PERFORMANCE OF FIVE COWPEA (*Vigna unguiculata* L.) VARIETIES IN COWPEA/MAIZE STRIP INTERCROPPING IN LIMPOPO PROVINCE

by

KATLEGO ALOCIA MAIMELA

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DECLARATION

I declare that this mini-dissertation hereby submitted to the University of Limpopo, for the degree of Master of Science in Agriculture (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.

Student's Name Date

DEDICATION

I dedicate this piece of work to my beloved parents Mr. Hezekiel Siwela and Alice Khukhumba Maimela. I also dedicate this dissertation to my husband Mammeudi Piet Mehlape and my kids, Nyeleti Happiness and Moloko Faith Maimela who have supported me throughout the process.

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ABSTRACT

The traditional practice of farmers in Limpopo Province is to mixed and broadcast crops at planting without definite row arrangement. This practice hinders farm input application and results in low crop yields. Strip intercropping, where crops are planted with definite row arrangement, has the advantage of reducing inter-species competition, optimise plant population and increasing crop yield. This study aimed at improving cowpea-maize cropping systems using strip intercropping. The experiment was conducted at University of Limpopo farm and Ga-Thaba village. Five cowpea varieties (Glenda (check)), IT86K-499-35, IT82E-16, IT86D -1010, TVu-13464 and maize (PAN 6479) were evaluated using randomised complete block design with three replications. Data collected were days to flowering, days to maturity, plant height, canopy width, peduncle length, pod length, number of pods/plant, 100 seed weight, grain yield, fodder weight and land equivalent ratio was also determined. Data were analysed using the Statistix 9.0. The results revealed that in both locations TVu 13464 flowered early (50 days) respectively. At University of Limpopo farm TVu 13464, IT82E-16 and IT86D-1010 matured early (89, 88 and 91 days). At University of Limpopo farm, IT82E-16 had high cowpea grain yield (2230 kg/ha) under monocropping and also produced high grain yield of 1373 kg/ha during 2016/17 season. At Ga-Thaba, IT86D-1010 produced high cowpea grain yield of 1085 kg/ha under monocropping and during 2015/16 (660 kg/ha) while IT86K-499-35 also produced high grain yield of 915 kg/ha during 2016/17. The varieties showed yield stability depending on different locations.

At University of Limpopo farm, strip intercropping achieved high maize grain yield of 3961 kg/ha during 2016/17. At Ga-Thaba, strip intercropping produced high maize grain yield 747 and 1024 kg/ha during 2015/16 and 2016/17, respectively. Monocropping produced low maize grain yield during 2015/16 with a mean of 425 kg/ha and mixed intercropping had mean of 499 kg/ha during 2016/17. The calculated LER for two crops over two seasons under strip intercropping ranged from 1.25 and 2.14, whereas under mixed intercropping, it ranged between 0.73 and 1.05 over two seasons at University of Limpopo farm. TVu 13464, IT82E-16 and IT86D-1010 are promising varieties for strip intercropping in low rainfall areas because of their early maturity and high grain yield. The calculated LER for two crops over two seasons under strip intercropping ranged from 1.62 and 2.98, whereas under mixed intercropping, it ranged between 0.76 and 1.67 in both seasons at Ga-Thaba.

Key words: cowpea, maize, intercropping, grain yield and land equivalent ratio

CHAPTER 1

GENERAL INTRODUCTION AND BACKGROUND

1.1 Background information

Cowpea (*Vigna unguiculata (L.))* is one of the most ancient crops. Cowpea is a protein-rich grain that complements staple cereal and starchy tuber crops. It also provides fodder for livestock, improves the soil by fixing nitrogen (N), and benefits households by bringing in cash and a diverse source of income. The sale of cowpea stems and leaves for animal feed during the dry earns vital household income (ICRISAT, 2010). Cowpea is commonly used as a companion crop in many intercrop systems in sub-Saharan Africa (SSA), because of its ability to provide fixed atmospheric N to cereal crops in rotation. For this reason, cowpea is commonly intercropped with cereals especially, maize, sorghum and millet (Woodruff, Durham & Hancock, 2010). It is of vital importance in the livelihoods of millions of people in the semi-arid regions of West and Central Africa, and is one of the most important grain legume crops in SSA (International Crops Research Institute for Semi-Arid Tropics (ICRISAT), 2010). According to Asiwe (2009), South African cowpea production is carried out by smallholder (SH) farmers under dryland conditions in the provinces of Limpopo, Mpumalanga, North West, and Kwazulu-Natal.

Globally, maize (*Zea mays* L.) is the third largest planted crop after wheat and rice; it is produced throughout South Africa in diverse environments (Tsubo, Walker, and Ogindo, 2005). Maize grain can be consumed by humans and animals in many communities, as it has nutritive value and the highest potential for carbohydrates (Tsubo et al., 2005). It is usually intercropped with legumes to increase yield. Many SH farmers in Limpopo province practice intercropping of maize with legumes due to land scarcity, and to enhance production (Thobatsi, 2009).

Intercropping is the practice of growing two or more crops in close proximity to each other. The most common goal of intercropping is to produce a greater yield on a given piece of land by using resources that would otherwise not be utilised by a single crop (Ayisi, Whitbread, and Mpangane*,* 2004). Intercropping is a dominant cropping system practiced by SH farmers in developing African, Asian, and South American countries to better utilise limited resources, especially land. Intercropping maize or grain sorghum (*Sorghum bicolor*) with leguminous species, especially cowpea, common bean (*Phaseolus vulgaris*), groundnuts (*Arachis hypogea*), lablab (*Lablab purpureus*), or bambara groundnut (*Vigna subterranean*) is a common practice among SH farmers in Limpopo province (Mpangane, 2001). Strip intercropping is an adaptation of this system to contemporary, mechanised agricultural practices. These multiple crops are grown in narrow, adjacent strips that allow interaction between the different species, but also allow management with modern equipment (Singh and Ajeigbe, 2007).

1.2 Problem statement

Strip intercropping is the act of growing two or more crops together in strips wide enough to permit separate crop production but narrow enough for the crops to interact agronomically (Singh and Ajeigbe, 2007). In Limpopo Province, SH farmers practice mixed intercropping, whereby they broadcast the seeds of legume crops with cereals with no definite row arrangement. This practice does not optimise plant density, does not allow efficient management of crops using modernised equipment, and it hinders the application of farm inputs. Therefore, strip intercropping has the potential of reducing inter-species competition, while simultaneously allowing individual management of intercrops and optimising plant density, thereby increasing productivity in the SH farming sector. Although strip intercropping has all of these benefits, the performance of grain legume cowpea in a strip intercropping system with maize has not been investigated in the Limpopo environment. Therefore, there was a need to investigate the response of cowpea varieties in a strip intercropping system with maize.

1.3 Rationale of the study

Cowpea is an important grain legume crop that is high in protein content and has the potential to improve food security, because it is widely adapted to different locations in South Africa due to its ability to withstand drought (Asiwe, 2009). Cowpea is a potential source of plant nutrients that supplement inorganic fertiliser in an intercropping system, thereby reducing its fertiliser demand and the costs in the SH farming sector (Mpangane, 2001). The traditional mixed interplanting with no definite row arrangement is very unproductive, it is low yielding, it does not allow the use of mechanisation, and it slows the application of farm inputs and agronomic operations. Strip intercropping has overwhelming advantages over traditional intercropping, but its application has not been studied locally. Therefore, this study sought to generate information on legume cereal strip intercropping in South Africa. The introduction of new agronomic practices such as strip intercropping of maize with cowpea is necessary to enhance the productivity of SH farmers.

1.4 Project aim and objectives

1.4.1 The main aim of the project was to improve cowpea-maize intercropping systems in Limpopo Province.

1.4.2 The objectives of the study were:

i. to determine the agronomic performance of five cowpea varieties in cowpea-maize strip intercropping;
ii. to determine the agronomic performance of maize in cowpea-maize strip intercropping; and
iii. to compare the performance of maize and cowpea in strip and mixed intercropping systems

1.5 Hypothesis

Performance of five cowpea varieties in strip intercropping with maize does not differ from the mixed intercropping of cowpea with maize.

CHAPTER 2

LITERATURE REVIEW

2.1. Origin and distribution of cowpea

Cowpea is one of the most ancient human food sources and has been used as a crop plant since Neolithic times (Department of Agriculture, Fisheries, and Forestry (DAFF), 2011). Cowpea (*Vigna unguiculata L. Walp*.) is a member of the Phaseoleae tribe of the Leguminosae family. There is a lot controversy surrounding the origin of cowpea. Some literature indicates that cowpea was introduced from Africa to the Indian subcontinent approximately 2 000 to 3 500 years ago, at the same time as the introduction of sorghum and millet, while others state that before 300 BC, cowpeas had reached Europe and possibly North Africa from Asia (DAFF, 2011). Some researchers believe that cowpea originated from West Africa, because both wild and cultivated species abound in the region, while others believe that it originated from Southern Africa (DAFF, 2011). Whatever its place of origin, the production of cowpea has spread to East and Central Africa, India, Asia, and South and Central America (Eskandari, Ghanbari, and Javanmard*,* 2009).

2.2. Importance and utilization of cowpea

Cowpea is an important grain legume in Africa, parts of the Americas, and in Asia (DAFF, 2011), and it plays a critical role in the lives of millions of people in Africa and other parts of the developing world, where it is a major source of dietary protein that nutritionally complements low-protein staple cereals and tuber crops, and is a valuable and dependable commodity that produces income for farmers and traders (Langyintuo et al., 2003). It is consumed by relatively rural and peri-urban people in less developed countries. It is also an important companion crop in most cereal-legume cropping systems, because of the benefit from the residual N originating from the decay of its leaf litter, roots, and root nodules (Okereke Egwu, and Nnabude*,* 2006). Cowpea improves soil fertility, and consequently helps to increase cereal crop yields when grown in rotation. In addition, the crop fixes 80% N for its growth demand from the atmosphere (Asiwe, Belane, and Dakora, 2009), thereby reducing the crop's N fertiliser demand and input costs.

Cowpea can be utilised in a number of ways. The plant can be used as forage or for hay or silage, and also as a nutritious and highly palatable food source. Cowpeas are one of the most important food legume crops (Woodruff *et al.,* 2010). Cowpea leaves can be harvested as early as 21 days after planting and seed after 60 days (Gomez, 2004). Cowpea leaves are used as vegetables, the young leaves are suitable for salad, grains can be cooked or used in confectionery products (biscuits, *moin-moin, akara*) or in feed mixtures, and the whole plant is used as fodder (Mathews, 2010). Fresh, harvested cowpea leaves are often consumed by many South Africans rural people either merely as *imfino* or in combination with stiff porridge (Moswatsi, Kutu and Mafeo, 2013). Leaves are among the top leaf vegetable used in many parts of Africa, and they are sold in fresh and dry form in many African countries (Dube and Fanadzo, 2013). Cowpea seeds can be consumed fresh along with the pods and leaves as a vegetable. Additionally, dried seeds are consumed after cooking (ICRISAT, 2010).

Currently in Southern Africa, cowpea is at primarily planted for fodder, although it is also used for grain production, green manure, and weed control in forestry plantations, and as a cover or anti-erosion crop (Summerfield, 1999). The Agricultural Research Council (ARC) (2000) reports that cowpea seeds are sometimes used in Nigeria as a coffee substitute, and the peduncles of certain cultivars are used for fibre production. These fresh cowpea pods, together with fresh green leaves, are the earliest foods available at the end of the 'hungry time' (the time when there is insufficient food for people due to a lack of rainfall) (Eskandari *et al.,* 2009).

2.3. Global cowpea production

Cowpea is an important grain legume throughout the world. Small-scale farmers are mostly cowpea producers operating under dryland farming conditions (Asiwe, 2009). It is estimated that the annual world cowpea crop is grown on 12,5 million hectares (ha), and the total grain production is 3 million tons, although only a small proportion of this production enters international trade (ICRISAT, 2010). West and Central Africa are the leading cowpea-producing regions in the world; these regions produce 64% of the estimated 3 million tons of cowpea seed produced annually (Singh and Ajeigbe, 2007).

Nigeria is the world's leading cowpea-producing country, followed by Brazil. Other cowpea-producing countries in Africa are Senegal, Ghana, Mali, and Burkina Faso. The major developed country production areas in the world are Asia, USA, Brazil, and West Indies, only the USA is a substantial producer and exporter (Eskandari *et al.,* 2009). More than 5.4 million tons of dried cowpea are produced worldwide, with Africa producing nearly 5.2 million tons. Nigeria, the largest producer and consumer, accounts for 61% of production in Africa and 58% worldwide (ICRISAT, 2010).

Cowpea production is widely distributed throughout the tropics, however, Central and West Africa account for more than 64% of the area, with about 8 million ha, followed by about 2,4 million ha in Central and South America, 1,3 million ha in Asia, and 0, 80 million ha in East and Central Africa (Singh and Ajeigbe, 2007). Cowpea can be regarded as the anchor of sustainable farming in semiarid lands. This applies to West and Central Africa. In these regions, the area of cowpea production extends in a westerly direction from Cameroon through Senegal, lying mainly between 10°N and 15°N, covering the dry savannah (northern Guinea and Sudan savannahs) as well as Sahel zones (Woodruff *et al.,* 2010).

2.4. Constraints in cowpea production

Over the last three decades, cowpea research and production have been neglected in South Africa. The lack of improved varieties, knowledge of good agronomic practices, lack of availability of good seeds for planting, and discouraging poor marginal returns to farmers have exacerbated efficient cowpea production in the country's provinces (Asiwe, 2009). Cowpea production in South Africa has recently experienced some major drawbacks caused by a significant reduction in farmers' cowpea yield (Asiwe *et al.,* 2009). Cowpea production faces numerous problems, some of which include pests, storage and handling problems, lack of quality seeds, the high cost of inputs, soil infertility, and transportation (Dzemo, Niba, and Asiwe, 2010). Smallholder farmers are not always able to reach the available markets and their products are not recognised by consumers, due to the lack of quality transport. Cowpea crops are attacked by pests during every stage of the plant's life cycle. Insects are the biggest constraint to cowpea production, both in the field and after harvest when the grain is stored. Insects can reduce yields by 95% unless the crop is treated with insecticides. Effective insecticide treatment can increase yields (Abiola and Abiola, 2010).

However, insecticides are expensive (sometimes prohibitively so for SH farmers), are not always available, and farmers often lack the necessary equipment and training for their safe use (Chege, 2004).

2.5 Advantages of cowpea in an intercrop system

In an intercropping system, cowpea is used as a companion crop, and is mostly intercropped with cereal crops such as maize, sorghum, etc. (Mead and Riley, 2001). The fast growth and spreading habit of cowpea varieties make it capable of suppressing weeds (Sanginga and woomer, 2009). Cowpea is a valuable component of farming systems in many areas because of its ability to restore soil fertility for succeeding cereal crops grown in rotation with it (Tarawali *et al.,* 2002). Carsky, Vanlauwe, and Lyasse (2002) report that early maturing cowpea varieties can provide the first food from the current harvest sooner than any other crop, thereby shortening the 'hungry period' that often occurs just prior to harvest of the current season's crop in farming communities in the developing world.

2.6. Cowpea adaptation

In comparison to other crop species, cowpea has considerable adaptation capabilities to high temperatures and drought (Hall *et al.,* 2002). According to Fery (2002), in comparison to other popular grain crops, cowpea is more tolerant of soil with low fertility, due to its high rates of N fixation, its effective symbiosis with mycorrhizae, and its ability to better tolerate soils over a wide range of pH. Hall and Patel (1985) report that cowpea has better tolerance for infertile and acidic soils than other crops. Additionally, early maturing cowpea varieties can thrive in semi-arid climates where rainfall is often less than 500mm.

2.7. Major insect pests affecting cowpea

There are many various types of insect pests that affect cowpea to such an extent that only low yields are attained due to heavy pest infestations. Thus, insect pests pose the greatest threat to cowpea production because crops can be severely attacked by insects at every stage of growth (Asante, Tamo, and Jackai, 2001). High pest densities occur at many locations resulting in complete loss of grain yield if no control measures are taken. The most damaging insect pests are aphids, leaf hoppers, foliage beetles, flower thrips, the Maruca pod borer, and pod-sucking bugs. The cowpea aphid causes direct economic losses by sucking sap and indirectly by transmitting viral diseases (ARC, 2000). The Maruca pod borer feeds on every part of the cowpea plant. Thrips occur every growing season, and result in yield losses through premature flower shedding. Pod bugs suck sap from green pods, causing abnormal pod and seed formation, and yield losses of 30-70% (Asante *et al.,* 2001). Therefore, to ensure good cowpea production, cowpea producers must evaluate and monitor their crops constantly.

2.8. Development of insect pest-resistant varieties

Due to the devastating effect of insect pests on cowpea crops at almost every stage of the plants' development, several approaches have been adopted in their control. Research into the control of these insect pests has centred primarily on the use of synthetic insecticides, however, these have insecticides have caused tremendous damage to the environment, and resulted in pest resurgence, pest resistance to insecticides, and lethal effects on non-target organisms (Adejumo, 2012). Therefore, development of insect and pest-resistant cowpea varieties were introduced by using modern biotechnology to produce Bacillus thuringiensis (Bt) crops, which are modified to produce specific Bt proteins in the plant cells to protect against specific pests (Alao and Adebayo, 2011). These crops do not need conventional pesticide sprays to destroy the pests that are controlled by the specific Bt protein. The Bt gene comes from the soil bacterium called Bacillus thuringiensis. For example, the Bt gene was used in Maruca-resistant cowpeas (Alao and Adebayo, 2011).

2.9. Origin and distribution of maize

Maize (*Zea mays* L.) is the only important cereal indigenous to the western hemisphere. There is some controversy regarding the origin of maize, though it is generally accepted that its centre of origin is located in Mesoamerica, primarily Mexico and the Caribbean (Tong, Hall, and Wang, 2003). Maize as we know it today has never been found growing in a wild state. Its domestication, probably from a wild *teosinte* form (*Euchlaena mexicana*), is believed to have started some 6000 to 7500 years ago in the Mexican highlands. Archaeological evidence from Mangelsdorf, Reeves, MacNeish, and others (reported by Purseglove, 1975), supported by radiocarbon dating, points to the existence of wild maize cobs in Mexico 5200-3400 BC, followed by a gradual extinction of wild maize in favour of modern varieties through a more intensive cultivation.

2.10. Importance and utilization of maize

Maize is one of the most important cereal crops in SSA and an important staple food for more than 1.2 billion people in SSA and Latin America (Sullivan, 2003). Maize is the most important South African grain crop and is produced throughout the country in diverse environments. All parts of the crop can be used for food and non-food products. In industrialised countries, maize is largely used as livestock feed and as a raw material for industrial products (Tsubo *et al.,* 2005). In developed countries, maize is consumed mainly as second-cycle produce, added to meat, eggs, and dairy products. In developing countries, maize is consumed directly and serves as a staple diet for some 200 million people. Many people regard maize as a breakfast cereal (Thobatsi, 2009). Maize is also processed into ethanol and starch (Mahapatra, 2011).

2.11. Maize production

Maize is the staple food for the majority of black people in South Africa, and this consumer segment accounts for 94% of white maize meal consumption (Thobatsi, 2009). It is the most important cereal crop produced by resource-poor farmers in Southern Africa (Mpangane, 2001). Approximately 10-12 million tons of maize are produced annually in South Africa on more-or-less 2.5 million hectares of land (Syngenta, 2012). Maize is produced by nearly all resource-poor farmers in South Africa in the semi-arid regions and the high rainfall provinces (ICRISAT, 2010). Dryland production of maize takes place mainly in the Free State (34%), North-West (32%), Mpumalanga (24%), Limpopo (17%), and KwaZulu-Natal (3%) provinces (ICRISAT, 2010). South African maize production is constrained by both biotic and abiotic factors. The economy of maize production in the summer-grain areas has deteriorated over the last few decades because the price of maize inputs rose more rapidly than the producer price of maize grain (ARC, 2000).

In Limpopo province, most maize producers are small-scale farmers. It is estimated that more than 8000 commercial maize producers are responsible for the majority of the South African crop, while the rest is produced by thousands of small-scale producers (Thobatsi, 2009). The worldwide production of maize is 785 million tons, with the largest producer, the United States, producing 42%. Nigeria is the largest African producer with nearly 8 million tons, followed by South Africa who produces 6.5% of worldwide production (DAFF, 2011). Africa imports 28% of its required maize from countries outside the continent (ARC, 2000). Maize accounts for 30−50% of low-income household expenditures in Eastern and Southern Africa (ARC, 2000). According to Sullivan (2003), a heavy reliance on maize in the diet can lead to malnutrition and vitamin deficiency diseases such as night blindness and kwashiorkor.

2.12. Constraints in maize production

Many farmers experience constraints to maize production, which are grouped into abiotic and biotic constraints. Abiotic constraints include droughts, floods, soil erosion, and soil infertility (Huang, Michaelsen, Funk*, et al.,* 2002). Drought is a major abiotic constraint affecting maize production. Climate instability has resulted in fluctuations in intra- and inter-annual rainfall levels and drought has become a recurrent problem in many regions (Marouf *et al.,* 2013). Biotic constraints include field diseases and insects and storage insects. Farmers have identified a wide range of field insect pests, including armyworm, maize stalk borer, cutworm, and maize leaf aphid, all of which are detrimental to maize (Tandzi *et al.,* 2015). Importantly, armyworms are the major biotic constraint that significantly diminished the 2016 agricultural seasonal cereal production, especially maize production (Food and Agricultural Organization (FAO), 2016). Additionally, major constraints facing farmers are inadequacy of improved varieties, post-harvest handling challenges, weed infestations, poor soil fertility, and the high cost of fertilisers. Therefore, it is necessary to explore more sustainable and affordable ways of increasing crop yields by identifying high-yielding and stable maize varieties that are tolerant to these constraints (Sibiya *et al.,* 2013). The practice of appropriate agricultural systems associated with the utilisation of improved and adapted varieties could significantly increase maize yields (Etoundi and Dia, 2008). Farmers also have to contend with constitutional and economic constraints. Farmers have serious concerns regarding the quality of inputs, low-quality seeds, and questionable purity, as well as the inability of farmers to detect these constraints due to a lack of knowledge (Banzige and Meyer, 2002).

2.13. Intercropping systems

Intercropping is the cropping system of cultivating two or more crops on the same piece of land at the same time. It is an old and commonly used cropping practice, which aims to match crop demands to the available growth resources and labour in an efficient way (Willey, 1979). Many smallholder farmers in Limpopo practice cereal/legume intercropping, and the most utilised intercrops are maize/dry bean, maize/cowpea, and maize/lablab. The most common advantage of intercropping is greater yields produced on a piece of land by efficiently using the available growth resources, i.e. using a mixture of crops of different rooting ability, canopy structure, light interception, height, and nutrient uptake (Eskandari *et al.,* 2009).

Moreover, intercropping improves soil fertility through biological N fixation with the use of legumes, it increases soil conservation through greater ground cover than sole cropping asynchrony for reduced pest invasion, and it provides better lodging resistance for crops susceptible to lodging when grown in monoculture (Zhang and Li, 2003). Intercropping provides insurance against crop failure due to biotic and abiotic factors and against unstable market prices for a given commodity, especially in areas subject to extreme weather conditions such as frost, drought, and flood. Thus, intercropping offers greater financial stability and distribution of farm labour than sole cropping, which makes the system particularly suitable for small, labour-intensive farms (Fenandez-Aparicio and Sillero*,* 2007).

2.14. Types of intercropping systems

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2.14.1 Row cropping

Row intercropping is a practice of growing two or more crops in well-defined rows. In farms growing perennial crops, annual crops such as maize, rice, and pineapple are commonly grown as the intercrop between the rows of the main crop (Francis *et al.,* 1986). Row intercropping can be divided into two types, namely inter-row and intra-row intercropping. The strategy is an efficient way of maximising farmland usage as it uses vacant spaces while simultaneously suppressing weed growth during the main crop's juvenile stage. Row intercropping has many advantages, such as wind passages between the inter-rows being enhanced, which increases gas exchange and prevents excessive humidity, and access between the inter-rows facilitates cultivation, weeding, and other farm operations, including haulage, etc. (Zhang and Li, 2003). Annual crops such as rice, maize, and pineapple are commonly used as intercrops between the rows. Banana, papaya, coffee, and cacao are commonly grown in multiple rows. The productivity of row intercropping is influenced by the specific combination of crops, their spacing, and planting dates.

2.14.2 Mixed cropping

Mixed cropping, also known as intercropping or co-cultivation, is a type of cropping system that involves planting two or more plants simultaneously in the same field, as shown in Figure 3.2.1c. In general, the theory is that planting multiple crops at once facilitates crop interaction. Possible benefits of mixed cropping are balancing input and output of soil nutrients, suppressing weeds, reducing insect pest movement, resisting climate extremes (wet, dry, hot, cold), suppressing plant diseases, increasing overall productivity, and using scarce resources for optimum benefit (Mead and Riley, 2001). Mixed cropping has no organised pattern of component crop arrangement and density of plants is varied across the field.

2.14.3 Relay intercropping

Relay intercropping is the practice of planting a second crop into a standing crop at a time when the standing crop is at its reproductive stage, but prior to harvesting (Zhang and Li, 2003). This helps to avoid competition between the main crop and the intercrop. The field is also productive for a longer period, since the relay crop usually continues to grow after the main crop is harvested (Zhang and Li, 2003). Relay intercropping is possible and useful when the growing season is long enough to grow two crops, or when there are two growing seasons (Lantican, 2001). In maize-bean intercrops, for example, the maize crop is planted first and when it is established, the bean crop is planted in between the maize. After the maize has been harvested, the bean crop continues growing and may use the maize as stakes. Soil moisture is used very efficiently and the soil is covered for longer period preventing nutrient losses and erosion resulting in less competition of water and nutrients (Mucheru-Muna et al., 2010).

