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Migration of Soil Ammonium- Nitrogen with Amended Poultry and Sheep Manures in Ultisols of Ihiagwa, Southeastern Nigeria

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Abstract: - Soil management to synchronizing nutrient release with crop uptake is essential for sustainable plant production and environmental quality. Ammonium- nitrogen (NH_4^+- N) dynamics of poultry and sheep manures amended Ultisols in Ihiagwa, Southeastern Nigeria were evaluated. Their levels equivalent to 0, 30 and 60 % N of both poultry and sheep manures were applied in a 3^2 factorial arranged in randomized complete block setup with three replications. The NH_4^+- N was determined from four soil depths (0 – 5, 5 – 10, 10 – 20 and 20 – 40 cm) at different weeks (1, 2, 3, 4, 6, 8 and 12 weeks) after manures application (WAMA) in wet and dry seasons of 2019 and 2020. Soil NH_4^+- N differed with rates of poultry and sheep manures only and the integration of both manure at various soil depths, seasons and years. Concentrations of NH_4^+- N in most soil depths at both seasons and years were better with 60 % then 30 % N of poultry and sheep manures alone and with integrations of both manures better than single applications. Averaged over soil depths and periods after manure applications, soil ammonium- nitrogen was better in wet than dry seasons and in 2019 than 2020. Averaged over soil depths, manure rates, seasons and years, concentrations of NH_4^+- N varied and better at 3rd WAMA. Equally, concentrations of NH_4^+- N decreased down soil depths. Generally, good soil nutrient management will be useful for efficiency of nutrient and sustained crop yields. Further research is needed on the field to substantiate the findings.

Keywords: Soil ammonium- nitrogen, poultry manure, sheep manure, Ultisols, Southeastern Nigeria.

I. Introduction

Soil is an essential resource and a vital part of the natural environment from which most of the global food is produced [10]. It is the only medium that interacts with the atmosphere, lithosphere, biosphere and hydrosphere. It is one of the Earth's life-sustaining components which serve as physical support for plants and source of water and nutrients for plants and soil microbes [37]. It is a non– renewable resource over the human time scale [33], with its growing problems making it imperative for sound management. Soil degradation lowers its fertility and productivity and as such crop response to applied nutrient is influenced by soil properties especially, the nutrients reserve ([25], [29], [43]). Based on its properties, soils could be classified (USDA) into different types with Ultisols constituting about 72 % of soils of Southeastern, Nigeria [22].

Ultisols are group of soils with an argillic or kandic horizon (silicate clay) and a few basic cations that have developed under forest vegetation in humid climates [53]. They are found in intensely weathered humid areas and have a subsurface acidic horizon with appreciable translocated clays [39]. The warm temperatures and abundant variability of moisture enhance its weathering process and increase the rate of leaching. Its base saturation decreases with depth [48], with the clay types mainly 1: 1 types and varying amounts of hydrous oxides of Fe and Al. High kaolinite content of its mineralogy cause a low shrink–swell potential and thus relatively favorable for water retention. Also, most Ultisols have a thick sandy epipedons and/ or horizons with high bulk density that may limit water storage and root proliferation [53]. Typically, productivity of Ultisols of Southeastern Nigeria is constrained by high acidity and poor fertility status [28]. The soil pH often ranges between 4.8 and 5.5. Organic matter content, total N, available P, exchangeable bases (Ca^{2+}, Mg^{2+} and K^+) and cation exchange capacity (CEC) are invariably low to very low [8] while the sand fractions are dominated by such minerals as haematite, goethite, gibbsite with quartz dominating the clay mineralogy [45]. Some of the crop production problems in Southeastern Nigeria include low fertility status, highly weathered soils, high leaching, and low organic matter and available nutrients. Hence, organic manure can be used to restore such fertility.

Plants use nitrogen from soils in form of ammonium and nitrates. The (NH_4^+- N) and (NO_3^-- N) are formed when nitrogen enters the soil solution. Nitrate – nitrogen accumulates in the soil, but ammonium – nitrogen does not. Nitrate – nitrogen can easily be leached from the soil than ammonium – nitrogen with rainfall or irrigation water [21]. Addition of manures to soils is accompanied by certain transformation processes that include mineralization, immobilization, nitrification and volatilization of nitrogen. There is therefore a need to understand the dynamics of NH_4^+- N with widespread deficiencies in Ultisols of Southeastern,

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue VII July 2023

Nigeria in order to sustain soil productivity. The main objectives of this study were to determine the effect of poultry and sheep manures on the: (i) soil NH_4^+- N at varying soil depths, (ii) soil NH_4^+- N at varying periods and years after manure application.

II. Materials and Methods

2.1 Site description

The study location was at Teaching and Research farm of Federal University of Technology, Owerri, Imo State on Latitudes 5° 05' and 5° 23' N and Longitudes 7° 02' and 7° 21' E in the humid rain forest agro-ecological zone of Nigeria with altitude 482 m/ 1581 ft. Its mean annual rainfall, mean monthly temperature and relative humidity were 2,500 mm, 32 °C and 85 % respectively [15]. Geographical positioning system (GPS) equipment was used to determine site specific coordinates which were Latitude 5^0 22' 55'' N Longitude 6^0 59' 44'' E and Latitude 5^0 22' 23'' N Longitude 6^0 59' 26'' E, Latitude 5^0 22′ and 54″ N Longitude 6^0 59′ 32″ E and Latitude 5^0 22′ 48″ and N Longitude 6^0 59′ 29″ E for the first, second, third and fourth seasons respectively. The climax vegetation of the site was dominated by *Acio bacteri* and *Abememia oduratum* with soil type being Arenic hapludult [47].

2.2 Soil and Manure Sampling and Preparations

The experimental design was a 3^2 factorial replicated three times in randomized complete block set-up. Pretreatment soil samples were collected from 0 - 5, 5 - 10, 10 - 20 and 20 - 40 cm depths in each season while post-treatment soil samples were collected per treatment plots from same depths as the former at various intervals (1, 2, 3, 4, 6,8 and 12 weeks) treatment applications in the wet and dry seasons of 2019. These intervals consisted of weekly in the first month, fortnightly in the second and ones in the third month after treatment applications (MAT) and given a total of seven samplings per cropping cycle. Both pre and post treatments soil samples collected were prepared by air drying, sieving using a 2 mm diameter mesh and the fine earth fractions stored ready for laboratory analyses. The poultry and sheep manures were oven dried for 103 °C for 12 hours and ground using wiley. They were digested using double acid (nitric/ perchloric acid) [52].

2.3 Laboratory Analyses

2.3.1 Manures, Pre - and Post Treatment Soil Analyses

The manures (poultry and sheep), pre and post treatment soil samples were subjected to laboratory analyses using standard methods. The pretreatment soil samples were analyzed for particle size fractions after dispersion with calgon [11], pH in 1: 2.5 sample/ water ratio using the glass electrode of a pH meter, total N [24], NH_4^+- N and NO_3^-- N [14], total, Bray II and water-soluble P [30], EC [34], OM [27], exchangeable bases (K^+, Ca^{2+}, Mg^{2+} and Na^+) [42], water- soluble K after extraction with 1: 5 soil/ water ratio and total K using double acid method [17]. Also, post treatment soil samples were analyzed for NH_4^+- N using the method above. Equally, manure samples were analyzed for pH, EC, total N, P, K, Na, Ca, Mg and organic carbon [44].

2.4 Statistical Analysis

All data generated were subjected to Analysis of Variance (ANOVA) and means separated using Fisher's Protected Least Significant Difference Test at 5 % probability level. All analyses were computed using Genstat Statistical package (discovery edition 12 software) [12].

