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Research Article

EVALUATING THE INTERRELATIONSHIP AND EFFECT OF DIFFERENT NUTRIENT COMBINATIONS AND PLANT DENSITIES ON SEED COTTON YIELD AND RELATED COMPONENTS

[1,*]Marco Mare, [2]Washington Mubvekeri, [2]Victor Chingwara and [1]Monica Chikonzo

[1]Cotton Research Institute, P. Bag 765, Kadoma, Zimbabwe
[2]Department of Crops Research, P.O. Box CY 594, Causeway, Harare, Zimbabwe

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Abstract

Cotton *(Gossypium Hirsutum, L.)* is an important cash crop which attracts foreign currency for improved agricultural, industrial and economic development. Like any other field crop, cotton production has greatly been affected by climate change; hence the requisite to pay attention to the effects by developing and testing improved production technologies for sustainable cotton production. Adoption of suitable plant population densities coupled with appropriate nutritional combinations can build a strong case for improved production and productivity in the face of climate variability. An experiment to determine the effects of plant density and nutritional composition on seed cotton yield and its related components was carried out at Cotton Research Institute during the 2023 season. Three plant densities 27889, 36056 and 64167 were established as whole plots and five nutritional combinations as sub-plots comprised of N: P: K: S: B (64.25N:42.50P:25K:15S:0.9gB), (64.25N:42.50P:30K:15S:2.25gB), (64.25N:42.50P:35K:15S:3.60gB), (64.25N:42.50P:40K:15S:4.95gB) and100N:42.50P:145K:15S:18.9gB) in a split plot experimental design replicated three times. Plant density significantly influenced fruiting branches and number of bolls whilst no significant differences were recorded for seed cotton yield, gin out turn, plant height, boll weight and seed weight. No significant differences were recorded for nutritional combinations and interaction on all tested parameters. Low plant density (27889 plants/ha) recorded significantly higher number of fruiting branches (28.93) which were comparable to the highest population density (64167 plants per ha) (28.03) whilst 36056 plants per ha recorded the least number of 26.44. Plant density of 27889 plants per ha recorded a significantly higher number of bolls per plant (14.36), and was followed by Plant density of 36056 (12.17) which was comparable to population plant density 64167 (10.23).

Keywords: Gossypium Hirsutum, Plant densities, Nutritional combinations and Fruiting branches.

INTRODUCTION

Cotton *(Gossypium Hirsutum, L.)* is an important cash crop which attracts foreign currency for improved agricultural, industrial and economic development. Like any other field crop, cotton production has greatly been affected by climate change; hence the requisite to pay attention to the effects by developing and testing improved production technologies for sustainable cotton production. Adoption of suitable plant population densities coupled with appropriate nutritional combinations can build a strong case for improved production and productivity in the face of climate variability. In Zimbabwe, cotton is a strategic industrial crop suitable for sustainable economic development and food and nutrition security as stipulated in the National Development Strategy (NDS1). Cotton provides livelihoods to 2 million households country-wide, also offers employment to over 3000 people and the country earns between US$30 –US$60 million foreign currency from lint exports annually. Cotton production in Zimbabwe has been declining since 2012 from 350703Mt (Figure 1) and this has negatively affected the performance of the cotton value chain (COTTCO report 2023). The deterioration in cotton production over the years is linked to many factors and amongst them includes high cotton production costs, droughts, inadequate and late supply of inputs, low producer prices, viability issues and climate change characterized by low rainfall leading to many farmers neglecting the crop (COTTCO, 2023). This is indicated by a five year rainfall analysis (Figure 2).

Corresponding Author:** ***Marco Mare,
Cotton Research Institute, P. Bag 765, Kadoma, Zimbabwe

The government of Zimbabwe intervened in 2015 through the introduction of the Presidential Input Scheme with the aim to revive the cotton sector (COTTCO, 2023).

