

Original Research Article

OPTIMIZING NITROGEN RATES AND PLANT DENSITY FOR COTTON CULTIVARS (*Gossypium spp.*) IN THE NIGERIAN SAVANNAH

ABSTRACT

Cotton production in Nigeria has been severely limited by low or blanket nutrient (especially nitrogen, N) input and poor crop management, involving use of low yielding varieties and sub-optimal plant spacing. A field experiment was conducted during the wet season (June-October) of 2013 planting season at two locations within the Research Farm of the College of Agriculture, Jalingo (longitude 11° 09' and 11° 30' east and latitude 8° 17' and 9° 01' North) to determine the (i) adaptability of some improved cotton cultivars to local climates, (ii) appropriate rates of N for optimizing cottonseed yield and (iii) optimal plant density for economic yield. The experiment was a 4 x 3 x 2 factorial arrangement of treatments placed in a randomized complete block design (RCBD) and replicated three times. The factorial combination consisted of four nitrogen (N) rates (0, 120, 150, 200 kg ha⁻¹) with the zero rate serving as control, three cotton varieties (Jalingo local, Samcot-13, Sketch-8) and two plant densities [75 x 30 cm or 44,444 plants ha⁻¹ and 60 x 30 cm or 60,000 plants ha⁻¹]. Plant height, boll weight, cottonseed yield, biological yield, monopodial and sympodial branches increased significantly (P < 0.05) with N application. The growth and yield components of cotton were optimum at N rate of 150 kg Nha⁻¹. For cottonseed (lint and seed yield) yield per boll, Samcot-13 treated with 150 kg Nha⁻¹ was the best. Cottonseed yield per hectare, interactively, was best optimized at 150 kg Nha⁻¹ x Jalingo local variety x low plant density. Therefore, farmers may keep using the local variety (Jalingo local) provided they sow at 44,444 plants ha⁻¹ and apply 150 kg Nha⁻¹ as urea in two equal splits (21 and 50 DAS). The improved varieties would need further fine-tuning to optimize their yield performance in the study area.

Keywords: [Biomass yield, cottonseed yield, cotton variety, monopodial/ sympodial branches, nitrogen rates, plant density]

1. INTRODUCTION

Cotton (*Gossypium spp*) is considered one of the oldest fibre producing crops in the world. Its importance as protein, oil and fibre producing crop has long been recognized globally and its high commercial value unarguably tremendous [1]. Cotton is commercially produced in most areas of the world including cool temperate and warm tropical regions.

23 China, USA, India, Pakistan, Turkey, Australia, Greece, Brazil, Egypt, etc. have been
24 recognized as the major cotton producing countries [2]. These areas have suitable climatic
25 conditions such as adequate moisture and hot and dry weather conditions which favour
26 cotton growth [2].

27 Nitrogen (N) is an important nutrient required by cotton for optimizing seed yield.
28 Nitrogen is the most limiting essential plant nutrient in the world and it needs to be supplied
29 in proper quantities and time [3]. Apart from water, N is the major nutrient element limiting
30 cotton production in most of the cotton growing regions of the world [4]. Nitrogen
31 management is essential and critical in a dynamic crop like cotton if its full yield potential is
32 to be realized. Therefore, too much or low application as well as wrong time of application of
33 fertilizer can result to poor growth and low yields [5, 3]. To manage N successfully for cotton
34 is to provide adequate amounts rather than too low or high to the crop [5]. Proper
35 management of cotton nutrition is critical to cottonseed yield because nitrogen is very
36 susceptible to losses. As [6] recognized the importance of nitrogen as an essential
37 macronutrient needed in larger quantities for cotton production, [4] reported that N
38 fertilization had a significant impact on plant growth, lint yield and fiber quality. Cotton usually
39 shows a good response to applied N fertilizer in soils low in N [7].

40 Nutrient management in cotton is difficult because of its vegetative re-growth and
41 reproductive structures during the growing period [8]. Shortage of nutrient reduces root
42 growth and ultimately, its capacity to absorb nutrients [9, 10]. For every 100 kg of cottonseed
43 produced, the crop depletes the soil by 6-7 kg N, 1.9-2.5 kg P, 6.8 kg K and 1.2-2.0 kg S [8].
44 Nitrogen deficiency in cotton from emergence to early blooming can result to poor vegetative
45 growth [4]. Nitrogen increased plant height, number of monopodial/sympodial branches and
46 matured bolls in cotton [11]. A decrease in seed oil contents with increasing nitrogen
47 application rate was reported by [12]. Nitrogen is very vital for the growth of cotton leaf
48 canopy and it also enhances photosynthesis [13, 14, 15]. Nitrogen deficiency has a profound
49 effect on yield and quality of cotton fibres [15]. The yield and quality of cotton fibres

50 increased with increasing N rate [16, 17, 18]. It was noted by [19] that managing nitrogen in
51 cotton is difficult either due to excessive or inadequate application. However, [20] observed
52 that nitrogen can be used at a moderate rate and more efficiently than was traditionally used.
53 Also [21] concluded that cotton production was directly related to doses and application
54 method of inorganic fertilizers while [22, 23] reported that application of nitrogen at all levels
55 improved cotton growth and yield when compared with the control (without fertilizer).
56 Determination of the optimum level of nitrogen is of prime importance because it plays a
57 dominant role in growth and development as an integral part of chlorophyll molecule, protein
58 and nucleic acid [24]. The N need of cotton depends on its concentration and mineralization,
59 soil type and environmental factors [7, 25].

60 Planting density is another agronomic practice influencing both fibre and seed yield
61 in cotton. It has a commanding effects on both the input and output resources of the farmer.
62 Inclement weather conditions coupled with reduced plant density will probably result in very
63 low plant populations and this will increase the chances of supplying to maintain an
64 acceptable plant stands. High plant population and nitrogen rates would lead to more
65 biomass yield but low seed cotton yield [10, 26] while [27] reported that increased plant
66 density or N rate delayed leaf senescence but significantly reduced boll load.

67 According to [28], cotton cultivars developed in different ecological zones respond
68 differently to inorganic fertilizers. The varieties behave differently in respect to sympodial
69 branches under different fertilizer rates [22, 29]. Since inorganic fertilizers are too expensive
70 to resource-poor farmers, there is a need for developing cultivars that are efficient in nutrient
71 use and could adapt to most ecological zones by being early maturing, tolerant and resistant
72 to plant diseases. Also the growing concerns over the environmental problems emanating
73 from indiscriminate use of inorganic fertilizers in intensive production system leading to
74 deterioration of soil fertility and productivity calls for alternative ways to fertilizer input
75 through intensification of high quality cultivars.

In Nigeria, considerable attention and resources have been devoted to the improvement of cotton production and utilization by both public and private organizations as well as individuals [30]. As a result, there is intensification of the development and multiplication of improved cotton varieties and specification of cultural practices for increasing cotton yields [31]. Despite the various measures taken to improve the fortune of cotton production in the country, the cotton output still remains below the desired yield potential for the textile industry. The lack of fertilizer use, use of recycled seeds and high input cost as well as poor soil fertility are the major factors responsible for low yield of cotton in Nigeria [32]. Therefore, this research work was designed to compare the adaptability of some improved cotton cultivars with a local one in the Nigerian savannah cotton belt and to determine the optimum combination of N rate and plant density for optimizing fibre yield.

2. MATERIAL AND METHODS

2.1 Experimental site

The field experiment was conducted during the wet season (June -October) of 2013 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. Jalingo lies within the northern guinea savannah region of Nigeria.

2.2 Experimental design and treatments

The experiment was a 4 x 3 x 2 factorial arrangement of treatments placed in a randomized complete block design (RCBD) and replicated three times. The main plots were assigned to four nitrogen rates (0, 120, 150 and 200 kg ha⁻¹), sub-plots to three cotton varieties (Jalingo local, Samcot-13, Sketch-8) and sub-sub plots to two plant densities (44,444 and 60,000 plants ha⁻¹). Thus, there were 24 treatment combinations, giving a total of 72 plots.

2.3 Land Preparation and planting

The experimental site was manually cleared, stumped, raked and burnt. The land was then ploughed manually and surface clods were pulverized. Each plot measured 2 m by

2.5 m. Alleyways between blocks was 2 m while those between plots were 1 m. The three cotton varieties (Samcot-13, Sketch-8 and Jalingo local) seeds were sown on a well-prepared moist seedbed at 75 cm by 30 cm for a density of 44,444 plants ha⁻¹ (low density) and 60 cm by 30 cm apart for a density of 60,000 plants ha⁻¹ (high density). Four seeds were sown per hole and were later thinned to one vigorous plant per stand. For each rate, nitrogen was applied in the form of urea in two equal splits. The first application was done 21-days after sowing (DAS) and the second was done 50 DAS. According to [8], nitrogen application to cotton should be completed on or before 60 days of sowing for better utilization. Weeding was done manually at 14, 50 and 90 days after sowing (DAS).

