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FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

TOPIC: ***EVALUATING THE EFFECTS OF DIFFERENT INTERCROPPING SYSTEMS ON THE GROWTH AND YIELD OF SC BOUNTY BEAN VARIETY.***

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE BACHELOR OF AGRICULTURAL SCIENCES HONORS DEGREE IN CROP SCIENCE.

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ABSTRACT

Intercropping is a conservation agricultural practice that is mainly suitable for smallholder farmers in Zimbabwe, which contributes to maximizing yields and reducing dependence on supplied inputs. The objective of the study was to determine the most suitable intercrop crop combination among sorghum/bean, maize/bean, groundnut/bean, and sole bean crop in terms of bean growth and yield parameters. A randomized complete block design was used to set up the experiment. Four treatments namely bean sole cropping, maize intercrop, sorghum intercrop, and groundnut intercrop were used. The study measured growth parameters (plant height, pod count, leaf count, and yield) of bean in different intercropping systems. In terms of plant height, the results showed the following order: sole bean>maize/bean>groundnut/bean> sorghum bean intercrop. On pod and leaf count, sole cropping had significantly ($p<0.05$) higher performance than sorghum and groundnut intercrops. There was no significant difference between sole cropping and maize intercropping on pod count and leaf count. The results showed no significant difference in yield between sole cropping and maize intercrop, with yields of 2054kg/ha and 1907kg/ha, respectively. Maize intercrop showed the best performance among other intercropping systems and produced 1907kg/ha, and this was followed by groundnut intercrop, which produced 1018kg/ha. The sorghum intercrop had the least yield with 774kg/ha. In intercropping, choosing the best intercropping combination is important to ensure high returns and more benefits from practicing intercropping. Selecting compatible crops can also help to take advantage of intercropping systems to improve soil health and reduce weed and pest invasions.

Keywords: intercropping, leaf count, pod count, yield, sole cropping

DEDICATION

For their aspirations and encouragement at every stage of my academic career, I dedicate this to my parents, Miller and Alice Gurenje.

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I am so grateful to God Almighty for making it possible for me to complete my study project. There would have been nothing worthwhile for the researcher to write about without Him. I am incredibly grateful to my parents, Miller and Alice Gurenje, for their love, support, and encouragement during my study period. In the absence of His grace, my project would not have succeeded. I also want to thank my supervisor, Professor R. Mandumbu, for supporting and helping me with ideas for my project.

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CHAPTER ONE: INTRODUCTION

1.1 Introduction and Background of Study

Worldwide, intercropping is one of the most common sustainable agriculture practices, which involves the growing of two or more crops on the same piece of land at the same time (Maitra 2021). Intercropping improves soil health, production, and biodiversity, whereas on the other hand, it reduces soil degradation and the impacts of climate change. Crops like *Glycine max*, which can fix nitrogen into the soil, can improve the ability of intercropping to improve yield and nutrient use efficiency (Raseduzzaman & Jensen, 2017). As climate change increases, sustainable agriculture practices, including intercropping, have become essential to sustain food production (Mudita, Chiduza, S. Richardson-Kageler, *et al.*, 2008).

In Africa, intercropping remains a vital agricultural practice that is practiced by the majority of smallholder farmers to buffer against risks arising from climate change, including declining soil fertility and erratic rainfall (Chivenge *et al*., 2021). In Africa, the intercropping system that involves a cereal and legume is mostly practised and well-documented for its synergistic effects on yield and resilience (Wahbi *et al.,* 2016). A study that was carried out in Kenya and Tanzania demonstrated that the intercrop combination of maize and beans can improve both soil organic matter and total yield (Mucheru-Muna *et al.*, 2017).

In Zimbabwe, due to climate change and pressure on land, smallholder farmers can utilize limited resources by implementing an intercropping system to cultivate different types of crops on the same piece of land (Gwenzi *et al.*, 2020). The intercropping system of maize and legume in central Zimbabwe showed that this combination improved land equivalent ratio and resource use efficiency under limited inputs. (Chivenge *et al.*, 2021). The intercropping combinations of maize and sorghum with SC Bounty bean reduce weed density by providing a canopy that reduces the light needed by weeds for photosynthesis, and this can help farmers in weed management. The intercropping of two legumes can boost nitrogen fixation, hence improve soil fertility and nitrogen content in the soil (Reckling *et al.*, 2016).

Many smallholder farmers in Zimbabwe rely on agriculture as their main source of income. As a result they face a lot of challenges, which include a lack of knowledge, shortage of resources, and climate change. These factors have resulted in a reduction in land productivity and low yields (Gwenzi *et al.,* 2020). Growing SC bean variety under intercropping is very important, as it is in demand in marketplaces across the country and has high nutrient content, which can improve the livelihoods of people.

The bean crop has a high market value because it has high nutritional value, and in intercropping, it allows farmers to diversify their crops, hence output is increased (Waddington *et al.*, 2007). The ecological interactions between crops in intercropping systems have been shown as an important strategy to suppress weeds and pest outbreaks (Reckling *et al*., 2016). This can reduce the costs of buying herbicides to control weeds.