III. Results and Discussion

3.1 Characterization of the manures used for the study

Chemical properties of the poultry and sheep manures used for this study were presented in Table 1. The manures were alkaline [32] with a pH of 7.8 and suggesting promoting soil pH on application. It has been noted that application of organic manure can improve the soil pH [13]. Several researchers have reported an increase in soil pH with poultry and livestock manures ([16], [20]). Electrical conductivity was higher in poultry (14.23) than sheep (9.45 dS m^{-1}) indicating the tendency of high salt concentration in the former than later.

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue VII July 2023

Table 1: Properties of Poultry and Sheep Manures Used for the Study.

Chemical	Manures Properties	
	Poultry	Sheep
PH	7.8	7.8
EC (dS m^{-1})	14.23	9.45
Total nitrogen (g kg^{-1})	89.66	83.36
Total – phosphorus (g kg^{-1})	4.68	4.22
Total potassium (g kg^{-1})	9.13	8.93
Total sodium (g kg^{-1})	0.89	0.79
Total – calcium (g kg^{-1})	6.89	6.92
Total magnesium (g kg^{-1})	5.64	5.69
Organic carbon (g kg^{-1})	298.98	515.44
Carbon: Nitrogen	3.34	6.18
Exchangeable acidity ($cmol^{+}$ kg^{-1})	0.6	0.6

The total sodium contents of poultry and sheep manures were 0.89 and 0.79 g kg^{-1} indicating more than 10 % higher in the former. Concentrations of nutrients such as N, P and K were higher in poultry manure while Ca, Mg and organic carbon were higher in sheep manure indicating variation in the nutrient contributions to the soil. The nutrients and pH concentrations in the manures (Table 1) relative to the soil (Table 2) indicates that the application to the soil could promote it. [32] classified pH range of between 7.4 – 7.8 as mildy alkaline and suggesting that the manures were alkaline in reaction. It is well known that poultry manure has higher nutritional value than sheep manure [1].

The EC values of both manures were above 3.2 dS m^{-1} classified as very strongly saline by [19]. Its higher value in poultry manure than sheep manure could be due to the high soluble salt contents and as such might have increased salt contents of applied soils. Other researchers have also noted high EC values of poultry manure than cattle and goat manures ([5], [6], [49]). The high sodium content of poultry manure than sheep manure could be responsible for its high EC value.

Nutrient concentrations especially total N, P and K were better in poultry than sheep manure with the values equivalent to 89.66, 4.68 and 9.13 g kg^{-1} in poultry manure and 83.36, 4.22 and 8.93 g kg^{-1} for sheep manure. This corroborated the work of [49], who stated that the fertility status of the soil proved to be beneficial, with poultry manure than any other organic manure in his research. Conversely, sheep manure was higher in calcium, magnesium and organic carbon with values equivalent to 6.92, 5.69 and 515.44 g kg^{-1} in sheep and 6.89, 5.64 and 298.98 g kg^{-1} in poultry manure. Sheep manure increased soil organic matter and soil CEC, and therefore the soil nutrient retention capacity. Hence, manure also contains large amounts of organic P such as phospholipids and nucleic acids, which could be released to increase soil inorganic P concentrations by mineralization. Mixing manure with sandy soils help to retain moisture levels. Manure produces increased soil carbon, which is an important source of energy that makes nutrients available to plants. It reduced runoff and leaching of nitrates in the soil [31]. Manure was quickly decomposed under warm, moist soil conditions [7].

Variations in composition of poultry and sheep manures could be due to differences in dietary intake. Sheep diet was composed of roughages whereas, poultry consisted mainly of concentrates. Sheep manure application improves soil properties through improving physiochemical and biological conditions of the soil. Sheep manure increased soil available N and improved plant N status. The impact of diet in the manures was demonstrated by the high organic carbon and C: N contents of sheep relative to poultry manure due to its carbonaceous nature [31]. A C: N ratio of less than 30 had been noted to portend net N mineralization of soils [40] indicating the ability of the manures to promote soil N contents. Generally, both manures properties (Table 1) were better than those of the soils (Table 2a and 2b), suggesting their ability to improve soil fertility on application.

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue VII July 2023

3.2 Characterization of Pretreatment Soils used for the Study

The Physico- chemical properties of the studied soils in wet (early) and dry (late) seasons in 2019 and 2020 are presented in Tables 2a and 2b, respectively. In Table 2a, sand, silt and clay contents ranged from 682.00 – 701.00, 41.00 – 48.00 and 25.70 – 28.80 and 726.00 – 741.00, 18.00 – 26.00 and 23.80 – 25.30 g kg^{-1} in wet and dry seasons of 2019, respectively. In both seasons, distribution of the various soil particles were irregular with soil depths and with mean concentrations being an increasing order of sand > clay > silt, texture of the soils between sandy loam and loam sandy in wet and dry seasons, respectively.

In Table 2b, ranges of sand, silt and clay were respectively 886.00 – 912.00, 42.00 – 72.00 and 28.00 - 62.00 (wet season) and 884.00 – 902.00, 54.00 – 62.00 and 40.00 – 62.00 g kg^{-1} (dry season), with their distributions down soil depths irregular for all fractions in the wet season and increase for sand, decrease for silt and irregular for clay in dry season. In both seasons and years, mean soil fractions decreased in the order sand > silt > clay with sand better than others. Generally, texture of the soils in both years (2019 and 2020) and seasons (wet and dry), was dominantly sandy, probably due to the nature of the parent material which is Coastal plain sand [50].

In Table 2a (2019), Soil pH, EC, total N, NH_4^+- N, NO_3^--N ranged respectively from 4.10 – 4.80, 0.10 - 0.20 dS m^{-1}, 1.99 – 2.07 g kg^{-1}, 118.50 – 126.50 mg kg^{-1} and 11.21 – 11.73 mg kg^{-1} (wet season) and 4.4 – 4.6, 0.20 - 0.20 dS m^{-1}, 1.70 – 1.79 g kg^{-1}, 118.80 – 120.00 mg kg^{-1} and 10.56 – 10.89 mg kg^{-1} (dry season) (Table 2a). While the ranges in 2020 (Table 2b) were 4.45 – 4.87, 0.20 - 0.40 dS m^{-1}, 0.60 – 0.80 g kg^{-1}, 52.70 – 92.63 mg kg^{-1} and 27.22 – 50.39 mg kg^{-1} in the wet season and 4.03 – 4.33, 0.20 - 0.30 dS m^{-1}, 0.80 – 1.10 g kg^{-1}, 71.08 – 83.44 mg kg^{-1} and 53.11 – 66.43 mg kg^{-1} in the dry season (Table 2a). Values for soil pH indicated that they were slightly to moderately acidic ([2], [46]) with the degree greater down soil depth, probably due to its poor organic matter content. In both season and years, values of the soil pH were below 5.0. This shows that the soils may suffer from aluminum toxicity [26].

