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Original Research Article

Nitrogen Rate and Plant Density Effects on Soil Properties and Leaf Areaof Cotton cultivars Grown on the Savanna Region of Nigeria

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Abstract: In Nigeria, cotton production is mostly done in the savanna regions where the soils are predominantly coarse textured, low in organic matter and nitrogen. Field experiment was conducted at two locations within the Research Farm, College of Agriculture, Jalingo to investigate the influence of nitrogen rates and plant density on soil properties and leaf area of cotton cultivars. A 4 x 3 x 2 factorial of four nitrogen (N) rates (0, 120, 150, 200 kg/ha), three cotton varieties (Jalingo Local, Samcot-13, Sketch-8) and two plant densities (75 x 30 cm or 44,444 plants/ha and 60 x 30 cm or 60,000 plants/ha) was arranged in a randomized complete block design and replicated three times. Results obtained indicated that pH of the soil was low both in the surface (5.5) and subsurface (5.4) irrespective of cotton cultivars, N rates and plant density compared with the initial status (5.7).Organic carbon, total nitrogen and available phosphorus contents were improved. Nitrogen rates at all growth stages significantly ($p < 0.05$) contributed to the widening of cotton leaf with the leaf area increasing as the N rate increases. Plants with lower density (44,444 plants/ha) significantly produced larger leaf area averaging 271.2 cm^2 compared with 109 cm^2 at high density of 60,000 plants/ha. However, cotton variety had no significant effect on leaf area. Interactively, Samcot-13 treated with 150 kg N/ha under lower density produced the largest leaves. Wider plant spacing and higher nitrogen rates enhanced the production of larger leaf thereby increasing photosynthetic rate in cotton.
Keywords: Cotton variety, leaf area, nitrogen rate, plant population, soil properties, urea fertilizer.

INTRODUCTION

The use of fertilizers as an agricultural input in crop production is inevitable particularly in Nigeria where the nutrient levels of the soils in most areas are low due to the sandy nature of tropical soils and continuous cropping of a piece of land year in year out. Sandy soils are low in nitrogen (N), phosphorous (P), sulphur (S) and cation exchange capacity owing to low clay and organic matter contents and the acidic nature of sandy soils. Thus, crops require fertilizers in sufficient amount to give the maximum economic return. Although, other techniques, such as crop variety, crop protection, plant population, could result in increased crop yields, fertilizer usage plays a major role in the universal need to increase food production to meet the demands of the growing world population (Agbede, 2009).

Amongst the three major essential nutrients namely nitrogen, phosphorus and potassium needed by plants in large quantities, nitrogen (N) is the most consistently required than other nutrients for cotton production (Houet *et al.*, 2007; Dong *et al.*, 2011).Nitrogen fertilization had significant impacts on plant growth, plant biomass, lint yields and fiber quality (Bondada *et al.*, 2001). It is an essential element forcanopy area development and photosynthesis (Wullschleger and Oosterhuis, 1990; Dong *et al.*, 2011)). Nitrogen being a mobile element is usually low in soils as it is prone to leaching and erosion losses.

Cotton plants usually show a good response to applied nitrogen fertilizer (Muhammad and Javed, 2006; Omadewu *et al.*, 2017; Iren and Aminu, 2017a, 2017b) most especially if its application is properly timed to enable the crop to use the applied N. Pundarikakshudu and Raju (1995) reported that for every 100kg of seed cotton produced, the crop depletes the soil by 6-7 kg of N, 1.9-2.5kg of P, 6.8kg of K and 1.2-2.0kg of S.