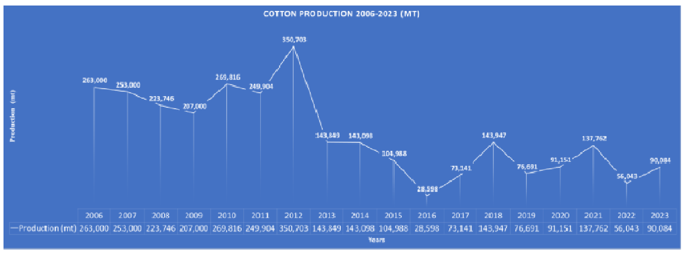

Figure 1. Production figures (Mt) from 2006 to 2023

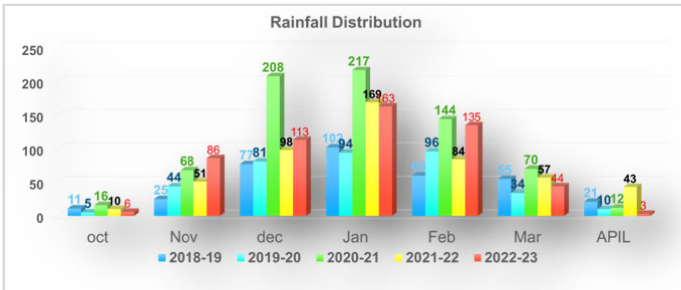

Figure 2. Five year rainfall analysis from 2019 - 2023

Efforts to improve the cotton sector in Zimbabwe persisted through a country to country project between Zimbabwe and Brazil under the South to South Cooperation. The project was implemented by the Brazilian Corporation Agency (ABC) with the aim of strengthening the Cotton Sector of Zimbabwe. The project is expected to contribute towards increased competitiveness of the cotton sector in Zimbabwe by strengthening its technological, institutional, human resources and technical assistance capabilities through Technical Demonstration Units (TDUs). The purpose of the TDU since its inception in 2021 was to present a new form of cotton production technology transfer through validation and dissemination of efficient cotton production systems. Therefore, to support the validation of the technologies, Cotton Research Institute implemented a research experiment in 2023 to evaluate the Brazilian technology. The project factors involved in the project included population density and nutritional combinations. Cotton growth and development is intensively affected by genetic, environmental and cultural factors and plant density is believed to be one of the most important factors (Keshavarz *et al.,* 2021a). According to Li *et al.,* 2019 and Keshavarz *et al.,* 2021 an appropriate plant density is important in optimizing the partitioning of assimilates which include the promotion of the water and fertilizer use efficiency which finally increase crop productivity. Other studies have shown that population is very decisive to achieve optimal crop growth and productivity due to the directly effects on the radiation objection, availability of moisture, humidity and wind activity (El-Sayed *et al.,* 2023). According to Munir (2014), a research study he carried out revealed that sympodia number per plant, plant height, bolls number per plant, boll weight, yield of seed cotton per plant and per hectare significantly varied among plant spacing examined (22.5, 30.0 and 37.5 cm) but the number of plants was greatly varied only by the spacing between plants. Liaqat *et al.,* (2018) carried out a study on three spacing, (21, 27 and 33cm) and tall plants were recorded with the smallest spacing of 21cm between plants whilst the highest yield was recorded at a spacing of 33cm, so to get higher yield recommendations were given to plant at 33cm. Other studies have shown that cotton growth and development is significantly influenced by climate adversaries, and seasonal management practices which include variety, sowing date, sowing method, plant spacing and appropriate fertilizer application (Tung *et al.,* 2018; Fahad *et al.,* 2021d, Fahad *et al.,* 2021e, Muhammad *et al.,* 2019; Fahad *et al.,* 2021a,c).Planting spacing at 40 cm significantly increased plant height, number of fruiting branches per plant, number of bolls per plant, boll weight (BW), lint percentage (L%), seed cotton yield (SCY), lint cotton yield (LCY), seed index and lint index (Ibrahim *et al.,* 2022). The application of N fertilizer rate at 125% caused a maximum increase in growth and yield parameters i.e., plant height, number of vegetative branches, number of fruiting branches per plant, number bolls per fruiting branch, number of bolls per plant, boll weight, lint percent, seed index, and lint index, while the plants treated with 100% N rates exhibited highest seed cotton yield and lint cotton yield (Ibrahim *et al.,* 2022). It is revealed through other studies that high nitrogen requirements are a common limiting factor in crop growth based on their role in cotton photosynthesis and canopy development (Muhammad *et al.,* 2019; Gross, 2022; Rivero *et al.,* 2022; Van Der Sluijs, 2022; Zhi *et al.,* 2022) and hence it is the most crucial component in cotton fertilization to get a desirable yield (Bondada and Oosterhuis, 2001). Another study found that nitrogen fertilizer had a substantial effect on cotton growth, boll development, lint output and fiber quality Luo *et al.,* 2018).It is therefore evident that there is limited research information on the effect of plant density and nutrient combination therefore an experiment to determine the effect of various nutrient combinations and different plant densities on seed cotton yield and related components was initiated.