The intercropping combination that includes a deep-rooted crop, such as sorghum, can improve water use efficiency in the field as water is used under different root zones in the soil *(Madembo et al.,* 2020). This combination is most suitable in low rainfall areas like the natural region V in Zimbabwe (Gwenzi *et al.*, 2020). This intercropping system can enhance ground cover, and in return, soil erosion is reduced and soil water retention is improved (Snapp *et al.*, 2018).

Intercropping systems that include a legume can increase land productivity by 22% compared to monoculture, demonstrating their potential in optimizing land use (Mekonnen *et al.,* 2020). Intercropping SC Bounty beans with other crops can improve yield, soil nitrogen availability, and nitrogen fixation, especially when integrated with crops like maize, sorghum, and groundnuts, which use high nitrogen.

The practice of intercropping systems can minimise pest incidence as some crops repel other pests (Mugabe *et al.,* 2019). This can reduce the need and use of pesticides to control pests in the fields. In Zimbabwe, intercropping enables farmers to optimize yields from scarce land without having to make extra capital expenditures (Waddington *et al.*, 2007). This is in line with regional nutrition programs to address micronutrient deficits, especially in rural communities, by emphasizing crop variety (Chagomoka *et al.*, 2017).

1.2 Problem Statement

Many smallholder farmers in Zimbabwe face challenges in producing different crops under intercropping due to factors like agronomic, economic, and environmental limitations. The success of intercropping is also affected by particular crop combinations and plant densities. In Zimbabwe, many smallholders lack knowledge of the benefits of choosing the best intercrop combination. For example, if not correctly spaced, intercropping SC Bounty beans with maize, for instance, may result in competition for light and nutrients; nevertheless, planting them with *Sorghum bicolor* or *Arachis hypogaea* may provide complementary growth patterns and improved resource utilization. To identify the best intercropping combinations that optimize SC Bounty bean productivity across different agro-ecological zones, a focused study is desperately needed.

1.3 Justification

Intercropping this bean variety with suitable crops such as sorghum, groundnuts, and maize can improve soil structure, boost land use efficiency, and promote the nutrient cycle through nitrogen fixation and which benefits the soil and the farmer's production. Intercropping practice can minimize the need for chemical inputs and prevent environmental contamination. It can also reduce pest populations, control weeds, and cut the incidence of several diseases that typically impact monocultures. In addition to helping farmers adjust to climate change, sustainable intercropping methods boost system resilience and maintain output over changing seasons. When farmers understand the impact of intercropping combinations, they can make informed decisions to boost their yields and maintain soil health over the long term.

1.4 Objectives

Main objectives

To evaluate the impact of intercropping systems (sorghum, maize, and groundnuts) on the yield and growth of the bean SC Bounty variety.

Specific objectives

- To compare the growth and yield of the bean SC Bounty variety under different intercropping systems and sole cropping.
- To compare the effects of sorghum, maize, and groundnuts intercropping systems on the growth (plant height, leaf number, and pod count) of the SC Bounty bean variety.

- To evaluate the effects of maize, groundnuts, and sorghum intercropping systems on the yield of the SC Bounty bean variety.

1.5 Hypotheses

H0: Intercropping systems have significant effects on the growth and yield of the SC Bounty bean variety.

H2: There is a significant difference in the yield of the SC bounty bean variety under different conditions

CHAPTER TWO: LITERATURE REVIEW

2.1 Intercropping Systems

According to Li *et al.,* (2020), highlighted that intercropping systems that incorporate legumes and cereals have the potential to increase soil fertility, land productivity, and yield stability in the face of climate stress. Ndou *et al.*, 2020 documented that enhanced yields in legume-cereal combinations, and intercropping has been demonstrated to outperform monocultures globally in terms of total land productivity. (Raseduzzaman and Jensen 2017) found that legume-cereal systems increased land production by 22%, with improved light interception and increased nitrogen usage efficiency being key factors.

Li *et al.,* (2020) intercropping of soybeans and maize in China has resulted in significantly higher biomass and grain yield due to less competition for essential elements such as nutrients and light. In India, the intercropping system of maize and soybeans increased gross returns by 35% compared to sole cropping, due to the complementary peak market periods for the crops (Belel *et al.,* 2016).

Maize-bean intercrop improves total yield per unit area, weed suppression, and reduces total crop failure, which can be caused by climate variability (Mucheru-Muna *et al.*, 2017; Muthamia *et al.*, 2019). In this type of system, a legume crop can contribute to nitrogen fixation, which can improve soil fertility, hence the availability of nutrients for both crops. The cereal crop shades the legume, and this can reduce the rate of transpiration during periods of high temperature (Mudare 2022).

Using correct wider spacing can help to reduce competition for resources between the two crops in intercropping systems (Gwenzi *et al.*, 2020) Intercropping can decrease the frequency of pests and diseases, which is one of the disadvantages of monoculture practices. Intercropping can also promote a more balanced ecosystem due to interactions between crops, and it can also minimise the need for agrochemicals as intercrops suppress other pests and diseases (Mupangwa and Thierfelder, 2014). Intercropping systems can improve food security and income diversification for smallholder farmers in Zimbabwe. The study by Ayaz *et al.* (2021) in Pakistan highlighted that the maize-legume intercropping system yields a profuse harvest and a high cost ratio when the two crops are in demand on the market.

