EFFECT OF MAIZE DENSITIES ON THE PRODUCTIVITY OF INTERCROPPED COWPEA VARIETIES IN LIMPOPO PROVINCE

by

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DECLARATION

I declare that the mini-dissertation hereby submitted to the University of Limpopo, for the degree Master of Science in Agronomy has not previously been submitted by me for a degree at this or any other University; that it is my work in design and in execution, and that all material contained herein has been duly acknowledged.

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Mafukatla A (Mr) Date

DEDICATION

I dedicate this research work to my late beloved mother, Ms. Tshuwela Suzan Lambani, and my father Mr. Johannes Mafokata, who taught me how best to take care of myself physically, mentally and spiritually. My heartfelt gratitude goes to my loving wife Sanah Morneng, who supported me throughout the research process.

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ABSTRACT

Intercropping maize and cowpea are among the best cultivation practice to increase the crop yield per unit area. However, the great challenge faced by researchers is finding an appropriate combination of planting density and intercropping pattern to preserve cowpea production when maize population density is high under intercropping conditions. A field experiment was conducted to evaluate the effect of maize planting densities on the growth and yield of intercropped cowpea varieties. Study was conducted at the Aquaculture Research Unit, University of Limpopo during 2022/2023 growing season. Maize variety (PAN7469) was intercropped with two cowpea varieties (Brown mix and Dr Saunders) in a 2×2×2 factorial arrangement in a Randomized Complete Block Design (RCBD) with four replications. The experiment consisted of eight treatments from three factors: two cowpea varieties (Brown mix and Dr Saunders), two maize densities (24 700 and 37 000 plants/ha), and two cropping systems which were sole and intercropping. For cowpea, days to 50% flowering, physiological maturity, plant height, number of branches per plant, canopy width, leaf chlorophyll content, above ground dry matter, pod length, number of pods per plant, seeds per pod, hundred seed weight and grain yield were determined. The data for all measured parameters were subjected to the analysis of variance using Statistix 10.0 version. The analysis of variance revealed that the interaction of maize density and cowpea varieties significantly influenced all growth parameters and yield components of cowpea except above ground dry matter and number of seeds per pod. Cowpea grain yield had the mean range of 0.8 to 0.32 t/ha, and the sole crops produced the highest grain yield than intercropped cowpea. Planting Brown mix variety at 37 000 plants/ha maize gave significantly higher grain yield than planting Dr Saunders at both maize densities. Maize-cowpea intercropping had a Land Equivalent Ratio (LER) greater than one, which clearly showed high productivity and better utilization of growth factors in intercropping than sole cropping. Therefore, the results suggest that the maximum of 37 000 plants/ha maize is suitable for maize/cowpea intercropping and should be adopted by farmers due to biological efficient and economic benefits.

Key words: Cowpea variety, Intercropping, LER, Maize density, Productivity

CHAPTER 1

GENERAL INTRODUCTION

1.1 Background Information

Cowpea (*Vigna unguiculata*) is a food grain legume grown under sole and various intercropping systems. It is nutritionally rich in protein and economically valuable for human and animal consumption (Sheahan, 2012; Asiwe, 2017). Cowpea has a significant potential to generate income for poor people (ICRISAT, 2010). In Southern Africa, many smallholder farmers use cowpea as a companion crop, and it is mainly intercropped with cereals such as sorghum, maize and pearl millet (Ewansiha *et al*., 2014). Including grain legumes such as cowpea in the cropping system helps to maximize land productivity by increasing nitrogen cycling through biological nitrogen fixation (Namatsheve *et al*., 2020). The intensified nitrogen cycling is very important to smallholder farmers with limited nutrient inputs (Tittonell and Giller, 2013; Nezomba *et al*., 2015).

Maize (*Zea mays L*.) is a major staple food crop for African people and is ranked as the third most cultivated cereal crop after wheat and rice (Dahmardeh *et al*., 2009). It is a productive food crop with high carbohydrate content and has the potential to contribute towards food security and achieve nutritional balance for poor people in both developed and developing countries (Thobatsi, 2009; Dahmardeh *et al*., 2010). In South Africa, maize is the source of many industrial products. It is mainly grown by smallholder farmers situated in semi-arid regions prone to drought and low soil fertility (Mpandeli *et al*., 2015).

The productivity of cereal-cowpea intercrops can be influenced by a number of factors, such as plant density, plant arrangements, selection of suitable varieties and soil fertility, which collectively determine the competition and the level of mutual benefits between component crops (Rusinamhodzi *et al*., 2012; Masvaya *et al*., 2017). Plant density of component crops is of great importance in the intercropping system as it influences the degree of competition for moisture, nutrients and sunlight (Lulie *et al*., 2016). The productivity of maize and cowpea intercrops can be enhanced by properly adjusting planting density and selecting suitable cowpea varieties. Previous studies reported that cowpea varieties perform differently in intercropping as they have different architecture and growth durations (Timko and Singh 2008; Namatsheve *et al*., 2020). Haruna *et al*., 2018 demonstrated that cowpea landrace varieties are spreading plant types that produce grains within 120 days and they performed well when intercropped with tall cereals such as maize. In an intercropping system, a plant population that is too low reduces the potential yield. In contrast, a high plant population increases the risk of diseases and plant stress due to competition (Molatudi and Mariga, 2012). There is limited information on the impact of different maize densities on the productivity of intercropped cowpea varieties in South Africa.

1.2 Problem statement

The intercropping system, especially maize-cowpea, is considered amongst the best option to improve food production in Africa and worldwide, particularly in countries with low land holding capacity (Legwaila *et al*., 2012; Maitra *et al*., 2020). According to Dwivedi *et al*., (2015), crop yields in intercropping are often greater than in sole cropping systems. This is probably due to the efficient use of light interception, water and nutrients resources than in a sole cropping system (Makgoga, 2013). Despite increased crop yields in intercropping, maize and legumes are still declining due to erratic rainfall, low soil fertility, lack of adequate improved varieties and poor agronomic practices (Mpandeli *et al*., 2015; ARC-GCI, 2015; Ndamani and Watanabe, 2015). Furthermore, population increase and climate change threaten food security (Feed the Future, 2014). Therefore, the rise in population density of a component crop per unit area under intercropping systems has been reported by several studies to enhance crop production (Thobatsi, 2009; Lulie *et al*., 2016). However, the big challenge facing researchers is finding an appropriate combination of planting density and intercropping pattern to preserve cowpea production when maize population density is high under intercropping conditions (Lulie *et al*., 2016).

1.3 Motivation of the study

Cowpea is a grain legume crop that can improve food security and is rich in protein (Asiwe, 2009; Sheahan, 2012; Asiwe, 2017). In areas characterised by marginal rainfall and poor soil fertility, such as Limpopo province, a drought-tolerant crop like cowpea has the potential to grow well and fix nitrogen that is in the atmosphere for it to be utilized by the host plant. The fixed nitrogen will also be available for the cereal crop that is intercropped during the growing season (Meena *et al*., 2015; Nndwambi, 2015; Layek *et al*., 2014). Sekgobela (2019) and Asiwe (2009) reported that fixed nitrogen aids in reducing the demand for nitrogen fertilizer and production costs. Furthermore, one of the most important reasons to cultivate cowpea as a companion crop is because it uses its robust tap root system to absorb nutrients from a deeper soil profile (Jat *et al*., 2012).

Multiple cropping has the benefits of improving soil fertility with the aid of legumes, improving soil infiltration and moisture conservation, providing a physical barrier to restrict pest movement, and providing insurance against crop failure than sole cropping (Undie *et al*., 2012; Dahmardeh, 2013; Nndwambi, 2015). Makgoga (2013) reported that intercropping helps farmers to obtain higher yields than the sole cropping system. The reasons are mainly due to better utilization of environmental resources, less intra-species competition and more excellent yield stability. Nevertheless, farmers are challenged to apply the proper combination of planting density to increase cowpea yield under the increased population density of a component crop. Plant density is one of the significant factors to be considered in a cropping system as it determines the degree of competition for moisture, nutrients and sunlight (Peksen and Gulumser, 2013; Lulie *et al*., 2016). Therefore, small-scale farmers need assistance with a proper combination of planting density and cowpea variety to achieve optimum cowpea yields using less land area.

1.4 Purpose of the study

1.4.1 Aim

The study aimed to evaluate the effect of different maize densities on the productivity of intercropped cowpea varieties in Limpopo province.

1.4.2 Objective

Determination of the effect of two different maize densities on the growth parameters and yield components of intercropped cowpea varieties.

1.5 Hypothesis

The two maize densities have similar influence to the intercropped cowpea varieties' growth parameters and yield components.

CHAPTER 2

LITERATURE REVIEW

2.1 Botanical description and adaptation of cowpea

Black-eyed pea, southern pea, asparagus bean, Chinese long bean, crowder pea, Luba hilo and Seub are some of the common names of cowpea (Timko and Singh, 2008). *Vigna unguiculata* is the scientific name of cowpea from the Fabaceae, subfamily Faboideae, tribe Phaseolinae and order Fabales. Cowpea is believed to be originated from West and Southern Africa due to the large existence of the primitive wild varieties in the regions (Sariah, 2010). Cowpea today is widely adapted and cultivated in Africa, Asia, Southern United States and Latin America (Timko and Singh, 2008). It is a summer crop with trifoliate leaves and is characterised by different growth habits, including erect and semi-erect, bushy and trailing (Kabululu, 2008). The erect type is the most improved that matures early and produces grain within 85 days after a crop emergency while the climbing type (landrace variety) produces grain within 120 days. Haruna *et al*. (2018) reported that the climbing types perform better when intercropped with tall cereals such as maize. Cowpea is a short-season crop which can reach a height of up to 80 cm under favourable conditions. It is characterised by a very deep taproot and many lateral branching roots spreading in the surface soil compared to other legume crops. The characteristics of the crop include the number of days to reach flowering and pod formation, the number of pod per plant, pod length and pod weight (Cobbinah *et al.,* 2011). Cowpea is a self-pollinating plant that produces a cluster of flowers at the end of the peduncle and two to three pods per peduncle (DAFF, 2011). The pod shapes are curved, cylindrical or straight, coming in various colours, usually light green during the early stages of maturity to light brown, yellow and pink or purple as the seeds reach maturity (Timko and Singh, 2008). The seeds' shape might be round or kidney with a wrinkled, rough or smooth coat with distinctive colouration such as white, green, speckled, cream, red-brown or black (DAFF, 2011). Cowpea can be grown in a wide range of soil textures, though it prefers well-drained sandy loam soil with a pH ranging from 5.5 to 6.5 (Masenya, 2016; Sheahan, 2012). Cowpea requires a day temperature of 20 to 30 °C and a night temperature of 18 to 24 °C for growth and development (Mathews, 2012). It is highly adaptable to dry conditions but susceptible to frost damage than most common beans. Hatfield and Prueger (2015) reported that extreme temperatures during reproduction results in less viable pollen, early flowering and shedding of flowers and poor pod formation that subsequently lessen crop yield, while temperature below 15 °C delay seed germination with the risk of seed rot, decreases the plant height and chlorophyll content of cowpea (Ntobela, 2012; DAFF, 2011). Cowpea can be grown from December to January, and flourishes well in areas receiving a summer rainfall of 400 to 700 mm per annum (Ndamani and Watanabe, 2015). Excessive rainfall increases insect and disease attacks, delays ripening, and reduces grain yield.

2.2 Importance of cowpea

Cowpea is a drought-tolerant crop that can be grown in tropical and sub-tropical regions where most staple food crops like cereals fail to produce effectively. Cowpea is an important food grain legume that offers necessary nutrients to the millions of black population in Africa and other developing countries, especially for poor families who cannot afford animal protein (Singh *et al*., 2011; Timko and Singh, 2008). Nutritionally, cowpea is a great source of affordable protein, starch, vitamins and minerals necessary for animal consumption and human diets (Asiwe, 2017; Ayo-Vaughan *et al*., 2013). According to Akyaw *et al. (*2014), cowpea contains an average of 23-25% of proteins and can be consumed in all growth stages as vegetable proteins. Cowpea production can improve food security in numerous ways; farmers can consume, and sell grain and fodder to generate income (Masenya, 2016; ICRISAT, 2010).

As a legume, cowpea makes a valuable contribution towards improving soil fertility and moisture conservation. Cowpea has the potential to fix nitrogen that is in the atmosphere through a symbiosis relationship with the help of *Rhizobia* bacteria in its root nodules, thus making much nitrogen available for the host plant while also leaving substantial amounts of nitrogen in the soil for succeeding crops (Meena *et al*., 2015; Nndwambi, 2015; Layek *et al*., 2014). This reduces the demand and expenses for nitrogen fertilizer for resource-poor farmers (Sekgobela, 2019). Furthermore, cowpea is highly effective in conserving soil moisture content and reducing soil erosion due to its biomass production.

2.3 Production of cowpea in South Africa and around the world

Cowpea is one of the major food legumes cultivated by millions of smallholder farmers in Africa and other parts of the world. According to Boukar *et al*. (2018), the world's annual cowpea production is approximately 6.5 million metric tons which is produced from an area of 14.5 million hectares. FAOSTAT (2017) reported that about 91% of cowpea is produced in West Africa, with Nigeria producing approximately 2.14 million metric tonnes annually. Nigeria is the world's leading cowpea producer and consumer, followed by Niger, Brazil and other African regions such as Senegal, Malawi, Kenya, Botswana and Tanzania (Rivas *et al*., 2016). Despite its importance and high production in Africa, there is insignificant commercial cowpea production in South Africa. Masenya (2016) reported that small-scale farmers mostly carried out cowpea production in South Africa under rain-fed conditions. The major cowpea producing provinces are KwaZulu-Natal, Mpumalanga, Limpopo and North West. However, there is no information on the quantities and size of the area cowpea produced.

2.4 Limitation to cowpea production

Despite its importance, cowpea in South Africa is underutilised compared to other staple crops such as wheat, maize and groundnut because it is less preferred than other crops. Previous studies indicated that poor agronomic practices, lack of improved varieties, insect pests and diseases, weeds, lack of storage facilities and market for the produce, as well as low marginal returns to farmers serve as the significant constraints to the increased cowpea production (Bolarinwa *et al*., 2021; Sekgobela, 2019; Asiwe, 2009). It was further indicated that insufficient soil moisture during germination and flower setting also serve as significant constraints to cowpea growth and development (Masenya, 2016).

2.4.1 Insect pests

Cowpea is more susceptible to many insect pests than most leguminous crops. Egho and Enujeke (2012) reported that unimproved cowpea varieties have a low resistance to insects, leading to very low crop yields. Major insects that attack cowpea are pod-sucking bugs, aphids and cowpea weevil (Asiwe, 2009). Insect pests cause a devastating effect at almost all stages of cowpea development resulting in high yield reduction unless the crop is sprayed with insecticides.

2.4.2 Diseases

Cowpea is susceptible to bacterial, viral and fungal diseases. In South Africa, cowpea is more affected by virus than bacterial and fungal diseases (Sekgobela, 2019). Major devastating cowpea diseases include cowpea yellow mosaic virus, Brown blotch and Bacterial blight. Cowpea yellow mosaic is a destructive disease caused by the yellow mosaic virus and is accountable to yield reduction of up to 80-100% (Kumar *et al*., 2017). Brown blotch and Bacterial blight (*Xanthomonas vignicola*) cause severe damage to cowpeas and consequently cause a huge reduction in cowpea production (Mark and Channya, 2016; Sheahan, 2012).

2.4.3 Weeds effects on cowpea

According to Masenya (2016), weeds are a serious threat to cowpea production due to the competition for nutrients, water and light. They harbour insects and diseases that suppress cowpea growth and development, reducing both the quality and grain yield. Weeds may act as hosts for insect pests, especially when are not removed periodically. Cowpea is more susceptible to weeds for 2-5 weeks after sowing. Parasitic weeds such as Striga and Alectra species constitute a serious problem to cowpea production in Africa (Masenya, 2016; Timko and Singh, 2008). Therefore, efficient weed control is necessary to guarantee high cowpea productivity.

2.4.4 Drought

Drought is one of the major factors that pose constraints to cowpea productivity in Africa and worldwide. As a drought-tolerant crop, cowpea is mostly grown by resources poor farmers under rain-fed conditions than in irrigated areas (Nkomo *et al*., 2021). Under drought stress, cowpea reacts by closing the stomata to reduce transpiration. However, cowpea productivity is solemnly reduced when the crop experiences serious moisture stress during reproductive stages such as flower development, pod and seed development (Sekgobela, 2019; DAFF, 2011). Therefore, proper planting densities, planting of early maturing varieties and high drought resistance varieties are necessary to reduce the degree of competition for moisture, nutrients and sunlight, and promote flowering, seed and pod filling to optimize grain yield.

2.5 Botanical description and adaptation of maize

Maize (*Zea mays L*.) is an annual grass crop from Poaceae, subfamily Panicoideae and order Poales (du Plessis, 2003). In South Africa, maize is a priority crop to farmers because is recognized as a major staple food for more than 70% of the black population (ARC-GCI, 2015). Maize is also known as a summer crop mostly grown in the semi-arid region across Africa and other countries (Baloyi *et al*., 2012). Climatic conditions characterised by low wind speed, long photoperiods, an annual rainfall of 500 to 750mm, and a temperature of 18 to 32 °C are suitable for maize production (Odgaard *et al*., 2011; Belfield and Brown, 2008). High temperature, erratic rainfall and frost period before flowering and during the development stages has a great impact on maize productivity (Moeletsi and Walker, 2012; Akpalu *et al*., 2009). Maize can be produced on a diverse range of soils, but the crop responds positively in an easily tilled and well-drained soil. According to FAOSTAT (2012), soils with a pH range between 5.0 and 7.0 are suitable for maize production.

