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NITROGEN RELEASE PATTERNS OF UREA AND NANO UREA FERTILIZER UNDER TWO CONTRASTING SOIL MOISTURE REGIMES

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ABSTRACT

Nitrogen is one of the key fertilizer input used by the farmers today. Nitrogen release from different N sources depends on the soil environment. Fertilizer material which showing slow N release could be useful to increase the efficiency of the inputs while minimizing the environmental contaminations. Therefore, this laboratory incubation study was designed to evaluate the nitrogen release pattern of the nano fertilizer and compared with that of a commercial fertilizer urea in Reddish Brown Latosol (RBL) under submerged and upland moisture regimes. Treatments were replicated five times and the incubation was end after two weeks. Differential N release kinetics of the nano urea (NU) and urea (U) were determined by measuring ammonium-N and nitrate-N contents at 2 days interval. Net N released, as a percentage of available N, was greater in the urea (65-73%) and nano urea scored respectively a low value (40%) under upland moisture condition 98% and 71% under submerged moisture regime in the short term incubation. The results indicate that nano urea shows slow release pattern of nitrogen in both submerged and upland moisture regime in RBL.

Key words: Available nitrogen, Commercial Fertilizer, Incubation, Nano urea

Introduction

Nitrogen is one of the key fertilizer input used by the farmers today. Nitrogen present mainly in organic form (98%) in soil. Remaining 2% inorganic part comprises of NH_4^+ (immobile) and NO_3^- (highly mobile) forms. More than half of the N fertilizer applied is lost and results not only in an environmental hazard but also a substantial economic loss (Matson et al., 1997). Urea is the most widely used fertilizer globally because of its high nitrogen content (46%), low cost, easy availability, rapid action and ease of application (Zheng et al,2009). Urea, when applied to crops is vulnerable to losses by, denitrification, volatilization, run off and leaching.

In Sri Lanka normal urea is the most popular and abundantly using nitrogen fertilizer. Owing to high responsiveness to the application famers tend to apply higher doses of N to their crops which in return increases susceptibility to pest and diseases. Apart from that use of higher N rates increases the risk of chemical contaminations of both food and ground water.

Slow release nitrogen fertilizer will be plant beneficiary. When comparing to chemical fertilizers requirement and cost, nano fertilizers are economically cheap and are required in lesser amount (Rameshaiah et al., 2015). Coating and binding of nano and sub nano-composites are able to regulate the release of nutrients from the fertilizer capsule (Liu et al., 2006). This is because a farmer can fertilize less often by providing the nutrients slowly and steadily. Besides being more efficient in the utilization of the applied nutrients, slow-release technologies also reduce the impact on the environment and the contamination of the subsurface water (Sartain., 2011). Therefore, this study was designed with followings objectives.

- To determine nitrogen release patterns of a urea and Nano urea fertilizer under submerged and upland conditions
- To compare the temporal N released from Nano urea and normal urea under two contrasting moisture condition.

MATERIALS AND METHODS

Location

The study was laboratory incubation study which was carried out at the soil science laboratory of Horticultural Crops Research and Development Institute HORDI, Gannoruwa- Peradeniya, which is located in WM2b agro ecological region of Sri Lanka at latitude of 7° 16 N and longitude of 80°43'E. The elevation is 530m above from the sea level. The study was conducted during the period of October 2015 to February 2016.

Climatic condition

The average maximum temperature of this area is around 30°C and minimum temperature is around 21°C. The relative humidity is about 75% in day time and 70% in the evening. The area has a bimodal rain fall pattern with a 75% expectancy of 1800-2200mm annual rain fall. The solar radiation is around 6.1 hours per day.

Soil Type

Major soil type of this area is Reddish Brown Latasolic (RBL) which is belongs to order Ultisol. The parent materials are mainly residuum and slope colluviums from the basic and intermediate rocks of the khondolite series and also there are few members associated with quartzites and acid charnockites.

