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Comparative effects of organic manure and inorganic fertilizer as nitrogen sources on leaf nutrient content and nitrogen use efficiency of cotton

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ABSTRACT

A field experiment was conducted at the Research Farm of the College of Agriculture Jalingo, Taraba State in two planting seasons (2020 and 2021) to determine the influence of nitrogen sources and rates on nutrient concentration in leaf and nitrogen use efficiency of cotton. The experiment was a 5x4 factorial of four nitrogen sources (poultry manure, organo-mineral fertilizer, urea and NPK15:15:15) and five N rates (0, 150, 200, 250 and 300 kg/ha), laid out in a randomized complete block design (RCBD) in the field. Soil pH, organic C, N, exchangeable bases, CEC and base saturation were determined before planting. Nitrogen, K and P contents of the plant leaf increased with increasing N rate. Sources of nutrients increased the N concentration of the plant leaves. Nitrogen uptake increased with N application rate. However, at 300 kg N ha^{-1}, N uptake decreased. Agronomic, internal use and recovery nitrogen efficiencies (aNUE, iNUE and NRE) decreased with increasing N rate. The highest value of N uptake, NRE and aNUE were obtained under NPK-treated plots, while iNUE and physiological nitrogen use efficiencies (pNUE) were at maximum under poultry manure amended plots. Cotton N use efficiency can be improved through conscientious use of fertilizers taking into consideration the soil nutrient status. Among the nitrogen sources, urea produced the lowest value for the nitrogen use efficiency of cotton. It is therefore, recommended that nitrogen dose of 150 kg/ha from either poultry manure or NPK be applied for optimum N use efficiency in the study area.
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1.0 Introduction

One of the major causes of insufficient food attainment is deficient organic matter content in soils, and consequently, the low infertility nature of soils in the West Africa region (Shiyam and Binang, 2013). Adopting efficient use of organic and inorganic fertilizers is necessary for enhancing yield increase (FAO, 2013). Efficient utilization of applied nutrients by plants is vital for ensuring profitable crop productivity. However, Oluwatosin (2016) asserted amongst many challenges hindering arable crop yield include insufficiency, that high cost of inorganic fertilizers is prominent. Shiyam and Binang (2013) inferred that inorganic fertilizer could only increase yield in the short term, while in the long term, it could become unprofitable and detrimental to the environment. The use of organic fertilizer was said to be beneficial to the environment and more sustainable to raise agricultural productivity. This is because organic manure had a positive influence on the chemical, physical and biological properties of the soil (Adeli *et al*., 2007; Adeli *et al*., 2010). The application of manure is more sustainable in crop production because it holds and binds nutrients to the soil and prevents nutrient loss through leaching (Kanyanjua and Obanyi, 2000). The combined application of organic fertilizers with inorganic fertilizers helps to promote better crop yield compared to the use of either of the amendments alone; and also reduces the quantity of organic fertilizer needed for optimum crop production and slows down quick soil destruction (Iren *et al.,* 2012 & 2014; Oyedeji *et al*., 2014).

Cotton is reported worldwide as the most important fibre-producing crop with high economic value for the textile industry and oil mill (Omadewu *et al.,* 2017). Because of its indefinite vegetative growth and reproductive structure, cotton requires high nutrient management. Cotton has a very high need for nitrogenous fertilizer to optimize seed yield (Hou *et al.,* 2007; Dong *et al.* 2011), especially under low soil nitrogen content (Muhammad and Javed, 2006; Iren and Aminu, 2017); because it is needed for cotton leaf canopy development to enhance photosynthesis (Bondada and Oosterhuis, 2001).

However, excessive application of nitrogen could result in excessive luxury N consumption (Muhammed *et al*., 2002). The mixed farming system in Africa is characterized by low rural incomes, high costs of fertilizer, inappropriate public policies and infrastructural constraints (Blazier *et al.* 2008; Ayeni *et al.,* 2008) that result in the widespread low use of inorganic fertilizers. Organic sources of plant nutrients have been the principal sources of nutrients for soil fertility maintenance and crop production in native African settings (Williams *et al.,* 1995). It was observed that the application of 2 t/ha farmyard manure increased cotton seed yield by 100 % (Adeli *et al*. 2010), which is equivalent to mineral fertilizers applied at 60 kg N/ha and 20 kg phosphorus/ha. The agronomic and cost-effectiveness of organic fertilizers usage have been reported (Hassan *et al.,* 2014) and organic fertilizers can be mixed with inorganic fertilizers for effective crop production by small-scale farmers to maintain good soil health (Olowoake, 2014; Akpan *et al.,* 2023). Gebaly (2011) noted that the application of organic manure and nitrogen fertilizers are the main factors that govern the balance between different vegetative and fruiting stages of cotton plants and consequently its effect on growth, yield and lint quality. As a way of safe disposal for a healthy environment, the application of poultry litter to croplands as a nutrient source is very important (Zhao and Tisdell, 2009). Worldwide, there is growing interest in the use of organic manures due to depletion in soil fertility (McGrath *et al.,* 2010). Hence, nutrients provided by poultry litter have been reported to have a positive effect on crop production and a healthy environment (Reddy *et al.,* 2007). Information on the evaluation of the effect of N rates and sources on N use efficiency on cotton crops is not available in the study area. Therefore, this study was to evaluate the impacts of nitrogen rates and nitrogen sources on nitrogen use efficiency and nutrient content of cotton plant leaves under rain-fed conditions.