2.6 Importance of maize

Maize is a crop of exceptional economic significance worldwide for animal and human consumption (Nyasasi and Kisetu, 2014; Moeletsi *et al*., 2016; SAMT, 2016). Maize is considered as major staple food for the main people in Africa and other developing countries, and it has the potential to meet the global food demand (Dahmardeh *et al*., 2010; Nyasasi and Kisetu, 2014). It is a cereal crop with high content of carbohydrates, protein, essential minerals and vitamins (Plessis, 2003; Dahmardeh *et al*., 2010). In industrialized countries, maize is used as a raw material for industrial products such as paper production, clothing, adhesives and pharmaceuticals (Teamir, 2011). Maize can be processed into bioethanol which can be used as a biofuel. Maize is mainly grown by small-scale farmers as an intercrop with various grain legumes. Intercropping maize and legume is considered as one of the best options to increase the yield per unit area (Thobatsi, 2009).

2.7 Production of maize

Maize is one the most important field crops widely cultivated worldwide in a range of agro-ecological environments. In South Africa, maize is mostly grown by smallholder farmers in semi-arid regions prone to drought and low soil fertility (Mpandeli *et al*., 2015). Approximately 15.3 million metric tons of maize was produced in 2021/2022 in South Africa. Free State Province obtained the highest maize production (44.3%), followed by Mpumalanga, North West and Limpopo Province. This shows a decline of 10 percent from previous years. Maize requires much nitrogen to achieve optimum yield which can be easily met through inorganic fertiliser application. However, small-scale farmers tend to practice maize/legume intercropping due to the unaffordability of chemical nitrogenous fertilizers (Javanmard *et al.,* 2009).

2.8 Intercropping as a practice

Intercropping is an old agricultural practice that allows the cultivation of two or more crops on the same plot of land simultaneously (Bedoussac *et al*., 2015; Sullivan 2003). It is a cropping system commonly practised by resource-poor farmers in Southern Africa; and is regarded as the best option to improve food productivity in areas with low land holding capacity (Maitra *et al*., 2020; Legwaila *et al*., 2012). One of the main advantages of maize/legume intercropping is that crop yields are often greater than in a sole cropping system (Dwivedi *et al*., 2015). This is probably due to the efficient use of light interception, water and nutrients resources than in a sole cropping system (Makgoga, 2013). In South Africa, many small-scale farmers practice cereal/legume intercropping due to the shortage of land and the most utilised intercrops are maize/cowpea, maize/lablab, and maize/dry bean (Odhiambo and Nemadodzi, 2007). Several factors have been reported to influence the productivity of maize/legume intercropping, including a selection of compatible crops, planting density, plant arrangements, plant architecture and maturing dates of the crops being grown (Masvaya *et al*., 2017; Peksen and Gulumser, 2013). According to Lulie *et al*. (2016), plant density is one of the significant factors to consider in intercropping as it determines the degree of competition for moisture, nutrients and sunlight. Therefore, there is a need to determine the relative maize population density for better productivity in maize/cowpea intercrop.

2.8.1 Planting density in cereal/legume intercropping

According to Lulie *et al*. (2016), planting density is one of the significant factors to consider in maize/legume intercropping as it determines the degree of competition between the intercrops. Molatudi and Mariga (2012) reported that factors such as nutrient availability, cultivars selection and soil moisture determine the optimum plant population per unit area. Plant population that is too low reduces the potential yield whereas too high plant population increase the risk of diseases and plant stress due to competition among the plants (Molatudi and Mariga, 2012; Makgoga, 2013). To optimize plant density, the seedling rate of the relative proportion of component crops is adjusted below its full seed rate (Ren *et al*., 2016). The optimization of plant population increases the rate of photosynthesis, light absorption, plant biomass and grain yield by both increasing plant density and decreasing row spacing (Bruns, 2011; Feng *et al*., 2019; Raza *et al*., 2019). The challenge is to find the ideal plant population that will preserve the cowpea productivity under maize-cowpea intercropping conditions.

2.8.2 Plant arrangement in intercropping

The spatial arrangement is another important agronomic factor to consider in cereal/legume intercropping as it improves the solar radiation interception through complete ground cover and determines whether intercropping is more beneficial as compared to sole cropping (Nthabiseng *et al.*, 2015; Yang *et al*., 2015). In cereal/legume intercropping system, there are various kinds of spatial arrangements which farmers can practice to maximize the plant growth and yield components, and to benefit the environment, especially regarding to soil fertility (Muhammad *et al*., 2010). These spatial arrangements are row intercropping, strip intercropping, mixed cropping and relay intercropping. Row-intercropping is the most improved cropping pattern commonly used by small-scale farmers throughout the world to maximize crop productivity due to the efficient use of resources, such as light, water and nutrients (Nthabiseng *et al.*, 2015; Varma *et al*., 2017). This cropping pattern allows the cultivation of two or more crops simultaneously.

2.8.3 Selection of compatible crops in intercropping

The ideal choice of crop species is a commonly used strategy to minimize crop competition and maximizes growth and yields when designing cereal/legume intercropping system (Makgoga, 2013). There are several factors to consider when choosing the choice of crop species including growth habits and duration, potential nitrogen fixation, and competitive and yield advantages (Thobatsi, 2009). According to Timko and Singh (2008), cowpea varieties perform differently as intercrops due to different growth habits. Therefore, the selection of compatible crops is important to enhance the productivity of intercrops.

2.9 Benefits of cereal /legume intercropping system

Cereal/legume intercropping is considered the best option to maximize food security in Africa and worldwide, particularly in countries with low land holding capacity (Legwaila *et al*., 2012; Maitra *et al*., 2020). This practice benefits small-scale producers in areas characterised by marginal rainfall and poor soil fertility, such as Limpopo province. Previous studies indicated that a well-established intercropping system gives numerous benefits to the farming practice such as maintaining and improving soil fertility, control of soil erosion (Punyalue *et al*., 2018; Matusso *et al*., 2014; Blanco-canqui *et al*., 2015). In addition, intercropping helps to improve soil infiltration and moisture conservation, control of insect pest and diseases, weed management and provides insurance against total crop failure (Nicholls *et al*., 2016; Maitra and Ray, 2019; Jensen *et al*., 2020). The main reason for intercropping is to ensure that natural resources are better utilized, and thus higher yields are obtained per unit area than sole cropping (Mobasser *et al*., 2014).

2.9.1 Nitrogen fixation by cowpea crop

Low soil nutrients, especially nitrogen, are the major limiting factor to crop growth and development. Due to the high cost of nitrogenous fertilizers, small-scale farmers tend to integrate grain legumes such as cowpea with cereals as an alternative way to replenish soil mineral nitrogen through biological nitrogen fixation (BNF), especially in areas where N is restricted (Nezomba *et al*., 2015; Namatsheve *et al*., 2020). According to Meena *et al*. (2015), legume fixes enough nitrogen for their use and transfer a substantial amount of fixed nitrogen to intercropped cereals during their joint growing period. Grain legumes, especially cowpea, groundnuts, soybean and lablab can accumulate 80 to 350 kg Nha^{-1} per year (Mobasser *et al*., 2014). Moreover, cowpea has been estimated to fix up to 200 kg Nha^{-1} per year in tropical soils (Rusinamhodzi *et al*., 2012). The addition of nitrogen-fixing legumes in intercropping can also improve phosphorus (P) availability and soil organic carbon (SOC) content, which are key determinants of soil fertility (Ngwira *et al*., 2012).

2.9.2 Better utilisation of natural resources

In the Limpopo province of South Africa, the productivity of cowpea, maize and other crops is still declining due to erratic rainfall and low soil fertility (Mpandeli *et al*., 2015). The compatible combination of cereal/legume Intercropping, especially maize/cowpea has been reported to use natural resources more efficiently than in corresponding monoculture (Thobatsi, 2009; Mobasser *et al*., 2014). Maize and cowpea differ in root architecture and penetration depth, which allows the crops to capture nutrient elements and soil moisture at different layers, thus reducing competition between species

(Jensen *et al*., 2020; Rodriguez *et al*., 2020). Cowpea uses their robust tap root system to absorb nutrients and water from a deeper soil profile (Jat *et al*., 2012), and conserve soil moisture by providing shade to the soil surface (Muoni *et al*., 2020). Cowpea has been reported to supply up to 72% of their N need through biological N fixation when intercropped with maize (Vesterager *et al.*, 2008). Previous studies demonstrated that approximately 15.98% of soil moisture content is conserved during the active period of crop development, while 16.70% are conserved after crop removal when cowpea intercropped with maize (Ayele, 2020).

2.9.3 Benefit of intercropping on weed control

Weeds infestation is the major factor affecting crop yield in small-scale farming. Weeds compete with cash crops for nutrients, light and water (Masenya, 2016). Cereal/ legume intercropping has been used as an economical option to suppress weed populations and increase crop yields compared to the mono-cropping system (Naher *et al*., 2019). In intercropping, the legume is used as a ground cover crop, which restricts the light availability of weeds. Hugar and Palled (2008) reported the highest weed control, lowest weed dry matter and weed populations when maize intercropped with cowpea. The study by Jamshidi *et al*. (2013) indicated that in the maize-cowpea intercropping system, weed biomass was reduced from 39.6% to 45.5%. Saudy (2015) also indicated that weed growth were reduced by more than 49% when maize intercropped with cowpea. The legume cover crop can potentially maintain agro-ecosystem sustainability by reducing tillage and herbicides (Islam *et al*., 2021).

2.9.4 Benefit of intercropping on soil erosion

Cereal/legume intercropping plays an important role in soil moisture conservation, subsequently increases crop productivity. Iqbal *et al*. (2018) reported that soil moisture conservation depends on the legume genotypes. In intercropping, soil erosion is controlled by reducing the impact of raindrop on bare soil, and thus prevents rainwater loss through evaporation and surface run-off (Egesa *et al.,* 2016; Muoni *et al*., 2020). Cowpea has been reported as the best cover crop to reduce soil erosion in maize-legume intercropping systems (Kariaga, 2004). In contrast, maize is regarded as a taller plant in intercropping, and acts as a wind barrier, protecting legumes from wind erosion (Kinama *et al*., 2018). For example, Sharma *et al*. (2017) reported that maize-cowpea intercropping reduced soil erosion by 26% compared with cowpea monoculture and by 43% compared with maize sole crop.

2.10 Maize-cowpea intercrops and productivity

The cultivation of cereal and legume crops in intercropping has become one of the solutions to reduce the risk of crop failure and intensify food security in the smallholder farming sector (Egbe and Idoko, 2012). However, intercropping may lead to low crop productivity due to competition by component crops for moisture, nutrient and light (Layek *et al*., 2018). It is well documented that maize obtained greater yields than cowpea crops in intercropping system due to mutual shading by taller maize crops, especially when late-maturing maize varieties and additive design used in intercropping (Ewansiha *et al*., 2015; Namatsheve *et al*., 2020). In intercrops, late-maturing maize varieties compromised cowpea yield, utilising more resources than an early-maturing maize variety. The study conducted by Masvaya *et al*. (2017) revealed that maize density in intercrops is generally higher than the cowpea crop density, and this gives maize higher land equivalent ratio (LER) values than cowpea crop. The total LER is used to determine the yield advantage of intercropping compared to sole crops.

According to Thobatsi (2009), one of the major benefits of the intercropping system is the increase and diversity of productivity per unit area as compared to monocropping system. For the assessment of land return, the yield of the pure stands and individual crops in the mixture are measured. LER is defined as the relative land area required under sole cropping system for comparison with yields obtained from intercropping, or the size of cultivation necessary to achieve the same yield per unit area of land in an intercropping system (Dariush *et al*., 2006). LER value of greater than 1.0 shows higher productivity of intercropping relative to sole cropping, whereas LER value of lower than 1.0 indicates the lower productivity of intercropping in comparison to sole crops (Dariush *et al*., 2006). When calculating the LER value, intercropping yields are divided by the sole cropping yields for each crop in the intercropping and the two figures are added together (Sullivan, 2003).

CHAPTER 3

METHODOLOGY AND ANALYTICAL PROCEDURES

3.1 Description of the research area

A field experiment was conducted during the 2022/2023 growing season at the Aquaculture research unit area, University of Limpopo, situated (23°53 '9.6'' S; 29°43' 4.8'' E) in Limpopo Province of South Africa. The location receives summer rainfall between 450-650 mm, and average temperatures ranging from 28 to 30°C.The site is distinguished by its sandy loam soil texture and corresponds to Hutton form soil type. Physico-chemical properties of soil samples collected before planting are presented in Table 1.

3.2 Treatments and research design

One maize variety (PAN7469) was intercropped with two cowpea varieties (Brown mix and Dr Saunders) in a 2×2×2 factorial arrangement in a Randomized Complete Block Design (RCBD) with four replications. The experiment consisted of eight treatments from three factors: two maize densities: M_1 - sole maize at 90 x 30 cm (37 000 plants/ha) and M_2 - Sole maize at 90 x 45 cm (24700 plants/ha), two cowpea varieties: Brown mix and Dr Saunders and two cropping systems which were sole cropping and intercropping arrangement (cowpea varieties × maize densities).

The resultant eight treatments were:

1) M_1 = Sole maize at 90×30 cm (37 000 plants/ha)
2) M_2 = Sole maize at 90×45 cm (24 700 plants/ha)
3) C_1 = Sole cowpea variety Brown mix
4) C_2 = Sole cowpea variety Dr Saunders
5) M_1C_1 = Maize at 90×30 cm and cowpea variety Brown mix
6) M_1C_2 = Maize at 90×30 cm and cowpea variety Dr Saunders
7) M_2C_1 = Maize at 90×45 cm and cowpea variety Brown mix
8) M_2C_2 = Maize at 90×45 cm and cowpea variety Dr Saunders

Table 1: Soil physical and chemical analyses before planting

Soil properties	Depth	
Physical parameters	0-15 cm	15-30 cm
Clay (%)	19.2	18.4
Silt (%)	6.4	7.8
Sand (%)	74.4	73.8
Textural class	Sandy loam	Sandy loam
Chemical parameters		
pH ($H_2$0)	6.7	6.5
pH (Kcl)	4.6	4.8
EC (ɥS/cm)	1.2	1.5
Ammonium (mg/kg)	-3.4	-3.6
Nitrate (mg/kg)	-10.8	-12.2
P (Bray1) (mg/kg)	0.7	1.2

3.3 Plot size and spacing

The size of each maize plot was 10.8 m^2 (3.6 m × 3 m), and each maize plot consisted of five rows planted at the same inter-row spacing of 90 cm and intra-row spacing of 30 and 45 cm. The intercrop plots comprised five rows of maize and four rows of Cowpea. The size of intercrop plots was also 10.8 m^2 (3.6 m × 3 m), and maize rows were planted at the same inter-row spacing of 90 cm and intra-row spacing of 30 and 45 cm. The size of each sole cowpea plot was also 9 m^2 (3 m × 3 m), and each sole cowpea plot consisted of five rows planted at an intra-row spacing of 30 cm and inter-row spacing of 75 cm. A 1 m and 1.5 m footpath was left between the plots and the blocks, respectively.

3.4 Data collection and measurements

3.4.1 Soil sampling and analysis

Before sowing, the surface litter were removed at the sampling spot. A representative soil sample was collected randomly using a soil auger at the soil depths of 0-15 and 15-30 cm from the experimental field. The samples were used to determine nitrogen (N), phosphorus (P), soil pH and soil texture. A pH meter was used to measure a soil pH in the soil of 1:2:5 to water ratio suspension (Eckert, 1988). Soil texture was measured using a Bouyoucos hydrometer (Day, 1965). Nitrogen was measured using the macro-Kjeldahl digestion method (Jackson, 1967). Available P was determined using the Bray1 extraction method (Kuo, 1996).

3.4.2 Data on the growth parameters and yield components of cowpea and maize

Cowpea crop

Days of 50% flowering - To determine days to 50% flowering, plants were monitored and recorded from days of planting until the days when plants reached 50% flowers.

Days to physiological maturity - Days to physiological maturity were monitored and recorded from days of planting to the date when cowpea plants were fully matured (cowpea leaves turns brown and seed shook loose).

Plant height (cm) - At maturity, five representative cowpea plants were randomly selected from each plot to determine the plant height. The average plant height was measured using a measuring tape.

Canopy width (cm) - Using a measuring tape, canopy width was measured from five representative plants per plot. The average was then calculated and recorded.

Leaf chlorophyll content (nm) - Chlorophyll content was recorded at the middle of the fully grown leaf from five representative plants per plot during flower initiation using a chlorophyll meter.

Number of branches per plant - The number of branches was counted from five representative cowpea plants per plot. The average was then calculated and recorded.

Above ground dry matter (t/ha) - Five representative cowpea plants per plot were sampled randomly at physiological maturity to determine plant biomass. Pods were separated, and the sample was oven-dried for 72 hours at 65°C. Thereafter, weigh and record the dry matter.

Pod length (cm) - At maturity, five pods were measured using a measuring tape from five representative plants per plot. The average was also calculated.

Number of pods per plant - At maturity, five representative cowpea plants were randomly selected from each plot and fully developed pods were counted per plant. The average was calculated and recorded.

Number of seeds per pod - At harvest, five representative plants were randomly selected from each plot and seeds were counted from each pod. The average was also computed.

Hundred seed weight (g) - The weight of a hundred seeds were recorded from two samples of hundred seeds per plot. Their average was computed.