In Masvingo and Midlands provinces, maize-bean intercropping produced land equivalent ratios (LER) ranging from 1.2 to 1.5, suggesting a 20% to 50% yield improvement over solitary planting (Ndou *et al.,* 2020). Both biological and ecological interactions between the crops are responsible for this yield benefit.

Mapfumo *et al.* (2019) highlighted that the excessive shading of leaves from maize decreased bean pod set and filling. The research done by Mapfumo *et al.* (2019) proved that the microbial interaction between soil microorganisms and crops improved nitrogen availability and reduced root diseases such as root rot. These results are evidence that the intercropping system is a conservation agriculture practice that can improve the farming systems of smallholder farmers in Zimbabwe.

Namatsheve (2021) demonstrated that the improved nutrient cycling in intercropping systems is due to different growth characterises of plants, as some plants are deep-rooted crops and some are shallow-rooted crops. This can help to utilize nutrients at all levels in the soil. The research of Kumar *et al.,* (2018) found that an intercropping system with beans or cowpeas can improve rhizobia nodulation and raise the availability of phosphate in the soil.

The intercropping systems that include beans are of great importance in Zimbabwe as they produce good yields in semi-arid areas of Zimbabwe (Chimonyo *et al.,* 2019). In low rainfall areas, the intercropping system of sorghum-bean improves water use efficiency Mugabe and Masamha, 2021). This makes intercropping systems more important than monoculture practices.

(Musambasi, Chivinge, and Mariga, 2002) highlighted intercropping as a strategy to minimize the effects of climate change in Zimbabwe. These effects include low rainfall and soil nutrient deficit. Smallholder farmers in Zimbabwe underestimate the benefits of intercropping systems as they lack the knowledge of how to completely adopt this conservation agriculture practice (Mutungamiri, Mariga, and Chivinge, 2001).

In field trials that were conducted by Ronald and Charles (2012) demonstrated that intercropping systems can help to suppress weeds. This can help farmers to reduce labour on weeding and costs of buying chemicals to control insects and pests (Tsubo 2003). The other advantage of intercropping systems that include the SC Bounty bean variety is improved nitrogen fixation, which helps to maintain soil fertility. Intercropping systems can improve land productivity, which can make the land sustain agricultural activities for a very long time, even if resources are scarce.

2.2 Intercropping Practices

Intercropping is a conservation agriculture technique where two or more crops are grown on the same piece of land at the same time (Musambasi *et., al* 2002). Intercropping is a conservation agriculture practice that can maximise yields if implemented correctly. Intercropping systems can also reduce the labour of weeding as there is suppression of weeds in these systems (Ronald and Charles, 2012).

2.3.1 Maize-Bean Intercropping

This is one of the most common intercrop combinations. Mutungamiri, Mariga, and Chivinge (2001) highlighted that maize can provide canopy support to beans by preventing direct sunlight and rainfall from reaching the beans directly. This canopy can also protect the flowers of beans and reduce the impacts of wind during flowering. To minimise competition between this intercropping system, there is a need for proper spacing and appropriate plant densities (Mudita *et al.*, 2008).

2.3.2 Groundnut-Bean Intercropping

This intercropping system involves combining two legumes and growing them together on the same piece of land. The growth characteristics of groundnuts can improve ground cover, hence the soil is protected from erosion (Hikwa and Waddington, 1998). This type of intercropping system is also important in weed suppression. The disadvantage of growing crops of the same family on the same piece of land is disease and pest outbreaks. There is a need for proper management to prevent and control pest and disease outbreaks in this combination (Gwenzi *et al.,* 2020).

2.3.3 Sorghum-Bean Intercropping

This intercropping system is more essential in low rainfall areas. The root structure of sorghum can improve water use efficiency in semi-arid regions (HARİPO 2023). This intercropping system can also improve nutrient use as sorghum and beans take nutrients from different levels in the soil (Madembo *et., al* 2020). However, high crop density can inhibit the growth of beans, which can reduce the yield of beans under this intercropping system. Gwenzi *et al.,* (2020) highlighted that making good choices of good cultivars and plant configurations is essential for maximising yields in intercropping systems.

2.4 Common Crop Mixes

In intercropping common crop mixes, there is a need to carefully select crops and practice good management to optimize complementary resource consumption and obtain high yields. (Namatsheve 2021). The most common crop mix is the intercropping of maize and beans in Sub-Saharan Africa, where food security is a concern and land is limited by population increase (Mupangwa and Thierfelder, 2014). The growth characteristics of the roots of maize make them extract nutrients from the lower level of the nutrient zone in the soil, and their leaves act as a protective canopy (Mudita *et al.*, 2008). If there is poor management of the plant density, the leaves may reduce the space for the growth of beans, hence its growth is reduced (HARİPO 2023).

