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Effects of maize seed density on yield and yield components

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Abstract
To meet the high food demand due to the increase in population and limited area, it is imperative to obtain high yield per unit area. This experiment was carried out at Africa University farm, Mutare, Zimbabwe to find out the effect of increasing seed density per planting station on yield and yield components. The experiment was laid out in a Randomized Complete Block Design with 3 replications and six (6) treatments. Treatments ranged from one (1) seed to six (6) per planting station at various spacing's. To minimize the effect of excess competition, the spacing was varied in the same unit area of 3.6 m x 4 m per plot/treatment. Treatment one (T_1) had a spacing of 90 cm x 25 cm, T_2 with a spacing of 90 cm x 50 cm, T_3 with a spacing of 90 cm x 50 cm, T4 with a spacing of 90 cm x 50 cm, T_5 with a spacing of 90 cm x 100 cm and T_6 with a spacing of 90 cm x 100 cm. Spacing's were adopted to accommodate all the seeded treatments and was not a variable of the experiment. Data were collected on: Plant height (cm), plant thickness (cm), Grain, Cob and core weights (kg), Infertility Number, Shelling percentage and grain yield. From this experiment, it was observed that Treatment four (4) had a higher yield of 9.38 kg followed by T_3 and T_6 with a yield of 7.77 kg and 7.51 kg respectively. It is therefore recommended to adopt treatment three (3) consisting of three (3) seeds per planting station with a spacing of 90 cm X 25 cm, or treatment four (4) with four (4) seeds per planting station with a spacing of 90 cm X 25 cm, to improve yield per unit area.

Keywords: Maize, seed density, grain yield

Introduction

Field performance of maize *(Zea mays L.)* is affected more by variation in plant density than other members of the grass family (Vega CRC, *et al*., 2001) [10]. Plant population affects most of the growth parameters of maize even under optimal growth conditions. Plant population is considered as a major factor determining the degree of competition among the plant causing growth and yield variation of maize (Sangakkara UR *et al*., 2004) [13]. Gradual increase in plant density has been a vital contributor to maize yield augmentation globally (Tokatlidis, I.S. and Koutroubas, 2004) [9]. The success of increased plant population and/or narrow row spacing is well-known in wet and humid environments such as in Southwestern China (Qin X, *et al*., 2016) [6], the United States Corn Belt (Duvick, 2005) [12], and the Argentine Pampas (Echarte, L. *et al*., 2000) [1]. Although increasing plant density has been known to improve grain yield, maize differs greatly in its various responses to plant density (Luque S, *et al*. 2006) [3]. Higher population enhances interplant competition for space, light, water, nutrients and other growth resources that affects final yield formation resulting in less ears per plant and kernels per ear (Sangoi L, Gracietti MA, Rampazzo C, 2002) [8]. It is therefore imperative to adjust optimum plant population to achieve maximum grain yield (MAK *et al*., 2021) [5]. The objective of this study was to determine how many maize seeds should be planted per planting station to maximize yield per unit area.

Materials and Methods

This experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications and six treatments. Treatment one (T_1) had row spacing of 90cm x 100cm and one seed per hole, Treatment two (T_2) had two seeds per hole, Treatment three (T_3) comprised of three seeds per hole and treatment four (T_4) had four seeds per hole, Treatment five (T_5) with five seed per hole and Treatment six (T_6) with six seed per hole. Each replication had 6 plots with four rows per plot. To minimize the effect of excess competition, the spacing was varied in the same unit area of 3.6m x 4m per plot/ treatment.

T_1 with a spacing of 90 cm x 25 cm, T_2 with a spacing of 90 cm x 50 cm, T_3 with a spacing of 90 cm x 50 cm, T_4 with a spacing of 90 cm x 50 cm, T_5 with a spacing of 90 cm x 100 cm and T_6 with a spacing of 90cm x 100cm. Spacing's were adopted to accommodate all the seeded treatments and was not a variables of the experiment.

Data collection: Data were collected as follows

Plant height (cm): The maize height was measured from the soil surface to the beginning of the tassel branch, using measuring tape.

Plant thickness (mm): The plant thickness was measured at 1 meter height using Vernier calliper.

Grain, Cob and core weights (kg): The weights were measured by using an electronic balance.

Infertility Number
The number of maize cobs found to be infertile or those with little kennels were counted from the total cobs harvested per plot.

Shelling percentage: The ratio between the grain weight and core weight was calculated as follows:

$$\text{Shelling percentage} = Grain\ weight/(Grain\ weight\ + core\ weight$$

$$Grain\ Yield\ \ field = \text{Cob weight from field(kg)} * \text{Shelling percentage} * \text{ Moisture correction}$$

Data Analysis
Data was evaluated according to the RCBD model of

$Y_{ij} = \mu + T_i + \beta_j + \epsilon_{ij}$

μ = overall mean
T_i = effect of the i^{th} treatment
β_j = the effect of the j^{th} block
ϵ_{ij} = experimental random error; identical, independent and normally distributed

The analysis of variance (ANOVA) was performed to examine the effects of seed density on maize and stover yield. Post hoc tests were conducted to ensure the correctness of the one-way ANOVA estimate.