Shelling percentage - The shelling percentage was calculated as follow:

$$\text{Shelling \%} = \frac{(\text{Shelled grain weight})\text{kg}}{(\text{Unshelled pod weight})\text{kg}} \times 100$$

Grain yield (t/ha) - To determine the grain yield, shelled grains were weighed using weighing balance. Thereafter, it was converted to ton per hectare using the following equation:

Grain yield (t/ha) = ((Grain yield (kg) / Area harvested (m^2))) × 10000m^2 / 1000

Maize crop

Days to 50% tasseling - Number of days to 50% tasseling were monitored and recorded from the date of planting until the days when plants reached 50% tasselling.

Days to 50% silking – Number of days to 50% silking were monitored and recorded on a daily basis from the date of 50% emergency until the date when plants reached 50% silking.

Above ground dry matter (t/ha) - At physiological maturity, five representative maize plants per plot were sampled randomly to determine plant biomass. Cobs were separated and the samples were oven-dried for 72 h at 65°C. Thereafter, weigh and record the dry mass.

Plant height (cm) - At maturity, five representative plants were randomly selected from each plot to determine the plant heights using measuring tape. The average plant height was calculated and recorded.

Cob length (cm) - Cob length was measured from five representative plants per plot using a measuring tape. Thereafter, the average cob length was calculated and recorded.

Number of cob per plant - Fully developed cobs from five representative plants per plot were counted. The average was calculated and recorded.

Shelling % - The shelling percentage was calculated as follow:

Shelling % = (shelled grain weight / unshelled weight) × 100

Grain yield (t/ha) - To determine the grain yield, shelled grains were weighed using weighing balance. Thereafter, it was converted to ton per hectare using the following equation:

Grain yield (t/ha) = ((Grain yield (kg) / Area harvested (m^2))) × 10000m^2 / 1000

3.4.3 Determination of Land Equivalent Ratio (LER)

To evaluate the productivity of intercropping system, Land equivalent ratio (LER) was calculate using the following equation:

$$\mathrm{LER} = \left[\frac{\text{Intercropped Maize yield}}{\text{Sole Maize yield}} + \frac{\text{Intercropped Cowpea yield}}{\text{Sole Cowpea yield}}\right]$$

LER value of greater than 1.0 shows higher productivity of intercropping relative to sole cropping. LER with a value of 1.0 shows no yield difference between intercropping and sole cropping and LER value of lower than 1.0 indicates the lower productivity of intercropping in comparison to sole crops.

3.5 Data analysis

The data for all measured parameters were subjected to the analysis of variance using Statistix 10.0 version. Least significant differences (LSD) were performed for treatment means separation at 0.05 level of probability.

CHAPTER 4

RESULTS

4.1 Growth parameters and yield components of cowpea varieties as affected by maize densities

A significant interaction between maize densities and cowpea varieties was observed in the number of days to 50% flowering (Figure 1), number of days to 90% maturity (Figure 2), plant height (cm) (Figure 3), canopy width (cm) (Figure 4), leaf chlorophyll content (nm) (Figure 5), number of branches per plant (Figure 6), pod length (cm) (Figure 8), number of pods per plant (Figure 9), hundred seed weight (g) (Figure 11), shelling percentage (Figure 12), and grain yield (t/ha) (Figure 13). Maize density and cowpea variety interaction increased the mean number of days to 50% flowering and 90% maturity, plant height, canopy width, leaf chlorophyll content, and the number of branches per plant by 12, 23, 42, 22, 83 and 55%, respectively (Figure 1-6). Conversely, the interaction of maize density and cowpea variety decreased pod length, pods per plant, hundred seed weight, shelling and grain yield by 27, 38, 42, 20 and 59% respectively (Figure 8, 9, 11, 12 and 13). Maize density did not influence the above-ground dry matter (Figure 7), and number of seeds per pod (Figure 10).

The higher mean values in days to 50% flowering (62 days) and 90% maturity (86 days) were observed where Dr Saunders cowpea variety was intercropped with 24 700 and 37 000 maize plants per hectare (Figure 1-2).

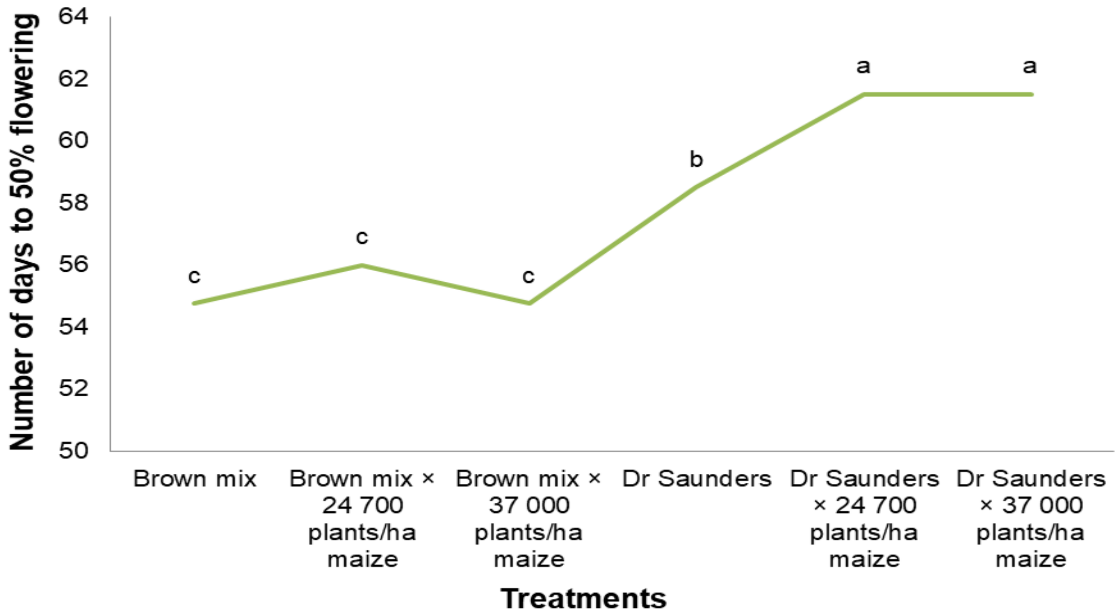

Figure 1: Number of days to 50% flowering of two diverse cowpea varieties under different maize densities

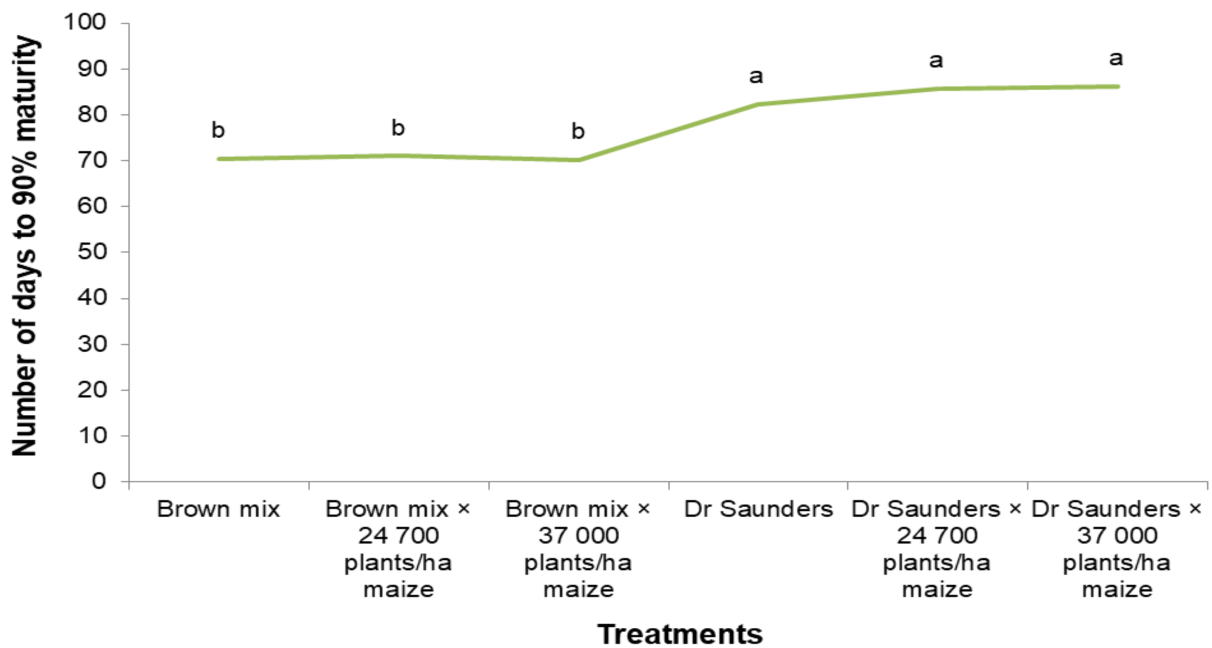

Figure 2: Number of days to 90% physiological maturity of two diverse cowpea varieties under different maize densities

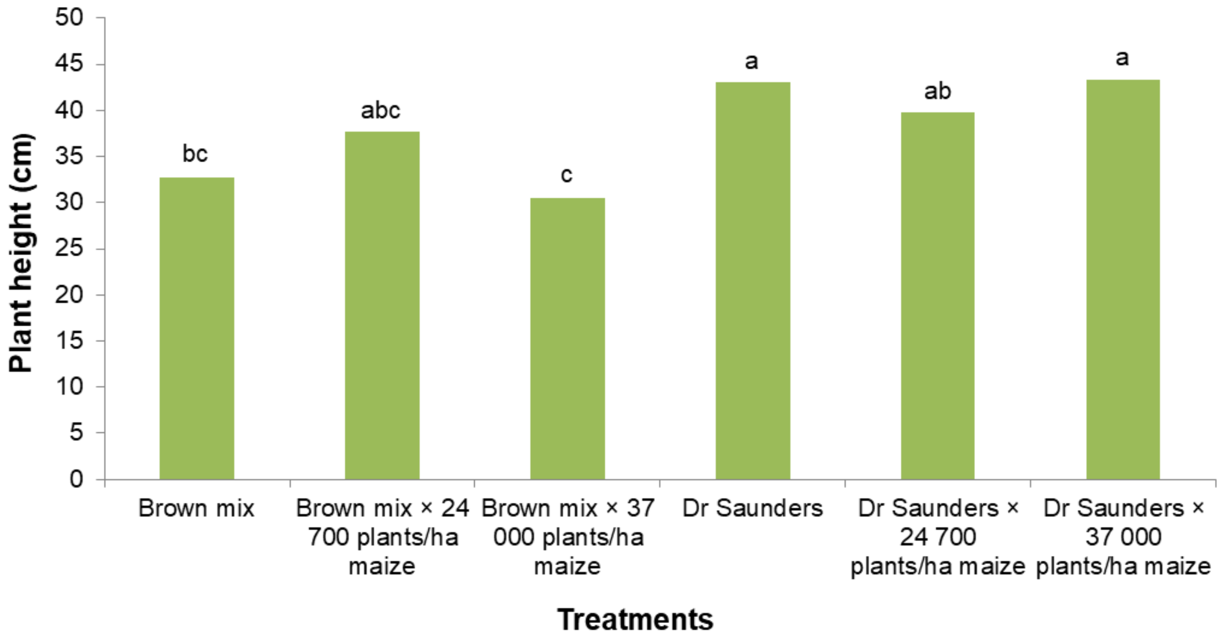

Figure 3: Plant height of two diverse cowpea varieties under different maize densities

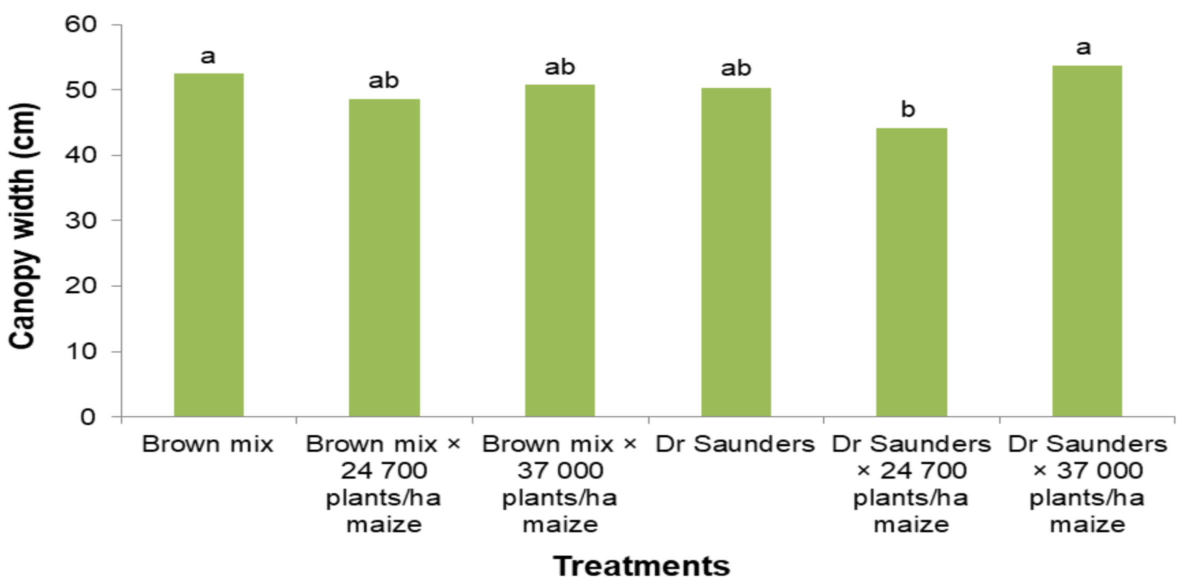

Figure 4: Canopy width of two diverse cowpea varieties under different maize densities

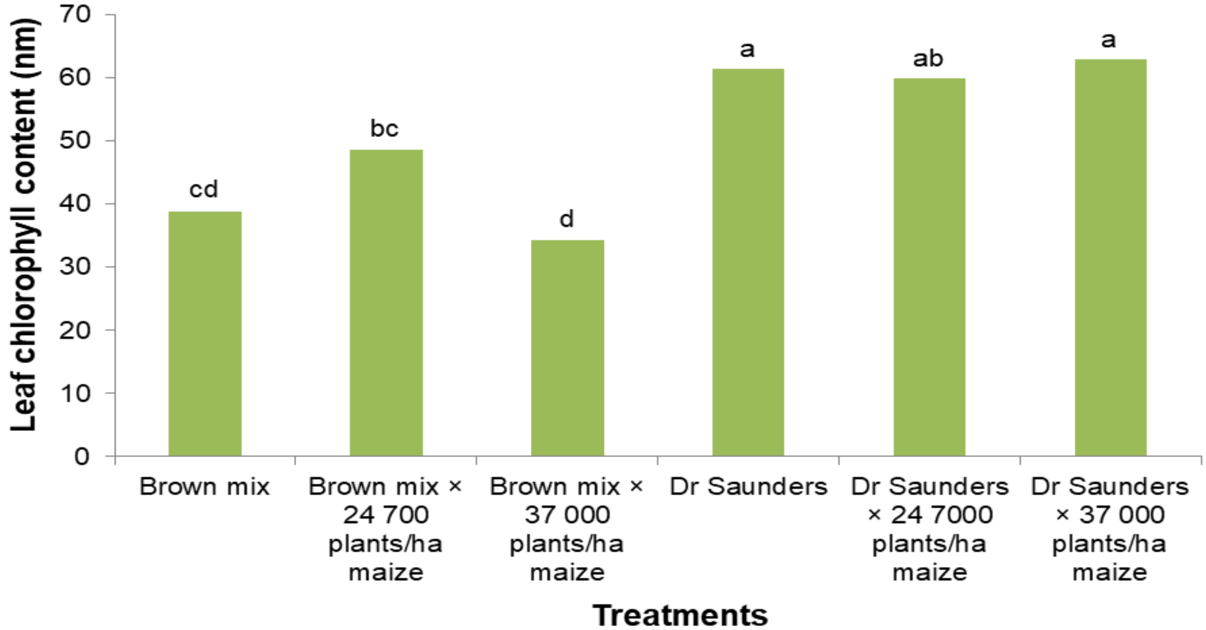

Figure 5: Leaf chlorophyll content of two diverse cowpea varieties under different maize densities

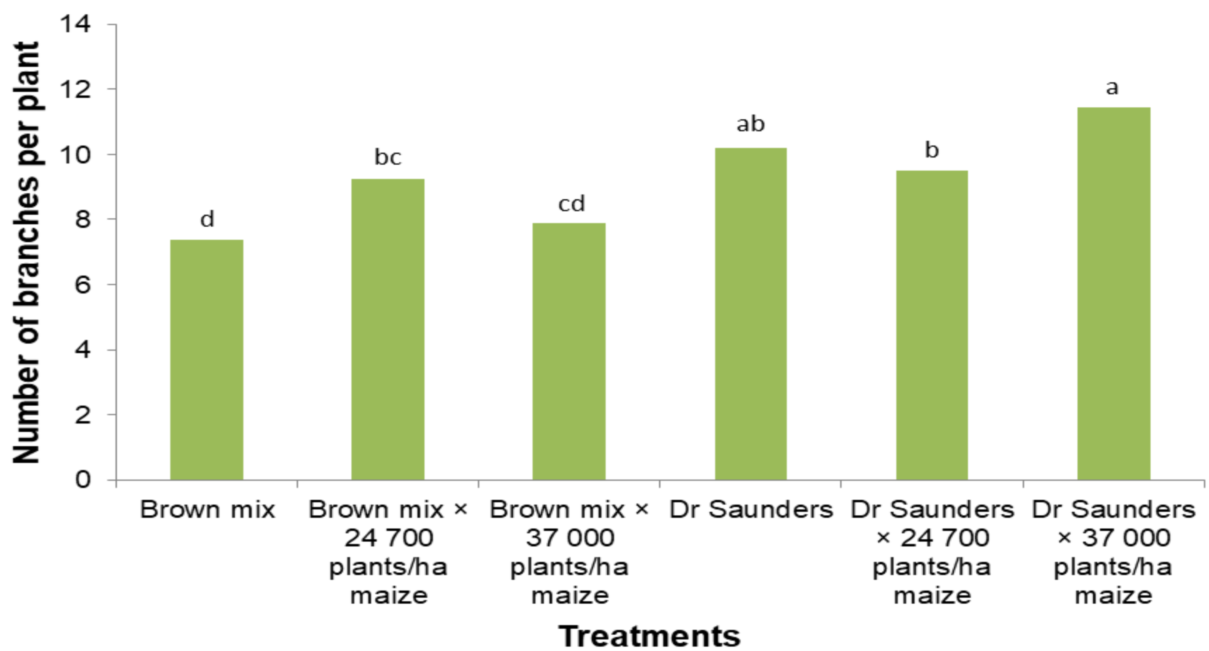

Figure 6: Number of branches per plant of two diverse cowpea varieties under different maize densities

