BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF CROP

A COMPARATIVE STUDY ON THE EFFECTS OF DIFFERENT PLANTING DENSITIES AND VARIETIES ON THE GROWTH AND YIELD OF SUGAR BEANS (*Phaseolus vulgaris).*

RUTENDO SHYLENE LABANA

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SUPERVISOR   Mr. K MUTSENGI

DECLARATION

I do hereby declare that this research project entitled **A COMPARATIVE STUDY ON THE EFFECTS OF DIFFERENT PLANTING DENSITIES AND VARIETIES ON THE GROWTH AND YIELD OF SUGAR BEANS (*Phaseolus vulgaris*)** was written by me and that it is the record of my own research work. It is neither in part nor in whole been presented for another degree elsewhere.

Sign.. Date..

Rutendo Shylene Labana

This is being submitted for the partial fulfilment of the requirements for the Bachelor of Science Honors degree in Crop Science with the approval of supervisors.

Sign.. Date...

Supervisor: Mr. K. Mutsengi

ABSTRACT

Sugar beans (*Phaseolus vulgaris)* is an economically significant seed crop. It can naturally fix nitrogen into the soil. However, there is lack of complete research and appreciation on the best planting density of sugar beans. With the objective of studying the effects of different planting densities on growth and yield characteristics, a research was carried out at Bindura University of Science Education farm. Two sugar beans varieties (Gloria and NUA45) and three plant spacing distances (5cm × 30cm, 10cm × 35cm and 15cm × 40cm) corresponding respectively to three planting densities (120, 60 and 26 plants/ $2m^2$) were evaluated for six quantitative traits in a randomized complete block design in a two by three factorial with three replicates. Measurements were taken on plant stem height, chlorophyll content, leaf area determination, and number of pods per plant, dry mass determination and yield. Analysis of Variance (ANOVA) was done using Genstat Seventeenth Edition. Whenever the treatment was significant, Fisher`s least significance difference (LSD) test was used for mean separation at $P<0.05$. Density (26 plants/$2m^2$) had a significant effect $P<0.05$ on Gloria variety with the highest height of (68.9cm). There was an interaction between planting densities and variety on chlorophyll content with density (26 plants/$2m^2$) having the highest chlorophyll content of 13,4 and 12,6 respectively to both varieties (Gloria and NUA45). On yield there was a greater significant effect $P<0.05$ between the three planting densities (120, 60 and 26 plants/ $2m^2$). Density (120 plants/ $2m^2$) had the highest yield of 1.283kgs followed by density (60 plants/ $2m^2$) with 1.120kgs and density (26 plants/ $2m^2$) with the least yield of 0.735kgs. In comparison of the different planting densities on different varieties from the reports of the study, it can be concluded that spacing of (5cm ×30cm) on Gloria among the tested varieties showed potential growth and greatest yield under ideal conditions. Other researchers can also test for the same parameters to see if this can also be true in other agro-ecological regions in Zimbabwe.

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DEDICATION

This research project is dedicated to my parents Mr. and Mrs. Labana for their constant prayers as well as materials support. They have given me much motivation and courage in my life to pursue my dreams together with my brothers and friends.

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CHAPTER ONE

BACKGROUND / INTRODUCTION

1.1 Background of the study

Beans are members of the Fabaceae family, commonly known as the legume plant family (Rama, 2014). One of the perks of this plant family is, they have the amazing ability to naturally increase nitrogen content in the soil, making the nitrogen accessible to other plants around them. This legume crop was first domesticated in the Central and Southern America and is now widely cultivated in the tropics, subtropical and temperate regions (Gepts and Debouck 1991; Burle *et al* 2010). In this way, beans do not just grow to be nutritious and delicious food rather they help to enrich the soil in which they grow (Kiple, 2007). *Phaseolus vulgaris* was established in Africa before the colonial era as a food crop. The wealth of local names given to different varieties is an evidence of the long establishment of beans as a food crop in East Africa (Greenway, 1945; Leakey, 1970). In Mexico, the Indians developed black beans, white beans, and other color patterns and colors. In Peru (Andes), there was also a wide array of colors, but their colors were more bright and lively. Indian tribes wandered across the American continent through a complex system of trade routes and trading centers, they migrated, explored, and traded with other tribes (Wehmeier, 2005). These native farming practices and beans spread gradually all over North and South America. After generations of cultivation and selection, each tribe had its own locally-adapted bean for trade, seed, food and gifts (Barry, 2000).

The agricultural sector plays an important role in Zimbabwe's economy, with crop production being a great contributor (Bautista, 2002). Among the vegetation cultivated in the country, sugar beans (*Phaseolus vulgaris*) holds a considerable significance due to their nutritional value, financial viability, and achievable for export. To optimize sugar bean production, quite a variety elements need careful consideration, which consist of planting densities and varieties. This research targets to conduct a comparative evaluation of the effects of different planting densities and varieties on the growth and yield of sugar beans in Zimbabwe.

The choice of planting density influence the spatial arrangement of crops in a given area, impacting their access to essential growth elements such as sunlight, water, and nutrients (Cayon *et al*, 2004). By examining different planting densities, this study seeks to determine the most suitable optimal density that maximizes sugar bean growth and yield. Additionally, the choice of varieties is important as different cultivars exhibit variants in growth habits and yield potential. By comparing different planting densities on different varieties, this study aims to identify the most suitable option for cultivation in Zimbabwe.

