Nitrogen Mineralization, Forms of Acidity and Fertility Status of a Paddy Soil as Influenced by Rice Stubble Management

Suravi Nandi¹*, Binoy K. Medhi¹, Rajen Barua¹, Mrinal Saikia¹, Hemanta Saikia², Kashyap P. Bezbaruah³, Prantika Kakati¹, Anupama Das¹ and Nilay Borah⁴

¹Department of Soil Science, ²College of Sericulture, ⁴College of Horticulture, Assam Agricultural University, Jorhat 785013 Assam, India
³Department of Agriculture, Nonoi, Nagaon 782001 Assam, India

*Corresponding author

A B S T R A C T

An experiment was conducted in the laboratory of department of Soil Science, Assam Agricultural University, Assam (India) during November 2018 to April 2019 to evaluate inorganic nitrogen fractions, forms of acidity and fertility status in a rice soil as influenced by rice stubble (RS) management practices through a fifteen weeks incubation period under constant moisture regime. Untreated and glyphosate-yogurt treated rice stubble was either incorporated or left on the surface of soil-filled (15 cm depth on 5 cm sand at the bottom) poly vinyl chloride (PVC) pipe (25 cm long and 8.44 cm diameter), mounted on tray maintaining a constant water depth of 5 cm and incubated for 105 days. Incorporation of rice stubble treated with glyphosate-yogurt mixture significantly increased NH₄-N in soil compared to all other treatments, but the NO₃-N in soil was affected neither by incorporation nor microbe culture spray. The variation in soil pH was not significant among the treatments except at 105 days after incubation. Incorporation of rice stubble, irrespective of glyphosate-yogurt treatment, significantly increased exchange acidity and total acidity in soil after 42 days of incubation. The total potential acidity in soil did not vary significantly throughout the study period. The exchangeable Ca²⁺, Mg²⁺ and K⁺ in soil increased significantly due to rice stubble incorporation with or without glyphosate-yogurt treatment, but the effect was not observed for cation exchange capacity of soil. Incorporation of rice stubble significantly increased available P and K contents in soil, irrespective of glyphosate-yogurt treatment.

Keywords
Rice stubble, Inorganic N-fractions, Exchangeable cations, Acidification

Article Info
Accepted: 10 July 2020
Available Online: 10 August 2020

Introduction

The productivity of winter rice in Assam has remained static during last decade (Anonymous, 2019) contrast to increase in high yielding variety acreage and total fertilizer consumption. Application of mineral fertilizer without organic manure or recycling of crop residues strongly affects soil productivity (Singh et al., 2001). The stubble management, which is left in the field till the next crop, in rice sole crop areas of the state deserves relook mainly for two reasons. First, simple and feasible rice stubble management
holds key to expansion of area under oilseeds and summer pulses through crop intensification and diversification. Second, the left over stubbles are subject to little or slow decomposition until the pre-monsoon rain in April-May (Borah et al., 2016b,c) and the decomposition during this period lead to substantial loss of nutrients from the soil without crop cover (Bezbaruah, 2017). The availability of winter rice stubble in Assam as per 2009 estimate was 6.29 million tones (88.9% of total rice crop residues), with a surplus of 3.75 million tonnes (Hiloidhari and Baruah, 2011). Rice straw contains about 0.6% N, 0.18% P and 1.38 % K (Mandal et al., 2004) and for every tonne removal of rice straw about 5-8 kg/ha N, 1.6-2.7 kg/ha P2O5 and 14-20 kg/ha K2O get lost (Dobermann and Fairhurst, 2002).

Incorporation of rice straw without pre-treatment may adversely affect nutrient availability in soil and ultimately succeeding crop yield (Singh et al., 1996), while in situ decomposition without pre-treatment is slow due to dry spell with low temperature (Borah et al., 2016b,c). Spraying mixture of glyphosate and commercial yogurt on rice stubble in situ (Borah et al., 2016 a, c) or their incorporation into soil (Bezbaruah, 2017) had significantly enhanced reduction of biomass weight and C:N ratio of the crop residues.

The major problem in the way of efficient utilization of cereal crop residues is microbial immobilization of nitrogen in soil (Mary et al., 1996), reduction of oxygen content and production of toxic carbon compounds in soil. Response of crop residues incorporation to soil pH had shown contrasting results (Naramabuye and Haynes, 2006; Rosolem, 2011), mainly due to the differences in composition and types of added residues, soil properties and location (Xu et al., 2006 a, b). Initial soil pH significantly affected the incorporation of crop residues with higher C: N ratio like rice and low soil pH inhibited the nitrification (Xiao et al., 2013). Incorporation of rice straw in situ without any treatment (Tuyen and Tan, 2001) or followed by their chopping (Bailey et al., 2013) or with phosphocompost and mineral fertilizer (Bhattacharjee et al., 2013) had been reported to increase nutrient content, cation exchange capacity (Weber et al., 2007), nitrogen availability due to acidification (Xu and Coventry, 2003) or liming effect (Conyers et al., 2011) in soils.

Carbon or nitrogen mineralized after incorporation of residues had been studied under both laboratory conditions (Vanlauwe et al., 1996; Vigil and Kissel, 1991) and in field experiments (Handayanto et al., 1994, Muller et al., 1988). However, the predictions of mineralizable nitrogen based on measurements of nitrogen mineralization under field study were significantly worse than that under laboratory condition (Ros et al., 2011). The knowledge on nitrogen mineralization with rice stubble management under controlled laboratory conditions would thus aid in formulating effective nutrient management in the succeeding crop, and efficient method for recycling of the crop residues. Accordingly, a laboratory incubation study was carried out to evaluate nitrogen mineralization, forms of soil acidity and available nutrients in soil as influenced by stubble management practices.

