Comparative Effects of Urea Intercalated with Poultry Manure on Soil Properties, Growth Parameters, Nitrogen Contents and Grain Yield of Rice

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Abstract

The study investigated the efficiency of intercalating Urea fertilizer with organic materials on Nitrogen (N) release, growth parameters, grain yield and N contents in soil and plant tissue under field condition at two locations. Urea fertilizer was intercalated with raw and composted poultry manure through a chemical method. Urea intercalated with raw poultry manure (UIP) and Urea intercalated with Poultry manure compost (UIC) were applied at three rates (40, 60 and 80 Kg N ha^{-1}) together with urea fertilizer at 60 kg N ha^{-1}and control. Three seeds of rice (FARO 64) per hole were sown at a spacing of 25 cm by 25 cm and the experiment was arranged in Randomized Complete Block Design with four replicates per treatment. Soil samples were collected at both sites before sowing and after harvesting for analyses. The greenness index, plant height, stem girth and tiller numbers of the rice plants were monitored and determined. Grain yields of the rice plants were also determined. Results showed positive effects of urea intercalated fertilizers on all parameters though not significantly different in both locations. Tissue N contents in Urea fertilizer alone, UIP and UIC at 60 Kg N ha^{-1} were 1.23, 1.12 and 1.19 % respectively. Intercalation of urea with poultry manure and compost had positive effects on grain yield. Greenness index in intercalated fertilizers were higher than Urea alone treated plots at eight weeks after planting. The UIP at 80 kg N ha^{-1} had the highest liming potential. This study showed the potential of Urea intercalated fertilizer as a slow-release N-fertilizer, liming ability, and environmentally friendly management strategy for sustainable crop production.

Keywords: Urea, Intercalation, Slow-Release Fertilizer, Compost, Nitrogen

Introduction

Nitrogen is an essential nutrient required in the large amounts in crop production (Walworth, 2013). Nitrogen is pertinent in the functioning of important components of biochemical reactions in plants such as chlorophyll and most often deficient in soils (Saidu *et al.,* 2012; Adepetu *et al.,* 2014), which limits efficient and profitable crop production (Mikkelson and Hartz, 2008). About 65% of N applied in crop production is lost through runoff, gaseous emissions, erosion, and leaching, due to high N mobility in soils (Bhattacharje *et al.,* 2008; Manikandan and Subramanian, 2015), resulting in groundwater pollution and eutrophication (Subramanian, 2011). Nitrogen inform of nitrate ion is easily lost in the soil because nitrate ion has a negative charge and does not attract to the negatively charged soil particles like ammonium ion, thus, rainfall can easily leach N down the soil profile (Bijay-Singh and Craswell, 2021). The current world population of about 8 billion is expected to reach 9.7 billion in 2050, thus, there is increase in global demand for food, feed, and fibre, with consequent increase demand for fertilizers to sustain large scale production of plants and animals. Therefore, there is need to improve N use efficiency in soils to achieve viable crop production.

Rice (*Oryza sativa*) is one of the most important grain crops of the world, that are widely grown in different climatic zones, to provide food for mankind. It has been found that judicious and proper use of fertilizers can improve the yield and quality of rice (Bahmaniar and Ranjbar, 2007). Adequate supply of N fertilizer to rice plant at early stage of planting could increase plant N uptake and agronomic parameters such as the plant height, stem girth, number of rice tillers. Inappropriate N management can be detrimental to rice production and the environment. It is therefore important to adopt optimal N management strategies aim at equating N supply with actual crop demand, thus maximizing crop N uptake and minimizing N losses to the environment (Dong *et al.,* 2016).