MATERIALS AND METHODS

Experimental Site and season

An experiment was conducted at Cotton Research Institute, Natural Region IIb during the 2022/23 growing season under dryland, which is a predominantly prototypical environment for under smallholder farmers in Zimbabwe. The season received a total of 865mm (Fig. 3).

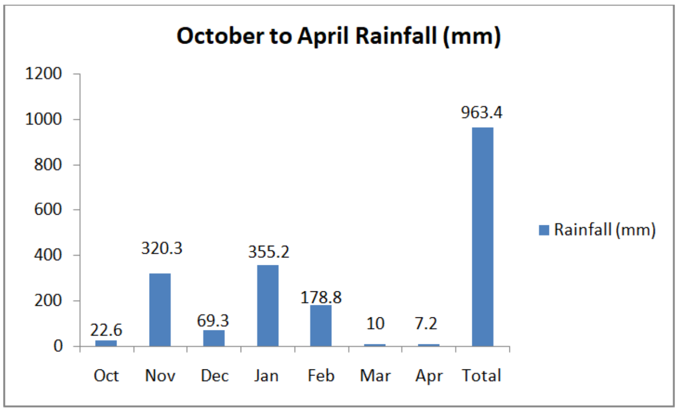

Figure 3. Rainfall from October 2022 to February 2023

Experimental Design and Treatments

A single variety CRIMS4 was used in the experiment. Three plant densities 27889, 36056 and 64167 were established as whole plots and five nutritional combinations as sub-plots comprised of N: P: K: S: B (64.25**N**:42.50**P**:25**K**:15**S**:0.9g**B**), (64.25**N**:42.50**P**:30**K**:15**S**:2.25g**B**), (64.25**N**:42.50**P**:35**K**:15**S**:3.60g**B**), (64.25**N**:42.50**P**:40**K**:15**S**:4.95g**B**) and100**N**:42.50**P**:145**K**:15**S**:18.9g**B**) in a split plot experimental design replicated three times.

Data Collection and Measurements

Critical measurements were done which included the following:

1. Total seed cotton yield (kg/ha)
2. Gin out turn (%)
3. Fruiting branches
4. Number of bolls
5. Boll weight (g)

Data Analysis

All measurements were conducted within the net plot and collected data was subjected to Genstat to perform Analysis of Variance(ANOVA), and treatment means. Fishers' protected LSD at 5% was used to separate treatment means.

RESULTS AND DISCUSSION

Seed Cotton Yield (kg/ha)

Variance analysis for plant densities recorded no significant differences (P=0.055) (Table 1), and this was the same observation for nutrient combinations and interaction which recorded P=0.498 and P=0.159 respectively. Generally, the highest plant density of 64167 plants per hectare produced higher yield of 1874kg/ha than the other two densities. The seed cotton yield increased with the increasing number of plants per unit area and the findings are in agreement with studies by Altundag *et al.,* 2021; Zaman *et al.,* 2021; Zuo*et al.,* 2023, Hall *et al.,* 2022; Akheteruzzaman., 2021, Shah *et al.,* 2021, Chen *et al.,* 2019 and Liu *et al.,* 2019).The authors observed a similar trend of increased yield under high plant density. According to Zaman *et al.,* 2021, the higher seed cotton yield was at 15.0 cm, while the lowest seed cotton yield was at 45.0 cm. This was the same observation made by Menefee *et al.,* 2023 where greater total yield was obtained in full row treatment (3360kh/ha) compared to a skip-row treatment (3035kg/ha). In contrast, Sadhik *et al.* 2022 and El-Sayed *et al.,* 2023 obtained higher yield on cotton sown at a wider spacing. The nutrient combination with high nitrogen, potassium and boron recorded higher yield of 1813kg/ha than the other combinations (Fig.4a &4b). The results concurred with what Menefee *et al.,* 2023 recorded in the study on effects of row spacing and potassium foliar application on yield of cotton where there was a significant impact of K rate on total biomass, but not on residue biomass with the greatest total biomass (3392 kg/ha) at the 40 kg/ha K rate and the lowest total biomass (3031 kg/ha) at the 0 kg/haK rate.