Materials and Methods

Location, soil and climate

The present investigation was carried out during November 2018 to April 2019 at Assam Agricultural University (26°44’N, 94°10’E and 91 m above MSL), Jorhat, India. The daily temperature of Jorhat decreases from November to January and then increases from February to April with an average
maximum temperature of 28°C in November to 23°C in January, and then 24°C in February to 28°C in April, and with an average minimum temperature of 16°C in November to 8°C in January, and thereafter 13°C in February to 19°C in April. Bulk surface (0-15 cm) soils were collected from field after harvest of winter rice crop, air dried and ground to pass through 2 mm sieve and the processed soil was used for the incubation experiment. The soil for the experiment had a sandy clay loam texture with 56.1 per cent sand, 25.1 per cent clay having bulk density and particle density of 1.39 and 2.36 Mg/m³, respectively.

The soil had total porosity of 41.1 per cent, maximum water holding capacity of 43.1 per cent and field capacity moisture content of 21.6 per cent (w/w). The pH of the soil was 4.6 with exchangeable acidity, total acidity and total potential acidity fractions as 0.55, 3.41 and 18.8 c mol (p⁺)/kg, respectively. The lime requirement (to raise the pH to 6.4) of the soil in terms of CaCO₃ was 11.9 t/ha. The cation exchange capacity of the soil was 5.46 c mol (p⁺)/kg soil, and exchangeable Al³⁺ content was 0.45 c mol (p⁺)/kg soil. The other exchangeable cations contents were 0.17, 0.23, 1.12, 0.78 and 0.11 c mol (p⁺)/kg soil for K⁺, NH₄⁺, Ca²⁺, Mg²⁺ and Na⁺, respectively with a base saturation of 38.6 per cent.

**Experimental set up**

The incubation was carried out using 25 cm long poly vinyl chloride (PVC) hollow pipe, the bottom of which was temporarily closed by fixing a woven stainless wire cloth (diameter ≤ 0.2 mm) with rubber and adhesive tape. Each PVC pipe (internal diameter 8.44 cm and wall thickness 0.28 cm) was filled with sand up to 5 cm from the bottom, followed by the processed soil to a thickness of 15 cm maintaining the dry bulk density of the soils, estimated earlier during collection of the samples. The soil-filled PVC pipes were mounted in a one litre beaker and required mass of rice stubble was applied to each column as per the treatments and incubated for 105 days. A water level of 5 cm thickness was maintained inside the beaker throughout the incubation period.

**Treatments and experimental design**

A mixture of glyphosate (2.05 g/L a.i.) and edible yogurt (5 g/L) in water was freshly prepared and used as spray solution (Borah et al., 2016 a, c). Glyphosate [N-(phosphonomethyl) glycine, C₃H₈NO₅P] is a non-selective herbicide with a water solubility of 12 g/L at 25°C. The edible yogurt was collected from the local market and used for the spray. The spray was done on 20-12-2019 using a manual operated knapsack sprayer fitted with hollow cone nozzle, with a spray volume of 550 L/ha.

After the spray the stubble was kept for one hour in the field before collection for laboratory incubation. Both the treated and untreated rice stubbles were collected from the field, immediately chopped into small pieces (2.0 to 2.5 cm) and added to the soil columns as per treatments. Accurately weighed 4.0 gram of fresh biomass (with 60.4% moisture content, w/w) was added to respective soil column for treated and untreated rice stubbles.

The mass of rice stubble to each soil column was calculated on the basis of surface area of the PVC pipe and average dry weight of stubbles in the field per unit area, taking five random samples using a 1m x 1m quadrate. Five treatments were imposed to respective columns and comprised of T₁ – without rice stubble (RS), T₂ - RS untreated and retained on the surface, T₃ - RS untreated and incorporated into soil, T₄ - RS treated (glyphosate + yogurt) and retained on the surface and T₅ - RS treated
(glyphosate + yogurt) and incorporated into soil. Five sets of the columns in a completely randomized design with four replications were incubated up to 105 days of imposition of the treatments.

**Sampling and soil analysis**

One of the several sets maintained for the experiment was dismantled periodically for analysis of soil properties at 21, 42, 63, 84 and 105 days after imposition of the treatments. The various physical chemical properties of the soils were estimated following standard procedures (table 1).

**Ammonical nitrogen (NH$_4$-N) and nitrate nitrogen (NO$_3$-N)**

The soil was extracted with 1 N Na$_2$SO$_4$-phenylmercuric acetate and NH$_4$-N and NO$_3$-N in the solution was estimated using a uv-vis spectrophotometer (Onken and Sunderman, 1977).

**Available nutrients in soil**

Available nitrogen in soil was determined by modified alkaline potassium permanganate method (Subbiah and Asija, 1956) and the available phosphorous in soil was determined by Bray and Kurtz (1945) No 1 method (Jackson, 1973). The available potassium in soil was determined by extracting the soil with neutral normal ammonium acetate and the potassium in the extract was determined using a flame photometer (Jackson 1973).

**Statistical analysis**

A one-way ANOVA was carried out to compare the means of the different treatments. When significant F-values were detected, the differences between individual means were tested using the least significant difference (LSD) test.

**Results and Discussion**

**Soil moisture content at different days after treatments**

The soil moisture content (w/w) at different days after incubation is shown in table 2. The soil moisture content was unaffected by the treatments and ranged from 27.2 to 31.6 per cent, which was 63.1 to 73.3% of the water holding capacity of the soil.

**NH$_4$-N and NO$_3$-N content in soil at different days after incubation**

The highest and the lowest values of NH$_4$-N content in soil were observed for incorporation of glyphosate-yogurt treated rice stubble and without rice stubble, respectively (table 3). The ammonium-nitrogen (NH$_4$-N) in soil significantly increased due to incorporation of yogurt treated rice stubble compared to all other treatments. In case of untreated rice stubble, incorporation did not affect NH$_4$-N content in soil throughout the incubation period.