2.0 Materials and Methods

The field experiment was conducted at the Research Farm of the College of Agriculture Jalingo during the 2020 and 2021 cropping seasons in Jalingo (11^0 09' and $11^0$30' East and latitude 8^0 17' and 9^0 01' North), about 212.7 m above sea level, in northern guinea savanna region of Nigeria (TSMLSD, 2012).

The experiments were conducted in two sites that were 1.0 km apart, with one site used for the 2020 planting and the second site used for the 2021 planting. Each site was on a land area of 1575 m^2 (0.1575 ha), it was cleared, stumped and all the debris raked, parked tilled with a traditional hand hoe. The field was demarcated into three blocks of 525m^2 each. In each block, plots measuring 3m by 3m (9 m^2) were marked out, with alleyways 2.0 m between blocks, and 1m wide between plots. The experiment was a 5x4 factorial arranged to fit into a randomized complete block design (RCBD) in three replications. The treatments consisted of five nitrogen rates (0, 150, 200, 250 and 300 kg/ha) and four nitrogen sources (urea, poultry manure, organo-mineral and NPK15:15:15) for a total of 20 treatment combinations and 60 experimental plots.

Initial composite soil samples were collected with the use of a soil auger at 0-15 cm depth. A total of three composite samples were collected, air dried, sieved through a 2-mm sieve and analyzed for physico-chemical properties. Raised seedbeds were prepared manually by the use of a traditional hoe. Poultry manure was collected from Yakubu Commercial Poultry Farm in Jalingo. The manure was cured and incorporated into the soil one week ahead of planting. Seeds of cotton (Samcot-13) obtained from AFCOT Nigeria Limited in Ngurore, Adamawa State, were sown on a well-prepared moist seedbed at 75 cm x 45 cm at Four seeds per hole. These were thinned to one vigorous plant per stand 14 days after sowing (DAS) to give a plant population of 29,629 plants/ha. Urea was applied in two equal splits at 21 and 50 DAS. Organo-mineral fertilizer obtained from Tropical Fertilizers, John Ker. Co. LTD was applied in one dose at 21 DAS. All four different N sources (urea, poultry manure, NPK15:15:15 and organo-mineral fertilizers) were applied at 0, 150, 200, 250 and 300 kg N/ha. Weeding was manually done twice at four and eight weeks after sowing. Pest control was done during boll formation and boll opening with the use of Cypermetrin-10% EC, a product of Yixin Chemical Product Limited, China.

Three soil samples, one from each block were analyzed in the laboratory using standard procedures outlined as follows: Particle size distribution was determined by the Bouyoucous hydrometer method. Soil pH was determined in a 1:2.5 soil water ratio with a pH meter, and organic carbon was determined by the Walkley Black Dichromate Oxidation Method (Udo *et al.,* 2009). Total nitrogen (N) was determined by the micro Kjeldahl method, available phosphorus (P) was extracted by the Bray 1 extraction method, and the content of P was determined colorimetrically using a Technico AAII auto analyser (Udo *et al.,* 2009). Exchangeable bases (K, Na, Ca, and Mg), exchangeable acidity, effective cation exchange capacity (ECEC) and base saturation were determined as outlined by Udo *et al.,* (2009). The poultry manure was analyzed for its nutrient compositions following the procedure of Peters *et al*.

(2003) before usage on the field.

Plant sampling was done at the initiation of boll formation on ten tagged plants from the two central rows in each plot. Twenty well-matured leaves (4^{th} leaf) from the apex of the main stem were taken from the tagged plants $plot^{-1}$. The leaves were oven-dried (75° C), milled and passed through a 0.5mm sieve. The leaf concentration for N, Mg, Ca, K and P were determined by the wet digestion procedure (Udo *et al*, 2009). Data collected were subjected to analysis of variance (ANOVA) and significant differences separated using Fisher's least significant difference (FLSD) at $p \leq 5\%$.