Results and Discussion
Grain Yield: On average the yield ranged between 4.58 to 9.6 kg as shown in Figure 1.

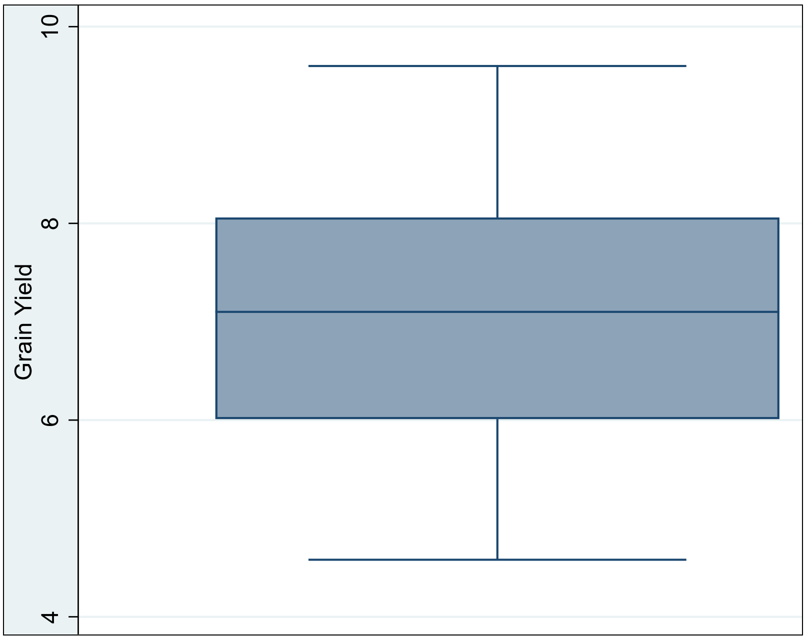

Fig 1: Box plot of maize Grain Yield Variable

The yield variable was found to have variation on its mean across treatments. As indicated in Table 1 and Figure 2, the average yield initially increased up to the 4^{th} treatment and started to decline. This could be because of the high plant population in treatment 4 with 64 maize plants compared to the rest with 48, 40, 38 maize plants in treatment 3, T_5, and T_6 respectively. In treatments 3 and 4, the grain yield reached its maximum of 7.77 and 9.38 kg. This is in line with the probability that when the plant population is minimum (one seed per hole) the amount of yield is minimum and when the plant population increase the grain yield increases as well.

Table 1: Average yield distribution per treatment

Pop no	Mean	Median
T_1	5.62	5.54
T_2	5.376667	5.24
T_3	7.766667	7.86
T_4	9.38	9.36
T_5	6.72	6.35
T_6	7.51	7.25
Total	7.06	7.1

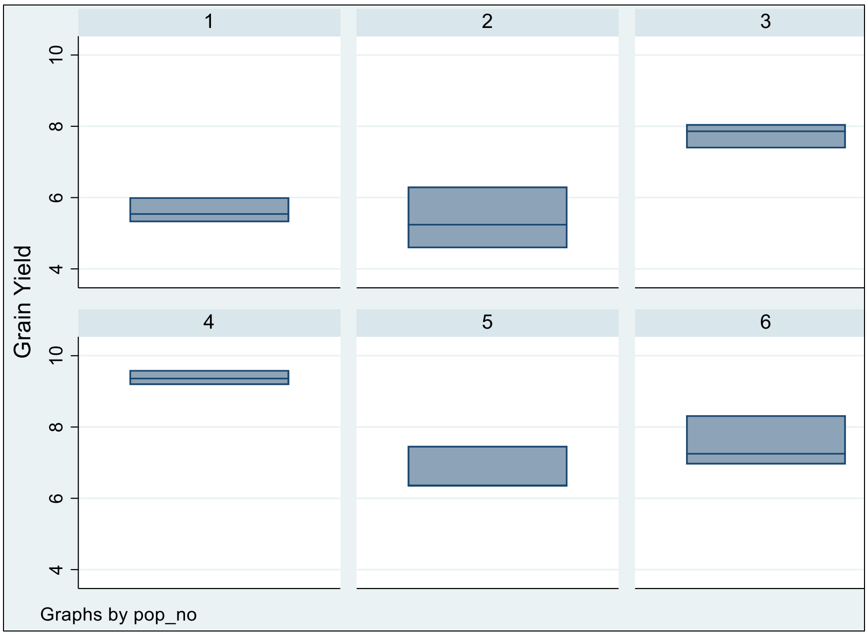

Fig 2: Box plot of maize grain yield per treatment

As shown in Figure 2, the yield variable shows an increasing trend across the increase in the number of plant populations per planting station.