The study of Mucheru-Muna *et al.,* (2019) in Kenya showed that when beans are planted in the alternative row with maize or in wider spacing, they grow faster than when the space for growth is limited. The bean crop aids nitrogen fixation to the soil, improving soil fertility, hence the other crop performs better. Maize can also offer structural support for beans to grow upwards, increasing in height (Tsubo 2003). The maize-bean intercropping system is more profitable to most smallholder farmers in Zimbabwe.

The intercrop mix that includes the growing of two leguminous crops is also important in improving soil fertility (Hikwa and Waddington, 1998). These crops enhance nitrogen fixation, hence there is an increase in microbial activities, and this can improve soil physical properties. These symbiotic relationships that occur in intercropping systems can also improve the ecosystem balance (Waddington *et al.*, 2007). The crop mix of crops from the same family encourages pests and diseases development, hence they are difficult to manage (Mudita *et al.*, 2008). There is a need for proper management practices to obtain better yields from this intercropping system.

The studies that were carried out in Eastern Zimbabwe showed that intercropping systems can significantly improve root development and biomass of the SC Bean variety Nyamadzawo *et* *al.*, 2021). For intercropping systems to reach their full potential, choosing the appropriate crop mix is crucial.

2.5 Land Equivalent Ratios

In agriculture, the land equivalent ratio (LER) refers to the amount of land required in an area for monoculture or solitary cropping to produce the same yields as intercropping or polyculture over time (Yu *et al.*, 2015). It can be employed when a producer can obtain multiple yields from the same field. Sustainable intensification of agriculture is essential to meet future rising food demand while lowering the agro-ecological impact. Diversification of agricultural production systems improves agroecological techniques such as increased biodiversity and longer crop protection time (Malézieux, E. 2016).

Intercropping as a strategy boosts agricultural productivity per unit of land by enhancing resource use. Intercropping can help to diversify agro-ecological systems by utilizing leguminous crops and lowering the usage of mineral fertilizers. In agroforestry, the LER serves as a productivity indicator by comparing crop and tree yields to those from a monoculture cropping system (Yu *et al.*, 2015). The integration of arable crops with trees has demonstrated benefits such as increased soil fertility, erosion protection, and biodiversity. An LER greater than 1 shows that production is higher in the agroforestry system than in a monoculture system (Malézieux, E. 2016).

CHAPTER THREE: METHODOLOGY

3.1 Research Methodology

The research was carried out in the natural farming region 1 in Zimbabwe. The research was done at Premier South Farm, which is in Mutasa District, Manicaland Province. Premier South is located at 18.6766˚ S and 32.8767˚ E. The area is characterized by red clay soils, rainfall ranges from 800mm to 1000mm, and temperatures range from 18 degrees Celsius and 28 degrees Celsius.

3.2 Research Design

The study employed a randomized complete block design (RCBD), to evaluate the effects of different intercropping systems on SC Bounty beans. This design controls for variability within the experimental field by randomizing treatment assignments and blocking thereby enhancing the reliability of the results. Each treatment (sole cropping and intercropping combinations) was replicated four times, resulting in a total of 16 plots. Each plot measured 5 metres by 4 metres, accommodating the respective intercropping cropping systems.

3.3 Research Method

A field experiment was conducted to gather primary data on the growth and yield of SC Bounty beans under various intercropping systems. This method allows for direct observation and measurement of plant performance in a controlled agricultural setting, providing empirical evidence to support or refute the research hypotheses.

3.4 Agronomic Practices

3.4.1 Land preparation

The land was first cleared using a slasher and hoes to remove the weeds that were on the land. This was to make the land clear so that it would be easier to use an ox-drawn plough to cultivate the land. After ploughing, a spike-toothed harrow was used to bring the soil to a fine tilt. This was to prepare for good seed germination.

3.4.2 Planting

Planting was done on the 12th of December 2024. The intercropping systems were planted at different planting spacings. On sole cropping with SC Bounty variety, spacing of 35 cm x 35 cm. The spacing for the maize-bean intercropping combination was 75cm by 45 cm for the SC 709 maize variety and 35cm by 35cm for the SC Bounty bean. The spacing for sorghum-bean intercropping combination was 60cm by 10cm for the Macia variety of maize and 35cm by 35cm for SC Bounty bean. On groundnut-bean intercropping, the planting spaces of 50cm by 45 cm for the Nyanda variety of groundnut and 35cm by 35cm for the SC Bounty bean. The planting arrangements were to allow resource use efficiency between the plants. The plantings spaces were chosen according to crop demand and the available space for planting.

