THE EFFECTS OF RELATIVE PLANTING DATES OF LEGUMES ON PRODUCTIVITY OF CASSAVA - LEGUME INTERCROP

by

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Dissertation for Master of Science (Msc) Degree in Agriculture (Plant production)

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2017

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DECLARATION

I, Legodi Khutso Debra, hereby declare that the research submitted for the degree of Master of Science (MSc.) in Agriculture (Plant Production) at University of Venda is my original work and has not been submitted for any degree or examination at any other University. I further declare that all sources cited or quoted are indicated and acknowledged by means of a comprehensive list of references.

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ACKNOWLEDGEMENTS

I would like to thank the following people for the support and guidance they gave me during the course of my study and dissertation writing:

- Almighty God for His protection, guidance and numerous blessings throughout the study period.
- My supervisor Prof JBO Ogola and co-supervisor Prof ET Gwata on their selfless guidance and dedication towards ensuring that this report is in line with the required prescripts. Although I initially found it hard to take the scorning and criticisms of my work, it was all worth it at the end as it added immense value and contributed to my overall growth as a researcher and individual.
- University of Venda (RPC) for funding this research project.
- My family for bearing with me through the times when I could not be with them during the holidays and I was preparing and finalising the dissertation.
- Last but not least, I would like to express my sincere gratitude to all my fellow colleagues with whom we took this journey together and supported each other and I would also like to thank everyone who made sure that this dissertation together with myself become a success.
- The acknowledgements wouldn't be complete without the mention of my cute little girl, Tokollo for staying strong during times when mommy was not home.

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TABLE OF CONTENTS

DECLARATION i
ACKNOWLEDGEMENTS ii
LIST OF FIGURES vi
LIST OF TABLES viii
ABSTRACT ix
CHAPTER 1: INTRODUCTION 1
1.1 Background Information 1
1.2 Objectives 3
1.2.1 Main objective 3
1.2.2 The specific objectives of the study were to evaluate the effect of: 3
1.3 Hypotheses 3
CHAPTER 2 LITERATURE REVIEW 4
2.1 Intercropping system 4
2.2 Benefits of legumes in intercropping systems 5
2.3 Effect of intercropping on growth of cassava and legumes 7
2.4 Effect of intercropping on yield and yield components of cassava and legumes 8
2.5 Effects of intercropping and the relative planting dates of legumes on cassava and legumes Land Equivalent Ratio 9
2.6 Effects of relative planting dates of legumes on growth of cassava and legumes 10
2.7 Effects of relative planting dates of legumes on yield and yield components of cassava and legumes 10
CHAPTER 3: MATERIALS AND METHODS 12
3.1 Study site 12
3.2 Experimental design 12
3.3 Cultural practices 13
3.4 Measurements 13
3.4.1 Plant height 14
3.4.2 Primary and Secondary branches 14
3.4.3 Stem diameter 15
3.4.4 Intercepted radiation 15
3.4.5 Yield and yield components for legumes 15

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3.4.6 Cassava yield and yield components 17
3.4.4 LER for cassava and legumes 18
3.5 Weather 19
3.6 Data analysis 22
CHAPTER 4: 23
4. EFFECTS OF RELATIVE PLANTING DATES OF LEGUMES ON YIELD, YIELD COMPONENTS AND LAND EQUIVALENT RATIO OF CASSAVA 23
4.1 Introduction 23
4.2 Materials and method 24
4.3 Results 24
4.3.1 Number of roots per plant 24
4.3.2 Root length 25
4.3.3 Root diameter 25
4.3.4 Shoot weight 26
4.3.5 Root yield 26
4.4.6 Land equivalent ratio 33
4.5 Discussion 35
4.6 Conclusion 37
CHAPTER 5: 38
5. EFFECTS OF RELATIVE PLANTING DATES OF LEGUMES ON YIELD AND YIELD COMPONENTS OF LEGUMES 38
5.1 Introduction 38
5.2 Materials and methods 38
5.3 Results 39
5.3.1 Yield and yield components for cowpea 39
5.3.2 Yield and yield components of chickpea 46
5.3.2.1 Shoot biomass 46
5.3.2.2 Number of pods per plant 46
5.3.2.3 100 seed weight 46
5.3.2.4 Grain yield 46
5.3.2.5 Harvest index 47
5.3.3. Yield and yield components of bambara groundnuts 50