Understanding the effects of planting densities and varieties on sugar bean growth and yield is important for several reasons. Firstly, it can provide farmers with treasured insights into optimizing their cultivation practices, enabling them to make knowledgeable choices associated to planting techniques and varietal selection (Bruns and Abbas, 2005). Secondly, it can make contributions to the enhancement of sugar bean production in the country, by provision of multiplied yields and enhanced food security. Lastly, the findings of this study might also additionally have broader implications for agricultural practices and can serve as a basis for future research and improvement of crop production methods in Zimbabwe.

To achieve the aim of this study, a comparative approach will be employed. Multiple planting densities will be tested, varying number of plants per unit area, while different varieties of sugar beans will be evaluated in response to their growth parameters and yield. Data will be collected on various traits such as vegetative growth, plant reproduction and overall yield. Statistical analysis will be carried out to determine extensive variations between planting densities and varieties providing valuable insights on their impact on sugar bean growth and yield.

1.2 Problem statement

Currently, there is limited research and understanding on the effects of different planting densities on sugar bean growth and yield in Zimbabwe.

1.3 JUSTIFICATION

There is a lack of complete research and appreciation concerning the outcomes of one of a kind planting density in response to a certain variety on the growth and yield of sugar beans in the local context. The findings can serve as a basis for future research, development, and improvement of sugar bean cultivation practices in Zimbabwe. This study will compare the effects of different planting densities (5cm ×30cm, 10cm ×35cm and 15cm ×40cm) on different varieties Gloria and NUA45 on sugar beans production.

1.4.1 Main objective

To compare the effects of different planting densities (30cm×5cm, 35cm×10cm, 40cmx15cm) and different varieties (Gloria and NUA45) on the growth and yield of sugar beans.

1.4.2 Other objectives

i) To evaluate effects of different planting densities and variety on vegetative growth of sugar beans.

ii) To determine the effects of different planting densities and variety on reproduction of sugar bean plant.

iii) To investigate the effects of different planting densities and varieties on final yield of sugar beans.

1.4 HYPOTHESIS

i) Planting density and varieties have no effect on sugar beans vegetative growth.

ii) Sugar bean reproductive stage is not determined by variety and planting density used.

iii) Final yield of a sugar beans is not determined by planting density and variety used.

CHAPTER TWO

LITERATURE REVIEW

2.1 Importance of *Phaseolus vulgaris* and its use in Africa

Phaseolus vulgaris has a broad commercial importance (Caicedo *et al* 1999). Worldwide, sugar beans is grown over an area of about 28,78 million hectares with an annual production of about 23,14 million tons that feed millions of people (FAO, 2013) Being a protein rich food 16% to 33% (Vidigal-Filho *et al*, 2011), it plays an important role in human nutrition, principally in developing countries. The grains are also good source of iron, zinc and aromatic amino acids that include lysine, leucine, isoleucine, aspartic acid and glutamic acid (Buruchara *et al*, 2011; Carrasco-Castilla *et al*, 2012), which are the protein building blocks that the body uses to heal and to make new tissues, such as bone, muscle, hair, skin, and blood. Protein is an essential nutrient. Sugar beans (*Phaseolus vulgaris)* is a very nutritious and favorable grain legume which is rich in protein. The leaves, green pods, young and mature seeds are edible. The crop residues are good for preparing feed for livestock and form a good basis for compost manure as well.

Sugar beans are cultivated for industrial purposes in Zimbabwe. Farmers grow them on a large scale and sell the harvested pods to neighborhood markets, supermarkets, and restaurants. There is a demand for sugar beans due to their taste and nutritional value. Many small-scale farmers in Zimbabwe grow sugar beans for their personal consumption and surplus for sale in nearby markets (Beyene *et al,* 2011). Sugar beans are pretty easy to cultivate and can provide an extra source of additional earnings for smallholder farmers.

People who consume beans regularly may be less likely to die of a heart attack or other cardiovascular problem. The authors of a 2017 meta-analysis suggested that one reason for the decrease in cardiovascular risk was that people had replaced higher fat animal meat proteins with beans (Marventano *et al* 2017). Enzymes in beans might also decrease how much starch the body absorbs. When a person eats beans, the fiber and healthful starches they contain can help create a feeling of fullness and satisfaction. As a long-term dietary strategy, this could help prevent overeating and may lead to weight loss, according to Clark and Slavin (2013). From the 1930s, common bean genetic improvement has historically been conducted by international programs in coordination with government institutions and following traditional methods. Those efforts have created successful varieties in recent decades. But, current climate change effects and the reduced adoption of adequate technologies for cultivation, have threatened common bean productivity (Jiménez, 2019). It will be important to provide varieties that respond well to agro-ecological management under an integral ecology approach (Namugwanya *et al,* 2013).

Together with bacteria, sugar bean forms root nodules. These bacteria are called rhizobia. In the root nodules, the bacteria can fix nitrogen from the air into a form that sugar bean can use for growth (Somasegaran & Hoben 2012). Part of the fixed nitrogen is used to make protein in the grains, but some of the nitrogen is also left behind through falling leaves and roots. The nitrogen that is left behind improves soil fertility. This makes sugar bean a good crop to grow as intercrop or in rotation with other crops, because these other crops then also benefit from the nitrogen. Beans are excellent for intercropping with other food crops, such as maize, potatoes, celery, cucumber and can help supply the other crops with nitrogen to a limited degree. Longer season varieties of beans can fix higher amounts of nitrogen than short season varieties (Shurtleff & Aoyagi, 2021).