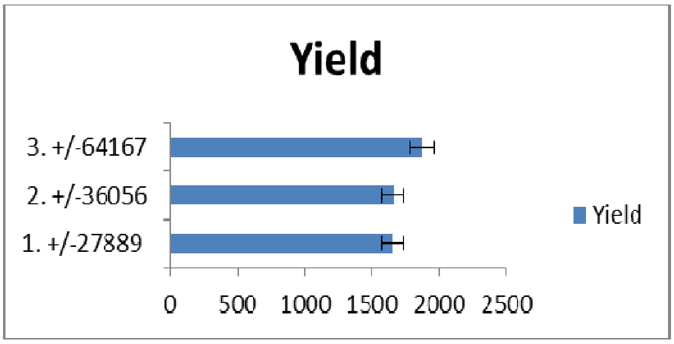

Fig 4a. Effect of different planting densities

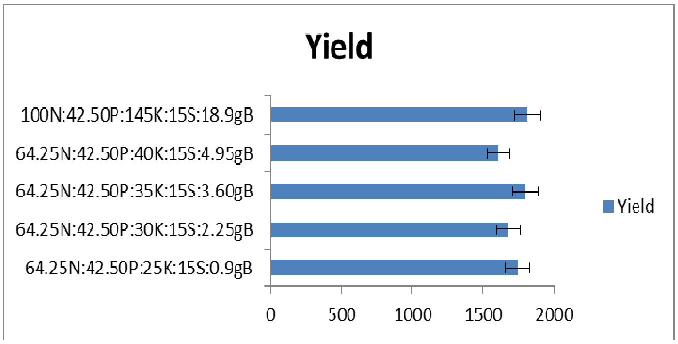

Fig 4b. Effect of fertilizer combinations

Gin-Out-Turn (%)

No significant differences were recorded from the effect of plant population densities, nutrient combinations and interaction (Table 1). All P-values were above 0.9. However, as the distance between rows and plants decreased (the plant density increases in the unit area), the GOT increased (Fig. 5a). This was different from findings reported by Altundag *et al.,* 2021, where the ginning percentage decreased as the distance between rows and plants decreased. Lack of variation on performance among treatments might have been varietal, since same variety was used in the experiment (Fig. 5b). Ibrahim *et al.,* 2021 realized that the lint percentage was affected by plant space and affected by the N fertilizer rate (Fig 5a & 5b). Planting at 40 and 30 cm recorded the highest lint percentage (42.13 and 42.32%) in both seasons, in respect. Increasing the N fertilizer levels from75 to 125% improved the lint percentage and observed the highest percentage compared to the low N fertilizer rate.