3.0 Results and Discussion

3.1. Physico-chemical properties of Plots A and B soils for the study

Results of the soil analysis of the sites used are presented in (Table 1). Data showed that the soils were similar in their physical properties but varied slightly in their chemical properties. The soil was sandy loam in texture with a clay content of 6-7 %. The soil reaction (pH) was moderately acidic (5.8) at site A (year 2020 plot) but strongly acidic (pH=5.4) at site B (year 2021 plot). The pH value falls within the range for optimum cotton cultivation (Idem, 1999). The soils from both years were low in both organic C and total N contents suggesting that response to nitrogen fertilizer would be high. It was opined that continuous crop removal, over-grazing and poor residue returns must have been the major causes of the low organic C and N in the soils, which are typical conditions of arable lands in the northern guinea savanna zone of Nigeria (Samuel *et al.*, 2024). The soil available P content was high (22.75 mg/kg) in Plot A but medium (12.50 mg/kg) in Plot B. Exchangeable K of 0.12 - 0.19 cmol(+)/kg was low, while, soil Ca (2.5 cmol(+)/kg) and Mg (1.28 and 1.2 cmol(+)/kg) contents were high. The base saturation of the soil of 91.9 and 89.2 % respectively for plots A and B were high, which implies that their responses to fertilizer application would be high (Ayoola and Agboola, 2022).

The chemical analysis of poultry manure used (Table 2) showed that pH was high which has a positive effect on nutrient availability in the soil. Carbon content was high and constituted the greatest fraction about 30 % of the total dry matter. Because of the high content of total C, its application may improve soil quality and crop productivity (Feng *et al.*, 2021). Total N was high enough to provide N in more readily available forms for plant use. The poultry manure contained a substantial quantity of P, K, Mg and Ca which are essential plant nutrients and could improve soil fertility status.

Table 3 shows the level of N, P, Ca, K and Mg contents of the cotton leaf at the squaring stage. The leaf N concentration was lowest with control (0 kg N/ha) and the value increased with an increase in application rates. The highest leaf N content was at the application rate of 300 kg N/ha in 2020 (4.35%) and 2021 (4.25 %) respectively while it was the least with control plots for both years with 2.90 % and 2.70 % for years 2020 and 2021 respectively. Considering sources of N, the NPK 15:15:15 resulted in the highest leaf N contents of 4.50% in 2020 and 4.25 % in 2021 (Table 3). The inorganic fertilizer resulted in higher leaf N content compared to the poultry manure (3.42 %), however, the four N sources led to increased leaf N content of cotton than in the control treatment (Table 3). However, the highest leaf N content of 5.25 %. was obtained with an NPK rate of 250 kg N/ha.

Table 1: Physico-chemical properties of Plots A and B soils for the study

Soil property	2020 Plot A	2021 Plot B
pH(H_20)	5.80	5.40
Org. C (%)	0.38	0.28
Total N. (%)	0.02	0.02
Av. P (mg/kg)	22.75	12.50
Exch. Ca^{++} (cmol/kg)	2.50	1.80
Mg^{++} (cmol/kg)	1.28	1.40
K^{+} (cmol/kg)	0.12	0.19
Na^{+} (cmol/kg)	0.14	0.06
Al^{+++} (cmol/kg)	0.00	0.02
H^{+} (cmol/kg)	0.36	0.40
ECEC (cmol/kg)	4.04	3.45
Base Saturation (%)	91.90	89.20
Clay (%)	7.00	6.00
Silt (%)	17.00	13.00
Sand (%)	76.00	81.00
Textural class	Sandy loam	Sandy loam

Table 2: Chemical analysis of poultry manure used

Properties	Poultry manure
pH	8.50
Org.C (%)	29.92
Total N (%)	2.94
P (%)	0.37
Ca (%)	4.16
K (%)	0.13
Mg (%)	1.58

On the phosphorus concentration of cotton leaf, the influence of N application rates was not significant ($p>0.05$) in the 2020 cropping season, but was significant for the 2021 season, with the highest P concentration of 0.14 % under the application rate of 250 kg N/ha. Phosphorus concentration increased with an increase

Table 3: Effect of N rates and sources on N, P, K, Ca and Mg contents of cotton leaf