2.14.4 Strip intercropping

Strip intercropping is the practice of producing two or more crops in narrow strips located across the length of a field (Sullivan, 2003), as shown in Figure 3.2.1.(b). The strips are wide enough so that each crop can be managed independently, yet narrow enough for each crop to influence the microclimate and the yield potential of adjacent crops (Singh and Ajeigbe, 2007). Crops are rotated annually. Strip intercropping use is typically based on agronomic and environmental considerations (Francis *et al.,* 1986). A well-managed strip intercropping system results in higher crop yields and greater profitability than monocropping systems. Environmentally, a well-designed system has greater soil and water conservation potential than most monocropping systems (Francis *et al.,* 1986).

Strip cropping has many of the advantages of intercropping: it produces a variety of crops; the legume improves the soil fertility; and rotation helps reduce pest and weed problems (Sanginga and Woomer, 2009). The residues from one strip can be used as soil cover for neighbouring strips. At the same time, strip cropping avoids some of the disadvantages of intercropping: managing the single crop within the strip is easy; and competition between the crops is reduced (Eskandari, 2012).

2.15. Advantages of intercropping

According to Sanginga and Woomer (2009), cereal-legume intercropping plays an important role in subsistence food production in developing countries, especially in areas where water resources are limited. This practice is an attractive strategy to SH farmers to increase productivity and to intensify land labour utilisation per unit of area of available land (Seran and Brintha, 2010). In comparison to pure cropping, intercropping's advantages in crop production are due to the interaction between components in intercrops, and the reduced competition for available environmental resources (Mahapatra, 2011).

The main advantage of intercropping, in contrast to sole crops, is the more efficient utilisation of available resources and increased productivity (Mucheru-Muna et al., 2010). Yield advantage occurs because growth resources such as light, water, and nutrients are more completely absorbed and converted to crop biomass by the intercrop over time and space, which is occasioned by competing crops' differences in competitive ability for growth resources, which exploits the variety of the mixed crops, i.e. differences such as rates of canopy development, final canopy size, photosynthetic adaptation of canopies to irradiance conditions, and rooting depth (Tsubo *et al.,* 2001). In comparison to single maize crops, intercropping maize with cowpea has reportedly increased light interception in the intercrops, reduced water evaporation, and improved conservation of the soil moisture (Ghanbari *et al.,* 2010).

Intercropping is much less risky than monocropping, considering that if one crop of an intercrop fails, the other component crop(s) may still be harvested. Moreover, farmers may be better able to cope with seasonal commodity price variations, which often can destabilise their income. For example, if the market price is more favourable for one crop than for others, farmers are able to benefit from good prices, and they may suffer fewer losses due to poor prices paid for particular crops, if they grow several crops together. In comparison to monocropping either of the two crops, intercropping maize with beans reduces nutrient declines and raises household incomes, thus insuring against crop failure (Onduru and Du Preez, 2007).

It is well known that the weeds interfere with crops, causing serious impacts either through competition (for light, water, nutrients, and space) or allopathy. Intercropping patterns are more effective than monocropping in the suppression of weeds, but their effectiveness varies greatly (Eskandari, 2012). Mucheru-Muna et al. (2010) state that intercrops might demonstrate weed control advantages over pure cropping in two ways. Firstly, a greater crop yield and less weed growth can be achieved if intercrops are more effective than pure cropping in taking resources from weeds, or by suppressing weed growth through allopathy.

Intercropping systems are able to reduce incidences of pests and diseases. Environmental changes and host plant quality directly affect the host plant's searching behaviour of herbivorous insects, and indirectly affects their developmental rates and interactions with natural enemies. Muli and Saha, (2008) report that mixed cropping of cowpeas with maize significantly reduces the population density and activity of legume flower bud thrips (*Megalurothrips sjostedti*) compared to sole cowpea crops. Similar results are also reported in intercrops of beans, cowpea, and maize, where the reduced pest incidence has been attributed to the increased populations of natural enemies occasioned by intercropping (Kyamanywa and Tukahirwa, 1988). Black aphid (*Aphis fabae*) infestation of beans was greatly reduced when beans intercropped with older and taller maize plants which interfered with aphid colonisation and only small proportions of beans were infested by the aphid (Muoneke, Ogwuche, and Kalu, 2007).

Legumes enrich soil by fixing the atmospheric N, changing it from an inorganic form to forms that are available for uptake by plants. The biological fixation of atmospheric N can replace N fertilisation wholly or partially. When N fertiliser is limited, biological N fixation is the major source of N in legume-cereal mixed cropping systems (Geren, Avcioglu, and Soya 2008). Moreover, because inorganic fertilisers have contributed to environmental damage, such as nitrate pollution, legumes grown in intercropping systems are regarded as an alternative and sustainable way of introducing N into lower input agro ecosystems (Fustec *et al.,* 2010).

2.16. Disadvantages of intercropping system

Intercropping can lead to poorer yields. The crops may not be compatible, or they may actually compete for the same nourishment and of course water, which may lead to unmanageable conflict. It is possible that neither crops yield enough produce, nor that the main crop has reduced yields due to productivity losses during drought periods, and high labour inputs in regions where labour is scarce and expensive (Gliessman, 1985). It is well documented that in most cases the main crop in an intercropping system will not achieve as high a yield as it would in a monoculture, because there is competition among intercropped plants for light, soil nutrients, and water (Willey, 1979). This yield reduction may be economically significant if the main crop has a higher market price than the other intercropped plants (Balasubramaniyan and Palaniappan, 2001). Intercropping obviously costs more money initially, more fertilisers and water are required, and harvesting is also more complicated. If something goes significantly wrong with either crop, then the other crop may also suffer damage (Balasubramaniyan and Palaniappan, 2001).

2.17. Measurement of productivity in an intercropping system

2.17.1. Land equivalent ratio (LER)

According to Wijesinha *et al.* (2002), the land equivalence ratio (LER) is a measure of the land area required for a monocrop of maize or legumes to equal that of the intercrop's output. Essentially, the LER measures the effect of both beneficial and negative interaction between crops (Sullivan, 2003). Mead and Willey (1980) define LER as the relative land area required for a sole crop to produce the same yield as intercropping. The LER provides a standardised basis so that crops can be added to form combined yields. A comparison between individual LERs could indicate competitive effects. Furthermore, it is important to note that the total LER can be taken as a measure of the yield advantage. For instance, an LER of 1.2 indicates a yield advantage of 20% (or strictly speaking, that 20% more land would be required for sole crops to produce the same yield as intercropping). Addo-Quaye,Darkwa and Ampiah (2011) found that the productivity of the intercropping system indicated a yield advantage of 2-63%, as depicted by the LER of 1.02-1.63, showing efficient utilisation of land resources by growing the crops together.

CHAPTER 3

RESEARCH MATERIALS AND METHODS

3.1 Description of the study sites

The experiment was conducted at two locations, namely, the University of Limpopo (UL) farm (the trials were planted on the 11th of January 2016 and 13th December 2016) and Ga-Thaba (the trials were planted on the 13th January 2016 and 15th December 2016) during the 2015/16 and 2016/17 seasons. The UL farm is located in the Mankweng area, in the Capricorn district of Limpopo province, at longitude and latitude of 23°53’ 9.6” S, 29°43’ 4.8” E. The area is located in the subtropical region of South Africa and the average temperature ranges from 28^0C to 30^0C. It is characterised by erratic low rainfall, which ranges between 450-650mm per annum, and falls predominantly in the summer. The farm has an average of 170 frost free days, extending from late October to mid-April. The climate of this area is classified as semi-arid and has sandy loam soil. Ga-Thaba village is also located in the Mankweng area, in the Capricorn district of Limpopo province, at longitude and latitude of 24°01’ 59” S, 29°47’ 56” E. The area is characterised by erratic low rainfall, which ranges between 450-650mm per annum, and falls predominantly in the summer. The area has an average of 170 frost free days extending from late October to mid-April.

3.2. Research design, treatments and procedures

The trials were laid out in a randomised, complete block design, consisting of three replications with five cowpea varieties and a maize variety. The treatments that were used were five cowpea varieties, namely: Glenda (check); IT86K-499-35; IT82E-16; IT86D-1010; and TVu-13464, with the maize cultivar, PAN 6479. The maize cultivar (PAN 6479) was planted at an inter-row spacing of 0.9m and intra-row spacing of 0.3m with 4m row length. The intercrops consisted of four rows of cowpea sandwiched between two rows of maize. The monocrop consisted of four rows of cowpea planted at an inter-row spacing of 0.75m and intra-row spacing of 0.5m. The same plant arrangement and spacing was used in both locations. The field plan is depicted in Figure 3.2.1.

R_1	R_2	R_3	R_4	R_5	R_6
O	O	O	O	O	O
O	O	O	O	O	O
O	O	O	O	O	O
O	O	O	O	O	O

R_1	R_2	R_3	R_4	R_5	R_6
X	X	X	X	X	X
X	X	X	X	X	X
X	X	X	X	X	X
X	X	X	X	X	X

a. Monocropping showing six rows of maize and six rows of cowpea

R_1	R_2	R_1	R_2	R_3	R_4	R_1	R_2
O	O	X	X	X	X	O	O
O	O	X	X	X	X	O	O
O	O	X	X	X	X	O	O
O	O	X	X	X	X	O	O

b. Strip intercropping showing four rows of cowpea sandwiched in between two rows of maize

O	X	O	X	O	X	O	X
X	O	X	O	X	O	X	O
O	X	O	X	O	X	O	X
X	O	X	O	X	O	X	O
O	X	O	X	O	X	O	X

c. Mixed intercropping showing a mixture of maize an cowpea

Figure 3.2.1. Trial plan (monocropping, strip and mixed intercropping). Where X = cowpea, O = Maize, R = Row

3.3. Crop management

The land was prepared using a disc and harrow plough. Roundup (isopropylamine salt of glyphosate) and Dual (S-metalachlor) were administered at rates of 3 L/ha and 0.5 L/ha respectively, and were used to control weeds before crop emergence. Manual weeding was done on weeds growing in the field when necessary. Karate (lambda-cyhalothrin) and Aphox (pirimicarb) were applied at a rate of 1 L/ha and 500 g/ha to control blister beetle on the cowpea crop from seedling stage until pod maturity.

3.4. Data Collection

3.4.1. Procedures for cowpea

Table 3.4.1. Procedures for cowpea

Parameter	**Description of the cowpea collection procedure.**
Days of 50% flowering	Number of days to 50% flowering was calculated by counting the number of days from plant emergence date to the date that 50% flowering was observed in the plot.
Days of 90% maturity	Number of days to 90% maturity was observed, and was calculated by counting the number of days from plant emergence date to the date that 90% maturity was observed in the plot
Plant height	Five plants from each plot were sampled randomly at maturity, and their heights were measured with a measuring tape. The average was then calculated and recorded.
Canopy width	Five plants from each plot were sampled randomly at maturity, and their canopy width was measured with a measuring tape. The average was then calculated and recorded.
Pod length	Five pods from five plants were sampled randomly at maturity, and the pod lengths were measured with a measuring tape. The average was then calculated and recorded.
Number of pods/plant	Five plants from each plot were sampled randomly at maturity, and the number of pods per plant were counted. The average was then calculated and recorded.
Seed weight	Pods from the two middle rows (net plot) were harvested, and after harvesting, the pods were threshed and weighed with a sensitive electronic scale to obtain the seed weights.
100 seed weight	One hundred good seeds were counted from five varieties and weighed to determine the 100 seed weight.
Grain yield	The grain yield (kg) was taken by weighing the grains shelled from each net plot using a measuring scale and this was converted into kg/ha using the formula: Grain yield (kg/ha) = ((Grain weight (kg) / (Area harvested (m2))) ×10000 m2.
Fodder weight	Fodder yields were taken at maturity after harvesting the pods, by weighing the haulm from each net plot and recording the weight.

3.4.2 Procedures for maize

Table 3.4.2. Procedures for maize

Parameter	**Description of maize data collection procedure**
Days to 50% tasseling	Date when 50% of the plant tasselled was recorded and converted into the number of days from the date of planting.
Days to 50% silking	Date to attain 50% silking was monitored on a daily basis. This was determined in each plot by counting the number of days taken from the date of 50% plant emergence to reaching 50% silking in the field.
Plant height	Five plants from each plot were sampled randomly at maturity, and the height was measured with a measuring tape. The average was then calculated and recorded.
Cob length	Five cobs from each plot were sampled randomly at maturity, and the cob length was measured with a measuring tape. The average was then calculated and recorded.
Number of cobs per plant	Five plants from each plot were sampled randomly at maturity, and number of cobs was counted per plant. The average was then calculated and recorded.
Grain yield	The grain yield (kg) was measured by weighing the grains shelled from the ears obtained from each net plot, using a scale, and then converted into kg/ha using the formula: Grain yield (kg/ha) = ((Grain weight (kg))/(Area harvested (m^2))) ×10000 m^2.
Stover yield	Stover was taken at harvesting by weighing the haulm from each net plot and recording the measurement.

3.4.3. Assessing intercrop productivity.

For assessing intercrop productivity, the following parameter was taken. The LER was calculated from the relative yield of cowpea and maize with their sole treatments, by using the following formulas:

$$\text{LER (Strips)} = \frac{\text{Intercropped yield of crop A}}{\text{Sole yield of crop A}} + \frac{\text{Intercrop yield of crop B}}{\text{Sole yield of crop B}}$$

$$\text{LER (Mixed)} = \frac{\text{Mixed intercropping yield}}{\text{Monocropping yield}} + \frac{\text{Mixed intercropping yield}}{\text{Monocropping yield}}$$

A LER value of less than 1.0 indicates lower productivity of intercropping relative to sole crops; an LER with a value of 1.0 shows no yield difference between intercropping and sole crops; and an LER value of greater than 1.0 shows the yield advantage of intercropping in comparison to sole crops.

3.5. Data analysis

Data was subjected to an analysis of variance using the Statistix 9.0 (Gomez, 2010) to check whether or not there were differences between the treatments. Differences between means were separated using the Least Significance Difference (LSD). The mean separation was performed at a probability level of 0.05.

CHAPTER 4

RESULTS AND DISCUSSION

The results of the experiments conducted to investigate the performance of five cowpea varieties and maize in strip intercropping system at UL farm and Ga-Thaba during 2015/16 and 2016/17 seasons are presented in this chapter.

Weather results during 2015/16 and 2016/17 season at the University of Limpopo farm

At the UL farm, the trial was planted on the 11th of January 2016 during the 2015/16 season, whereas during the 2016/17 season, the trial was planted on the 13 December 2016. The 2015/16 season received a lower average rainfall (353.64mm) (Figure 4.1) compared to the 2016/17 season that had an average rainfall of 606.29mm (Figure 4.2). However, during the 2015/16 season, high rainfall was only received in March 2016 (126.73mm) (Figure 4.1). In the 2016/17 season, comparable rainfall was received during December 2016 (120.9mm) and January 2017 (101.01mm) (Figure 4.2). During the 2015/16 season, the minimum temperatures ranged from 13^{0}C to 18^{0}C, while maximum temperatures ranged from 25^{0}C to 30^{0}C (Figure 4.1). At the UL farm during the 2016/17 season, the minimum temperatures ranged from 3^{0}C to 17^{0}C, while maximum temperatures ranged from 21^{0}C to 27.24^{0}C (Figure 4.2). The first season was very short compared to the second season, since the planting was delayed, thus causing frost damage on the final maize yield. In the first season, between the month of January and February 2016, temperatures were very high, with little rainfall of about 87.36mm and 57.89mm respectively. During the second season, the temperatures were lower, with rainfall of about 120.9mm and 101.09mm in December and January respectively.

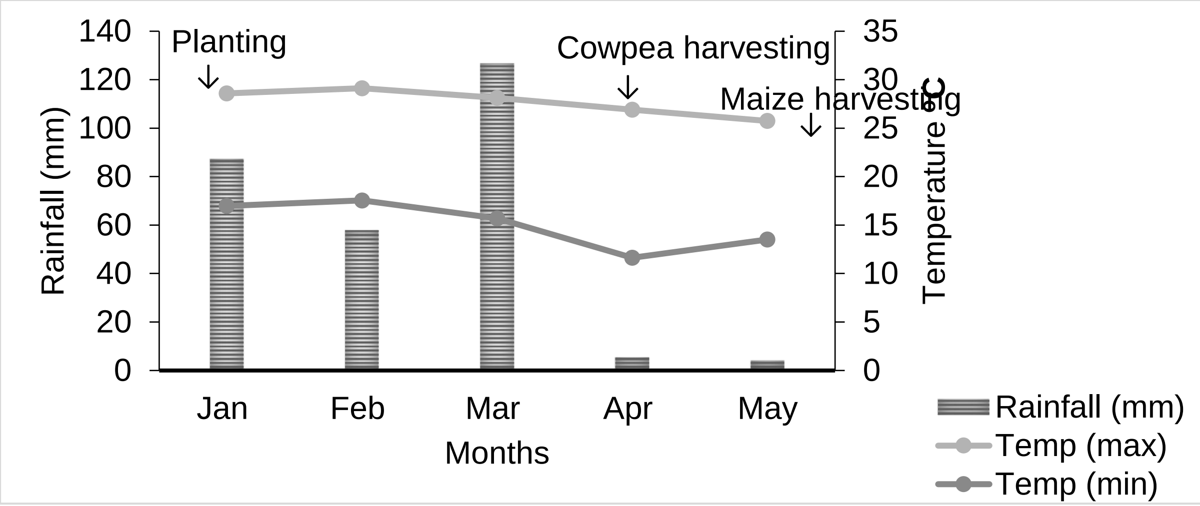

Figure 4.1: Monthly rainfall and mean minimum and maximum temperatures during the 2015/16 season at the University of Limpopo farm.

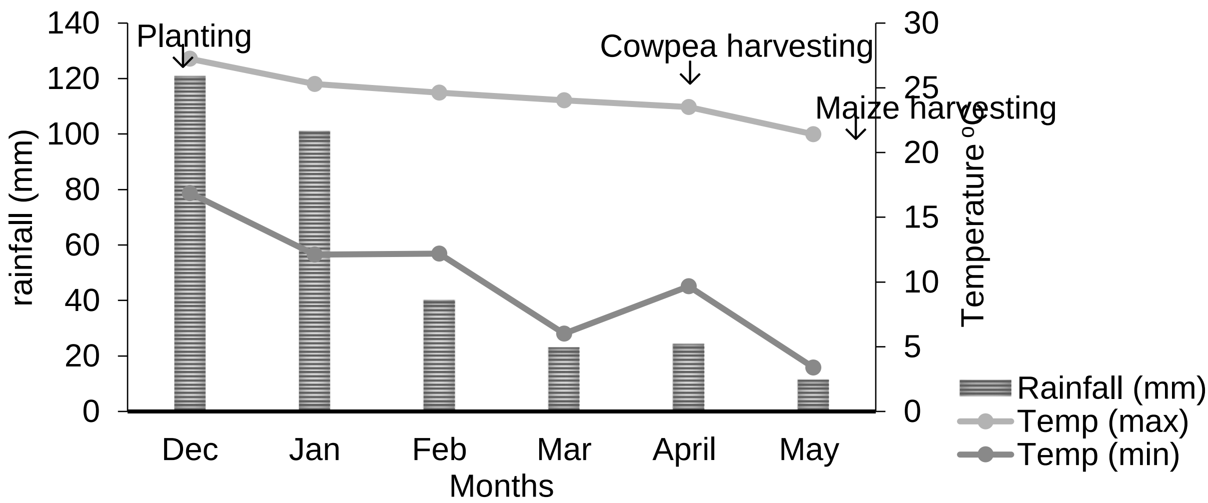

Figure 4.2: Monthly rainfall and mean minimum and maximum temperatures during the 2016/17 season at the University of Limpopo farm.

4.1. Performance of five cowpea varieties at the University of Limpopo farm

4.1.1 Number of days to 50% flowering

The results show that the interaction between crop variety, cropping system, and season were significant (P<0.05) for the number of days to 50% flowering (Table 4.1).

Species TVu 13464 attained flowering early (48 to 58 days) when strip intercropped, mixed intercropped, and monocropped during the 2015/16 and 2016/17 seasons. The Glenda variety (control) was late, with 52 to 61 days to reach 50% flowering under strip intercropping, mixed intercropping, and monocropping during 2015/16 and 2016/17 seasons (Figure 4.3). The differences could be due to the influence of rainfall and temperature. The plants reached 50% flowering around February 2016, with rainfall of about 57.89mm, and minimum and maximum temperatures of 17.55^{0}C and 29.12^{o}C respectively during the first season (Figure 4.1), whereas during second season, 50% flowering was achieved around March 2017, with rainfall of 101.09mm, and a minimum and maximum temperatures of 12.11^{o}C and 25.29^{0}C (Figure 4.2) respectively. These results are similar to DAFF's (2011) findings, where it was reported that cowpea varieties differ in their genetic makeup and the time of flowering, which depends on the time and location of sowing. Even in early flowering varieties, the flowering period could be extended by high rainfall conditions, leading to asynchronous maturity, due to overlapping flowering. According to Gabatshele et al. (2012), maize is usually taller, with a faster growing or more extensive root system, particularly a larger mass of fine roots, and competes for soil N. The maize plants in the intercrops in the present study could have overshadowed the cowpeas, reducing the amount of light required to stimulate flower production.

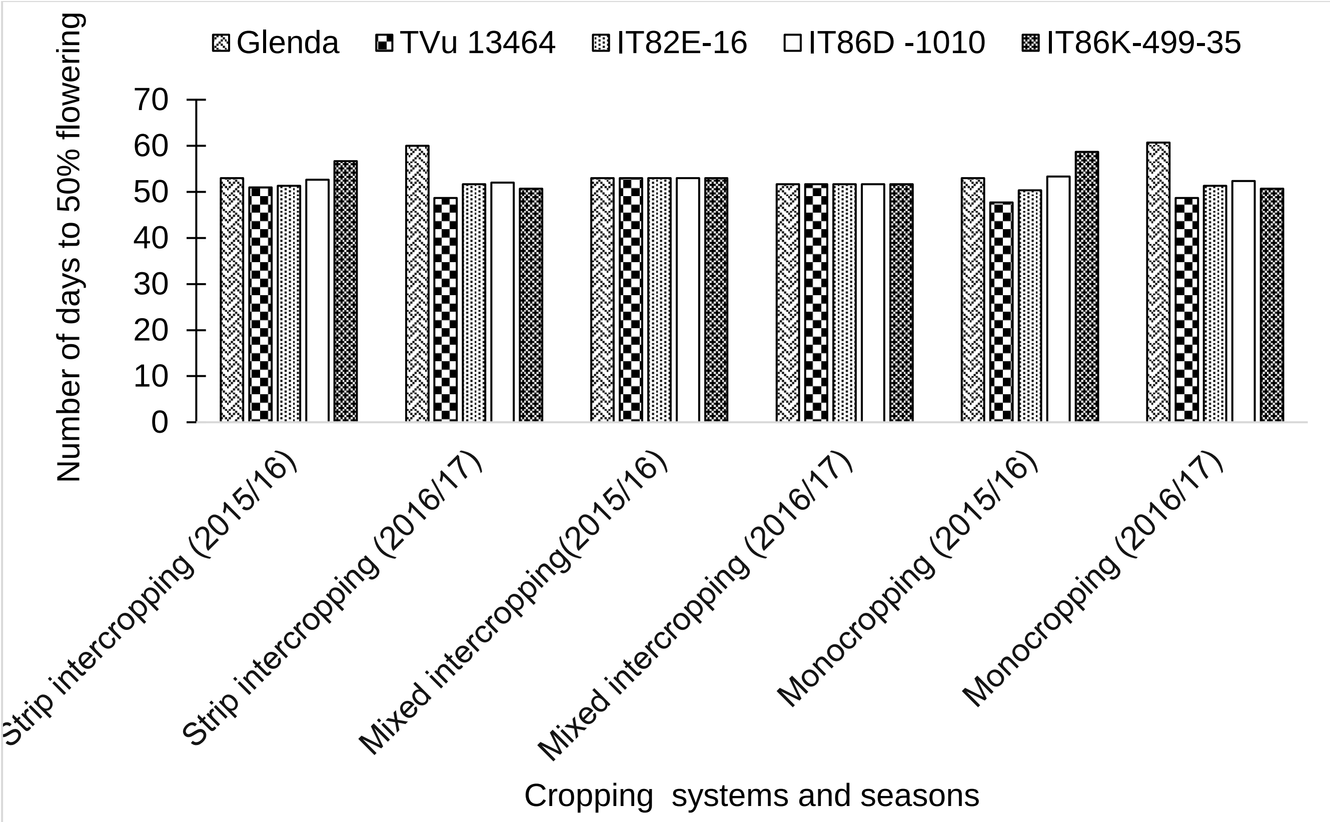

Figure 4.3: Interaction between cowpea varieties, cropping systems, and seasons in terms of days to 50% flowering of cowpea at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

4.1.2 Number of days to 90% maturity

The results show that the interaction between variety and season, and between cropping system and season significantly influenced (P<0.05) the number of days to 90% maturity (Table 4.1). However, there was no significant interaction between variety and cropping system on the number of days to 90% maturity (Table 4.1). Varieties TVu 13464, IT82E-16 and IT86D-1010 were the earliest to reach 90% maturity during the 2015/16 season, with 86, 87, and 88 days respectively. Variety IT86K-499-35 was late and took 93 days to attain 90% maturity during 2015/16. IT86D-1010 was the earliest to reach 90% maturity during the 2016/17 season, and took 87 days. The Glenda variety was late (98 days) to reach 90% maturity during the 2016/17 season, compared to the rest of the varieties in both seasons (Figure 4.4). Monocropping and strip intercropping reached 90% maturity early during the 2015/16 season (87 and 86 days respectively) as opposed to the 2016/17 season (97 days), whereas mixed cropping matured early during the 206/17 season (86 days), and late during the 2015/16 season (94 days) to reach 90% maturity (Figure 4.5). Kamai Gworgwor, and Sodangi (2014) report that days to flowering and days to maturity are always related, because when the plant flowers early it is most likely to mature early as well. These results are also similar to Mafakheri et al. (2017), who found that local cowpea varieties were late to mature both in flowering and maturity. The cowpea varieties that were tested showed little difference in reproductive growth duration, and the same applies to cropping system and seasons (Table 4.2).