The NO$_3$-N in soil was not affected by the treatments at 21 days of incubation (table 4). Thereafter, addition of rice stubble, irrespective of glyphosate-yogurt treatment or incorporation, increased NO$_3$-N in soil over without rice stubble. The effect of yogurt or incorporation was non-significant. However, incorporation of glyphosate-yogurt treated RS showed significant increase in NO$_3$-N content of soil compared to untreated RS without incorporation.

The low NH$_4$-N content and non-significant effect on NO$_3$-N due to rice stubble application at early period of the incubation may be attributed to immobilization of nitrogen in soil (Mohanty et al., 2010). Further, as the N-mineralization is strongly dependent on C:N ratio (van Asten et al.,...
2005; Pandey et al., 2009) the process was enhanced during later part of the incubation upon reduction in C:N ratio of the substrate (Borah et al., 2016a,b,c) following mineralization of organic carbon. Positive changes in the contents of NH$_4$-N and NO$_3$-N in soil due to rice straw addition were reported earlier (van Asten et al., 2005; Mohanty et al., 2010; Yang et al., 2018). Use of cellulose degrading microbes during organic residue decomposition was reported to facilitate N-mineralization from the substrate (Mikola et al., 2002). Increased mineralization of nitrogen with application of $^{15}$N-labelled rice straw from pot culture laboratory experiment was reported (Takahashi et al., 2003). The significantly higher NH$_4$-N content in soil incorporated with yogurt treated rice stubble was due to faster decomposition or organic matter (van Asten et al., 2005).

The NO$_3$-N content of soils was higher than NH$_4$-N content up to 84 days of incubation which was reverse beyond this stage. Higher NH$_4$-N and NO$_3$-N contents in soil with rice straw retention than removal was reported (Yana et al., 2018). The transient organic intermediates like acetate, propionate, or butyrate undergo simultaneous oxidation and alternative redox processes like denitrification (Kusel et al., 2002). Nitrate is subjected to both assimilation and dissimilation under most oxic conditions (Tiedje, 1988). Further NO$_3$-N leaching takes place from top soil (0-10 cm) due to addition of rice straw during rice season under rice-wheat cropping system (Yang et al., 2018). The present work was carried out with 15 cm soil column under about 70% of the water holding capacity and might have created anoxic condition at the bottom soil layer resulting in lower NO$_3$-N content compared to NH$_4$-N after 84 days of incubation. A decrease in NO$_3$-N content of soil following flooding (Knoblauch et al., 2014), and at 90 days after incubation of rice straw compost (Latifah et al., 2018) was earlier reported.

**Soil reaction and forms of acidity at different days after incubation**

The soil pH values for respective treatments at different stages of the incubation are shown in table 5. The soil pH was not affected by the treatments except at 105 days after incubation, where incorporation of glyphosate-yogurt treated rice stubble significantly decreased it compared to that without rice stubble.

**Forms of acidity in soil at different days after incubation**

The values for exchange acidity and total acidity in soil at various stages of the incubation are presented in Fig 1 and Fig 2, respectively. The exchange acidity in soil significantly increased after 42 days and up to 105 days of incubation due to incorporation of rice stubble, both treated and untreated compared to without rice stubble or unincorporated rice stubble (Fig 1). Similar to exchange acidity in soil, the total acidity in soil significantly increased due to incorporation of rice stubble (both treated and untreated) over without rice stubble or both treated and untreated unincorporated rice stubble (Fig 2). However, in case of unincorporated rice stubbles, glyphosate-yogurt treatment increased exchange acidity in soil over untreated rice stubble after 63 days of incubation.

The total potential acidity in soil was not affected by the treatments irrespective of the stages of the incubation (table 6).

The soil pH was not affected by the treatments except at 105 days after incubation, where significant reduction was
observed due to incorporation of yogurt treated rice stubble compared to soil without it. A decrease in pH of the medium during anaerobic fermentation of rice straw followed by increase in the later stage of the experiment was reported (Zhao et al., 2014). A decrease in soil pH with rice straw application was earlier observed (Ayinla et al., 2016). On the other hand, an increase in soil pH with production of various organic acids following a decrease in early stage of rice straw decomposition was also reported (Kumari et al., 2008). Contrary to the changes in pH during short-term decomposition of rice straw in soil, the pH had remained unchanged or slightly increased under long-term experiments (Qin et al., 2011; Saothongnoi et al., 2014). The exchange acidity and total acidity of soil increased significantly due to incorporation of rice stubble, irrespective of treatment with yogurt. Increase in exchange acidity but decrease in total potential acidity during three months submergence was reported (Savant and Kibe, 1971). The bottom layer of the soil in the present work remained near saturation throughout the incubation which might have contributed to the observed change in exchange acidity.