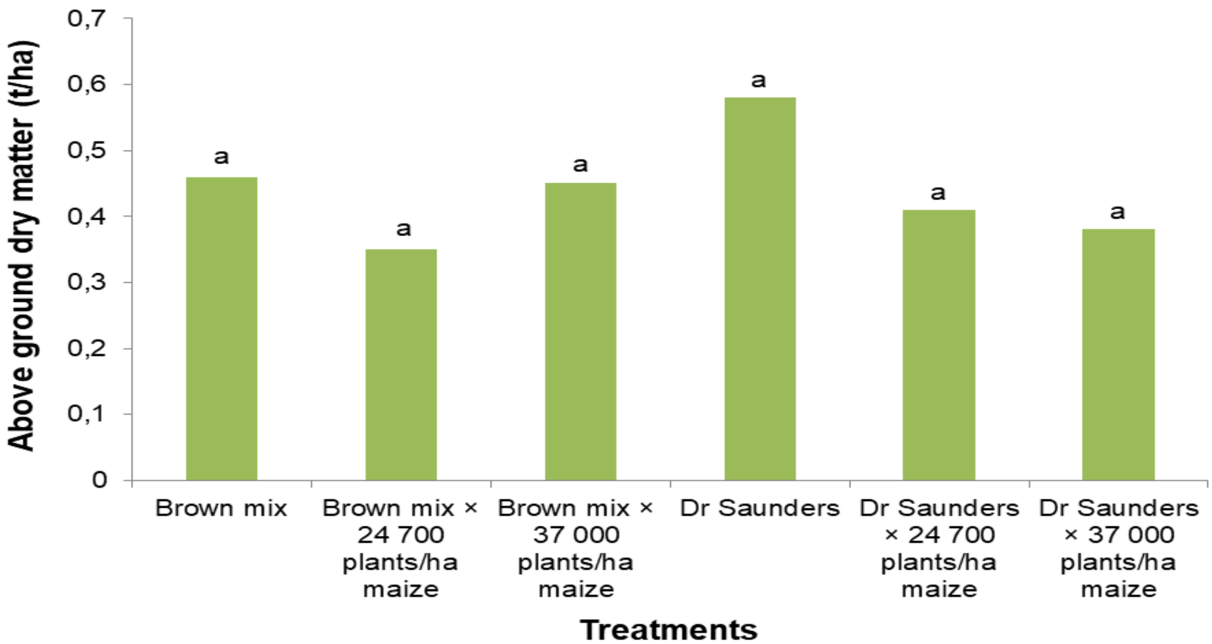

Figure 7: above ground dry matter of two cowpea varieties under different maize densities

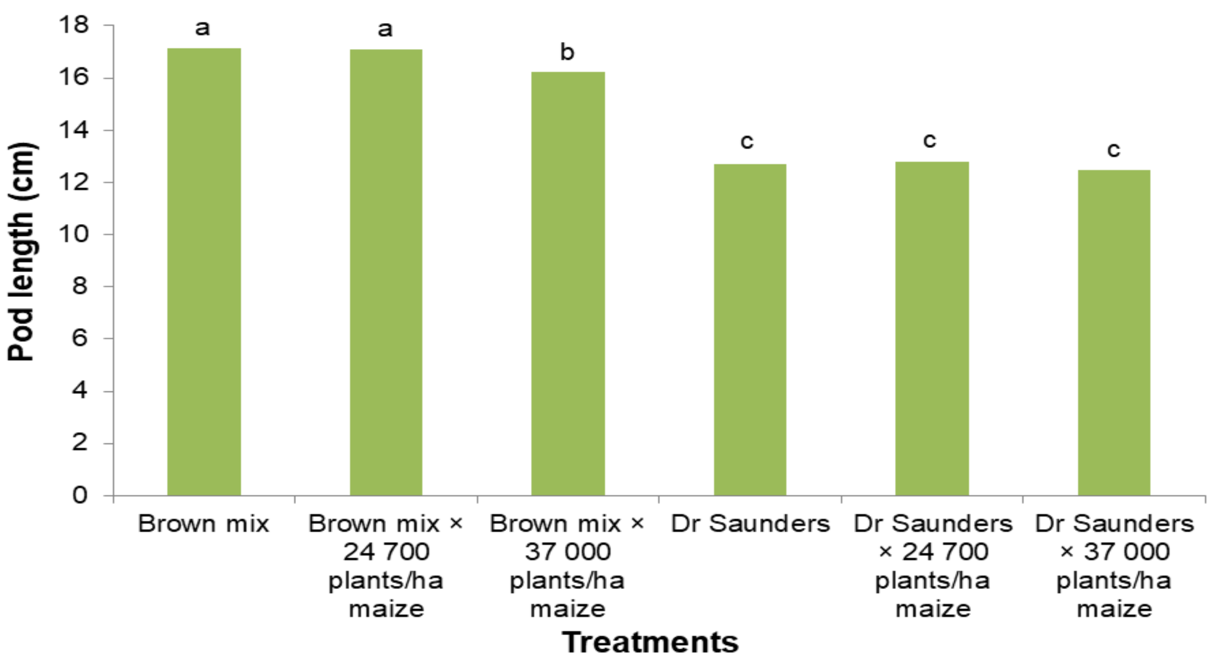

Figure 8: Pod length of two diverse cowpea varieties under different maize densities

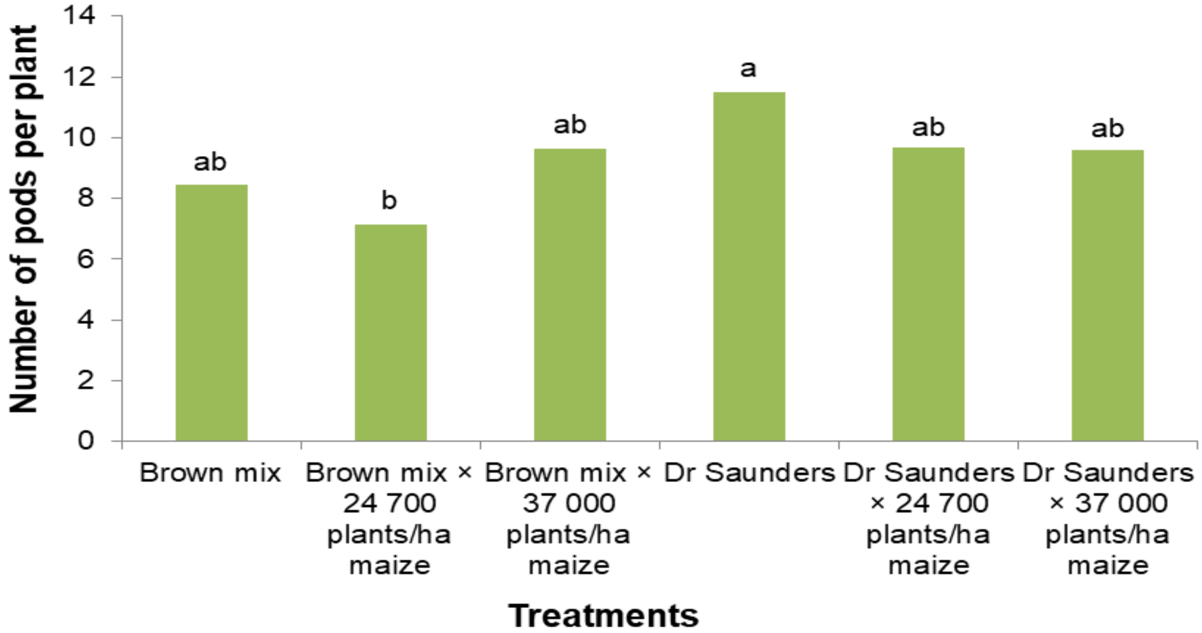

Figure 9: Number of pods per plant of two diverse cowpea varieties under different maize densities

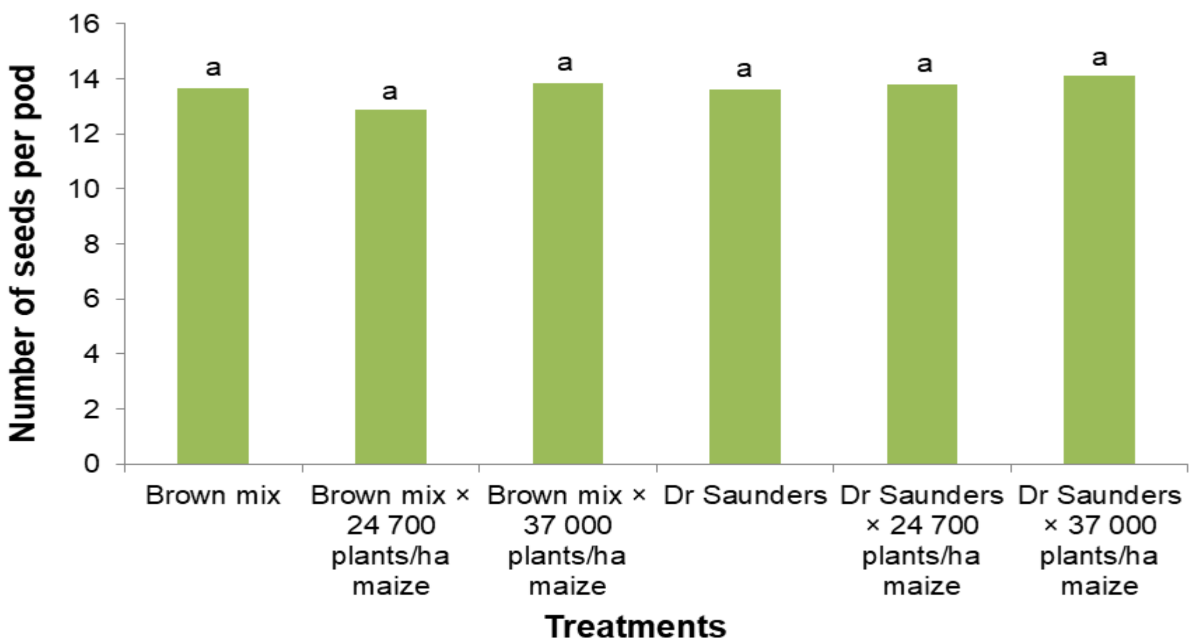

Figure 10: Number of seeds per pod of two diverse cowpea varieties under different maize densities

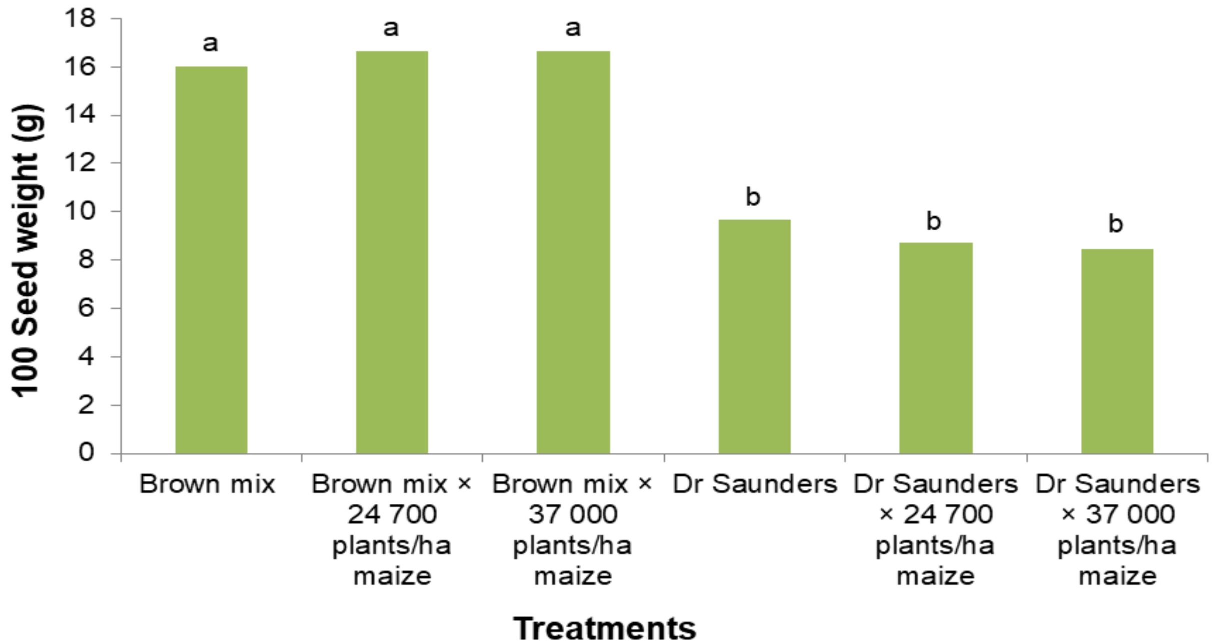

Figure 11: Hundred seeds weight of two diverse cowpea varieties under different maize densities

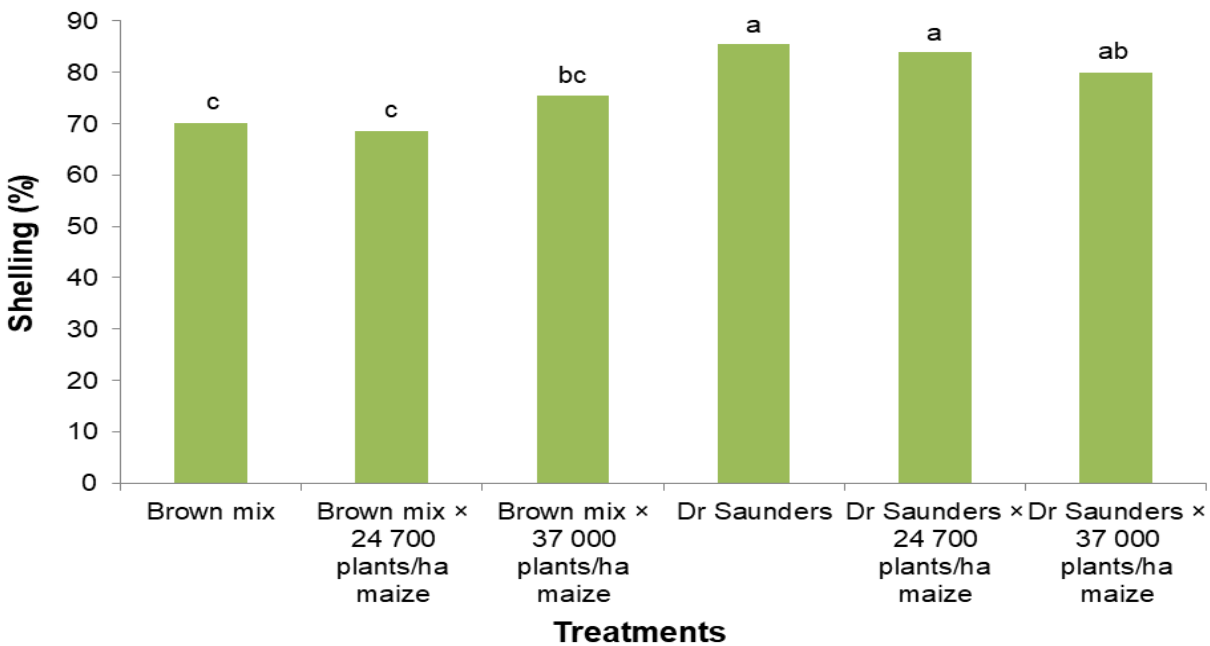

Figure 12: Shelling percentage of two diverse cowpea varieties under different maize densities

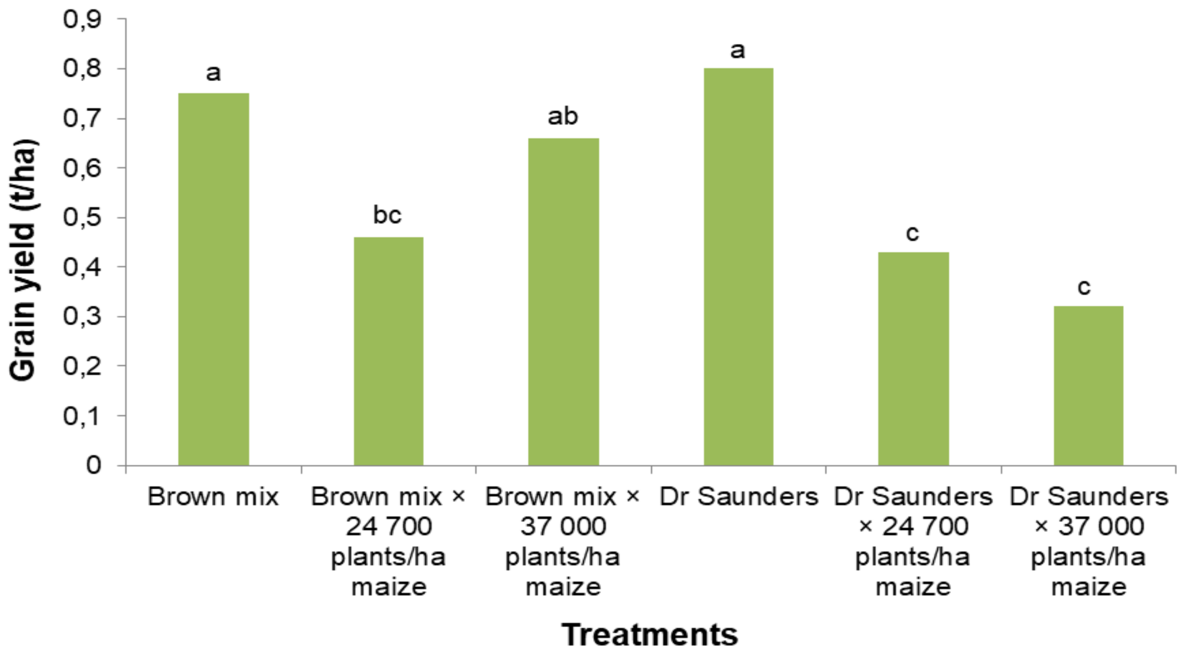

Figure 13: Grain yield of two diverse cowpea varieties under different maize densities

4.2 Growth parameters and yield components of maize as affected by maize densities and cowpea varieties

Non-significant interaction between maize densities and cowpea varieties was observed in the mean number of days to 50% tasseling (Figure14), number of days to 50% silking (Figure 15), plant height (cm) (Figure 16), cob length (cm) (Figure 18), number of cobs per plant (Figure 19), shelling percentage (Figure 20), and grain yield (t/ha) (Figure 21). Although the results shows no significant effect of maize density on plant height, intercropping 24 700 plants/ha maize with Dr Saunders reduced plant height by 12.1%. The analysis of variance showed that maize density and cowpea interaction increased above ground dry matter by 58% (Figure 17).