Table 4.1: Analysis of variance in respect of the number of days to 50% flowering and 90% maturity of five cowpea varieties at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

Source variation	**DF**	**Number of days to 50% flowering**				**Number of days to 90% maturity**			
		SS	**MS**	**F**	**P**	**SS**	**MS**	**F**	**P**
Replication (Rep)	2	35.82	17.91			10.82	5.41		
Variety (V)	4	271.51	67.88	31.41	0.0001***	721.82	180.46	8.96	0.0047***
Error REP*V	8	17.29	2.16			161.18	20.15		
Cropping system (CS)	2	3.09	1.54	0.83	0.4506ns	100.82	50.41	2.19	0.1382ns
V*CS	8	149.36	18.67	10.03	0.0000***	390.84	48.86	2.12	0.0826ns
Error REP*V*CS	20	37.22	1.86			460.67	23.03		
Season (S)	1	5.88	5.88	2.56	0.1204ns	372.10	372.10	20.22	0.0001***
V*S	4	208.62	52.16	22.68	0.0000***	195.07	48.77	2.65	0.0525*
CS*S	2	8.42	4.21	1.83	0.1777ns	1736.47	868.23	47.19	0.0000***
V*CS*S	8	115.58	14.45	6.28	0.0001***	117.87	14.73	0.80	0.6067ns
Error REP*V*CS*S	30	69.00	2.30			552.00	18.40		
Total	89	921.79				4819.66			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance at (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

Table 4.2: Reproductive growth period and mean number of days to 50% flowering and 90% maturity at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

Variety (V)	Number of days to 50% flowering	Number of days to 90% maturity	Reproductive growth period
Glenda	55.22a	94.56a	39.34
TVu 13464	50.11d	89.00b	38.89
IT82E-16	51.56c	90.61b	39.05
IT86D -1010	52.50bc	87.78b	35.28
IT86K-499-35	53.56b	94.67a	41.11
Grand mean	52.59	91.32	38.73
Cropping System (CS)			
Monocropping	52.67a	92.20a	39.53
Strip Intercropping	52.77a	91.93a	39.16
Mixed intercropping	52.33a	89.83a	37.5
Season (S)			
2015/16	52.84a	89.29b	36.45
2016/17	52.33a	93.36a	41.03

Means followed by the same letter in a column do not differ significantly (P≤ 0.05) from each other.

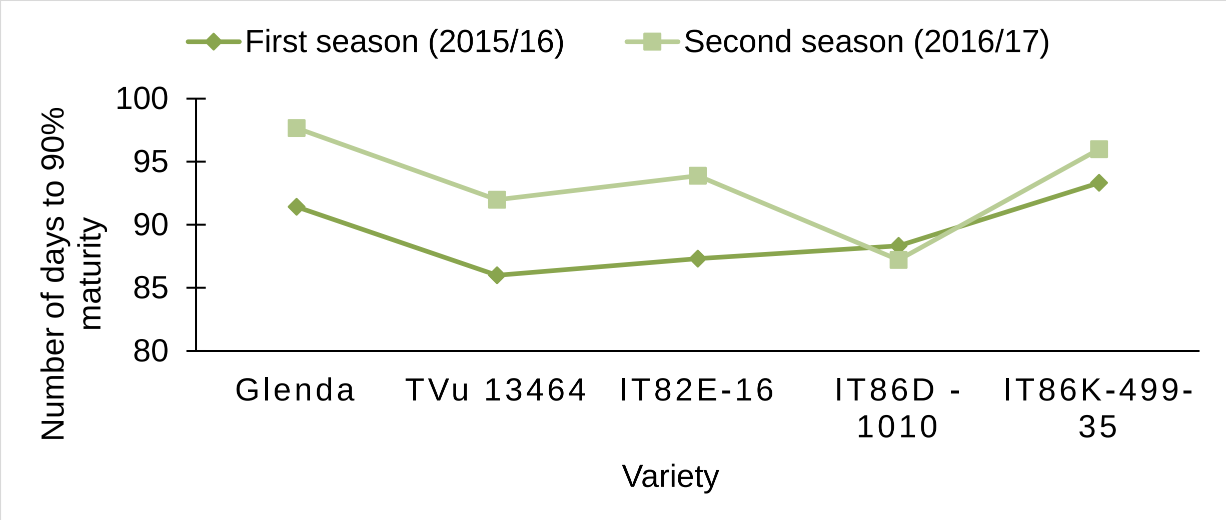

Figure 4.4: Interaction between cowpea varieties and seasons in terms of number of days to reach 90% maturity at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

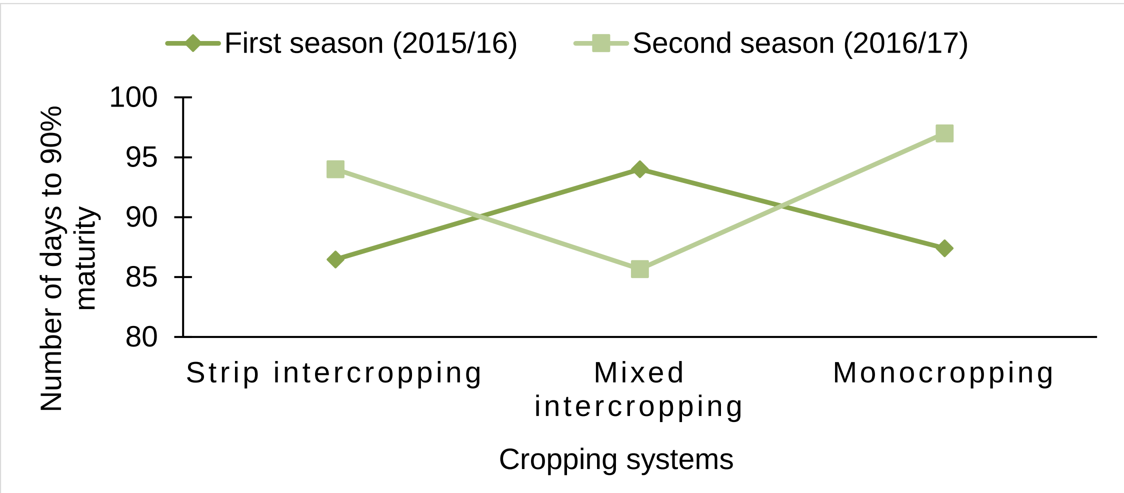

Figure 4.5: Interaction between cropping systems and seasons in terms of the number of days to 90% maturity at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

4.2 Treatment effects on growth and yield parameters of cowpea varieties

4.2.1 Plant height

The results show that the interaction between varieties and cropping systems, and between cropping systems and seasons significantly influenced ($P<0.05$) plant height (Table 4.3). The Glenda variety produced the tallest plants, reaching a height of 56.93cm under monocropping. Variety TVu 13464 produced the shortest plants (34.73cm) under strip intercropping and monocropping (Figure 4.7). Monocropping and strip intercropping showed no significant difference in plant heights, reaching 52.48cm and 51.27cm respectively, while mixed intercropping recorded the lowest height of 40.53cm during the 2015/16 season. During the 2016/17 season, there was no significant interaction between cropping systems and varieties in terms of plant height (Figure 4.7). Similar observations were obtained by Ndiso et al. (2017), who reported that cowpea planted on its own achieved a significantly higher plant height than when it was intercropped. Nwofia et al. (2015) also reported a significantly higher ($P<0.01$) genotypic effect among the cowpea genotypes in terms of the number of branches per plant and plant height. The results also corroborate Kelechukwu, Adewale, and Ezekial’s (2007) findings, where it was reported that cowpea height is dependent on the type of variety, as certain varieties are genetically taller than other varieties. Maturity duration has an influence on plant height among varieties. Normally, if there were shading effects of maize on cowpea, the cowpea height from the intercrop should have been higher than the height achieved in a monocrop, due to production of growth hormones such as auxin, etc. which are induced by shading effects, but there were no significant differences among the cowpea plants from the intercrop. The monocrop had higher plants, which reveals that the crops had more light penetration than they did in the mixtures.

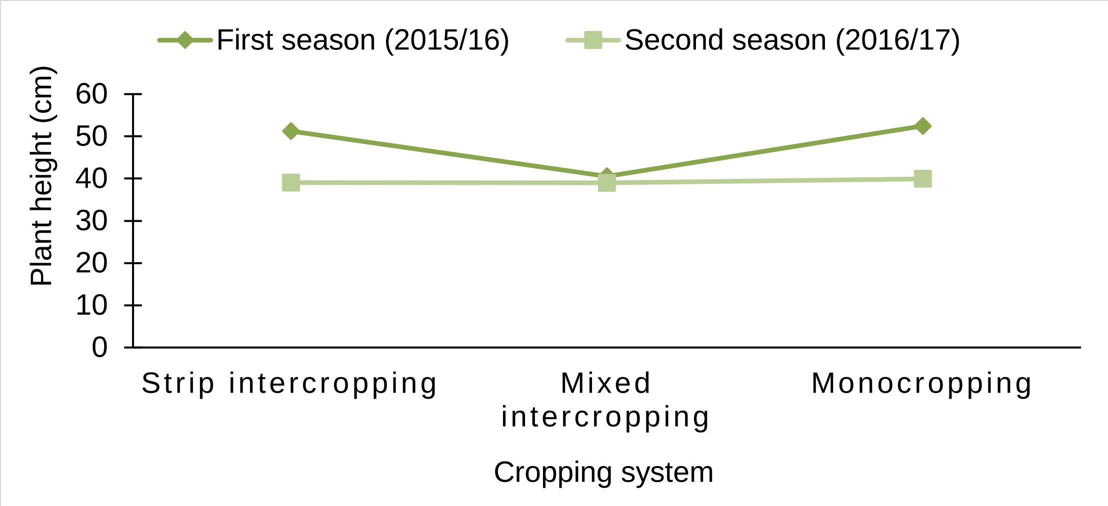

Figure 4.6: Interaction between cropping systems and seasons in terms of plant height at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

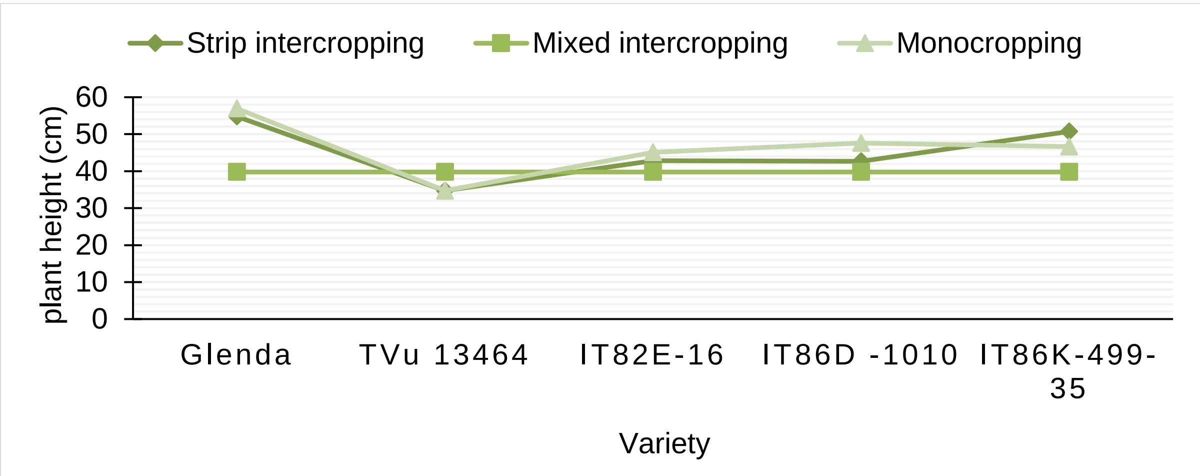

Figure 4.7: Interaction between cowpea varieties and cropping systems in terms of plant height at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

4.2.2 Peduncle length

The results show that there was no significant interaction between all the factors for peduncle length (Table 4.3). However, there was a significant difference ($P<0.05$) among the seasons (Table 4.3). During 2015/16 season, the plants produced a longer peduncles, up to 32.70cm in length, than they did in the 2016/17 season where a mean length of 23.52cm was recorded (Table 4.4). These lengths could be due to different rainfall and temperature patterns in the two seasons. High rainfall of 126.73mm was received during March 2016 while in the 2016/17 season, the low rainfall of 23.12mm in March 2017, could have enhanced the production of long peduncles. According to Kamai et al. (2014), the mean peduncle lengths were significantly different between years. Kamai et al. (2014) also report that the was no significant difference between average peduncle lengths across locations.

Table 4.3: Analysis of variance in terms of plant height and peduncle length of five cowpea varieties at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

Source variation	DF	Plant height (cm)				Peduncle length (cm)			
		SS	MS	F	P	SS	MS	F	P
Replication (Rep)	2	468.1	234.04			39.55	19.77		
Variety (V)	4	1882.8	470.71	4.08	0.0431**	93.04	23.26	0.80	0.5575ns
Error REP*V	8	923.0	115.37			232.43	29.05		
Cropping system (CS)	2	714.4	357.21	7.51	0.0037***	28.50	14.25	1.19	0.3257ns
V*CS	8	1075.4	134.43	2.83	0.0284**	107.48	13.44	1.12	0.3924ns
Error REP*V*CS	20	951.4	47.57			240.15	12.01		
Season (S)	1	1733.6	1733.61	34.59	0.0000***	1921.00	1921.00	79.52	0.0000***
V*S	4	452.1	113.03	2.26	0.0866ns	111.64	27.91	1.16	0.3500ns
CS*S	2	590.8	295.40	5.89	0.0069	128.30	64.15	2.66	0.0867ns
V*CS*S	8	640.9	80.11	1.60	0.1672ns	86.31	10.79	0.45	0.8830ns
Error REP*V*CS*S	30	1503.7	50.12			724.73	24.16		
Total	89	10936.2				3713.12			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

4.2.3 Canopy width

The results show that the interactions between the crop variety and cropping system, and that of crop variety and season were significant ($P<0.05$) for canopy width (Table 4.5). The local variety, Glenda, gave a wider canopy width of 55.10cm under strip intercropping while TVu 13464 had the narrowest canopy width of (40.30cm and 40.63cm) under strip intercropping and monocropping respectively (Figure 4.8). The varieties planted during the 2015/16 season (52.2cm) had a wider canopy width than the varieties planted during the 2016/17 season (38.88cm). However, no significant differences were observed among the varieties during the 2015/16 season, but during the 2016/17 season, the Glenda variety had a wider plant canopy width of 47.53cm, while the TVu 13464 variety (32.44cm) and IT86K-499-35 variety (35.80cm) had narrow canopy widths (Figure 4.9). These differences could be due to different rainfall and temperature patterns. For example, high rainfall of 126.73,mm was recorded in March 2016 (Figure 4.1) during the flowering stage, while in the 2016/17 season, a low rainfall of 23.12mm was recorded in March 2017 (Figure 4.2). This is likely to have caused the plants to refresh their vegetative growth during the 2015/16 season, thus resulted in wider canopy width than during the 2016/17 season. These results also show that physiological maturity has significant influence on canopy width. The varieties that matured late and reached 50% flowering late, exhibited wider canopies than those that reached physiological maturity early. The Glenda variety, which was late maturing, out-performed all of the varieties, and recorded the widest canopy, and TVu 13464, which matured early, had the narrowest canopy width.

Table 4.4: The effect of varieties and cropping systems on plant height, peduncle length, and canopy width at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

Variety (V)	**Plant height (cm)**	**Peduncle length (cm)**	**Canopy width (cm)**
Glenda	50.49a	28.29a	50.06a
TVu 13464	36.41b	27.10a	41.84d
IT82E-16	42.58ab	26.92a	44.98c
IT86D -1010	43.34ab	29.60a	47.84b
IT86K-499-35	45.70a	28.29a	43.13d
Grand mean	43.70	28.14	45.51
Cropping System (CS)			
Monocropping	46.20a	28.94a	45.42ab
Strip intercropping	45.15a	27.77a	46.69a
Mixed intercropping	39.77b	27.73a	44.60b
Season (S)			
2015/16	48.09a	32.76a	52.27a
2016/17	39.32b	23.52b	38.88b

Means followed by the same letter in a column do not differ significantly (P≤ 0.05) from each other.

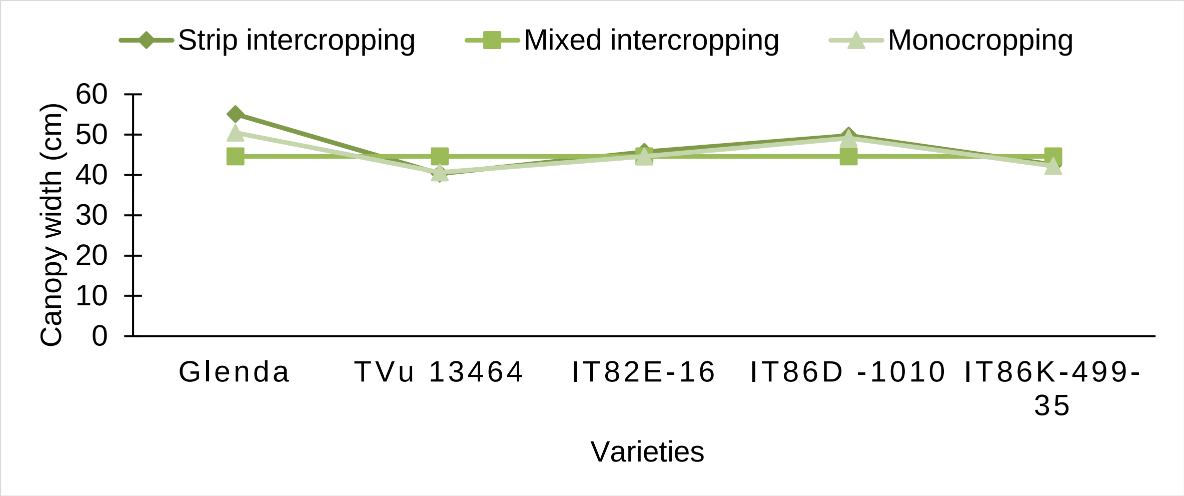

Figure 4.8: Interaction between cowpea varieties and cropping systems in terms of canopy width at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

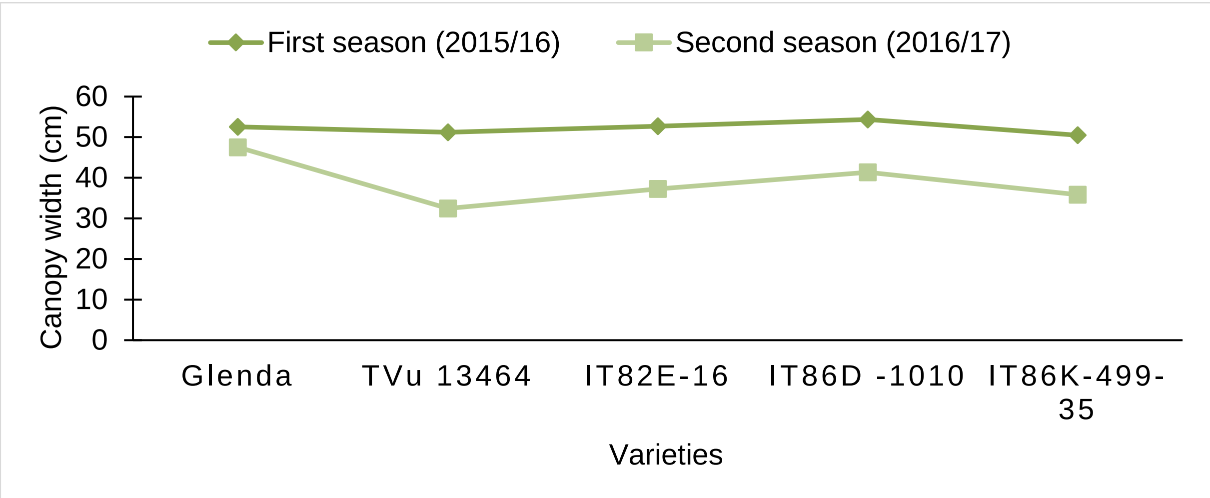

Figure 4.9: Interaction between cowpea varieties and seasons in terms of canopy width at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

4.2.4 Pod length

The results show that the interactions between the varieties and cropping systems, and that between cropping systems and seasons are significant ($P \leq 0.05$) for pod length (Table 4.5). Under monocropping, the IT82E-16 variety produced a longer pod length (16.48cm) than the Glenda and TVu 13464 varieties, which produced shorter pod lengths of 11.53 and 10.31cm respectively, under strip intercropping (Figure 4.10). Mixed intercropping, as opposed to other cropping, exhibited high pod lengths in both seasons, with a means of 15.87 and 16.07cm respectively. Strip intercropping achieved a low pod length of 11.06cm during the 2015/16 season (Figure 4.11). These differences can be attributed to the varieties' genetic structure, and their responses to the shading effect under different conditions. However, Kamai et al. (2014) reported a pod length that was similar among varieties tested when they were averaged across both locations and years. In terms of pod length, the cultivars under study did not reveal much difference between the two seasons. This shows that the environment has little influence over this parameter.

Table 4.5: Analysis of variance in terms of the canopy width and pod length of five cowpea varieties at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

Source variation	DF	Canopy width (cm)				Pod length (cm)			
		SS	MS	F	P	SS	MS	F	P
Replication (Rep)	2	118.54	59.27			6.202	3.1008		
Variety (V)	4	818.30	204.58	37.51	0.0000***	85.765	21.4414	15.34	0.0008***
Error REP*V	8	43.63	5.45			11.179	1.3974		
Cropping system (CS)	2	66.76	33.38	3.83	0.0391**	139.327	69.6633	39.92	0.0000**
V*CS	8	454.65	56.83	6.52	0.0003***	53.874	6.7343	3.86	0.0067**
Error REP*V*CS	20	174.38	8.72			34.902	1.7451		
Season (S)	1	4034.74	4034.74	92.14	0.0000***	17.091	17.0912	6.13	0.0192**
V*S	4	471.65	117.91	2.69	0.0498*	21.984	5.4961	1.97	0.1244ns
CS*S	2	185.48	92.74	2.12	0.1379ns	109.877	54.9386	19.71	0.0000***
V*CS*S	8	253.38	31.67	0.72	0.6697ns	15.123	1.8904	0.68	0.7068ns
Error REP*V*CS*S	30	1313.65	43.79			83.633	2.7878		
Total	89	7935.16				578.958			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

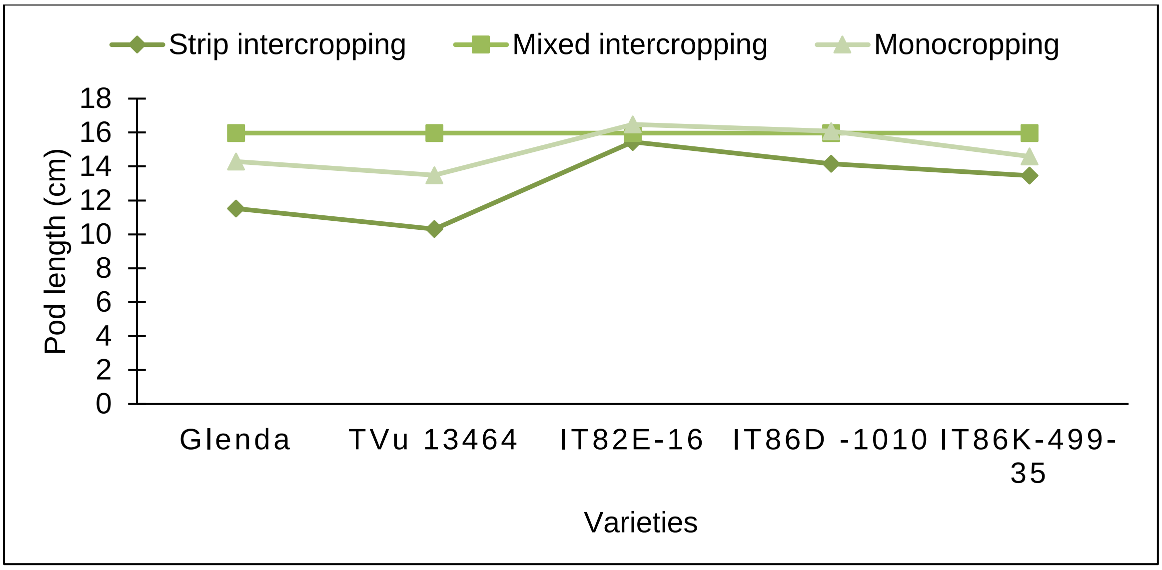

Figure 4.10: Interaction between cowpea varieties and cropping systems in terms of pod length at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

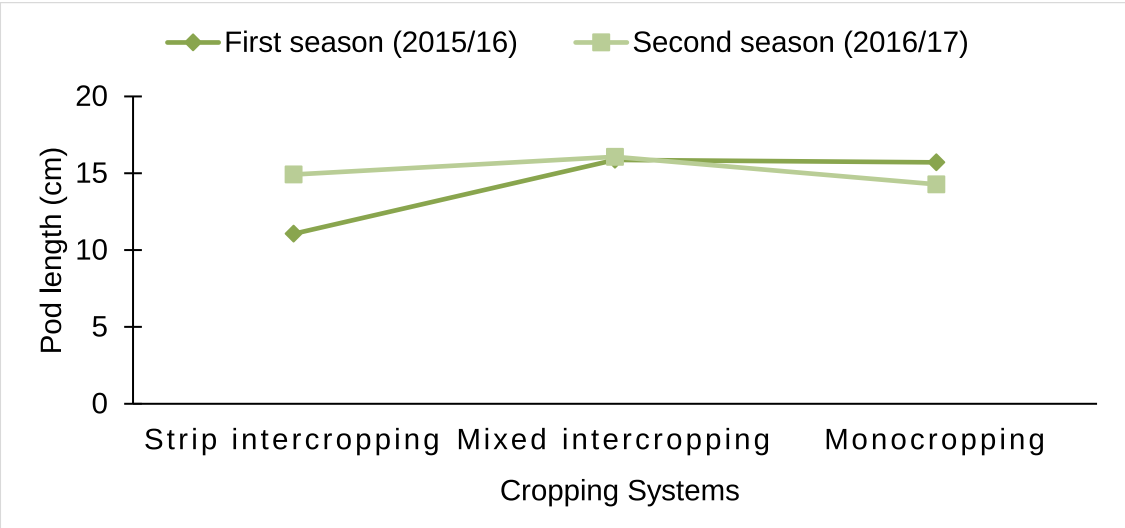

Figure 4.11: Interaction between the cropping systems and seasons in terms of pod length at the University of Limpopo farm during the 2015/16 and 2106/17 seasons.