| Parameter                        | Method                                                                 | Reference                      |
|----------------------------------|------------------------------------------------------------------------|--------------------------------|
| Bulk density                     | gravimetric method using undisturbed soil core (5.4 cm dia. and 12 cm height) | Blake and Hartge, 1986        |
| Particle density                 | pycnometer box                                                         | Baruah and Borthakur, 1997    |
| Water holding capacity           | Keen-Raczkowski box                                                   | Baruah and Borthakur, 1997    |
| Soil moisture content            | gravimetric method                                                     | Baruah and Borthakur, 1997    |
| Soil pH                          | soil:water (1:2.5) suspension, glass electrode pH meter                | Jackson, 1973                 |
| Cation exchange capacity         | centrifuge method                                                      | Baruah and Borthakur, 1997    |
| Exchangeable cations extraction  | leaching the soils with 1N CH₃COONH₄ (pH 7.0) solution under suction   | Baruah and Borthakur, 1997    |
| Ca²⁺ and Mg²⁺                    | Versenate titration method                                             | Richards, 1954                |
| Na⁺ and K⁺                       | flame photometer                                                       | Jackson, 1973                 |
| Al³⁺ extraction                  | 1 N KCl solution                                                       | Hesse, 1971                   |
| Al³⁺ estimation                  | spectrophotometer                                                      | Sivasubramaniam and Talibudeen, 1972 |
| NH₄⁺                             | 1 N Na₂SO₄-phenylmercuric acetate extraction and colorimetric estimation | Onken and Sunderman, 1977     |
| Exchange Acidity                 | 1 N KCl solution extraction and titration with 0.1 N NaOH (Sokolov, 1939) | McLean, 1965                  |
| Total acidity                    | 1N CH₃COONa extraction and titration with 0.1 N NaOH solution           | Kappen, 1934                  |
| Total potential acidity          | 0.5 N BaCl₂ and triethanolamine (pH 8.0-8.2) extraction, titration with 0.2 N HCl | Baruah and Borthakur, 1997    |
| Lime requirement                 | buffer solution (pH 6.5) extraction                                    | Shoemaker et al., 1961         |
Table 2: Soil moisture (%) content (w/w) at different days after incubation

| Treatments                                | Days after incubation |
|-------------------------------------------|-----------------------|
|                                           | 21       | 42       | 63       | 84       | 105      |
| Without rice straw (RS)                   | 29.5     | 30.8     | 28.6     | 27.2     | 29.1     |
| RS unincorporated                         | 27.4     | 31.6     | 28.6     | 27.2     | 29.1     |
| RS incorporated                           | 30.2     | 28.4     | 30.1     | 28.4     | 28.8     |
| RS treated, unincorporated                | 30.5     | 27.8     | 28.2     | 27.6     | 27.2     |
| RS-treated, incorporated                   | 28.6     | 30.1     | 29.6     | 30.2     | 29.5     |
| LSD<sub>P=0.05</sub>                      | NS       | NS       | NS       | NS       | NS       |
| CV %                                      | 6.3      | 5.8      | 8.3      | 6.8      | 5.8      |

Table 3: NH₄-N in soil at different days after incubation

| Treatments                                | NH₄-N (mg/kg) at days after incubation |
|-------------------------------------------|---------------------------------------|
|                                           | 21       | 42       | 63       | 84       | 105      |
| Without rice straw (RS)                   | 0.25     | 0.29     | 0.31     | 0.56     | 0.77     |
| RS unincorporated                         | 0.28     | 0.32     | 0.36     | 0.87     | 0.95     |
| RS incorporated                           | 0.28     | 0.34     | 0.39     | 0.91     | 1.10     |
| RS treated, unincorporated                | 0.30     | 0.36     | 0.42     | 0.82     | 1.07     |
| RS-treated, incorporated                   | 0.36     | 0.43     | 0.54     | 1.02     | 1.25     |
| LSD<sub>P=0.05</sub>                      | 0.06     | 0.05     | 0.08     | 0.11     | 0.08     |
| CV %                                      | 12.3     | 8.6      | 11.0     | 8.5      | 7.8      |

Table 4: NO₃-N content in soil at different days after incubation

| Treatments                                | NO₃-N (mg/kg) at days after incubation |
|-------------------------------------------|---------------------------------------|
|                                           | 21       | 42       | 63       | 84       | 105      |
| Without rice straw (RS)                   | 0.45     | 0.48     | 0.46     | 0.58     | 0.54     |
| RS unincorporated                         | 0.44     | 0.56     | 0.69     | 0.77     | 0.85     |
| RS incorporated                           | 0.47     | 0.64     | 0.76     | 0.82     | 0.81     |
| RS treated, unincorporated                | 0.48     | 0.59     | 0.70     | 0.85     | 0.77     |
| RS-treated, incorporated                   | 0.54     | 0.67     | 0.81     | 0.84     | 0.84     |
| LSD<sub>P=0.05</sub>                      | NS       | 0.10     | 0.12     | 0.11     | 0.14     |
| CV %                                      | 9.5      | 11.3     | 10.8     | 8.7      | 10.3     |

Table 5: Soil pH at different days after incubation

| Treatments                                | Soil pH at different days after incubation |
|-------------------------------------------|-------------------------------------------|
|                                           | 21       | 42       | 63       | 84       | 105      |
| Without rice straw (RS)                   | 4.70     | 4.73     | 4.60     | 4.63     | 4.60     |
| RS unincorporated                         | 4.63     | 4.68     | 4.55     | 4.53     | 4.50     |
| RS incorporated                           | 4.68     | 4.70     | 4.50     | 4.50     | 4.40     |
| RS treated, unincorporated                | 4.60     | 4.58     | 4.53     | 4.43     | 4.43     |
| RS-treated, incorporated                   | 4.63     | 4.58     | 4.50     | 4.40     | 4.38     |
| LSD<sub>P=0.05</sub>                      | NS       | NS       | NS       | NS       | 0.14     |
| CV %                                      | 3.7      | 5.5      | 1.9      | 4.7      | 4.1      |
### Table 6: Total potential acidity in soil at different days after incubation

| Treatments                      | Days after treatment [c mol (p⁺)/kg] | 21    | 42    | 63    | 84    | 105   |
|---------------------------------|--------------------------------------|-------|-------|-------|-------|-------|
| Without rice straw (RS)         |                                      | 18.9  | 17.6  | 18.6  | 17.8  | 18.1  |
| RS unincorporated               |                                      | 16.8  | 17.8  | 16.9  | 18.4  | 19.5  |
| RS incorporated                  |                                      | 17.6  | 18.2  | 18.2  | 20.1  | 18.8  |
| RS treated, unincorporated      |                                      | 19.2  | 19.1  | 18.6  | 19.4  | 20.3  |
| RS-treated, incorporated         |                                      | 17.8  | 19.5  | 19.3  | 20.0  | 20.5  |
| LSD_{P<0.05}                     |                                      | NS    | NS    | NS    | NS    | NS    |
| CV %                            |                                      | 8.2   | 7.0   | 5.9   | 5.7   | 6.7   |