2.4 Soil sampling and processing

Composite soil samples were collected before sowing for the determination of background fertility status of the two experimental sites at 0-15cm (topsoil) and 15-30cm (subsoil) depths using soil auger. Each composite sample was properly bagged and labeled. Thereafter, the soil samples were air dried, ground and sieved using a 2 mm sieve before analysis.

2.5 Laboratory Studies

The soil samples were analyzed in the laboratory using standard procedures as outlined by [33]. Particle size distribution was determined by the Bouyoucous hydrometer method, using sodium hexametaphosphate as a dispersant. 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 AAll auto analyser (Technico, Oakland, Calif). Exchangeable cations (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 Ca, Mg, K and Na and exchangeable acidity. Base saturation was calculated by dividing the sum of exchangeable bases by ECEC and multiplying by 100.

2.6 Plant data

Ten plants from the central rows were selected and tagged for the determination of agronomic parameters. Plant height was determined with a measuring tape stretching from the ground level to the tip of the youngest mature shoot at 45 and 90 days after sowing. Boll weight was determined by picking the boll from the tagged plants from each plot and weighed. Cottonseed weight per boll was determined from the tagged plants using the weighing balance. Sympodial/Monopodial branches were counted for all tagged plants in each plot at 60 and 100 DAS. Only sympodial (fruiting branches) and monopodial (vegetative branches) branches on the main stem were counted and averaged for each plot. Cottonseed is the seed of the cotton plant that are surrounded by fibres which grow from the surface of the seed i.e. the seed with the lint still attached. This was determined after the remains of the reproductive part were removed and the cottonseed weighed using weighing balance.

Biological yield was taken after the second picking. All the plants in each plot were cut down from the ground level, dried for two weeks to a constant weight and weighed including all the reproductive parts and the cottonseed. The weight was expressed in kg per hectare.

2.7 Statistical analysis

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

3. RESULTS AND DISCUSSION

3.1 Background properties of the experimental soil

159 The preliminary analysis of the experimental soil in locations 1 and 2 were similar
 160 (Table 1). The results showed the soil texture to be loamy sand either at the topsoil or
 161 subsoil with clay content increasing down the profile in both locations. The soil reaction (pH)
 162 was moderately acidic at the topsoil but strongly acidic at the subsoil based on the ratings
 163 given by [34] for Nigerian soils. The soil was characterized by low organic carbon and total
 164 nitrogen contents suggesting that response to nitrogen fertilizer would be high. The low
 165 organic carbon and total nitrogen is typical of arable lands in the northern savannah zone as
 166 crop residues are usually used up by livestock after harvest, leaving no material on the
 167 surface for decomposition. Therefore nutrient removal by both plants and livestock left little
 168 or no material for organic carbon build up in the soil. The available phosphorus (P) content of
 169 the soil was medium (8.12 mgkg^{-1} , 8.30 mgkg^{-1} in locations 1 and 2 respectively) for the
 170 topsoil but low (7.42 mgkg^{-1} , 7.86 mgkg^{-1}) at the subsoil. Exchangeable potassium was low,
 171 while exchangeable calcium and magnesium were high. High exchangeable calcium and
 172 magnesium is a common feature of soils of the Nigerian savannah due to moderate rainfall.
 173 The base saturation of the soil was high either at the top or sub soil.

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Table1: Background physico-chemical properties of the experimental soil

Property	Location 1		Location 2	
	Surface soil (0-15cm)	Sub soil (15-30cm)	Surface soil (0-15cm)	Sub soil (15-30cm)
Clay (%)	6.0	11.0	9.0	11.0
Silt (%)	10.7	11.7	12.1	12.7
Sand (%)	83.3	77.3	78.9	76.3
Textural Class	Loamy sand	Loamy sand	Loamy sand	Loamy sand
pH(H ₂ O)	5.70	5.40	5.74	5.38
Org. C (%)	0.29	0.24	0.29	0.23
Total N (%)	0.01	0.01	0.02	0.01
Av. P (mgkg ⁻¹)	8.12	7.12	8.30	7.86
Exch. Ca ⁺⁺ (cmolkg ⁻¹)	1.8	1.8	2.0	1.8
Exch. Mg ⁺⁺ (cmolkg ⁻¹)	1.4	1.0	1.5	1.2
Exch. K ⁺ (cmolkg ⁻¹)	0.19	0.15	0.18	0.15
Exch. Na ⁺ (cmolkg ⁻¹)	0.14	0.12	0.13	0.12
Exch. Acidity (cmolkg ⁻¹)	0.36	0.40	0.44	0.50
ECEC (cmolkg ⁻¹)	3.89	3.47	4.25	3.77
BS (%)	90.8	88.5	89.6	86.7

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3.2 Plant growth and yield as influenced by nitrogen rates, cotton varieties and plant densities

3.2.1 Plant height

191 Table 2 shows the summary of analysis of variance for plant height and yield.
192 Nitrogen rates significantly affected plant height at 45 and 90 days after sowing (DAS)
193 whereas there were no significant effects of plant density, cotton varieties and their
194 interactions on cotton plant height (Table 2). At the early stages of cotton growth (45 DAS)
195 the 120 kg Nha⁻¹ rate produced slightly taller plants than the other rates (Figure 1a). At 90

DAS, plants receiving 150 kg N_{ha}⁻¹ were significantly taller (118.67 cm) than plants treated with 120 kg N_{ha}⁻¹ (112 cm) and 0 kg N_{ha}⁻¹ (control) as shown in Figure 1 but height differences between 150 and 200 kg N_{ha}⁻¹ rates were not significant. This is in line with the report of [7] who observed significant differences in cotton height at various nitrogen application rates. Although, [23] reported highest cotton plant height at 250 kg N ha⁻¹ when they used cattle manure for cotton production in Nigeria, [35] reported the highest cotton plant height at the highest application rate of 120 kg N_{ha}⁻¹ whereas [3] noted highest plant height (147 cm) of cotton by using ½ N at sowing + ½ N at 52 DAS (2nd irrigation) at the rate of 153 kg N_{ha}⁻¹ in Pakistan. It has been reported by [11] that nitrogen application increased cotton plant height.

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Table 2: Summary of analysis of variance for cotton plant height and yield

Source of variation	Plant height (cm)@45 DAS	Plant height (cm)@90 DAS	Boll weight (g)	Cottonseed yield (g/boll)	Cottonseed yield (kg ha ⁻¹)
Nitrogen rate(N)	<.0001*	<.0001**	<.0001*	<.0001*	<.0001*
Plant density (PD)	0.5533 ^{NS}	0.8795 ^{NS}	0.3820 ^{NS}	0.0437*	<.0001*
Variety (V)	0.1260 ^{NS}	0.640 ^{NS}	<.0001*	<.0001*	<.0001*
N * PD	0.3785 ^{NS}	0.7897 ^{NS}	0.2650 ^{NS}	0.0609 ^{NS}	0.0620 ^{NS}
N * V	0.4197 ^{NS}	0.2493 ^{NS}	<.0001*	<.0001*	0.0101*
PD *V	0.4378 ^{NS}	0.8982 ^{NS}	0.0566 ^{NS}	0.0785 ^{NS}	0.0136*
N *PD* V	0.1169 ^{NS}	0.9914 ^{NS}	<.0001*	<.0001*	<.0001*

210 * = significant at $P < .05$; ^{NS} = not significant

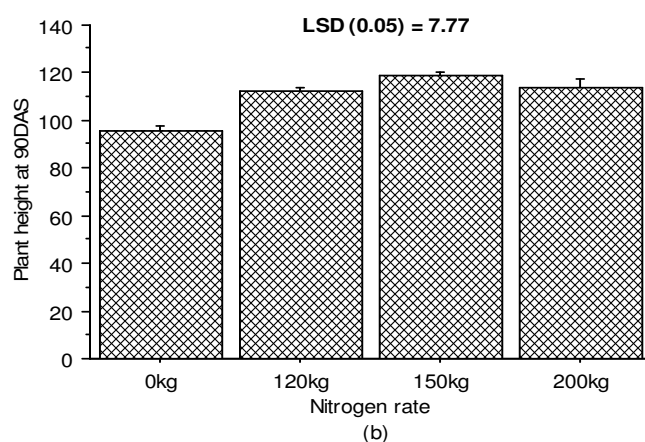
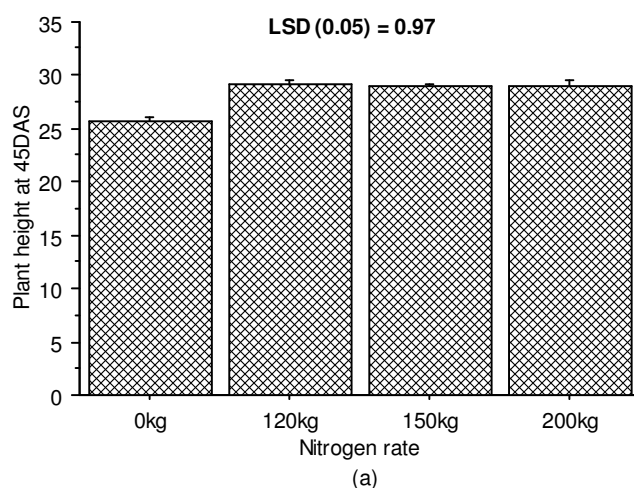