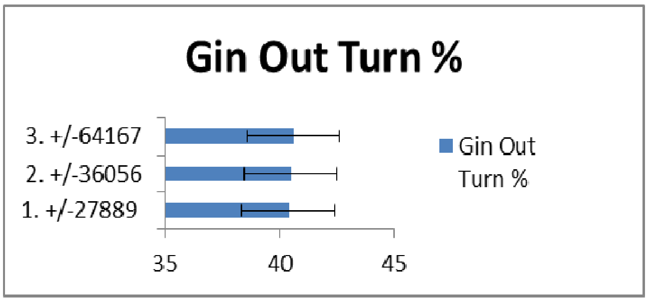

Fig 5a. Effect of different planting densities

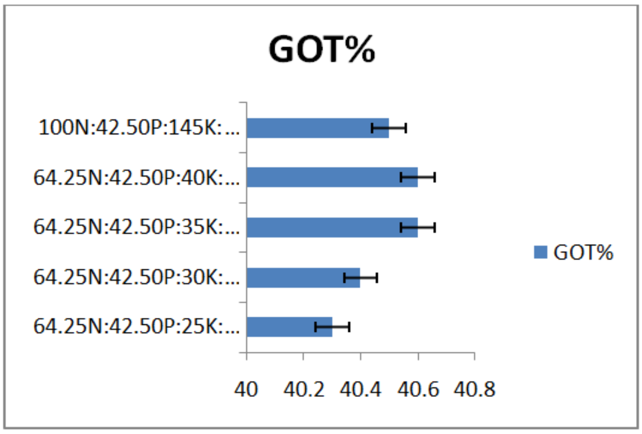

Fig 5b. Effect of fertilizer combinations

Fruiting Branches

Plant population densities significantly affected the number of fruiting branches (P=0.038). Low plant density (27889 plants/ha) recorded a higher number of fruiting branches (28.93) but comparable to the highest population density (28.03) (Fig 6a and 6b). This might have been influenced by normal growth of plants in the treatment, thus normal height to node ratio (HNR) in the case of low plant population density, whilst under high plant population density might have been linked to taller plants in the treatment. This is supported by the shorter average plant heights recorded at 123.2cm under lower plant population density and taller average plant heights recorded at 129.5cm under higher plant population density (Table 1). Plant population density of 36056 recorded the least number of fruiting branches (26.44) though it was similar to that of the highest population density. Nutrient combinations and interaction had no significant effects to the number of fruiting branches. The results were similar to those reported by Morsy *et al.* (2022) who reported an increase in the number of bolls per plant was a direct consequence of more fruit branches per plant. In addition, Hashem *et al.* (2022) revealed that an increase in the number of bolls per plant with an increase in plant space can reduce competition between plants. According to fig 7, the number of bolls increased with increasing plant spacing, and this is in disagreement with the findings by Zaman *et al.,* 2021, where narrow plant spacing was found to be better for the number of sympodial branches per plant than wider plant spacing. This is in affirmation with the earlier findings of Stephenson, IV *et al.* (2011), who concluded that higher plant density decreased the number of monopodial and sympodial branches (fig 7). The study findings had higher number of fruiting branches under low plant population and low number under high population (Fig 7). Alfaqeih *et al.* (2002) also reported similar results and indicated that an increase in the number of fruit branches per plant in low planting density could be due to less competition and more space available for the growth of plants.

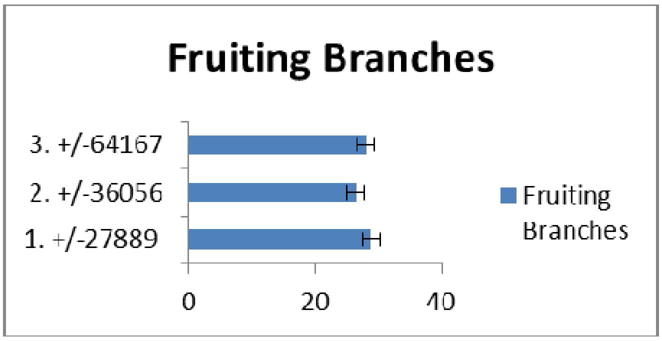

Fig 6a. Effect of different planting densities

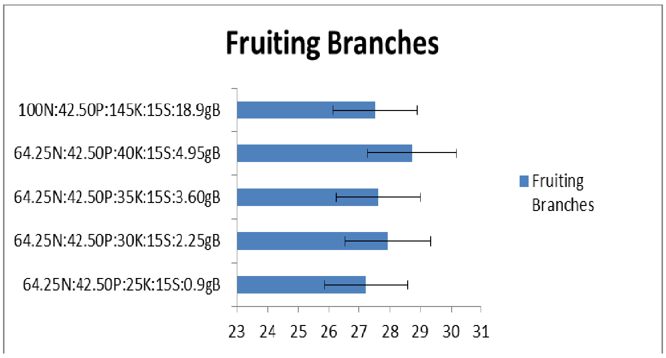

Fig 6b. Effect of fertilizer combinations

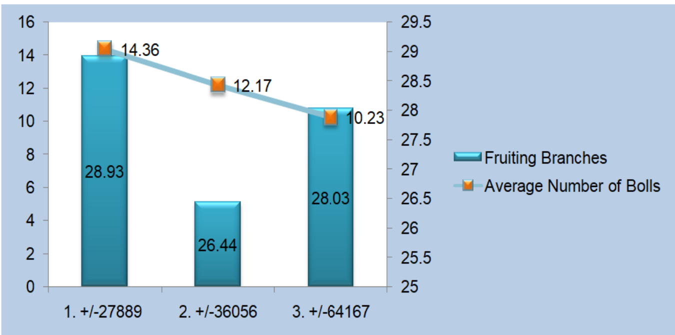

Fig 7. Relationship between fruiting branches and average number of bolls from the effect of plant density