### Table 7: Cation exchange capacity (CEC) and exchangeable cations [c mol (p⁺)/kg] in soil

| Treatments                      | CEC and exchangeable cations at 105 days after treatment | CEC | Ca^{2+} | Mg^{2+} | K⁺  | Na⁺  | Al^{3+} | *NH₄⁺  |
|---------------------------------|----------------------------------------------------------|-----|---------|---------|-----|------|---------|--------|
| Without rice straw (RS)         |                                                          | 5.49| 1.12    | 0.77   | 0.18logen | 0.14  | 0.46  | 4.26   |
| RS unincorporated               |                                                          | 5.74| 1.11    | 0.80   | 0.18 | 0.15 | 0.48   | 5.75   |
| RS incorporated                  |                                                          | 5.94| 1.21    | 0.87   | 0.21 | 0.16 | 0.50   | 6.11   |
| RS treated, unincorporated      |                                                          | 5.65| 1.15    | 0.79   | 0.19 | 0.16 | 0.45   | 5.96   |
| RS-treated, incorporated         |                                                          | 6.23| 1.24    | 0.88   | 0.22 | 0.15 | 0.52   | 6.37   |
| LSD_{P<0.05}                     |                                                          | 0.45| 0.09    | 0.07   | 0.03 | NS   | NS     | 0.64   |
| CV %                            |                                                          | 5.8 | 4.8     | 5.5    | 8.6  | 6.6  | 5.1    | 7.4    |

*× 10⁻³

### Table 8: Lime requirement (LR), WHC and available nutrients in soil at 105 days after treatment

| Treatments                      | LR* (t/ha) | %WHC (%) | Available nutrients (kg/ha) |
|---------------------------------|------------|----------|-----------------------------|
|                                 |            |          | N  | P  | K      |
| Without rice straw (RS)         | 11.9       | 43.28    | 259.7 | 5.77 | 161.8 |
| RS unincorporated               | 11.7       | 41.10    | 273.3 | 5.67 | 167.6 |
| RS incorporated                  | 11.8       | 44.90    | 266.6 | 6.24 | 174.8 |
| RS treated, unincorporated      | 10.9       | 42.90    | 271.0 | 5.97 | 161.3 |
| RS-treated, incorporated         | 12.2       | 46.43    | 278.1 | 6.38 | 182.3 |
| LSD_{P<0.05}                     | NS         | NS       | NS  | 0.47 | 12.5  |
| CV %                            | 8.2        | 8.7      | 5.3  | 5.1  | 4.8   |

*To raise the pH to 6.4, %WHC – water holding capacity.
Cation exchange capacity and exchangeable cations in soil

The cation exchange capacity and exchangeable cations in soil at 105 days of incubation are presented in table 7. The cation exchange capacity of soil significantly increased due to incorporation of rice stubble irrespective of glyphosate-yogurt treatment. The highest value was recorded for soil with rice stubble removal and the lowest for soil with incorporation of glyphosate-yogurt treated rice stubble. The effect of glyphosate-yogurt treatment was statistically not significant irrespective of incorporation or leaving stubbles on the surface. The exchangeable Ca\(^{2+}\), Mg\(^{2+}\) and K\(^+\) in soil were significantly increased due to rice stubble incorporation with or without glyphosate-yogurt treatment (table 7). The highest values for exchangeable Ca\(^{2+}\), Mg\(^{2+}\) and K\(^+\) were recorded for incorporation of glyphosate-yogurt treated rice stubble, while the lowest values were recorded for soil with removal of rice stubble. Similar to cation exchange capacity, the effect of glyphosate-yogurt treatment was statistically not significant irrespective of incorporation or leaving stubbles on the surface for exchangeable Ca\(^{2+}\), Mg\(^{2+}\) and K\(^+\) in soil. The exchangeable NH\(_4^+\) in soil significantly increased due to addition of rice stubble compared to their removal (table 7). The highest values for exchangeable NH\(_4^+\) were recorded for incorporation of glyphosate-yogurt treated rice stubble, while the lowest values were recorded for soil with removal of rice stubble. The effect of incorporation or glyphosate-yogurt treatment was not
statistically significant for exchangeable NH$_4^+$ in soil. The exchangeable Na$^+$ and Al$^{3+}$ in soil were not affected by the treatments during the incubation. The highest values for exchangeable Na$^+$ and Al$^{3+}$ in soil were recorded for unincorporated untreated rice stubble and incorporation of glyphosate-yogurt treated rice stubble, respectively. The lowest values for exchangeable Na$^+$ and Al$^{3+}$ in soil were recorded for rice stubble removal (table 7).