3.3 Ammonium- Nitrogen (NH_4^+- N)

Ammonium- nitrogen (NH_4^+- N) differed with manure types with concentrations for only poultry manure in wet and dry seasons of 2019 and 2020 respectively ranging from 129.91 - 134.02 and 124.57 - 126.84 and 23.03 - 157.97 and 84.40 - 130.13 in 1st week after manure application (1st WAMA), 134.85 - 138.30 and 126.52 - 127.79 and 32.46 - 155.31 and 81.27 - 116.67 mg kg^{-1} (2nd WAMA), 147.48 - 149.15 and 128.16 - 136.39 and 83.10 - 147.77 and 99.00 - 116.67mg kg^{-1} (3rd WAMA), 145.61 - 148.87 and 133.52 - 141.39 and 115.97 - 161.40 and 95.03 - 129.00 mg kg^{-1} (4th WAMA), 135.20 - 147.61 and 133.08 - 138.14 and 92.70 - 153.61 and 105.81 - 128.35 mg kg^{-1}(6th WAMA), 143.69 - 147.39 and 136.65 - 139.68 and 118.40 - 141.42 and 105.47 - 29.27 mg kg^{-1} (8th WAMA) and 129.19 - 145.84 and 137.38 - 142.36 and 109.93 - 132.67 and 95.77 - 115.57 mg kg^{-1} (12th WAMA). This indicated the least and highest NH_4-N concentrations at specific soil depths and manure rates with the highest of 149.15 mg kg^{-1} being with P_{60} at 0 - 5 cm depth in wet season of 2019 after the 3rd WAMA. The values of soil NH_4^+- N were high [21] and might be as a result of extremely wet soils or manure residue during the experiment. The high NH_4^+- N would not be detrimental to both the soils and the crop planted because NH_4^+- N does not accumulate in the soil. The soil temperature and moisture (wet) and 0 - 5, 5 - 10 and 20 – 40 cm (dry seasons) of 2019 during the research (Table 3) were suitable for the plant growth and also ideal for conversion of NH_4^+- N to NO_3^-- N. In most weeks after manure application, the concentrations increased relative to the control with both P_{30} and P_{60} poultry rates at 5 - 10, 10 - 20 and 20 - 40 cm depths in dry season of 2019, 0 - 5 and 5 - 10 cm (wet) and 0 - 5, 5 - 10 and 10 - 20 cm (dry) seasons of 2020 at 1st WAMA, 0 - 5, 5 - 10, 10 - 20 and 20 - 40 cm (wet) and 20 - 40 cm (dry seasons) of 2019 and 0 - 5 and 5 - 10 (wet) and 0 - 5, 5 - 10, 10 - 20 and 20 - 40 cm (dry seasons) in 2020 at 2nd WAMA, 20 - 40 cm (wet) and 0 - 5, 10 - 20 and 20 - 40 cm (wet season) in 2019 and 0 - 5,5 - 10 and 20 - 40 cm (wet) and all depths in dry season of 2020 in 3rd WAMA, 5 - 10, 10 - 20 and 20 - 40 cm (wet) and 0 - 5, 5 - 10 and 10 - 20 cm (dry season of 2019) and all depths (0 - 5, 5 - 10, 10 - 20 and 20 - 40 cm) in wet and dry seasons of 2020 at 4th WAMA. It also included 0 - 5 and 10 – 20 (wet) and 0 - 5 and 5 - 10 cm (dry seasons in 2019 and all depths (0 - 5, 5 - 10, 10 - 20 and 20 - 40 cm) in wet and dry seasons of 2020 at 6th WAMA, 0 - 5, 5 - 10 and 20 - 40 cm depths (0 - 5, 5 - 10, 10 - 20, and 20 - 40 cm) in wet and dry seasons of 2020 at 8th WAMA and finally at 0 - 5 and 5 - 10 (wet) and 0 - 5, 5 - 10 and 10 - 20 cm (dry season of 2019) and all depths (0 - 5, 5 - 10, 10 - 20 and 20 - 40 cm) in wet and dry seasons of 2020 at 12th WAMA. In some seasons, years, rates of manure and weeks of applications, NH_4^+- N decreased down most soil depths.

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue VII July 2023

Table 2a: Selected Physico-chemical Properties of the Soils Studied in Early and Late Seasons of 2019.

Physico chemical properties	Wet Season 2019					Dry Season 2019				
	Soil Depths (cm)					Soil Depths (cm)				
	0 - 5	0 - 10	10 - 20	20 - 40	Mean	0 - 5	0 - 10	10 - 20	20 - 40	Mean
Sand (g kg^{-1})	682	680	701	684	686.75	726	741	738	728	733.25
Silt (g kg^{-1})	46	41	42	48	44.25	21	18	24	26	22.25
Clay (g kg^{-1})	27.2	27.1	25.7	28.8	27.2	25.3	24.1	23.8	24.6	24.45
Textural Class	sandy loam					Loamy sand				
pH	4.8	4.4	4.1	4.5	4.45	4.6	4.5	4.4	4.5	4.5
EC (d Sm^{-1})	0.2	0.2	0.2	0.1	0.175	0.3	0.3	0.2	0.2	0.25
Total N (g kg^{-1})	1.99	2.07	2.05	1.99	2.025	1.79	1.7	1.77	1.71	1.7425
$NH4^{+}$- N (mg kg^{-1})	124.6	118.5	123.8	126.5	123.35	116.3	118.8	120	119.2	118.575

Table 2b: Selected Physico-chemical Properties of the Soils Studied in Early and Late Seasons of 2020.

Physico chemical properties	Wet Season 2020					Dry Season 2020				
	Soil Depths (cm)					Soil Depths (cm)				
	0 - 5	0 - 10	10 - 20	20 - 40	Mean	0 - 5	0 - 10	10 - 20	20 - 40	Mean
Sand (g kg^{-1})	906	904	912	886	902.00	886	884	894	902	891.50
Silt (g kg^{-1})	66	48	42	72	57.00	62	58	58	54	58.00
Clay (g kg^{-1})	28	52	42	62	46.00	52	62	40	48	50.50
Textural Class	Sand					Loamy sand				
pH	4.53	4.87	4.76	4.45	4.65	4.03	4.07	4.23	4.33	4.17
EC (d Sm^{-1})	0.4	0.4	0.3	0.2	0.33	0.3	0.3	0.2	0.2	0.25
Total N (g kg^{-1})	0.8	0.7	0.7	0.6	0.70	0.9	1.1	0.9	0.8	0.93
$NH4^{+}$- N (mg kg^{-1})	124.6	118.5	123.8	126.5	123.35	116.3	118.8	120	119.2	118.58

Averaged over manure rates and soil depths its mean contents in wet and dry seasons at 1st, 2nd, 3rd, 4th, 6th, 8th and 12th WAMA varied as 132.20 and 126.25 (2019) and 91.35 and 97.05 (2020), 136.41 and 126.95 (2019) and 87.46 and 97.83 (2020), 148.31 and 132.00 (2019) and 110.67 and 103.73 (2020), 147.00 and 136.62 (2019) and 133.35 and 109.54 (2020), 146.13 and 135.02 (2019) and 129.50 and 117.63 (2020), 146.22 and 138.26 (2019) and 118.75 and 119.92 (2020) and 138.67 and 140.19 (2019) and 121.18 and 109.87 mg kg^{-1} (2020) respectively. This means that mean contents were better in wet than dry seasons of both years at most weeks after poultry manure applications. It was also better in 2019 than 2020. Also, range of soil NH_4^{+}- N with addition of sheep manure only in rain and dry seasons were 129.75 - 134.57 and 124.91 - 126.84 (2019) and 14.63 - 128.86 and 75.70 - 113.37 mg kg^{-1} (2020) in 1st WAMA, 134.58 - 137.58 and 126.62 - 127.77 (2019) and 32.15 - 160.92 and 81.93 - 121.93 mg kg^{-1} (2020) at