4.2.5 Number of pods per plant

The results show that the interaction between varieties and cropping systems ($P \leq 0.05$), and that between cropping systems and seasons ($P \leq 0.001$) were significant ($P < 0.05$) for the number of pods achieved per plant (Table 4.6). Variety IT82E-16 produced more pods (16 pods) under strip intercropping, whereas variety TVu 13464 produced fewer pods under strip intercropping, with a mean of nine pods. Mixed intercropping showed no significant difference among the varieties, with an average of 15 pods being achieved (Figure 4.12). No significant differences were observed between monocropping and strip intercropping during the 2015/16 season, with more pods per plant (16 pods), and fewer pods (10 pods) during the 2016/17 season. However, mixed intercropping produced more pods (16 pods) during the 2016/17 season (Figure 4.13). Iderawumi and Friday's (2013) research reveals that sole cowpea plants produce a significantly higher number of harvested pods per plant than those that are intercropped with maize. Matusso, Mugwe, and Muceru-Muna (2014) also found that the number of pods, pod weight, and seed yield are significantly reduced when cowpea is intercropped with maize.

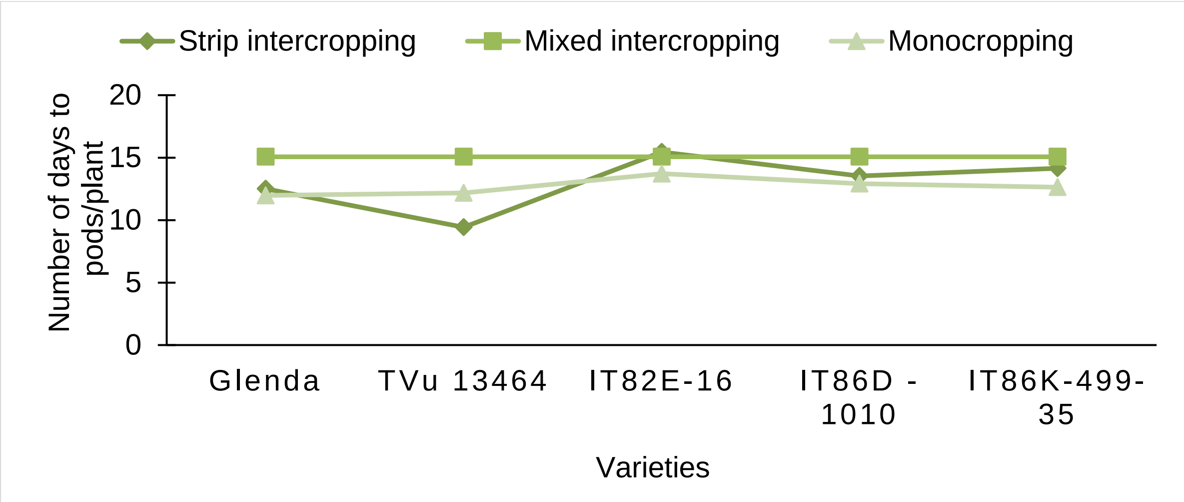

Figure 4.12: Interaction between cowpea varieties and cropping systems in terms of the number of pods/plant produced at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

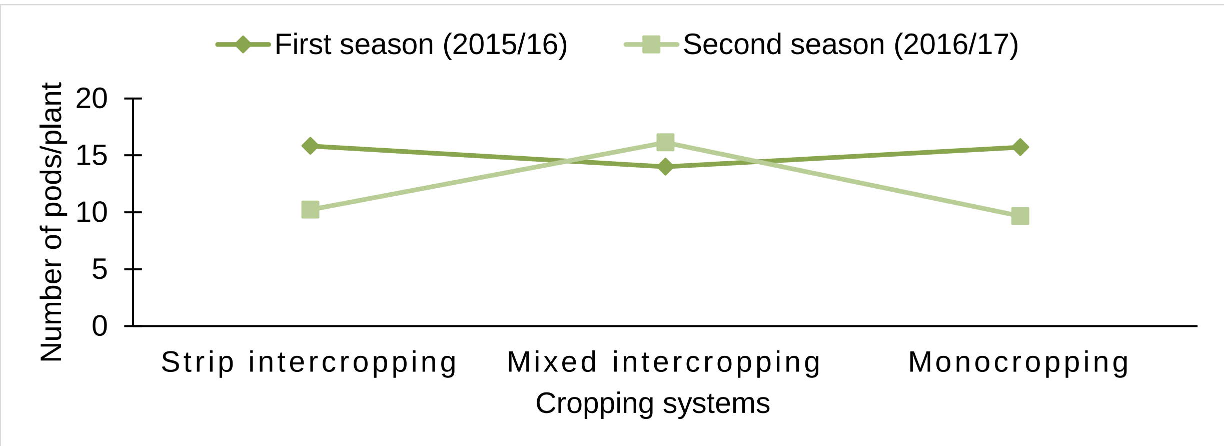

Figure 4.13: Interaction between cropping systems and seasons in terms of the number of pods achieved per plant at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

4.2.6. 100 seed weight

The results show that the interaction between varieties and cropping systems, and that between cropping systems and seasons are significant (P<0.05) for seed weight (Table 4.6). Under strip intercropping, variety IT86K-499-35 produced a high 100 seed weight of 22.24 g, whereas TVu 13464 obtained low 100 seed weight of 16g under strip intercropping and monocropping (Figure 4.15). Monocropping (21.35g) and strip intercropping (21.40g) showed significant differences with high 100 seed weight than mixed intercropping (20.33g) during 2015/16. During 2016/17, there was no significant difference among the cropping systems (Figure 4.14). However, 2015/16 season produced heavier seed than what was produced during the 2016/17 season, with a means of 21.03g and 16.63g respectively (Table 4.7). These differences could be due to the difference in rainfall and temperature patterns over the two seasons. The high rainfall of 126.73mm received during the flowering stage in the 2015/16 seasons, with its low temperature, as opposed to the 2016/17 season (23.12mm), is likely to have favoured the good seed development. Ndiso et al. (2017) report that strip and mixed intercropping significantly reduces cowpea 100-grain weight when cowpea is intercropped with maize. They also report that there is no significant difference between sole crop cowpea and cowpea intercropped with maize.

Table 4.6: Analysis of variance in terms of the number of pods per plant and the 100 seed weight of five cowpea varieties at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

Source variation	**DF**	**Number of pods per plant**				**100 seed weight**			
		SS	**MS**	**F**	**P**	**SS**	**MS**	**F**	**P**
Replication (Rep)	2	11.78	5.892			0.831	0.416		
Variety (V)	4	64.15	16.038	4.94	0.0265**	228.868	57.217	184.60	0.0000***
Error REP*V	8	25.97	3.247			2.480	0.310		
Cropping system (CS)	2	99.60	49.799	15.18	0.0001***	2.690	1.345	4.16	0.0309**
V*CS	8	70.82	8.852	2.70	0.0343**	119.227	14.903	46.08	0.0000***
Error REP*V*CS	20	65.63	3.281			6.469	0.323		
Season (S)	1	225.44	225.435	56.63	0.0000***	434.764	434.764	304.45	0.0000***
V*S	4	11.37	2.842	0.71	0.5889ns	1.211	0.303	0.21	0.9298ns
CS*S	2	316.62	158.308	39.77	0.0000***	9.579	4.789	3.35	0.0485*
V*CS*S	8	19.98	2.498	0.63	0.7481ns	5.282	0.660	0.46	0.8726ns
Error REP*V*CS*S	30	119.43	3.981			42.841	1.428		
Total	89	1030.78				854.242			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

Table 4.7: Mean pod length, number of pods/plant, and 100 seed weight recorded at the University of Limpopo farm during the 2015/2016 and 2016/2017 seasons.

Variety (V)	Pod length (cm)	Number of pods/plant	100 seed weight(g)
Glenda	13.93cd	13.19bc	17.66c
TVu 13464	13.26d	12.22c	16.69d
IT82E-16	15.97a	14.75a	18.50b
IT86D -1010	15.40ab	13.85ab	20.63a
IT86K-499-35	14.68bc	13.95ab	20.68a
Grand mean	14.65	13.60	18.83
Cropping System (CS)			
Monocropping	14.99b	12.69b	18.88ab
Strip Intercropping	12.98c	13.02b	19.01a
Mixed intercropping	15.97a	15.07a	18.60b
Season (S)			
2015/16	14,20b	15.17a	21.03a
2016/17	15.08a	12.01b	16.63b

The means followed by the same letter in a column do not differ significantly at P≤ 0.05 from each other.

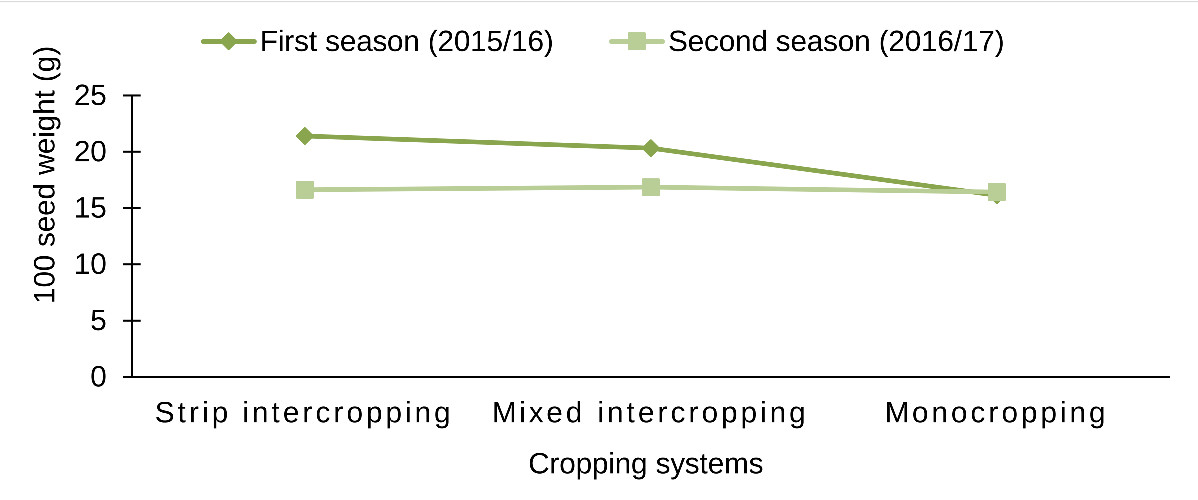

Figure 4.14: Interaction between cropping systems and seasons in terms of the 100 seed weight at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

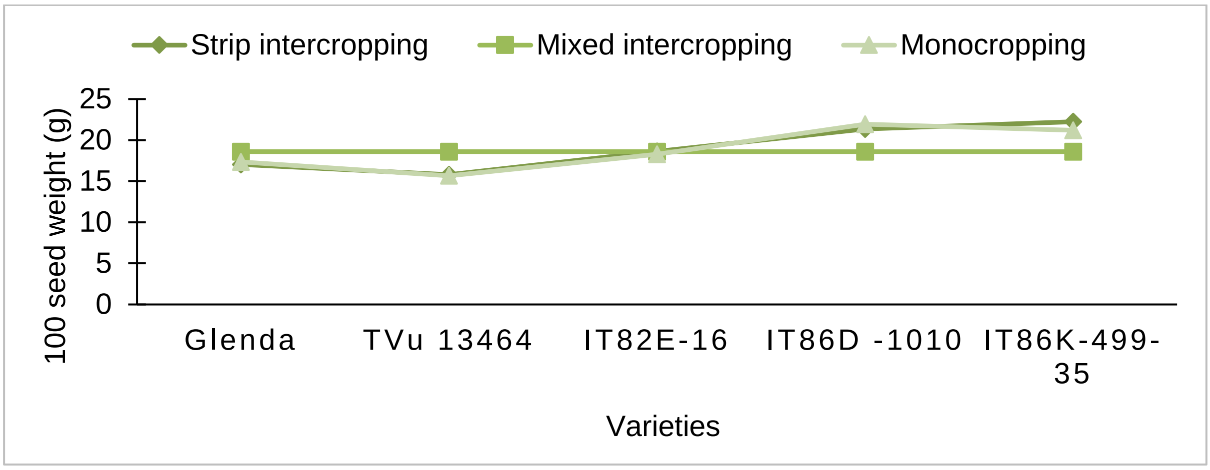

Figure 4.15: Interaction between cowpea varieties and cropping systems for the 100 seed weight at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

4.2.7. Grain yield

The results show that the interactions between varieties and cropping systems, and that between varieties and seasons are significant ($P<0.05$) for grain yield (Table 4.8). Variety IT82E-16 produced a higher grain yield under monocropping, with a mean of 2230 kg/ha, while mixed intercropping performed poorly, with the lowest grain yield (273 kg/ha) out of all varieties (Figure 4.16). Variety IT82E-16 produced a higher grain yield of 1373 kg/ha during the 2016/17 season, while variety TVu 13464 produced the lowest grain yield of 517 kg/ha during the 2015/16 season (Figure 4.17). However, the 2016/17 season produced a higher grain yield (934 kg/ha) than the 2015/16 season, which had a mean of 730 kg/ha (Table 4.9). Sebetha (2009) reported significant difference between cropping system by cowpea variety interaction on cowpea grain yield at this test site. In corroboration with these results, Barry, Ward, and Roe (2013) report that strip intercropping can generate greater crop yields and total revenue than planting the equivalent number of acres in large, monoculture fields. Kadam and Salunkhe (1998) also report that variety IT82E-16 produced a higher grain yield than the Red Caloona variety over two planting seasons, and suggest that this could be due to better pod filling.

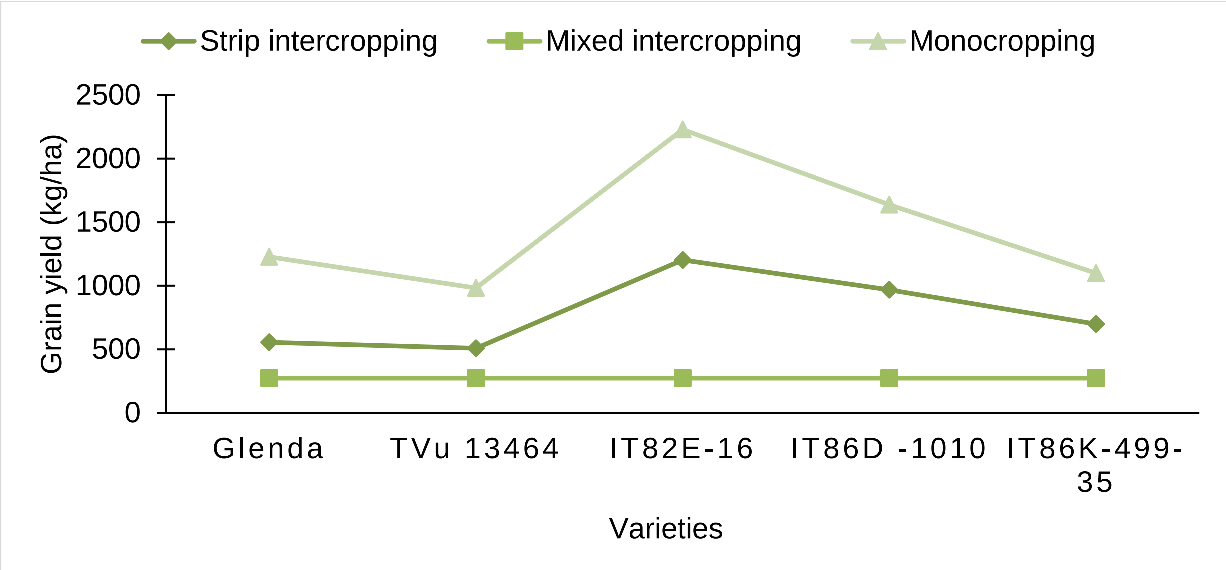

Figure 4.16: Interaction between cowpea varieties and cropping systems in terms of grain yield at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

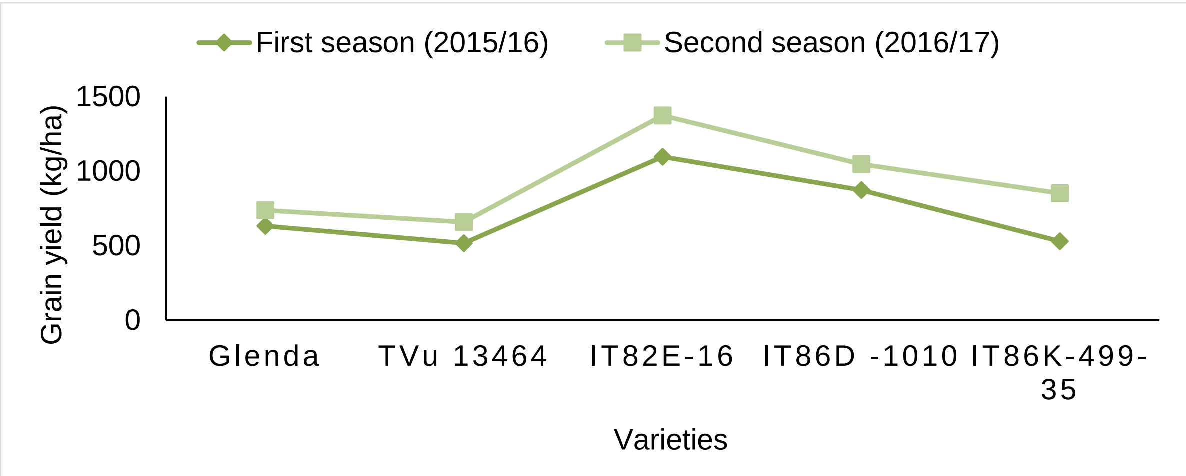

Figure 4.17: Effect of interaction between cowpea varieties and seasons in terms of grain yield at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

4.2.8. Fodder weight

The results show that the interaction between varieties and cropping systems, and that between cropping systems and seasons are significant (P<0.05) in terms of fodder weight (Table 4.8). The Glenda variety produced a higher fodder weight of 3025kg/ha under monocropping. Mixed intercropping produced the lowest fodder weight of 500kg/ha in all crop mixtures (Figure 4.18). Glenda outperformed all the varieties with the highest fodder weight of 2233 kg/ha during the 2016/17 season, and variety IT82E-16 gave the lowest fodder weight of 822kg/ha during the 2016/17 season (Figure 4.19). IT82E-16 is a grain cowpea, while Glenda is a dual-purpose cowpea with a lot of leaves. These results also show that maturity and canopy width have a significant influence on fodder weight. For example, the Glenda variety matured later and produced a wide canopy (Table 4.4), due to more leaf and branch development, which resulted in the plant producing more fodder. According to Blümmel, Anandan, and Wright (2012a), late-maturing cowpea varieties are often used for fodder because they can take advantage of a longer growing season to produce more biomass. However, longer growing periods can make the crop susceptible to late drought.

Table 4.8: Analysis of variance in terms of the grain yield and fodder weight of five cowpea varieties at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

Source variation	DF	Grain yield (kg/ha)				Fodder weight (kg/ha)			
		SS	MS	F	P	SS	MS	F	P
Replication (Rep)	2	255605	127803	22.76		1968167	984083		
Variety (V)	4	5043829	1260957		0.0002***	8808056	2202014	5.92	0.0162**
Error REP*V	8	443234	55404.2	384.50	0.0000***	2974611	371826		
Cropping system (CS)	2	2.035E+07	1.017E+07	15.25	0.0000***	3.182E+07	1.591E+07	55.77	0.0000***
V*CS	8	3227909	403489		0.0000***	5737111	717139	2.51	0.0452*
Error REP*V*CS	20	529286	26464.3	87.79		5705556	285278		
season (S)	1	937380	937380	3.59	0.0165**	72250.0	72250.0	0.15	0.6973ns
V*S	4	153513	38378.2	3.11	0.0594*	5227611	1306903	2.79	0.0441**
CS*S	2	66340.6	33170.3	1.62	0.1594ns	718167	359083	0.77	0.4735ns
V*CS*S	8	138796	17349.4			5558222	694778	1.48	0.2049ns
Error REP*V*CS*S	30	320308	10676.9			1.405E+07	468500		
Total	89	3.147E+07				8.265E+07			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

Table 4.9: Mean for grain yield and fodder weight at the University of Limpopo farm during the 2015/2016 and 2016/2017 seasons.

Variety (V)	**Grain yield (Kg/ha)**	**Fodder weight (Kg/ha)**
Glenda	685.3c	1769.4a
TVu 13464	588.1c	1005.6b
IT82E-16	1235.6a	858.3c
IT86D -1010	959.7b	1277.8b
IT86K-499-35	690.6c	1130.6b
Grand mean	831.83	1208.3
Cropping System (CS)		
Monocropping	1435.5a	1955.0a
Strip Intercropping	786.7b	1170.0b
Mixed intercropping	273.3c	500.0c
Season (S)		
2015/16	729.78b	1180.0a
2016/17	933.89a	1236.7a

Means followed by the same letter in a column do not differ significantly (P≤ 0.05) from each other.

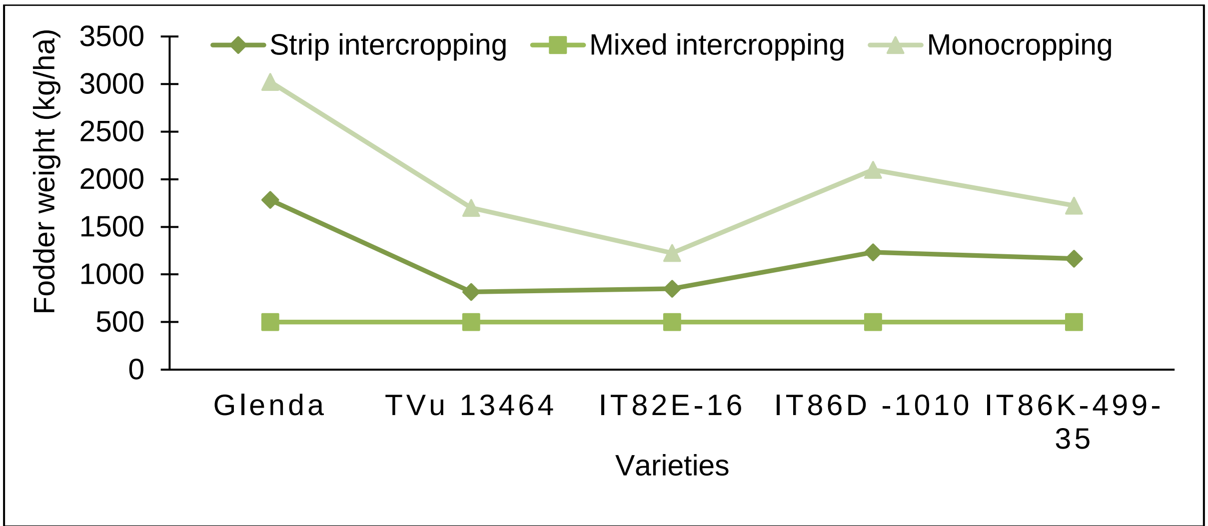

Figure 4.18: Interaction between cowpea varieties and cropping systems in terms of fodder weight at the University of Limpopo farm during the 2015/2016 and 2016/2017 seasons.

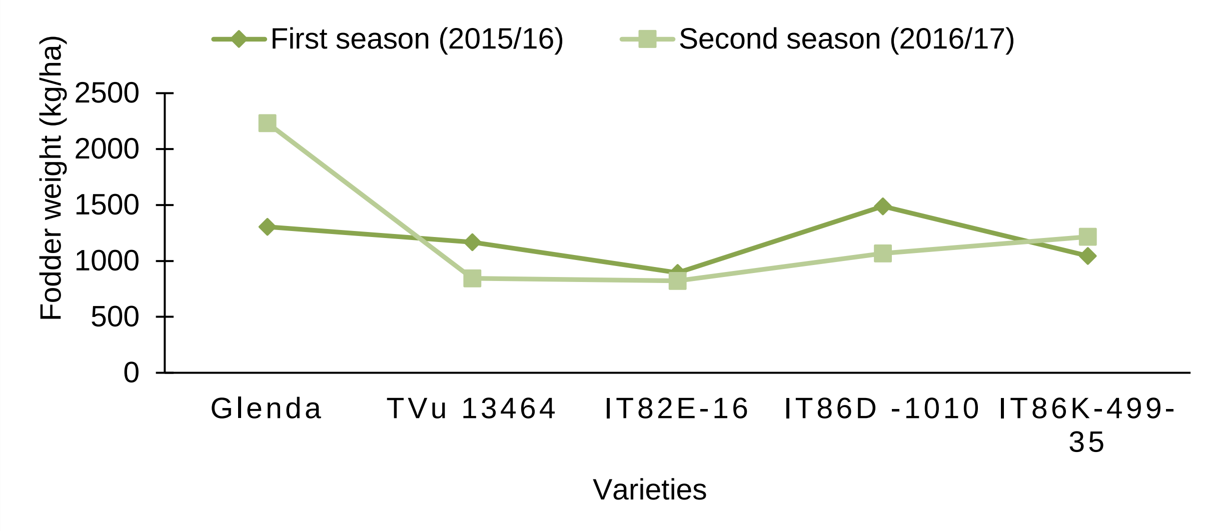

Figure 4.19: Interaction between cowpea varieties and seasons in terms of fodder weight at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

4.3 Performance of maize at the University of Limpopo farm

4.3.1 Number of days to 50% tasselling

The results show that the interaction between cropping systems and seasons had no significant influence ($P<0.05$) on the number of days to 50% tasselling (Table 4.10). However, the seasons showed to have a significant effect ($P<0.05$) on days to 50% tasselling (Table 4.19). Tasselling occurred earlier during the 2015/16 with an average of 65 days than 2016/17, which took 71 (Table 4.11). This could be due to higher rainfall during the 2016/17 season (Figure 4.2) in comparison to the 2015/16 season (Figure 4.1). The maximum temperatures for the 2016/17 season were lower (Figure 4.2) than those recorded in the 20015/16 season (Figure 4.1), and this must have resulted in plants accumulating moisture, which probably prolonged their tasselling during the 2016/17 season, as opposed to the 2015/16 season, which was warmer and recorded lower rainfall. These plants needed more time to accumulate the require GDD. According to Harrison et al. (2011), warmer growing season temperatures can directly reduce yields in two important ways. Firstly, higher temperatures accelerate crop growth in crops where phenology is predominantly regulated by temperature, such as maize. This reduces the time for plant and grain development, limiting the attainment of yield potential. Secondly, if extreme heat occurs during flowering, such as maize's silk-tasselling' phase, pollination and grain filling may be inhibited, and the development of grain may be prevented entirely.