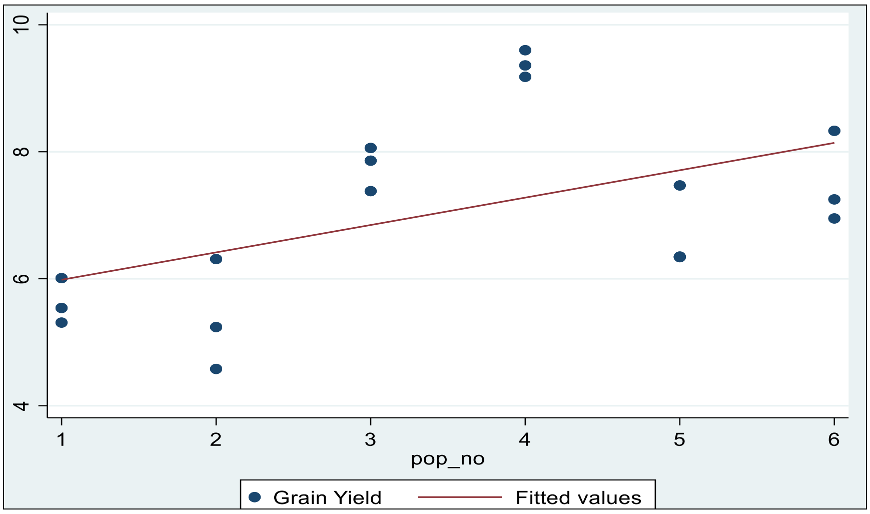

Fig 3: Trend of Grain Yield per seed density per planting station

Other variable of Interest

Table 2: Summary of Variables of Interest

Variable	Observation	Mean	Std. dev.	Min	Max
Cob number	18	36.72	8.14	26.00	53.00
Infertility no	18	2.56	1.38	1.00	5.00
Cob weight	18	1.41	0.26	0.98	1.96
Grain weight	18	7.19	1.50	4.70	9.79
Total cob weight	18	8.60	1.74	5.71	11.47
Shelling percentage	18	0.84	0.01	0.82	0.85
Moisture content	18	14.04	0.38	13.40	14.70
Moisture Correction	18	0.98	0.01	0.97	0.99
Plant population	6	44	12.13	32	64
Plant height	6	2.29	.05	2.26	2.39
Plant thickness	6	20.34	.44	19.80	21.00

Cob number

The average number of cobs in all treatments was 36.72 which ranged between 26 and 53. Table 2 expresses the mean of selected variables per each treatment. The cob number showed an increasing trend reaching a maximum in Treatment 4. The cob number increased with the increase in plant population per unit area. Plot 4 had the highest plant population, followed by treatments 3 and 6 with the second highest plant population and then T5.

Infertility Number

This variable captured the number of maize cobs found to be infertile or those with little kennels from the total cobs harvested per plot. Infertility number was high in treatment six (6). This could be because a large number of seed density per planting station had a greater number of failures. The association of grain yield and infertility presented in Figure 4 reveals an inverse relationship between the association of grain yield and infertility.