Number of Bolls per Plant

Highly significant differences (P=0.001) as a result of plant population densities were recorded on number of bolls per plant, with plant population density of 27889 recording a significantly higher number (14.36), and this was followed by plant population density of 36056 (12.17) which was comparable to population plant density 64767 (10.23) (Table 1, Fig 7a). This is in line with the earlier findings by Sadhik et al, 2022 who found that the total number of bolls per plant in a single branch was highest in branching pattern 1 (90 x 45cm) and 2 (60 x 30cm), while it was lowest in branching pattern 3 (45 x 15cm), on average it was 1.3, 1.1 and 0.8 bolls per branch respectively. He further clarified that spacing (90 x 45cm) had more bolls 18.8 than spacing (60 x 30cm) with spacing 16.3 and spacing (45 x 15cm) with 11.9. The findings were also similar to Hashem *et al.* (2022) who revealed that an increase in the number of bolls per plant with an increase in plant space can reduce competition between plants. However, Akheteruzzaman *et al.* 2021, found that there were no significant differences in all the four spacings under investigation though he found that there was highest number of bolls per plant in spacing (90 x 10cm) followed by spacings 3, 2 and 1 which had 19.1, 17.5, and 16.7 respectively. This is a normal attribute linked low densities where low competition amongst plants, more floriferous and higher boll retention rates are experienced unlike for high plant densities where boll load is minimal due to plant competition for resources. Nutrient combinations and interaction revealed no significant differences.

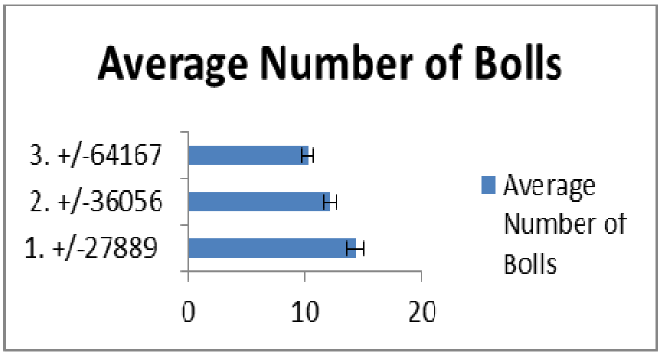

Fig 8a. Effect of different planting densities

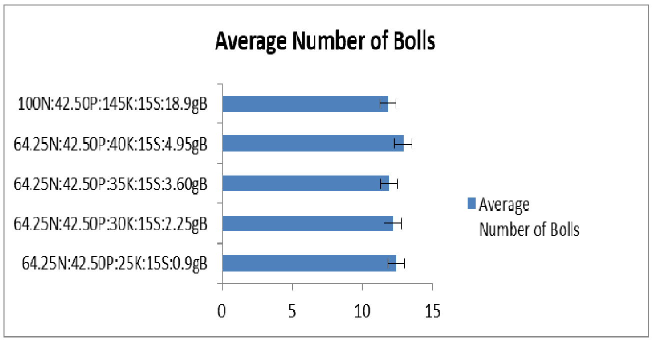

Fig 8b. Effect of fertilizer combinations

Boll Weight

Boll weight varied between 6.3g and 6.7g, but there were no statistically significant differences. The lowest boll weight was obtained in the densely populated spacing (0.75m x 0.15m) and the highest boll weight was obtained at a spacing of 0.75m x 0.30cm) (Table 1, Fig 9a). Different spacing did not have significant effect on boll weight. The findings are in agreement with results reported by Altundag *et al.,* 2021 and Akheteruzzaman *et al.* 2021, where lowest boll weight was recorded on no thinned treatment and highest boll weight was obtained at 10cm plant density. According to Shah et al, 2021, found the results that are in contrast with these findings in which the high plant density (3.4g) had higher significant difference than lower plant density and medium plant density that had 2.9g and 2.8g respectively. The obtained results were also contrary to Ibrahim *et al.,* 2022, who found out in a study that plant spacing affected boll weight whereas 40 cm between cotton plants gave the highest BW of (3.73 and 3.78 g) in the 2019 and 2020 seasons, respectively. Additionally, nitrogen fertilizer rates application varied significantly ($p \leq 0.001$). The application of 125% nitrogen fertilizer rate exhibited the heaviest BW (4.20 and 4.07 g) in both seasons, respectively.