The cation exchange capacity (CEC), exchangeable Ca$^{2+}$, Mg$^{2+}$ and K$^+$ significantly increased due to rice stubble incorporation with or without yogurt treatment. Similar results were earlier reported for CEC (Ogbodo, 2011), Ca$^{2+}$ and Mg$^{2+}$ (Ogbodo, 2011; Ayinla et al., 2016) and K$^+$ (Ogbodo, 2011; Ayinla et al., 2016). The increase in CEC and exchangeable Ca$^{2+}$, Mg$^{2+}$ and K$^+$ may be attributed to corresponding increase in organic carbon contents of the soils due to enhanced decomposition of rice stubbles followed by retention of the cations in the exchange sites. The exchangeable NH$_4^+$ content in soil increased significantly due to addition of rice stubbles compared to without addition, irrespective of yogurt treatment or incorporation. Exchangeable NH$_4^+$ was the main pool of weakly fixed NH$_4^+$ in paddy soil (Matsuoka and Moritsuka, 2011) and application of rice straw significantly increased it corresponding to an increase in exchangeable NH$_4^+$, indicating weakly fixed NH$_4^+$ played as an intermediate pool between strongly fixed and exchangeable NH$_4^+$.

**Water holding capacity, lime requirement and available nutrients in soil**

The values for lime requirement (LR), water holding capacity (WHC) and available nutrients of soil at 105 days after incubation are presented in table 8. The lime requirement and water holding capacity of the soils were not affected by the treatments.

In case of available nutrients, the available nitrogen content of soil was not affected by the treatments (table 8). The available phosphorous and potassium in soil significantly increased due to incorporation of rice stubble, irrespective of glyphosate-yogurt treatment. The effect of adding rice stubble with or without glyphosate-yogurt treatment was statistically not significant compared to without rice stubble for both available phosphorous and potassium in soil. The organic carbon content (K$_2$Cr$_2$O$_7$ wet oxidation) of the soils (data not presented here) was not affected by the treatments up to 84 days of incubation, and increased with incorporation of glyphosate-yogurt treated rice stubble compared to without rice stubble.

The non-significant difference in water holding capacity and lime requirement, and significant increase in available phosphorous content of soils due to stubble addition are in conformity to those reported elsewhere (Zhou et al., 2002; Wei et al., 2015). The significant increase in phosphorous content of soils can be attributed to the fact that phosphorous as a constituent of crop residues was mineralized and released into the soil increasing the phosphorous content in soil. The available potassium content of soil increased due to incorporation of rice stubble with or without yogurt treatment and conform to the results reported earlier (Li et al., 2014; Zhu et al., 2019). The significant increase in potassium content in soils due to rice stubble incorporation can be attributed to enhanced decomposition of the substrate.

In conclusion the decomposition of rice stubble in paddy soil under constant moisture regime had greater effect on NH$_4$-N than NO$_3$-N, exchange and total acidity than pH.
and selected exchangeable cations and available nutrients than cation exchange capacity. The changes in N-fractions, forms of acidity, available nutrient contents and specific biological parameters in soil during and after decomposition of rice stubble need further study in response to fertilizer, organic manure, soil amendment application and crop growth.

References

Anonymous (2019). Agricultural Statistics - District wise Area, Production and Average Yield of Different Crops, Directorate of Economics and Statistics, Government of Assam. https://des.assam.gov.in/information-services/agriculture. Accessed on 24th June 2019.

Ayinla, A.A., Olayinka, B.U. and Etejere, E.O. 2016. Rice straw: a valuable organic manure for soil amendment in the cultivation of groundnut (Arachis hypogaea). Environmental and Experimental Biology, 14: 205–211.

Bailey, A., Deasy, C., Quinton, J., Silgram, M., Jackson, B. and Stevens, C. 2013. Determining the cost of in-field mitigation options to reduce sediment and phosphorus loss. Land Use Policy, 30: 234-242.

Baruah, T.C. and Barthakur, H.P. 1997. A textbook of soil analysis. Vikash Publishing, PVT Ltd., New Delhi.

Bezbaruah, K.P. 2017. Soil properties and summer moong bean yield under winter rice stubble management. M. Sc. (Agri) Thesis, Assam Agricultural University, Jorhat-785013, Assam, India.

Bhattacharjee, B., Saha, N., Debnath, A., Sen, S., Roy, S.S. and Mukherjee, D. 2013. In situ Management of Rice Stubble in Relation to Soil Nitrogen Status Vis-a-Vis Performance of Wheat Crop in an Entisol. American-Eurasian Journal of Agricultural & Environmental Sciences, 13 (7): 943-956.

Blake, G.R. and Hartge, K.H. 1986. Bulk density In: Methods of Soil Analysis. Part I – Physical and Mineralogical Methods. Second edition. Klute, A. (ed.). American Society of Agronomy, Madison WI.

Borah, N.; Barua, R., Pathak, P.K., Barua, I.C., Hazarika, K. and Phukan, A. 2016a. Rice stubble decomposition by cellulose degrading microbe and yogurt with glyphosate under rainfed upland ecosystem. International Journal of Agriculture Sciences, 8(20): 1350-1353.

Borah, N.; Barua, R., Nath, D., Hazarika, K., Phukon, A., Goswami, K. and Barua, D.C. 2016b. Low energy rice stubble management through in situ decomposition. Procedia Environmental Science, 35: 771-780.

Borah, Nilay., Pathak, P.K., Barua, R., Hazarika, K., Phukon, A. and Bezbaruah, K.P. 2016c. Stubble decomposition (in situ) of two rice varieties through microbial inoculation. In Ghosh, S.K. (ed) Utilization and Management of Bioresources. Proceedings of 6th IconSWM 2016, Pages 65-76.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total organic and available forms of phosphorus in soils. Soil Science, 59: 39-45.

Conyers, M.K., Tang, C., Poile, G.J., Liu, D.L., Chen, D., Nuruzzaman, M. 2011. A combination of biological activity and the nitrate form of nitrogen can be used to ameliorate sub surface soil acidity under dryland wheat farming. Plant and Soil, 348: 155-166.

Doberman, A. and Fairhurst, T.H. 2002. Rice straw management. Better crops international. 16 (Special supplement), pp. 7-11.