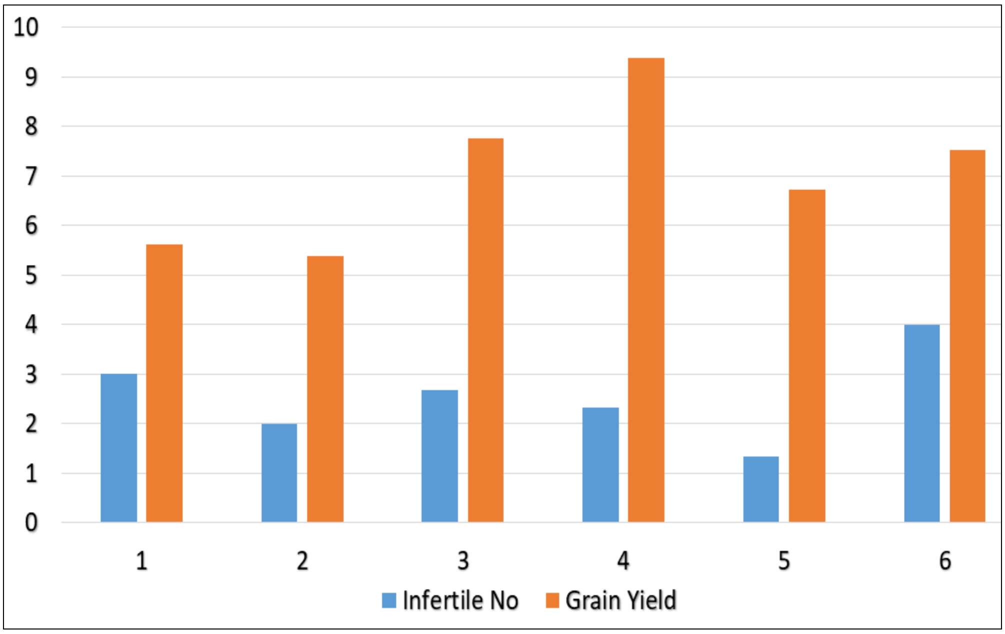

Fig 4: Infertility and maize grain yield

Core Weight: Core weight explains how much of the total cob mass is of the kernels/ grains and of the core. On average, the weight of each cob was found to be about 1,4kg. Even though in almost all planting stations, the core weight was about 1.4 kg. The cob weight in treatment number 4 was found to be a bit higher due to the higher cob number.

Table 3: Mean of selected variables per treatment

Treatment	Plant population	Cob Number	Infertility No	Core weight (kg)	Grain Weight (kg)	Shelling percentage	Moisture content %
1	32	28.00	3.00	1.10	5.70	0.84	13.67
2	32	28.00	2.00	1.12	5.49	0.83	14.33
3	48	40.00	2.67	1.51	7.93	0.84	14.27
4	64	49.33	2.33	1.78	9.53	0.84	13.83
5	40	33.67	1.33	1.45	6.85	0.83	14.17
6	48	41.33	4.00	1.50	7.64	0.84	14.00

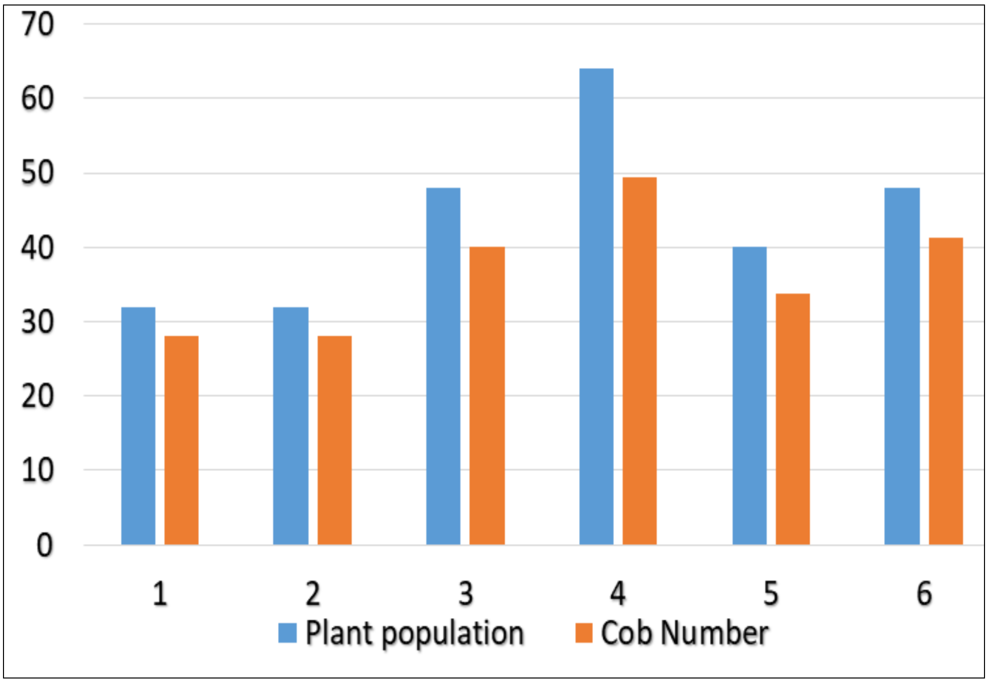

Fig 5: Relation of plant population and cob number

Shelling percentage: The ratio between the grain weight and core weight indicate how much of the cob has turned into yield. Although all the shelling percentages from the treatments were above 80%, treatment 2 had the least shelling percentage followed by treatment 5.