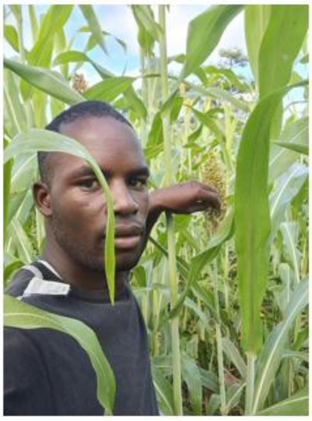
3.4.3 Weeding

The weeding was timely so that competition between plants and weeds is reduced for more reliable results to be produced. Integrated weed management was also applied to minimise weed infestations in all plots. Integrated weed management practices that were used include crop cover, fertilizer management and optimized plant densities

3.4.4 Harvesting

Beans were harvested when the pods had reached physiological maturity at 110 days. Timely harvesting ensured maximum quality and yield. Harvesting in time also reduces contamination from aflatoxins. The method used for harvesting was hand harvesting using sacks.

3.5 Sampling



a) Sample Size

The sample size was determined based on the experimental design requirements, ensuring sufficient replication to achieve statistical power.

b) Sampling Method

A purposive sampling method was employed to select the experimental site and treatments, focusing on prevalent intercropping practices in the region. Within each plot, plants were randomly sampled to measure growth parameters and yield components, ensuring unbiased data collection.

3.6 Data Collection

Data was collected through direct field measurements of growth parameters (plant height and leaf number) and yield components (pod number and total yield per hectare) of SC Bounty beans. Standard agronomic procedures were followed to ensure accuracy and consistency in data collection. Hand harvesting was used for all crops where they were harvested separately using 50kgs plastic bags for easy transportation and handling. Hand harvesting method is cheap and fast on a small area that what made it to be a first choice harvesting method.

3.7 Equation Estimation

Yij = u + bi +sc + mi + si +gi + Eijk

u= mean

sc= sole cropping

mi= maize intercrop

si= sorghum intercrop

gi= groundnut intercrop

Eijk= error

3.8 Data Analysis

One-way analysis of variance (ANOVA) was used using Genstat 17th generation to assess the effects of different combinations of intercropping systems. The parameters to be measured include yield and growth of the SC Bounty variety of bean. Plant height, pod count, leaf count, and yield were the primary variables that were analysed across different treatments.

CHAPTER FOUR: RESULTS

4.0 Results Analysis

4.1 Effects of intercropping systems on bean height.

This study investigated the effects of various bean intercrop combinations on the growth and yield of the intercrop systems. The results on plant height indicated that sole cropping had significantly ($P<0.05$) taller plants compared to the rest of the intercropping systems (Figure 4.1).

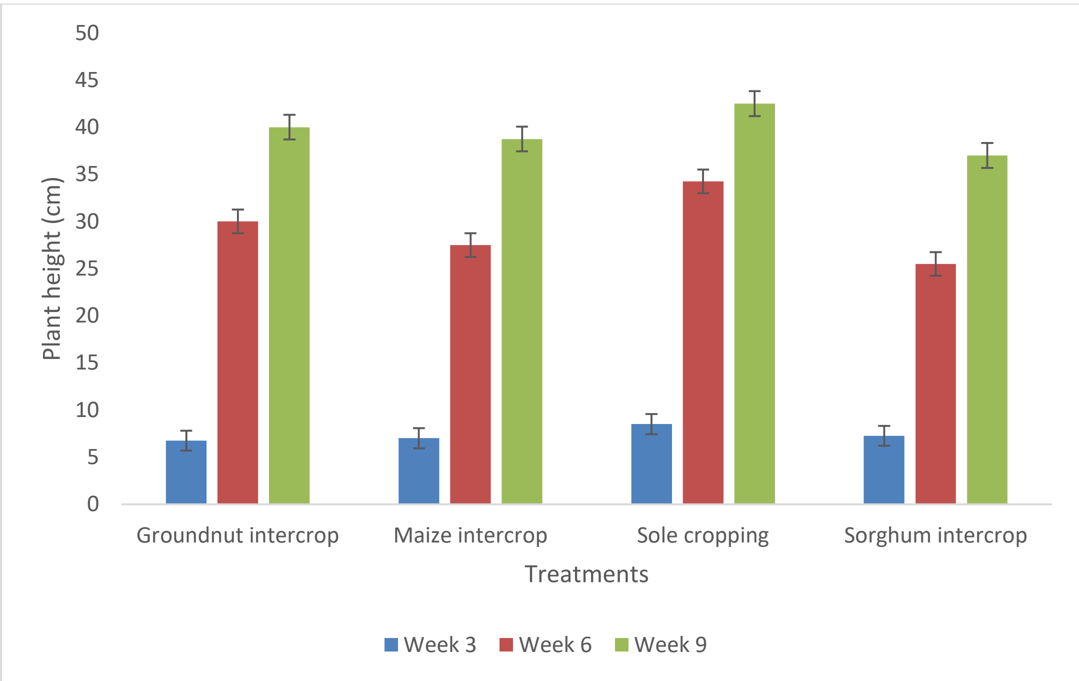


Figure 4.1: Plant height of SC Bounty under different intercropping systems.

4.2 Effects of intercropping systems on leaf count.

This study investigated the effects of various bean intercrop combinations on the growth and yield of the intercrop systems. The results on leaf count showed that sole cropping had a significantly ($P<0.05$) higher leaf count compared to the sorghum intercropping system. Maize and groundnut intercropping systems had significantly ($P<0.05$) higher leaf count compared to the sorghum intercrop (Figure 4.2). There is no significant difference in leaf count between groundnut and maize intercrop combinations.