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue VII July 2023

2nd WAMA, 147.50 - 149.06 and 128.03 - 136.12 (2019) and 81.90 - 154.33 and 96.30 - 114.70 mg kg^{-1} (2020) in 3rd WAMA, 145.83 - 149.00 and 133.70 - 142.63 (2019) and 117.80 -194.64 and 98.80 - 137.00mg kg^{-1} (2020) in 4th WAMA, 144.97 - 147.74 and 133.67 - 136.72 (2019) and 104.91 - 152.33 and 111.00 - 123.97 mg kg^{-1} (2020) in the 6th WAMA, 143.77 - 147.54 and 136.82 - 139.94 (2019) and 121.40 - 139.07 and 110.63 - 127.94 mg kg^{-1} (2020) in 8th WAMA and 128.23 - 145.97 and 136.41 - 14.64 (2019) and 110.57 - 131.73 and 96.33 - 116.47 mg kg^{-1} (2020) in 12th WAMA. This shows that the best and least concentrations at varying soil depths, manure rates, weeks of application, seasons and years were at 5 - 10 cm soil depth with S_{60} in the second week after manure application in wet season of year 2020 and 10 - 20 cm with S_0 in the first week after manure application in the wet season of 2020. Also, addition of S_{30} and S_{60} sheep manure rates increased soil NH_4^+- N relative to the

Table 3: Ammonium - Nitrogen at various Soil Depths and Weeks After Manure Application (WAMA) in Wet and Dry Seasons of 2019 and 2020.

Years and Seasons	2019 a				2019 b				2020 a				2020 b			
Soil Depths	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Manure Rates	First Week After Manure Application															
P_0S_0	132.50	131.60	128.60	127.50	125.63	125.23	124.70	122.53	89.30	81.60	8.40	46.88	82.30	83.00	76.20	77.20
P_0S_{30}	134.37	133.83	132.87	132.60	125.90	126.03	126.23	125.90	103.56	104.40	107.82	141.96	85.50	87.00	87.80	121.60
P_0S_{60}	135.20	134.23	132.10	129.87	127.63	126.80	125.90	125.27	92.78	89.40	71.81	70.57	85.40	87.00	83.40	84.60
Mean	**134.02**	**133.22**	**131.19**	**129.99**	**126.39**	**126.02**	**125.61**	**124.57**	**95.21**	**91.80**	**62.68**	**86.47**	**84.40**	**85.67**	**82.47**	**94.47**
$P_{30}S_0$	134.93	134.40	132.43	132.13	126.20	126.03	125.63	125.40	159.13	142.50	16.72	61.66	128.40	129.10	80.10	70.70
$P_{30}S_{30}$	134.50	132.73	129.60	131.23	125.90	125.70	126.33	126.60	124.96	109.60	11.60	109.82	127.00	92.00	81.60	93.90
$P_{30}S_{60}$	132.50	132.23	131.03	131.80	126.80	127.10	127.30	127.40	171.81	159.60	134.43	102.44	141.00	138.50	115.40	123.10
Mean	**133.98**	**133.12**	**131.02**	**131.72**	**126.30**	**126.28**	**126.42**	**126.47**	**151.97**	**137.23**	**54.25**	**91.31**	**132.13**	**119.87**	**92.37**	**95.90**
$P_{60}S_0$	133.36	132.73	131.03	129.63	127.83	127.37	127.27	126.80	100.47	91.30	18.77	52.27	97.40	86.80	82.10	79.20
$P_{60}S_{30}$	134.83	134.03	128.80	129.47	125.47	125.97	126.60	127.10	158.05	144.90	24.94	77.48	127.60	125.10	88.30	94.80
$P_{60}S_{60}$	133.83	133.27	132.60	130.63	126.10	126.43	127.03	126.80	97.87	86.00	25.37	98.42	86.90	86.30	85.30	92.40
Mean	**134.01**	**133.34**	**130.81**	**129.91**	**126.47**	**126.59**	**126.97**	**126.90**	**118.80**	**107.40**	**23.03**	**76.06**	**103.97**	**99.40**	**85.23**	**88.80**
S_0	133.60	132.91	130.69	129.75	126.55	126.21	125.87	124.91	116.30	105.13	14.63	53.60	102.70	99.63	79.47	75.70
S_{30}	134.57	133.53	130.42	131.10	125.76	125.90	126.39	126.53	128.86	119.63	48.12	109.75	113.37	101.37	85.90	103.43
S_{60}	133.84	133.24	131.91	130.77	126.84	126.78	126.74	126.49	120.82	111.67	77.20	90.48	104.43	103.93	94.70	100.03
LSDs (0.05) P	*7.16*	*5.20*	*18.52*	*6.32*	*4.98*	*4.48*	*6.75*	*19.10*	*1.67*	*8.56*	*1.01*	*1.62*	*20.34*	*9.26*	*5.96*	*21.35*
" S	*7.16*	*5.20*	*18.52*	*6.32*	*4.98*	*4.48*	*6.75*	*19.10*	*1.67*	*8.56*	*1.01*	*1.62*	*20.34*	*9.26*	*5.96*	*21.35*
' P x S	*12.40*	*9.01*	*32.08*	*10.95*	*8.63*	*7.77*	*11.70*	*33.08*	*2.89*	*14.82*	*1.74*	*2.80*	*35.23*	*16.03*	*10.32*	*36.98*
	Second Week After Manure Application															
P_0S_0	134.73	133.93	135.67	134.57	126.17	125.97	126.07	125.63	74.90	70.54	5.70	44.30	71.84	74.50	71.00	75.14
P_0S_{30}	137.47	137.00	135.93	135.27	127.47	128.20	128.80	126.67	158.80	163.51	40.20	47.50	129.79	132.10	88.20	89.58
P_0S_{60}	137.73	137.13	136.10	135.00	128.00	127.77	127.60	127.27	100.70	96.71	70.93	73.30	88.09	91.00	84.60	87.73
Mean	**136.64**	**136.02**	**135.90**	**134.95**	**127.21**	**127.31**	**127.49**	**126.52**	**111.47**	**110.25**	**38.94**	**55.03**	**96.57**	**99.20**	**81.27**	**84.15**
$P_{30}S_0$	138.60	138.17	137.20	135.83	126.53	126.33	126.40	127.53	100.80	98.78	37.60	39.40	87.78	89.40	86.30	91.03
$P_{30}S_{30}$	138.20	137.77	136.70	135.80	126.50	126.33	125.87	127.33	147.20	148.84	48.10	49.80	123.89	120.80	88.40	89.46
$P_{30}S_{60}$	136.07	135.43	134.53	133.83	127.50	126.97	125.50	127.87	214.00	218.32	11.69	48.40	137.61	139.80	92.70	93.43
Mean	**137.62**	**137.12**	**136.14**	**135.15**	**126.84**	**126.54**	**125.92**	**127.58**	**154.00**	**155.31**	**32.46**	**45.87**	**116.43**	**116.67**	**89.13**	**91.31**
$P_{60}S_0$	139.23	138.83	138.00	136.87	127.20	127.57	127.20	127.17	88.80	85.46	98.39	98.40	86.17	88.70	91.00	93.38
$P_{60}S_{30}$	136.73	133.93	132.87	132.67	125.97	126.33	126.60	128.03	109.60	108.23	12.39	42.40	97.27	98.80	93.10	94.17
$P_{60}S_{60}$	138.94	138.57	138.10	137.30	126.83	126.83	126.13	128.17	166.10	167.74	13.83	47.20	134.02	135.00	91.80	94.51