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However, (Dong *et al.*, 2012) inferred that plant density and N rate affect leaf defoliation and boll load. Premature or late season senescence causes reduced crop yield and quality, therefore, good crop management through appropriate seeding rate must be ensured to achieve the desired plant population (Wright, 1999; Dong *et al.*, 2012).In Nigeria, cotton production is mostly done in the savanna regions where the soils are predominantly coarse textured, low in organic matter and nitrogen. The African savanna ecosystem is tropical grassland with warm temperatures year-round and with its highest seasonal rainfall in the summer (www.nationalgeographic.org). The savanna is characterized by grasses and small or dispersed trees that do not form a closed canopy, allowing sunlight to reach the ground. It is also characterized as hot and dry areas but there are instances when it can get extremely wet in these regions. According to Kerby*et et al.*, (1990), cotton cultivars developed in different ecological zones respond differently to inorganic fertilizers while Bronson *et al.* (2001) concluded that cotton production was directly related to doses and application method of chemical fertilizers. However, Ogunwole *et al.*, (2003) found that the variation in varietal response to nitrogen nutrition was non-significant, but the effect of fertility levels was significant. Thus, poor fertility status of soils is a major factor responsible for low yield of cotton in Nigeria (Ogunlela, 2004; Omadewu *et et al.*, 2017; Iren and Aminu, 2017a, 2017b).

This research work was therefore carried out to investigate the effect of applying different nitrogen rates using low and high plant density of cotton cultivars in improving soil nutrient status of Nigerian savanna as well as their effects on leaf area of cotton plant.

MATERIALS AND METHODS

Study Area

The field experiment was conducted at two locations within the Research Farm of the College of Agriculture, Jalingo (longitude 11° 09′and 11° 30′ E and latitude 8° 17′ and 9° 01′ N),Taraba State, Nigeria during the wet season. Jalingo lies within the northern guinea savanna region of Nigeria. The wet season usually commence in April, peak in August and ends in October while dry period begins in November and ends in March, with its peak in January and February when the dusty north-east trade winds blow across the entire area. The basement complex rock underlines the geology of Jalingo Local Government Area.

Land Preparation, Experimental Design and Treatments

The site was manually cleared, stumped, raked and burnt. The land was then tilled manually and plots measuring 2 m x 2.5 m were made. Alleyways between blocks were 2 m while those between plots were 1 m.

The experiment was laid out as a 4 x 3 x 2 factorial arrangement of treatments fitted into a randomized complete block design (RCBD) and replicated three times. The treatment combinations consisted of four nitrogen rates (0,120, 150 and 200 kg/ha) in urea fertilizer, three cotton varieties (Jalingo Local, Samcot-13, Sketch-8) and two plant densities [low plant density (44,444 plants/ha or 75 cm by 30 cm) and high plant density (60,000 plants/ha or 60 cm by 30 cm)].Thus, there were 24 treatment combinations, giving a total of 72 experimental plots.

Soil Sampling and Processing

Composite soil samples were collected before sowing at 0-15 cm (topsoil) and 15-30 cm (subsoil) depths. At the end of the experiment, composite soil samples were taken per plot using soil auger for chemical analysis. Each composite sample was properly labeled. Thereafter, the soil samples were air dried, ground, and passed through a 2-mm sieve to remove materials greater than 2 mm in diameter before analysis.

Planting and Cultural Practices

Seeds of the three cotton varieties (Samcot-13, Sketch-8 and Jalingo Local) were sown on awell-prepared moist seedbed at 75 cm by 30 cm for a density of 44,444 plants/ha (low density) And 60 cm by 30 cm apart for a density of 60,000plants/ha (high density). Four seeds were sown per hole and the seedlings were thinned to one vigorous plant per stand 10 days after sowing (DAS). Nitrogen was applied as urea in two equal splits. The first application was done 21 DAS and the second at 50 DAS. According to Pundarikakshudu and Raju (1995), nitrogen application to cotton should be completed on or before 60 days of sowing for better utilization of the applied nutrient. Weeding was done manually at 14, 50 and 90 DAS.

Data Collection

Ten plants from the central rows were selected and tagged for the determination of cotton plant leaf area at 45 DAS and at 90 DAS.