FIG 1: Effect of nitrogen rates on cotton plant height (cm) at (a) 45 DAS and (b) 90 DAS

3.2.2 Boll Weight (g/boll)

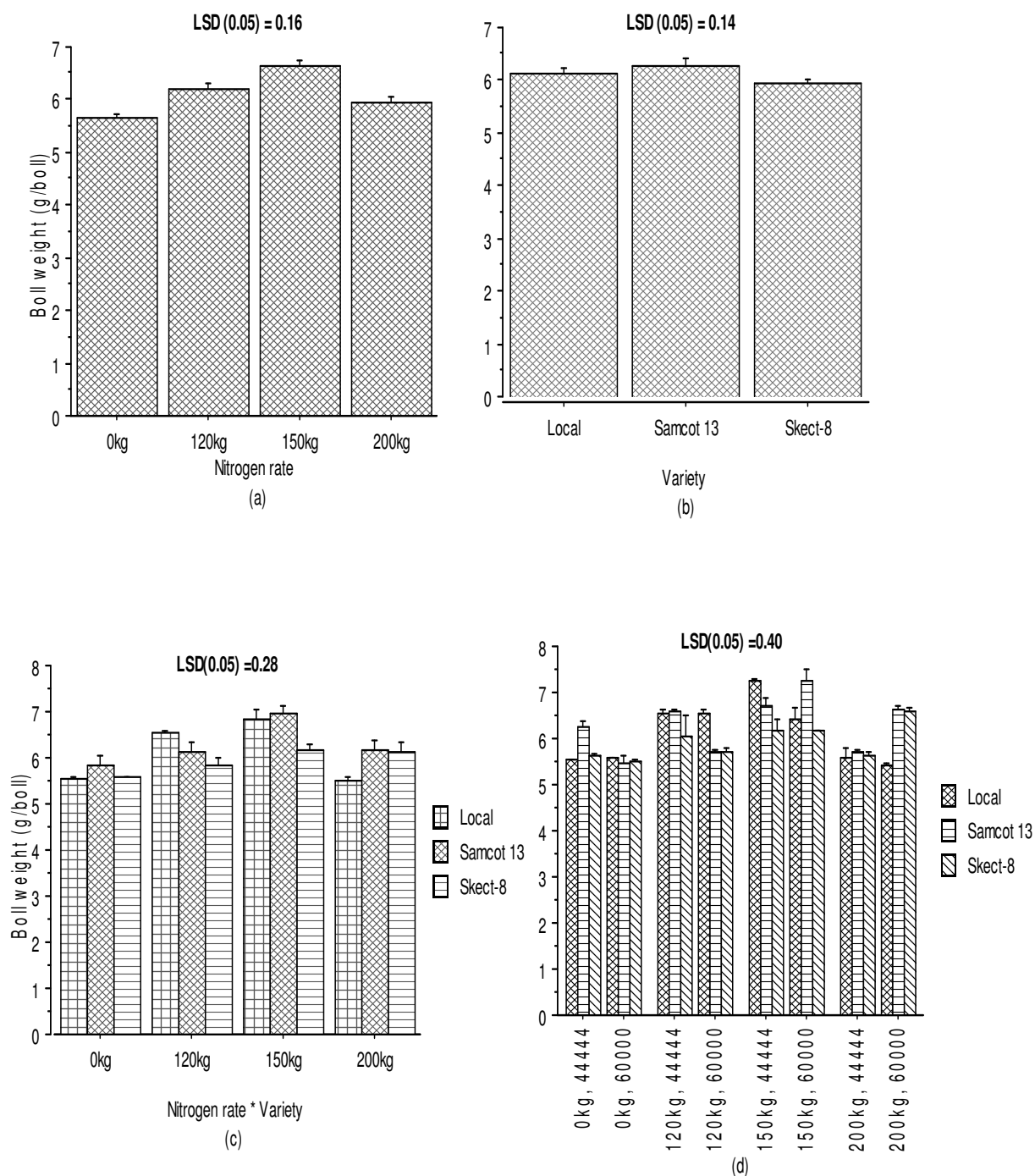
A summary of analysis of variance of nitrogen rates, variety and plant density on cotton boll weight is presented in Table 2. Cotton boll weight was significantly increased by nitrogen rates (N), cotton variety (V), the interaction of nitrogen rates with cotton variety (N x V) and the interaction with nitrogen rates with cotton variety with plant density (N x V x PD) (Table 2). Plots receiving 150 kg Nha^{-1} significantly produced heavier bolls (6.63 g) followed

220 by the 120 kg N ha^{-1} (6.19 g), then 200 kg N ha^{-1} (5.92 g) compared with the control (Figure
221 2a). it has been reported by [11] that nitrogen application produced matured bolls in cotton.
222 The main effect of variety on boll weight showed that Samccot-13 produced heaviest boll
223 weighting 6.27 g followed by Jalingo local with boll weight of 6.11 g while sketch-8 boll
224 weighed 5.93 g (Figure 2b).

225 Interaction of nitrogen rates of 150 kg N ha^{-1} with Samcot-13 produced the heaviest
226 boll of 6.96 g while the lowest boll weight of 5.49 g was produced by the plot treated with 200
227 kg N ha^{-1} and planted with Jalingo local variety (Figure 2c). A significant difference in boll
228 weight was observed among the three varieties, it was evidence that samcot-13 was very
229 responsive to nitrogen at 150 kg N ha^{-1} . Interaction of 150 kg N ha^{-1} with samcot-13 under high
230 plant density (60,000 plants ha^{-1}) produced the heaviest boll weight of 7.25 g (Figure 2d).
231 But the weight differences between the two plant densities (44,444 and 60,000 plants ha^{-1})
232 at 150 kg N ha^{-1} using either samcot-13 (7.25 g) or Jalingo local variety interaction (7.23 g)
233 was not significant. An increase in boll weight by increasing nitrogen rate from 95 kg N to
234 150 kg N ha^{-1} was recorded by [36]. Increasing nitrogen fertilization resulted in higher
235 accumulation of metabolites which impacted on boll weight. Similar increase in boll weight of
236 cotton when nitrogen was applied at 150 kg/ha has been reported by [7].

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240 FIG 2: Effects of (a) nitrogen rates, (b) variety, (c) the interaction of nitrogen with variety and
 241 (d) the interaction of nitrogen with variety with plant density on cotton boll weight (g/boll)
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244 **3.2.3 Cottonseed (seed with lint) yield per boll**

245 A summary of the analysis of variance of N rates, plant density and variety on
246 cottonseed yield per boll as shown in Table 2 indicated that cottonseed yield per boll was
247 highly significant at various nitrogen rates. Plots treated with 150 kg Nha⁻¹ yielded highest
248 cottonseed per boll (4.24 g) followed by the 120 kg Nha⁻¹ (3.84 g) then the 200 kg Nha⁻¹
249 treated plot (3.64 g) while the control plot recorded the least yield of 3.63 g (Figure 3a).
250 However, [37] reported that cottonseed yield increased with increasing nitrogen application
251 rate while [38] reported that cottonseed yield was best when optimum doses of nutrients,
252 particularly of nitrogen were applied. Lower plant density produced slightly higher cottonseed
253 yield per boll relative to higher plant density (Figure 3b). Cottonseed yield was affected by
254 variety; Samcot-13 gave the highest yield (3.98 g) per boll followed by Jalingo local (3.80 g)
255 while the least was from Sketch-8 variety (3.75 g) (Figure 3c).

256 Various interactions significantly affected cottonseed yield. For the interaction of
257 nitrogen rate with plant density, better cottonseed yield was obtained from plants treated with
258 150 kg Nha⁻¹ using a density of 60,000 plants ha⁻¹ (Fig. 4a). For the interaction of nitrogen
259 rate with variety, the best cottonseed yield was from plots treated with 150 kg Nha⁻¹ yielded
260 (4.58 g) using Samcot-13 variety (Fig. 4b) while the interaction between nitrogen rate, plant
261 density and variety shows that cottonseed could be optimized at 150 kg Nha⁻¹ with 60,000
262 plants ha⁻¹ using Samcot-13 variety (Fig. 4c).