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue VII July 2023

Mean	**138.30**	**137.11**	**136.32**	**135.61**	**126.67**	**126.91**	**126.64**	**127.79**	**121.50**	**120.48**	**41.54**	**62.67**	**105.82**	**107.50**	**91.97**	**94.02**
S_0	137.52	136.98	136.96	135.76	126.63	126.62	126.56	126.78	88.17	84.93	47.23	60.70	81.93	84.20	82.77	86.52
S_{30}	137.47	136.23	135.17	134.58	126.65	126.95	127.09	127.34	138.53	140.19	33.56	46.57	116.98	117.23	89.90	91.07
S_{60}	137.58	137.04	136.24	135.38	127.44	127.19	126.41	127.77	160.27	160.92	32.15	56.30	119.91	121.93	89.70	91.89
LSDs (0.05) P	*4.65*	*4.21*	*5.26*	*6.19*	*4.65*	*7.93*	*12.88*	*5.86*	*5.39*	*3.64*	*1.29*	*8.38*	*4.43*	*6.13*	*6.57*	*5.07*
" S	*4.65*	*4.21*	*5.26*	*6.19*	*4.65*	*7.93*	*12.88*	*5.86*	*5.39*	*3.64*	*1.29*	*8.38*	*4.43*	*6.13*	*6.57*	*5.07*
' P x S	*8.05*	*7.29*	*9.12*	*10.72*	*8.05*	*13.74*	*22.31*	*10.16*	*9.33*	*6.31*	*2.24*	*14.51*	*7.67*	*10.62*	*11.38*	*8.79*

a = wet season, b = dry season, 1 = 0-5 cm, 2 = 5-10 cm, 3 = 10-20 cm, 4 = 20-40 cm depths, P = poultry, S = sheep and P x S = poultry and sheep manure interaction.

Table 3 cont'd.

Years and Seasons	2019 a				2019 b				2020 a				2020 b			
Soil Depths	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Manure Rates	Third Week After Manure Application															
P_0S_0	148.23	147.20	146.87	146.37	134.13	132.43	128.80	127.07	114.40	141.90	62.17	55.30	98.50	102.20	86.70	91.00
P_0S_{30}	149.57	149.20	148.90	147.60	136.00	134.27	129.50	127.80	117.50	121.50	79.90	62.60	101.20	102.50	92.30	93.90
P_0S_{60}	149.03	148.77	148.53	148.47	135.60	133.97	128.80	129.60	114.40	117.80	125.40	131.40	97.30	101.50	108.20	112.10
Mean	**148.94**	**148.39**	**148.10**	**147.48**	**135.24**	**133.56**	**129.03**	**128.16**	**115.43**	**127.07**	**89.16**	**83.10**	**99.00**	**102.07**	**95.73**	**99.00**
$P_{30}S_0$	148.97	148.20	147.77	147.33	136.13	134.47	131.83	129.60	118.70	132.00	71.80	77.30	106.10	113.00	95.50	92.90
$P_{30}S_{30}$	148.67	147.90	147.43	147.30	136.83	134.80	130.03	128.27	127.90	128.70	96.90	96.80	97.10	113.10	107.60	102.20
$P_{30}S_{60}$	148.20	147.87	147.47	148.20	136.20	132.80	129.93	128.80	130.60	144.60	91.60	87.70	107.60	123.90	102.00	96.40
Mean	**148.61**	**147.99**	**147.56**	**147.61**	**136.39**	**134.02**	**130.60**	**128.89**	**125.73**	**135.10**	**86.77**	**87.27**	**103.60**	**116.67**	**101.70**	**97.17**
$P_{60}S_0$	148.93	148.50	148.57	148.80	134.83	133.40	129.23	127.43	165.70	189.10	122.40	126.70	121.40	128.90	125.50	117.50
$P_{60}S_{30}$	148.93	148.40	147.90	147.80	134.43	132.77	131.57	128.93	119.80	133.10	76.40	86.30	100.40	113.00	93.90	94.70
$P_{60}S_{60}$	149.60	149.80	149.37	148.60	136.57	132.77	132.43	129.80	114.50	121.10	89.10	91.10	96.80	104.20	96.80	98.80
Mean	**149.15**	**148.90**	**148.61**	**148.40**	**135.28**	**132.98**	**131.08**	**128.72**	**133.33**	**147.77**	**95.97**	**101.37**	**106.20**	**115.37**	**105.40**	**103.67**
S_0	148.71	147.97	147.74	147.50	135.03	133.43	129.95	128.03	132.93	154.33	85.46	86.43	108.67	114.70	102.57	100.47
S_{30}	149.06	148.50	148.08	147.57	135.75	133.95	130.37	128.33	121.73	127.77	84.40	81.90	99.57	109.53	97.93	96.93
S_{60}	148.94	148.81	148.46	148.42	136.12	133.18	130.39	129.40	119.83	127.83	102.03	103.40	100.57	109.87	102.33	102.43
LSDs (0.05) P	*8.04*	*9.91*	*5.71*	*7.94*	*4.08*	*6.05*	*20.34*	*4.43*	*11.51*	*8.77*	*9.90*	*16.69*	*8.60*	*8.42*	*5.48*	*6.33*
" S	*8.04*	*9.91*	*5.71*	*7.94*	*4.08*	*6.05*	*20.34*	*4.43*	*11.51*	*8.77*	*9.90*	*16.69*	*8.60*	*8.42*	*5.48*	*6.33*
' P x S	*13.93*	*17.16*	*9.88*	*13.75*	*7.07*	*10.47*	*35.23*	*7.68*	*19.94*	*15.19*	*17.14*	*28.91*	*14.90*	*14.58*	*9.49*	*10.96*
	Fourth Week After Manure Application															
P_0S_0	147.60	146.30	144.43	144.80	135.97	138.67	132.37	132.47	115.10	115.50	57.30	17.61	92.20	91.60	81.48	78.39
P_0S_{30}	148.80	146.83	145.50	145.53	138.57	139.23	133.97	135.57	117.50	120.80	117.00	113.32	94.90	98.50	103.99	109.87
P_0S_{60}	148.93	148.07	146.90	146.70	137.73	139.40	134.40	136.40	115.30	118.00	149.70	190.66	98.00	99.70	117.15	136.36
Mean	**148.44**	**147.07**	**145.61**	**145.68**	**137.42**	**139.10**	**133.58**	**134.81**	**115.97**	**118.10**	**108.00**	**107.20**	**95.03**	**96.60**	**100.87**	**108.21**
$P_{30}S_0$	148.40	147.37	146.40	145.80	141.13	141.23	133.43	133.47	121.00	133.80	133.50	132.60	101.70	109.10	113.58	119.90
$P_{30}S_{30}$	148.33	147.80	146.70	146.43	138.77	140.10	134.33	134.43	123.90	127.70	122.70	114.74	101.80	102.40	106.05	112.04
$P_{30}S_{60}$	148.50	147.13	145.60	145.43	137.53	141.00	133.33	132.67	127.50	135.60	158.90	170.17	102.30	111.90	123.21	130.54
Mean	**148.41**	**147.43**	**146.23**	**145.89**	**139.14**	**140.78**	**133.70**	**133.52**	**161.40**	**132.37**	**138.37**	**139.17**	**101.93**	**107.80**	**114.28**	**120.83**