Common N fertilizers in Nigeria are Urea (46% N), Ammonium sulphate (21% N, 24% S) and Diammonium phosphate or DAP (18% N; 44−46% P_2O_5), but urea is the most commonly use N fertilizer due to its high N value (Gardinier *et al.,* 2013; Adepetu *et al.,* 2014). Leaching, volatilization and denitrification are common pathways of N loss in the soil (Adhikari and Chen, 2011; Lamb *et al.,* 2014). Due to high rainfall intensity common in humid regions like Nigeria, N leaching is especially a serious problem (Nielson, 2006; Esu, 2010). Continuous use of N fertilizers often leaves acidic residues in soil and nutrient imbalance, with consequent reduction in nutrient uptake (Aduayi, 1980; Ojeniyi, 2000). To minimize N loss in soil while maintaining a sustainable environment and economic benefits to the farmers, it is therefore necessary to develop a technology that will promote N sustainability in the soil by adopting appropriate methods such as application of fertilizer in splits, varying the timing of fertilizer application (Alonge *et al.,* 2007; Koochekzadeh *et al.,* 2009; Amujoyegbe *et al.,* 2007; Law-Ogbomo, 2013). Some of the shortcomings of these methods includes, time consuming and laborious, difficulty in quantifying the amount of N from manure (Mikkelsen and Hartz, 2008). Therefore, research on the rational method of N application is of great importance in the fertilization of rice plants.

The use of slow- release N fertilizer such as urea intercalated with organic materials, has been found to enhance growth parameters and N uptake in rice plants, because of potential reduced N loss, and in reducing split applications of N in soils. Previous findings have reported the efficacy of organically intercalated urea as a source of slow-release N fertilizer (Manikandan and Subramanian, 2013; 2015). This method has dual advantages; slow release of N and addition of organic matter (OM) to soil, which helps to neutralize acidic residual effect arising from long term application of N fertilizers. In Nigeria, not much works have been done on the use of urea intercalated with organic materials as slow release N fertilizers (Ogundiran *et al.,* 2015). The use of raw and composted poultry droppings to intercalate urea will slow down the rate of N release, thus, enhance N use efficiency and reduced N loss to the environment.

Therefore, the objective of this study was to determine the efficiencies of slow-release N fertilizers derived from urea intercalated with different organic materials on soil properties, growth parameters, grain yield and N contents of soil and plant tissues.

Materials and Methods

Description of the study areas

The study was conducted at two locations: The Teaching and Research Farm, Obafemi Awolowo University, Ile – Ife (TRF) (Ultisol, the field is in a rainforest and lies between longitude 4°32`E and latitude 7°32`N); and The International Institute of Tropical Agriculture (IITA) (Alfisol, located in derived savannah and lies between longitude 3°99`E and latitude 7°42`N). The average annual temperature and rainfall in Ile-Ife and Ibadan respectively are 25.3 °C and 1509 mm; and 25.9 °C and 1467 mm.

Preparation of intercalated fertilizers

Two organic materials (raw and dried poultry manure and composted poultry manure) were used to intercalate urea using the method described by Manikandan and Subramanian (2015). Ten gram of urea fertilizer was weighed and mixed with 10 mL of deionised water to obtain urea suspension. The slurry was heated on a hot plate at 105°C with constant stirring till the crystals turned into solution. Ten gram of the organic material was thoroughly mixed with the N-fertilizer solution. Mixture was dried in a hot air oven at 65°C till the moisture was completely exhausted. One gram of adhesive polymer (starch) air dried and powdered before use, was added to the mixture. The product was used as intercalated Urea fertilizer for field experimentation.

Field Experiment

The land was ploughed and harrowed and thereafter levelled manually. For each location, the fertilizer treatments, urea intercalated raw poultry manure (3 rates), urea intercalated composted poultry manure (3 rates), were applied at the rate of 40, 60 and 80 kg N/ha^{-1} in one dose, urea alone (1 rate) was applied at the standard recommended rate of 60 kg N/ha^{-1} in two doses to reduce N losses, and control (1 rate). The plots were replicated four times to give a total of 32 plots which were arranged in a randomized complete block design. Upland rice (FARO 64 variety) was planted and all treatments received basal application of P and K based on the soil test values. Three seeds of rice were planted at a depth of 2-3 cm with the dribbling method. Sixty four hills of rice were planted per plot with a plot size of 2 m by 2 m, and at planting distance of 25 cm by 25 cm with 1 m alley (Oikeh *et al.,* 2008). The urvea intercalated fertilizer at all the rates were applied at 26 DAS (days after seeding), just after first weeding. Urea alone at 60 kg N/ha, which is the standard blanket rate (Oikeh *et al.,* 2008) was applied in two splits. First at 26 DAS, and then at 4 weeks afterwards (54 DAS). The crops in TRF were harvested at 14th weeks after seeding while the crops at IITA were harvested at 15th weeks after seeding when the grains were hard and turning yellow or brown.