Experimental design and Treatments

The laboratory incubation experiment was focused on two fertilizers with two moisture levels. The study was arranged in a completely randomized design (CRD) consists of three treatments and five replicates (Table 1). Urea and nano urea fertilizer was applied to upland and submerged soil at the rate of 100kg/ha Nitrogen.

Table 1 Description of treatments

Treatment	Description
T1	No fertilizer
T2	Urea (100kg/ha of N)
T3	Nano urea (100kg/ha of N)

Laboratory incubation experiment was conducted by using 4 inch size polythene bags. This was tested for upland and submerged moisture regime and totally fifteen samples were maintained for one type of moisture regime. Each bag was filled with 250 g air dried soil. Four holes were made at the bottom of the polythene bags for upland moisture regime treatments to facilitate drainage and completely sealed polythene bags were used in submerged moisture regime treatments. One week after incubation, small scale soil samples were incorporated with fertilizers at the rate of 100 kg/ha and poly bags were filled with tap water in accordance to the water holding capacity and evaporation rate. Additionally, the 100 ml of water was added to submerged moisture regime. During the period of experiment constant moisture content was maintained.

Analysis of soil samples

Differential N release kinetics of the nano urea (NU) and urea (U) were determined by measuring ammonium- and nitrate-N contents at 2 days interval over 2 weeks. Soil samples were drawn in every two days from experimental bags to test nitrate and ammonium. Ammonical nitrogen was determined by steam distillation with MgO, titration using kjeldahl equipment (Bremner and Keeney, 1965). Nitrate nitrogen was determined by was measured calorimetrically using a Spectrophotometer (Kalra and Maynard 1991).

Statistical Analysis

The data collected from laboratory incubation experiments were tabulated and Analysis of Variance (ANOVA) was done by using Minitab 14 version and Microsoft Excel 2007 package.

RESULTS AND DISCUSSION

Soil characterization

The soils used in this study were taken from two different places. Upland soil was taken from upland field and low land soil was taken from submerged paddy field. Reddish Brown Latasol (RBL) is the major soil type in this area. Soil characterization was done before the start of the experiment. Results of physiochemical analysis of soils are presented in table 2.

Table 2. Physiochemical properties of study soil

Soil property	Upland soil	Submerged soil
pH(1:1)	5.72	5.59
Electric conductivity(EC)(1:5)	153.7µs/cm	85.65 µs/cm
Organic matter content	2.44	3.4
Amonical Nitrogen	10.83 mg/Kg	12.053 mg/Kg
Nitrate nitrogen	6.31 mg/Kg	5.12 mg/Kg
Available P	14.83 mg/Kg	22.4 mg/Kg
Available K	221.89 mg/Kg	107.69 mg/Kg
Water holding capacity	46.05%	49.17%

Nutrient composition of two different N sources

The fertilizer sources used in this study were analyzed initially for nutrient composition. Results of nutrient analysis presented in table 3.