Table 1. Effect of Plant density and Nutrient combinations on seed cotton yield and its related components

Treatment	Yield	Gin Out Turn %	Fruiting Branches	Average Number of Bolls	Average Boll Weight
a) Plant Density					
1. +/-27889	1653	40.4	28.93b	14.36b	6.380
2. +/-36056	1659	40.5	26.44a	12.17a	6.547
3. +/-64167	1874	40.6	28.03ab	10.23a	6.413
P Value	0.055	0.907	0.038	0.001	0.442
LSD	203.0	0.89	1.901	2.050	0.2788
b) Nutrient Combinations					
64.25N:42.50P:25K:15S:0.9gB	1743	40.3	27.22	12.44	6.378
64.25N:42.50P:30K:15S:2.25gB	1680	40.4	27.94	12.18	6.344
64.25N:42.50P:35K:15S:3.60gB	1797	40.6	27.61	11.91	6.700
64.25N:42.50P:40K:15S:4.95gB	1611	40.6	28.72	12.89	6.489
100N:42.50P:145K:15S:18.9gB	1813	40.5	27.52	11.84	6.322
P Value	0.498	0.983	0.763	0.926	0.211
LSD	262.0	1.15	2.454	2.647	0.3599
c) Interaction					
P Value	0.159	0.908	0.975	0.265	0.841
GRAND MEAN	1729	40.5	27.80	12.25	6.447
CV%	15.7	2.9	9.1	22.4	5.8

Means in the same part of the table and in the same column followed by the same letter are not significantly different after separation by Fisher's LSD (P> 0.05)

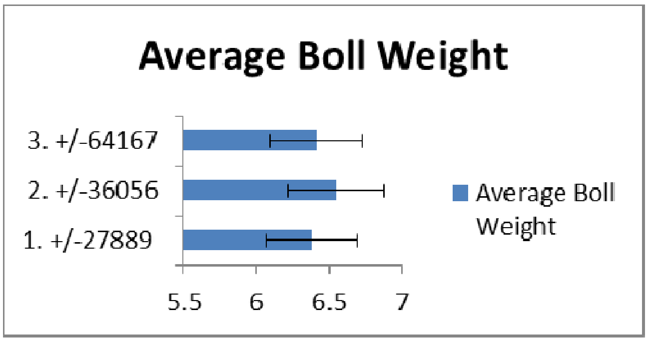

Fig 9a. Effect of different planting densities

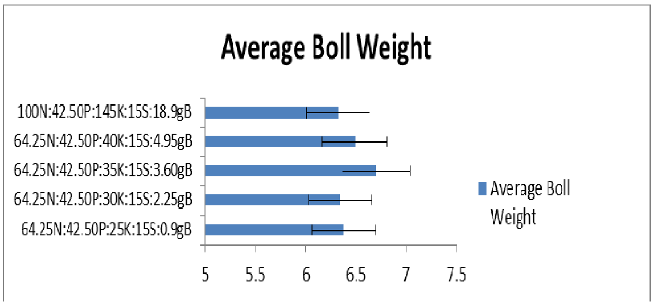

Fig 9b. Effect of fertilizer combinations

Conclusion

According to the findings of this study, variance analysis results of plant density revealed no significant differences on most of the parameters except for number of fruiting branches per plant and number of bolls per plant. More fruiting branches were recorded under the lowest plant density, and whilst it also recorded the highest number of bolls per plant. Positively correlated number of bolls per plant and fruiting branches resulted in improved seed cotton yield. More bolls per plant were obtained under low densities, which is in agreement with Sekloka *et al.* (2016) who through an experiment found that at low densities, cotton plants were more floriferous and retained their bolls better, with average numbers of fruiting sites per plant and retention rates. Though there were no significant differences for variance analysis of nutrient combinations and interaction on all parameters, higher seed cotton yield was obtained at almost doubled rate of nitrogen, potassium and boron whilst a high plant density favored a high yield.

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