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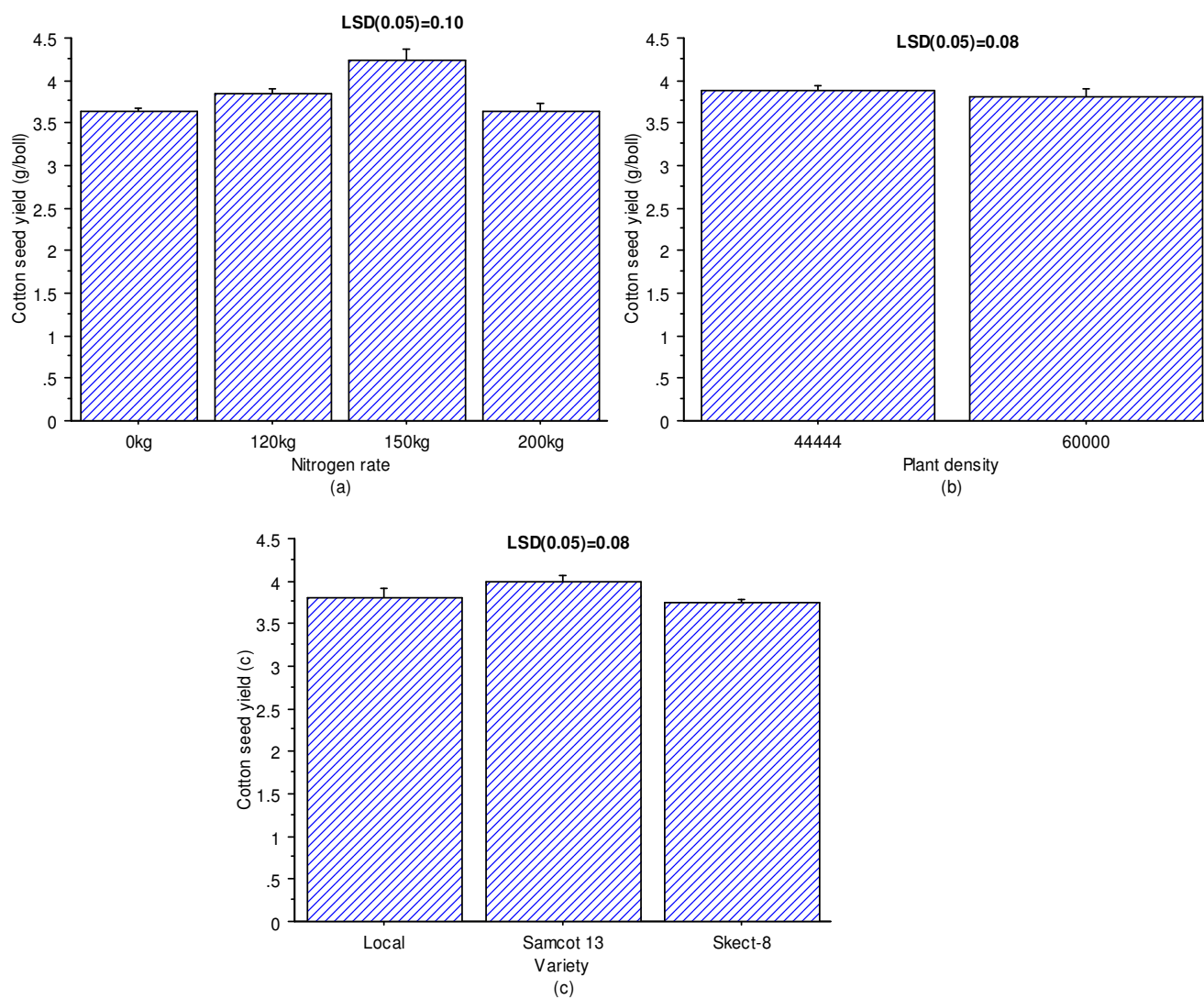
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275 FIG 3: Effects of (a) nitrogen rates, (b) plant density and (c) variety on cottonseed yield

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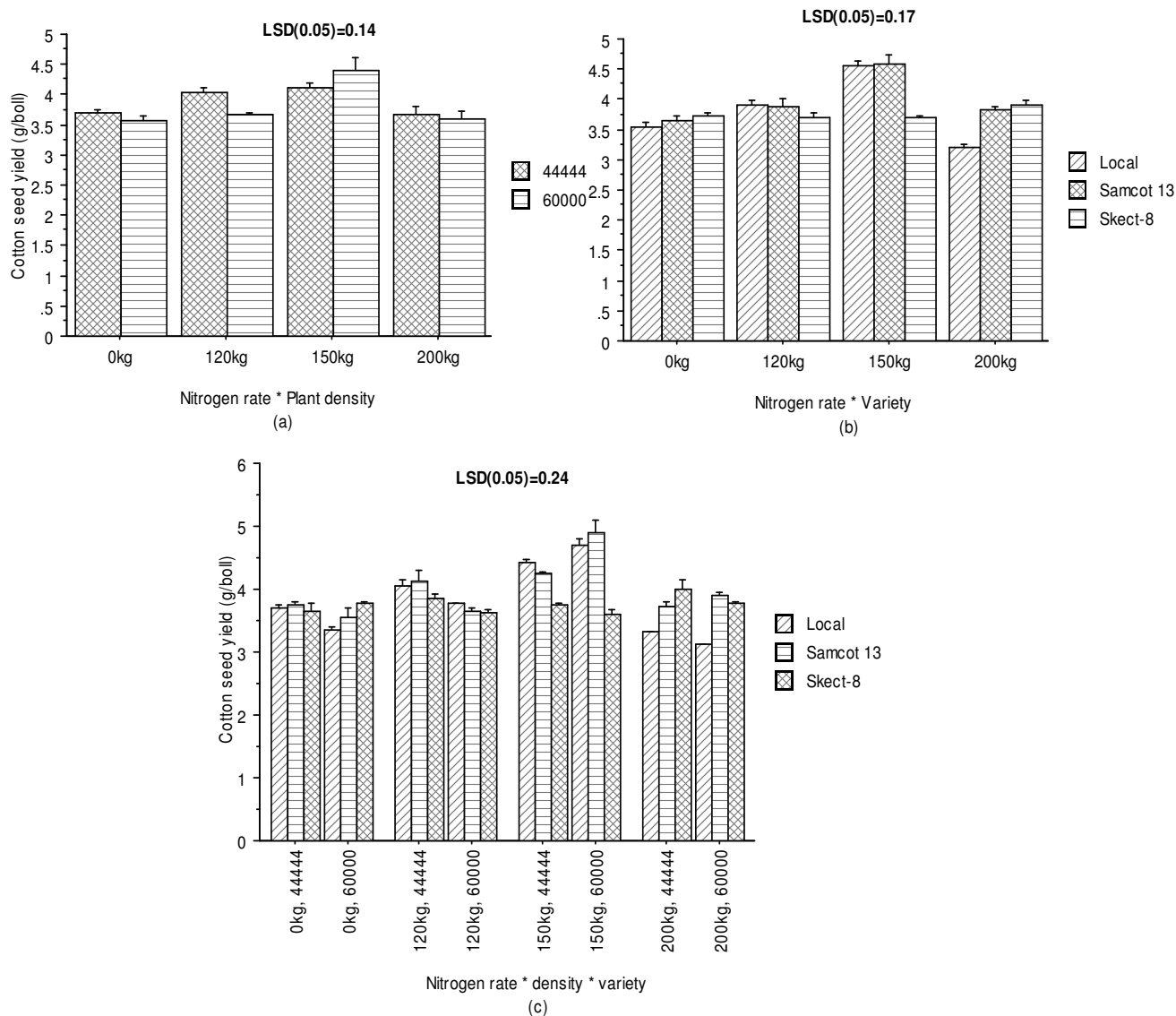
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FIG. 4: Interactive effects of (a) nitrogen x variety, (b) nitrogen x plant density and (c) nitrogen x variety x plant density on cottonseed yield (g/boll).

290 **3.2.4 Cottonseed (seed with lint) yield per hectare**

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292 A summary of the analysis of variance of nitrogen rates, plant density and variety on
293 cottonseed yield per hectare as shown in Table 2 indicated that cottonseed yield was
294 affected by nitrogen rates, plant density and variety. Plots treated with 200 kg Nha⁻¹ were
295 significantly ($P < 0.05$) higher in cottonseed yield (1171.2 kgha⁻¹) compared with the 120 kg
296 Nha⁻¹ (723.4 kgha⁻¹) and the control plots but not significantly ($P > 0.05$) higher than the yield
297 obtained from plots treated with 150 kg Nha⁻¹ (1169.2 kgha⁻¹), suggesting 150 kg Nha⁻¹ as
298 the optimum level for maximizing cottonseed yield (Figure 5a). This is in agreement with the
299 results of [23, 39] who reported increased in cottonseed yield as a result of fertilizer
300 treatments in Bangladesh and in Nigeria respectively.