4.3.2 Number of days to 50% silking

The results show that the interaction between cropping systems and seasons had a significant difference (P<0.05) on days to 50% silking (Table 4.10). Strip intercropping was the earliest, with a mean of 65 days to attain 50% silking during the 2015/16 season, as opposed to the 2016/17 season during which monocropping and strip intercropping took 83 days to reach 50% silking, with no significant difference between them (Figure 4.20). This could be due to higher rainfall during the 2016/17 season (Figure 4.1 & 4.2) in comparison to the 2015/16 season (Figure 4.1). Additionally, the maximum temperatures recorded during the 2016/17 season (Figure 4.2) were lower than those recorded in the 20015/16 season (Figure 4.1), and this resulted in crops accumulating more moisture than during the warmer period of the 2015/16 season. Hot and dry weather conditions both hasten pollen shed and delay silk emergence, narrowing the duration of synchronisation. In addition, pollen's ability to germinate on silks is greatly reduced at temperatures above 32°C (Saxena, Kumar, and Rao, 2010).

Table 4.10: Analysis of variance in terms of the number of days to 50% tasselling and 50% silking in maize at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

Source	DF	Days to 50% Tasselling				Days to 50% Silking			
		SS	MS	F	P	SS	MS	F	P
Replication (Rep)	2	27.27	13.633			20.47	10.23		
Cropping system (CS)	2	9.60	4.800	3.89	0.1152ns	113.87	56.93	8.80	0.0343**
Error REP*CS	4	4.93	1.233			25.87	6.47		
Season (S)	1	915.21	915.211	794.95	0.0000***	4766.94	4766.94	1508.61	0.0000***
CS*S	2	3.29	1.644	1.43	0.2459ns	194.49	97.24	30.78	0.0000***
Error	78	89.80	1.151			246.47	3.16		
Total	89	1050.10				5368.10			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

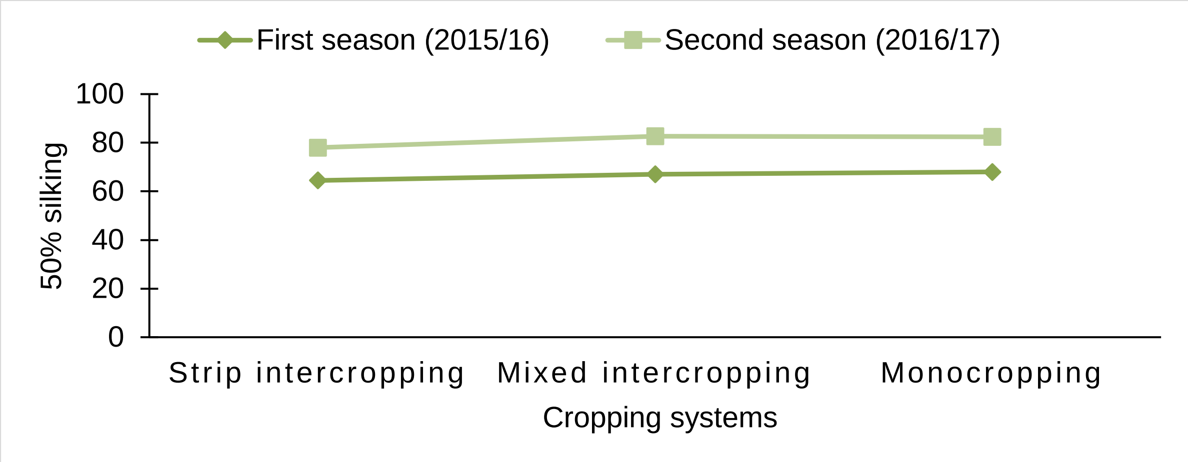

Figure 4.20: Interaction between cropping systems and seasons in respect of maize and the number of days to 50% silking at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

4.3.3 Plant height

The results show that the interaction between cropping systems and seasons has a significant difference (P<0.05) on plant height (Table 4.12). In contrast to strip and mixed intercropping, monocropping produced higher plants of 149.27cm during the 2016/17 season. Mixed intercropping produced shorter plants (134cm) during the 2016/17 season, and monocropping had a mean of 138cm during the 2015/16 season (Figure 4.21). Lemlem (2003) established that intercropping maize with cowpea reduces maize height, due to environmental factors and competition.

Table 4.11: Mean of number of days to 50% tasselling, 50% silking, and plant height of maize at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

	50% tasselling	**50% silking**	**Plant height (cm)**
	Cropping system (CS)		
Monocropping	68.30a	75.23a	143.63a
Strip intercropping	67.90ab	73.57ab	146.33a
Mixed intercropping	67.50b	72.50b	141.00a
	Season (S)		
2015/16	64.71b	66.49a	143.98a
2016/17	71.09a	81.04b	143.33a

Means followed by the same letter in a column do not differ significantly (P≤ 0.05) from each other.

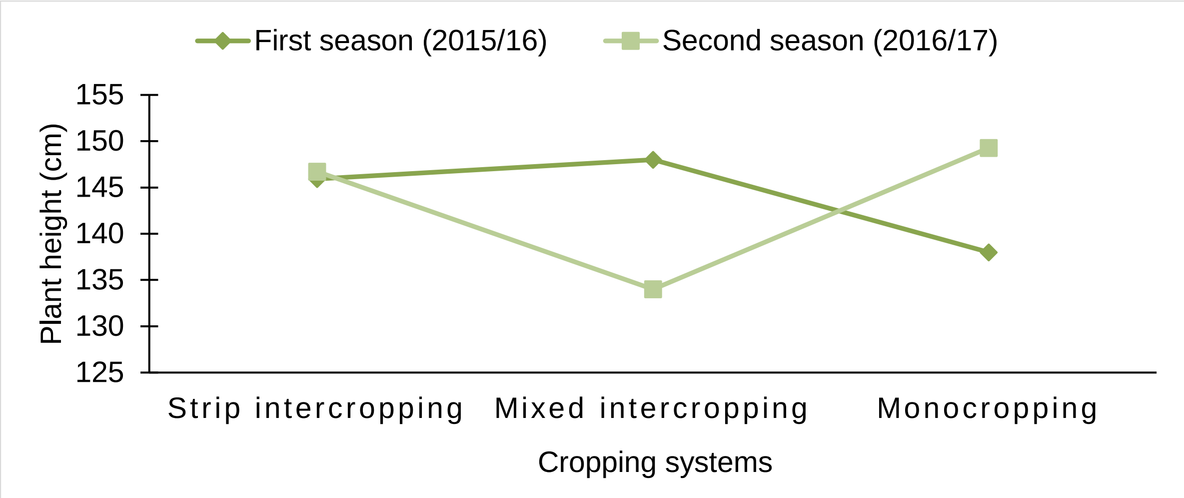

Figure 4.21: Interaction between cropping systems and seasons in terms of maize plant height at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

4.3.4 Cob length

The results show that the interaction between cropping systems and seasons have a significant effect (P<0.05) on cob length (Table 4.12). In comparison to the other cropping systems, monocropping produced longer cobs of 17.67cm during the 2015/16 season. However, monocropping produced shorter cobs during the 2016/17 season (15.53cm) as opposed to strip and mixed intercropping that recorded an average cob length of 16cm (Figure 4.22). Cob length is a significant factor, as it contributes to the final grain yield. Longer cobs observed under monocropping were due more space between plants than in optimised plant density under strip and mixed intercropping, and the longer cobs recorded during the 2015/16 season may be attributed to the moderate rainfall received in March 2016 during the vegetative stage.

Table 4.12: Analysis of variance in terms of maize plant height and cob length at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

Source	DF	Plant height (cm)				Cob length (cm)			
		SS	MS	F	P	SS	MS	F	P
Replication (Rep)	2	2590.6	1295.28			8.956	4.4778		
Cropping system (CS)	2	426.7	213.34	1.44	0.3380ns	1.156	0.5778	0.25	0.7876ns
Error REP*CS	4	592.6	148.14			9.111	2.2778		
Season (S)	1	9.3	9.34	0.05	0.8320ns	45.511	45.5111	54.84	0.0000***
CS*S	2	2417.5	1208.74	5.86	0.0043***	6.756	3.3778	4.07	0.0208**
Error	78	16085.7	206.23			64.733	0.8299		
Total	89	22122.3				136.222			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

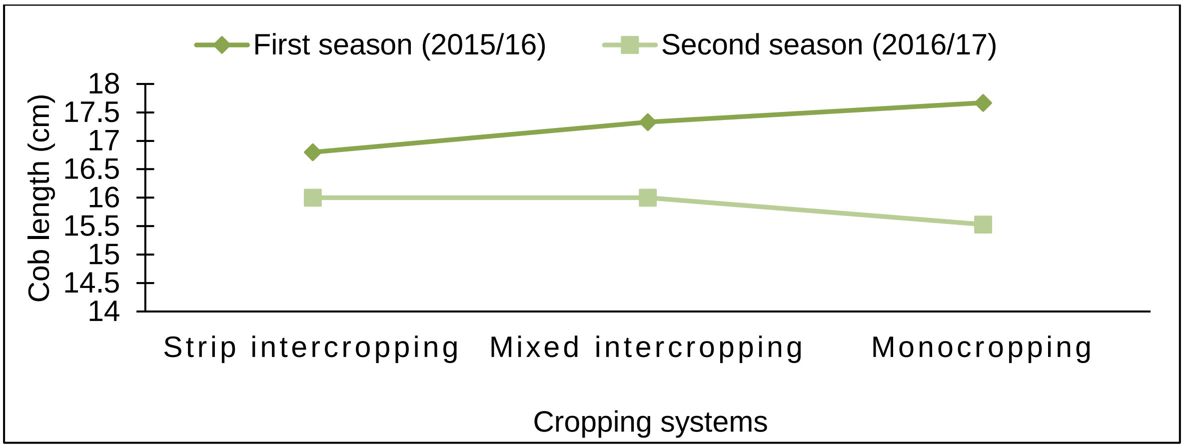

Figure 4.22: Interaction between cropping systems and seasons in respect of maize cob length at the University of Limpopo farm during the 2015/2016 and 2016/2017 seasons.

4.3.5 Number of cobs per plant

The results show that the interaction between cropping systems and seasons had no significant effect (P<0.05) on the number of cobs per plant (Table 4.13). However, seasons showed a significant difference (P<0.05) (Table 4.13). Number of cobs per plant during the 2015/16 season were higher with a mean of 1.87 where in the 2016/17 season there was a mean of 1.67cm (Table 4.15). These results could be due to the high rainfall of 126.73mm received in March 2016 (Figure 4.1), as opposed to the 2016/17 season, which received low rainfall of 23.12mm in March 2017 (Figure 4.2). This is likely to have resulted in the development of more cobs per plant. According to Park, Rozelle, and Huang (2004), cob number and size can vary greatly between cultivars, and can also be enhanced by good environments, such as rainfall.

4.3.6 Grain yield

The results of the maize grain yield show that the interaction between cropping systems and seasons is significant (P<0.05) (Table 4.13). Strip intercropping produced a higher grain yield of 3961kg/ha during the 2016/17 season, while mixed intercropping produced the lowest grain yield of 1320kg/ha and 2041kg/ha during both seasons. Monocropping showed no significant difference, with a mean of 2966kg/ha in both seasons in terms of grain yield (Figure 4.23). These results are in line with those of Muhammad et al. (2008) and Chitra and Shrestha (2014) who report significant differences among maize cultivars and cropping systems in terms of grain yield.

Table 4.13: Analysis of variance in terms of number of cobs per maize plant and grain yield at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

Source		**Number of cobs/plant**				**Grain yield (Kg/ha)**			
	DF	**SS**	**MS**	**F**	**P**	**SS**	**MS**	**F**	**P**
Replication (Rep)	2	0.16	0.07			7713863	3856931		
Cropping system (CS)	2	2.49	1.24	2.91	0.1660ns	5.255E+07	2.628E+07	31.22	0.0036***
Error Rep*CS	4	1.71	0.48			3366430	841608		
Season (S)	1	0.71	0.71	4.00	0.0490*	5961132	5961132	21.17	0.0000***
CS*S	2	0.62	0.31	1.75	0.1805ns	5133995	2566997	9.12	0.0003***
Error	78	13.87	0.18			2.197E+07	281608		
Total	89	19.56				9.669E+07			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

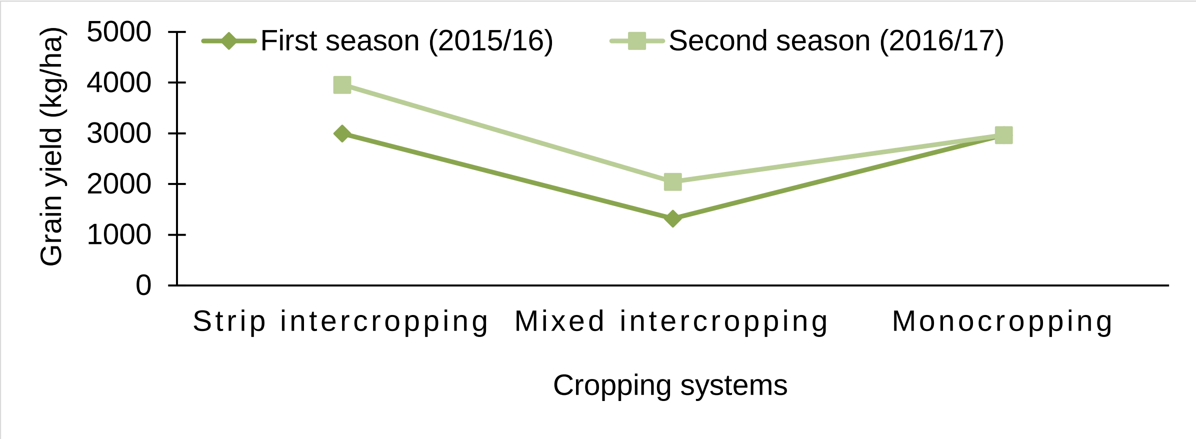

Figure 4.23: Interaction between cropping systems and seasons in terms of maize grain yield at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

4.3.7 Stover yield

The results show that the interaction between cropping systems and seasons has a significant effect ($P<0.05$) on stover yield (Table 4.14). Stover yield is an important factor in livestock feeding. During the 2016/17 season, strip intercropping produced a high stover yield of 48601kg/ha, higher than monocropping and mixed intercropping. However, no significant differences were observed between monocropping, strip, and mixed intercropping, where stover yields of 3083, 2722, and 3472 kg/ha were realised respectively in the 2015/16 season (Figure 4.24). These results are not in line with those of Hamd Alla et al. (2014) who reported that the effect of intercropping on maize stover yield in different growing seasons (1997 and 1998) was significant.

Table 4.14: Analysis of variance in terms of the maize stover yield at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

Source variation	DF	Stover yield (Kg/ha)			
		SS	MS	F	P
Replication (Rep)	2	1.286E+07	6431759		
Cropping system (CS)	2	6836127	3418064	1.81	0.2757ns
Error REP*CS	4	7558041	1889510		
Season (S)	1	3.030E+07	3.030E+07	37.82	0.0000***
CS*S	2	1.174E+07	5871038	7.33	0.0012***
Error	78	6.250E+07	801254		
Total	89	1.318E+08			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

Table 4.15: Mean for maize yield parameters at the University of Limpopo farm during the 2015/2016 and 2016/2017 seasons.

	Cob length (cm)	No of cobs/plant	Grain yield (kg/ha)	Stover yield (kg/ha)
Cropping system				
Monocropping	16.60a	1.60a	3039.2a	3291.7a
Strip intercropping	16.40a	1.73a	3478.6a	3791.3a
Mixed intercropping	16.67a	2.00a	1683.1b	3934.7a
Season (S)				
2015/16	17.27a	1.87a	2476.3b	3092.3b
2016/17	15.84b	1.69b	2991.0a	4252.8a

Means followed by the same letter in a column do not differ significantly (P≤ 0.05) from each other.

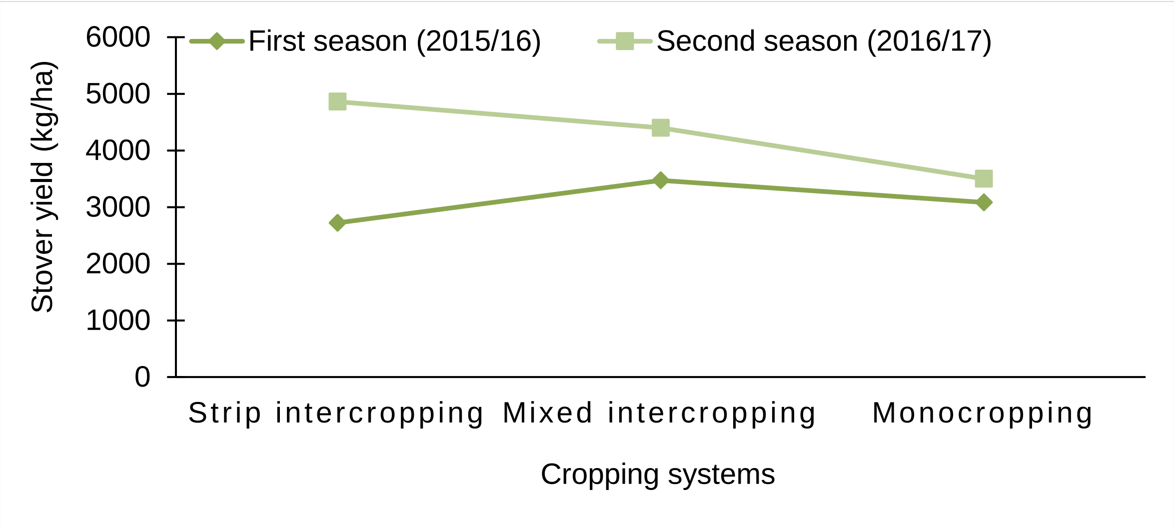

Figure 4.24: Interaction between cropping systems and seasons in terms of maize stover yield at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

4.3.8. Land equivalent ratio

The calculated LER for two crops over two seasons under strip intercropping ranged from 1.25 and 2.14, whereas under mixed intercropping, it ranged between 0.73 and 1.05 in both seasons. The mean for LER was greater than 1, thus indicating more efficient and productive land utilisation by strip intercropping in comparison to mixed intercropping. In mixed intercropping, only the Tvu 13464 and PAN 6479 varieties during the 2015/16 season and the Glenda and PAN 6479, and IT86K-499-35 and PAN 6479 varieties during the 2016/17 season exhibited LER values greater than 1 (Table 4.16). According to Hamd Alla et al. (2014), when the LER < 1.00 there is an obvious disadvantage to intercropping, and the available resources are used more efficiently by a sole crop as opposed to an intercrop.

Table 4.16: Partial LER and total LER for strip and mixed intercropping at the University of Limpopo farm during the 2015/16 and 2016/17 seasons.

2015/16 season						
	Strip intercropping			**Mixed intercropping**		
Crop mixture	**PLER maize**	**PLER Cowpea**	**Total LER**	**PLER maize**	**PLER Cowpea**	**Total LER**
Glenda + PAN 6479	0,80a	0.45a	1.25	0,60a	0.13b	0.73
Tvu 13464 + PAN 6479	0,95a	0.56a	1.51	0,81a	0.24a	1.05
IT82E-16 + PAN 6479	1.02a	0.57a	1.59	0,75a	0.11b	0.86
IT86D -1010 + PAN 6479	1,03a	0.62a	1.65	0,85a	0.14b	0.99
IT86K-499-35 + PAN 6479	1,04a	0.56a	1.60	0,72a	0.18ab	0.90
Mean	0,97	0.55	0.76	0,75a	0.16	0.46
P-level	0,6849ns	0.3601ns		0,7199ns	0.0531*	
2016/17 season						
	Strip intercropping			**Mixed intercropping**		
Crop mixture	PLER maize	PLER Cowpea	Total LER	PLER maize	PLER Cowpea	Total LER
Glenda + PAN 6479	1,43a	0.46b	1.89	0,73a	0.31ab	1.04
Tvu 13464 + PAN 6479	1,24a	0.52b	1.76	0,61a	0.39a	1
IT82E-16 + PAN 6479	1,42a	0 .54ab	1.96	0,69a	0.14c	0.83
IT86D -1010 + PAN 6479	1,30a	0.59ab	1.89	0,70a	0.21bc	0.91
IT86K-499-35 + PAN 6479	1,45a	0.69a	2.14	0,73a	0.31ab	1.04
Mean	1,37	0.56	0.97	0,69	0.27	0.48
P-level	0,9459ns	0.0581ns		0,5723ns	0.0378**	

Means followed by the same letter in a column do not differ significantly ($P \leq 0.05$) from each other. P = Probability, level of significance (* =$P \leq 0.05$; ** =$P \leq 0.01$; *** =$P \leq 0.001$).

Weather results during the 2015/16 and 2016/17 seasons at the Ga-Thaba village

At Ga-Thaba, the trial was planted on the 13th of January 2016 during 2015/16 planting season, whereas for the 2016/17 season it was planted on the 15th of December 2016. Both seasons, 2015/16 and 2016/17, received low rainfall, 7.58mm and 1.48mm) respectively (Figures 4.25 & 4.26). At Ga-Thaba village, during the 2015/16 season, the minimum temperatures ranged from 4^0C to 18.31^0C, while maximum temperatures ranged from 23^0C to 33.87^0C (Figure 4.25). During the 2016/17 season, the minimum temperatures ranged from 4^0C to 18^0C, while maximum temperatures ranged from 24^0C to 30.8 ^{0}C (Figure 4.26).

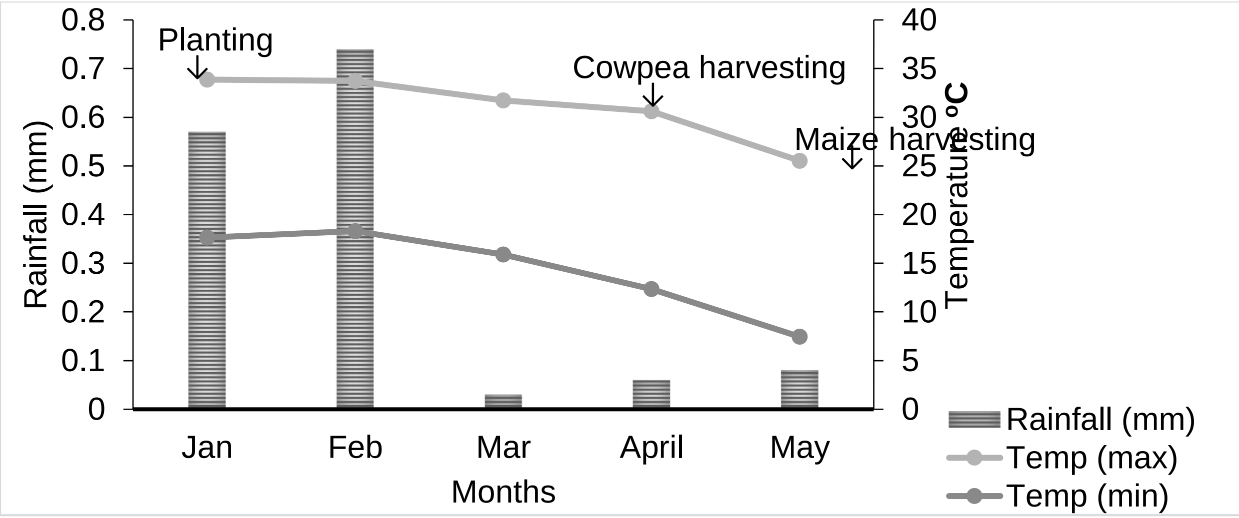

Figure 4.25: Monthly rainfall and mean minimum and maximum temperatures during the 2015/16 season at Ga-Thaba village.

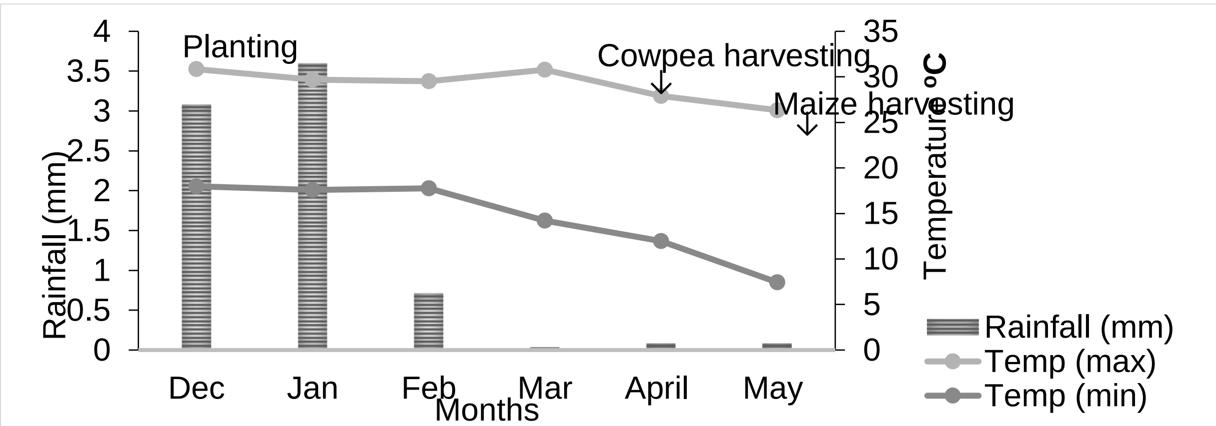

Figure 4.26: Monthly rainfall and mean minimum and maximum temperatures during the 2016/17 season at the Ga-Thaba village.