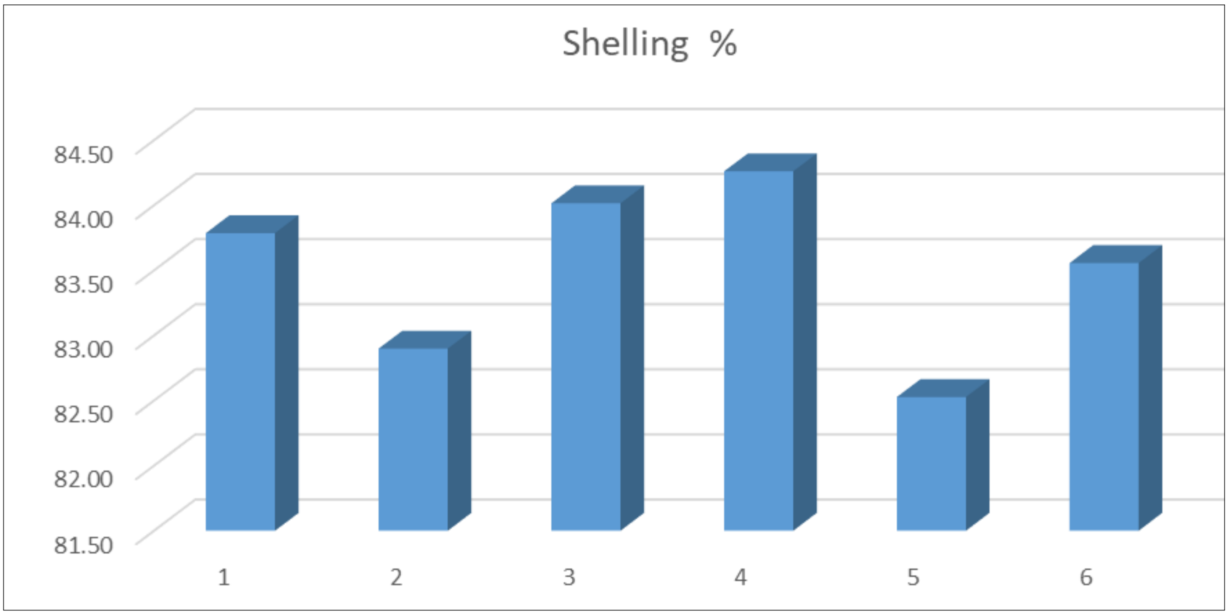

Fig 7: Shelling Percentage

As shown in Table 3, plant population ranged from 32 to 64 with an average of 44. Figure 9 indicates distribution of harvested plant population per treatment.

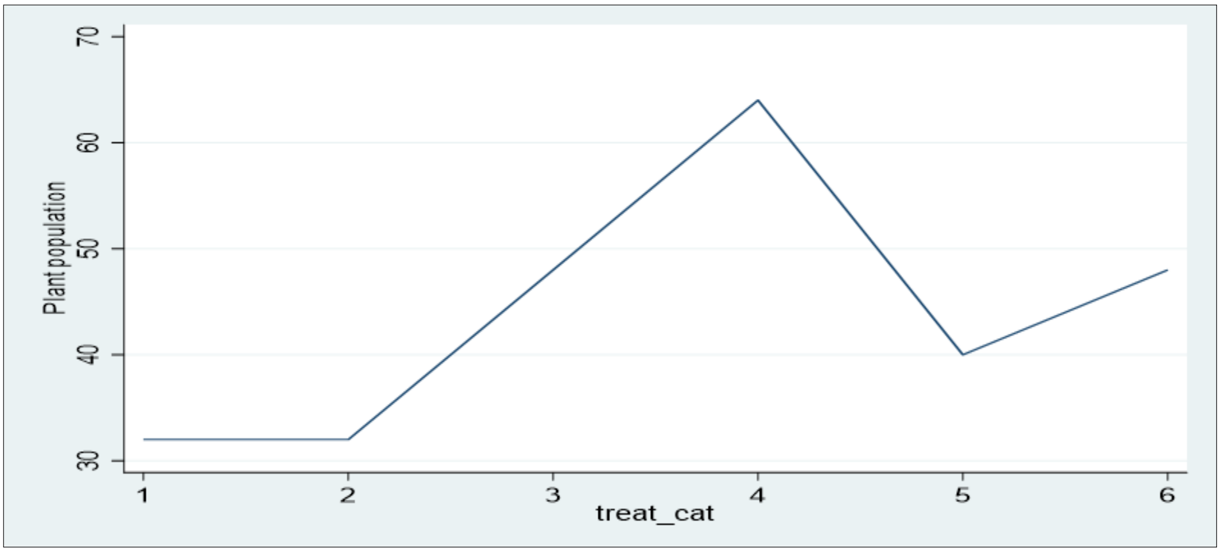

Fig 9: Trend of harvest plant population per treatment category

Plant population increased with the increase of seed density per planting station (Fig 9) with the exception of T4 which had a higher plant population. The spacing of 90cm x 50cm produced 64 harvested plants. Plant population and grain yield had a similar trend where by an increase in plant population resulted in yield increase (Fig 5 and 10). The high number of plants per planting station or plant population for any given scenario results in mature plants that are sufficiently crowded to efficiently use resources such as water, nutrients, and sunlight, yet not so crowded that some plants die or are unproductive. At high number of plants per station, production from the entire plot is optimized, although an individual plant might produce less than would have occurred with less number of plants per planting station.