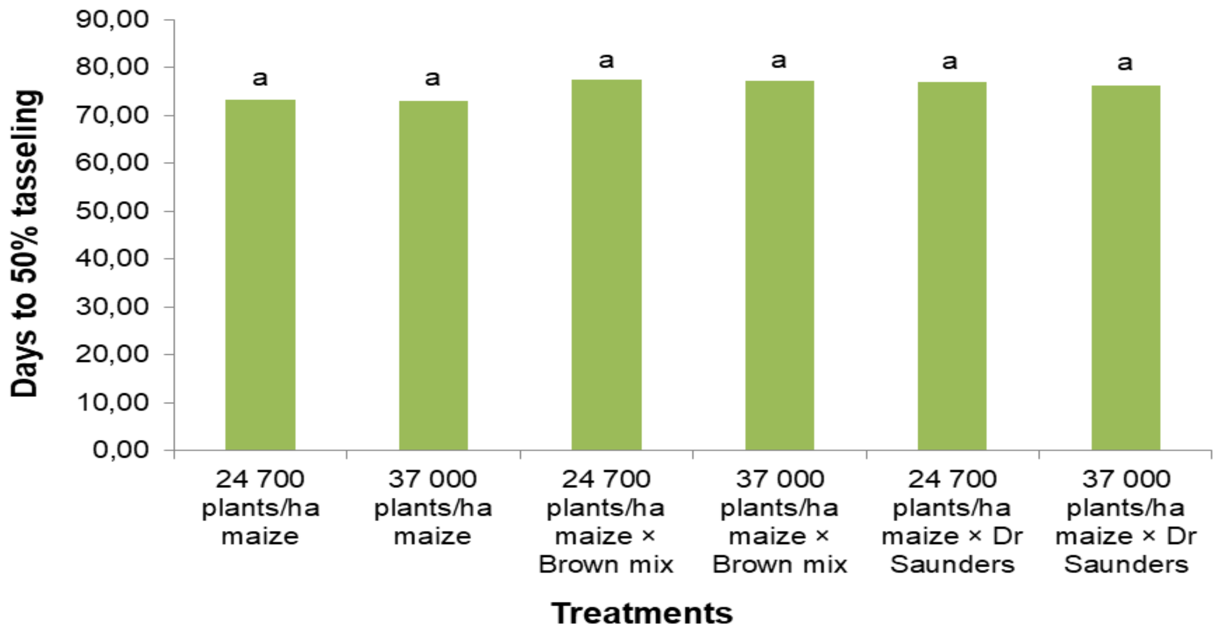

Figure 14: Number of days to 50% tasseling of maize under different maize densities and cowpea varieties

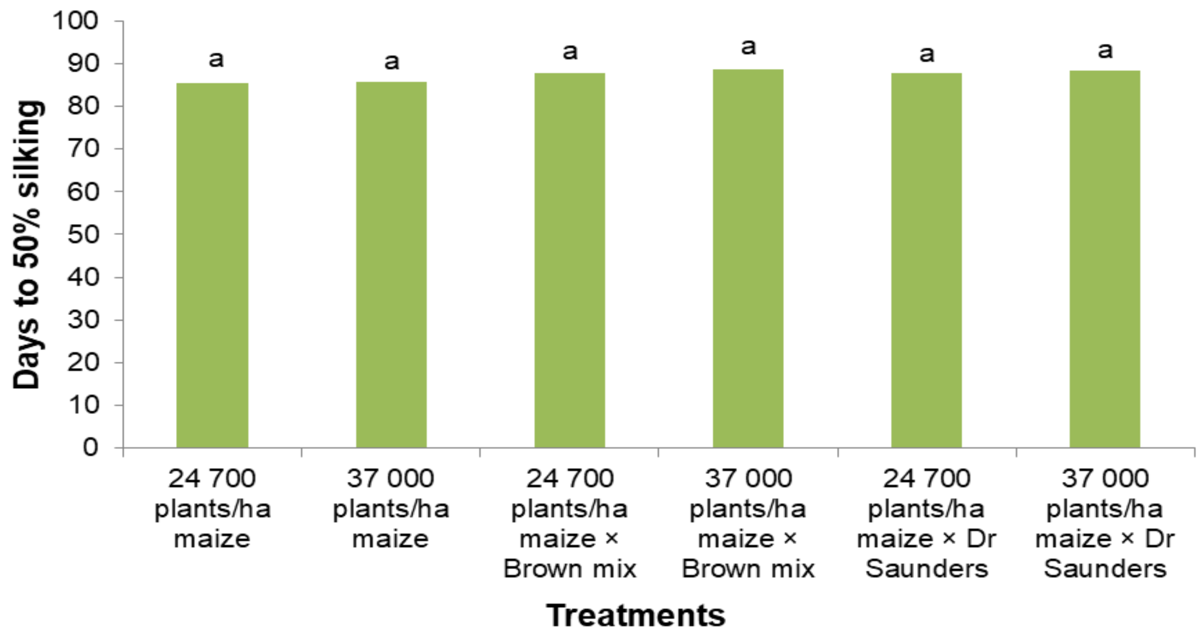

Figure 15: Number of days to 50% silking of maize under different maize densities and cowpea varieties

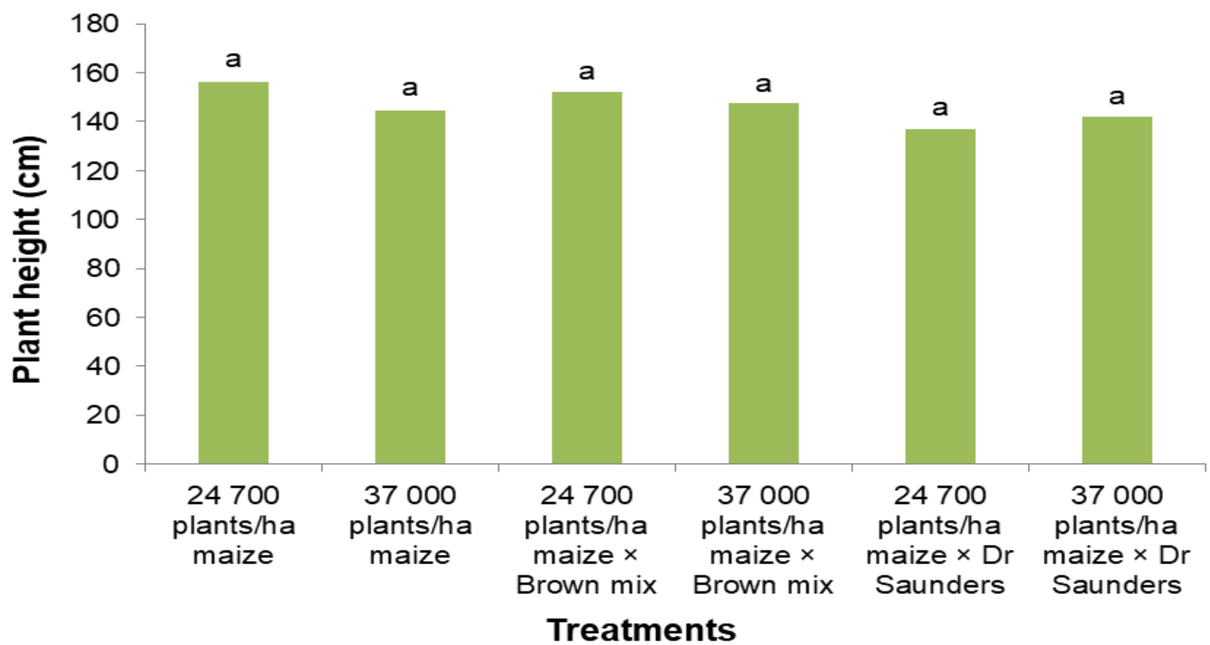

Figure 16: Plant height of maize under different maize densities and cowpea varieties

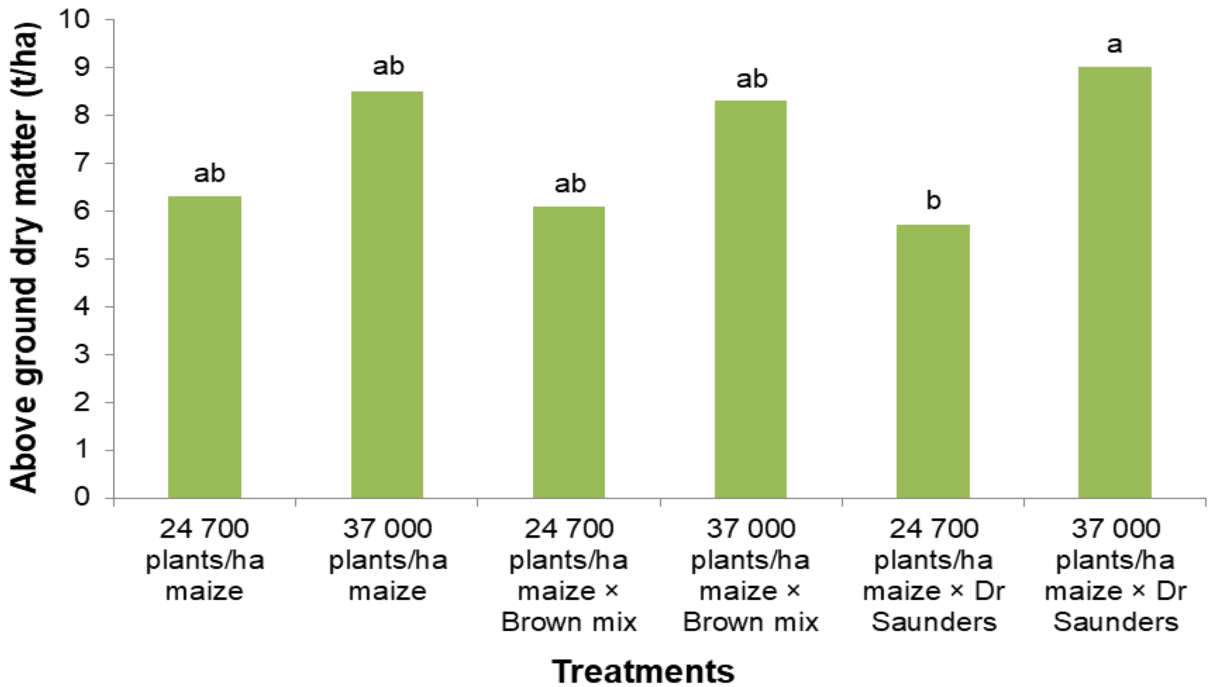

Figure 17: Above ground dry matter of maize under different maize densities and cowpea varieties

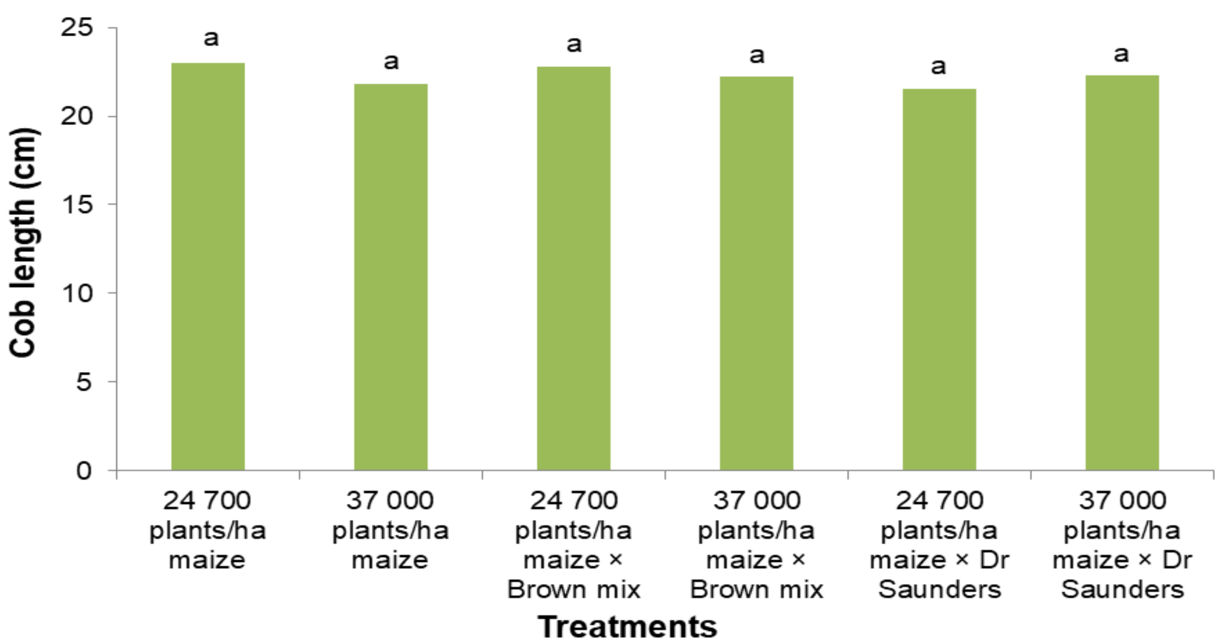

Figure 18: Cob length of maize under different maize densities and cowpea varieties

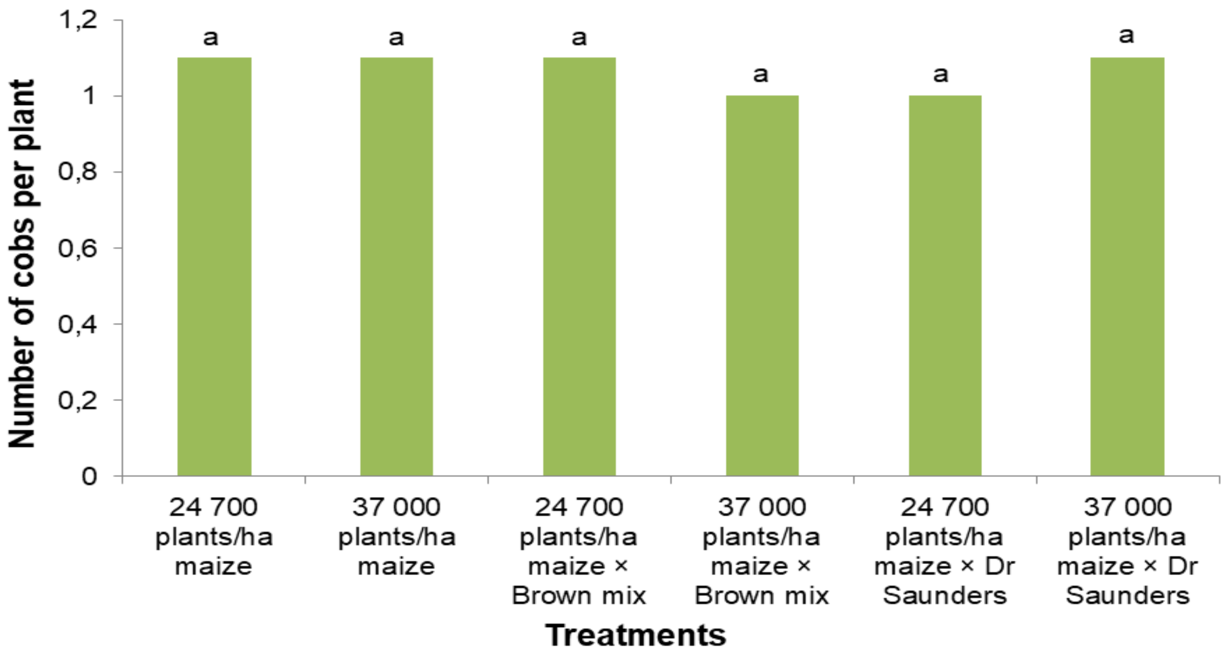

Figure 19: Number of cobs per plant of maize under different maize densities and cowpea varieties