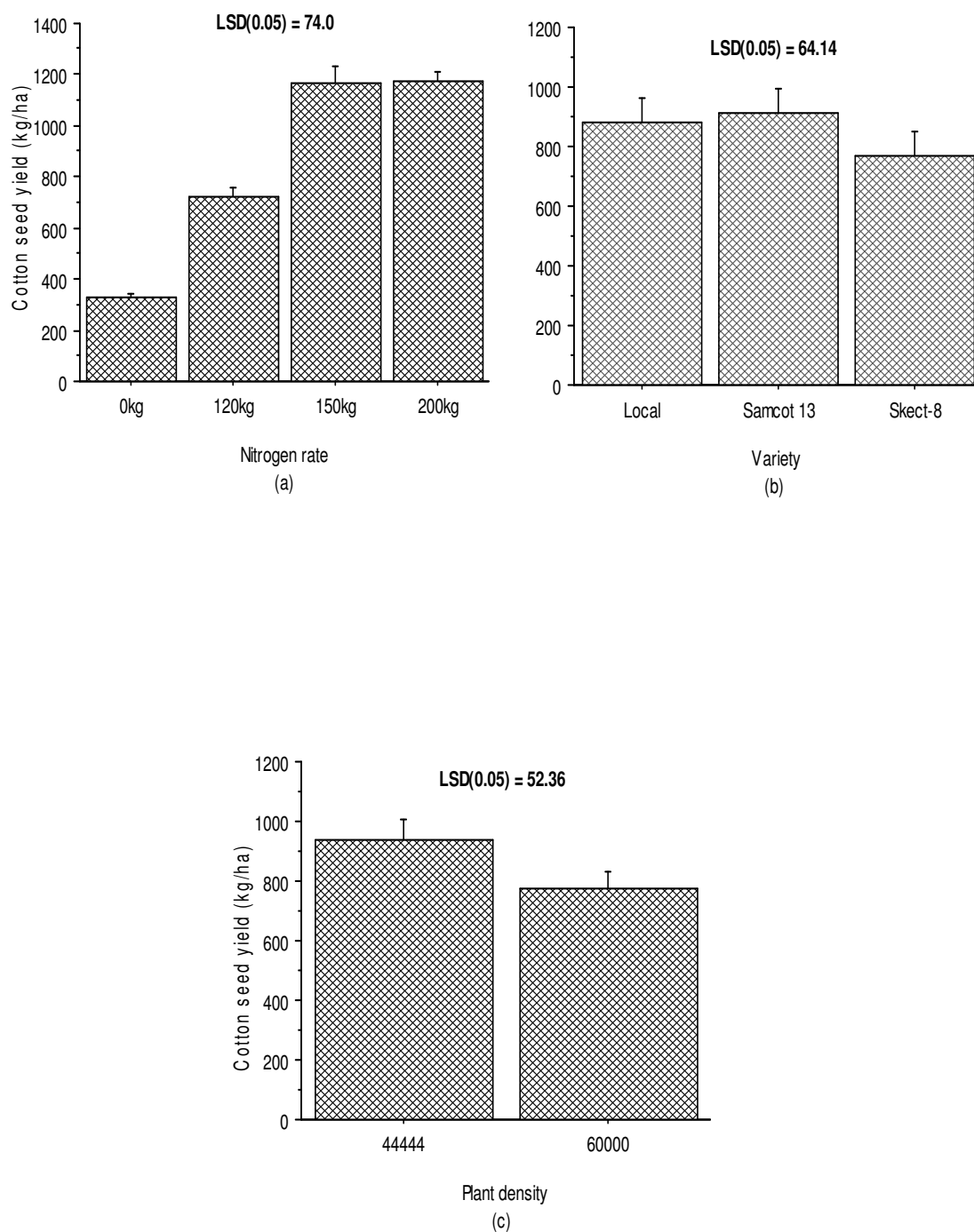
301 However, the highest cottonseed yield of 1171.2 kgha⁻¹ obtained from plants treated
302 with 200 kg N/ha in this study was lower than the yield of 3543 kgha⁻¹ obtained from cotton
303 plants treated with 100% N from urea by [39] in Bangladesh, 1559 kgha⁻¹ obtained by [3]
304 during 2011 planting season in Pakistan by using ten split application of N at each irrigation,
305 1453 kgha⁻¹ obtained from 250 kg Nha⁻¹ of cattle manure in Nigeria by [23] but falls within
306 the yield of 1135.7 kgha⁻¹ obtained by [3] during 2012 planting seasons in Pakistan by using
307 ten split application of N at each irrigation. The disparity in yield could be as a result of the
308 prevailing climatic conditions in each location. This was also pointed out by several
309 researchers [7, 25] that the N need of cotton depends on its concentration and
310 mineralization, soil type and environmental factors.

311 Among varieties, Samcot-13 produced the highest cottonseed yield per boll of 914.7
312 kgha⁻¹ followed by Jalingo local (880.33 kgha⁻¹) and the lowest was obtained from Sketch-8
313 (766.16 kgha⁻¹) (Figure 5b). Cottonseed yield per boll was significantly affected by plant
314 density, plot with lower density (44,444 plants ha⁻¹) had the highest seed yield averaging
315 935.72 kgha⁻¹ compared with the yield of 772.27 kgha⁻¹ obtained at the density of 60,000
316 plants ha⁻¹ (Figure 5c).

317 Interactions of nitrogen x variety, plant density x variety and nitrogen x plant density
318 x variety significantly ($P < 0.05$) affected cottonseed yield per hectare as shown in Table 2.
319 The combination of 150 kg Nha⁻¹ with Jalingo local produced the highest cottonseed ha⁻¹
320 compared with the control but was not significantly higher than the combination of 200 kg
321 Nha⁻¹ with Samcot-13 (Figure 6a). The interaction of Jalingo local with low plant density of
322 44,444 plants ha⁻¹ significantly gave the highest cottonseed yield ha⁻¹ (Figure 6b) while the
323 combination of 150 kg Nha⁻¹ with Jalingo local at 44,444 plants/ha produced the highest
324 cottonseed yield (Figure 6c). The lower plant population gave higher cottonseed yield than
325 the higher population. Several reports [40, 41, 42, 43, 44] also showed maximum cottonseed
326 yield at a density of 44, 444 plants ha⁻¹.

327 Although nitrogen at all levels increased the cottonseed yield relative to control (no
328 fertilizer application), the overall results suggested that 150 kg Nha⁻¹ would be the rate for
329 cottonseed yield. This application rate of 150 kg Nha⁻¹ was also reported by [7] but [23]
330 reported cattle manure rate of 250 kg Nha⁻¹ while [45, 46] stressed that nitrogen application
331 above the optimum level will result in decreased yield.