Handayanto, E., Cadish, G. and Giller, K.E. 1994. Nitrogen release from prunings of legume hedgerow trees in relation to
quality of the prunings and incubation method. *Plant and Soil*, 160: 237-248.

Hesse, P.R. 1971. *A textbook of soil chemical analysis*. John Murray Publishers Ltd. London.

Hiloidhari, M. and Baruah, D.C. 2011. Crop residue biomass for decentralized electrical power generation in rural areas (part 1): Investigation of spatial availability. *Renewable and Sustainable Energy Review*, 15: 1885-1892.

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi, India.

Kappen, G. 1934. Pochvennaya Kislotnost, Selkhogiz, Moscow, (cf. *J. Indian Soc. Soil Sci.* 39: 246, 1991).

Knoblauch, R., Ernani, P.R., Deschamps, F.C., Gatiboni, L.C., Walker, T.W., Lourenço, K.S., Martins, A.A. and Pegoraro, A. 2014. Rice straw incorporated just before soil flooding increases acetic acid formation and decreases available nitrogen. *Revista Brasileira de Ciencia do Solo*, 38: 177-84.

Kumari, A., Kapoor, K.K., Kundu, B.S. and Mehta, R.K. 2008. Identification of organic acids produced during rice straw decomposition and their role in rock phosphate. *Plant and Soil Environment*, 54: 72-77.

Kusel, K., Roth, U. and Drake, H. L. 2002. Microbial reduction of Fe(III) in the presence of oxygen under low pH conditions. *Environmental Microbiology*, 4: 414-421.

Latifah, O., Ahmeda, O.H. and Majid, N.M.A. 2018. Soil pH buffering capacity and nitrogen availability following compost application in a tropical acid soil. *Compost Science and Utilization*, 26: 1-15.

Li, J., Lu, J., Li, X., Ren, T., Cong, R. and Zhou, L. 2014. Dynamics of potassium release and adsorption on rice straw residue. *PLOS ONE*, 9: 904-940.

Mandal, K.G., Mishra, A.K.; Hati, K.M., Bandyopadhyay, K.K., Ghosh, P.K. and Mohanty, M. 2004. Rice residue management options and effects on soil properties and crop productivity. *Food Agriculture and Environment*, 2 (1): 224-231.

Mary, B., Recous, S., Darwis, D. and Robin, D. 1996. Interactions between decomposition of plant residues and nitrogen cycling in soil. *Plant Soil*. 181: 71–82.

Matsuoka, K. and Moritsuka, N. 2011. Dynamics of clay-fixed ammonium as a sink or source of exchangeable ammonium in a paddy soil. *Soil Science and Plant Nutrition*, 57: 751–758.

McLean, E.O. 1965. In Methods of Soils Analysis, Part II, (C.A. Black, Ed.), *American Society of Agronomy Inc*. Madison, Wisconsin, USA.

Mikola, J., Bardgett, R.D. and Hedlund, K. 2002. Biodiversity, ecosystem functioning and soil decomposer food webs. In M. Loreau, S. Naeem and P. Inchausti (eds), *Biodiversity and Ecosystem Functioning: synthesis and perspectives*. Oxford University Press. pp. 169-180.

Mohanty, M., Probert, M.E., Reddy, K.S., Dalal, R.C., Rao, A.S. and Menzies, N.W. 2010. Modelling N mineralization from high C:N rice and wheat crop residues. *19th World Congress of Soil Science, Soil Solutions for a Changing World, 1-6 August 2010, Brisbane, Australia.*

Muller, M.M., Sundman, V., Soininvaara, O. and Merilainen, A. 1988. Effect of chemical composition on the release of nitrogen from agricultural plant materials decomposing in soil under field conditions. *Biology and Fertility of Soils*, 6: 78-83.

Naramabuye, F.X. and Haynes, R.J. 2006.
Effect of organic amendments on soil pH and Al solubility and use of laboratory indices to predict their liming effect. *Soil Science*, 171: 754-763.

Ogbodo, E.N. 2011. Effect of crop residue on soil chemical properties and rice yield on an Ultisol at Abakaliki, Southeastern Nigeria. *World Journal of Agricultural Sciences*, 7: 13-18.

Onken, A.B. and Sunderman, H.D. 1977. Colorimetric determination of exchangeable ammonium, urea, nitrate and nitrite in a single soil extract. *Agronomy Journal*, 69: 49-58.

Pandey, A.K., Gaind, S., Ali, A. and Nain, L. 2009. Effect of bioaugmentation and nitrogen supplementation on composting of paddy straw. *Biodegradation*, 20: 293-306.

Qin, R., Chen, F. and Gao, J. 2011. Long-Term Application of chemical fertilizers and rice straw on soil aluminum toxicity. *Communications in Soil Science and Plant Analysis*, 42: 66–74.

Richards, L.A. 1954. Diagnosis and improvement of saline-alkali soils. *Agricultural Handbook*, USDA, pp. 60.

Ros, G.H., Temminghoff, E.J.M. and Hoffland, E. 2011. Nitrogen mineralization: a review and meta-analysis of the predictive value of soil tests. *European Journal of Soil Science*, 62: 162-173.

Rosolem, C.A., 2011. Exchangeable basic cations and nitrogen distribution in soil as affected by crop residues and nitrogen. *Brazilian Archives of Biology and Technology*, 54: 441-450.

Saonthongnoi, V., Amkha, S., Inubushi, K. and Smakgahn, K. 2014. Effect of rice straw incorporation on soil properties and rice yield, *Thai Journal of Agricultural Science*, 47: 7-12.

Savant, M.K. and Kibe, M.M. 1971. Influence of continuous submergence on pH, exchange acidity and pH-dependent acidity in rice soils. *Plant and Soil*, 25: 205-208.