Table 1: Nutritional Value of sugar beans

Phytochemicals	Value/100g(unit)	Phytochemical	Value/100g(unit)
Energy	71kcal	Water	81.17 g

Proteins	4.07 g	**Vitamins**	
Total lipids(fats)	0.29 g	Vitamin C , total ascorbic acid	7.3 mg
Carbohydrates by difference	13.33 g	Thiamin	0.029 mg
Fiber, total dietary	3.6 g	Riboflavin	0.043 mg
Minerals		Niacin	0.532 mg
Calcium	28 mg	Vitamin B^6	0.062 mg
Iron	1.61 mg	Folate, DFE	16 µg
Magnesium	34 mg	Vitamin B^{12}	0.00 µg
Phosphorus	71 mg	Vitamin A, RAE	8 µg
Potassium	285 mg	Vitamin A, IU	1150 IU
Sodium	252 mg	Vitamin D (D^2 + D^3)	0.0 µg
Zinc	0.64 mg	Vitamin D	0 IU
Lipids			
Fatty acids, total saturated	0.066 g	Fatty acids, total polyunsaturated	0.139 g
Fatty acids, total monounsaturated	0.016 g	Cholesterol	0 mg

Adapted after http://ndb.nal.usda.gov/ndb/foods

2.2 Effects of different planting densities on the growth and yield of sugar beans

For any crop species, an optimum plant population density exists for maximum economic yield and this varies with cultivar and environment (Bruns and Abbas, 2005). A major factor influencing optimal seed spacing for any particular environment is the genotype. The effect of plant density on growth and yield attributes in sugar beans could vary due to varietal features. Plant density is considered a vital factor in obtaining higher seed yield. Air, temperature, solar radiation, moisture, fertility, photosynthesis, respiration and transpiration are elements required by plants for their nutrition, growth and yield performance. A dense population (30cm×5cm with 120 plants per 2 square meters) may have limitations for the maximum availability of these factors. As for example, there is usually competition for sunlight within a plant community (Cayon *et al*, 2004). It is then necessary to determine the optimum density of plants for obtaining maximum yield. Sparsely spaced crops (15cm×40cm with 26 plants per 2 square meter) allow for the availability of the required factors for sugar bean growth and development. Taurira and Moses (2014), observed that there was a positive association between plant density and plant elongation in common bean.

2.3 Effects of different varieties on the growth and yield of sugar beans

Good variety choice is of paramount importance in crop production in response to the region under cultivation. Some varieties have a relatively short maturity period and are suitable for areas with low rainfall, or when planted late in the season. Late maturing varieties are less suitable for drier environments, but often produce higher grain and biomass yields, fix more nitrogen and contribute more to soil fertility than early maturing varieties (Zimdahl, 2007).

According to the National tested seeds, Gloria is believed to have agronomic characteristics that include early maturity that is 90 days, it is a semi-determinate bushy type variety, if well managed has high yielding of up to 3 tonnes per hectare, it is good tolerance to bean rust, good tolerance to common bacterial blight and recommended for low, medium and high veld of Zimbabwe (Clark, 2008). According to SeedCo NUA45 is an early maturing variety that takes 94 days, the yield is 1 to 2 tonnes per hectare. It is tolerant to bean common mosaic virus.

Different varieties of sugar beans may have varying yield potentials. Some varieties are bred to produce higher yields, while others may be more suitable for specific growing conditions (Pratap and Kumar, 2011). When selecting a variety, farmers often consider the local climate, disease resistance, and market demand to maximize yield potential.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Site Description

The research study was conducted at Bindura University of Science Education farm, located along Shamva road just near Shamva Agricultural College. It is situated in the north eastern part of the country in Mashonaland central region. The farm is found in Natural Region IIa. According to the Ministry of Agriculture, natural region IIa receives 700 to 1050 millimetres of rainfall per year confined to summer. The farm's geographical coordinates are 17° 14' 29" S, 31° 03' 54" E and it is situated at an elevation of 1400 meters above sea level with a warm and dry climate and the average temperature is 20°C. The landscape is mostly hilly, with some flat areas. The soil is mostly sandy and of low fertility.

3.2 Experimental Design

The research was aligned in a full two factorial treatment pattern with two factors variety and densities. The first factor was variety and it had 2 levels NUA45 and Gloria. The second factor was plant density which had 3 levels that were 30cm by 5cm (120 plants in $2m^2$), 35cm by 10cm (60 plants in $2m^2$) and 40cm by 15cm (26 plants in $2m^2$). The trial was replicated three times. The treatments were laid out using the Randomized Complete Block Design.

3.2.1 Picture: Plot layout

3.3 Agronomic Management 3

.3.1 Land preparation and planting

Firstly, there was allocation of the area where the experiment was supposed to take place. An area of 5 meters by 17 meters was measured using a garden liner. Land was firstly cleared using a slasher and a hoe was used to uproot the weeds and remove them from the field. Digging was done and 18 plots that measured 2 meters by 1 meter were prepared with the use of pegs, hoes and garden liner. Planting stations were marked using the different planting densities 30cm by 5cm (120 plants per $2m^2$), 35cm by 10cm (60 plants per $2m^2$) and 40cm by 15cm (26 plants per $2m^2$) and basal fertilizer compound D was used (N 7%, P 14%, K 7%), at a rate of 1000Kgs/ha.. A small hole of 0.5cm to 1cm deep was used to put the seed and cover the seed lightly with soil.