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue VII July 2023

$P_{60}S_0$		148.77	147.50	146.27	146.47	136.83	142.23	134.50	133.90	120.80	166.10	140.80	138.09	116.80	124.10	119.92	122.88
$P_{60}S_{30}$		148.83	147.73	146.57	146.53	136.63	142.63	135.63	135.30	120.80	136.10	146.20	157.89	104.50	110.80	118.52	126.52
$P_{60}S_{60}$		149.00	147.27	146.90	145.83	138.03	138.70	133.70	134.03	117.80	125.50	174.00	194.64	98.80	104.20	125.41	137.76
Mean		**148.87**	**147.50**	**146.58**	**146.28**	**137.16**	**141.19**	**134.61**	**134.41**	**119.80**	**142.57**	**153.67**	**163.54**	**106.70**	**113.03**	**121.28**	**129.05**
S_0		148.26	147.06	145.70	145.69	137.98	140.71	133.43	133.28	118.97	138.47	110.53	96.10	103.57	108.27	104.99	107.06
S_{30}		148.65	147.45	146.26	146.16	137.99	140.65	134.64	135.10	120.73	128.20	128.63	128.65	100.40	103.90	109.52	116.14
S_{60}		148.81	147.49	146.47	145.99	137.76	139.70	133.81	134.37	120.20	126.37	160.87	185.16	99.70	105.27	121.92	134.89
LSDs (0.05)	P	*5.42*	*6.49*	*8.89*	*2.44*	*21.35*	*6.85*	*6.55*	*8.21*	*11.38*	*9.15*	*12.32*	*1.59*	*10.55*	*7.56*	*4.19*	*2.73*
"	S	*5.42*	*6.49*	*8.89*	*2.44*	*21.35*	*6.85*	*6.55*	*8.21*	*11.38*	*9.15*	*12.32*	*1.59*	*10.55*	*7.56*	*4.19*	*2.73*
'	P x S	*9.39*	*11.25*	*15.39*	*4.23*	*36.99*	*11.87*	*11.34*	*14.22*	*19.72*	*15.84*	*21.34*	*2.75*	*18.28*	*13.10*	*7.26*	*4.72*

a = wet season, b = dry season, 1 = 0-5 cm, 2 = 5-10 cm, 3 = 10-20 cm, 4 = 20-40 cm depths, P = poultry, S = sheep and P x S = poultry and sheep manure interaction.

Table 3 cont'd.

Years and Seasons	2019 a				2019 b				2020 a				2020 b			
Soil Depths	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Manure Rates	Sixth Week After Manure Application															
P_0S_0	146.17	145.97	144.50	145.10	128.77	128.93	132.63	132.67	102.50	127.45	104.15	59.71	100.40	90.18	94.78	89.70
P_0S_{30}	148.13	147.33	145.70	145.20	134.77	134.00	135.27	136.47	153.70	146.95	136.85	70.78	120.10	124.70	127.62	112.40
P_0S_{60}	147.43	147.07	145.60	145.90	135.70	135.20	135.87	137.07	142.14	102.52	117.35	147.61	102.50	102.55	105.85	116.60
Mean	**147.24**	**146.79**	**145.27**	**145.40**	**133.08**	**132.71**	**134.59**	**135.40**	**132.78**	**125.64**	**119.45**	**92.70**	**107.67**	**105.81**	**109.42**	**106.23**
$P_{30}S_0$	147.43	146.27	145.10	144.80	136.13	135.10	133.87	133.60	176.25	167.61	157.51	143.34	126.00	129.93	133.27	137.00
$P_{30}S_{30}$	147.47	146.17	145.13	145.00	137.23	136.60	135.10	135.00	108.29	106.97	103.54	102.10	108.30	106.93	102.24	102.10
$P_{30}S_{60}$	147.93	146.97	145.60	145.80	133.33	132.60	132.13	132.10	141.66	135.37	125.27	115.64	128.40	129.67	125.63	119.10
Mean	**147.61**	**146.47**	**145.28**	**145.20**	**135.56**	**134.77**	**133.70**	**133.57**	**142.07**	**136.65**	**128.77**	**120.36**	**120.90**	**122.18**	**120.38**	**119.40**
$P_{60}S_0$	147.13	146.17	145.30	145.10	141.33	140.60	136.37	134.73	144.25	139.25	129.15	111.69	126.70	129.01	127.91	114.90
$P_{60}S_{30}$	147.63	146.83	145.27	145.20	138.17	138.10	136.97	136.43	195.00	184.77	174.67	155.60	134.80	137.82	142.05	142.60
$P_{60}S_{60}$	147.03	146.27	145.43	145.50	134.93	134.10	134.17	134.77	121.59	119.24	109.14	82.50	121.60	118.21	108.50	98.90
Mean	**147.26**	**146.42**	**145.33**	**145.27**	**138.14**	**137.60**	**135.84**	**135.31**	**153.61**	**147.75**	**137.65**	**116.60**	**127.70**	**128.35**	**126.15**	**118.80**
S_0	146.91	146.14	144.97	145.00	135.41	134.88	134.29	133.67	141.00	144.77	130.27	104.91	117.70	116.37	118.65	113.87
S_{30}	147.74	146.78	145.37	145.13	136.72	136.23	135.78	135.97	152.33	146.23	138.35	109.49	121.07	123.15	123.97	119.03
S_{60}	147.46	146.77	145.54	145.73	134.65	133.97	134.06	134.65	135.13	119.04	117.25	115.25	117.50	116.81	113.33	111.53
LSDs (0.05) P	*5.87*	*5.32*	*4.04*	*5.11*	*6.46*	*2.52*	*7.91*	*4.81*	*1.55*	*4.06*	*4.96*	*0.52*	*6.05*	*3.84*	*3.84*	*6.34*
" S	*5.87*	*5.32*	*4.04*	*5.11*	*6.46*	*2.52*	*7.91*	*4.81*	*1.55*	*4.06*	*4.96*	*0.52*	*6.05*	*3.84*	*3.84*	*6.34*
' P x S	*10.16*	*9.22*	*7.00*	*10.10*	*11.19*	*4.37*	*13.70*	*8.33*	*2.68*	*7.03*	*8.58*	*0.90*	*10.49*	*6.65*	*6.64*	*10.98*
	Eighth Week After Manure Application															
P_0S_0	136.07	144.47	146.70	144.60	136.37	138.37	135.47	134.00	96.90	122.43	114.86	100.10	99.30	106.40	107.00	94.30
P_0S_{30}	147.73	146.50	147.60	146.20	137.03	139.37	137.80	138.33	137.00	139.95	137.28	117.80	116.50	127.00	130.33	123.70
P_0S_{60}	147.27	146.23	147.50	145.80	138.93	139.80	138.80	137.63	124.00	101.27	119.71	137.30	100.60	106.20	109.40	117.60
Mean	**143.69**	**145.73**	**147.27**	**145.53**	**137.44**	**139.18**	**137.36**	**136.65**	**119.30**	**121.22**	**123.95**	**118.40**	**105.47**	**113.20**	**115.58**	**111.87**
$P_{30}S_0$	147.73	146.97	146.70	145.20	137.60	139.67	138.40	139.20	156.60	161.94	158.85	155.70	137.30	140.00	141.60	138.30
$P_{30}S_{30}$	147.47	146.43	146.40	146.10	137.80	139.23	137.80	139.00	103.00	103.82	105.02	105.50	101.90	104.00	103.90	102.10