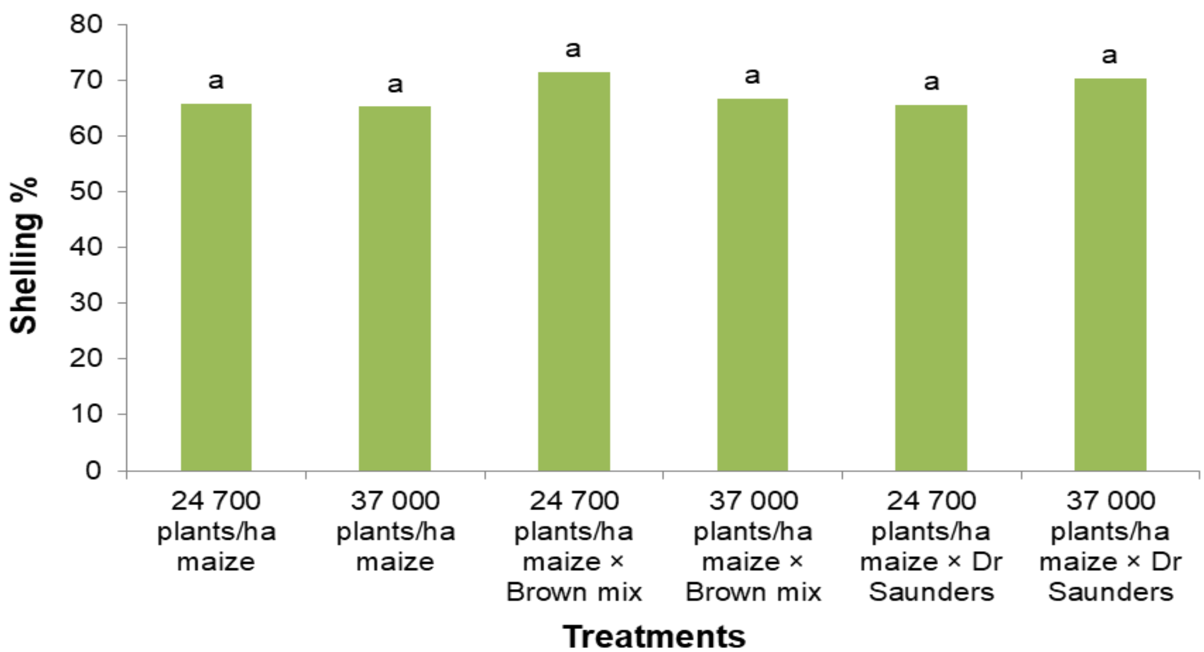

Figure 20: Shelling percentage of maize under different maize densities and cowpea varieties

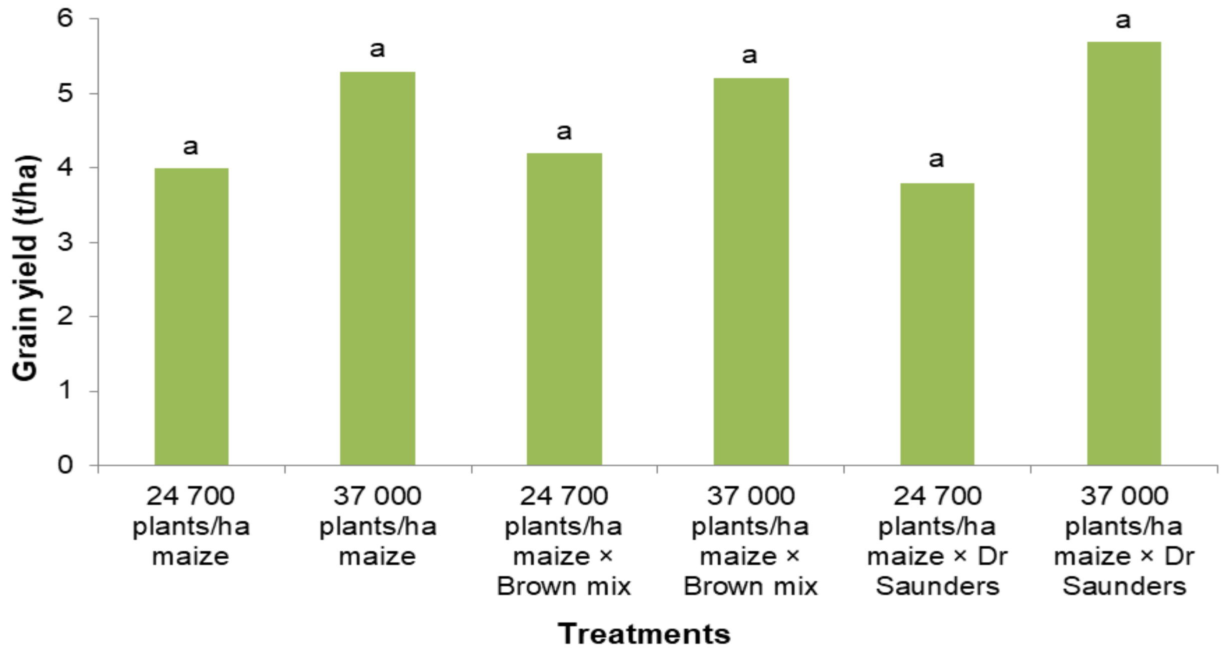

Figure 21: Grain yield of maize under different maize densities and cowpea varieties

4.3 Productivity of maize/cowpea intercrops system

The results showed that the partial land equivalent ratios (PLERs) of maize and cowpea ranged from 1.06 to 1.27, and 0.37 to 0.96 respectively, and maize/cowpea intercrop system achieved LER values ranging between 1.57 and 2.22 (Table 2).

Table 2: Productivity of maize/cowpea intercrop under different maize densities and cowpea varieties

Treatment	PLER maize	PLER cowpea	Total LER
24 700 plants/ha maize × Brown mix	1.19a	0.67ab	1.86a
37 000 plants/ha maize × Brown mix	1.27a	0.96a	2.22a
24 700 plants/ha maize × Dr Saunders	1.06a	0.54b	1.59a
37 000 plants/ha maize × Dr Saunders	1.2a	0.37b	1.57a
Mean	1.1769	0.6319	1.8088
P-Level	0.9799ns	0.0578ns	0.6787ns

Ns=Non-significant. Means followed by the same letter in the same column are not significantly different from each other at 5% level.

CHAPTER 5

DISCUSSION

5.1 Effect of maize planting densities on the growth parameters and yield components of cowpea varieties

An increase in the mean number of days to 50% flowering and 90% physiological maturity observed in this study concurred with the findings reported by Kamai *et al.* (2014), who indicated that days to maturity are always related to days to flowering, because when the plant flowers early is more likely to mature early as well. Legese *et al*. (2021) reported that intercropping delayed cowpea flowering and maturity, and attributed it to shading effect of maize under intercropping condition. Plant height is one of the plant biophysical parameters used as a critical indicator of growth and is essential for many applications, such as phenology tracking, crop health evaluation, and total yield prediction. A significant increase in plant height observed in this study is in line with what Alla *et al*. (2015) had reported and attributed it to, reduced intra and inter-specific competition for growth factors, such as light under intercropping systems and genetic make-up of cowpea varieties (Kelechukwu *et al*., 2007). The increase in the number of branches per plant ranged from 12 to 55% (Figure 6) might be due to plant height variations and each genotype's photosynthetic ability (El-Lateef *et al*., 2015).

Ndiso *et al*. (2017) reported that, maize-cowpea intercropping had a greater groundcover compared to sole cowpea, thus increasing moisture conservation by reducing water evaporation. In this study, the results obtained with regards to significant increase in canopy width are in agreement with the findings of Shamsi *et al*. (2011), who reported that high population density increased canopy width, and attributed it to less interspecific competition between the plants and better utilization of natural resources such as soil moisture. Leaf chlorophyll content is widely considered as an important plant physiological trait that determines the leaf photosynthetic capacity and hence crop growth (Li *et al.*, 2018). A significant increase in leaf chlorophyll content observed in the current study might be explained by the differences in genetic make-up of cowpea varieties and due to the absence of intra and interspecific competition between the combined crops. These results are similar to those of Ndiso *et al*. (2017), who found that maize/cowpea intercropping significantly reduced cowpea leaf chlorophyll content, and attributed it to aggressive nature of maize over cowpea, thereby suppressing cowpea plants.

According to the present study, the above-ground dry matter had the mean range of 0.58 to 0.35 t/ha, and the sole crops produced the highest above-ground dry matter than intercropped cowpea, indicating that the taller maize crop sheds cowpea plants. Consistent with this finding, El-Lateef *et al*. (2015) reported higher dry matter accumulation in sole compared to intercropped cowpea, and attributed it to the absence of interspecific competition which resulted in a high transmission of light under sole treatments. A significant reduction in cowpea pod length observed in this study might be explained by the genetic structure of cowpea varieties, and their responses to shading effect under different maize densities. Muoneke *et al*. (2012) reported similar results of lowest pod length when cowpea intercropped with the highest population of maize.

Number of pods per plant is considered as the primary determinant of yield in several types of legumes including cowpea (Ilunga, 2014). Previous studies have reported positive correlation between legumes number of pods per plant and grain yield (Wofia *et al*., 2013). A significant reduction in number of pods per plant observed in the current study is similar with what Ewansiha *et al*. (2015), Temesgen *et al*. (2015), and Muoneke *et al*. (2007) had reported and attributed it to, interspecific competition and negative impact of maize plant (C4 species) to grain legumes (C3 species). Lulie *et al*. (2016) also reported the highest number of pod per plants in sole cropping, due to higher Leaf Area Index in sole haricot bean which consequently increase photosynthetic capacity of the crops. In the present study, number of seeds per pod was not significantly influenced by interaction of maize density and cowpea varieties. In line with this results, Molatudi and Mariga (2012) reported non-significant effect of maize densities on the number of seeds per pod of common beans.

Previous study indicated that number of branches per plant and hundred seed weight are the most important determinant of seed yield at both genotypic and phenotypic levels (Meena *et al*., 2015). In the current study, the significant variations in hundred seed weight and shelling percentage among the two varieties might be explained by the fact that cowpea varieties differ in terms of seed size and endosperm which determined the seed weight (Nurgi *et al*., 2023). In agreement to this result, Abera *et al*. (2017) reported significant difference in hundred seed weight of bean, attributed it to genetic make-up of bean varieties. Molatudi and Mariga (2012) reported significantly lower shelling percentage for small white haricot bean at both 24 700 and 37 000 plants/ha maize compared to red speckled sugar bean at 24 700 plants/ha maize.

Feng *et al*. (2019) reported that, the optimization of plant population increases the rate of photosynthesis, light absorption, plant biomass and grain yield by both increasing plant density and decreasing row spacing. In this study, the maximum grain yield of 0.8 t/ha was observed from Dr Saunders at sole cropping while the lowest grain yield of 0.32 t/ha was recorded for intercropped Dr Saunders at 37 000 plants/ha maize. This yield reduction in an intercropping system might be explained by a large root system of maize, which compete more for soil moisture and nutrients. Ewansiha *et al*. (2015) had reported similar yield reduction of 63 % in cowpea when intercropped with 53,333 plants/ha maize, and attributed it to depressive effect of maize on cowpea crop. On the other hand, the response of grain yield to maize density differed with cowpea varieties. For an example, Brown mix recorded the highest grain yield when intercropped with maize at 37 000 plants/ha compared to Dr Saunders at both maize densities, suggesting that brown mix had a better tolerance levels to shading effect of taller maize plants than Dr Saunders.

5.2 Effect of maize planting densities and cowpea varieties on the growth parameters and yield components of maize

Non-significant effect of maize density and cowpea variety in the mean number of days to 50% tasseling and silking observed in the current study agreed with the findings of Muoneke *et al*. (2007) who reported non-significant influence of maize planting density and soybean variety on the days to 50% tasseling and silking of maize, and attributed it to absence of competitive effect of soybean variety and population density on maize crop. Plant height, cob length, number of cobs per plant, and shelling percentage were not influenced by interaction of maize density and cowpea variety. This might be explained by less aggressive nature of cowpea over maize. Muoneke *et al*. (2007) and Molatudi and Mariga (2012) reported similar findings of obtaining non-significant results between sole maize and when maize intercropped with soybean and dry bean, respectively.

Above ground dry matter was higher at 37 000 plants/ha compared to 24 700 plants/ha in both cropping systems with both cowpea varieties. A significant increase in above ground dry matter presented in this study concurred with the findings of Nthabiseng *et al*. (2015) who reported that, higher maize density of 37 000 plants/ha significantly increased maize biomass by 63.2 % compared to lower maize density of 18 500 plants/ha, and suggested lack of competition for growth factors such as light, moisture and nutrients. Morgado and Willey (2008) also reported that intercropped maize at 40 000 plants/ha achieved a significantly higher total biomass yield than maize plants at 20 000 plants/ha.

The interaction of maize densities and cowpea varieties shows that, the maize density of 37 000 plants/ha obtained higher grain yield than lower maize density of 24 700 plant/ha although there was no significant differences. The highest grain yield increment might be explained by increased dry matter observed under high maize population density. In agreement with this, Muoneke *et al*. (2007) reported the highest maize grain yield as the maize density increased from 38 000 to 53 000 plants/ha in maize/soybean intercropping.

5.3 Productivity of maize/cowpea intercrop as affected by different maize densities and cowpea varieties

The observed Land Equivalent Ratio in maize/cowpea intercropping shows the highest productivity and better utilisation of growth factors compared to maize and cowpea in sole cropping. Brown mix variety recorded the highest LER values of 2.22 at higher maize densities of 37 000 plants/ha. This clearly indicates that intercropping had a yield advantage of 57 % over sole cropping, and suggests that maize density and cowpea variety offered less competition to intercrop productivity. Muoneke *et al*. (2007) reported that maize/soybean intercropping had a yield advantage 63 % with LER values of 1.02 to 1.63, showing productive utilization of growth factors for plant growth and development.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

Conclusion

The current study showed that the interaction of maize densities and cowpea varieties delayed mean number of days to 50% flowering and 90% physiological maturity, thus decreased pod length, pods per plant, hundred seed weight, and grain yield of cowpea. However, the rate of reduction differed with cowpea varieties. Cowpea grain yields were considerably higher in sole cropping compared to intercropping. For intercropping, the highest grain yield was observed where Brown mix variety was intercropped with 37 000 plants/ha maize. The calculated Land Equivalent Ratio (LER) for Maize-cowpea intercropping was greater than one, clearly showed a favourable grain yield advantages for all intercrop combinations.

Recommendation

Therefore, the results suggest that the maximum of 37 000 plants/ha maize is suitable for maize/cowpea intercropping and should be adopted by farmers due to biological efficient and economic benefits. It is also recommended that, further research should be conducted to improve the productivity of the intercropping system by taking into account other production related aspects such as plant arrangement, diseases and pests in addition to component crop population densities.

REFERENCES

ABERA, R., WORKU, W. and BEYENE, S. 2017. Performance variation among improved common bean (*Phaseolus vulgaris* L.) genotypes under sole and intercropping with maize (*Zea mays* L.). *African Journal of Agricultural Research*, *12*(6), pp.397-405.

AGRICULTURAL RESEARCH COUNCIL-GRAIN CROP INSTITUTE (ARC-GCI). 2015. Maize Information Guide. Shereno Printers, South Africa.

AKPALU, W. and HASSAN, R.M. 2009. Climate variability and maize yield in South Africa: Results from GME and MELE Methods. Intl Food Policy Res Inst.

AKYAW, M.O., BAIDOO, P.K. and MOCHIAH, M.B. 2014. The effect of time harvest on the damage caused to Cowpea by storage bettle, *Callosobruchus maculatus* (FAB.) (*Coleoptera: Bruchidae*). *Global advanced research journal of agricultural science*, Vol. 3(11) pp. 351-355.

ALLA, W.H., SHALABY, E.M., DAWOOD, R.A. and ZOHRY, A.A. 2015. Effect of cowpea (*Vigna sinensis* L.) with maize (*Zea may*s L.) intercropping on yield and its components. *International Journal of Agricultural and Biosystems Engineering*, *8*(11), pp.1258-1264.

ASIWE, J.A.N. 2009. Insect mediated outcrossing and gene flow in Cowpea (*Vigna unguiculata* (L.) Walp): Implication for seed production and provision of containment structures for genetically transformed Cowpea. *African Journal of Biotechnology*, 8(2): 226-230.

ASIWE, J.A. 2017, OCTOBER. Determination of nutrient and mineral contents of some selected Cowpea lines for better quality trait improvement. In *Abstract, AGRI2017-Agriculture and Horticulture Conference, under subtitle-Food and Nutrients* (pp. 2-4).

AYELE, H.M., 2020. Evaluation of the effect of maize-legume intercropping on soil moisture improvement in arid area of Bena-Tsemay district, South omo zone, Southern

Ethiopia. *International Journal of Agricultural Research, Innovation and Technology*, *10*(1), pp.80-86.

AYO-VAUGHAN, M.A., ARIYO, O.J. and ALAKE, C.O. 2013. Combining ability and genetic components for pod and seed traits. *Italian Journal of Agronomy*. Vol. 8. No.10. pp. 73-78.