Plant Height

The average plant height was 2.29m which had a similar length across treatments ranging between 2.26 to 2.39. Plant height had an association with cob number and grain weight. Figure 11 indicates that plant height had a uniform trend across the treatment group signifying minimum impact on the grain yield or cob number. Lashkari, *et al.* (2011) [2] argues that the association between plant height and other parameters is due to increased plasticity under which the Far-red/Red ratio of the intercepted radiation increases with increased plant population triggering physiological events and leading to prioritization and allocation of assimilates to the main stem to increase stem height.

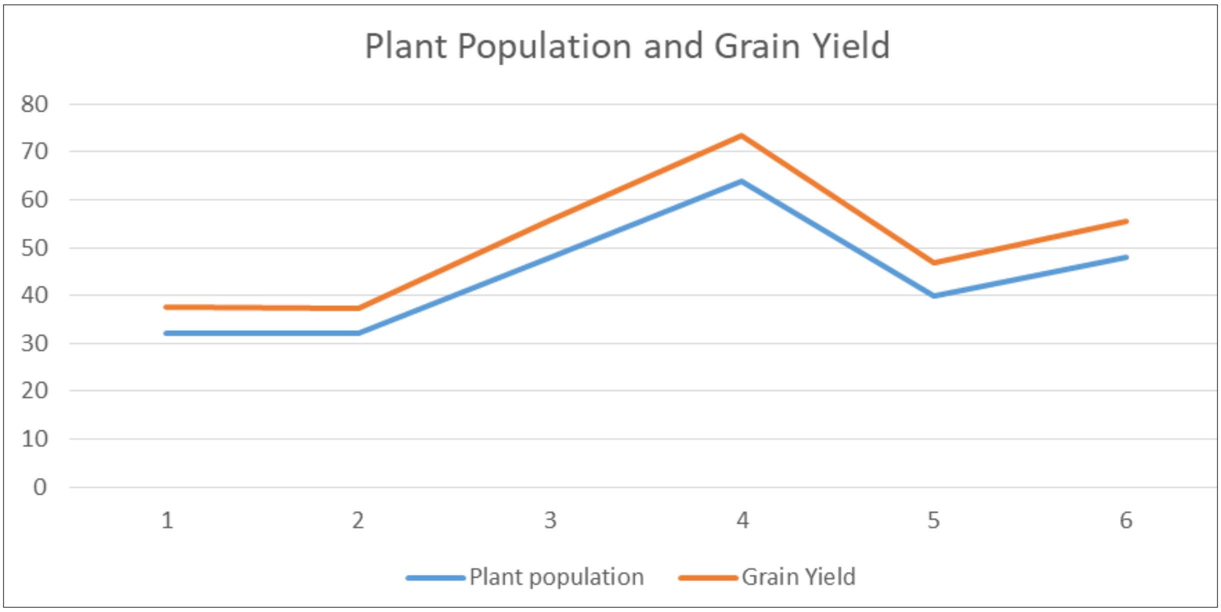

Fig 10: Trend of Harvested Plant population and grain yield

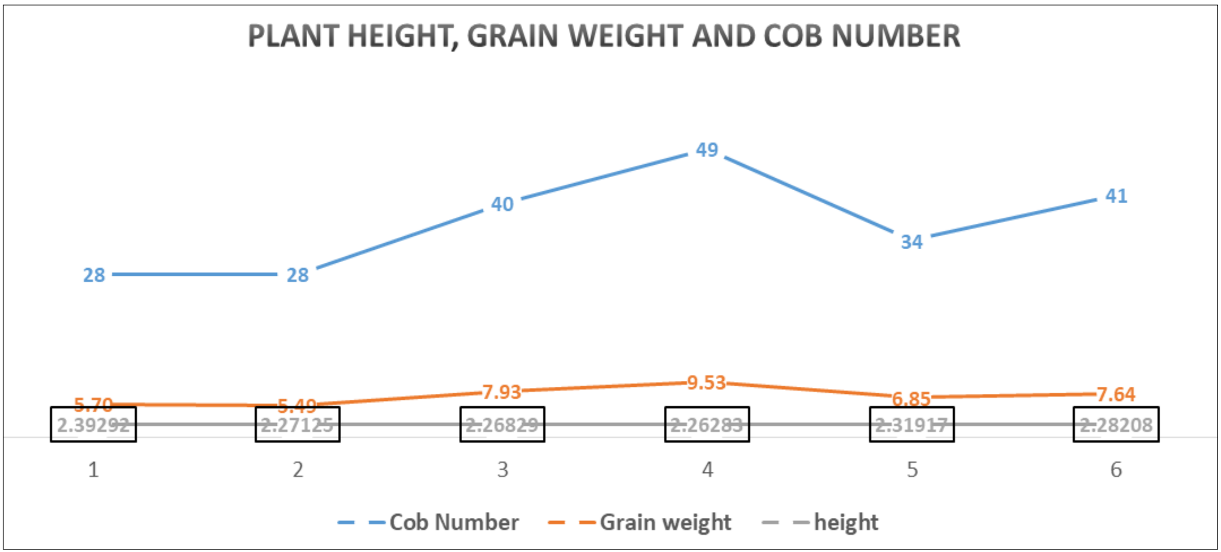

Fig 11: Plant height, grain weight and cob number

Plant thickness: The average plant thickness was 20cm. Figure 12 indicates no significant relation between the plant thickness and the grain yield.