Laboratory Studies

The soil samples were analyzed in the laboratory using standard procedures as outlined by Udo *et al.*, (2009). Particle size distribution was determined by the Bouyoucous hydrometer method. Soil pH was determined in 1:2.5 soil: water ratio with a pH meter. Organic carbon was determined by Walkley Black Dichromate Oxidation Method. Total nitrogen (N) was determined by the microkjeldahl 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 (Technico, Oakland, Calif). Exchangeable bases (K, Na, Ca, and Mg) were extracted with 0.1N ammonium acetate; K and Na were read with a flame photometer while Ca and Mg were determined through the EDTA titration method. Exchangeable acidity was determined by leaching the soils with 1N KCl and titrating aliquots with 0.01 NaOH. Effective cation exchange capacity (ECEC) was calculated as the sum of exchangeable bases (Ca, Mg, K and Na) and exchangeable acidity (H and Al). Base saturation was calculated by dividing the sum of exchangeable bases by ECEC and multiplying by 100.

Statistical Analysis

Plant data collected were subjected to analysis of variance using the Stat View Software and Least Significant Difference (LSD) at the 5% level of probability was used for comparison of treatment means.

RESULTS AND DISCUSSION

Properties of the soil used for the experiment

The analysis of the experimental soil in locations 1 and 2 are as presented in Table 1. From the result it was observed that the soil used for the experiment in the two locations were similar. The soil was loamy sand in texture either at the surface or subsurface soil with clay content increasing down the profile in both locations. The soil reaction (pH) was moderately acidic (5.7) at the surface but strongly acidic (5.4) at the subsurface. The pH value of the Experimental soil fall within the optimum soil pH of 5.8 to 6.5 for cotton as stated by Idem (1999), but he however stressed that the crop can be grown successfully on more acidic soil with a pH as low as 5.2 and on alkaline soil with a pH above 8.0.The soil was low in organic carbon and total nitrogen contents suggesting that response to nitrogen fertilizer would be high. The low organic carbon and total nitrogen is typical of arable lands in the northern savanna zone of Nigeria as crop residues are usually used up by livestock after harvest, leaving no material on the surface for decomposition. Therefore nutrient removal by both plants and livestock left little or no material for organic carbon build up in the soil. The available phosphorus (P) content of the soil was medium (8.12 mg/kg, 8.30 mg/kg in locations 1and 2 respectively) for the topsoil but low (7.42 mg/kg, 7.86 mg/kg) at the subsoil. Exchangeable potassium was low, while exchangeable calcium and magnesium were high. High exchangeable calcium and magnesium is a common feature of soils of the Nigerian savanna due to moderate rainfall. The base saturation of the soil was high either at the top or sub soil.

Table-1: Physico-chemical properties of the soil used for the experiment

Property	Location 1		Location 2	
	Surface soil (0 - 15 cm)	Subsurface soil (15 - 30 cm)	Surface soil (0 - 15 cm)	Subsurface soil (15 - 30 cm)
Clay (%)	6.00	11.00	9.00	11.00
Silt (%)	10.70	11.70	12.10	12.70
Sand (%)	83.30	77.30	78.90	76.30
Textural class	Loamy sand	Loamy sand	Loamy sand	Loamy sand
pH(H_2O)	5.7	5.4	5.7	5.4
Org. C (%)	0.29	0.24	0.29	0.23
Total N (%)	0.01	0.01	0.02	0.01
Av. P (mg/kg)	8.12	7.12	8.30	7.86
Exch. Ca^{2+} (cmol/kg)	1.80	1.80	2.00	1.80
Exch. Mg^{2+} (cmol/kg)	1.40	1.00	1.50	1.20
Exch. K^{+} (cmol/kg)	0.19	0.15	0.18	0.15
Exch. Na^{+} (cmol/kg)	0.14	0.12	0.13	0.12
Exch. acidity (cmol/kg)	0.36	0.40	0.44	0.50
ECEC (cmol/kg)	3.89	3.47	4.25	3.77
BS (%)	90.8	88.5	89.6	86.7

Soil Properties As Influenced By Nitrogen Rates and Plant Density after Cotton Harvest