3.3.2 Weed and pest control

Weeds were controlled mechanically using hoes and hand weeding was done to keep the plots weed free. Coragen 10mls per 16 liters knapsack to control grasshoppers and carbaryl 5mls per 16 liters knapsack were used to control pests like beetles and aphids on the growth and development of the sugar bean plant.

3.3.3 Fertilizer Management

Fertilizer (Compound D) was applied at planting at 5 grams per planting station but covering the fertilizer with 2cm of soil to avoid burning the seed. Top dressing was done 21 days after planting using Ammonium nitrate at the rate of 1000Kgs/ha broadcasting the field and days after flowers appeared to facilitate vegetative growth.

3.3.4 Irrigation and Scouting

To sustain the period of drought experienced in 2023 the sugar beans crops were irrigated weekly using a horse pipe the solar pumped water from a borehole to the taps. A range of 30 mm to 35 mm of water was supplied to the field at weekly intervals. Scouting was done before and after irrigation to ensure that the plots are free from best and diseases and the beds are still intact to avoid water flowing out of the plots.

3.3.5 Harvesting

The grains of the sugar beans were harvested when they matured and dry after the plant reached its physiological maturity stage that is 3 and half months after planting. Harvesting was done before the pods become too dry to avoid shattering. Harvesting was done collecting pods from each plot to avoid mixing the outputs.

3.4 Data Collection

3.4.1 Height of sugar beans plant

The height in cm of selected plants in each plot was measured from 2 weeks after planting until the plant reach its physiological maturity stage. Three plants were randomly selected from the plot and their average height was recorded.

3.4.2 Leaf area determination

Leaf area of the plant was measured at two weeks by measuring the length and width to find the area and record the average area of three plants per plot.

3.4.3 Chlorophyll Content

The chlorophyll content of sugar beans plants was detected using a pedometer chlorometer. The chlorophyll content was measured by randomly selecting plants per plot and record the results as they appeared on the chlorometer.

3.4.4 Sugar bean yield

The yield of sugar beans was measured by weighing the harvested seeds. This was done by collecting a representative sample of the harvested grains and weighing them and then record. The yield was expressed in terms of weight per unit area (kilograms per hectare).

3.4.5 Number of pods per plant

This was done to three randomly selected plants and their average number of pods were recorded per plot after most of the plants have developed pods.

3.4.6 Dry mass determination

Three whole plants were collected from each plot and taken into the oven at 80ºC to dry, after fully dried measurements were taken using a scale and the average number of three plants was recorded.

3.5 Data Analysis

Analysis of Variance (ANOVA) was done using Genstat Seventeenth edition. Whenever the treatment was significant; Fisher`s least significance difference (LSD) test was used for mean separation at $P<0.05$.

CHAPTER 4

RESULTS

4.1 Effects of different planting densities and variety on sugar beans with respect to stem height

Table 2: Effects of density on sugar beans stem height

Density	Height(cm) 2WAP	Height(cm) 4WAP	Height(cm) 6WAP	Height(cm) 8WAP
1 (5cm×30cm)	10.52[a]	37.32[a]	45.12[a]	57.93[a]
2 (10cm×35cm)	10.77[a]	34.35[b]	43.82[a]	61.25[b]
3 (15cm×40cm)	12.00[b]	32.95[b]	49.63[b]	54.33[c]
P- Value	0.008	0.005	0.007	< .001
C.V %	6.1	5.0	5.5	2.2
S.E.D	0.391	1.015	1.480	0.727
L.S.D	0.870	2.262	3.297	1.619

Means followed by the same letters are not significantly different.

There were no interaction effect ($P>0.05$) between density and variety on sugar beans stem height. Density had an effect ($P<0.05$) at 2WAP, 4WAP, 6WAP and 8WAP on sugar beans stem height. Density had no effect ($P>0.05$) on sugar beans stem height at 10WAP. Variety had an effect on stem height a ($p<0.05$) at 8 and 10 WAP.

4.1.1 Effect of planting density on stem height

There was a significant difference ($P<0.05$) between density 1, 2 and 3 at 8WAP on sugar beans stem height with density 2 with the highest stem height (61.25cm) followed by density 1 (57.93cm) and least being density 3 (54.33cm). At 2, 4 and 6 WAP there was a difference ($p <0.05$) between density 1 (5cm by 30cm), 2 (10 cm by 35cm) and 3 (15cm by 40cm).

Table 3: Effects of variety on sugar beans stem height (cm)

Variety	Height(cm) 8WAP	Height(cm) 10WAP
1 (Gloria)	58.77[a]	68.9[a]

2 (NUA45)	56.91[b]	61.8[b]
P-Value	0.011	0.009
C.V%	2.2	7.2
S.E.D	0.593	2.18
L.S.D	1.322	4.86

Means followed by the same letters are not significantly different.