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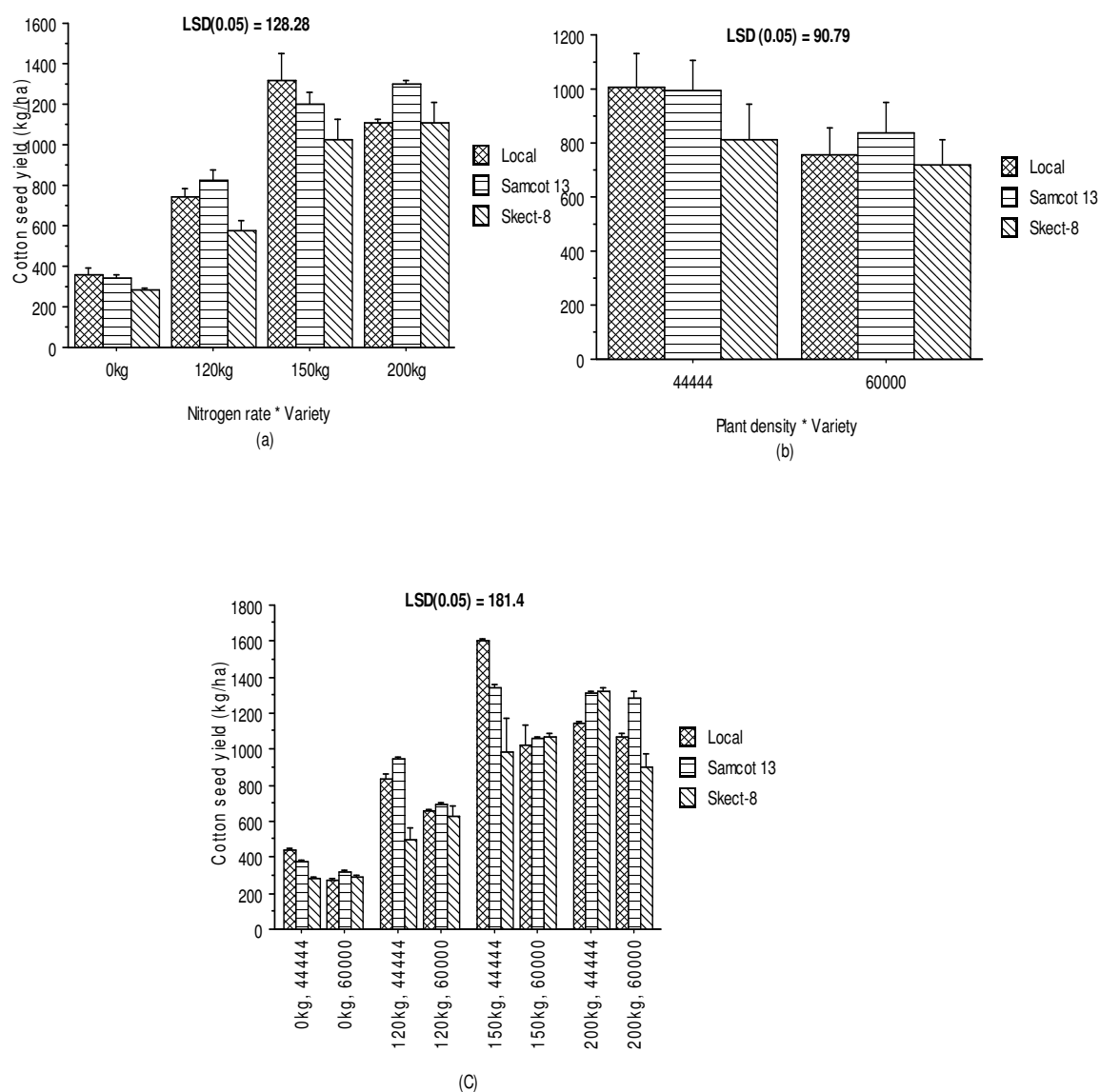


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334 FIG 5: Effects of (a) nitrogen rates, (b) variety and (c) plant density on cottonseed yield
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340 FIG 6: Interactive effects of (a) nitrogen x variety, (b) plant density x variety and (c) nitrogen
 341 x plant density x variety on cottonseed yield (kg/ha)
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3.3 Monopodial and sympodial branches of cotton as influenced by nitrogen rates, cotton varieties and plant densities

3.3.1 Monopodial branches

Table 3 shows a summary of analysis of variance of different nitrogen levels, plant density and cotton variety on monopodial branches of cotton plant. The effects of nitrogen rates were significant at 60 and 100 DAS for monopodial branches. Plots treated with 150 kg Nha^{-1} produced the highest number of monopodial branches at 60 (2.85) and 100 DAS (3.37) as presented in Figures 7a and b. However, nitrogen at all levels had a significant effect on the monopodial branches, but the differences in the number of branches between 150 and 200 kg Nha^{-1} rates were not significant, suggesting that 150 kg Nha^{-1} could be the optimum rate. Effects of plant density on branches were significant at 60 and 100 DAS. At 60 DAS, higher density of 60,000 plants ha^{-1} produced more number of monopodial branches (2.63) compared to 2.52 branches produced at low density of 44,444 plants ha^{-1} (Figure 7c). At 100 DAS, plot with higher density of 60,000 plants/ha produced slightly higher number of branches averaging 3.63 compared with 3.47 at low density of 44,444 plants ha^{-1} (Figure 7d).

Monopodial branches were also significantly affected by variety as shown in Table 3. Samcot-13 produced the highest number of branches (2.68) at 60 DAS followed by Jalingo local with 2.52 and the least was from Sketch-8 (Figure 8a). Similar trend was observed at 100 DAS (Figure 8b). Interactively, at 60 DAS, nitrogen rates interaction with plant density was not significant. However, at 100 DAS it was significant, the lower plant density (44,444 plants ha^{-1}) under N- rate of 150 kg Nha^{-1} produced the highest branches of 3.78 (Figure 8c). Nevertheless, the low plant density on control plot produced the least numbers of monopodial branches averaging 2.37 (Figure 8c). Plot sown to Samcot-13 and treated with N-rate of 150 kg Nha^{-1} produced the highest number of branches (2.91) at 60 DAS while Sketch-8 variety in the control plot produced the least number of monopodial branches of 2.11 at 60 DAS (Figure 8d). This result is in line with that of [11, 47, 48], they have

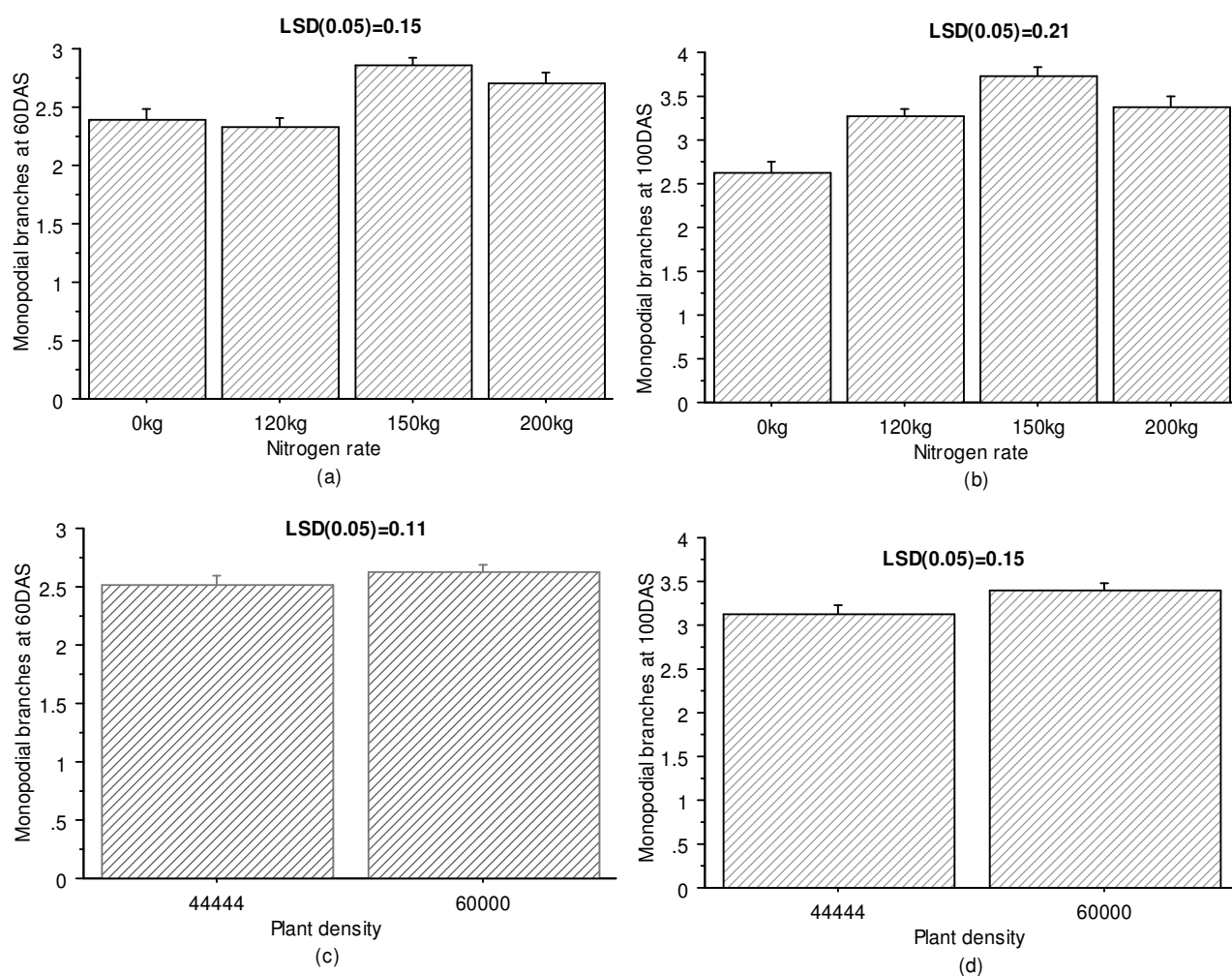
independently reported that different nitrogen levels have significant effect on cotton monopodial branches. Plant density had a significant effect on the sizes of plant, from this study, lower plants population produced plant with larger and very robust branches while higher density significantly produced plant with many but weak branches. The effect of variety on cotton branches as reported in this study is in agreement with that of [22, 29] who reported that cotton varieties behaved differently in respect to branches under different fertilizer rates.