Treatment	N		P		Ca		K		Mg	
				%						
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
N Rate (kg/ha)										
0	2.91	2.70	0.14	0.09	1.62	1.39	1.76	1.62	0.39	0.33
150	4.14	4.02	0.17	0.12	1.74	1.50	2.53	2.19	0.50	0.42
200	4.19	3.96	0.16	0.13	1.83	1.54	2.34	2.11	0.62	0.57
250	4.26	4.20	0.17	0.14	1.74	1.55	2.55	2.19	0.52	0.47
300	4.35	4.15	0.17	0.12	1.88	1.64	2.44	2.25	0.60	0.57
LSD(0.05)	**0.42**	**0.33**	**Ns**	**0.20**	**Ns**	**0.11**	**0.39**	**0.22**	**0.14**	**0.13**
Nitrogen source										
NPK	4.50	4.25	0.18	0.13	1.83	1.53	2.72	2.39	0.58	0.49
OMF	3.71	3.46	0.16	0.12	1.44	1.55	2.25	2.03	0.43	0.42
PM	3.59	3.42	0.21	0.17	1.98	1.69	2.40	2.21	0.46	0.46
UREA	4.10	4.21	0.18	0.06	1.78	1.33	1.92	1.67	0.67	0.52
LSD(0.05)	**0.38**	**0.30**	**Ns**	**0.18**	**Ns**	**0.09**	**0.34**	**0.19**	**0.12**	**Ns**

NPK=NPK 15:15:15, OMF=organo-mineral fertilizer, PM=poultry manure. LSD (0.05) = least significant value at 0.05 probability level

in N rates, however, at 300 kg/ha, there was a decrease in P with a value of 0.09 %. Cotton leaf P content was significantly affected by N sources, resulting in to increase in cotton leaf P content with the maximum P of 0.21 and 0.17 % P under poultry manure amendment for 2020 and 2021 respectively. The minimum P (0.08 and 0.06 %) was obtained under urea-treated plots for 2020 and 2021 respectively (Table 3). Similarly, nitrogen rates and sources significantly impacted the K accumulation levels in cotton leaf. The control plot produced the cotton leaves with the lowest K concentration for the two years, while the highest was obtained at a treatment rate of 250 kg N/ha with values of 2.55 % and 300 kg/ha with 2.25 % respectively for 2020 and 2021 cropping periods. The NPK-treated plots had the highest K accumulation in the cotton leaves with values of 2.72 (2020) and 2.39 % (2021) while the least was observed from the urea-treated plot (1.92 and 1.67 %) for 2020 and 2021 respectively. Nitrogen rates and sources did not significantly ($p>0.05$) influence the leaf Ca content of cotton.

3.2. Effects of N rate and source on uptake, pNUE, iNUE, aNUE and NRE

Effects of N rates and sources on N-uptake and use efficiency by cotton plant (Table 4) indicate that there was a significant increase in nitrogen uptake with an increase in application rate. Maximum nitrogen uptake by cotton (101.99 kg/kg) for the 2020 crop year and (78.18 kg/kg) for the 2021 crop year were obtained at the application rate of 250 kg/ha.The least nitrogen uptake was produced under the control plot with a value of 12.41 kg/ha for 2020 and 6.73 kg/ha for 2021. Plot amendment with NPK 15:15:15 produced the highest nitrogen uptake of 101.0 kg/ha for 2020 and 73.85 kg/ha for 2021, while the least uptake values (54.89 and 44.61 kg/ha) were obtained under urea treated plot for 2020 and 2021 crop years respectively.

Physiological nitrogen use efficiency (pNUE) was influenced by N rates and sources. Maximum pNUE of 23.61 kg/kg was recorded with the application of 200 kg N/ha for the 2020 season while the highest value of 24.33 kg/kg was obtained in 2021 at 200 kg N/ha. The lowest values were obtained at the N rate of 150 kg N/ha for both 2020 and 2021 cropping. However, the highest value of 20.50 kg/kg was produced with poultry manure application while the lowest value of 15.33 kg/kg was recorded under NPK usage. However, a plot treated with urea as a source of nitrogen produced the least value of pNUE in 2021. Internal nitrogen use efficiency (iNUE) for cotton reached an optimal level of 24.74 kg/kg in 2020 and 25.69 kg/kg in 2021 cropping years at 200 kg N/ha, while the lowest value of 23.80 kg/kg (2020) and 24.54 kg/kg (2021) was obtained at 300 kg/ha. The maximum value of internal nitrogen use efficiency was obtained in 2020 (21.48 kg/kg) and 2021 (22.38 kg/kg) using poultry manure as source of N. Agronomic nitrogen use efficiency (aNUE) showed that highest value of 9.56 kg/kg in 2020 and 8.49 kg/kg in 2021 was obtained under 150 kg N/ha, while the least value of 6.17 and 5.38 kg/kg was at 300 kg N/ha in 2020 and 2021 respectively.