Variety 1 (Gloria) and 2 (NUA45) had an effect ($P<0.05$) on sugar beans stem height at 8WAP and 10WAP. Variety 1 (Gloria) and 2 (NUA45) had no effect ($P>0.05$) on sugar beans stem height at 2WAP, 4WAP and 6WAP. Variety 1 (Gloria) exhibited the highest stem height of 58.77cm at 8WAP and 68.9cm at 10 WAP whereas variety 2 (NUA45) had the least stem height of 56.91cm at 8WAP and 61.8cm at 10WAP.

4.2 Effects of different planting densities and varieties on sugar beans in respect to chlorophyll content (micromoles per square meter).

Table 4: Effects of density on sugar beans chlorophyll content

Density	2 WAP	4 WAP	8 WAP
1 (5cm×30cm)	9.350[a]	11.07[a]	24.63[a]
2 (10cm×35cm)	11.567[b]	10.52[a]	24.00[a]
3 (15cm×40cm)	13.017[c]	12.88[b]	28.15[b]
P-Value	< .001	0.004	< .001
C.V%	3.5	8.2	4.6
S.E.D	0.2280	0.541	0.676
L.S.D	0.5079	1.206	1.507

Means followed by the same letters are not significantly different.

There was no interaction effect between density and variety on sugar beans chlorophyll content. Density had an effect (P<0.05) on sugar beans chlorophyll content at 2WAP, 4WAP and 8WAP. There was a significant difference (P<0.05) between density 1, 2 and 3 with density 3 with the highest chlorophyll content of 13.017 and 28.15 at 2WAP and 8WAP respectively. Variety had no effect (P>0.05) on sugar beans chlorophyll content.

4.2.1 Effects of planting density on chlorophyll content

There was an interaction effect between density 1 (5cm by 30cm), 2 (35cm by 10cm) and 3 (15cm by 45cm). At 2 WAP density 3 (13.017) had the highest chlorophyll content followed by density 2 (11.567) and the least was density 1 (9.350).

4.3 Effects of different planting densities and varieties on sugar beans in response to leaf area

Table 5: Effects of density on sugar beans leaf area

Density	2 WAP	8 WAP
1 (5cm×30cm)	35.23[a]	59. 48[a]
2 (10cm×35cm)	34.62[a]	56.92[a]
3 (15cm×40cm)	36.90[b]	62.95[b]
P-Value	0.001	0.004
C.V%	2.2	3.9
S.E.D	0.453	1.334
L.S.D	1.009	2.976

Means followed by the same letters are not significantly different.

There were no interaction effects (P>0.05) between planting densities and variety on sugar beans leaf area determination. Density had an effect (P<0.05) on sugar bean plant leaf area at 2WAP and 8WAP. Density had no effect (P>0.05) at 4WAP and 6WAP on sugar beans leaf area.

Table 6: Effects of variety on sugar beans leaf size

Variety	2 WAP	8 WAP
1 (Gloria)	34.40[a]	56.81[a]
2 (NUA45)	36.77[b]	62.76[b]
P- Value	< .001	< .001
C.V%	2.2	3.9
S.E.D	0.370	1.089
L.S.D	0.825	2.427

Means followed by the same letters are not significantly different

Variety had an effect (P<0.05) on sugar bean plant leaf area at 2WAP and 8WAP. There was a significant difference (P<0.05) on variety of sugar beans in response to leaf area determination. Variety 2 (NUA45) had the highest leaf area of 36.77cm² and 62.76cm² at 2WAP and 8WAP respectively. Variety 1 (Gloria) and 2 (NUA45) had no effect (P>0.05) at 4WAP and 6WAP on sugar beans leaf area.

4.4 Effects of different planting densities and varieties on sugar beans in terms of number of pods per plant

There were no interaction effects (P>0.05) between planting densities 1(5cm×30cm), 2(10cm×15cm) and 3(15cm×40cm) and variety 1 (Gloria) and 2 (NUA45) on sugar beans number of pods per plant. Density had no effect (P>0.05) on sugar bean plant in terms of number of pods per plant. Variety 1 (Gloria) and 2 (NUA45) had no effect (P>0.05) on sugar bean in response to number of pods per plant. Variety 1 (Gloria) generated the highest number of pods per plant with 35.89 pods and variety 2 (NUA45) with 33.00 pods per plant.

4.5 Effects of different planting densities and varieties on sugar beans in terms of dry mass (grams)

Table 8: Effects of density on dry mass

Density	Dry mass
1 (5cm×30cm)	0.962[a]

2 (10cm×35cm)	1.320[b]
3 (15cm×40cm)	1.516[c]
P-Value	< .001
C.V %	8.6
S.E.D	0.0630
L.S.D	0.1403

Means followed by the same letters are not significantly different

There were no interaction effect (P>0.05) between density and variety on sugar beans dry mass. Density had an effect (P<0.05) on sugar beans dry mass. There was a significant difference (P<0.05) between density 1 (5cm by 30cm), 2 (10cm by 35cm) and 3 (15cm by 40cm) with density 3 with the highest dry mass of 1.516, followed by density 2 and the least was density 1 with dry mass of 0.962. Variety had no effect (P>0.05) on sugar beans dry mass.

4.6 Effects of different planting densities and varieties on sugar beans in response to yield

Table 9: Effects of density on yield

DENSITY	Yield (kgs)
1 (5cm×30cm)	1.592[a]
2 (10cm×35cm)	1.278[b]
3 (15cm×40cm)	0.735[c]
P-Value	< .001
C.V%	10.9
S.E.D	0.0753

L.S.D	0.1677

Means followed by the same letters are not significantly different.