BALOYI, R.T., BELETE, A., HLONGWANE, J.J. and MASUKU, M.B. 2012. Technical efficiency in maize production by small-scale farmers in Ga-Mothiba of Limpopo Province, South Africa. *African Journal of Agricultural Research* 7,pp. 478-5482.

BEDOUSSAC, L., JOURNET, E.P., HAUGGAARD-NIELSEN, H., NAUDIN, C., CORRE-HELLOU, G., JENSEN, E.S., PRIEUR, L. and JUSTES, E. 2015. Ecological principles underlying the increase of productivity achieved by cereal-grain legume intercrops in organic farming. A review. *Agronomy for sustainable development*, *35*, pp.911-935.

BELFIELD, S. and BROWN, C. 2008. Field Crop Manual: Maize-A guide to upland production in Cambodia. NSW department of primary industries. *New South Wales, Australia*.

BLANCO-CANQUI, H., SHAVER, T.M., LINDQUIST, J.L., SHAPIRO, C.A., ELMORE, R.W., FRANCIS, C.A. and HERGERT, G.W. 2015. Cover Crops and Ecosystem Services: Insights from Studies in Temperate Soils. *Agronomy journal*, *107*(6), pp.2449-2474.

BOLARINWA, K.A., OGUNKANMI, L.A., OGUNDIPE, O.T., AGBOOLA, O.O. and AMUSA, O.D. 2021. An Investigation of Cowpea Production Constraints and Preferences among Smallholder Farmers in Nigeria. *GeoJournal*, pp.1-13.

BOUKAR, O., BELKO, N., CHAMARTHI, S., TOGOLA, A., BATIENO, J., OWUSU, E., HARUNA, M., DIALLO, S., UMAR, M.L., OLUFAJO, O. and FATOKUN, C. 2018. Cowpea (*Vigna unguiculata*): Genetics, Genomics and Breeding. *Plant Breeding*, *138*(4), pp.415-424.

BRUNS, H.A. 2011. Comparisons of single-row and twin-row soybean production in the mid-south. *Agronomy Journal*, *103*(3), pp.702-708.

COBBINAH, F.A., ADDO-QUAYE, A.A. and ASANTE, I.K. 2011. Characterization, evaluation and selection of Cowpea (*Vigna unguiculata* (L.) Walp) accessions with desirable traits from eight regions of Ghana. *Journal of Agricultural and Biological Science, 6*(7), pp.21-32.

DAHMARDEH, M., GHANBARI, A., SYASAR, B. and RAMROUDI, M. 2009. Effect of intercropping maize (*Zea mays* L.) with Cowpea (*Vigna unguiculata* L.) on green forage yield and quality evaluation. *Asian journal of plant sciences*, *8*(3), pp.235-239.

DAHMARDEH, M., GHANBARI, A., SYAHSAR, B.A. and RAMRODI, M. 2010. The role of intercropping Maize (*Zea mays L.*) and Cowpea (*Vigna unguiculata L.*) on yield and soil chemical properties. *African Journal of Agricultural Research*, *5*(8), pp.631-636.

DAHMARDEH, M. 2013. Intercropping two varieties of maize (*Zea mays* L.) and peanut (*Arachis hypogaea* L.): biomass yield and intercropping advantages. *International Journal of Agriculture and Forestry, 3*(1), pp.7-11.

DARIUSH, M., AHAD, M. and MEYSAM, O. 2006. Assessing the land equivalent ratio (LER) of two corn [Zea mays L.] varieties intercropping at various nitrogen levels in Karaj, Iran. *Journal of Central European Agriculture*, *7*(2), pp.359-364.

DAY, P.R. 1965. Particle fractionation and particle-size analysis. *Methods of Soil Analysis: Part 1 Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling*, *9*, pp.545-567.

DEPARTMENT OF AGRICULTURE, FORESTRY AND FISHERIES (DAFF). 2011. Directrorate Plant Production. Production guide for Cowpea.

DU PLESSIS J. 2003. *Maize production* (pp. 1-38). Pretoria, South Africa: Department of Agriculture.

DWIVEDI, A., DEV, I., KUMAR, V., YADAS, R.S., YADAV, M., GUPTA, D., SINGH, A. and TOMAR. S. 2015. Potential role of maize-legume intercropping systems to improve soil fertility status under smallholder farming systems for sustainable agriculture in India. *International Journal of Life Sciences Biotechnology and Pharma Research, 4*(3), p.145.

ECKERT, D.J. 1988. Recommended pH and lime requirement tests. *Recommended chemical soil test procedures for the north central region. North central regional publication*, *221*, pp.6-8.

EGBE, M.O. and IDOKO, J.A. 2012. Evaluation of pigeon pea genotypes for intercropping with maize and sorghum in southern Guinea Savanna: Economic benefits. *International journal of Agriculture and forestry*, *2*(1), pp.108-114.

EGESA, A.O., NJAGI, S.N. and MUUI, C.W. 2016. Effect of facilitative interaction of sorghum-cowpea intercrop on sorghum growth rate and yields. *Journal of Environmental and Agricultural Sciences*, *9*, pp.50-58.

EGHO, E.O. and ENUJEKE, E.C. 2012. Effect of native soap on insect pests and grain yield of Cowpea (*Vigna unguiculata (L.)* Walp) in Asaba and Abraka during the Late Cropping Season in Delta State, Nigeria. *Sustainable Agriculture Research*, *1*(526-2016-37845).

EL-LATEEF, A., EL-SALAM, A., EL-HABBASHA, S.F. and AHMED, M.A. 2015. Effect of maize-cowpea intercropping on light interception, yield and land use efficiency. *International Journal of ChemTech Research*, *8*(6), pp.556-564.

EWANSIHA, S.U., KAMARA, A.Y. and CHIEZEY, U.F. 2014. Cowpea response to planting date under different maize maturity types in West African Sudan savannah. *Journal of Tropical Agriculture*, *52*(2), pp.139-144.

EWANSIHA, S.U., KAMARA, A.Y., CHIEZEY, U.F. and ONYIBE, J.E. 2015. Performance of Cowpea grown as an intercrop with maize of different populations. *African Crop Science Journal*, *23*(2), pp.113-122.

FAOSTAT, 2017. Food and Agriculture Organization of the United Nations. In: FAOSTAT Data- base Gateway.

FAO. 2012. Food and Agriculture Organization of the United Nations. Production. Cited February 12, 2014.

FEED THE FUTURE. 2014. Feed the Future Progress Report: Accelerating Progress to End Hunger, Washington DC.

FENG, L., RAZA, M.A., CHEN, Y., KHALID, M.H.B., MERAJ, T.A., AHSAN, F., FAN, Y., DU, J., WU, X., SONG, C., LIU, C., BAWA, G., ZHANG, Z., YUAN, S., YANG, F. and Yang, W. 2019. Narrow-wide row planting pattern improves the light environment and seed yields of intercrop species in relay intercropping system. *PloS one*, *14*(2), p.e0212885.

HARDEV, C. 2016. Performance of farmers' pigeon pea [*Cajanus cajan* L. Millsp.] varieties: opportunities for sustained productivity and dissemination of varieties. *International Journal of Agriculture Sciences, ISSN*, pp.0975-3710.

HARUNA, A., KOMBIOK, J.M., MOHAMED, A.M., SARKODIE-ADDO, J., LARBI, A. and RAHMAN, N.A. 2018. Profitability of Cowpea intercropped with maize in West Africa Guinea savanna. *Journal of Agricultural Science*, *10*(11).

HATFIELD, J.L. and PRUEGER, J.H. 2015. Temperature extremes: Effect on plant growth and development. *Weather and climate extremes*, *10*, pp.4-10.

HUGAR, H.Y. and PALLED, Y.B. 2008. Effect of intercropping vegetables on maize associated with weeds in maize-vegetable intercropping systems. *Karnataka Journal of Agricultural Sciences*, *21*(2), pp.159-161.

INTERNATIONAL CROPS RESEARCH INSTITUTE FOR SEMI-ARID TROPIC (ICRISAT). 2010. Lessons of Tropical Legumes II: Second Annual Review and Planning Meeting. Bamako, Nairobi, Kenya, ICRISAT.

ILUNGA, K., 2014. *Physiological responses of cowpea (Vigna unguiculata) to water stress under varying water regimes* (Doctoral dissertation).

IQBAL, M.A., HAMID, A., AHMAD, T., SIDDIQUI, M.H., HUSSAIN, I., ALI, S., ALI, A. and AHMAD, Z. 2018. Forage sorghum-legumes intercropping: effect on growth, yields, nutritional quality and economic returns. *Bragantia*, *78*, pp.82-95.

ISLAM, R., DIDENKO, N. and SHERMAN, B. 2021. Cover crops and agroecosystem services. *Cover crops and sustainable agriculture*, pp.1-15.

JACKSON, M.L. 1967. Soil chemical analysis prentice. *Hall of India Private Limited, New Delhi*, *498*(1).

JAMSHIDI, K., YOUSEFI, A.R. and OVEISI, M. 2013. Effect of Cowpea (*Vigna unguiculata*) intercropping on weed biomass and maize (*Zea mays* L.) yield. *New Zealand Journal of Crop and Horticultural Science, 41*(4), pp.180-188.

JAT, S.L, SHIVAY, Y.S., PARIHAR, C.M. and MEENA, H.N. 2012. Evaluation of summer legumes for their economic feasibility, nutrient accumulation and soil fertility. *Journal of Food Legumes*, *25*(3), pp.240-243.

JAVANMARD, A., NASAB, A.D.M., JAVANSHIR, A., MOGHADDAM, M. and JANMOHAMMADI, H. 2009. Forage yield and quality in intercropping of maize with different legumes as double-cropped. *J. Food Agric. Environ*, *7*(1), pp.163-166.

JENSEN, E.S., CARLSSON, G. and HAUGGAARD-NIELSEN, H. 2020. Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: A global-scale analysis. *Agronomy for Sustainable Development*, *40*, pp.1-9.

KABULULU, M.S. 2008. Cowpea (*Vigna unguiculata*) variety mixtures for stable and optimal leaf and seed yields when intercropped with maize in Central Tanzania. *MSc: Georg-August-Universität, Göttingen, Germany*.

KAMAI, N., GWORGWOR, N.A. and SODANGI, I.A. 2014. Morphological basis for yield differences among cowpea varieties in the Sudan Savanna zone of Nigeria. *Journal of Agriculture and Veterinary Science*, *7*(12), pp.49-53.

KARIAGA, B.M. 2004. Intercropping maize with cowpeas and beans for soil and water management in Western Kenya. In *Proceedings of the 13th international soil conservation organization conference* (pp. 1-5).

KELECHUKWU, N.E., ADEWALE, M.O. and EZEKIAL, A.A. 2007. Aluminium, influence on performance of some cowpea (*Vigna unguiculata*) varieties on Nigeria Alfisol. *World J. Agric. Sci*, *3*(4), pp.512-522.

KINAMA, J.M., HABINEZA, J.P. and JEAN PIERRE, H.M. 2018. A review on advantage of cereals-legumes intercropping system: Case of promiscuous soybeans varieties and maize. *International Journal of Agronomy and Agricultural Research. 12*(6), pp.155-165.

KUMAR, D., GOLAKIA, B.A. and PARAKHIA, A.M. 2017. Characterization and Genetic Diversity of Cowpea (*Vigna unguiculata* L.) genotypes linked to Cowpea yellow mosaic virus. *Legume Research- An International Journal 41(1), pp.27-33.*

KUO, S. 1996. Phosphorus. p. 869-919. In D.L. Sparks (ed.) Methods of Soil Analysis. Part 3. Chemical Methods. Soil Science Society of America Book Ser. 5. SSSA and ASA, Madison, Wisconsin.

LAYEK, J., ANUP, D., RAMKRUSHNA, G.I., VENKATESH, A., VERMA, B.C., ROY, A., PANWAR, A.S. and NGACHAN, S.V. 2014. Improving productivity of *jhum* rice through agronomic management practices. In *Book of abstracts. National seminar on shifting cultivation*.

LAYEK, J., DAS, A., MITRAN, T., NATH, C., MEENA, R.S., YADAV, G.S., SHIVAKUMAR, B.G., KUMAR, S. and LAL, R. 2018. Cereal+ legume intercropping: An option for improving productivity and sustaining soil health. *Legumes for soil health and sustainable management*, pp.347-386.

LEGESE, S., TOLEMARIAM, T. and DESALEGN, K. 2021. Agronomic Performance of Different Cowpea (*Vigna unguiculata* (L.) walp) Varieties Cultivated as Sole and Intercropped with Maize in Chewaka District, South West Ethiopia. *Agriculture, Forestry and Fisheries*, *10*(2), p.75.

LEGWAILA, G.M., MAROKANE, T.K. and MOJEREMANE, W. 2012. Effects of Intercropping on the Performance of Maize and Cowpeas in Botswana, *International Journal of Agriculture and Forestry, 2*(6), pp. 307-310.

LI, Y., HE, N., HOU, J., XU, L., LIU, C., ZHANG, J., WANG, Q., ZHANG, X. and WU, X. 2018. Factors influencing leaf chlorophyll content in natural forests at the biome scale. *Frontiers in Ecology and Evolution*, *6*, p.64.

LULIE, B., WORKU, W. and BEYENE, S. 2016. Determinations of haricot bean (*Phaseolus vulgaris* L.) planting density and spatial arrangement for staggered intercropping with maize (*Zea mays* L.) at Wondo Genet, Southern Ethiopia. *Acad. Res. J. Agric. Sci. Res*, *4*(6), pp.297-320.

MAITRA, S. and RAY, D.P. 2019. Enrichment of biodiversity, influence in microbial population dynamics of soil and nutrient utilization in cereal-legume intercropping systems: A Review. *International Journal of Bioresource Science*, *6*(1), pp.11-19.

MAITRA, S., SHANKAR, T. and BANERJEE, P. 2020. Potential and advantages of maize-legume intercropping system. *Maize-Production and Use*, pp.1-14.

MAKGOGA, M.W. 2013. Influence of lablab (*Lablab purpureus*) and dry bean (*Phaseolus vulgaris*) intercrops with maize (*Zea mays l.*) on maize grain yield and soil fertility status. Thesis, Master of Science. University of Limpopo, South Africa, pp 4-10.

MARK, W.A. and CHANNYA, K.F. 2016. Control of Colletotrichum capsica (Pathogen of Brown Blotch of Cowpea in the Savanna) Using Garlic Oil. *International Journal of Research*, *22*.

MASENYA, T.B. 2016. Evaluation of introduced cowpea breeding lines in South Africa. Master of Science thesis. Retrieved from ulspace.ul.ac.za.

MASVAYA, E.N., NYAMANGARA, J., DESCHEEMAEKER, K. and GILLER, K.E. 2017. Is maize-cowpea intercropping a viable option for smallholder farms in the risky environments of semi-arid southern Africa? *Field Crops Research*, *209*, pp.73-87.

MATHEWS, C. 2012. Cowpeas. Technology Research Development Publication. Lowveld Research Unit. Department of Agriculture. Rural Development and Land Administration. Nelspruit, Mpumalanga.

MATSUOKA, Y., VIGOUROUX, Y., GOODMAN, M.M., SANCHEZ, G.J., BUCKLER, E. and DOEBLEY, J. 2002. A single domestication for maize shown by multilocus microsatellite genotyping. *Proceedings of the National Academy of Sciences*, *99*(9), pp.6080-6084.

MATUSSO, J.M.M., MUGWE, J.N. and MUCHERU-MUNA, M. 2012.Potential role of cereal-legume intercropping systems in integrated soil fertility management in smallholder farming systems of sub Saharan Africa. *Research Journal of Agriculture and Environmental Management*, *3*(3), pp.162-174.

MEENA, R.S., YADAV, R.S., MEENA, H., KUMAR, S., MEENA, Y.K. and SINGH, A. 2015. Towards the current need to enhance legume productivity and soil sustainability worldwide: a book review. J Clean Prod 104: 513–515.

MOBASSER, H.R., VAZIRIMEHR, M.R. and RIGI, K. 2014. Effects of intercropping on resources use weed management and forage quality. *International Journal of Plant, Animal and Environmental Sciences*, *4*(2), pp.706-713.

MOELETSI, M.E. and WALKER, S. 2012. Assessment of agricultural drought using a simple water balance model in the Free State Province of South Africa. *Theoretical and applied climatology, 108, pp.425-450.*

MOELETSI, M.E., TONGWANE, M. and TSUBO, M. 2016. The study of frost occurrence in Free State Province of South Africa. *Advances in Meteorology*, *2016*.

MOLATUDI, R. L. and MARIGA, I. K. 2012. Grain yield and biomass response of a maize/dry bean intercrop to maize density and dry bean variety. *African Journal of Agricultural Research*, *7*(20), pp.3139-3146.

MORGADO, L.B. and WILLEY, R.W., 2008. Optimum plant population for maize-bean intercropping system in the Brazilian semi-arid region. *Scientia Agricola*, *65*, pp.474-480.

MPANDELI, S., NESAMVUNI, E. and MAPONYA, P. 2015. Adapting to the Impacts of Drought by Smallholder Farmers in Sekhukhune District in Limpopo Province, South Africa. *Journal of Agricultural Science*, *7*(2), p.115.

MUONEKE, C.O., NDUKWE, O.O., UMANA, P.E., OKPARA, D.A. and ASAWALAM, D.O., 2012. Productivity of vegetable cowpea (*Vigna unguiculata* (L.) Walp) and maize (*Zea mays* L.) intercropping system as influenced by component density in a humid tropical zone of South-eastern Nigeria. *International Journal of Agriculture and Rural Development*, *15*(1), pp.835-847.