Table 3: Summary of analysis of variance for monopodial, sympodial and biological yield

Source of variation	Monopodial branches @60 DAS	Monopodial branches @100 DAS	Sympodial branches @60 DAS	Sympodial branches @100 DAS	Biological yield (kg/ha)
Nitrogen rate(N)	<0.0001*	<0.0001*	<0.0001*	<0.0001*	<.0001*
Plant density (PD)	0.0261*	0.0004*	0.173 ^{NS}	0.0004*	0.0015*
Variety (V)	0.0133*	0.0109*	0.8402 ^{NS}	0.2143 ^{NS}	0.0887 ^{NS}
N * PD	0.0986 ^{NS}	0.0121*	0.4314 ^{NS}	0.0041*	0.3431 ^{NS}
N * V	<0.0001*	0.0001*	0.0753 ^{NS}	0.3005 ^{NS}	0.0040*
PD *V	<0.0001*	0.0006*	0.8619 ^{NS}	0.1825 ^{NS}	0.8507 ^{NS}
N *PD* V	0.2897 ^{NS}	0.6781 ^{NS}	0.1495 ^{NS}	0.1566 ^{NS}	<0.0001*

*=significant at $P < .05$; ^{NS} = not significant

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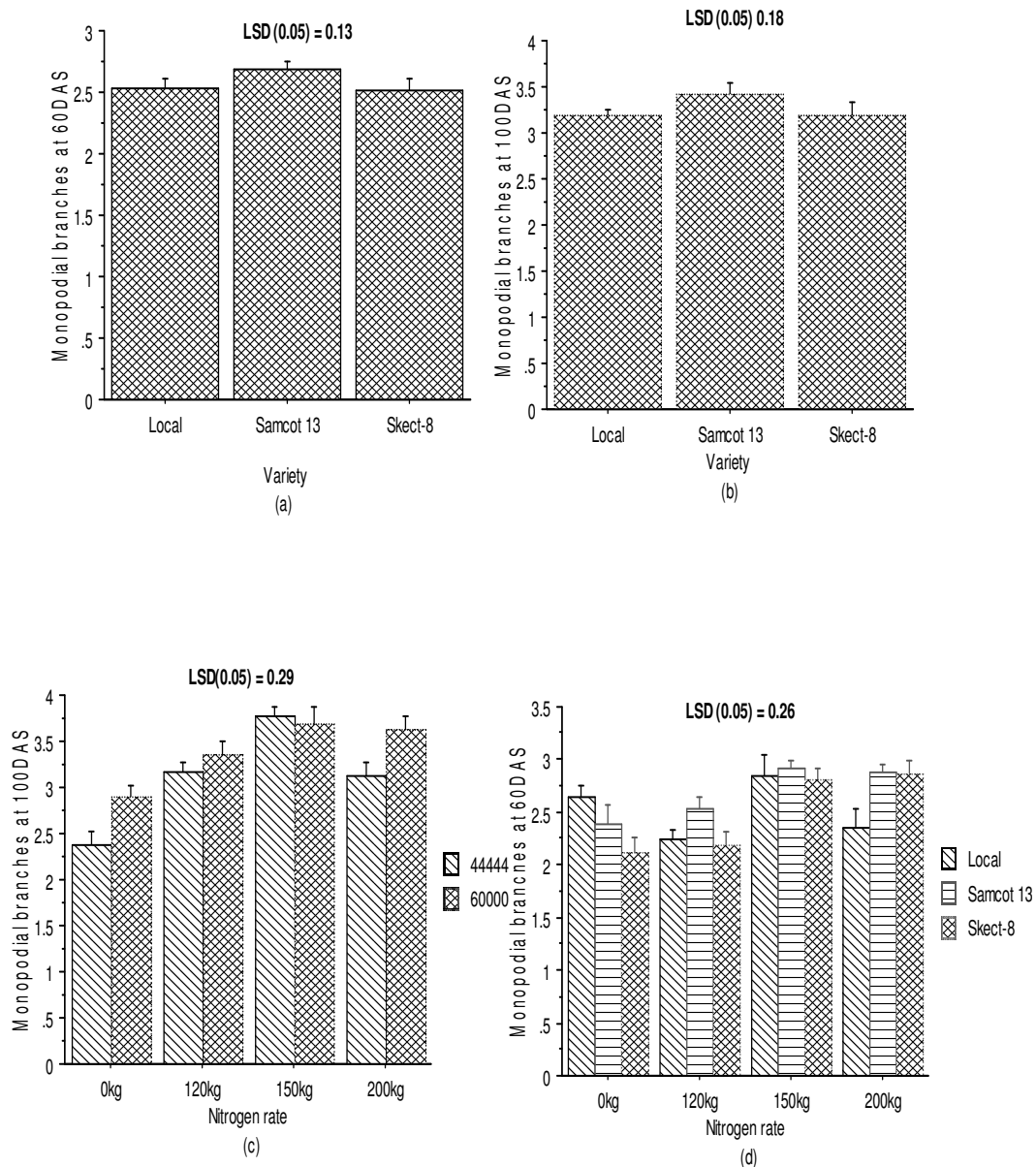
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FIG 7: Effects of nitrogen rates at (a) 60 DAS, (b) 100 DAS and plant density at 60 DAS and at 100 DAS (c and d) on monopodial branches



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400 FIG 8: Effects of variety at (a) 60 DAS and (b) 100 DAS and the interaction of N with
 401 plant density variety at 100 DAS (c) and nitrogen with variety (d) on monopodial branches of
 402 cotton
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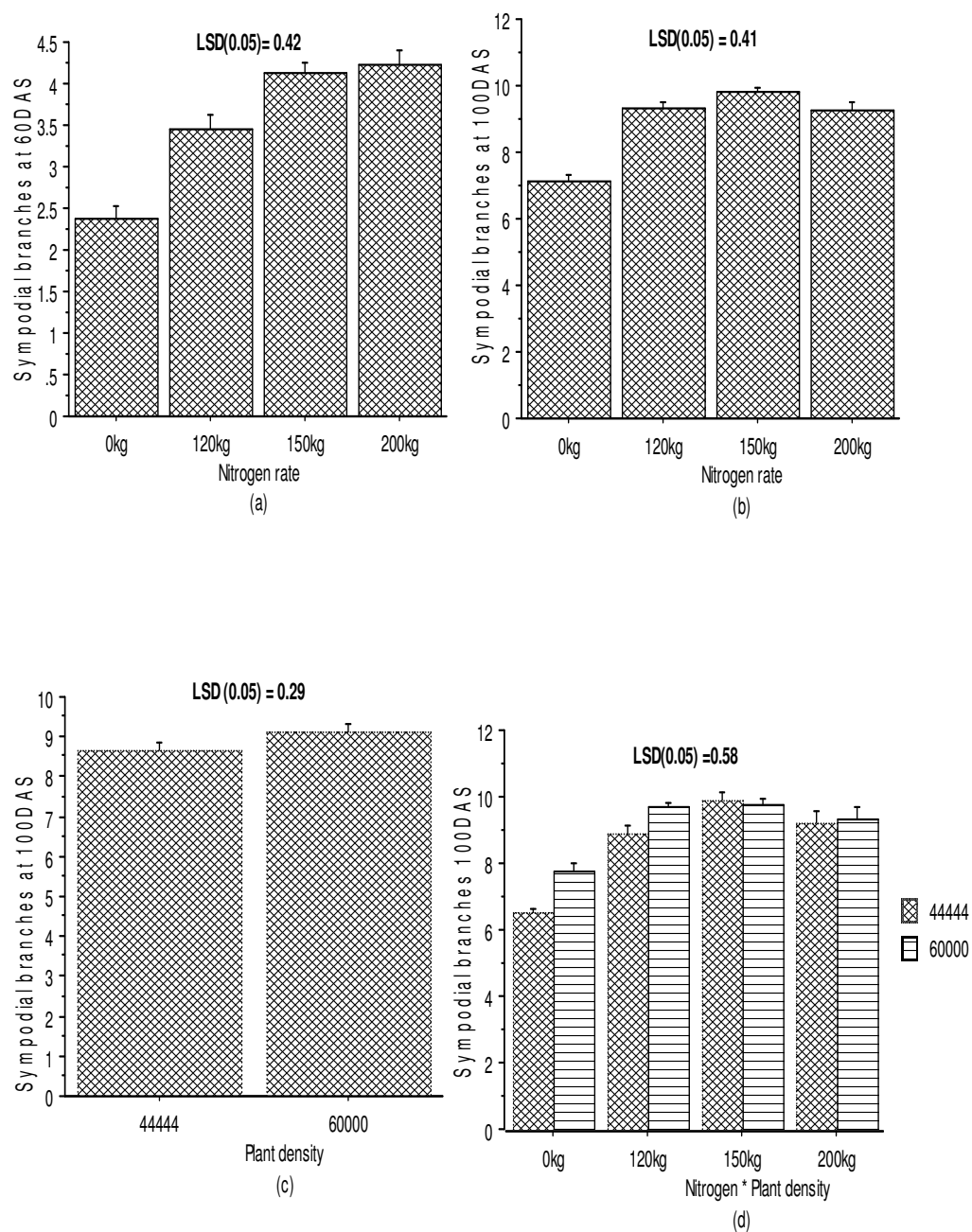
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407 **3.3.2 Sympodial branches**