Changes in chemical properties of the experimental soil after cotton harvest indicated that pH of the soil were generally low both in the surface (Table-2) and subsurface (Table-3) soils irrespective of cotton cultivars, N rates and plant densities. It was also observed that plot treated with 200 kg N/ha with low plant density (44,444 plants/ha) irrespective of the cotton cultivars recorded the lowest pH value. The plots with high plant density had a mean pH value of 5.5 in both the surface and subsurface soils whereas the plots with low plant density had a mean pH value of 5.4. The reduction in pH values under the control plot (0 kg N/ha) may be connected to basic ion removal by cotton plants and leaching of soluble cations. The decrease in pH observed from the post- harvest analysis in both the surface and subsurface soils when compared with the result obtained before experiment could be attributed to the effect of nitrogen fertilizer, cations removal and leaching. This is in agreement with the report in Brady and Weil (2004) that low pH value in tropical soil usually resulted from high leaching of basic ions.

Total nitrogen and organic carbon after cotton harvest were still low but were however improved when compared with the initial value before experiment with no marked increase observed based on nitrogen rate, plant density and cotton cultivars. Mean values of total nitrogen in the surface and subsurface soils ranged between 0.02 and 0.03%. For organic carbon, plots with high plant density had a mean value of 0.44% in the surface and 0.27% in the subsurface whereas the low plant density plots had mean values of 0.47 and 0.32% in the surface and sub surfaces respectively. Iren and Aminu (2017) also observed similar low values of total N and organic carbon contents even after applying high doses of nitrogen in cattle manure. This show that nitrogen being a very mobile element is prone to leaching loses as well as its high demand by cotton plants. This goes to confirm the assertion made by Pundarikakshudu and Raju (1995) that for every 100kg of seed cotton produced; the crop depletes the soil by 6-7 kg of N.

Application of the treatments increased the soil available P content compared to the initial status before experiment and control plot at both the surface and subsurface soils irrespective of cotton cultivars and plant density. This contradicts the findings of Iren and Aminu (2017a) who reported reductions in soil available P after cotton harvest when different rates of N in cattle manure were used. They however attributed the reduction to the activities of soil microbes in breaking down the manure during decomposition unlike the inorganic form of P that was used in this study. Effective cation exchange capacity of the experimental soil after harvest did not differ in value from the background analysis as the values were found to be low both before and after harvest.

Table -2: Mean values of soil properties planted with cotton cultivars as influenced by nitrogen rates and plant density (surface soil)