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5.4 Discussion 55
5.5 Conclusion 57
CHAPTER 6: 58
6. EFFECTS OF RELATIVE PLANTING DATES OF LEGUMES AND CROPPING SYSTEMS ON GROWTH OF CASSAVA 58
6.1 Introduction 58
6.2 Materials and method 58
6.3 Results 59
6.3.1 Plant height 59
6.4 Discussion 73
6.4.1 Cassava Plant height 73
6.4.2 Stem diameter 74
6.4.3 Number of primary branches per plant 74
6.4.4 Number of secondary branches per plant 75
6.4.5 Intercepted radiation 75
6.5 Conclusion 76
CHAPTER 7: 77
7 EFFECTS OF RELATIVE PLANTING DATES OF LEGUMES AND CROPPING SYSTEMS ON PLANT HEIGHT OF LEGUMES 77
7.1 Introduction 77
7.2 Materials and method 77
7.3 Results 78
7.3.1 Cowpea 78
7.3.2 Chickpea 81
7.4 Discussion 83
7.5 Conclusion 84
CHAPTER 8: 85
8 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS 85
8.1 Summary 85
8.2 Conclusion and recommendations 85
REFERENCES 87

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LIST OF FIGURES

Figure 3.1:	Cassava - legumes intercrop at Thohoyandou	13
Figure 3.2:	Measuring cowpea plant height at Thohoyandou	14
Figure 3.3:	Harvesting of chickpea at maturity	16
Figure 3.4:	Measuring root weight	17
Figure 3.5:	Measuring root diameter	18
Figure 3.6	Monthly rainfall and average monthly temperature after planting during a) 2014/2015 b) 2015/2016 cropping seasons in Thohoyandou	21
Figure 4.1:	Effects of the relative planting dates of legumes and cropping systems on number of roots in 2015/2016 at Thohoyandou	30
Figure 4.2:	Effects of the relative planting dates of legumes and cropping systems on Root length in 2014/2015 in Thohoyandou	30
Figure 4.3	Effects of the relative planting dates of legumes and cropping systems interaction on cassavas shoot weight in 2015/2016 in Thohoyandou	31
Figure 4.4	Effects of the relative planting dates of legumes and cropping systems interaction on cassava Root yield in (a) 2014/2015 (b) 2015/2016 at Thohoyandou	32
Figure 6.1:	Effects of relative planting dates of legumes on cassava plant height in (a) Thohoyandou in 2014/2015 season (b) Thohoyandou in 2015/2016 season (c) Nelspruit in 2015/2016 season.	60
Figure 6.2:	Effects of cropping systems on cassava plant height in (a) Thohoyandou in 2014/2015 season (b) Thohoyandou in 2015/2016 season (c) Nelspruit in 2015/2016 season	61
Figure 6.3:	Effects of the relative planting dates of legumes on cassava stem diameter at (a)Thohoyandou in 2015/2016 season (b) Nelspruit in 2015/2016	63
Figure 6.4:	Effects of cropping systems on cassava stem diameter at (a)Thohoyandou in 2015/2016 season (b) Nelspruit in 2015/2016 season	64
Figure 6.5:	Effects of the relative planting dates of legumes and cropping systems interaction of cassava stem diameter in 2015/2016 in Nelspruit	65
Figure 6.6	Effects of the relative planting dates of legumes on the primary branching	66

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cf cassava in (a) Thohoyandou in 2014/2015 season (b) Thohoyandou in 2015/2016 season (c) 2015/2016 season in Nelspruit

Figure 6.7 Effects of cropping systems on the primary branching of cassava in (a) Thohoyandou in 2014/2015 season (b)Thohoyandou in 2015/2016 season (c) 2015/2016 season in Nelspruit 67

Figure 6.8: Effects of the relative planting dates of legumes on secondary branching cf cassava in (a)Thohoyandou in 2014/2015 season (b) Thohoyandou in 2015/2016 season (c) 2015/2016 in Nelspruit 69