There were no interaction effect (P>0.05) between density 1(5cm×30cm), 2(10cm×15cm) and 3(15cm×40cm) and variety 1 (Gloria) and 2 (NUA45) on sugar beans final yield. Density had an effect (P<0.05) on sugar beans final yield. There was a significant difference (P<0.05) between density 1, 2 and 3 on sugar beans final yield with density 1 generating the highest yield of 1.283kgs (6415kgs/ha) followed by density 2 with 1.120kgs (5600kgs/ha) and the least density 3 with 0.735kgs (3675kgs/ha).

Table 10: Effects of variety on yield

Variety	Yield (kgs)
1 (Gloria)	1.283[a]
2 (NUA45)	1.120[b]
P-Value	0.024
C.V%	10.9
S.E.D	0.0615
L.S.D	0.1370

Means followed by the same letters are not significantly different.

Variety 1 (Gloria) and 2 (NUA45) had an effect (P<0.05) on sugar beans final yield. Variety 1 (Gloria) had the highest yield of 1.283kgs (6415kgs/ha) and variety 2 (NUA45) had least yield of 1.120kgs (5600kgs/ha).

CHAPTER 5

DISCUSSION OF RESULTS

5.1 Effects of different planting densities and variety on sugar beans with respect to stem height

According to the study, the results indicate that there was no significant interaction effect between density and variety on sugar beans stem height. This suggests that the impact of density on stem height was consistent across different varieties of sugar beans. There was a significant difference between densities 1(5cm×30cm), 2(10cmcm×35), and 3(15cm×40cm) in terms of sugar beans stem height. Density 2 (10cm × 35cm) exhibited the highest stem height at 61.25cm, followed by density 1 (5cm × 30cm) at 57.93cm, with density 3 (15cm × 45cm) showing the least height at 54.33cm. This association between plant density and plant vegetative growth in terms of stem height exhibit that medium density (10cm × 35cm) grew taller than densely populated plants (5cm × 30cm). Similar observations were obtained by Taurira and Moses (2014); Kazemi *et al* (2012); Seif *et al* (2016) who found a positive association between plant density and plant elongation in common bean. The study found that while density significantly influenced sugar beans stem height at various stages of growth, variety also played a role in determining the plant's height particularly in the later stages of growth. Different effects on variety may be due to different varieties used which exhibited different growth rate at different stages.

5.2 Effects of different planting densities and varieties on sugar beans in respect to chlorophyll content

Density 1 (5cm x 30cm), this high density planting method led to increased competition among plants for resources like water, nutrients, and sunlight. As a result, the chlorophyll content per plant was lower compared to lower planting densities. Density 2 (10cm x 35cm), this planting density allows for slightly more space for each plant compared to the previous density. The reduced competition among plants resulted in higher chlorophyll content per plant as they have more access to essential resources. Density 3 (15cm x 40cm), this planting density provided even more room for individual plants to grow without intense competition. As a result, sugar beans planted at this density exhibited higher chlorophyll content per plant due to better resource availability. Density 3 (15cm ×40) exhibited the highest chlorophyll content values, with readings of 13.017 at 2 weeks after planting and 28.15 at 8 weeks after planting. The reduction of chlorophyll content at high plant population was also reported in snap bean (Seif *et al.* 2016). This suggests that sugar beans chlorophyll content is influenced by both the variety of beans planted and the spacing (density) used.

5.3 Effects of different planting densities and varieties on sugar beans in response to leaf area

The results indicated that there were no significant interaction effects ($P>0.05$) between planting densities and variety on sugar beans leaf area determination. However, both density and variety individually had notable effects on sugar bean plant leaf area at different stages of growth. Planting density had a significant effect ($P<0.05$) on sugar bean plant leaf area at 2 weeks after planting (2WAP) and 8 weeks after planting (8WAP) with density 3 (15×40) with the highest leaf area determination of 36.90cm² and 62.95cm² at 2WAP and 8WAP respectively and density 2 (10cm×35cm) with the least leaf area determination of 34.62 and 56.92 at 2WAP and 8WAP respectively and density. These results are consistent with previous studies on common bean by Seif *et al* (2016). This suggests that the density at which sugar beans are planted can influence the leaf area development of the plants during these specific growth stages. Variety had a significant effect ($P<0.05$) on sugar bean plant leaf area at 2WAP and 8WAP. This implies that different varieties of sugar beans can lead to variations in leaf area development during these growth stages. There was a greater significance observed

($P<0.05$) in the response of different varieties of sugar beans to leaf area determination. Variety 2, identified as NUA45, exhibited the highest leaf area measurements of 36.77cm² at 2WAP and 62.76cm² at 8WAP compared to Gloria. Mondal *et al.,* (2012), found that leaf area varied between 2.8 to 5.2 on different varieties in mung bean grown in Australia. The differences can be because of different absorbtion of sunlight, nutrient uptake and moisture supply at different densities. On variety difference can be because of genotypic difference of NUA45 and Gloria.