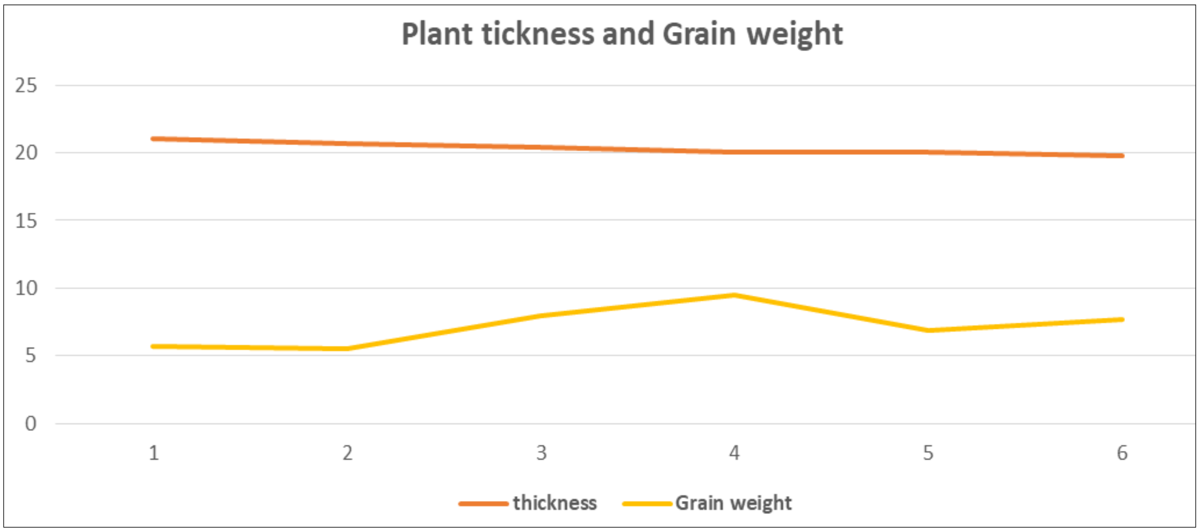

Fig 12: Plant thickness and Grain weight

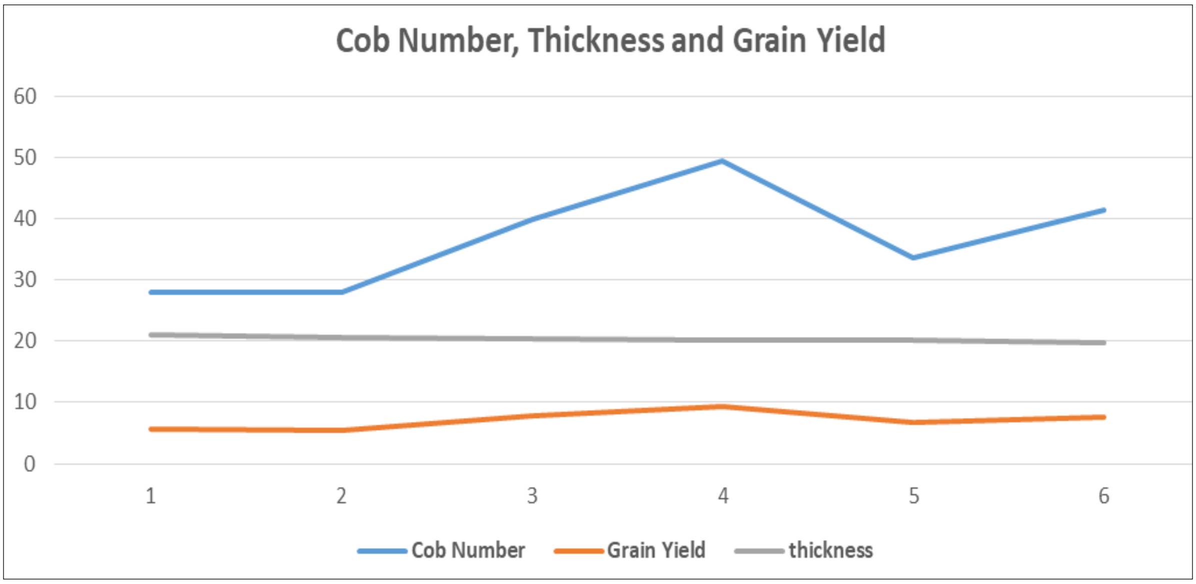

Fig 13: Plat thickness, grain yield and cob number

The result of one-way ANOVA (figure 14) indicate a highly statistically significant difference among the treatment groups on maize grain yield.