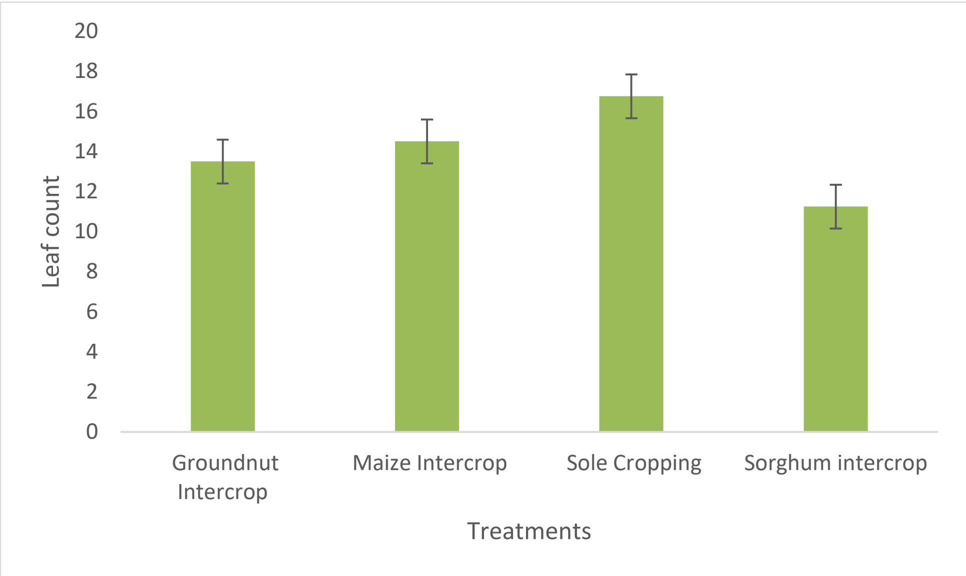


Figure 4.2: Leaf count of SC Bounty under different intercropping systems.

4.3 Effects of intercropping systems on pod count.

This study investigated the effects of different bean intercrop combinations on the growth and yield of the intercrop systems. The results on pod count indicated that sole cropping had a significantly ($P<0.05$) higher pod count compared to sorghum and groundnut intercropping systems (Figure 4.3). Maize intercrop had significantly ($P<0.05$) more pod count compared to sorghum and groundnut intercropping systems. (Figure 4.3). There is no significant difference in pod count between groundnut and sorghum intercropping systems.

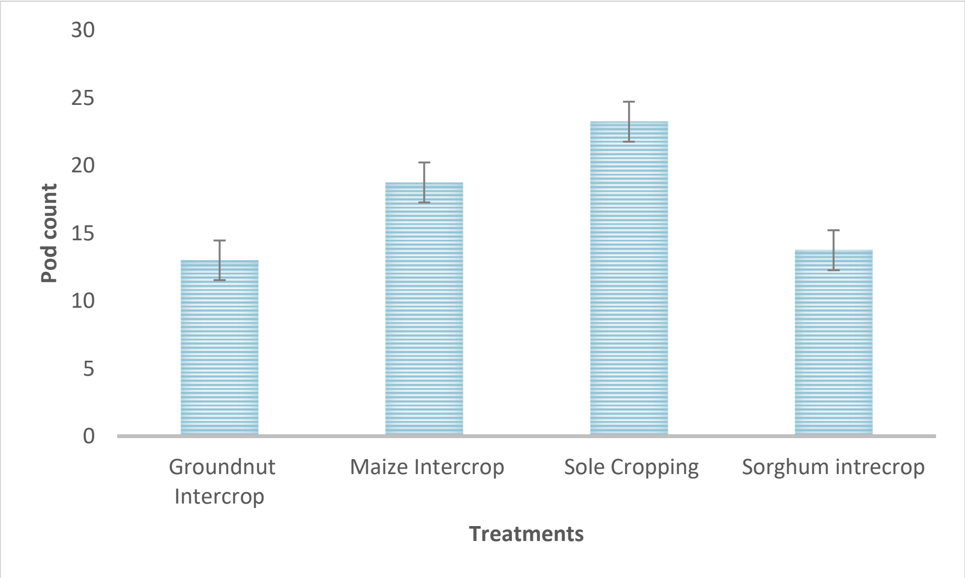


Figure 4.3: Pod count of SC Bounty under different intercropping systems.

4.4 Effects of intercropping systems on the yield.

This study investigated the effects of different bean intercrop combinations on the growth and yield of the intercrop systems. The results showed that there is no significant difference between sole cropping and maize intercropping, with yields of 2054kg/ha and 1907kg/ha, respectively. This shows that there is no significant difference between sole cropping and maize intercropping (Figure 4.4). Sorghum intercrop produced 1018kg/ha. There is a significant difference between maize intercrop and sorghum intercrop (Figure 4.4). Groundnut was the least productive combination, which produced 774kg/ha.