Table 3 Nutrient composition in the fertilizer

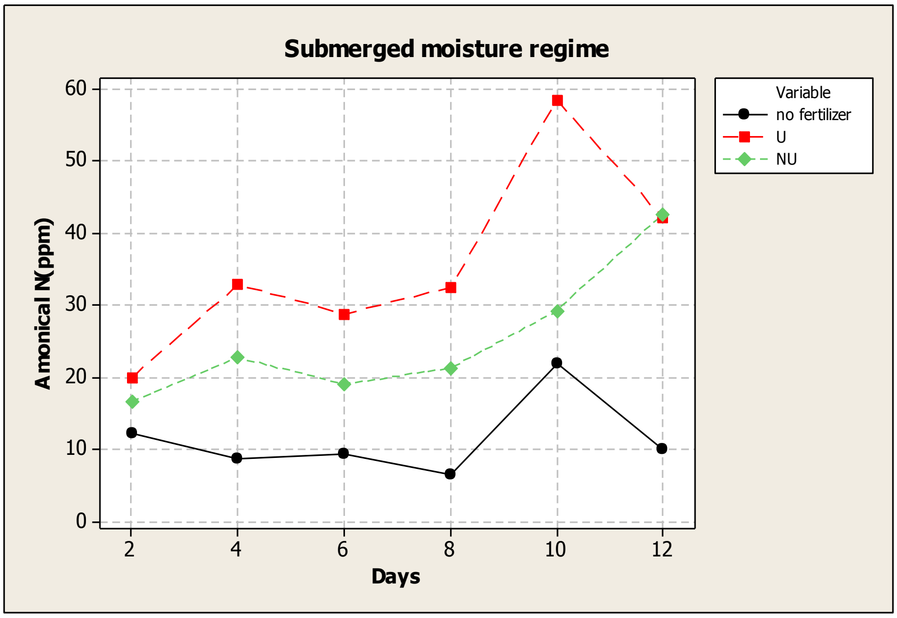
Nutrient	NU	U
Total Nitrogen(N)	37.6%	46%
Potassium (K)	0	0
Phosphorous (P)	21.53%	0

Urea is major N source which consist only N. But nano urea has $Ca_3(PO4)_2$. Because of that nano urea consist typically high phosphorous content.

Behavior of ammonical N in submerged soil

Behavior of ammonical nitrogen in submerged soil showed an increasing trend (figure 1). Significant differences were noticed on ammonical N among all the treatments.

Figure 1 Behavior of ammonical N under submerged condition



There was significant difference between urea (U) and nano urea (NU) pattern, after two days and ammonical nitrogen in urea treated soil sample showed a drop and coincide with nano urea after twelve days. How ever U maintained a higher amonical N content correspond to T3 (NU) during the incubation period.

Table 4 Behavior of ammonical N under submerged condition.

	Ammonical N (mg/Kg)					
	2 days	4 days	6 days	8 days	10 days	12 days
No fertilizer	12.052^{c}	8.586^{c}	9.200^{b}	6.470^{c}	21.880^{b}	12.030^{b}
U	19.932^{a}	32.810^{a}	28.750^{a}	32.420^{a}	58.310^{a}	42.012^{a}
NU	16.478^{b}	22.660^{b}	18.970^{b}	21.240^{b}	29.190^{b}	42.510^{a}

Means followed by the same letter in each column are not significantly different to Tukey's family error rate at 5% level

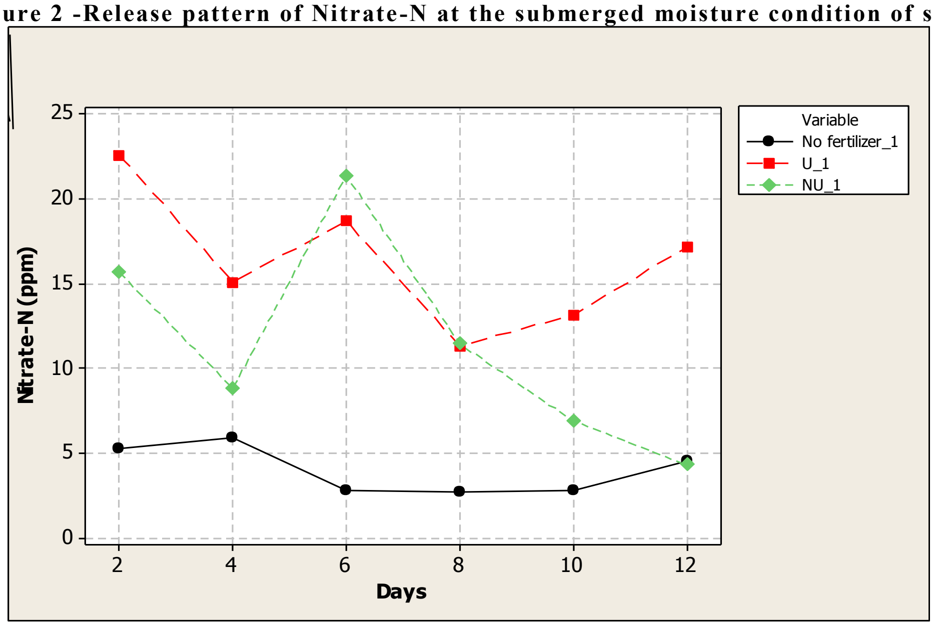
Ammonical N in T3(NU) increased slowly indicating the slow release nature under the submerged condition, the soil oxidation-reduction potential decreased rapidly after the initial submergence (Patrick., 1964). Hence, ammonification is prominent and NH_4 –N is dominant compared to NO_3 –N. Prolonged duration of soil submergence increased phenolic content of soil organic matter and increased mobile humic acid and calcium humate content (Buresh et al., 2008) which can be the reason for enhance acidity. Increase in acidity favors the n retention in the form of ammonium.