Nitrogen rate (kg N/ha)	Cotton Variety	pH (H_2O)	Org. C (%)	T.N (%)	Av. P (mg/kg)	Ca^{2+}	Mg^{2+}	K^+	Na^+	Al^{3+}	H^+	ECEC	BS (%)
						← cmol/kg →							
High plant density (60,000 plants/ha)													
0	Local	5.5	0.28	0.02	7.00	1.8	0.4	0.16	0.11	0.00	0.92	3.39	73.0
	Samcot 13	5.5	0.24	0.01	9.62	2.0	1.0	0.14	0.09	0.00	1.04	4.27	76.0
	Sketch8	5.5	0.26	0.02	8.16	1.6	0.4	0.13	0.10	0.00	0.84	3.01	73.0
120	Local	5.5	0.34	0.02	17.62	1.0	0.8	0.11	0.08	0.00	0.96	2.95	67.0
	Samcot 13	5.6	0.28	0.02	16.75	1.4	1.2	0.12	0.10	0.01	0.08	3.94	72.0
	Sketch8	5.6	0.40	0.02	25.25	2.0	1.8	0.14	0.10	0.01	1.08	5.20	78.0
150	Local	5.5	0.34	0.08	10.62	2.0	1.8	0.18	0.11	0.00	0.92	5.10	80.0
	Samcot 13	5.6	0.84	0.02	10.00	2.4	1.8	0.14	0.10	0.01	1.00	5.08	80.0
	Sketch8	5.5	0.50	0.03	11.62	1.8	1.6	0.13	0.10	0.01	0.96	4.63	78.0
200	Local	5.6	0.47	0.03	16.25	1.8	1.4	0.12	0.10	0.00	1.00	4.42	77.0
	Samcot 13	5.5	0.58	0.03	13.62	1.8	1.6	0.12	0.10	0.04	1.20	4.86	74.0
	Sketch8	5.5	0.71	0.02	12.50	3.0	2.2	0.17	0.12	0.00	1.00	6.49	84.0
Mean		5.5	0.44	0.03	13.25	1.88	1.3	0.14	0.10	0.02	0.92	4.45	76.0
Low plant density (44,444 plants/ha)													
0	Local	5.5	0.19	0.02	11.05	1.6	1.2	0.15	0.11	0.0	0.88	3.94	78.0
	Samcot 13	5.4	0.24	0.02	9.25	2.4	1.4	0.17	0.11	0.0	1.04	5.12	80.0
	Sketch8	5.4	0.28	0.02	8.65	1.6	1.4	0.12	0.09	0.0	1.12	4.33	74.0
120	Local	5.6	0.36	0.02	20.00	1.4	0.8	0.12	0.09	0.01	1.04	3.49	69.0
	Samcot 13	5.5	0.42	0.02	23.87	2.8	1.8	0.13	0.10	0.01	1.04	5.91	82.0
	Sketch8	5.4	0.38	0.02	17.00	2.0	1.4	0.14	0.11	0.02	0.96	4.73	77.0
150	Local	5.5	0.55	0.02	12.37	2.0	1.4	0.13	0.09	0.01	1.00	4.66	78.0
	Samcot 13	5.5	0.73	0.02	10.12	2.8	1.8	0.15	0.10	0.00	0.92	8.77	84.0
	Sketch8	5.5	0.63	0.02	11.50	2.4	1.2	0.14	0.09	0.00	0.96	4.79	80.0
200	Local	5.3	0.57	0.04	13.62	2.2	1.4	0.15	0.11	0.00	1.20	5.06	76.0
	Samcot 13	5.3	0.65	0.03	15.25	2.2	1.6	0.13	0.10	0.04	1.16	5.23	77.0
	Sketch8	5.3	0.68	0.04	14.75	2.4	1.8	0.14	0.11	0.00	0.96	5.41	82.0
Mean		5.4	0.47	0.02	13.95	2.2	1.4	0.14	0.10	0.02	1.02	5.12	78.1

Table-3: Mean values of soil properties planted with cotton cultivars as influenced by nitrogen rates and plant density (subsurface soil)