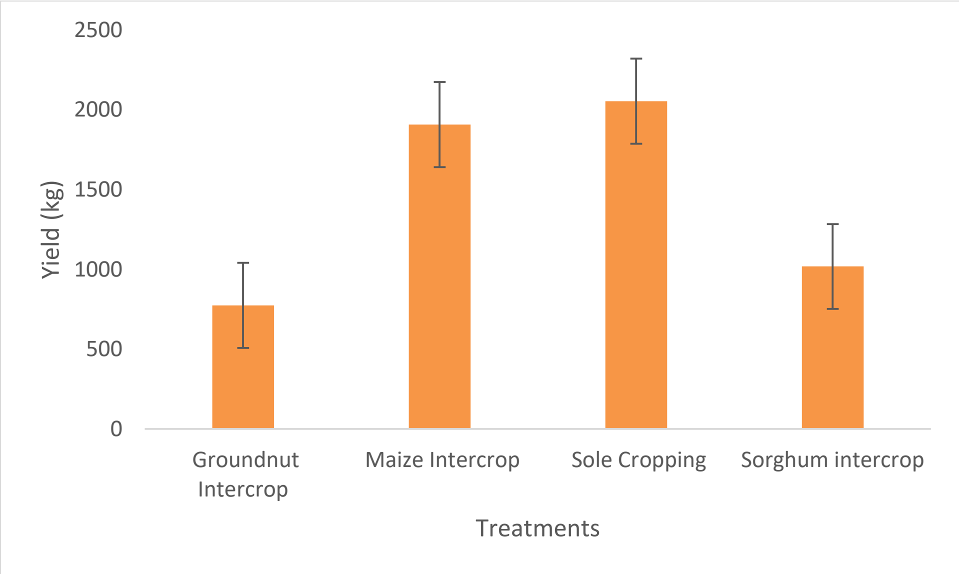


Figure 4.4: Yield of SC Bounty under different intercropping systems.

CHAPTER FIVE: DISCUSSION

5.0 Discussion

The research showed that sole cropping promotes better height growth in the SC Bounty variety. In the first 3 weeks, there was less variation in plant height. The demand for resources increases with the age of crops. (Madembo *et., al* 2020) highlighted that the more crops grow, the more they demand more resources such as nutrients, sunlight, and water.

As time goes on in week 6, there is a variation in plant height as plants start to demand more resources. Intercropping systems with fewer resources available for plant growth have the least plant height. In week 9, there was a slight decrease in plant height for all intercropping systems. Mbanyele *et al.* (2021) mentioned that as crops reach physiological maturity, the rate of metabolic processes such as photosynthesis decreases. Some crop interactions can result in the production of substances such as allelopathic toxins that inhibit the growth of other crops (Musambasi *et., al* 2002).

Maize and groundnuts intercropping systems showed intermediate growth of SC Bounty bean, and this shows that these combinations may not heavily affect the height of the bean variety. Intercropping systems effects on the growth of beans are shown over time as the crops grow, their demand for nutrients and other resources also increases, hence competition also increases (Mudita *et al.*, 2008).

Higher leaf count in sole cropping of SC Bounty beans was a result of higher photosynthesis, as all crops are exposed to the light due to uniform height and good spacing. Maize and groundnut intercrop combinations have a viable and slightly reduced leaf count. This is due to the greater competition for resources between plants, such as nutrients and sunlight, than in sorghum intercrop (HARİPO 2023).

In sorghum intercrop, there was the least leaf count, and this was due to the high density of crops as sorghum planting spaces are low, which can result in high density of crops per unit area. This can increase the rate of competition between crops, hence the growth of beans is negatively affected (Namatsheve 2021). There is a need to modify the spacing of sorghum intercrop to produce better yields in this intercropping system. Sorghum produces compounds that inhibit the growth of other crops, and this might also have affected the leaf count of beans (HARİPO 2023).

Sole cropping had the highest pod count compared to different intercropping systems. This was because there was maximum sharing of resources between the crops, hence their growth was affected less than in intercropping systems. Maize intercrop has the second-largest pod count. This was a result of reduced competition for resources such as nutrients and sunlight, which are needed for the growth of crops. The spacing of 75cm by 45cm for maize in this intercropping system increased the space for growth of the crops in this combination, hence there was resource use efficiency, which contributed to higher pod count.