Behavior of Nitrate-N in submerged soil

Significant changes were noticed on soil nitrate nitrogen within whole the period among treatments. But significant difference among T3 (NU) and T2 (U) was observed at twelfth day only. After 8 days there was significant difference among U and NU(

figure 2). In case of U showed deviation from no fertilizer and NU shows convergence to no fertilizer. Depletion of oxygen is main process which is affecting N transformations in submerged soil (Ponnamperuma, 1972).

Figure 2 -Release pattern of Nitrate-N at the submerged moisture condition of soil.



When a soil is submerged with water, the supply of O_2 into the soil is greatly reduced because the diffusivity of O_2 in water is less than its diffusivity in air. As a result of this decrease in gas exchange between air and soil after submergence, the supply of O_2 cannot meet the demand of aerobic organisms. After a few hours to days, anaerobic microorganisms accumulate in soil layers. Facultative and anaerobic organisms use oxidized soil substrates as electron acceptors in their respiration, thus reducing the soil components in a sequence predicted by thermodynamics (Buresh et al,. 2008). So due to O_2 depletion NO_3-N content in submerged soils can convert to amonical N. The other hand nitrate is also subjected to denitrification.

Behavior of available N (NH_4^+-N + NO_3^- -N) in submerged soil

The result indicated that there was significant difference in available N content between U and NU treated soil relative to the untreated soil (Table 5). In U treated soil 98.2% of applied N was released after twelve days when NU released only 73%. Hito-ichi (1976) cites 12 kg/ha of mineralized nitrogen, after two weeks from application of urea in flooded Maahas clay soil under field and laboratory conditions during dry season.

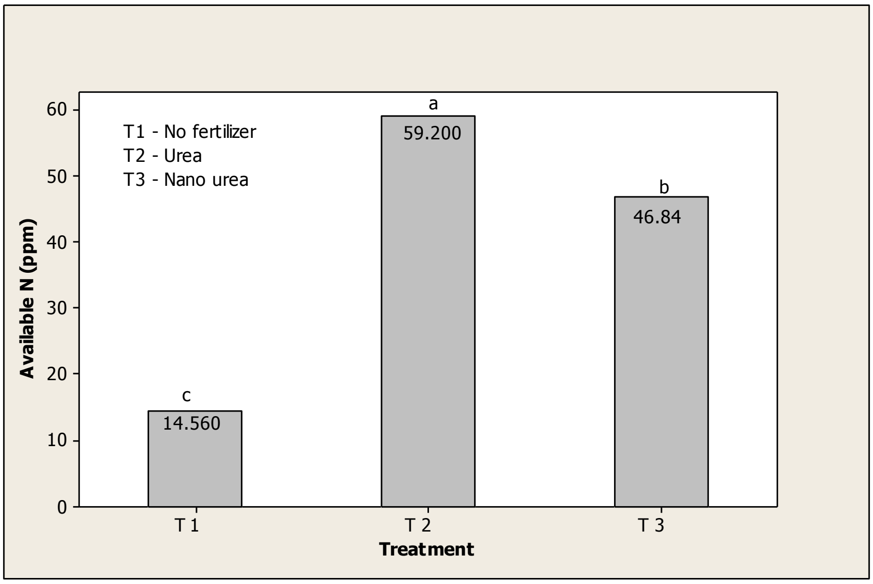
Table 5 Behavior of available N (NH_4^+-N + NO_3^- -N) at submerged condition