Nitrogen rate (kgN/ha)	Cotton Variety	pH (H_2O)	Org. C (%)	T.N (%)	Av. P (mg/kg)	Ca^{2+}	Mg^{2+}	K^+	Na^+	Al^{3+}	H^+	ECEC	BS (%)
						← cmol/kg →							
High plant density (60,000 plants/ha)													
0	Local	5.6	0.23	0.03	13.28	2.0	1.8	0.15	0.11	0.00	0.92	4.98	81.0
	Samcot 13	5.5	0.26	0.03	12.87	2.0	3.0	0.17	0.12	0.00	0.92	6.21	85.0
	Sketch8	5.4	0.25	0.02	14.37	2.0	2.4	0.16	0.10	0.00	0.88	5.62	83.0
120	Local	5.3	0.30	0.02	11.75	1.4	2.0	0.12	0.09	0.00	0.92	4.53	80.0
	Samcot 13	5.4	0.30	0.03	11.25	2.6	1.4	0.14	0.10	0.00	0.96	5.20	81.0
	Sketch8	5.4	0.12	0.01	11.75	2.0	1.2	0.13	0.11	0.04	0.84	6.32	80.0
150	Local	5.6	0.36	0.03	10.37	2.8	2.0	0.15	0.11	0.00	0.80	5.86	86.0
	Samcot 13	5.6	0.22	0.02	10.37	2.4	1.2	0.13	0.10	0.04	0.84	3.71	76.0
	Sketch8	5.5	0.26	0.02	13.62	2.4	1.0	0.13	0.10	0.08	0.68	4.39	83.0
200	Local	5.6	0.22	0.01	9.62	1.4	2.0	0.13	0.10	0.02	0.44	4.25	86.0
	Samcot 13	5.5	0.36	0.03	13.20	1.8	1.2	0.12	0.10	0.04	0.68	3.94	82.0
	Sketch8	5.4	0.34	0.03	12.50	1.8	2.0	0.13	0.10	0.04	0.72	4.70	84.0
Mean		5.5	0.27	0.02	12.08	1.88	1.3	0.14	0.10	0.04	0.80	4.98	82.3
Low plant density (44,444 plants/ha)													
0	Local	5.4	0.26	0.01	11.62	2.4	2.6	0.14	0.11	0.00	0.96	6.21	84.0
	Samcot 13	5.4	0.29	0.02	13.00	2.6	2.0	0.12	0.09	0.00	0.88	5.69	83.0
	Sketch8	5.4	0.27	0.03	13.00	2.2	3.0	0.13	0.10	0.00	0.84	6.27	87.0
120	Local	5.4	0.32	0.03	11.25	2.8	1.0	0.14	0.10	0.00	0.84	4.88	83.0
	Samcot 13	5.5	0.30	0.02	10.12	2.4	1.0	0.12	0.10	0.00	0.76	4.38	83.0
	Sketch8	5.4	0.34	0.03	9.37	2.8	1.2	0.14	0.11	0.06	0.68	6.09	86.0
150	Local	5.5	0.34	0.03	9.62	1.8	1.2	0.12	0.09	0.08	0.68	3.97	80.0
	Samcot 13	5.5	0.30	0.03	8.75	1.8	1.0	0.13	0.11	0.00	0.76	3.80	80.0
	Sketch8	5.5	0.34	0.03	8.75	2.4	1.0	0.14	0.11	0.00	0.60	4.25	86.0
200	Local	5.4	0.42	0.04	11.75	1.6	2.4	0.14	0.10	0.00	0.80	5.04	84.0
	Samcot 13	5.4	0.30	0.03	13.75	2.0	1.8	0.14	0.11	0.04	0.72	4.81	84.0
	Sketch8	5.4	0.30	0.03	10.12	1.8	1.2	0.12	0.10	0.03	0.60	3.93	81.0
Mean		5.4	0.32	0.03	10.93	2.2	1.6	0.13	0.10	0.05	0.76	4.94	83.0

Effects of Nitrogen Rates And Plant Density On Cotton Cultivars Leaf Area

A summary of the analysis of variance of N rates, plant density and cotton variety on leaf area of cotton plant is shown in Table 4, while effects of various nitrogen levels, plant density and variety on cotton leaf area are shown in Figures 1a, b and c. Nitrogen rates of 120 kg N/ha produced larger leaf area than other rates at the early stages (45 DAS) of cotton growth (Figure 1a). At 90 DAS, cotton plant leaves receiving 200 kg N/ha were significantly larger compared with other nitrogen treated plots (Figure 1b). Nitrogen at all levels significantly increased leaf area; this indicated that nitrogen is very vital for vegetative growth in cotton. Variety has no significant effect on cotton leaf area, however, of the three varieties; Samcot-13 produced the largest leaf area of 319.7 cm^2 at 45 DAS and 236.3 cm^2 at 90 DAS. There was a reduction in the size of leaf area during boll formation and boll opening which occurs during 90 DAS. Leaf area was affected by plant density a little at 45 DAS while at 90 DAS, plot with lower density (44,444 plants/ha) significantly produced larger leaf area averaging 271.2 cm^2 compared with 109 cm^2 at high density of 60,000 plants/ha (Figure 1c). Interactively, Samcot-13 treated with 150 kg N/ha under lower density (44,444 plants/ha) produced the largest leaves while Jalingo local in the control plot at higher density (60,000 plants/ha) produced the smallest leaf area, however, the differences were not significant.