4.4 Performance of five cowpea varieties at the Ga-Thaba village

4.4.1. Number of days to 50% flowering

The results show that interaction between varieties, cropping systems, and seasons had significant effects ($P<0.05$) on the number of days to 50% flowering (Table 4.17). Variety IT86K-499-35 took 62 days to reach 50% flowering, while variety IT86D-1010 was the first (47 days) to reach 50% flowering during the 2015/16 season under monocropping. The Glenda variety attained 50% flowering in 56 days during the 2016/17 season under strip intercropping. Mixed intercropping flowered early with a mean of 50 days during the 2016/17 season across all varieties (Figure 4.27). The variation in 50% flowering among varieties is likely due to their genetic makeup. The difference between the varieties shows that they differ genetically with respect to 50% flowering. These findings are in line with those of Kamai et al. (2014) who report that cowpea varieties vary in terms of flowering duration.

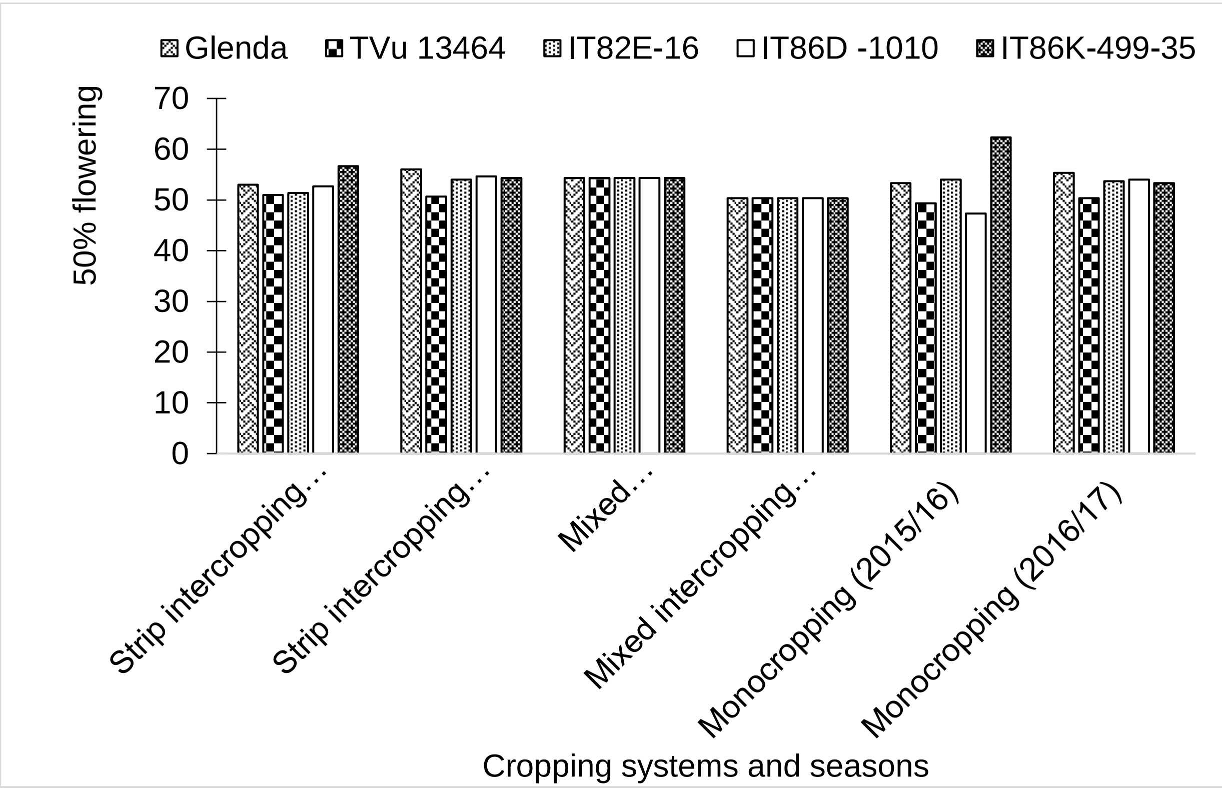

Figure 4.27: Interaction between cowpea varieties, cropping systems, and years for days to 50% flowering at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

4.4.2 Number of days to 90% maturity

The results show that interaction between varieties, cropping systems, and seasons had no significant effect (P<0.05) on the number of days to 90% maturity (Table 4.17). However, the growing seasons and cropping systems had significant effects (P<0.05) (Table 4.17). The 2015/16 season took 90 days compared to 84 days for the 2016/17 season (Table 4.18). Monocropping and strip intercropping reached 90% maturity earlier than mixed cropping, 86 and 85 days respectively, with no significant difference. Mixed intercropping was late, with a mean of 90 days (Table 4.18). The year-to-year variations in temperature and rainfall may have influenced performance of the varieties and cropping systems during the two different seasons. High rainfall causes crops to have prolonged vegetative stages, which delays the production of flowers and this results in late crop maturity and pod development.

Table 4.17: Analysis of variance in terms of the number of days to 50% flowering and 90% maturity of five cowpea varieties at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

Source variation	**DF**	**Days to 50% flowering**				**Days to 90% maturity**			
		SS	**MS**	**F**	**P**	**SS**	**MS**	**F**	**P**
Replication (Rep)	2	39.02	19.51			155.49	77.74		
Variety (V)	4	181.18	45.29	13.06	0.0014***	477.78	119.44	2.62	0.1151ns
Error REP*V	8	27.76	3.469			365.29	45.66		
Cropping system (CS)	2	21.62	10.81	1.89	0.1775ns	290.49	145.24	9.27	0.0014***
V*CS	8	140.82	17.60	3.07	0.0198**	249.96	31.24	2.00	0.1005ns
Error REP*V*CS	20	114.56	5.73			313.22	15.66		
Season (S)	1	21.51	21.51	4.07	0.0528*	666.94	666.94	21.45	0.0001***
V*S	4	114.38	28.59	5.41	0.0021***	227.56	56.89	1.83	0.1491ns
CC*S	2	106.02	53.01	10.02	0.0005***	163.82	81.91	2.63	0.0883ns
V*CS*S	8	112.42	14.05	2.66	0.0247**	143.51	17.94	0.58	0.7884ns
Error REP*V*CS*S	30	158.67	5.29			932.67	31.09		
Total	89	1037.96				3986.72			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

Table 4.18: The cowpea's reproductive growth period and mean number of days to 50% flowering and days to 90% maturity at the Ga-Thaba farm during the 2015/16 and 2016/17 seasons.

Variety (V)	**Days to 50% flowering**	**Days to 90% maturity**	**Reproductive growth period**
Glenda	53.72b	89.72a	36.00
TVu 13464	51.00d	87.28ab	36.28
IT82E-16	52.94bc	84.06b	31.12
IT86D -1010	52.22cd	84.83ab	32.61
IT86K-499-35	55.22a	89.39a	34.17
Grand mean	53.02	87.06	34.04
Cropping System (CS)			
Monocropping	53.30a	86.43b	33.14
Strip Intercropping	53.43a	85.23b	31.8
Mixed intercropping	52.33a	89.50a	37.17
Season (S)			
2015/16	53.51a	89.78a	36.27
2016/17	52.53a	84.33b	31.8

Means followed by the same letter in a column do not differ significantly (P≤ 0.05) from each other.

4.5 Treatment effects on the growth parameters of five cowpea varieties

4.5.1 Plant height

The results show that interaction between varieties and cropping systems and between cropping systems and seasons are significant (P<0.05) for plant height (Table 4.19). Glenda under strip intercropping was not significantly different with IT86K-499-35 under monocropping and strip intercropping. Both types produced plants with plant heights of 47.33cm and 47.62cm respectively under strip intercropping and IT86K-499-35 with 47.07cm under monocropping. The TVu 13464 variety produced shorter plants of 30.20cm under monocropping (Figure 4.29). Monocropping and strip intercropping showed no significant difference with the plant height of 48.43 and 51.27cm respectively. Mixed intercropping produced shorter plants of 33.93cm during the 2015/16 season with no significant difference between monocropping and strip intercropping during the 2016/17 season with means of 30.65cm and 33.72cm respectively (Figure 4.28). These observations support the earlier reports by Agbogidi and Egho (2012) who report that plants respond differently to environmental factors, based on their genetic structure and their adaptation capabilities, indicating that variability exists among species. These results are also similar to those of Hamd Alla et al. (2014) who reported that cowpea plant height was higher in intercropping than it was in sole crops.

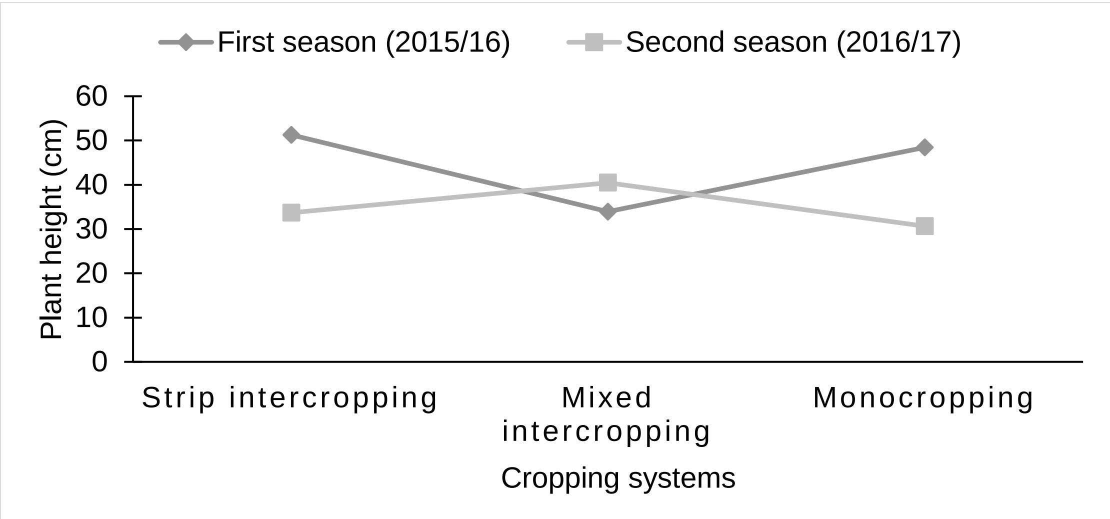

Figure 4.28: Interaction between cropping systems and seasons in terms of plant height at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

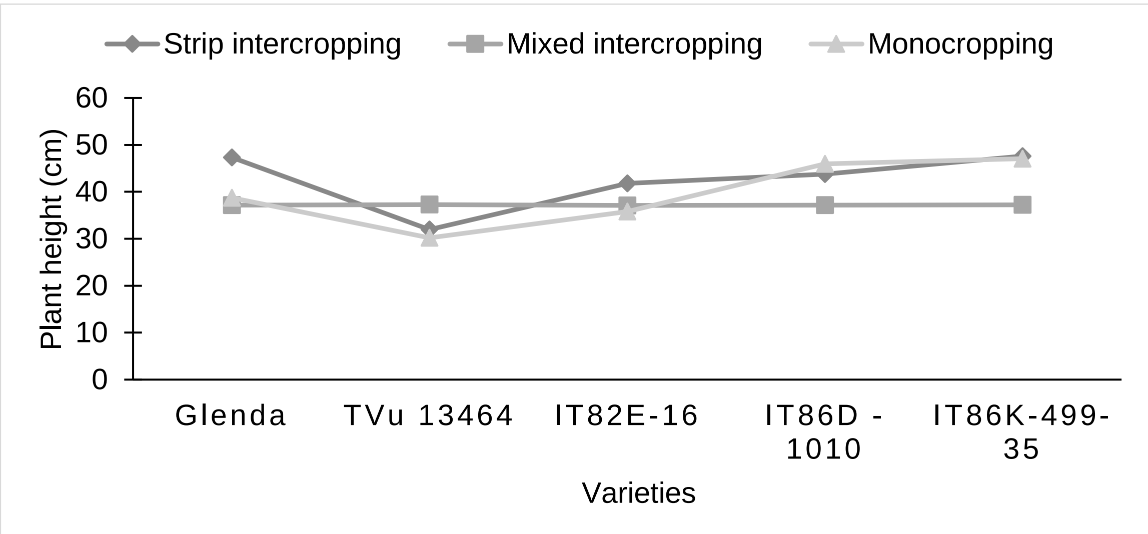

Figure 4.29: Interaction between cowpea varieties and cropping systems in terms of plant height at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

4.5.2 Peduncle length

The results show that interaction between varieties and seasons and between cropping systems and seasons has a significant effect(P<0.05) on peduncle length (Table 4.19). Variety IT86K-499-35 produced plants with the longest peduncle length of 33cm during the 2016/17 season than the 2015/16 season, while variety TVu 13464 produced plants with a short peduncle length of 22.17cm during the 2016/17 season than during the 2015/16 season (Figure 4.30). Monocropping and strip intercropping showed no significant difference with the highest mean of 32.39cm and 31.65cm respectively, while mixed intercropping had the shortest mean of 22.67cm during the 2015/16 season. During the 2016/17 season, there was no significant influence of cropping system and season interaction on peduncle length (Figure 4.31). The variations among varieties, cropping systems, and seasons are probably caused by the differences in rainfall, rainfall distribution, and temperature. In the two seasons at the Ga-Thaba village, there was low rainfall and high temperatures, which significantly influenced the performance of the treatments on peduncle length.

Table 4.19: Analysis of variance in respect of plant height and peduncle length of the five cowpea varieties at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

Source variation		**Plant height (cm)**				**Peduncle length (cm)**			
	DF	**SS**	**MS**	**F**	**P**	**SS**	**MS**	**F**	**P**
Replication(Rep)	2	128.30	64.15			42.98	21.49		
Variety (V)	4	1297.86	324.46	22.46	0.0002***	474.15	118.54	6.29	0.0137**
Error REP*V	8	115.58	14.45			150.72	18.84		
Cropping system (CS)	2	423.50	211.75	10.76	0.0007**8	325.09	162.54	9.08	0.0016***
V*CS	8	877.88	109.73	5.58	0.0009***	319.16	39.90	2.23	0.0700ns
Error REP*V*CS	20	393.56	19.68			358.21	17.91		
Season (S)	1	2074.08	2074.08	52.72	0.0000***	54.91	54.91	3.97	0.0555ns
V*S	4	275.23	68.81	1.75	0.1654ns	362.21	90.55	6.54	0.0007***
CS*S	2	2922.75	1461.38	37.14	0.0000***	574.62	287.31	20.76	0.0000***
V*CS*S	8	270.60	33.83	0.86	0.5599ns	217.44	27.18	1.96	0.0865ns
Error REP*V*CS*S	30	1180.29	39.34			415.14	13.84		

Total	89	9959.64				3294.62			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

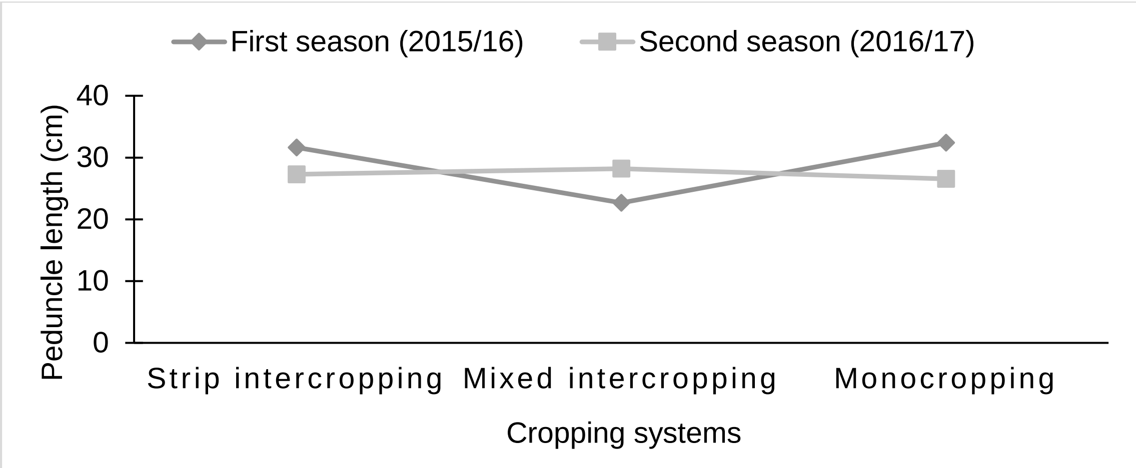

Figure 4.30: Interaction between cropping systems and seasons in terms of peduncle length at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

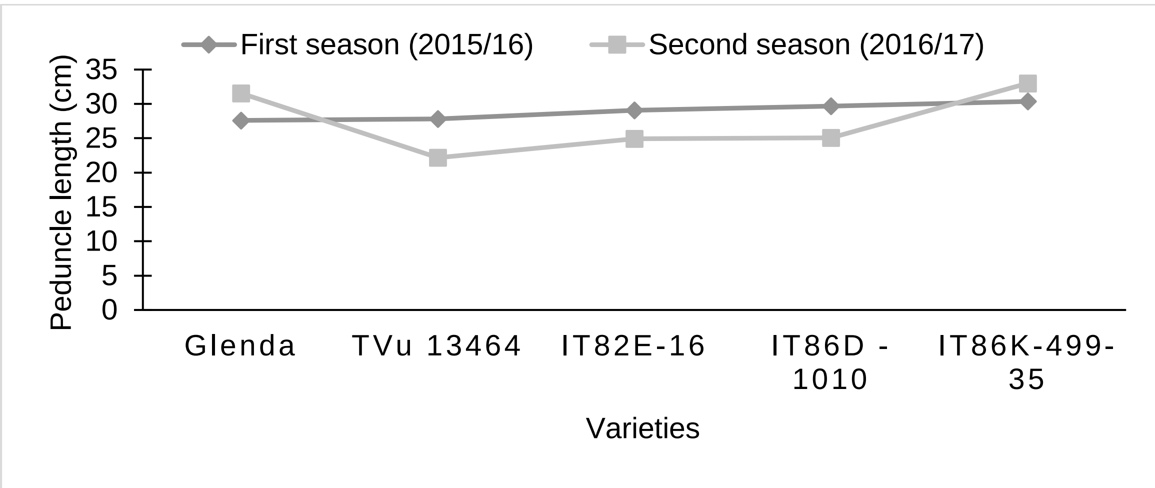

Figure 4.31: Interaction between cowpea varieties and seasons in terms of peduncle length at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

4.5.3 Canopy width

The results show that interaction between varieties and cropping systems, varieties and seasons, and that of cropping systems and seasons were significant ($P<0.05$) in terms of canopy width (Table 4.21). The Glenda variety achieved a wider canopy of 53.77cm under monocropping, while the TVu 13464 variety had a narrow canopy width of 40cm under the strip, intercropped, and monocropped systems. Mixed intercropping showed no significant differences in varieties, with a mean of 40.17cm (Figure 4.32). There were no significant differences between all of the cowpea varieties during the 2015/16 season, with the wider canopy width, in comparison to the 2016/17 season with means of 51.38cm, 49.18cm, 50.40cm, 51.56cm, and 51.98cm respectively. The TVu 13464 variety exhibited plants with the narrow canopy width of 30.71cm during the 2016/17 season (Figure 4.33). Monocropping and strip intercropping showed no significant difference achieving a wider canopy width of 55cm, while mixed intercropping had the narrowest canopy width of 43.67cm during the 2015/16 season. During 2016/17, there was no significant difference between cropping system snd season on canopy width with the narrowest canopy (36-38cm) (Figure 4.34). However, 2015/16 had wider canopy width (50.90cm) than 2016/17 with mean of 37.30cm (Table 4.20). These results also indicate that physiological maturity has a significant influence on canopy width. The varieties that matured late and reached 50% flowering late achieved wider canopies than those that reached physiological maturity early in the cycle. The Glenda variety, which was late in maturing, outperformed all the varieties with the widest canopy, and the TVu 13464 variety, which was matured early had the narrowest canopy.

Table 4.20: Mean cowpea plant heights, peduncle lengths, and canopy widths at the Ga-Thaba during the 2015/16 and 2016/17 seasons.

Variety (V)	Plant height (cm)	Peduncle length (cm)	Canopy width (cm)
Glenda	41.08ab	29.57ab	48.42a
TVu 13464	33.14c	24.99c	39.94d
IT82E-16	38.22b	27.00bc	43.06c
IT86D -1010	42.29a	27.37bc	45.82ab
IT86K-499-35	43.97a	31.68a	43.24bc
Grand mean	39.74	28.12	44.10
Cropping System (CS)			
Monocropping	39.54b	29.46a	46.05a
Strip Intercropping	42.49a	29.47a	46.07a
Mixed intercropping	37.19b	25.43b	40.17b
Season (S)			
2015/16	44.54a	28.90a	50.90a
2016/17	34.94b	27.34a	37.30b

Means followed by the same letter in a column do not differ significantly (P≤ 0.05) from each other.

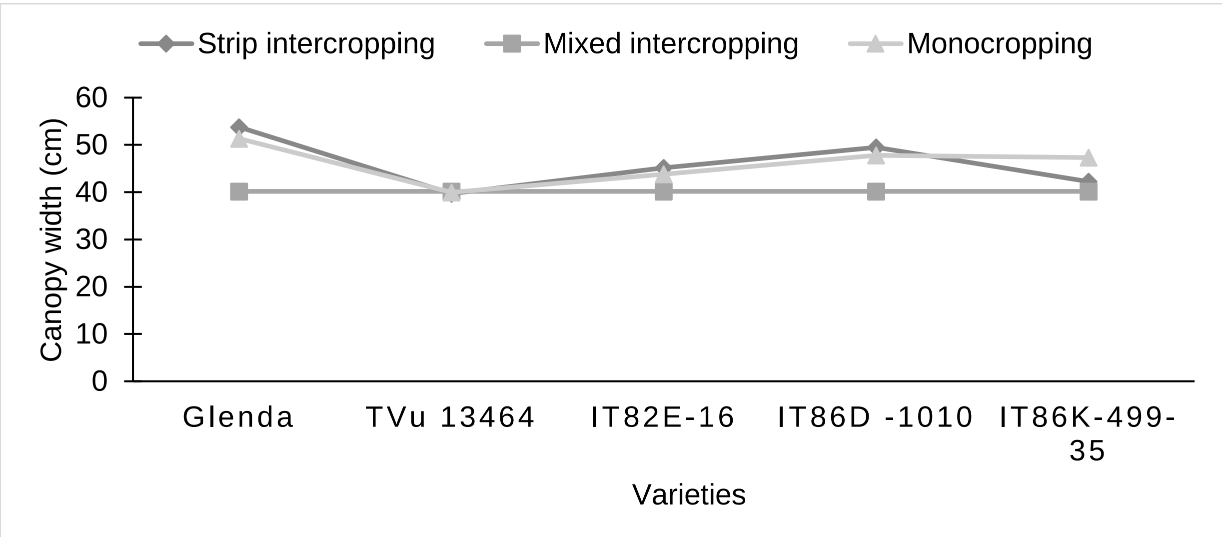

Figure 4.32: Interaction between cowpea varieties and cropping systems in terms of canopy width at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

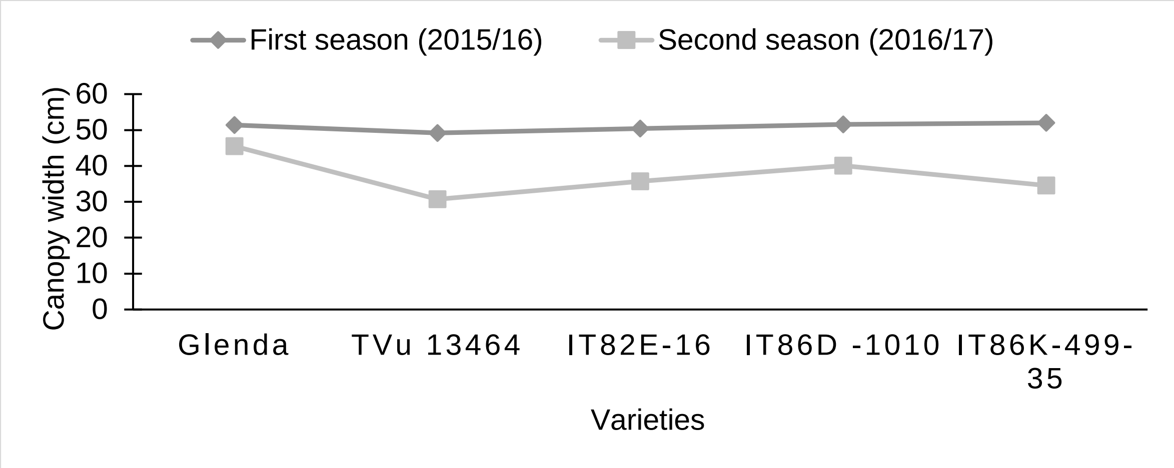

Figure 4.33: Interaction between cowpea varieties and seasons in terms of canopy width at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

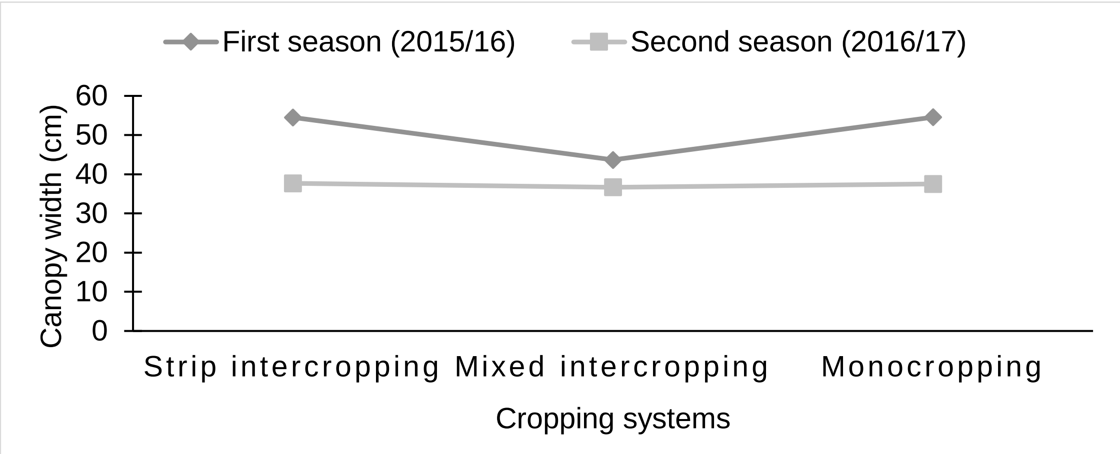

Figure 4.34: Interaction between cropping systems and seasons in terms of canopy widths at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

4.5.4 Pod length

The results show that interaction between varieties and cropping systems and between cropping systems and seasons are significant ($P<0.05$) for pod length (Table 4.21). Varieties IT82E-16 and IT86D -1010 under strip intercropping produced longer pods of 17.93cm and 17.23cm respectively, while variety TVu 13464 produced shorter pods under strip intercropping (11.54cm) (Figure 4.35). Strip intercropping, as opposed to monocropping and mixed intercropping, produced a longer pod length of 15.82cm during the 2015/16 season. Mixed intercropping produced pods with mean of 15.47cm during the 2016/17 season. However, mixed intercropping produced shorter pods of 11.22cm during both the 2015/16 and 2016/17 seasons (Figure 4.36). These differences are likely to due to environmental factors. According to Gyenes-Hegyi et al. (2010), delayed flowering is due to the combination of long days and very hot environments, resulting in flowers not produced and delayed flowering, thus late flowering, which in turn results in delayed pod development with short pod lengths.

