.95

Table 3. Influence of amendments and nitrogen on the NO_3–N content (kg ha^{-1}) of soil at different incubation periods

T.No.	Treatments	NO_3–N content (kg ha^{-1})			
		15^{th} DAI	30^{th} DAI	45^{th} DAI	60^{th} DAI
T_1	Control (no application of amendments)	52	53	52	53
T_2	GYP + GM @ 6.25 t ha^{-1}	60	61	62	65
T_3	GLM @ 12.5 t ha^{-1}	61	65	68	72
T_4	DSW @ 5lakh liters ha^{-1}	76	82	77	73
T_5	Nitrogen alone @ 75 kg ha^{-1}	68	65	60	56
T_6	GYP +GM @ 6.25 t ha^{-1} + N @ 75 kg ha^{-1}	72	68	62	60
T_7	GLM @12.5 t ha^{-1} + N @ 75 kg ha^{-1}	75	71	65	62
T_8	DSW @5 lakh liters ha^{-1}+ N @ 75 kg ha^{-1}	102	96	84	78
SE d		1.11	1.02	1.06	0.97
CD (0.05)		2.41	2.22	2.29	2.11

and nitrogen levels on the NO3-N concentration of soil sampled at 15-day intervals during the incubation period. At 15 days after incubation (DAI), the maximum amount of NO_3- N (102 kg ha^{-1}) was registered in treatment T_8 (DSW + N 75 kg ha^{-1}), followed by T_4, T_7, T_6, T_5, and T_2, and treatment T_1 showed a minimum value of 52 kg ha^{-1}. At 30 DAI, the content of NO_3- N was highest (96 kg ha^{-1}) in the T_8 treatment, followed by T_4, T_7, T_6, T_5, T_3, T_2, and the control (T_1), which showed the lowest value (53 kg ha^{-1}). The application of various amendments and nitrogen significantly influenced the NO_3- N content 45 days after incubation, as depicted in the table. Treatment T_8 showed the highest value (84 kg ha^{-1}), followed by T_4, T_5, T_7, T_6, T_2 and T_5. The one that showed the lowest value (52 kg ha^{-1}) was the control (T_1). At 60 DAI, treatment T_8 (DSW + N) recorded the highest value (78 kg ha^{-1}), followed by T_4, T_3, T_2, T_7 and T_6. The control (T_1) recorded the lowest value (53 kg ha^{-1}).

Higher nitrogen availability in DSW-applied soil could be due to direct nitrogen supply as well as increased microbial activity due to organic matter addition. The organic form of N given by DSW may have slowly leached into the manageable pool, thus increasing the available N content. This is consistent with Naorem *et al*., (2017) who reported the efficacy of raw DSW in reclaiming sodic soil. The release of N from plant material during decomposition and prolonged N mineralization in flooded soils could explain the increase in available N caused by the application of GLM (Lakshmi *et al*., 2020). Microbial oxidation of NH4-N to NO3-N may be responsible for the increase in the NO3-N concentration of the soil at the end of the incubation period (Lakshmi *et al*., 2019).

Conclusion

The present study concluded that the available nitrogen, nitrate nitrogen and ammoniacal nitrogen were significantly increased due to the addition of amendments like green leaf manure, green manure, gypsum and distillery spent wash. When nitrogen was applied along with amendments, a significant buildup in available N content was observed over the application of N alone. The application of nitrogen alone without any amendments recorded higher values of nitrogen and its fractions during an initial period (15 days) and later declined sharply due to various losses, *i.e.*, volatilization, denitrification or fixation. However, the decline in available N with incubation period was only marginal when nitrogen was applied along with amendments, as the application of amendments supplied additional nitrogen to the soil, which balanced the nitrogen losses. Management of nitrogen levels is necessary even after the reclamation of sodic soil to get a higher crop yield. Therefore, the application of the amendments along with nitrogen can be a better option promoting sustainable agriculture and good soil health.

Conflict of interest

The authors declare that they have no conflict of interest.

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