The Nitrogen recovery efficiency (NRE) was highest at

43.60 and 35.83 % respectively for the 2020 and 2021 cropping years, with a rate of 150 kg N/ha, and it was at least, 29.05 and 22.41 % at 300 kg N/ha for the same periods. With N source, NPK produced the highest N recovery efficiency, with a value of 40.86 and 31.04 % respectively for 2020 and 2021 cropping years. The lowest values of 20.29 and 18.20 % were obtained under urea-treated plots during the same period.

The effect of interaction of N rate and source on N uptake, aNUE and NRE (Figure 1 to 3) show that in the 2020 and 2021 cropping seasons, the maximum value of 110 and 150 kg/ha of nitrogen was taken up by the plants with NPK 15:15:15 applied at 250 kg/ha while the least value of 9 and 12 kg/ha were obtained for the control for the same period. In figure 2, ANUE had a maximum value of 13kg/ha with NPK applied at 150 kgN/ha in 2020 while in 2021poultry manure at 150 kgN/ha rate produced the maximum value of 11kg/ha. The lowest value (4 and 3 kg/ha) was recorded with urea applied at 300kgN/ha for the period 2020 and 2021. Interaction of NPK with 150kgN/ha rate produced maximum value of 57 and 46% for 2020 and 2021cropping years respectively (Figure 3).

Table 4: Effect of N rates and sources on N uptake, pNUE, iNUE, aNUE and NRE.

Treatment	N-uptake Kg/ha		pNUE kg/kg		iNUE %		aNUE		NRE	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
N rate (kg/ha)										
0	12.41	6.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150	77.90	60.42	22.06	23.98	24.08	25.49	9.56	8.49	43.60	35.83
200	81.96	66.17	23.61	24.33	24.74	25.69	7.67	7.12	34.73	30.42
250	101.99	78.18	23.06	22.59	24.38	23.97	7.47	6.29	35.80	28.60
300	99.65	75.37	22.28	23.19	23.80	23.54	6.17	5.38	29.05	22.41
LSD	**12.77**	**5.77**	**3.19**	**2.05**	**2.56**	**2.02**	**0.83**	**0.49**	**5.57**	**02.54**
Nitrogen source										
NPK	101.00	73.85	15.33	16.70	16.61	17.71	7.83	6.38	40.86	31.04
OMF	65.93	51.13	19.72	20.87	20.49	21.86	5.81	5.29	24.38	20.89
PM	77.32	59.89	20.52	21.60	21.48	22.38	7.29	6.53	29.02	24.20
UREA	54.89	44.61	17.24	16.09	19.02	17.80	4.00	3.64	20.29	18.20
LD	**11.43**	**5.26**	**2.86**	**1.87**	**2.29**	**1.84**	**0.73**	**0.44**	**4.98**	**2.31**

NPK=NPK 15:15:15, OMF=organo-mineral fertilizer, PM=poultry manure, pNUE, iNUE, aNUE and NRE=physiological, internal, agronomic nitrogen use efficiency and nitrogen recovery efficiency.

3.3. Discussion

The soil Organic C and total N buttressed the general characteristics typical of tropical soils (Ayoola and Agboola, 2002). This becomes more problematic with the soil Clay content that is low and with a sandy loam texture. Soil pH was moderately acidic to strongly acidic for the two sites used, which must have caused variability in soil properties. Calcium and magnesium were high in the soil; a common characteristic of the soil in the Guinea savannah zone due to reduced rain-fall (Iren *et al.*, 2017). Nitrogen content increased with rate but at 300kg N/ha, the leaf nitrogen decreased. This indicated that a nitrogen dose above the requirement would lead to luxury consumption and further excesses would be lost through leaching (Dong *et al.*, 2012). The NPK-treated plots had the highest leaf N contents, probably because N from NPK is easily released compared to the poultry manure and organo-mineral fertilizer (Ipinmoroti *et al.*, 2008). The observed least nitrogen content in the leaf of cotton-applied urea could be due to high losses of N through volatilization, while P content increases with N dosage. The positive N uptake correlation with P was highest from poultry manure compared to other N sources. The slow mineralization of poultry manure must have increased P-uptake, while it was reduced using urea. There were no significant effects on Ca and Mg contents in cotton leaf across N applications but there was a significant difference effect over the control plots, with N sources having a positive effect on Ca and Mg content. The high accumulation of leaf K, Ca and Mg observed under poultry manure emphasized the importance of organic manure in maintaining soil health and improving crop productivity. However,