The results of the effect of nitrogen on leaf area showed that nitrogen at all level contributed to the widening of cotton leaf area and the leaf area increases as the application rate of urea fertilizer increases. Increased nitrogen fertilizer rate increased leaf photosynthetic rate which would result in higher accumulation of metabolites(Cadena and Cothren, 1995).The result of this study on significant increase in cotton leaf area showed that nitrogen application at all levels contributed to larger leaf; this is because of the robustness of plants resulting from the available nitrogen uptake. It has been reported by Dong *et al.*, (2011) that nitrogen fertilization had a significant impact on plant biomass production while Bondada *et al.*, (2001) confirmed that nitrogen is essential for cotton canopy area development and photosynthesis. Densely populated plants produced smaller leaf because of inadequate space for light interception. Overcrowded plants harbor insect pest thereby causing diseases to plants hence the reduction in leaf area. Wider plant spacing and higher nitrogen application rates resulted in luxury consumption which enhanced larger leaf area of the plant.

CONCLUSION

Nitrogen rate, plant density and variety had a positive effect on soil organic carbon, total nitrogen and available phosphorus but not on soil pH value when compared with the initial status of the soil. Nitrogen fertilization significantly ($p < 0.05$) affected leaf area, plots receiving N had larger leaves compared to control plots with the leaf area increasing as the N rate increases. Plants with lower density (44,444 plants/ha) significantly produced larger leaf area compared with high density of 60,000 plants/ha. However, cotton variety had no significant effect on leaf area. Interactively, Samcot-13 treated with 150 kg N/ha under lower density produced the largest leaves. Wider plant spacing and higher nitrogen rates enhanced the production of larger leaf thereby increasing photosynthetic rate in cotton.

Table-4: Summary of analysis of variance for leaf area of cotton plant

Source of var.	Leaf area (cm^2) @ 45 DAS	Leaf area (cm^2) @ 90 DAS
Nitrogen Rate(N)	<.0001*	0.0001*
Plant density (PD)	0.3327^{NS}	<.0001*
Variety (V)	0.2863^{NS}	0.2689^{NS}
N * PD	0.2772^{NS}	0.5481^{NS}
N * V	0.7811^{NS}	0.2579^{NS}
PD *V	0.9690^{NS}	0.1016^{NS}
N *PD* V	0.9373^{NS}	0.4127^{NS}

*=significant at p<0.05; ^{NS}= not significant

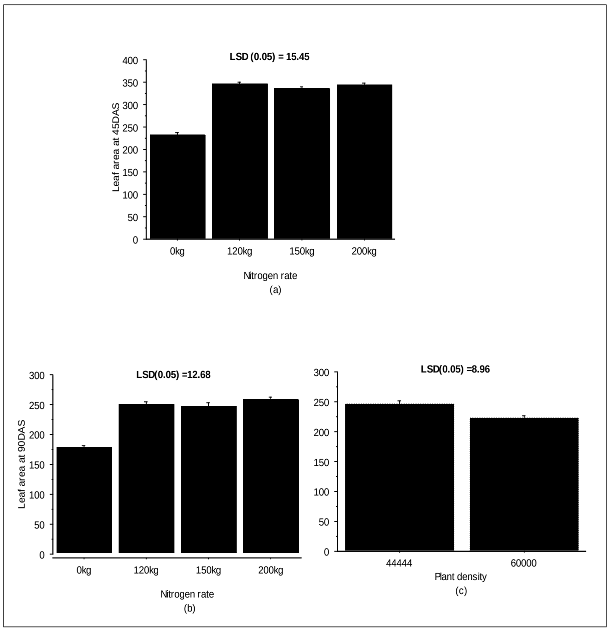

Fig.-1: Effects of nitrogen rates at (a) 45DAS, at (b) 90DAS and (c) plant density at 90DAS on cotton leaf area (cm^2)

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