Shoemaker, H. E., McLean, E. O. and Pratt, P.F. 1961. Buffer methods for determining lime-requirement of soils with appreciable amounts of extractable aluminium. *Proceedings of the Soil Science Society of America*, 25: 274-277.

Singh, B.; Bronson, K. F.; Singh, Y.; Khera, T. S. and Pasuquin, E. (2001). Nitrogen-15 balance as affected by rice residue management in a rice-wheat rotation in northwest India. *Nut. Cycl. Agroeco*. 59: 227–237.

Sivasubramaniam, S. and Talibudeen, O. 1972. Potassium-aluminium exchange in acid soil. 1. Kinetics. *Journal of Soil Science*, 23: 163-176.

Sokolov, A. V. 1939. Kimizastia sots Zemledelia, 7, (c.f. J. Indian Soc. Soil Sci. 246, 1991).

Subbiah, K. and Asija, G.L. 1956. A rapid procedure for determination of available nitrogen in soils. *Current Science*, 25: 259-260.

Takahashi, S., Uenosono, S. and Ono, S. 2003. Short- and long-term effects of rice straw application on nitrogen uptake by crops and nitrogen mineralization under flooded and upland conditions. *Plant and Soil*, 251:291–301.

Tiedje, J.M. 1988. Ecology of denitrification and dissimilatory nitrate reduction to ammonium. In A. J. Zehnder and W. Stumm (eds.), Biology of Anaerobic Microorganisms. Wiley, New York. pp. 179–243.

Tuyen, T.Q. and Tan, P.S. 2001. Effects of straw management, tillage practices on soil fertility and grain yield of rice. *Omonrice*, 9: 74–78.

Vanlauwe, B., Nwoke, O.C., Sanginga, N. and Merckx, R. 1996. Impact of residue quality on the C and N mineralization of leaf and root residues of three agroforestry species. *Plant and Soil*, 183:
Van Asten, P.J.A., van Bodegom, P.M., Mulder, L.M. and Kropff, M.J. 2005. Effect of straw application on rice yields and nutrient availability on an alkaline and a pH-neutral soil in a Sahelian irrigation scheme. *Nutrient Cycling in Agroecosystems*, 72: 255-266.

Weber, J., Karczewska, A., Drozd, J., Licznar, M., Licznar, S., Jamroz, E. and Kocowicz, A. 2007. Agricultural and ecological aspects of a sandy soil as affected by the application of municipal solid waste composts. *Soil Biology and Biochemistry*, 39: 1294-1302.

Wei, T., Zhang, P., Wang, K., Ding, R., Yang, B., Nie, J., Jia, Z. and Han, Q. 2015. Effects of wheat straw incorporation on the availability of soil nutrients and enzyme activities in semiarid areas. *PLoS One*, 10(4).

Xiao, X.; Cheng, Z., Meng, H., Liu, L., Li, H. and Dong, Y. 2013 Intercropping of green garlic (*Allium sativum* L.) induces nutrient concentration changes in the soil and plants in continuously cropped cucumber (*Cucumis sativus* L.) in a plastic tunnel. *PLoS ONE*, 8(4): 62-173. https://doi.org/10.1371/journal.pone.0062173.

Xu, R.K. and Coventry, D.R. 2003. Soil pH changes associated with lupin and wheat plant materials incorporated in a red-brown soil. *Plant and Soil*, 250: 113-119.

Xu, J.M., Tang, C. and Chen, Z.L. 2006a. Chemical composition controls residue decomposition in soils differing in initial pH. *Soil Biology and Biochemistry*, 38: 544-552.

Xu, J.M., Tang, C. and Chen, Z.L. 2006b. The role of plant residues in pH change of a acid soils differing in initial pH. *Soil Biology and Biochemistry*, 38: 709-719.

Yana, C., Dua, T., Yana, S., Donga, S., Gonga, Z. and Zhang, Z. 2018. Changes in the inorganic nitrogen content of the soil solution with rice straw retention in northeast China. *Desalination and Water Treatment*, 110: 337-348.

Yang, S., Wang, Y., Liu, R., Xing, L. and Yang, Z. 2018. Improved crop yield and reduced nitrate nitrogen leaching with straw return in a rice-wheat rotation of Ningxia irrigation district. *Scientific Reports*, 8: 9458. DOI:10.1038/s41598-018-27776-5.

Zhao, H., Yu, H., Yuan, X., Piao, R., Li, H., Wang, X. and Cui, Z. 2014. Degradation of lignocelluloses in rice straw by BMC-9, a composite microbial system. *Journal of Microbiology and Biotechnology*, 24: 585-591.

Zhou, J., Xu, D. and Xue, C. 2002. Study of comprehensive utilization efficiency of returning rice straw to field. *Chinese Agricultural Science Bulletin*, 4: 3-13.

Zhu, D., Zhang, J., Wang, Z., Muhammad, R.K., Lu, J. and Li, X. 2019. Soil available potassium affected by rice straw incorporation and potassium fertilizer application under a rice–oilseed rape rotation system. *Soil Use and Management*, https://doi.org/10.1111/sum.12507.

How to cite this article:

Suravi Nandi, Binoy K. Medhi, Rajen Barua, Mrinal Saikia, Hemanta Saikia, Kashyap P. Bezbaruah, Prantika Kakati, Anupama Das and Nilay Borah. 2020. Nitrogen Mineralization, Forms of Acidity and Fertility Status of a Paddy Soil as Influenced by Rice Stubble Management. *Int.J.Curr.Microbiol.App.Sci*. 9(08): 720-733. doi: [https://doi.org/10.20546/ijcmas.2020.908.078](https://doi.org/10.20546/ijcmas.2020.908.078)