408 A summary of the analysis of variance of the effects of various nitrogen rates, plant
409 density and variety on number of sympodial branching as presented in Table 3 indicated that
410 nitrogen rates were highly significant at 60 and 100 DAS. Plot treated with 200 kg N ha⁻¹ at
411 60 DAS had an average of 4.22 branches which was significantly higher compared with
412 those treated with 120 kg N ha⁻¹, 150 kg N ha⁻¹ and control (Figure 9a). Plant density, variety
413 and the various interactions were not significant at 60 DAS. At 100 DAS, nitrogen rates,
414 plant density and the interaction of nitrogen rate with plant density was significant ($P < .05$).
415 Plot treated with 150 kg N ha⁻¹ produced the highest number of sympodial branches (9.80)
416 compared with other N rates and control plots (Figure 9b). Higher plant density (60,000
417 plants ha⁻¹) produced average of 9.13 sympodial branches at 100 DAS while lower density
418 (44,444 plants ha⁻¹) produced 8.63 sympodial branches (Figure 9c). Interaction of nitrogen
419 rates with density at 100 DAS showed that low density with N rate of 150 kg N ha⁻¹ produced
420 the highest sympodial branches (9.84) compared with other N rates x plant density
421 interaction and control plots (Figure 9d). Similar results for cotton fruiting branches have
422 been independently reported by [47, 48].

423



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425 FIG 9: Effects of nitrogen rates at 60 and 100 DAS (a and b), plant density at 100 DAS (c)
 426 and interaction of nitrogen with plant density at 100 DAS (d) on sympodial branches
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3.4. Biological (Biomass) Yield as influenced by nitrogen rates, cotton varieties and plant densities

A summary of the analysis of variance as shown in Table 3 indicated that N rate, plant density, the interaction of N rate x variety and N x PD x V significantly affected the biomass yield of cotton plant. The main effect of nitrogen rates indicated that biomass yield was highest under the plot treated with 150 kg Nha⁻¹ (9778.94 kgha⁻¹) while the control plot produced the lowest yield of 6098.61 kgha⁻¹ (Figure 10a).

Plant density showed a significant effect on biological yield. It was noted that lower plant density of 44,444 plants ha⁻¹ produced more biomass (Figure 10b). Varietal effects on biomass yield were not significant. Interactively, nitrogen rates interaction with variety was significant. Sketch-8 treated with 150 kg Nha⁻¹ produced the largest quantity of biomass (1,096.42 kgha⁻¹) while the same variety in control plots produced the lowest biomass yield of 5,300.00 kgha⁻¹ (Figure 10c). Also, interaction of nitrogen rates at 150 kg Nha⁻¹ with sketch-8 under low plant density significantly produced the largest biomass yield (Figure 10d). The result of this study on biomass yield showed that nitrogen application at all levels contributed to increase in biological yield; this is because of the greater amount of vegetative growth and robustness of plants resulting from the available nitrogen uptake. It has been reported by [4] that nitrogen fertilization had a significant impact on plant biomass production while [15] confirmed that nitrogen is essential for cotton canopy area development and photosynthesis. Lower plant density produced larger plant size hence it resulted in larger biological yields.

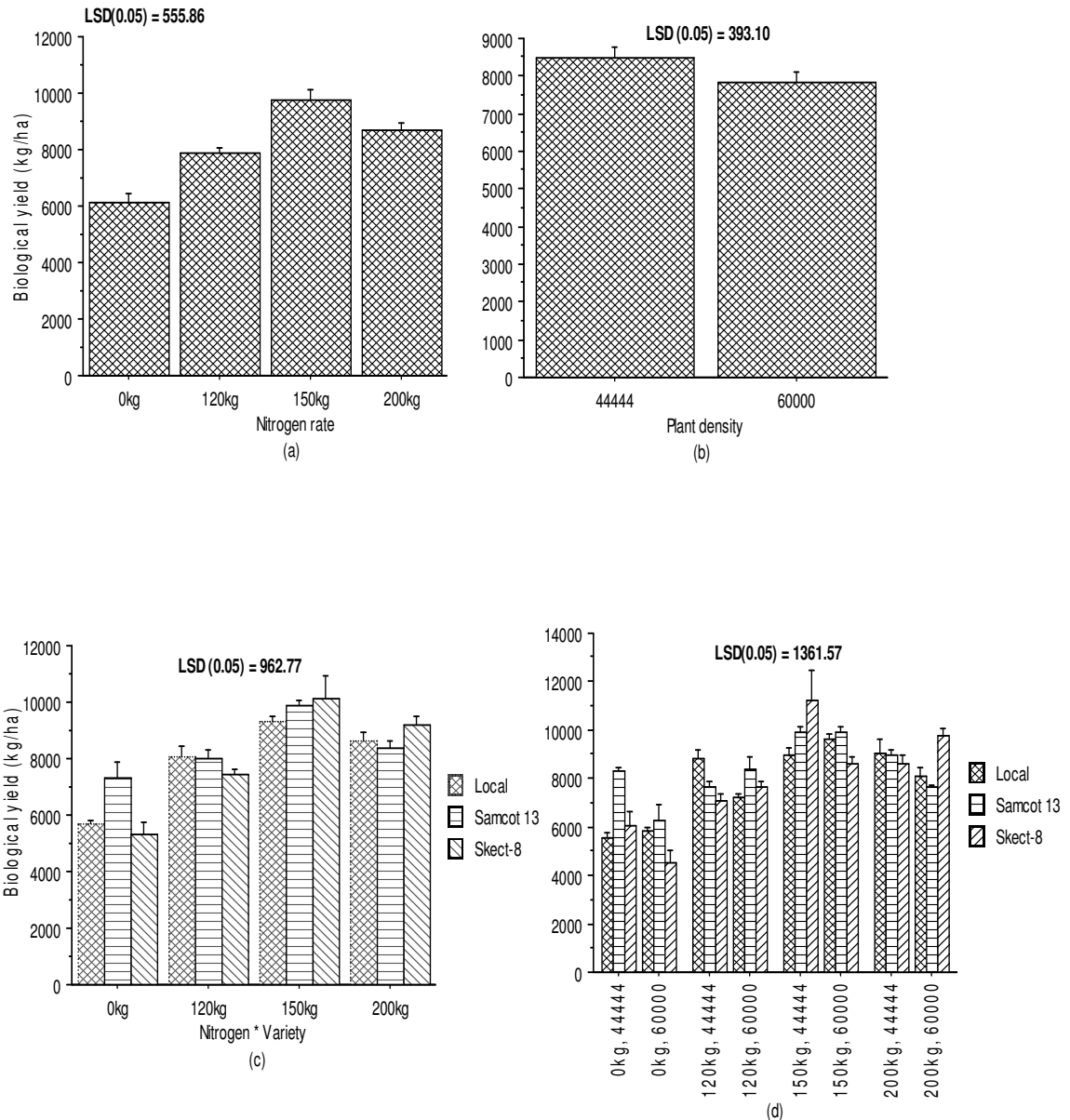


FIG 10: Effect of (a) nitrogen rates, (b) plant density, (c) the interaction of nitrogen with variety and (d) nitrogen with variety with plant density on biological yield

4. CONCLUSION

The growth and yield components of cotton were optimum at N rate of 150 kg Nha⁻¹. For cottonseed yield per boll, Samcot-13 treated with 150 kg Nha⁻¹ was the best in the study area. Interactively, cottonseed yield per hectare was highest for Jalingo local treated with 150 kg Nha⁻¹ and at the lower plant density (44,444 plants ha⁻¹). Nitrogen at all levels significantly increased cottonseed yield, however, cottonseed yield per hectare (fibre and seed yield) was best optimized at 150 kg Nha⁻¹ x Jalingo local variety x low plant density. Therefore, farmers may keep using the local variety (Jalingo local) provided they sow at 44,444 plants ha⁻¹ and apply 150 kg Nha⁻¹ as urea in two equal splits (21 and 50 DAS). The improved varieties would need further fine-tuning to optimize their yield performance in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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