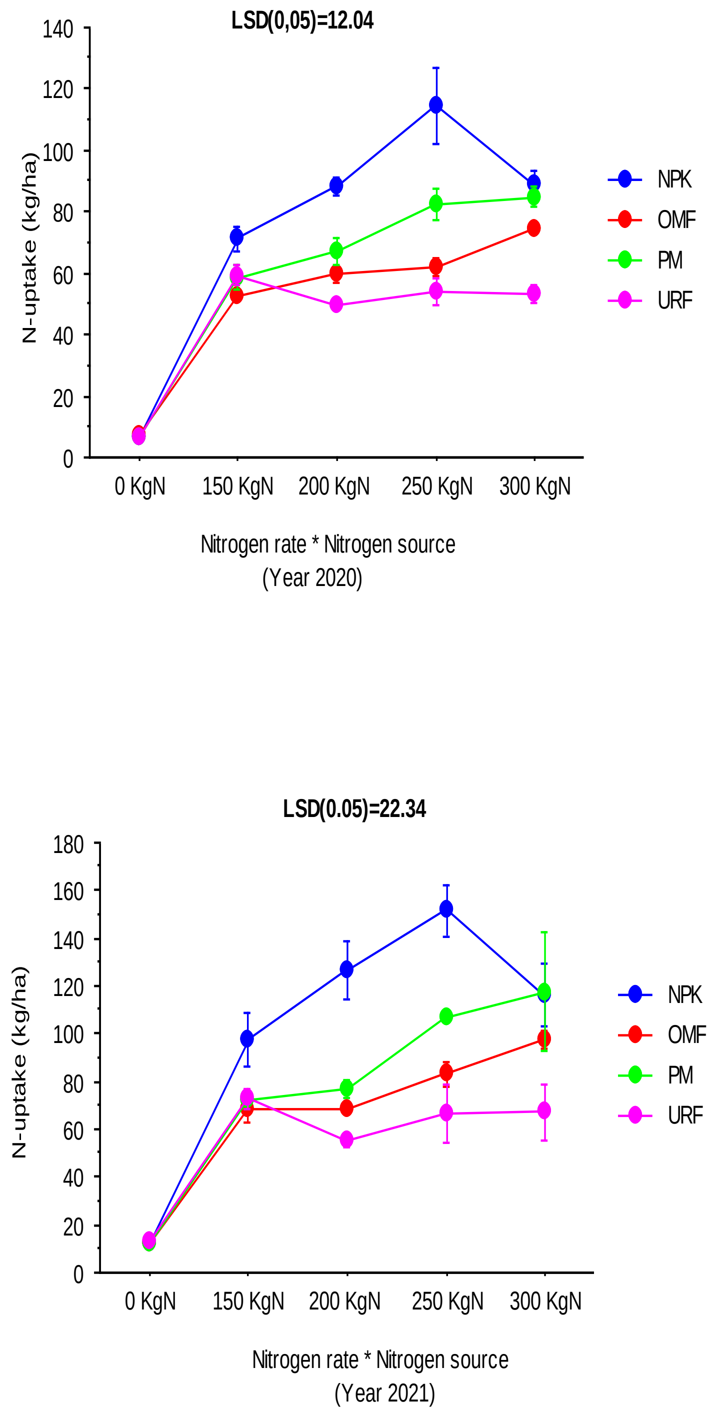

Fig.1 Effect of N rate Interaction with N sources on N Uptake by Cotton in Year 2020 and 2021.