At harvest, grain yield and tissue N content were determined. Two crops per plot were sampled for their plant growth parameters and these plants were used as reference crops for data collection throughout sampling. The plants were sampled for plant height, stem girth and tiller numbers. To determine greenness index, the chlorophyll reading of the leaves were taken using the Chlorophyll meter (SPAD, Konica Minota) for 5 weeks from 8 WAS (weeks after seeding) to 12 WAS. According to Beegle and Lingenfelter (2008), it is advisable to take the readings before the six-leaf stage of growth of the cereal crop because physiological maturity is reached at this stage. The Flag leaves of selected plants per plot were harvested at 91 DAS and taken to the Soil Science Laboratory of Obafemi Awolowo University, Ile-Ife, Nigeria immediately for nutrient composition analysis.

Soil Sampling and Analyses

Soil sample (0-15 cm) was collected before planting and after harvesting from TRF and IITA. Before laboratory analyses, air-dried soil samples were sieved to <2 mm. Particle size analysis was determined using modified hydrometer method by dispersing the soil with 100 ml of 0.2 M sodium hydroxide (Bouyoucos, 1962). Soil pH was determined with a standardized digital pH meter in a 1:2 w/v suspension of air-dry soil and 0.01 M $CaCl_2$ after a 1-hour equilibration period. Soil organic carbon was determined using Walkley and Black (1934) method, while the total N was determined using micro-Kjeldahl digestion and distillation procedure (Bremner and Mulvaney, 1982). The available phosphorus was determined using Bray-1 method (Bray and Kurtz, 1945). Exchangeable cations were extracted using 1 N neutral ammonium acetate solution (Soil Survey Staff, 2003). The concentrations of Na and K were determined using flame photometer while Ca and Mg were determined using Atomic Absorption Spectrophotometer.

Plant samples from different plots were oven-dried at 68°C for 48 h before analyses. Concentration of N in the plant samples was determined on a 0.5 g dry samples using micro-Kjeldahl digestion and distillation procedure (Bremner and Mulvaney, 1982).

Statistical Analysis

All analyses were carried out using SAS 9.4 (SAS Institute, 2013). Data generated were subjected to Analysis of Variance and differences in mean were separated using the Tukey's Honest Significant Difference (HSD) Test at 95 % confidence interval.

Results and Discussion

Chemical Properties of Organic materials before and after Intercalation

The chemical properties of organic

materials before and after intercalation are shown in Table 1. Total N in the raw poultry droppings was found to be higher than in the compost as confirmed by earlier work done by Carl and Bierman (2005). Total N in intercalated materials increased as expected compared with raw and composted poultry droppings which was because of the presence of urea and the success of intercalation process. For example, total N in raw poultry droppings and intercalated poultry droppings were 1.33 and 29.27 %, respectively. The result of FTIR and Pyrolysis GC analyses of urea intercalated with raw poultry and composted poultry manure were in close conformity (Ogunseiju, 2017). However, Urea fertilizer alone had the highest N content.

The pH values of raw poultry manure (9.1) were higher than composted (6.5). This could be because of formation of humic acids during the composting process which was in line with the finding of Khoi *et al.* (2010). After intercalation, the pH of raw poultry manure decreased, while pH of composted poultry droppings increased. In addition, the pH values of compost and urea intercalated compost remained the same in 0.01 M $CaCl_2$. However, the final pH values showed the liming effects of the organically intercalated fertilizers.