	Ammonical N (mg/Kg)					
	2 days	4 days	6 days	8 days	10 days	12 days
No fertilizer	17.280 ^{c}	14.530 ^{c}	11.980 ^{c}	9.170 ^{c}	19.816 ^{c}	14.560 ^{c}
U	42.520^a	47.900 ^{b}	47.440 ^{a}	43.750 ^{a}	58.520 ^{a}	59.200 ^{a}
NU	32.160^b	31.460 ^{c}	40.400 ^{b}	32.690 ^{b}	29.590 ^{b}	46.840 ^{b}

Means followed by the same letter in each column are not significantly different to Tukey's family error rate at 5% level

Nitrification is the biological conversion of NH_4^+ to NO_3^- requires free O_2. As a result the magnitude of nitrification is regulated by the availability of O_2, which determines the fraction of the total soil volume occupied by aerobic zones, and $NH4^+$ concentration in these aerobic zones. Ammonium in aerobic zones originates from formation by ammonification within the aerobic zone, inputs of external N including fertilizer, and diffusion of NH4+ from adjacent anaerobic soil zones. Nitrate does not accumulate in the anaerobic zone because of the high demand for NO_3^- to serve as an electron acceptor in the absence of O_2. Denitrification is the reduction of NO_3^-, to gaseous end products of nitrous oxide (N_2O) and nitrogen gas (N_2). Denitrification is mediated by heterotrophic microorganisms; and its rate is regulated by NO_3^- concentration and available C, which serves as an energy source or electron donor (Aulakh et al., 2000).

Figure 3 Available-N at 12 days after fertilizer application under submerged condition of soil.

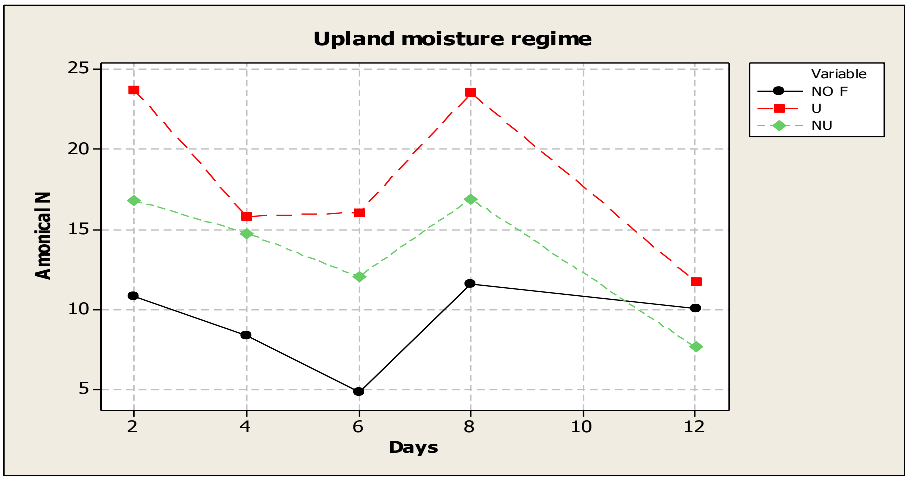


In this study percolation and leaching was limited. So volatilization is the major transformation can be occurred as a loss. NU shows maximum 71.016% release within twelve days, and it is typically low value related to U release. Because of surface modification with hydroxyl appetite nano particles nano urea shows such behavior. Sahrawat and Narteh (2001, 2003) indicated that mineralizable N under anaerobic incubation is controlled by the contents of OM and reducible iron. Mineralization in the soils may depend on the soil order and the associated clay type, as well as the fraction of residual N that is fixed on to the clays (Jensen et al., 2000).