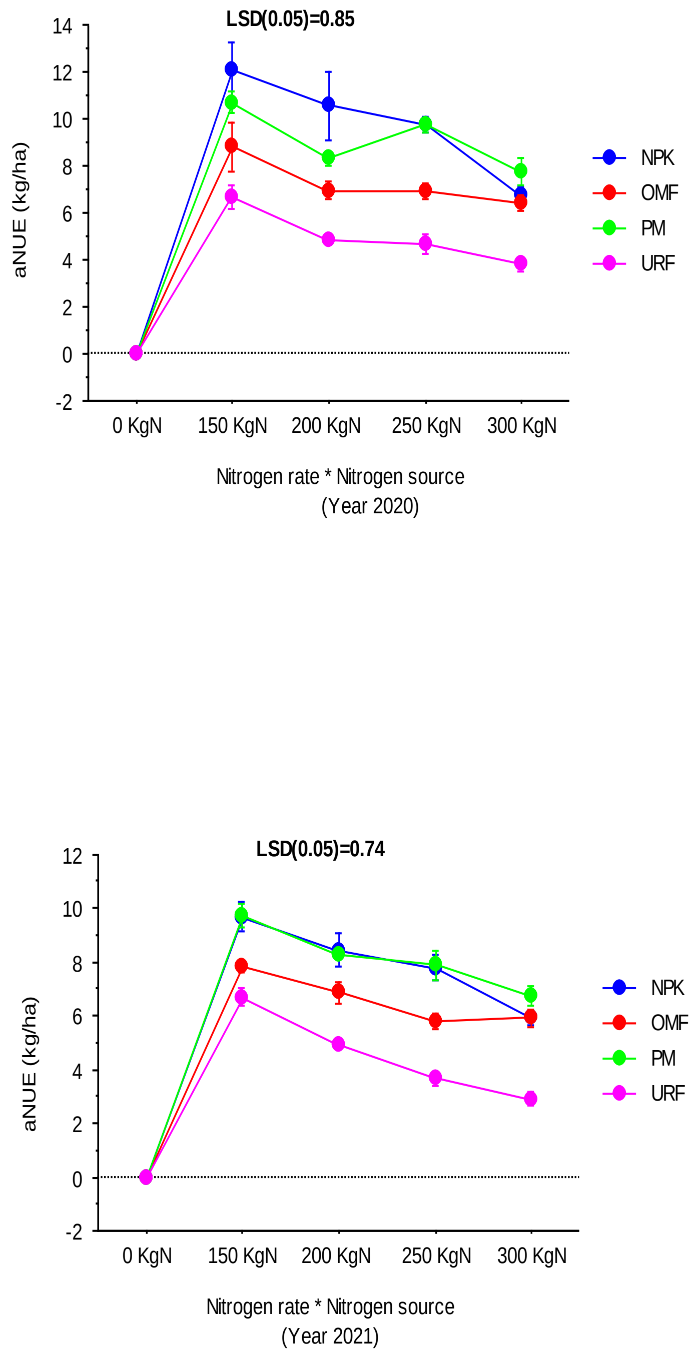

Fig.2: Effect of Interaction of Nitrogen rate with Nitrogen Source on Agronomic Use Efficiency of Cotton in Year 2020 and 2021.