Noteworthy observations were the increase in total N and decrease in organic carbon contents of the poultry droppings after intercalation, but no change in % organic carbon was observed with compost after intercalation. This could be due to the fact that compost had been degraded up to a stable point. The C: N ratios of raw and composted poultry manure also reduced after intercalation (Table 1). This suggests that application of intercalated raw and composted poultry manure to soil will enhance microbial activities with consequent increase in organic matter decomposition and mineralization.

Table 1: Chemical Properties of Organic Materials before and after Intercalation

Parameters	Poultry manure	Urea intercalated raw poultry manure	Compost	Urea intercalated composted poultry manure
pH(0.01 M $CaCl_2$)	9.1	8.7	6.5	8.0
Organic C (%)	10.52	4.09	5.45	5.45
Total N (%)	1.33	29.27	0.84	23.64
C: N	7.91	0.14	6.49	0.23

Table 2: Physical and Chemical Properties of the Soil used for the Study

Parameters	TRF, OAU (Rainforest)	IITA (Derived Savannah)
Sand (%)	72	74
Silt (%)	16	14
Clay (%)	12	12
Textural Class	**Sandy loam**	**Sandy loam**
Soil pH (0.01 M $CaCl_2$)	5.0	5.6
Total Nitrogen (%)	0.175	0.525
Organic Carbon (%)	1.52	1.32
Available P (mg kg^{-1})	1.87	30.54
Exch. Cations (cmolkg^{-1})		
K	0.15	0.49
Na	0.02	0.03
Ca	1.71	1.32
Mg	0.21	0.13

Physical and Chemical Properties of Soil used for the Study

The physical and chemical properties of soils used for the study are shown in Table 2. The particle size class of both soils were sandy loam with 72, 16 and 12 % sand, silt and clay in TRF respectively, and 74, 14, 12 % in IITA for sand, silt and clay respectively. The high sand content was expected because both soils had their origin from granite gneiss which has an average quartz content of 25 % (Esu, 2010; Buol *et al.,* 1973). The pH of soil samples in 0.01 M CaCl2 from TRF, OAU (5.0) was lower than soil samples from IITA (5.6), indicating a strongly acidic condition (Foth *et al.,* 1990, Esu 2010). This could be due to the differences in base saturation, as ultisol is more weathered than alfisol with consequent lower base saturation and that could explain lower pH recorded in TRF, OAU (Baquy *et al.,* 2018).

Lower values in total N and organic carbon (OC) were recorded for soil samples from OAU compared with soil samples from IITA. This could be as a result of continuous cropping without adequate replenishment of lost nutrients which was prevalent at the TRF, OAU (Esu 2010, Buol *et al.,* 2011, Adepetu *et al.,* 2014).

Greenness Index

The recording of the values for greenness index, chlorophyll content, (Tables 3 and 4) started five weeks after seeding because the

Table 3: The greenness index of rice field in TRF, OAU

Treatments	Weeks				
	8	9	10	11	12
Control	25.3d	33.3b	33.9bc	39.9ab	39.6a
UIC 40	28.3cd	32.4b	31.1c	38.6b	39.6a
UIC 60	31.4abc	33.0b	33.4bc	38.4b	40.2a
UIC 80	32.5a	36.3ab	36.3ab	41.4ab	41.3a
UIP 40	27.7cd	32.7ab	34.1bc	39.8ab	40.1a
UIP 60	31.3abc	35.7ab	34.2bc	39.7ab	40.8a
UIP 80	32.1ab	35.7ab	34.2bc	39.8ab	39.6a
Urea 60	30.4ab	40.0a	40.7a	45.3a	42.4a

Means with the same letters in the same column are not significantly different from each other at ($p \leq 0.05$) according to Tukey's Honest Significant Difference Test. Where Urea 60 = Urea at rate 60 kg N ha^{-1}; UIC 40, UIC 60 and UIC 80 = urea intercalated compost at rates 40, 60 and 80 kg N ha^{-1} while UIP 40, UIP 60 and UIP 80 = urea intercalated poultry manure at rates 40, 60 and 80 kg N ha^{-1} respectively.