5.4 Effects of different planting densities and varieties on sugar beans in terms of number of pods per plant

There were no significant interaction effects observed between the planting densities (1, 2, and 3) and the two varieties (Gloria and NUA45) concerning sugar beans number of pods per plant. The planting density did not have a significant effect on the sugar bean plants in terms of the number of pods per plant. The statistical analysis showed that the differences in planting densities did not lead to a significant variation in pod production. Similarly, the two varieties (Gloria and NUA45) did not show a significant difference in response to the number of pods per plant. Both varieties exhibited similar pod production levels, with Gloria producing slightly more pods per plant compared to NUA45. Variety 1 (Gloria) generated the highest number of pods per plant with an average of 35.89 pods, while variety 2 (NUA45) produced an average of 33.00 pods per plant. The results of this study are in line with the findings of Hang *et al.* (1993) who reported no significant effects of grains per pods of adzuki beans and dry beans due to planting density. However, the study contradicts the findings by Moniruzzaman *et al.* (2009) who observed higher pod yield of French bush bean varieties in the highest plant density and the lowest pod yield with the lowest plant density. Varieties had a difference because they may be genotypically different.

5.5 Effects of different planting densities and varieties on sugar beans in terms of dry mass

There were no interaction effect ($P>0.05$) between density and variety on sugar beans dry mass. This means that the combination of different densities and varieties did not significantly influence the dry mass of sugar beans. Density had an effect ($P<0.05$) on sugar beans dry mass. The density of the growing conditions for sugar beans had a significant impact on the amount of dry mass produced. Specifically, there was a greater significant figure ($P<0.05$) between density 1, 2, and 3. The highest dry mass was observed at density 3, with a value of 1.516 grams per plant. In comparison, density 2 had a dry mass of 1.218 grams per plant, and density 1 had the least amount of dry mass at 0.962 grams per plant. There are other studies that found dry biomass vary among different varieties. For example, Ahamed *et al*. (2011) investigated the effects of cultivars on mung bean in Bangladesh and found that total dry matter varied from 10.72 to 12.32 g/plant.

5.6 Effects of different planting densities and varieties on sugar beans in response to yield

In the study conducted on sugar beans, it was found that there was no interaction effect between the different densities (1, 2, and 3) and varieties (1 and 2) on the final yield of sugar beans. The p-value for this interaction effect was greater than 0.05, indicating that the combination of density and variety did not significantly impact the final yield. However, when looking at the effect of density alone on sugar bean final yield, a significant difference was observed. Among the three densities tested (1, 2, and 3), there was a notable difference in yield. Density 1(5×30) produced the highest yield at 1.283 kgs, followed by density 2(10×35) at 1.120 kgs, and finally density 3(15×40) with the lowest yield at 0.735 kgs (3675kgs/ha). Similarly, the variety also had a significant effect on sugar beans final yield. Both varieties tested (Gloria and NUA45) showed a significant difference in their yields. Gloria (variety 1) had the highest yield at 1.283 kgs (6415kgs/ha), while NUA45 (variety 2) had a lower yield at 1.120 kgs (5600kgs/ha). The results support the findings of Eftekhar *et al*. (2012) who reported significant effect of planting density on biological and grain yield of white bean cultivars.

CHAPTER 6

RECOMMENDATIONS AND CONCLUSION

6.1 CONCLUSION

For each crop production system, there is optimum planting density that maximizes growth and seed yield. From the results of this study it shows that density has an effect on growth and yield of sugar beans. As planting density increases (120 plants/ $2m^2$), low chlorophyll content, low dry matter determination, reduced leaf area and low number of pods per plant were observed however, more yield is obtained. At the lowest planting density of 26 plants/2m, seed yield correlated poorly with related quantitative traits comparing to high planting densities. Quality seed yield was at was at 26 plants/$2m^2$ as they received adequate sunlight, water and nutrients in both varieties Gloria and NUA45. Moderate planting density of 60 plants/ $2m^2$ exhibits a good performance in terms of growth and yield. For more yield of sugar beans with better quality planting density of 60 plants/$2m^2$ can be used. The results show that density is an important factor in the cultivation of sugar beans varieties affecting significantly growth and yield attributes. Density and variety had an interaction effect due to the genotypic difference in NUA45 and Gloria and difference in densities was due to competitive ability to nutrients, water and sunlight of the plants depending with spacing used.

6.2 RECOMMENDATIONS

It is thus recommended from the research study that farmers use high planting densities 120 plants/2m² for more yield production using Gloria. Plants in this density fully express themselves with the adequate supply of nutrients, fertilizers, water, easy scouting and there is reduced competition in sugar beans growth and development.

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APPENDICES

Appendix 1: Analysis of variance of different planting density and variety on sugar beans with respect to stem height

<u>Analysis of variance</u>

Variate: Height2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	0.6978	0.3489	0.76	
BLOCK.*Units* stratum					
DENSITY	2	7.5678	3.7839	8.27	0.008
VARIETY	1	0.8450	0.8450	1.85	0.204

DENSITY.VARIETY	2	0.5233	0.2617	0.57	0.582
Residual	10	4.5756	0.4576		
Total	17	14.2094			

<u>**Analysis of variance**</u>

Variate: Height4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	3.548	1.774	0.57	
BLOCK.*Units* stratum					
DENSITY	2	59.658	29.829	9.65	0.005
VARIETY	1	1.334	1.334	0.43	0.526
DENSITY.VARIETY	2	15.604	7.802	2.52	0.130
Residual	10	30.912	3.091		
Total	17	111.056			