Sorghum intercrop has the third highest pod count, as there was competition for resources in this intercropping system. High crop density reduces the rate of metabolic processes such as photosynthesis, which are responsible for pod formation in legumes (Mudita *et al.*, 2008). Photosynthesis is a metabolic process that is essential for food production for the growth of crops, and its disturbance can also reduce the growth of crops (Mhlanga *et al.*, 2017). The competition in the sorghum intercropped reduced the number of pods in this system

Groundnut intercrop has the least pod count, as there was high competition for resources between the plants. This intercropping system that includes crops of the same family increases the rate of competition as the crops compete for the same resources, such as nutrients (Mudita, Chiduza, S. Richardson-Kageler, *et al.*, 2008). These intercropping systems also suffer from stresses of diseases, as the crops are also affected by the same type of diseases (HARİPO 2023). This can make the crops divide their energy to fight diseases and grow, and this reduces the growth of the crops

The research showed that sole cropping produced the best yield. In intercropping combinations, the maize intercrop produced the best yield of 1907kg/ha. There was a study that was carried out in Africa where maize-common bean intercrop produced the highest yield, while in China, maize-faba bean intercrop produced the highest yield (Mudare 2022). This was due to limited competition between crops for resources. The wider spacing of maize intercrop also contributed to higher yield among the intercropping systems, as the crops have enough space for growth and physiological activities such as photosynthesis and respiration. (Musambasi *et., al* 2002) highlighted that the maize and legume intercropping system can also reduce weed pressure, which can lead to higher yields in this system.

Sorghum intercrop produced the third highest yield of 1018kg/ha. This was a result of competition for resources between crops. When sorghum is intercropped with another crop, it can produce allelopathic compounds that inhibit the growth of other crops (HARİPO 2023).

Sorghum has a small spacing, which resulted in dense population in all sorghum intercrop treatments. This increased the rate of competition for resources such as sunlight and aeration between plants.

The negative results of competition between plants for resources include reduced metabolic activities such as photosynthesis and respiration, which contribute more on the final yield of crops. (Musambasi *et., al* 2002). If respiration and other metabolic processes are affected, it means food production and energy needed for growth are also reduced, hence the final yield is affected. (Mbanyele *et al.*, 2021) There is water use efficiency in the sorghum-bean combination, which can make this intercropping system produce a moderate yield.

In the groundnut-bean intercrop, there was the least yield of 774kg/ha. The yield was reduced as a result of high competition for nutrients among the crops. The same family competes for the same resources, such as nutrients and sunlight (HARİPO 2023). This means that there is pressure for survival for the crops; hence, low yields are produced.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study on the effects of intercropping SC Bounty beans with maize, sorghum, and groundnuts on the growth and yield of SC Bounty has provided valuable insights about different intercropping systems. Sole cropping outperformed all intercrop combinations in terms of plant height, pod count, leaf count, and yield. In intercropping systems, maize intercrop performed better than other intercropping combinations in terms of yield. This was due to high compatibility between the crops and enhanced nitrogen fixation.

The sorghum intercrop was affected by incompatibilities from different factors, which reduced its output in the intercropping system. Some of the factors that reduced the performance of beans in sorghum intercrop could be production of allelopathic compounds. Groundnut intercropping system was also affected by growing the same weeds and pest invasion. This was a result of growing crops of the same family in the intercropping system. In conclusion, maize intercrop showed the best performance, which showed that it is the best intercropping combination choice for smallholder farmers.

6.2 Recommendations

Smallholder farmers should implement the best intercropping system, which is the maize intercrop system. This is because maize and beans proved to share resources in a compatible mode, which resulted in all crops performing well. The spacing between plants in the maize-bean intercropping system should be considered to avoid high plant densities, which reduce competition between plants. Farmers need to avoid the intercropping system that includes groundnut and beans. This is to reduce the competition for resources and to break the life cycle of pests. Smallholder farmers should also exclude crops that produce substances that inhibit the growth of other crops to fully take advantage of intercropping. Future studies should use more diverse intercrop species or types of beans to ensure generalizability. Comparative trials among different bean types in various agro-ecological zones could also provide broader recommendations for farmers.

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APPENDIX

Appendix 1: *Analysis of variance*

Variate: plant_at_3_wks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	4.250	1.417	0.63	
Replication.*Units* stratum					
Treatment	3	7.250	2.417	1.07	0.408
Residual	9	20.250	2.250		
Total	15	31.750			

Appendix 2: *Analysis of variance*

Variate: plant_height_at_6_wks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	10.188	3.396	1.07	
Replication.*Units* stratum					
Treatment	3	170.688	56.896	17.93	<.001
Residual	9	28.562	3.174		
Total	15	209.438			

Appendix 3: *Analysis of variance*

Variate: plant_at_9_wks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	20.688	6.896	2.00	
Replication.*Units* stratum					
Treatment	3	64.188	21.396	6.20	0.014
Residual	9	31.062	3.451		
Total	15	115.938			

Appendix 4: *Analysis of variance*

Variate: Leaf_Count

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	8.000	2.667	1.12	
Replication.*Units* stratum					
Treatment	3	62.500	20.833	8.72	0.005
Residual	9	21.500	2.389		
Total	15	92.000			

Appendix 5: *Analysis of variance*

Variate: Pod_Count

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	1.188	0.396	0.09	
Replication.*Units* stratum					
Treatment	3	274.188	91.396	21.06	<.001
Residual	9	39.062	4.340		
Total	15	314.438			

Appendix 6: *Analysis of variance*

Variate: Total_Yield_kg_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	701688.	233896.	1.65	
Replication.*Units* stratum					
Treatment	3	4868121.	1622707.	11.45	0.002
Residual	9	1275790.	141754.		
Total	15	6845599.			