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue VII July 2023

$P_{30}S_{60}$	146.10	147.37	146.29	145.80	138.20	140.80	139.10	139.50	124.30	129.73	133.35	131.00	119.40	123.70	127.60	125.30
Mean	**147.10**	**146.92**	**146.46**	**145.70**	**137.87**	**139.90**	**138.43**	**139.23**	**127.97**	**131.83**	**132.41**	**130.73**	**119.53**	**122.57**	**124.37**	**121.90**
$P_{60}S_0$	147.50	145.53	146.80	145.50	136.83	140.07	136.60	138.80	127.60	131.59	128.21	129.00	118.30	125.00	123.50	123.30
$P_{60}S_{30}$	147.43	146.03	147.20	146.40	138.23	139.73	136.40	138.97	168.40	173.44	170.68	162.60	142.10	146.40	149.60	145.80
$P_{60}S_{60}$	147.23	146.00	146.80	146.20	137.40	139.23	137.23	139.77	115.90	119.23	120.16	107.50	111.90	115.30	114.70	104.90
Mean	**147.39**	**145.85**	**146.93**	**146.03**	**137.49**	**139.68**	**136.74**	**139.18**	**137.30**	**141.42**	**139.68**	**133.03**	**124.10**	**128.90**	**129.27**	**124.67**
S_0	143.77	145.66	146.73	145.10	136.93	139.37	136.82	137.33	127.03	138.65	133.97	128.27	118.30	123.80	124.03	118.63
S_{30}	147.54	146.32	147.07	146.23	137.69	139.44	137.33	138.77	136.13	139.07	137.66	128.63	120.17	125.80	127.94	123.87
S_{60}	146.87	146.53	146.86	145.93	138.18	139.94	138.38	138.97	121.40	116.74	124.41	125.27	110.63	115.07	117.23	115.93
LSDs (0.05) P	*5.72*	*5.40*	*19.14*	*6.12*	*6.00*	*7.07*	*8.75*	*14.89*	*8.28*	*4.57*	*5.17*	*18.62*	*6.02*	*7.04*	*6.93*	*9.12*
" S	*5.72*	*5.40*	*19.14*	*6.12*	*6.00*	*7.07*	*8.75*	*14.89*	*8.28*	*4.57*	*5.17*	*18.62*	*6.02*	*7.04*	*6.93*	*9.12*
' P x S	*9.91*	*9.35*	*33.15*	*10.60*	*10.39*	*12.24*	*15.15*	*25.79*	*14.34*	*7.92*	*8.95*	*32.24*	*10.43*	*12.20*	*12.00*	*15.80*

a = wet season, b = dry season, 1 = 0-5 cm, 2 = 5-10 cm, 3 = 10-20 cm, 4 = 20-40 cm depths, P = poultry, S = sheep and P x S = poultry and sheep manure interaction.

Table 3 cont'd.

Years and Seasons	2019 a				2019 b				2020 a				2020 b			
Soil Depths	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Manure Rates	Twelfth Week After Manure Application															
P_0S_0	143.93	143.20	128.10	129.10	134.83	131.13	136.60	138.83	92.50	117.40	103.40	108.00	91.60	93.40	96.10	93.40
P_0S_{30}	144.40	145.27	131.30	131.80	142.60	141.20	140.03	139.03	124.70	128.30	132.60	109.11	103.30	108.00	116.90	109.40
P_0S_{60}	144.93	145.33	131.60	131.20	140.83	139.80	140.13	139.83	112.60	98.10	113.40	118.60	92.40	96.40	100.00	106.30
Mean	**144.42**	**144.60**	**130.33**	**130.70**	**139.42**	**137.38**	**138.92**	**139.23**	**109.93**	**114.60**	**116.47**	**111.90**	**95.77**	**99.27**	**104.33**	**103.03**
$P_{30}S_0$	145.30	147.30	128.40	131.53	139.37	139.10	138.97	138.80	139.20	143.60	146.50	150.30	124.90	125.50	128.90	131.60
$P_{30}S_{30}$	146.73	146.30	128.93	130.20	142.03	141.13	141.33	138.40	94.30	97.80	103.60	104.80	94.10	97.60	102.10	103.50
$P_{30}S_{60}$	145.50	146.77	130.23	132.03	143.60	142.10	141.30	140.20	114.30	120.00	123.00	126.90	101.90	105.60	112.00	112.70
Mean	**145.84**	**146.79**	**129.19**	**131.25**	**141.67**	**140.78**	**140.53**	**139.13**	**115.93**	**120.47**	**124.37**	**127.33**	**106.97**	**109.57**	**114.33**	**115.93**
$P_{60}S_0$	146.27	145.00	128.20	130.80	141.50	139.60	140.40	141.10	119.90	124.90	123.90	124.60	107.20	111.90	114.20	117.80
$P_{60}S_{30}$	145.67	144.73	132.03	130.43	143.30	141.60	141.33	140.80	148.70	154.10	159.00	159.30	118.30	126.80	130.40	134.50
$P_{60}S_{60}$	145.53	145.80	130.57	130.83	142.28	140.80	141.30	141.63	104.80	109.20	115.10	104.80	94.70	96.40	102.10	101.50
Mean	**145.82**	**145.18**	**130.27**	**130.69**	**142.36**	**140.67**	**141.01**	**141.18**	**124.47**	**129.40**	**132.67**	**129.57**	**106.73**	**111.70**	**115.57**	**117.93**
S_0	145.17	145.17	128.23	130.48	138.57	136.61	138.66	139.58	117.20	128.63	124.60	127.63	107.90	110.27	113.07	114.27
S_{30}	145.60	145.43	130.75	130.81	142.64	141.31	140.90	139.41	122.57	126.73	131.73	124.40	105.23	110.80	116.47	115.80
S_{60}	145.32	145.97	130.80	131.35	142.24	140.90	140.91	140.55	110.57	109.10	117.17	116.77	96.33	99.47	104.70	106.83
LSDs (0.05) P	*2.40*	*2.24*	*6.12*	*12.81*	*13.40*	*2.95*	*5.28*	*4.67*	*9.02*	*7.78*	*7.04*	*14.69*	*10.50*	*0.09*	*7.11*	*6.42*
" S	*2.40*	*2.24*	*6.12*	*12.81*	*13.40*	*2.95*	*5.28*	*4.67*	*9.02*	*7.78*	*7.04*	*14.69*	*10.50*	*0.09*	*7.11*	*6.42*
' P x S	*4.16*	*3.89*	*10.60*	*22.18*	*23.22*	*5.12*	*9.14*	*8.09*	*15.63*	*13.47*	*12.19*	*25.44*	*18.19*	*0.14*	*12.32*	*11.13*

a = wet season, b = dry season, 1 = 0-5 cm, 2 = 5-10 cm, 3 = 10-20 cm, 4 = 20-40 cm depths, P =poultry, S = sheep and P x S = poultry and sheep manure interactions.

control at 0 - 5, 5 - 10 and 20 - 40 cm in wet season and all depths (0 - 5, 5 - 10, 10 - 20 and 20 - 40 cm) in dry seasons of 2019 and all also all depths in wet and dry seasons of 2020 in 1st WAMA, 0 - 5, 5 - 10 and 0 - 40 cm in dry season of 2019 and 0 - 5 and 5 - 10 and 0 - 5 (wet), 5 - 10 and 20 - 40 cm (dry) seasons of 2020 at 2nd WAMA, all depths (wet) and 0 - 5, 10 - 20 and 20 - 40 cm (dry) seasons in 2019 of 3rd WAMA, 0 - 5, 5 - 10, 10 - 20 and 20 - 40 cm (wet) and 10 - 20 and 20 - 40 cm (dry) seasons of 2019 and 0 - 5, 10 - 20 and 20 - 40 cm (wet) and 10 - 20 and 20 - 40 cm (dry) season of 2020 at 4th WAMA, 0 - 5, 5 - 10, 10 - 20 and 20