<u>**Analysis of variance**</u>

Variate: Height6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	45.098	22.549	3.43	
BLOCK.*Units* stratum					
DENSITY	2	111.848	55.924	8.52	0.007
VARIETY	1	1.742	1.742	0.27	0.618
DENSITY.VARIETY	2	19.221	9.611	1.46	0.277
Residual	10	65.669	6.567		
Total	17	243.578			

<u>**Analysis of variance**</u>

Variate: Height8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	3.018	1.509	0.95	

BLOCK.*Units* stratum					
DENSITY	2	143.601	71.801	45.32	<.001
VARIETY	1	15.494	15.494	9.78	0.011
DENSITY.VARIETY	2	7.668	3.834	2.42	0.139
Residual	10	15.842	1.584		
Total	17	185.623			

<u>**Analysis of variance**</u>

Variate: Height10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	23.20	11.60	0.54	
BLOCK.*Units* stratum					
DENSITY	2	78.32	39.16	1.83	0.211
VARIETY	1	222.60	222.60	10.38	0.009
DENSITY.VARIETY	2	46.66	23.33	1.09	0.374
Residual	10	214.39	21.44		
Total	17	585.18			

Appendix 2: Analysis of variance of different planting densities and varieties on sugar beans in respect to chlorophyll content

<u>**Analysis of variance**</u>

Variate: Chlorophyll2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	2.7144	1.3572	8.71	
BLOCK.*Units* stratum					
DENSITY	2	40.9211	20.4606	131.25	<.001
VARIETY	1	0.7200	0.7200	4.62	0.057
DENSITY.VARIETY	2	4.4633	2.2317	14.32	0.001
Residual	10	1.5589	0.1559		
Total	17	50.3778			

Analysis of variance

Variate: Chlorophyll4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	1.7344	0.8672	0.99	
BLOCK.*Units* stratum					
DENSITY	2	18.4078	9.2039	10.47	0.004
VARIETY	1	1.5022	1.5022	1.71	0.220
DENSITY.VARIETY	2	1.9211	0.9606	1.09	0.372
Residual	10	8.7922	0.8792		
Total	17	32.3578			

Analysis of variance

Variate: Chlorophyll6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	1.921	0.961	0.70	
BLOCK.*Units* stratum					
DENSITY	2	59.981	29.991	21.85	<.001
VARIETY	1	0.347	0.347	0.25	0.626
DENSITY.VARIETY	2	0.714	0.357	0.26	0.776
Residual	10	13.726	1.373		
Total	17	76.689			

Appendix 3: Analysis of variance of planting densities and varieties on sugar beans in response to leaf area

Analysis of variance

Variate: Leaf_Area2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	3.6400	1.8200	2.96	
BLOCK.*Units* stratum					

DENSITY	2	16.7433	8.3717	13.61	0.001
VARIETY	1	25.2050	25.2050	40.96	<.001
DENSITY.VARIETY	2	2.5033	1.2517	2.03	0.181
Residual	10	6.1533	0.6153		
Total	17	54.2450			

Analysis of variance

Variate: leaf_Area4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	6.408	3.204	1.06	
BLOCK.*Units* stratum					
DENSITY	2	18.048	9.024	2.97	0.097
VARIETY	1	5.556	5.556	1.83	0.206
DENSITY.VARIETY	2	3.308	1.654	0.55	0.596
Residual	10	30.339	3.034		
Total	17	63.658			

Analysis of variance

Variate: Leaf_Area6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	3.893	1.947	0.36	
BLOCK.*Units* stratum					
DENSITY	2	110.013	55.007	10.31	0.004
VARIETY	1	159.014	159.014	29.79	<.001
DENSITY.VARIETY	2	43.631	21.816	4.09	0.050
Residual	10	53.373	5.337		
Total	17	369.925			

Appendix 4: Analysis of variance of different planting density and varieties on sugar beans in terms of number of pods per plant

Analysis of variance

Variate: Number of pods

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	21.444	10.722	1.39	
BLOCK.*Units* stratum					
DENSITY	2	23.111	11.556	1.50	0.270
VARIETY	1	37.556	37.556	4.86	0.052
DENSITY.VARIETY	2	7.111	3.556	0.46	0.644
Residual	10	77.222	7.722		
Total	17	166.444			

Appendix 5: Analysis of variance of different planting densities and variety on sugar beans in terms of dry mass

Analysis of variance

Variate: Dry_mass

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	0.00132	0.00066	0.06	
BLOCK.*Units* stratum					
DENSITY	2	0.94721	0.47360	39.82	<.001
VARIETY	1	0.00224	0.00224	0.19	0.673
DENSITY.VARIETY	2	0.05763	0.02882	2.42	0.139
Residual	10	0.11893	0.01189		
Total	17	1.12734			

Appendix 6: Analysis of variance of different planting densities and variety on sugar beans in response to yield

Analysis of variance

Variate: Yield_kg_1_2

Source of variation d.f. s.s. m.s. v.r. F pr.

BLOCK stratum	2	0.02263	0.01132	0.67	
BLOCK.*Units* stratum					
DENSITY	2	2.25453	1.12727	66.30	<.001
VARIETY	1	0.12005	0.12005	7.06	0.024
DENSITY.VARIETY	2	0.01120	0.00560	0.33	0.727
Residual	10	0.17003	0.01700		
Total	17	2.57845			