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. oneway grainyield treatment, tabulate

            |      Summary of Grain Yield
  Treatment |        Mean   Std. dev.       Freq.
------------+------------------------------------
         T1 |        5.62   .35679141           3
         T2 |   5.3766665   .87305978           3
         T3 |   7.7666669   .34947593           3
         T4 |   9.3800001   .21071315           3
         T5 |   6.7199999   .64953816           3
         T6 |   7.5099999   .72580992           3
------------+------------------------------------
      Total |   7.0622222   1.4818652          18

                        Analysis of variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      33.321181      5   6.6642362     19.95     0.0000
 Within groups      4.0095336     12    .3341278
------------------------------------------------------------------------
    Total           37.3307146     17   2.19592439

Bartlett's equal-variances test: chi2(5) =   4.1465    Prob>chi2 = 0.529
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Fig 14: One-way ANOVA estimate on effect of the number of plant population on yield.

Yu C-T (2015) [11] observed that when there is a statistically significant difference between the groups, it is advisable to determine which specific groups were significantly different from each other. This enables to break down the significance level across each treatment group to exactly identify the relations as well as for policy advice. This is because one-way ANOVA cannot tell which specific groups differ from each other. The Tukey-Kramer pairwise procedure (table 4) allowed to tell the difference by performing pairwise comparisons on absolute mean differences.

Based on the result of pairwise comparison presented in Table 4; there was a significant increase on maize grain yield when comparing T_3 from T1 by 2.1kg/ha. Similarly yield of T_3 was greater than T_2 significantly by 2.39kg/ha. T_4 had the highest yield for all 6 treatments being significantly higher than T_3 by 1.61 kg, T_5 by 2.66 kg and T_6 by 1.87 kg. Treatment 5's yield was greater than treatment 1 and 2 by 1.1kg and 1.32 kg respectively. But lower than T_3 by 1.04. Treatment 6 was significantly higher than T1 by 1.89 kg, T_2 by 2.13 kg, and T_5 by 0.79 kg. T_6's yield was greater than T_4 by 1.87 kg and insignificantly lower than T_3 by 0.25 kg. Treatments 1 and 2 had no significant yield difference. Lashkari *et al.* (2011) [2] suggest that high yields are associated with high plant density. The differences in yield might be due to efficient use of resources at high plant densities which results in high dry matter accumulation at optimum plant densities (Magagula, *et al.* 2019) [4].

Table 4: Tukey-Kramer pairwise comparison

Grain yield			Contrast	Std. err.	Tukey		Tukey	
Pop No					t	P > |T|	[95% Conf. Interval]	
2	vs	1	-0.243	0.472	-0.520	0.994	-1.829	1.342
3	vs	1	2.147	0.472	4.550	0.007	0.561	3.732
3	vs	2	2.390	0.472	5.060	0.003	0.805	3.975
4	vs	1	3.760	0.472	7.970	0.000	2.175	5.345
4	vs	2	4.003	0.472	8.480	0.000	2.418	5.589
4	vs	3	1.613	0.472	3.420	0.045	0.028	3.199
5	Vs	1	1.100	0.472	2.330	0.254	-0.485	2.685
5	Vs	2	1.343	0.472	2.850	0.116	-0.242	2.929
5	Vs	3	-1.047	0.472	-2.220	0.298	-2.632	0.539
5	Vs	4	-2.660	0.472	-5.640	0.001	-4.245	-1.075
6	Vs	1	1.890	0.472	4.000	0.017	0.305	3.475
6	Vs	2	2.133	0.472	4.520	0.007	0.548	3.719
6	vs	3	-0.257	0.472	-0.540	0.993	-1.842	1.329
6	vs	4	-1.870	0.472	-3.960	0.018	-3.455	-0.285
6	vs	5	0.790	0.472	1.670	0.571	-0.795	2.375

Conclusion

ANOVA analysis indicated that the average yield of each treatment varied based on seed density per planting station. Treatment four (4) with four (4) seeds per unit area had the highest yield because of the high plant population. Treatment 3 and Treatment 6 had the same plant population but different population densities per planting station. When assessing the yield from these two different treatments with the same plant population, the grain yield of treatment 3 had a better yield than treatment 6 by 0.25kg but with no significant difference. Treatments 1 and 2 had an average low grain yield of 5.62 and 5.38kg because of the low population number. Thus higher seed density and higher plant population results in better yield. From this experiment that revolved around different seed densities per planting station in a given area, it is recommended that to obtain a higher yield per area, three (3) to four (4) seeds per planting station may be adopted because at those levels higher yields were recorded.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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