Behavior of ammonical N in upland moisture condition

Table 6 shows irregular pattern in both NU and U. The results of ammonical nitrogen of NU and U of upland soil did not show significant difference up to 6 days (figure 4).

Figure 4 Behavior of ammonical N in upland moisture condition



On 4th day shows typically high Ammonical-N value in U treated sample than NU treated sample, but not significant difference and rest of the part NU shows typically low values than U.

Table 6 Behavior of ammonical N in Upland soil condition.

	Ammonical N (mg/Kg)				
	2 days	**4 days**	**6 days**	**8 days**	**12 days**
No fertilizer	10.828 ^{b}	8.324 ^{a}	4.800^{b}	11.562^{c}	10.044^{ab}
U	23.711^{a}	15.813^{a}	16.022^{a}	23.534^{a}	11.740^{a}
NU	16.802 ^{a}	14.742^{a}	12.025^{a}	16.888^{b}	7.618^{b}

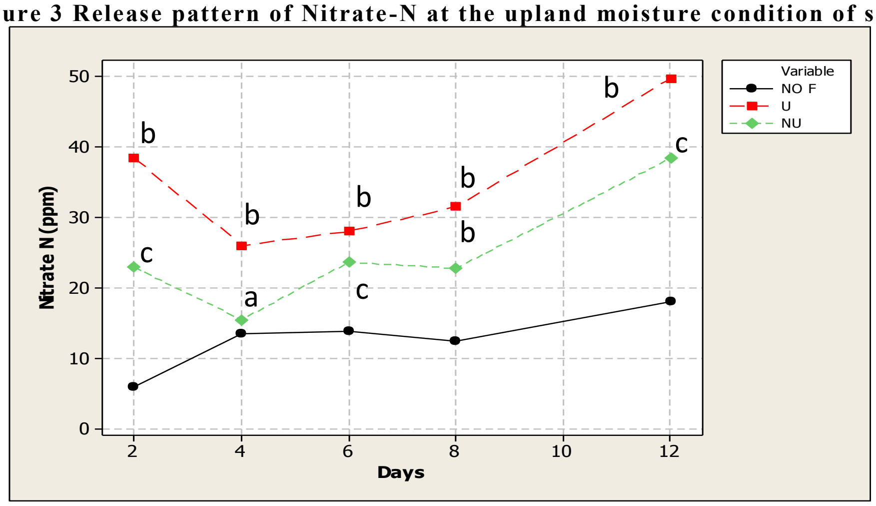
Means followed by the same letter in each column are not significantly different toTukey's family error rate at 5% level

Nitrification is oxidation process which carried out by soil microorganisms. So acceleration or deduction of nitrification rate is depend on environmental conditions. It may be cause to fluctuation of ammonical N. Under the aerobic condition NH_4^+ is convert in to NO_3^- rapidly. So NH_4^+ nitrogen can be typically less than NO_3^- nitrogen. The soil which has high organic matter content has high nitrification.

Behavior of Nitrate-N in upland moisture condition

Nitrate nitrogen content in soil was significantly influenced by application of U and NU. After four days significant differences were observed between NU and U (Figure 3).

Figure 3 Release pattern of Nitrate-N at the upland moisture condition of soil.



The graph shows gradual increasing trend in U treated sample from 4th day .The ammonical N in NU treated sample showed gradual reduction, rapid increase and sudden drop. Nitrification is prominent in upland soil, because of aerobic condition. Regarding upland soil O_2 is not limited so nitrification can be occur easily and can be increase NO3- nitrogen in soil. Nitrate formed by nitrification is stable within an aerobic zone. But under low oxygen concentrations giving rise to the phenomena of nitrifier denitrification (Colliver and Stephensen, 2000) and which causes deduction in NO_3- nitrogen in soil

Behavior of Available N in upland moisture condition

The effects of applied U and NU on available nitrogen of soil are presented in Table 7. There was significant difference in available soil nitrogen between U and NU treated samples. But both U and NU showed an increasing trend with the time period.