Table 4: The greenness index of rice field in IITA

Treatments	Weeks				
	8	9	10	11	12
Control	35.8a	35.2b	35.7b	34.2b	37.2a
UIC 40	36.2a	36.2b	36.4a	34.0b	36.4a
UIC 60	36.9a	36.5b	35.7b	35.4b	36.7a
UIC 80	37.6a	36.7b	36.5b	34.3b	36.6a
UIP 40	36.1a	35.6b	35.1b	33.9b	37.4a
UIP 60	36.8a	35.2b	35.7b	33.9b	35.7a
UIP 80	37.2a	35.9b	37.0b	35.5b	37.3a
Urea 60	38.0a	44.8a	44.0a	40.8a	39.5a

Means with the same letters in the same column are not significantly different from each other at ($p \leq 0.05$) according to Tukey's Honest Significant Difference Test. Where Urea 60 = Urea at rate 60 kg N ha-1; UIC 40, UIC 60 AND UIC 80 = urea intercalated compost at rates 40, 60 and 80 kg N ha^{-1} while UIP 40, UIP 60 AND UIP 80 = urea intercalated poultry manure at rates 40, 60 and 80 kg N ha^{-1} respectively.

ability of the chlorophyll meter to effectively measure the greenness index is best noticed during the later weeks of planting (Beegle and Lingenfelter, 2008). The greenness index recorded for plants grown in plots amended with the intercalated fertilizers showed higher values, (32.1, 31.3, 31.4) than urea (30.4) at eight weeks after seeding and significantly different from control plots except for plots treated with Urea intercalated fertilizers at 40 kg N kg^{-1}. However, in the ninth week, after the second split application of urea fertilizer, an increase in the greenness value for urea treated plot was observed, and the value gradually decreased until the 12th week after seeding, when the recording was stopped. The result was in close conformity with earlier research findings (Adhikari and Chen, 2011; Collins, 2013). At the 12th week of application, it was found that there was no significant difference ($p \leq 0.05$) in the greenness index among rice plants on the urea intercalated plots and the urea alone treated plots. This has serious implication in rice production because, booting often starts after the 12th week which is a critical period in which rice plants need nitrogen (Oikeh *et al.,* 2008). Furthermore, rates of application of treatments had no significant effect on the greenness index observed among the rice plants on urea intercalated plots and urea alone treated plots. However, steady and gradual increase in greenness index was observed in plots treated with only intercalated fertilizers, thus affirming their slow release of nitrogen potentials at both locations.

Effect of Intercalated Fertilizers on grain yield and growth parameters of rice across locations (*Oryza Sativa*)

The effect of intercalation on growth parameters of the rice plants was observed on the field and recorded in Table 5. There was no significant difference ($p \leq 0.05$) in all the growth parameters measured among plants grown on plots treated with intercalated fertilizer and urea alone, though slightly higher values of stem girth and plant height were recorded for plots amended with the intercalated fertilizers as against urea treated plots and control plots at the 4th and 8th week. This is an indication that the nutrients supplied from the intercalated fertilizers application were effective enough to those supplied with sole inorganic fertilizer. This is in conformity with findings of Saidu *et al.* (2012) in which there was no significant differences ($p \leq 0.05$) in plots treated with urea and poultry droppings and urea alone. For instance, stem girth of rice plants in plots treated with intercalated poultry manure and compost at rate of 40 kg N ha^{-1} both had values of 0.93 cm