MUONEKE, C.O., OGWUCHE, M.A.O. and KALU, B.A. 2007. Effect of maize planting density on the performance of maize/soybean intercropping system in a guinea savannah agroecosystem. *African Journal of Agricultural Research*, *2*(12), pp.667-677.

MUONI, T., KOOMSON, E., ÖBORN, I., MAROHN, C., WATSON, C.A., BERGKVIST, G., BARNES, A., CADISCH, G., and DUNCAN, A. 2020. Reducing soil erosion in smallholder farming systems in East Africa through the introduction of different crop types. *Experimental Agriculture*, *56*(2), pp.183-195.

MUHAMMAD, M., LEITCH, M.H., IQBAL, M. and SAHI, F.U.H. 2010. Spatial arrangement affects growth characteristics of barley-pea intercrops. *International Journal of Agriculture and Biology*, *12*(5), pp.685-690.

NAHER, Q., KARIM, S.M.R. and BEGUM, M. 2019. Performance of Legumes on Weed Suppression with Hybrid Maize Intercropping. *Bangladesh Agronomy Journal*, *21*(2), pp.33-44.

NAMATSHEVE, T., CARDINAEL, R., CORBEELS, M. and CHIKOWO, R. 2020. Productivity and biological N2-fixation in cereal-cowpea intercropping systems in sub-Saharan Africa. A review. *Agronomy for Sustainable Development*, *40*, pp.1-12.

NDAMANI, F. and WATANABE, T. 2015. Farmers' perceptions about adaptation practices to climate change and barriers to adaptation: A micro-level study in Ghana. *Water*, *7*(9), pp.4593-4604.

NDISO, J.B., OLUBAYO, F.M. and SAHA, H.M. 2017. Effect of cropping system on soil moisture content, canopy temperature, growth and yield performance of maize and Cowpea. *International Journal of Agricultural Sciences*, *7*(3), pp.1271-1281.

NEZOMBA, H., MTAMBANENGWE, F., CHIKOWO, R. and MAPFUMO, P. 2015. Sequencing integrated soil fertility management options for sustainable crop intensification by different categories of smallholder farmers in Zimbabwe. *Experimental Agriculture*, *51*(1), pp.17-41.

NGWIRA, A.R., AUNE, J.B. and MKWINDA, S. 2012. On-farm evaluation of yield and economic benefit of short term maize-legume intercropping systems under conservation agriculture in Malawi. *Field crops research*, *132*, pp.149-157.

NICHOLLS, C., ALTIERI, M.A. and VAZQUEZ, L. 2016. Agroecology: Principles for the conversion and redesign of farming systems. J Ecosyst Ecography S5: 010.

NKOMO, G.V., SEDIBE, M.M. and MOFOKENG, M.A., 2021. Production constraints and improvement strategies of cowpea (*Vigna unguiculata* L. Walp.) genotypes for drought tolerance. *International Journal of Agronomy*, *2021*, pp.1-9.

NNDWAMBI, F.H. 2015. Evaluation of dryland maize/pigeonpea intercropping under variable phosphorus application rates. M Agric Thesis. University of Limpopo, South Africa.

NTHABISENG, R.T., IRVINE, M.K. and MOSHIBUDI, M.P. 2015. Response of a maize or dry bean intercrop to maize density and dry bean arrangement under rainfed conditions. *Int. J. Agron. Agric. Res*, *6*, pp.18-29.

NTOBELA, Z. 2012. Growth and yield responses of cowpeas *(Vigna unguiculata L.)* to water stress and defoliation. MSc thesis, University of KwaZulu-Natal, Pietermaritzburg, South Africa.

NURGI, N., TANA, T., DECHASSA, N., TESSO, B. and ALEMAYEHU, Y. 2023. Effect of spatial arrangement of faba bean variety intercropping with maize on yield and yield components of the crops. *Heliyon*.

NYASASI, B.T. and KISETU, E. 2014. Determination of land productivity under maize-cowpea intercropping system in agro-ecological zone of Mount Uluguru in Morogoro, Tanzania. *Global Journal of Agricultural Sciences*, *2*(2), pp.147-157.

ODGAARD, M.V., BØCHER, P.K., DALGAARD, T. and Svenning, J.C. 2011. Climate and non-climatic drivers of spatiotemporal maize-area dynamic across the northern limit for maize production – A case study from Denmark. *Agriculture, Ecosystems and Environment*, *142*(3-4), pp.291-302.

ODHIAMBO, J.J. and NEMADODZI, L.E. 2007. Soil fertility management practices by smallholder farmers in Vhembe District, Limpopo Province. *South African Journal of Agricultural Extension*, *36*, pp.53-61.

PEKSEN, E. and GULUMSER, A. 2013. Intercropping Efficiency and Yields of Intercropped Maize (*Zea mays* L.) and Dwarf Bean (*Phaseolus vulgaris* L.) affected by planting arrangements, planting rates and relative time of sowing. *International Journal of Current Microbiology and Applied Sciences*, *2*(11), pp.290-299.

PUNYALUE, A., JAMJOD, S. and RERKASEM, B. 2018. Intercropping maize with legumes for sustainable highland maize production. *Mountain Research and Development*, *38*(1), pp.35-44.

RAZA, M.A., BIN KHALID, M.H., ZHANG, X., FENG, L.Y., KHAN, I., HASSAN, M.J., AHMED, M., ANSAR, M., CHEN, Y.K., Fan, Y.F. and YAND, F. 2019. Effect of planting patterns on yield, nutrient accumulation and distribution in maize and soy-bean under relay intercropping systems. *Scientific reports*, *9*(1), p.4947.

REN, Y., LIU, J., WANG, Z. and ZHANG, S. 2016. Planting density and sowing proportions of maize-soybean intercrops affected competitive interactions and water-use efficiencies on the Loess Plateau, China. *European Journal of Agronomy*, *72*, pp.70-79.

RIVAS, R., FALCÃO, H.M., RIBEIRO, R.V., MACHADO, E.C., PIMENTEL, C. and SANTOS, M.G. 2016. Drought tolerance in Cowpea species is driven by less sensitivity of leaf gas exchange to water deficit and rapid recovery of photosynthesis after rehydration. *South African Journal of Botany*, *103*, pp.101-107.

RODRIGUEZ, C., CARLSSON, G., ENGLUND, J.E., FLÖHR, A., PELZER, E., JEUFFROY, M.H., MAKOWSKI, D. and JENSEN, E.S. 2020. Grain legume-cereal intercropping enhances the use of soil-derived and biologically fixed nitrogen in temperate agroecosystems. A meta-analysis. *Eur.J. Agron. 2020, 118, 126077.*

RUSINAMHODZI, L., CORBEELS, M., NYAMANGARA, J. and GILLER, K.E. 2012. Maize grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in Central Mozambique. *Field crops research*, *136*, pp.12-22.

SARIAH, J. E. 2010. Enhancing cowpea (*Vigna unguiculata (L.)* Walp) production through insect pest resistant line in east Africa. Department of Agriculture and Ecology, University of Copenhagen.

SAUDY, H.S. 2015. Maize-cowpea intercropping as an ecological approach for nitrogen-use rationalization and weed suppression. *Archives of Agronomy and Soil Science*, *61*(1), pp.1-14.

SEKGOBELA, M.M. 2019. Performance of elite Cowpea (*Vigna unguiculata*) genotypes at Mankweng and Bela-Bela, Limpopo Province. MSc Agriculture (Agronomy) Thesis. University of Limpopo, South Africa.

SHAMSI, K., KOBRAEE, S. and RASEKHI, B. 2011. The effects of different planting densities on seed yield and quantitative traits of rainfed chickpea (*Cicer arietinum* L.) varieties. *African Journal of Agricultural Research*, *6*(3), pp.655-659.

SHARMA, N.K., SINGH, R.J., MANDAL, D., KUMAR, A, ALAM, N.M. and KEESSTRA, S. 2017. Increasing farmer's income and reducing soil erosion using intercropping in rainfed maize-wheat rotation of Himalaya, India. *Agriculture, ecosystems and environment*, *247*, pp.43-53.

SHEAHAN, C.M. 2012. Plant guide for Cowpea (*Vigna unguiculata*). *USDA-Natural Resources Conservation Service, Cape May Plant Materials Center, Cape May, NJ*.

SINGH, A., BAOULE, A.L., AHMED, H.G., DIKKO, A.U., ALIYU, U., SOKOTO, M.B., ALHASSAN, J., MUSA, M. and Haliru, B. 2011. Influence of phosphorus on the performance of Cowpea (*Vigna unguiculata (L)* Walp.) varieties in the Sudan Savanna of Nigeria. *Agricultural Sciences*, *2*(03), p.313.

SOUTH AFRICAN MAIZE TRUST, (SAMT). 2016. Prospectus on the South African Maize Industry. South Africa.

SULLIVAN, P. 2003. Intercropping principles and production practices. Agronomy systems guide.

TEAMIR, M. 2011. Industrial Use of Maize Grain in Ethiopia: A Review. In *Meeting the Challenges of Global Climate Change and Food Security through Innovative Maize Research* (p. 268).

TEMESGEN, J., KUFA, T. and WONDIMU, Z. 2015. Effect of plant density of hybrid maize and common bean varieties on the productivity of intercropping system at Jimma, South West Ethiopia.

THOBATSI, T.J. 2009. Growth and yield response of Maize (*Zea mays* L.) and Cowpea (*Vigna unguiculata* L.*)* in intercropping system. Masters dissertation. University of Pretoria, South Africa, 58-67.

TIMKO, M.P. and SINGH, B.B. 2008. Cowpea, a multifunctional legume. *Genomics of tropical crop plants*, pp.227-258.

TITTONELL, P. and GILLER, K.E., 2013. When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture. *Field Crops Research*, *143*, pp.76-90.

UNDIE, U.L., UWAH, D.F. and ATTOE, E.E. 2012. Effect of Intercropping and crop arrangement on yield and productivity of late season maize/soybean mixtures in the humid environment of south southern Nigeria. *Journal of Agricultural Science*, *4*(4), pp.37-50.

VARMA, D., MEENA, R.S. and KUMAR, S. 2017. Response of mungbean to fertility and lime levels under soil acidity in an alley cropping system in Vindhyan region, India. *Int J Chem Stud*, *5*(4), pp.1558-1560.

VESTERAGER, J.M., NIELSEN, N.E. and HØGH-JENSEN, H. 2008. Effects of cropping history and phosphorus source on yield and nitrogen fixation in sole and intercropped cowpea-maize systems. *Nutrient Cycling in Agroecosystems*, *80*, pp.61-73.

YANG, F., WANG, X., LIAO, D., LU, F, GAO, R., LIU, W., YONG, T., WU, X., DU, J., LIU, J. and YANG, W. 2015. Yield response to different planting geometries in maize-soybean relay strip intercropping systems. *Agronomy Journal*, *107*(1), pp.296-304.

APPENDICES

Appendix 1. Analysis of variance for cowpea number of days to 50% flowering

Source of variation	DF	SS	MS	F	P
Replication	3	6.333	2.1111		
Treatment	5	198.833	39.7667	42.11	0.0000
Error	15	14.167	0.9444		
Total	23	219.333			

Appendix 2. Analysis of variance for cowpea number of days to 90% physiological maturity

Source of variation	DF	SS	MS	F	P
Replication	3	32.33	10.778		
Treatment	5	1243.33	248.667	28.33	0.0000
Error	15	131.67	8.778		
Total	23	1407.33			

Appendix 3. Analysis of variance for cowpea plant height

Source of variation	DF	SS	MS	F	P
Replication	3	300.02	100.008		
Treatment	5	567.87	113.574	4.77	0.0083
Error	15	356.90	23.793		
Total	23	1224.79			

Appendix 4. Analysis of variance for cowpea canopy width

Source of variation	DF	SS	MS	F	P
Replication	3	190.376	63.4586		
Treatment	5	229.933	45.9867	2.12	0.1187
Error	15	324.779	21.6519		
Total	23	745.088			

Appendix 5. Analysis of variance for cowpea leaf chlorophyll content

Source of variation	DF	SS	MS	F	P
Replication	3	320.27	106.755		
Treatment	5	3047.72	609.545	9.05	0.0004
Error	15	1009.86	67.324		
Total	23	4377.85			

Appendix 6. Analysis of variance for cowpea number of branches per plant

Source of variation	DF	SS	MS	F	P
Replication	3	19.0961	6.36538		
Treatment	5	44.5234	8.90469	9.18	0.0004
Error	15	14.5495	0.96997		
Total	23	78.1691			

Appendix 7. Analysis of variance for cowpea above ground dry matter

Source of variation	DF	SS	MS	F	P
Replication	3	0,09581	0,03194		
Treatment	5	0,12785	0,02557	0.75	0.6001
Error	15	0,51284	0,03419		
Total	23	0,73650			

Appendix 8. Analysis of variance for cowpea pod length

Source of variation	DF	SS	MS	F	P
Replication	3	1.008	0.3359		
Treatment	5	106.320	21.2640	86.16	0.0000
Error	15	3.702	0.2468		
Total	23	111.030			

Appendix 9. Analysis of variance for cowpea number of pods per plant

Source of variation	DF	SS	MS	F	P
Replication	3	20.965	6.98824		
Treatment	5	41.843	8.36854	2.00	0.1365
Error	15	62.656	4.17707		
Total	23	125.463			

Appendix 10. Analysis of variance for cowpea number of seeds per pod

Source of variation	DF	SS	MS	F	P
Replication	3	4.7343	1.57810		
Treatment	5	3.4216	0.68432	0.55	0.7339
Error	15	18.5542	1.23695		
Total	23	26.7101			

Appendix 11. Analysis of variance for cowpea hundred seed weight

Source of variation	DF	SS	MS	F	P
Replication	3	10.390	3.4632		
Treatment	5	341.145	68.2291	21.56	0.0000
Error	15	47.470	3.1647		
Total	23	399.005			

Appendix 12. Analysis of variance for cowpea shelling percentage

Source of variation	DF	SS	MS	F	P
Replication	3	86.99	28.997		
Treatment	5	997.38	199.477	9.38	0.0003
Error	15	319.03	21.268		
Total	23	1403.40			

Appendix 13. Analysis of variance for cowpea grain yield

Source of variation	DF	SS	MS	F	P
Replication	3	0,04860	0,01620		
Treatment	5	0,73336	0,14667	7.05	0.0014
Error	15	0,31203	0,02080		
Total	23	1,09399			

Appendix 14. Analysis of variance for maize number of days to 50% tasseling

Source of variation	DF	SS	MS	F	P
Replication	3	115.792	38.5972		
Treatment	5	83.708	16.7417	0.80	0.5660
Error	15	313.458	20.8972		
Total	23	512.958			

Appendix 15. Analysis of variance for maize number of days to 50% silking

Source of variation	DF	SS	MS	F	P
Replication	3	32.333	10.7778		
Treatment	5	38.333	7.6667	0.82	0.5557
Error	15	140.667	9.3778		
Total	23	211.333			

Appendix 16. Analysis of variance for maize plant height

Source of variation	DF	SS	MS	F	P
Replication	3	618.42	206.141		
Treatment	5	933.09	186.617	0.60	0.7037
Error	15	4697.49	313.166		
Total	23	6249.00			

Appendix 17. Analysis of variance for maize above ground dry matter

Source of variation	DF	SS	MS	F	P
Replication	3	37.265	12.4215		
Treatment	5	41.157	8.2314	1.92	0.1504
Error	15	64.288	4.2859		
Total	23	142.710			

Appendix 18. Analysis of variance for maize cob length

Source of variation	DF	SS	MS	F	P
Replication	3	15.720	5.24015		
Treatment	5	5.746	1.14920	0.18	0.9645
Error	15	93.945	6.26298		
Total	23	115.411			

Appendix 19. Analysis of variance for maize number of cob per plant

Source of variation	DF	SS	MS	F	P
Replication	3	0.00667	2.222E-03		
Treatment	5	0.04000	8.000E-03	0.90	0.5062
Error	15	0.13333	8.889E-03		
Total	23	0.18000			

Appendix 20. Analysis of variance for maize shelling percentage

Source of variation	DF	SS	MS	F	P
Replication	3	253.70	84.5666		
Treatment	5	141.77	28.3537	0.61	0.6921
Error	15	694.38	46.2922		
Total	23	1089.85			

Appendix 21. Analysis of variance for maize grain yield

Source of variation	DF	SS	MS	F	P
Replication	3	17.2946	5.76486		
Treatment	5	12.2337	2.44675	1.01	0.4459
Error	15	36.3579	2.42386		
Total	23	65.8862			

Appendix 22. Analysis of variance for maize Partial Land Equivalent Ratio (PLER)

Source of variation	DF	SS	MS	F	P
Replication	3	0.33352	0.11117		
Treatment	3	0.09467	0.03156	0.06	0.9799
Error	9	4.79116	0.53235		
Total	15	5.21934			

Appendix 23. Analysis of variance for cowpea Partial Land Equivalent Ratio (PLER)

Source of variation	DF	SS	MS	F	P
Replication	3	0.19962	0.06654		
Treatment	3	0.74667	0.24889	3.63	0.0578
Error	9	0.61696	0.06855		
Total	15	1.56324			

Appendix 24. Analysis of variance for Total Land Equivalent Ratio (LER_T)

Source of variation	DF	SS	MS	F	P
Replication	3	0.46073	0.15358		
Treatment	3	1.12333	0.37444	0.52	0.6787
Error	9	6.47293	0.71921		
Total	15	8.05698			