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue VII July 2023

- 40 cm (wet) and 20 - 40 cm (dry) seasons in 2019 and 20 - 40 (wet) and 5 - 10 and 10 - 20 cm (wet) seasons of 2020 at 6th WAMA, 0 - 5, 5 - 10 and 20 - 40 cm (wet) and all depths in dry season in 2019 at 8th WAMA and 0 - 5, 5 - 10, 10 - 20 and 20 - 40 cm (wet) and 0 - 5, 5 - 10 and 10 - 20 cm (dry) seasons in 2019 at 12th WAMA. Concentrations at all other soil depths increased or decreased with either S_{30} or S_{60} additions relative to the control. Also, among seasons, years and rates, distribution of NH_4^+- N decreased down soil depths at most weeks after sheep manure application. Averaged over soil depths and sheep manure rates, NH_4^+- N contents in wet and dry seasons varied respectively as 132.19 and 126.24 (2019) and 91.35 and 97.02 mg kg^{-1} (2020) at 1st WAMA, 136.41 and 126.95 (2019) and 85.04 and 97.82mg kg^{-1} (2020) at 2nd WAMA, 148.31 and 131.19 (2019) and 110.67 and 103.72mg kg^{-1} (2020) at 3rd WAMA, 147.00 and136.62 (2019) and 130.4 and 109.55mg kg^{-1} (2020) at 4th WAMA, 146.16 and 135.02(2019) and 129.54 and 117.63mg kg^{-1} (2020) at 6th WAMA, 146.22 and 138.26 (2019) and 129.77 and 119.91 mg kg^{-1} (2020) at 8th WAMA and 137.92 and 140.19 (2019) and 121.43 and 108.31mg kg^{-1} (2020) at 12th WAMA. This shows that NH_4-N contents were better in wet than dry seasons of both years and also in 2019 than 2020. The low soil NH_4^+- N in dry seasons compared with wet in both

years could be due to denitrification and volatilization of ammonia ($NH_{3(g)}$) gas which might have led to losses of ammonium ions (NH_4^+) in the soils as a result of high atmospheric and soil temperatures during the periods (Table 3) because volatilization is favored by warm temperature, wet soils under drying conditions [18] and pH from 4.50 up to 8.50 [54]. According to [54], he proposed that volatilization commonly occurs after the application of manure. Increase in temperature could decrease the activities of nitrifying bacteria which might have resulted in a greater level of NH_4^+ available for conversion to NH_3 during this work. According to [9], increased temperature at 30 ºC increases the volatilization of NH_3 over 78 days from a sandy soil.

Equally, soil NH_4^+- N differed with integration of manure rates. Best and least rates in wet and dry seasons were with $P_{30}S_0$ (134.93) and P_0S_0 (127.50) and $P_{60}S_0$ (127.83) and P_0S_0(8.40) in 2019 and $P_{30}S_{60}$ (171.80) and P_0S_0 (8.40) and $P_{30}S_{60}$ (141.00) and P_0S_0 (76.20 mg kg-1) in 2020 at 1st WAMA, $P_{60}S_0$ (139.23) and $P_{60}S_{30}$ (132.67) and P_0S_{60} (128.80) and $P_{30}S_{60}$ (125.50) in 2019 and $P_{30}S_{60}$ (218.32) and P_0S_0 (5.70) and $P_{30}S_{60}$ (139.80) and P_0S_0 (71.00 mg kg-1) in 2020 at 2nd WAMA, $P_{60}S_{60}$ (149.80) and P_0S_0 (146.37) and $P_{30}S_{30}$ (136.83) and P_0S_0 (127.07) in 2019 and $P_{60}S_0$ (189.10) and P_0S_0 (55.30) and $P_{60}S_0$ (128.90) and P_0S_0 (91.00 mg kg^{-1}) in 2020 at 3rd WAMA, $P_{60}S_{60}$ (149.00) and P_0S_0 (144.43) and $P_{60}S_0$ (142.63) and P_0S_0 (132.47) in 2019 and $P_{60}S_{60}$ (194.64) and P_0S_0 (17.61) and $P_{60}S_{60}$ (137.00) and P_0S_0 (78.10 mg kg^{-1} in 2020 at 4th WAMA, $P_{30}S_{60}$ (147.93) and $P_{30}S_0$ (144.80) and $P_{60}S_0$ (141.33) and P_0S_0 (128.77) in 2019 and $P_{60}S_{30}$ (195.00) and P_0S_0 (59.71) and $P_{60}S_{30}$ (142.05mg kg^{-1}) and P_0S_0 in 2020 at 6th WAMA, $P_{30}S_0$ (147.73) and P_0S_0 (136.07) and $P_{30}S_{60}$ (140.80) and P_0S_0 (134.00) in 2019 and $P_{60}S_{60}$ (173.44) and P_0S_0 (96.90) and $P_{60}S_{30}$ (149.60) and P_0S_0 (94.30 mg kg^{-1}) in 2020 at 8th WAMA and $P_{30}S_0$ (147.30) and $P_{30}S_0$ (128.40) and $P_{30}S_{60}$ and P_0S_0 (131.13) in 2019 and $P_{60}S_{30}$ (159.30) and P_0S_0 (92.50) and $P_{60}S_{30}$ (134.50) and P_0S_0 (91.60 mg kg^{-1}) in 2020 at 12th WAMA. In both seasons and years, best NH_4^+-N at most weeks after manure applications varied with rates of application but occurred mainly within the 0 - 10 cm soil depths while least concentrations were mostly with P_0S_0 rate and at 20 - 40 cm depths. The highest and lowest concentrations in the soils were in wet season of 2020 using $P_{30}S_{60}$ (218.32) and P_0S_0 (5.70 mg kg^{-1}) at 5 - 10 and 10 - 20 cm depths respectively in the 2nd WAMA. The irregularity could be attributed to volatilization [23]. Averaged over manure rates, weeks after application and soil depths, soil NH_4^+- N were better in wet (141.15 and 116.97) than dry (133.09 and 111.85 mg kg^{-1}) seasons of 2019 and 2020 respectively. Also, concentrations were better in 2019 than 2020 with integration of treatments as was the case for addition of only poultry and sheep manures. Equally, trend in NH_4^+- N distribution was a decrease down soil depths with manure rates and weeks of application in most seasons and years. Generally, increased soil NH_4^+- N with rates of poultry or sheep manures only and the integration relative to the control could be due to the high nutrient contents in the manures applied. Similar observations have been reported for only poultry ([3], [4]) and sheep ([41], [38]) and with the impact on soil NH_4^+- N due to priming of organic nitrogen mineralization ([6], [36]). Nitrogen mineralization is the process by which organic nitrogen is converted to inorganic nitrogen due to the activities of nitrifying bacteria [51]. It involves a two-step process of ammonification and nitrification. Ammonification refers to the process in which organic nitrogen is converted to ammonium nitrogen by groups of nitrobacteria [35]. The nutrient contents in integration of both manures could be responsible for the NH_4^+- N concentration. Also, the decreasing trend with soil depth could be due to low oxygen content and poor microbial activity with depths. It has been reported that mineralization and ammonification are promoted by conditions such as high oxygen content, temperature, moisture and soil reaction. Equally, increased NH_4^+- N content in wet seasons of both years could be due to the enhanced moisture conditions in the wet than dry seasons during the experiment. Furthermore, due to probable better environmental conditions, ammonification and thus ammonium concentration was higher in 2019 than 2020.

IV. Conclusion

Generally, incorporation of poultry and sheep manures on the soils improved the soil ammonium- nitrogen compared with control. Highest application of integration of manures improved soil NH_4^+- N with the trend of $P_{60}S_{30} > P_{30}S_{60} > P_{60}S_{60}$. In relation to soil depths, NH_4^+- N decreased as the depth increased. Soil NH_4^+- N during dry seasons at the weeks after treatments applications decreased relative to wet seasons in the year 2019 and 2020. The data demonstrated that interaction between poultry and sheep manures had a substantial impact on soil NH_4^+- N than single application.

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