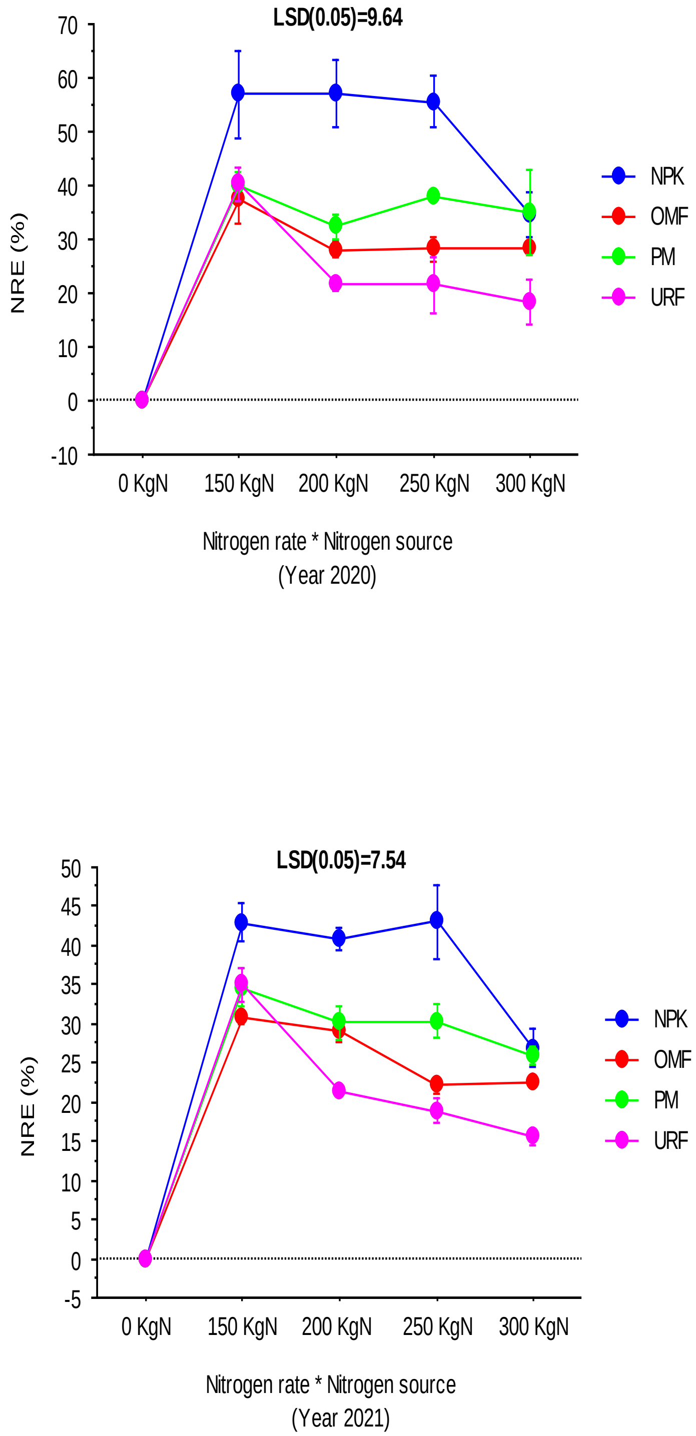

Fig. 3: Effect of Interaction of Nitrogen Rate with Nitrogen Source on Recovery Nitrogen Efficiency of Cotton in year 2020 and 2021.

low values of the nutrients on plots applied urea showed that sole Urea is not advisable for cotton production. Obtained values for nutrient content were significantly different compared with the control treatment. The significant nitrogen uptake by cotton agreed with reports by Omadewu *et al* (2017) and Fixen *et al.* (2014) that increasing the application rate of nitrogen fertilizer in cotton increased the nitrogen uptake and crop yield. Similarly, higher nutrient uptake by cotton was reported with increased application rate of cattle dung (Iren and Aminu, 2017). Dong *et al.* (2011) and Mushtaq *et al.* (2010) also reported that high nitrogen rate resulted to the accumulation of more nitrogen than those treated with lower rates. The reduced nitrogen uptake at the higher N rate of 300 kg N/ha indicated that excessive N input may lead to crops becoming unresponsive (Kumbhar *et al.*, 2008). Also, at a higher N rate, the pNUE of cotton decreased, agreed with the finding of Dong *et al.* (2012). Very low physiological N use efficiency suggests an unbalanced fertilization probably due to excessive N applications or deficiency of other nutrients or mineral toxicity; and high pNUE suggests high internal N use efficiency (Dobermann 2007). However, excessive N application leads to decreased N use efficiency (Fixen *et al.*, 2014). The physiological nitrogen use efficiency of cotton differs from one season to another across all the treatments, the higher N levels decrease iNUE while the low to moderate rates result in higher iNUE. This trend was in agreement with Dong *et al. (*2011) and Tang *et al.* (2012) from their studies. The various N sources showed that poultry manure produced the highest value of iNUE (24.93 kg/ha), this was followed by the organo-mineral fertilizer with iNUE value of 21.18 kg/ha. Internal nitrogen use efficiency was however observed to vary slightly between the two seasons, which may be due to variation in rain fall and other environmental factors (Tang *et al.*, 2012). At low nitrogen application; nitrogen recovery efficiency was higher, while it at higher rates, there was lesser nitrogen recovery. This trend might be due to less immobilization at the higher rates by plants and loss of N due to leaf fall (Brentrup and Palliere, 2010). Nitrogen recovery efficiency, however, depends on the congruence between the plant demand for N and N release from fertilizer (Dong *et al.*, 2012; Brentrup and Palliere, 2010). This phenomenon is affected by the fertilizer application methods, amount, timing, placement, N form, and other factors that determine the size of the crop nitrogen sink - the plant genotype (Dong *et al.*, 2012). This experiment showed that nitrogen recovery efficiency became increasingly less as the application rate increased.

Generally, the low recovery efficiency of urea fertilizer could be due to its high volatility which causes excessive N loss from the soil surface after application. Poultry manure and organo-mineral treated plots that resulted in less nitrogen recovery efficiency compared to NPK treated plots might be due to the slow release of nitrate from the manure treatment, resulting from incomplete decomposition of the organic residues during the active nitrogen uptake by plant (Dobermann, 2017).

4.0 Conclusion

The response of cotton at various nitrogen sources and rates over two cropping seasons was studied. The study revealed that N rate and sources significantly ($p < 0.05$) affected leaf nutrient concentration and nitrogen use efficiency in cotton plants. An increase in N rates led to an increase in leaf N contents up to 250 kg N/ha and thereafter decreased. The concentration of N and K were at peak using NPK, while poultry manure resulted in higher leaf concentrations of Ca and P. The cotton leaf nutrient contents and N use efficiency were significantly affected by N rates, sources and their interaction. Optimum N use efficiency could be achieved with either poultry manure or NPK at apply rate of 150 kg N/ha in the study area. It was therefore concluded that cotton N use efficiency can be improved through meticulous use of fertilizers taking into consideration the soil nutrient status.

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