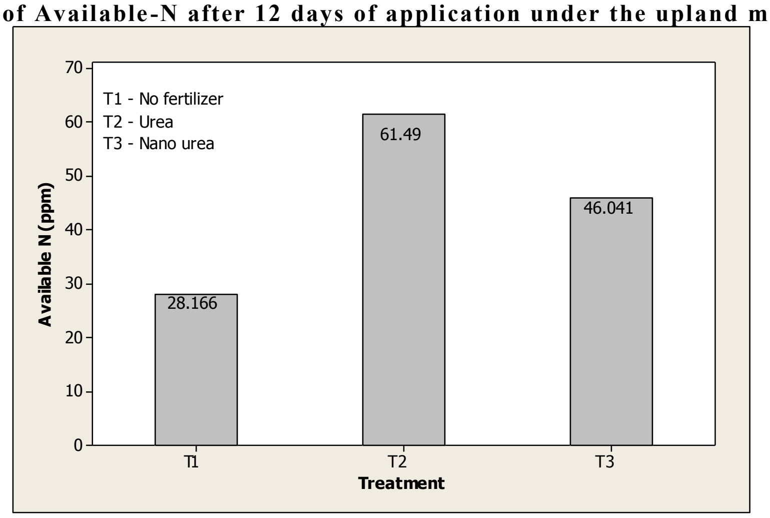
Table 7 Behavior of Available N in Upland soil condition.

	NH_4^+-N + NO_3^--N (mg/Kg)				
	2 days	4 days	6 days	8 days	12 days
No fertilizer	16.750^{c}	21.810^{c}	18.710^{b}	23.960^{c}	28.166^{c}
U	62.130^{a}	41.900^{a}	44.14^{a}	55.090^{a}	61.490^{a}
NU	39.754^{b}	30.270^{b}	35.73^{a}	39.580^{c}	46.041^{b}

Means followed by the same letter in each column are not significantly different toTukey's family error rate at 5% level

Initial values of available-N both urea and nano urea shows somewhat unbelievable high values, it may be due to improper mixing or due to contamination of fertilizer particle which have not dissolved. But rest of the data shows a U and NU shows gradual increasing trend. However at the end of two weeks 73% of applied N was released by U. But in case of NU it was 39%. The N release pattern of U is differs from N release pattern of untreated soil. N releasing behavior of NU shows a slow and sustained release of N. Kottegoda et al (2011) reported that, 35% of N in Urea-modified hydroxyapatite nanoparticles encapsulated wood and 48% of N in convectional urea was released within 16 days after application at 5.2 pH soil. Urea-encapsulated HA nanoparticles localized within the smaller volumes of intercellular spaces may release nitrogen at the final stages during slow release. Manikandan et al (2013) reported that the N release from the urea blended with NZ (1:1) was up to 48 days while the conventional Zeo - urea (1:1) mix was up to 34 day and the N release ceased to exist in urea within 4 days under ambient conditions. Regarding to this experiment, NU and U both showed higher N release under in submerged soil condition than upland soil during the period of two weeks. The available N in upland soil and submerged soil were different on 12th day after application may be due to different composition of microbial in different soils**.**

Figure 4 Quantity of Available-N after 12 days of application under the upland moisture condition.



CONCLUSION

This study revealed that there was significant difference in N release behavior between the two N sources. In both upland and submerged condition nano urea showed a delay in N release compared to urea. More than 70% N was released from urea in two week's time period while only 39% N was released from NU in the incubation study under upland moisture condition. It is interesting to that the release of N was much quicker and greater under submerged conditions. Slow release pattern of Nano urea was observed clearly and, the study reveals that NU has slow releasing property under both aerobic and anaerobic condition of soil. So Nano Urea can be recommended as suitable nitrogen source for upland and submerged soil.

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