Table 5: Growth parameters for the rice crops across locations

Treatments	Weeks								
	4			8			12		
	Plant height (cm)	Stem girth (cm)	No. of tillers	Plant height (cm)	Stem girth (cm)	No. of tillers	Plant height (cm)	Stem girth (cm)	No. of tillers
Control	7.94a	0.80a	3a	17.7a	0.98a	3a	65.2a	1.39b	4a
UIC 40	7.97a	0.93a	3a	18.8a	1.05a	4a	69.5a	1.53ab	4a
UIC 60	6.95a	0.84a	4a	18.3a	1.07a	4a	65.2a	1.58ab	4a
UIC 80	8.41a	0.90a	3a	20.9a	1.15a	4a	71.7a	1.56ab	4a
UIP 40	8.12a	0.93a	4a	18.8a	0.98a	4a	66.1a	1.41ab	4a
UIP 60	7.70a	0.84a	3a	20.3a	1.10a	4a	71.0a	1.46ab	4a
UIP 80	8.53a	0.87a	3a	20.7a	1.15a	4a	73.8a	1.51ab	4a
Urea 60	7.95a	0.87a	4a	19.0a	1.04a	4a	71.5a	1.64a	4a

Means with the same letters in the same column are not significantly different from each other at ($p \leq 0.05$) according to Turkey's Honest Significant Difference Test. Where Urea 60 = Urea at rate 60 kg N ha^{-1}; UIC 40, UIC 60 AND UIC 80 = urea intercalated compost at rates 40, 60 and 80 kg N ha^{-1}while UIP 40, UIP 60 AND UIP 80 = urea intercalated poultry manure at rates 40, 60 and 80 kg N ha^{-1} respectively.

as against 0.87 cm of urea alone treated plots at the end of the 4th week. Similarly, plant height of rice plants treated with urea intercalated raw poultry droppings was 73.8 cm as against 71.5 cm of urea alone treated plots at the 12th week. No significant difference was observed among the different rates, but intercalated fertilizer applied at 80 kg N ha^{-1} performed best for both urea intercalated poultry manure and urea intercalated compost. Our result is comparable with the findings of Saidu *et al.* (2012) in which the application of 80 kg N ha^{-1} resulted in highest plant height at 60 days after seeding. Fertilizer types and rates did not significantly affect the number of tillers across the two locations.

There were no significant treatment effects on grain yield parameter at both locations, although, treated plots had positive effects on grain yield. At T&RF OAU, the grain yield in plots treated with UIC 80 (773 kg ha^{-1}) and UIP 80 (770 kg ha^{-1}) were comparable with Urea alone (655 kg ha^{-1}) (Fig. 1), suggesting that urea intercalated fertilizers had potentials for enough nutrients release to those supplied by urea alone. Similar results were obtained at IITA (data not shown).

Chemical properties of soil after harvesting

The effect of the urea intercalated fertilizers on the chemical properties of soil after harvesting for both locations are shown in Table 6. There was no significant difference (p≤0.05) in all the parameters between the chemical properties of soils amended with the intercalated fertilizers and that of urea alone. Although, an increase in the soil pH was observed in the urea intercalated plots, showing the liming properties of the added treatment. Among the intercalated treated plots, highest values of soil pH were observed with plots treated with 80 kg N ha^{-1} of the intercalated fertilizers. Similar trends were observed with soil organic carbon (OC) and total N. This result suggested that urea intercalated fertilizers with organic manure have potential to release enough nutrients for plant uptake comparable to urea fertilizer alone.

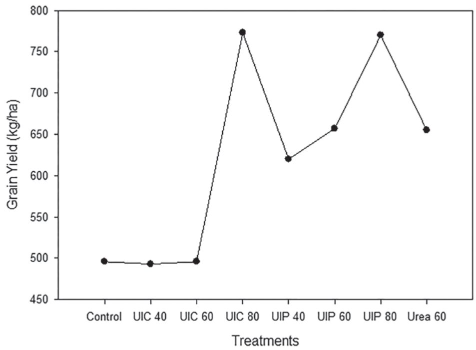

Figure 1: The grain yield of rice crop at T&RF, where Urea 60 = Urea at rate 60 kg N ha^{-1}; UIC 40, UIC 60 AND UIC 80 = urea intercalated compost at rates 40, 60 and 80 kg N ha^{-1}while UIP 40, UIP 60 AND UIP 80 = urea intercalated poultry manure at rates 40, 60 and 80 kg N ha^{-1} respectively.