Table 4.21: Analysis of variance in terms of canopy width and pod length of five cowpea varieties the Ga-Thaba farm during the 2015/16 and 2016/17 seasons.

Sources of variation	**DF**	**Canopy width (cm)**				**Pod length (cm)**			
		SS	**MS**	**F**	**P**	**SS**	**MS**	**F**	**P**
Replication (Rep)	2	127.16	63.58			5.934	2.9668		
Variety (V)	4	733.30	183.33	14.47	0.0010***	109.256	27.3139	23.15	0.0002***
Error REP*V	8	101.36	12.67			9.440	1.1800		
Cropping system (CS)	2	695.42	347.71	47.11	0.0000***	62.305	31.1525	18.05	0.0000***
V*CS	8	476.66	59.58	8.07	0.0001***	79.756	9.9694	5.78	0.0007***
Error REP*V*CS	20	147.60	7.38			34.509	1.7255		
Season (S)	1	4161.60	4161.60	155.89	0.0000***	41.412	41.4123	12.21	0.0015***
V*S	4	465.71	116.43	4.36	0.0067***	7.005	1.7511	0.52	0.7244ns
CS*S	2	490.24	245.12	9.18	0.0008***	110.577	55.2887	16.30	0.0000***
V*CS*S	8	329.78	41.22	1.54	0.1840ns	18.184	2.2730	0.67	0.7135ns
Error REP*V*CS*S	30	800.87	26.70			101.776	3.3925		
Total	89	8529.70				580.153			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

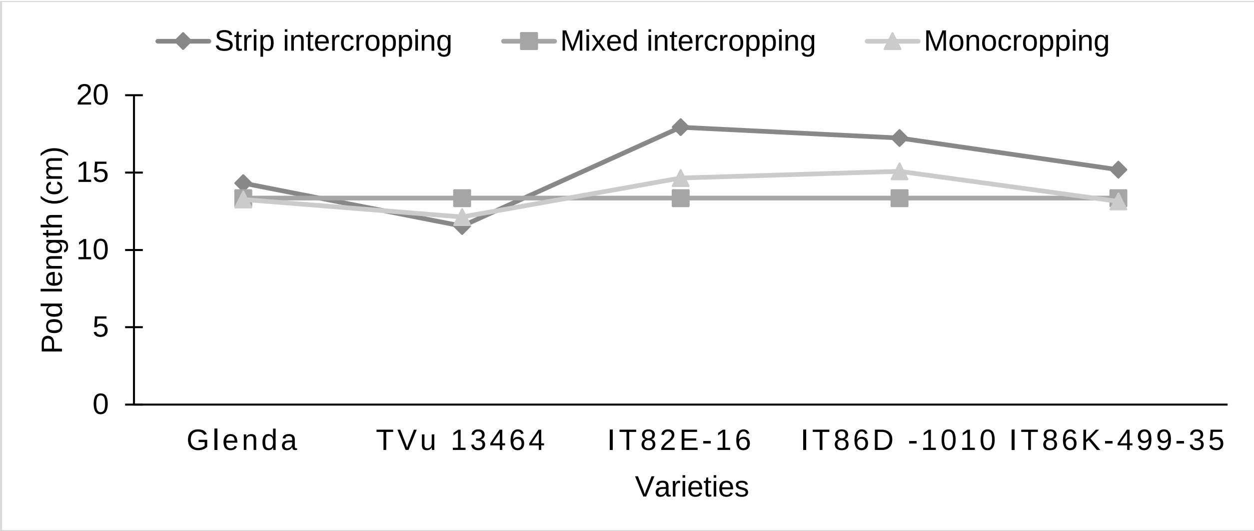

Figure 4.35: Interaction of cowpea varieties and cropping systems in terms of pod length at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

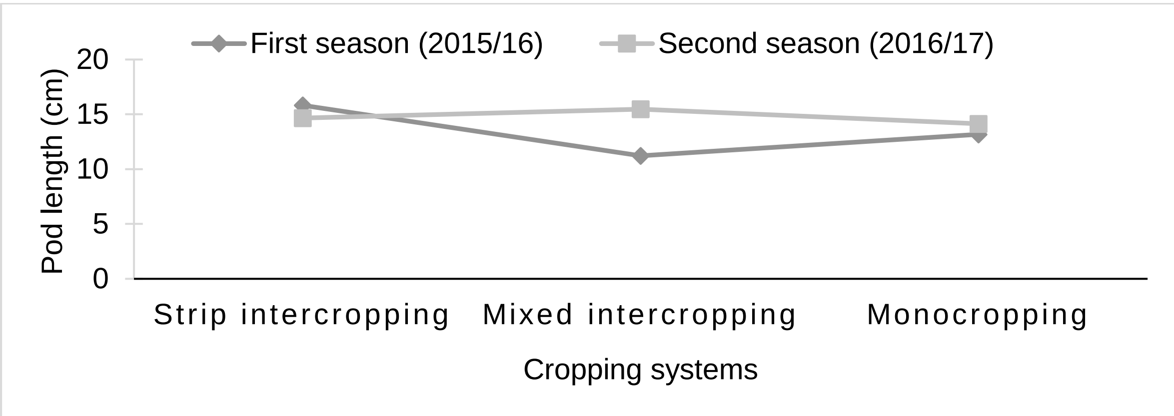

Figure 4.36: Interaction between cropping systems and seasons in terms of pod length at Ga-Thaba village during the 2015/16 and 2016/17 seasons.

4.5.5 Number of pods per plant

The results show that interaction between cropping systems and seasons has significant effects (P<0.05) on the number of pods produced per plant (Table 4.22). Mixed intercropping produced more pods per plant with a mean of 30 pods during the 2016/17 season, than strip intercropping (13 pods). Monocropping during the 2016/17 season produced a lower number of pods per plant with a mean of 11.24. There was no significant difference between monocropping and mixed intercropping during the 2015/16 season with means of 16 and 15 pods respectively (Figure 4.37). However, varieties, cropping systems, and growing seasons had no significant effect (P<0.05) on number of pods produced per plant (Figure 4.37). The reduction in number of pods per plant under monocropping and mixed intercropping was due to high competition for growth resources, such as nutrients and water (Alhaji, 2008).

4.5.6 100 seed weight

The results show that interaction between varieties, cropping systems, and growing seasons had significant effects ($P<0.05$) on the 100 seed weight (Table 4.22). Varieties IT86K-499-35 and IT86D-1010 produced high seed weights of 24.17g and 23.67g respectively in intercropping during the 2015/16 season than during the 2016/17 season, while the Glenda variety produced a low 100 seed weight of 13.68g under strip intercropping during the 2016/17 season in comparison to other varieties during the 2015/16 season, with a mean of 19.73g (Figure 4.38). These observations are in contrast Ndiso et al.'s (2017) findings, where it was reported that mixed and strip intercropping significantly reduce cowpea's 100-grain weight when cowpea is intercropped with maize. They also observed no significant difference between sole cowpea and cowpea intercropped with maize.

Table 4.22: Analysis of variance for number of pods per plant and 100 seed weight of five cowpea varieties at the Ga-Thaba farm during the 2015/16 and 2016/17 seasons.

Sources of variation	DF	Number of pods per plant				100 seed weight (g)			
		SS	MS	F	P	SS	MS	F	P
Replication (Rep)	2	161.74	80.87			8.98	4.490		
Variety (V)	4	23.81	5.95	0.26	0.8947ns	186.13	46.532	175.46	0.0000***
Error REP*V	8	182.20	22.78			2.12	0.265		
Cropping system (CS)	2	1114.49	557.24	40.84	0.0000***	8.75	4.374	4.25	0.0290**
V*CS	8	65.48	8.18	0.60	0.7670ns	95.98	11.998	11.66	0.0000***
Error REP*V*CS	20	272.92	13.65			20.58	1.029		
Season (S)	1	16.68	16.68	0.72	0.4020ns	786.65	786.651	1433.92	0.0000***
V*S	4	86.06	21.51	0.93	0.4588ns	11.33	2.833	5.16	0.0027**
CS*S	2	2177.04	1088.52	47.14	0.0000***	7.91	3.956	7.21	0.0028**
V*CS*S	8	119.11	14.89	0.64	0.7341ns	11.78	1.472	2.68	0.0236**
Error REP*V*CS*GS	30	692.73	23.09			16.46	0.549		
Total	89	4912.26				1156.68			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

Table 4.23: Means for pod length, number of pods per plant, and 100 seed weight at the Ga-Thaba farm during the 2015/16 and 2016/17 seasons.

Variety (V)	Pod length (cm)	Number of pods per plant	100 seed weight(g)
Glenda	13.64b	18.24a	17.87d
TVu 13464	12.34c	17.20a	17.66d
IT82E-16	15.31a	16.83a	18.67c
IT86D -1010	15.22a	17.79a	20.59b
IT86K-499-35	13.8b	17.96a	21.19a
Grand mean	14.08	17.61	19.20
Cropping System (CS)			
Monocropping	13.65b	13.83c	19.61a
Strip Intercropping	15.24a	16.69b	18.85b
Mixed intercropping	13.35b	22.30a	19.13ab
Season (S)			
2015/16	13.40b	17.17a	22.15a
2016/17	14.76a	18.04a	16.24b

Means followed by the same letter in a column do not differ significantly (P≤ 0.05) from each other.

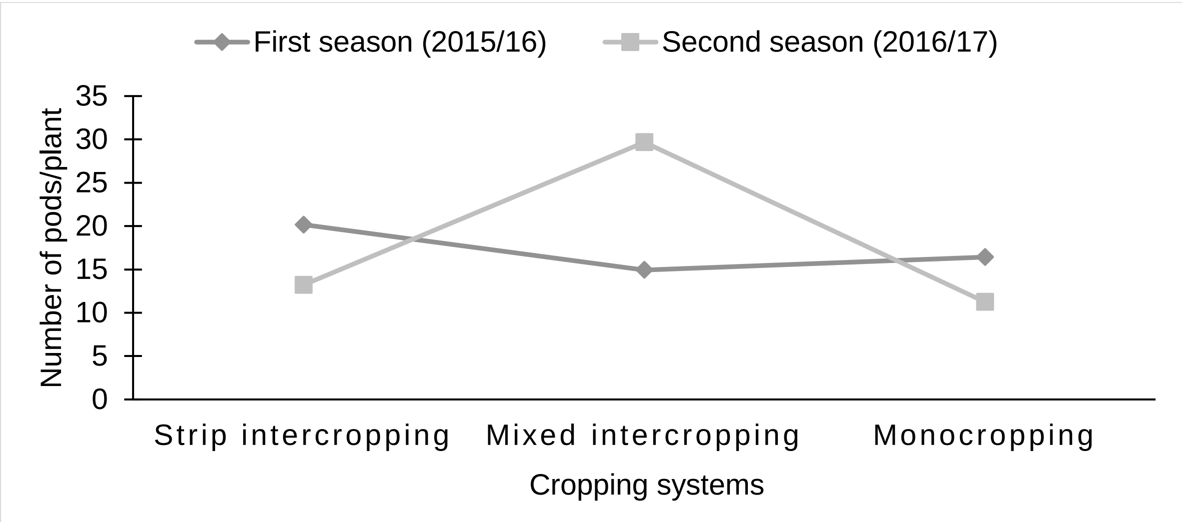

Figure 4.37: Interaction between the cropping systems and seasons in terms of the number of pods produced per plant at the Ga-Thaba village during the 201/16 and 2016/17 seasons.

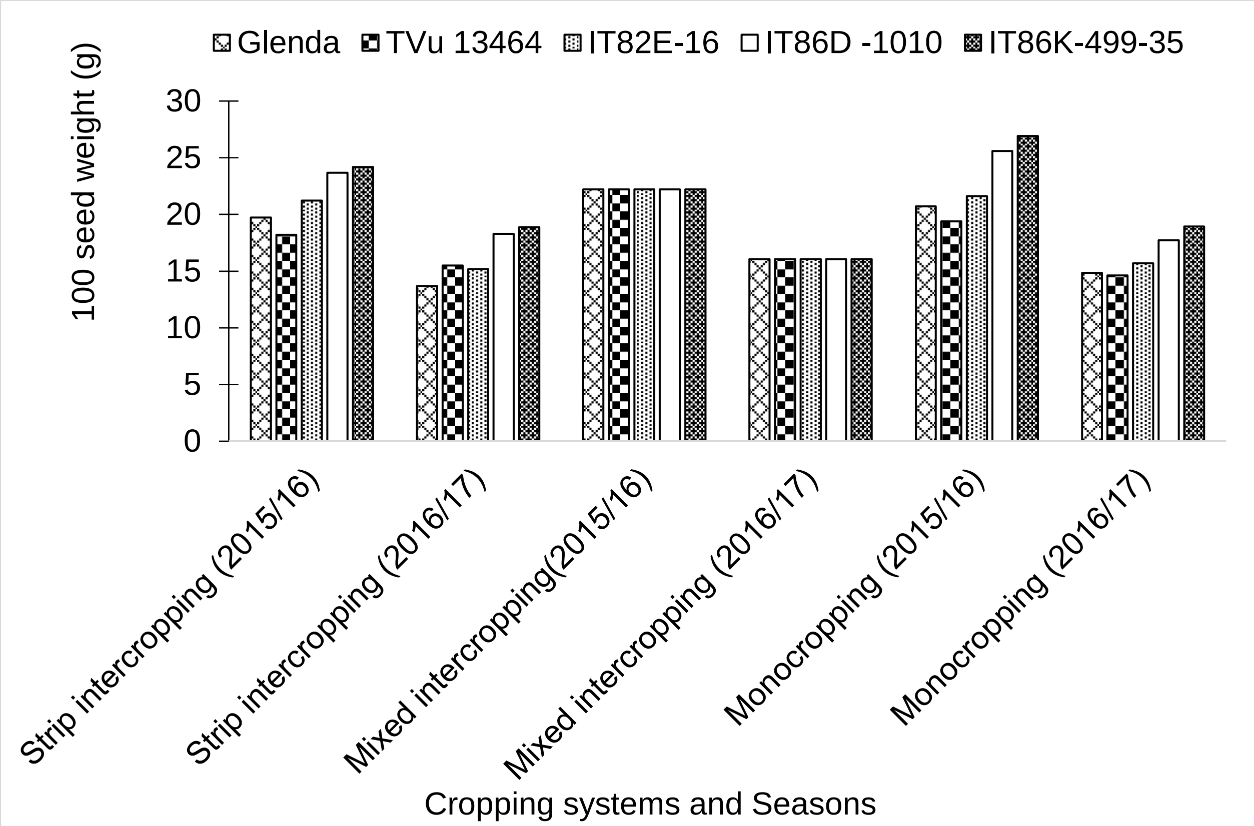

Figure 4.38: Interaction between cowpea varieties, cropping systems, and seasons for 100 seed weight at the Ga-Thaba village during the 201/16 and 2016/17 seasons.

4.5.7 Grain yield

The results show that interactions between varieties and cropping systems, and between varieties and seasons were significant (P<0.05) in terms of grain yield (Table 4.24). Variety IT86D-1010 achieved a high grain yield of 1085kg/ha under monocropping, while mixed intercropping produced a lower grain yield of 32 kg/ha across all varieties. However, no significant differences were observed between the Glenda and IT86K-499-35 varieties, with means of 918kg/ha and 915kg/ha respectively, under monocropping (Figure 4.39). In comparison to other varieties, variety IT86D-1010 produced a higher grain yield of 660kg/ha during the 2015/16 season. Variety IT86K-499-35 also produced a higher grain yield of 915kg/ha during the 2016/17 season. Variety TVu 13464 produced a low grain yield of 333kg/ha and 454kg/ha during the 2015/16 and 2016/17 seasons respectively (Figure 4.40). However, in the 2016/17 season, a higher grain yield of 721kg/ha was produced than the 2015/16 season yield, with a mean of 489kg/ha (Table 4.25). This may be due to higher rainfall volume during the planting and growing season, which was higher in the

2016/17 season (Figure 4.26) than in the 2015/16 season (Figure 4.25). The maximum temperatures for the 2016/17 season were lower (Figure 4.26) than the maximum temperatures in the 20015/16 season (Figure 4.25). Dahmardeh et al. (2010), reported higher grain yields under sole cowpea as opposed to intercropping. Competition for water, nutrients, and shading are probably the two factors that reduces cowpea yield under high density of maize plants in intercropping.

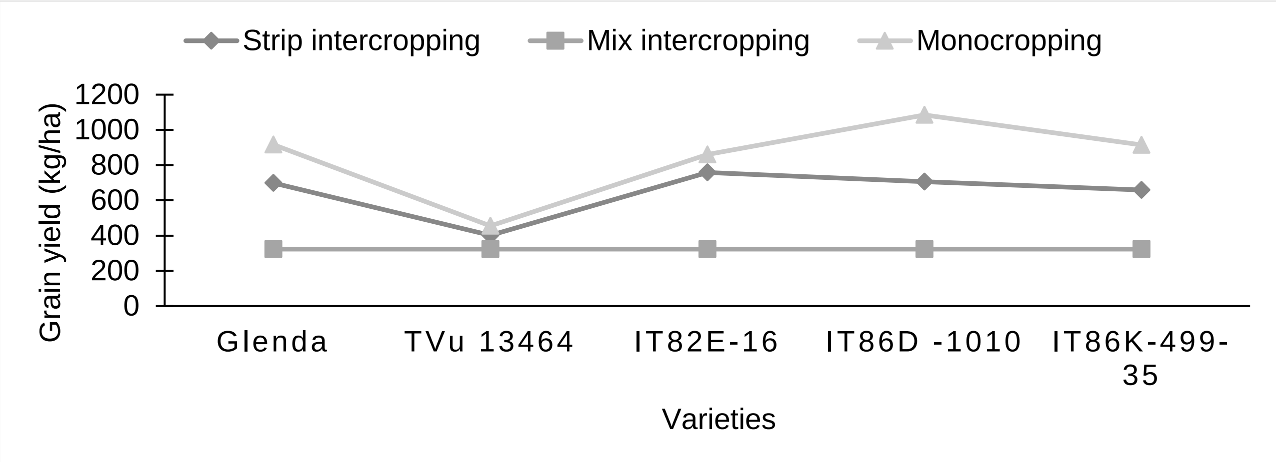

Figure 4.39: Interaction of cowpea varieties and cropping systems in terms of grain yield at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

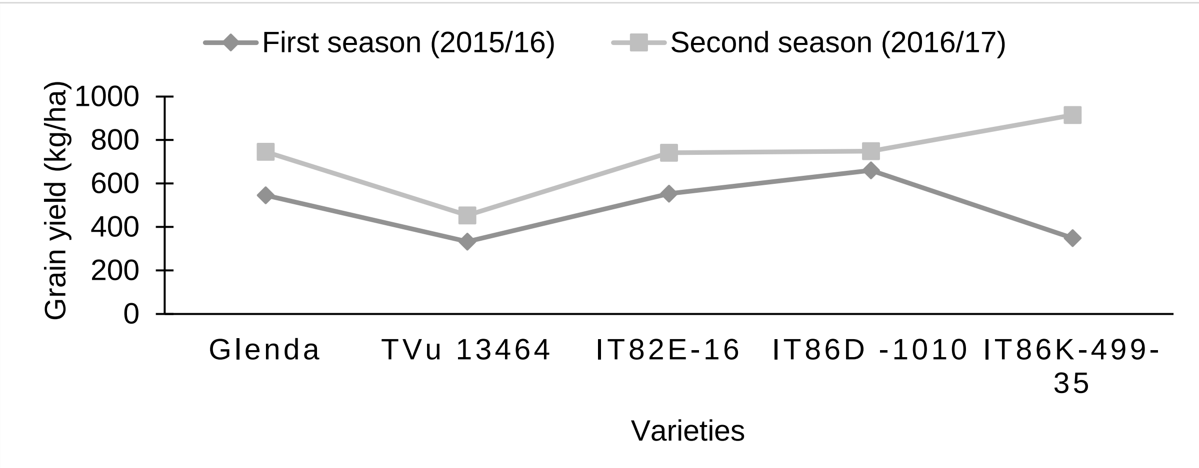

Figure 4.40: Interaction between cowpea varieties and seasons in terms of grain yield at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

4.5.8 Fodder weight

The results show that interactions between varieties and cropping systems as well as varieties and seasons are significant ($P<0.05$) for fodder weight (Table 4.24). The

Glenda and IT86K-499-35 varieties produced higher fodder weights of 2175kg/ha and 2125kg/ha under monocropping, while mixed intercropping produced a lower fodder weight of 625 kg/ha in all varieties (Figure 4.41). The Glenda and IT86K-499-35 varieties produced higher fodder weights of 2244kg/ha and 2027kg/ha respectively during the 2016/17 season than during the 2015/16 season, with corresponding means of 756kg/ha and 872kg/ha respectively. The TVu 13464 variety produced a low fodder weight of 1156kg/ha during the 2016/17 season than during the 2015/16 season, with a mean of 878kg/ha (Figure 4.42). The results show that varieties differed in their performances throughout the two seasons. However, varieties that were late maturing had high fodder compared to early maturing varieties. For example, the Glenda variety (control) had a higher fodder weight in comparison to the TVu 13464 variety. Agyeman et al. (2014) report that fodder yield in cowpea is the result of many interacting components, such as number of branches, number of leaves, and leaf area.

Table 4.24: Analysis of variance in terms of grain yield and fodder weight of five cowpea varieties at the Ga-Thaba farm during the 2015/16 and 2016/17 seasons.

Source variation	**DF**	**Grain yield (kg/ha)**				**fodder weight (kg/ha)**			
		SS	**MS**	**F**	**P**	**SS**	**MS**	**F**	**P**
Replication (Rep)	2	48101.7	24051			816889	408444		
Variety (V)	4	1062710	265677	7.60	0.0078***	3210111	802528	7.37	0.0086***
Error REP*V	8	279598	34950			870889	108861		
Cropping system (CS)	2	4176952	2088476	149.32	0.0000***	2.178E+07	1.089E+07	199.72	0.0000***
V*CS	8	730990	91374	6.53	0.0003***	1658222	207278	3.80	0.0073***
Error REP*V*CS	20	279733	13987			1090556	54527.8		
Season (S)	1	1216847	1216847	29.87	0.0000***	1.863E+07	1.863E+07	157.83	0.0000***
V*S	4	661727	165432	4.06	0.0095***	3662889	915722	7.76	0.0002***
CS*S	2	155184	77592	1.90	0.1664ns	582167	291083	2.47	0.1020ns
V*CS*S	8	509163	63645	1.56	0.1781ns	1869778	233722	1.98	0.0841ns
Error REP*V*CS*S	30	1222017	40734			3541667	118056		
Total	89	1.034E+07				5.772E+07			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.0

Table 4.25: Mean grain yield and fodder weight at the Ga-Thaba farm during the 2015/16 and 2016/17 seasons.

Variety (V)	Grain yield (Kg/ha)	Fodder yield (Kg/ha)
Glenda	646.39b	1500.0a
TVu 13464	393.33c	1016.7b
IT82E-16	647.22b	1100.0b
IT86D -1010	705.00a	1269.4ab
IT86K-499-35	646.39b	1450.0a
Grand mean	604.83	1267.22
Cropping System (CS)		
Monocropping	846.50a	1820.0a
Strip Intercropping	644.67b	1356.7b
Mixed intercropping	323.33c	625.0c
Season (S)		
2015/16	488.56b	812.2b
2016/17	721.11a	1722.2a

Means followed by the same letter in a column do not differ significantly (P≤ 0.05) from each other.