Table 6: Selected soil chemical properties after harvest at TRF, OAU and IITA

Treatments	pH (0.01 M $CaCl_2$)	Organic Carbon (%)	Total N (%)
Control	5.8a	1.61a	1.267a
UIC 40	5.8a	2.03a	1.382a
UIC 60	5.9a	2.05a	1.286a
UIC 80	6.0a	1.89a	1.382a
UIP 40	5.8a	1.71a	1.348a
UIP 60	5.8a	1.83a	1.286a
UIP 80	5.9a	1.89a	1.356a
Urea 60	5.7a	1.79a	1.266a

Means with the same letters within the same column are not significantly different from each other at (p ≤ 0.05) according to Tukey's Honest Significant Difference Test. Where Urea 60 = Urea at rate 60 kg N ha^{-1}; UIC 40, UIC 60 and UIC 80 = urea intercalated compost at rates 40, 60 and 80 kg N ha^{-1} while UIP 40, UIP 60 and UIP 80 = urea intercalated poultry manure at rates 40, 60 and 80 kg N ha^{-1} respectively.

Nitrogen content of plant tissue

The effect of intercalation on tissue N content for both locations was determined by the N tissue content and presented in Table 7. Rice plant grown on plots treated with Urea fertilizer alone had the highest N content at the T&RF, OAU and was significantly ($p \leq 0.05$) higher than rice plants grown on urea intercalated fertilizer at 60 and 80 kg ha^{-1}. Rice plant grown on control plot had the lowest N content in the plant tissue. At IITA, there was no significant difference in the N content of the rice plants in the plots amended with the urea intercalated fertilizers and urea treated plots. However, urea intercalated compost at the rate of 60 kg N ha^{-1} had the highest tissue N concentration, similar to previous study where compost in complementary application with inorganic N fertilizer had higher N, P and K contents than sole application of inorganic N fertilizer (Law-Ogbomo, 2013).

Table 7: Tissue concentrations (%) of N at the TRF, OAU and IITA

Treatment	TRF OAU	IITA
Control	0.86b	0.64a
UIC 40	0.95ab	0.77a
UIC 60	1.19ab	0.98a
UIC 80	1.19ab	0.77a
UIP 40	0.98ab	0.81a
UIP 60	1.12ab	0.63a
UIP 80	1.02ab	0.84a
Urea 60	1.23a	0.77a

Means with the same letters within the same column are not significantly different from each other at ($p \leq 0.05$) according to Tukey's Honest Significant Difference Test. Where Urea 60 = Urea at rate 60 kg N ha^{-1}; UIC 40, UIC 60 and UIC 80 = urea intercalated compost at rates 40, 60 and 80 kg N ha^{-1} while UIP 40, UIP 60 and UIP 80 = urea intercalated poultry manure at rates 40, 60 and 80 kg N ha^{-1} respectively.

Conclusions

This study was carried out to compare the efficiencies of slow-release N fertilizers derived from urea intercalated with different organic materials. The total N content in urea intercalated poultry manure was about 30%, a little lower than urea fertilizer thus showing the success of intercalation. The Greenness index was indicative of slow and sustained release of nitrogen from the urea intercalated fertilizer amended soils than urea alone fertilized soils. The tissue N content of rice plants from plots treated with urea intercalated fertilizers clearly revealed the potentials of these fertilizers to reduce N loss and improve N use efficiency. Soil acidity was drastically reduced in all the plots treated with Urea intercalated with organic materials compared with Urea treated plots and control, indicative of their liming potentials. Plots amended with urea intercalated poultry manure at the rate 80 kg N ha^{-1} had the highest liming potential. The study revealed the potential of urea-intercalated fertilizers as slow-release fertilizers. However, further work should be carried out to determine the residual effects of these intercalated fertilizers on the field.

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