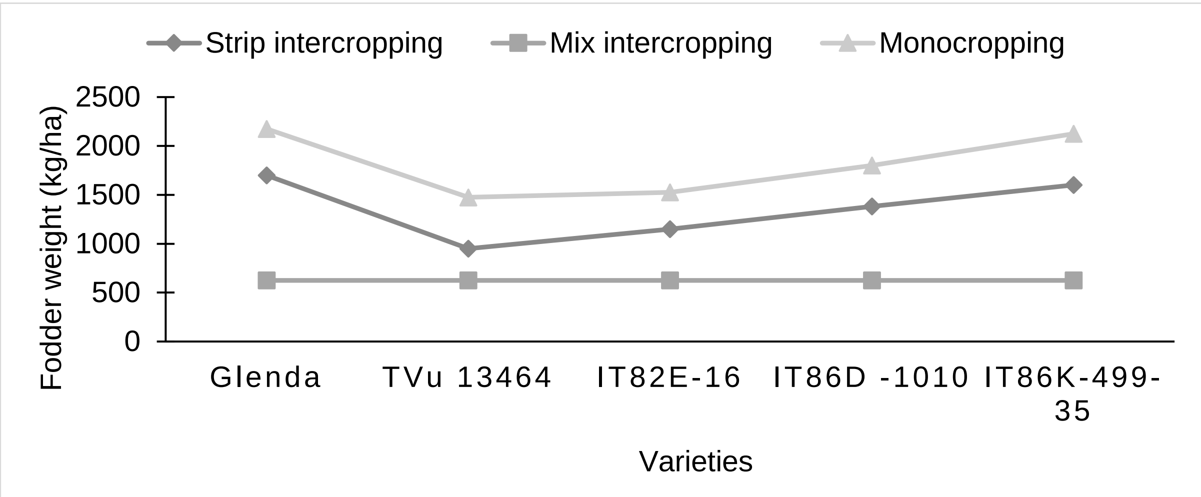

Figure 4.41: Interaction of cowpea varieties and cropping systems in terms of fodder weight at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

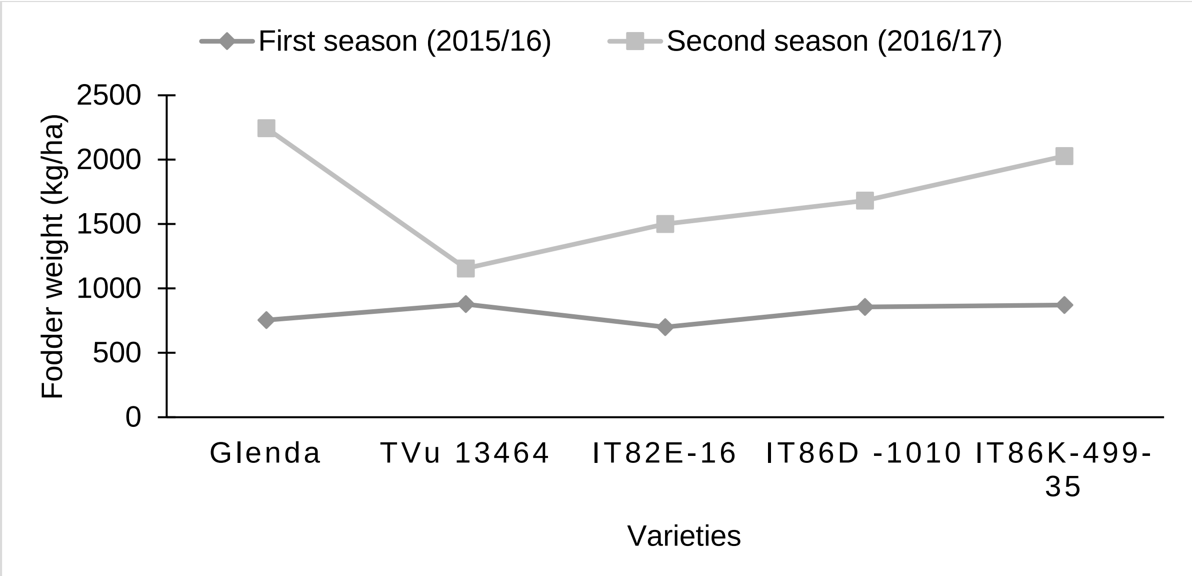

Figure 4.42: Interaction between cowpea varieties and seasons in terms of fodder weight at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

4.6 Performance of maize at the Ga-Thaba village

4.6.1 Number of days to 50% tasselling

The results show that interaction between cropping systems and seasons has no significant effects (P<0.05) on days to 50% tasselling. However, season contributes a significant difference (Table 4.26). During the 2015/16 season, the days to 50% tasselling were early (68 days), while during the 2016/17 season, they were late (70 days) (Table 4.27). The Ga-Thaba village received low rainfall and high temperatures throughout the seasons. According to Harrison et al. (2011), warmer growing season temperatures can accelerate crop growth for crops whose phenology is predominantly regulated by temperature. This reduces the time for plant and grain development, limiting the attainment of yield potential, and if extreme heat occurs during flowering, such as the maize ‘silk-tasselling’ phase, pollination may be inhibited, and the development of grain may be prevented entirely.

4.6.2 Number of days to 50% silking

The results show that the interaction between cropping systems and seasons has no significant difference (P<0.05) on 50% silking. However, cropping systems and seasons showed significant differences (P<0.05) (Table 4.26). During the 2015/16 season, 50% silking was attained in 70 days, while in 2016/17 it took 82 days (Table 4.27). Strip and mixed intercropping took 75 days, with no significant difference to reach 50% silking, and mixed took 76 days (Table 4.27). This was due to higher rainfall and lower temperatures during the 2016/17 season (Figure 4.26) as compared to the 2015/16 season (Figure 4.25). This must have resulted in crops absorbing more moisture, which enhanced vegetative growth, delaying and prolonging silking time during the 2015/16 season. Hot and dry weather hastens pollen shed and delays silk emergence, narrowing the duration of co-occurrence. In addition, the pollens' ability to germinate on silks is greatly reduced at temperatures above 32°C (Saxena,Kamar and Rao, 2002).

Table 4.26: Analysis of variance for maize in terms of the number of days to 50% tasselling and 50% silking at the Ga-Thaba farm during the 2015/16 and 2016/17 seasons.

Source	**DF**	**50% Tasselling**				**50% Silking**			
		SS	**MS**	**F**	**P**	**SS**	**MS**	**F**	**P**
Replication(Rep)	2	4.87	2.43			78.42	39.21		
Cropping system (CS)	2	10.47	5.23	4.91	0.0839ns	17.62	8.81	8.18	0.0386**
Error REP*CS	4	4.27	1.07			4.31	1.08		
Season (S)	1	86.044	86.04	44.88	0.0000***	2992.90	2992.90	586.06	0.0000***
CS*S	2	4.42	2.21	1.15	0.3209ns	8.47	4.23	0.83	0.4403ns
Error	78	149.53	1.92			398.33	5.11		
Total	89	259.60				3500.06			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

4.6.3 Plant height

The results show that interaction between cropping systems and seasons has no significant influence (P<0.05) on plant height (Table 4.28). No significant difference was observed between monocropping and strip intercropping, with the highest plant heights of 150.53cm and 143.20cm respectively, but they were significantly different to mixed intercropping that achieved 132.33cm during the 2016/17 season. However, monocropping produced shorter plants of 86cm during the 2015/16 season than the other cropping systems in both growing seasons (Figure 4.43). The 2016/17 season produced plants with a higher height of 143.69cm than during the 2015/16 season with mean of 106.91cm (Table 4.27). The maize plant height is a genetic trait, thus the number and length of the internodes determine plant height. According to Gyenes-Hegyi et al. (2010), plant height can vary from 0.3m to 7.0m, depending on the variety and growing conditions. Usually, early maturing varieties are shorter in height, while late maturing varieties tend to be taller. Lemlem (2003) also reported that strip and mixed intercropping maize with cowpea reduces maize plant height, as determined by the competition between the two crops and environmental factors.

Table 4.27: Maize phenological development and plant height at the Ga-Thaba farm during the 2015/16 and 2016/17 seasons.

	50% Tasselling	**50% Silking**	**Plant height (cm)**
Cropping systems			
Monocropping	69.33a	76.33a	118.27b
Strip intercropping	68.97ab	75.03b	128.97a
Mixed intercropping	68.50b	75.30b	128.67a
Season (S)			
2015/16	67.96b	69.96b	106.91b
2016/17	69.91a	81.49a	143.69a

Means followed by the same letter in a column do not differ significantly at $P \leq 0.05$ from each other.

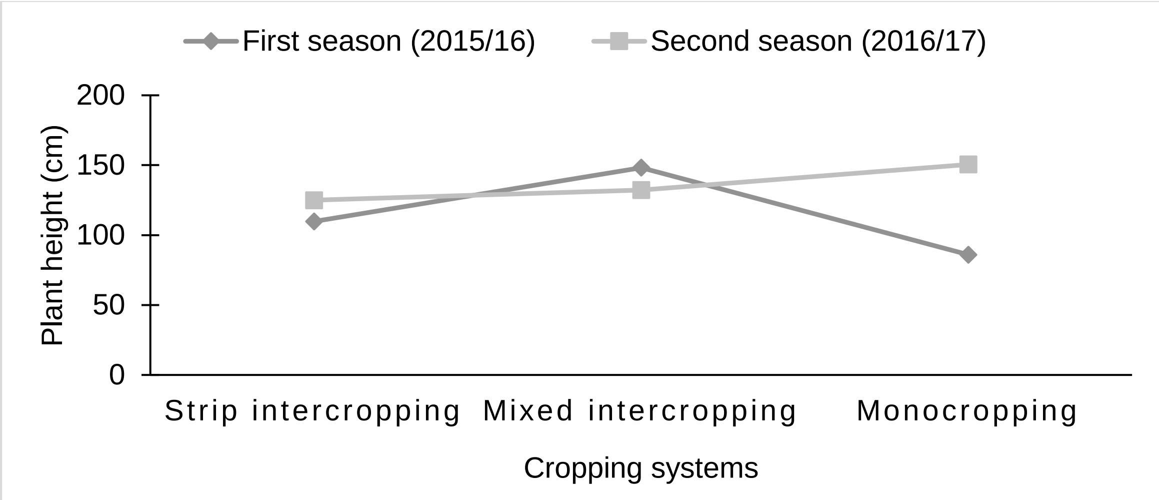

Figure 4.43: Interaction between cropping systems and seasons in terms of plant height at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

4.6.4 Cob length

The results show that the interaction between cropping systems and seasons has significant influence (P<0.05) on cob length (Table 4.28). Mixed intercropping produced long cobs with a mean of 16.33cm, and monocropping produced the lowest cob length of 14cm during the 2015/16 season. However, during the 2016/17 season, there were no significant differences among the cropping systems with a mean of 15cm (Figure 4.44).

Table 4.28: Analysis of variance in terms of maize plant height and cob length at the Ga-Thaba farm during the 2015/16 and 2016/17 seasons.

Source variation	DF	Plant height (cm)				Cob length (cm)			
		SS	MS	F	P	SS	MS	F	P
Replication(Rep)	2	454.2	227.1			9.80	4.90		
Cropping system (CS)	2	2227.4	1113.7	5.33	0.045*	26.87	13.43	8.22	0.0383**
Error REP*CS	4	836.2	209.0			6.53	1.63		
Season (S)	1	30433.6	30433.6	166.30	0.0000***	1.60	1.60	1.61	0.2079ns
CS*S	2	12301.5	6150.7	33.61	0.0000***	19.40	9.70	9.78	0.0002***
Error	78	14274.0	183.0			77.40	0.99		
Total	89	60526.9							

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

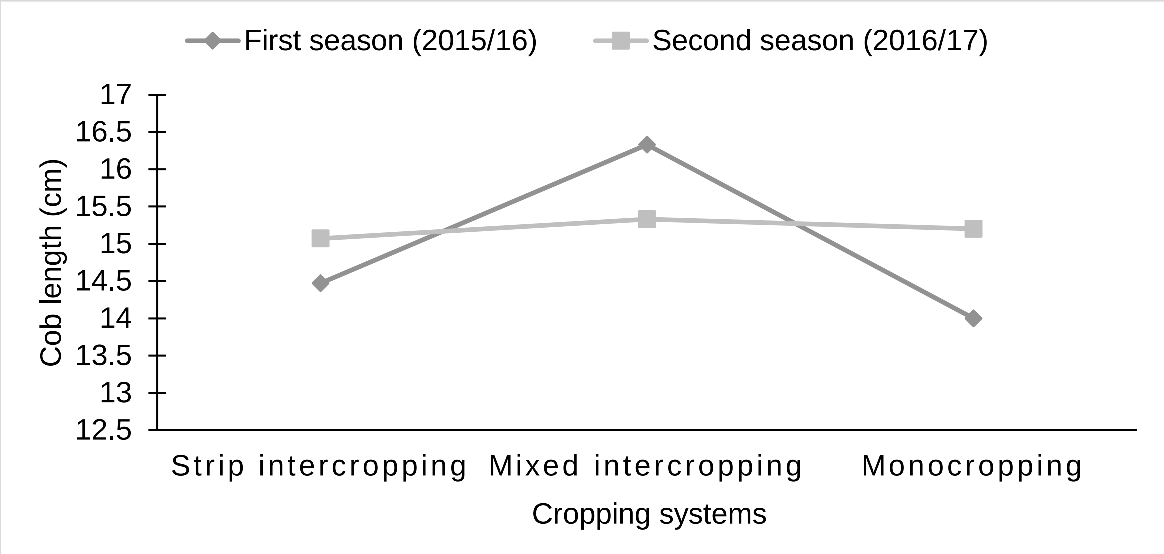

Figure 4.44: Interaction between cropping systems and seasons in terms of cob length at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

4.6.5 Number of cobs per plant

The results show that interaction between cropping systems and seasons has no significant difference (P<0.05) for stover yield (Table 4.29). This implies that the number of cobs per plant is genetically determined and is not influenced by the environment.

4.6.6 Grain yield

The results show that the interaction between cropping systems and seasons has a significant influence (P<0.05) on grain yield (Table 4.29). Strip intercropping produced a high grain yield of 747kg/ha and 1024kg/ha during the 2015/16 and 2016/17 seasons respectively. However, in comparison to strip intercropping (747 kg/ha), monocropping showed no significant difference with 777kg/ha during the 2016/17 season, but produced a low grain yield (425 kg/ha) during the 2015/16 season. Mixed intercropping produced a low grain yield of 499kg/ha during the 2016/17 season, and a grain yield of 547kg/ha during the 2015/16 season (Figure 4.45). These results are not in line with Gabatshele et al.'s (2012) findings, where it was observed that there were significant differences between cropping systems and seasons, and the yield reduction in cowpea and maize in maize-cowpea intercrops was due to lower plant densities. However, higher rainfall and low temperatures probably caused high grain yields during the 2016/17 season during the period (Figure 4.26) as opposed to the recorded rainfall and temperatures recorded during the 2015/16 season (Figure 4.25). Maize that is planted earlier develops better, and has a higher yield potential, because the vegetative period of its development occurs during the cooler part of the season when moisture stress is less likely (ARC-GCI, 2011).

Table 4.29: Analysis of variance in terms of number of cobs per maize plant and grain yield at the Ga-Thaba farm during the 2015/16 and 2016/17 seasons.

Source variation	DF	Number of cobs/plant				Grain yield (kg/ha)			
		SS	MS	F	P	SS	MS	F	P
Replication (Rep)	2	0.16	0.078			358517	179259		
Cropping system (CS)	2	0.62	0.31	0.40	0.6944ns	2191705	1095852	16.52	0.0117**
Error REP*CS	4	3.11	0.78			265287	66322		
Season (S)	1	0.54	0.54	3.96	0.0702ns	841845	841845	14.61	0.0003***
CS*S	2	0.62	0.31	2.26	0.1111ns	677374	338687	5.88	0.0042***
Error	78	10.73	0.14			4494980	57628		
Total	89	15.79				8829708			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

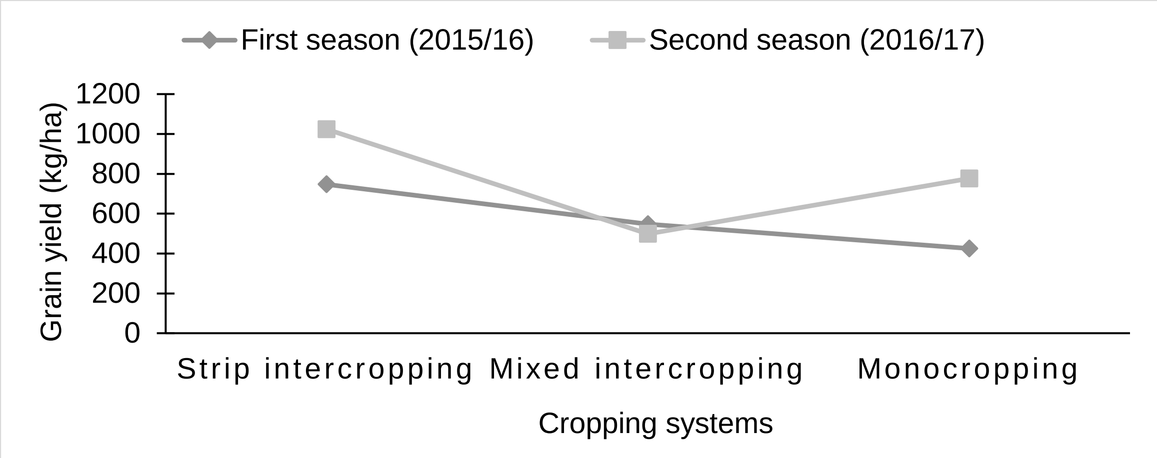

Figure 4.45: Interaction between cropping systems and seasons in terms of grain yield at the Ga-Thaba village during the 2015/16 and 2016/17 seasons.

4.6.7 Stover yield

The results show that interaction between cropping systems and seasons has no significant difference (P<0.05) for stover yield. However, the season variable shows a significant difference (P<0.05) (Table 4.30). During the 2016/17 season, a higher stover yield of 4274kg/ha was achieved than the 2015/16 season yield with a mean of 3345kg/ha (Table 4.31). The observed results are probably due to climatic variations, especially rainfall experienced during the two-year period of the investigation. The high stover yield observed during the 2016/17 season was probably due to the high rainfall experienced.

Table 4.30: Analysis of variance in terms of maize stover yield at the Ga-Thaba farm during the 2015/16 and 2016/17 seasons.

Source	**DF**	**Stover yield (kg/ha)**			
		SS	**MS**	**F**	**P**
Replication (Rep)	2	3482211	1741106		
Cropping system (CS)	2	4578282	2289141	0.74	0.5338ns
Error REP*CS	4	1.24	3104713		
Season (S)	1	1.94	1.94	18.94	0.0000***
CS*S	2	4661867	2330934	2.28	0.1095ns
Error	78	7.99	1024373		

Total	89	1.24			

DF = degree of freedom, SS = sum of squares, MS = mean squares, P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

Table 4.31: Means of maize yield parameters at the Ga-Thaba farm during the 2015/16 and 2016/17 seasons.

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	Cob length (cm)	Number of cobs/plant	Stover yield (kg/ha)	Grain yield (kg/ha)
Cropping system				
Monocropping	14.60b	1.70a	3545.8a	600.73b
Strip intercropping	14.77b	1.90a	3786.5a	885.71a
Mixed intercropping	15.83a	1.83a	4096.8a	522.59c
Season (S)				
2015/16	14.93a	1.89a	3345.4a	572.96b
2016/17	15.20a	1.73a	4274.0b	766.39a

Means followed by the same letter in a column do not differ significantly (P≤ 0.05) from each other.

4.6.8 Land equivalent ratio

The calculated LER for two crops over two seasons under strip intercropping ranged from 1.62 and 2.98, whereas under mixed intercropping, it ranged between 0.76 and 1.67 in both seasons. The means for LER was greater than 1; therefore it indicated more efficient and productive land utilisation by strip intercropping compared with mixed intercropping. Mariotti Ariotti et al. (2006) and Kitonyo et al. (2013) reported that when LER is equal to 1 there is no advantage or disadvantage of the intercropping in respect to sole crop but when LER > 1.00, indicates that intercropping system has an advantage in terms of improved use of available resources for plant growth and development. In other words, these results signify that it is advantageous having both crops in mixture than growing them in a monoculture system.

Table 4.32: Partial LER and total LER in respect of strip and mixed intercropping at the Ga-Thaba farm during the 2015/16 and 2016/17 seasons.

2015/16 season						
	Strip intercropping			**Mixed intercropping**		
Crop mixture	PLER maize	PLER Cowpea	Total LER	PLER maize	PLER Cowpea	Total LER
Glenda + PAN 6479	1,50ab	0.45b	1.92	1.38a	0.13ab	1.51
Tvu 13464 + PAN 6479	1,09b	0.53ab	1.62	1.38a	0.18a	1.56
IT82E-16 + PAN 6479	2,35a	0.57ab	2.92	1.38a	0.08c	1.46
IT86D -1010 + PAN 6479	2,37a	0.61a	2.98	1.38a	0.11bc	1.46
IT86K-499-35 + PAN 6479	1,81ab	0.56ab	2.37	1.38a	0.18a	1.56
Mean	1,82	0.54	1.18	1,38	0.14	0.76
P-level	0,1479ns	0.6253ns		0,0025***	0.0070***	
2016/17 season						
	Strip intercropping			**Mixed intercropping**		
Crop mixture	PLER maize	PLER Cowpea	Total LER	PLER maize	PLER Cowpea	Total LER
Glenda + PAN 6479	1,48a	0.46b	1.94	0,64b	0.31ab	0.95
Tvu 13464 + PAN 6479	1,44a	0.49b	1.93	1,29a	0.38a	1.67
IT82E-16 + PAN 6479	1,32a	0.52b	1.84	0,67b	0.15c	0.82
IT86D -1010 + PAN 6479	1,19a	0.57ab	1.76	0,64b	0.22bc	0.86
IT86K-499-35 + PAN 6479	1,23a	0.69a	1.92	0,45b	0.31ab	0.76
Mean	1,33	0.55	0.94	0,74	0.23	0.49
P-level	0,6104ns	0.0521*		0,0056**8	0.0021***	

Means followed by the same letter in a column do not differ significantly (P≤ 0.05) from each other. P = Probability, ns = Not significant and level of significance (* =P≤ 0.05; ** =P≤ 0.01; *** =P≤ 0.001).

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CHAPTER 5

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.1 Summary

5.1.1 Yield performance of cowpea varieties

At the UL farm, the TVu 13464 variety flowered (50 days) and matured (89 days) earlier than the control varieties of Glenda and IT86K-499-35, which flowered (55 and 54 days respectively) and matured late (95 days). At the Ga-Thaba farm, the TVu 13464 variety flowered early (51 days), while the IT86K-499-35 variety flowered late (55 days). However, the TVu 13464, IT82E-16, and IT86D-1010 varieties matured earlier (84-87 days) than the Glenda and IT86K-499-35 varieties with means of 90 and 89 days respectively. The IT82E-16 variety produced a high grain yield of 1234kg/ha at the UL farm, and the IT86D-1010 variety (705kg/ha) at the Ga-Thaba farm. Varieties differ in their genetic variations. In comparison to the other varieties, IT82E-16 and IT86D-1010 were stable across the varieties because they produced high grain yields across the locations.

5.1.2 Cowpea performance in different locations

At the UL farm and the Ga-Thaba farm, all of the varieties flowered in a short time with a grand mean of 53 days. The varieties at Ga-Thaba village matured earlier than the UL farm, with a grand mean of 87 and 91 days respectively. The difference was attributed to their genetic variability and their response to the environmental factors. The UL farm produced a higher grain yield of 932kg/ha than the Ga-Thaba farm (605 kg/ha). The higher grain yield at the UL farm was due to the high rainfall received in the area in comparison to the Ga-Thaba farm. The soil types differ across locations, and the UL farm has sandy loam, which is good in water-holding capacity, and the Ga-Thaba farm has sandy soil with stones.

5.1.3 Cowpea performance over two seasons

No signification differences were observed for the number of days to 50% flowering between the two seasons (52 and 53 days). The UL farm attained 90% maturity early during the 2015/16 season (89 days) in comparison to the 2016/17 season (93 days). At the Ga-Thaba farm, the 2016/17 season realised 90% maturity earlier than the

2015/16 season with 84 and 90 days respectively. During the 2016/17 season the UL farm and the Ga-Thaba farm produced the highest grain yields of 934kg/ha and 721.11kg/ha, than the 2015/16 yield with a mean of 730kg/ha and 489kg/ha respectively. The variations between rainfall, rainfall distribution, and temperatures probably resulted in the differences in flowering, maturity, and grain yields across the seasons.

5.1.4 Effect of cropping systems on cowpea performance

No significant differences were observed between the cropping systems on days to 50% flowering (52 and 53 days) and 90% maturity (90 and 92 days) respectively at the UL farm. At the Ga-Thaba village, no significant differences were observed on 50% flowering across all cropping systems (52 and 53 days). Strip intercropping and monocropping showed no significant differences, with early maturity at 85 and 86 days respectively, in comparison to mixed intercropping (90 days). Monocropping produced high grain yields (1436kg/ha and 847kg/ha), followed by strip intercropping (787kg/ha and 645kg/ha), and mixed intercropping produced the lowest grain yields of 273kg/ha and 324kg/ha at the UL farm and Ga-Thaba village respectively.

5.1.5 Effect of cropping system and season interaction on maize performance

Strip intercropping and monocropping produced high grain yields of 3479kg/ha and 3039kg/ha at the UL farm. At the Ga-Thaba farm, strip intercropping produced a high grain yield of 886kg/ha. At the UL farm and the Ga-Thaba farm, the 2016/17 season produced the highest grain yield of 2991.00kg/ha and 766 kg/ha respectively, in comparison to the 2015/16 season with 2476kg/ha and 573kg/ha at the respective sites.

5.2 Land equivalent ratio

At the UL farm, strip intercropping obtained an LER greater than 1 in all crop mixtures, which ranged from 1.25 and 2.14, whereas under mixed intercropping, the LER ranged between 0.73 and 1.05 in both seasons. At the Ga-Thaba farm the calculated LER for two crops over two seasons under strip intercropping ranged from 1.62 and 2.98, whereas under mixed intercropping, it ranged between 0.76 and 1.67 in both seasons.

5.3 Conclusion and recommendations

Variety TVu 13464 at the UL farm and the Ga-Thaba village, variety IT82E-16 at the UL farm, and variety IT86D-1010 at the Ga-Thaba village proved to be promising varieties for strip intercropping in low rainfall areas due to their early maturity and better grain yields. Therefore, it is recommended that strip intercropping be used for improved cowpea and maize grain yield over mixed intercropping in both locations. The calculated LER for the cropping mixtures was greater than 1, which suggests that the twofold productivity value for maize/cowpea strip intercropping is possible to produce when the same land area is used, rather than monocropping. For future research, the promising cultivars must be evaluated in strip intercropping that varies the number of component crop rows. On-farm farmer evaluation of which trials can be considered should be taken in the future.

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