Figure 6.9: Effects of cropping systems on secondary branching of cassava in (a) Thohoyandou in 2014/2015 season (b) Thohoyandou in 2015/2016 season (c) 2015/2016 in Nelspruit 70

Figure 6.10: Effects of relative planting of legumes of cassava intercepted radiation in 2015/2016 in Thohoyandou 72

Figure 6.11: Effects of cropping systems on cassava intercepted radiation in Thohoyandou in 2015/2016 season 72

Figure 7.1: Effects of the relative planting dates of legumes on cowpea plant height at Thohoyandou in (a) 2014/2015 and (b) 2015/2016 seasons 79

Figure 7.2: Effects of cropping system on cowpea plant height at Thohoyandou in (a) 2014/2015 and b 2015/2016 seasons 80

Figure 7.3: Effects of the relative planting dates of legumes and cropping systems interaction on cowpea Plant height in 11WAP at Thohoyandou 81

Figure 7.4: Effects of the relative planting dates of legumes on chickpea plant height in 2015/2016 in Thohoyandou 82

Figure 7.5: Effect of cropping systems on chickpea plant height in 2015/2016 in Thohoyandou 82

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LIST OF TABLES

Table 3.1:	Summary of weather data during 2014/2015 and 2015/2016 cropping season in Thohoyandou	20
Tale 3.2:	Analysis of variance (ANOVA)	22
Table 4.1:	Effects of relative planting dates of legumes and cropping systems on yield and yield components of cassava at Thohoyandou	28
Table 4.2:	Effects of relative planting dates of legumes and cropping systems on yield and yield components of cassava in Nelspruit	29
Table 4.3:	Effects of cropping systems on land equivalent ratio of cassava - legume intercrop	34
Table 5.1:	Effects of relative planting dates of legumes and cropping systems on yield and yield components of cowpea at Thohoyandou	42
Table 5.2:	Effect of relative planting dates of legumes and cropping systems on yield and yield components of cowpea (*Vigna uguiculata*) at Nelspruit.	43
Table 5.3:	Comparison of the means of yield and yield components of cowpea sole and cowpea intercropped with cassava same time, 2 weeks and 4 weeks after cassava using T- test at Thohoyandou	44
Table 5.4:	Comparison of the means of yield and yield components of cowpea sole and cowpea intercropped with cassava same time, 2 weeks and 4 weeks after cassava using T- test in Nelspruit	45
Table 5.5:	Effect of relative planting dates of legumes and cropping systems on yield and yield components of chickpea (*Cicer arietinum*) at University of Venda Thchoyandou.	48
Table 5.6:	Comparison of the means of yield and yield components of chickpea sole and chickpea intercropped with cassava same time, 2 weeks and 4 weeks after cassava using T- test at Thohoyandou	49
Table 5.7:	Effects of the relative planting dates of legumes and cropping systems on the yield and yield components of Bambara groundnut at Mpumalanga	53
Table 5.8:	Comparison of the means of yield and yield components of bambara sole and bambara intercropped with cassava same time, 2 weeks and 4 weeks after cassava using T- test at Thohoyandou	54

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ABSTRACT

Crop production in the Limpopo Province of South Africa is limited by inadequate rainfall and poor soils, particularly in the smallholder sector. The incorporation of cassava into the existing cropping systems could be beneficial. However, cassava is a long duration crop that develops slowly during its early growth stages. Therefore, it may be necessary to introduce legumes that will grow and be harvested before cassava matures. Inclusion of legumes in cassava legume intercropping systems not only helps in improving soil fertility through biological nitrogen fixation and solubilisation of phosphorus but also provides compensation for food security and income generation as cassava reaches maturity. However, there is inadequate information regarding the optimum time to introduce legumes into cassava cropping systems under specific agro-ecological conditions. This study aimed at evaluating the effect of relative planting date of legumes on the productivity of cassava-legume intercrop.

Field experiments were conducted during 2014/2015 and 2015/2016 cropping seasons in Thohoyandou, Limpopo Province and Nelspruit, Mpumalanga Province. The experiments were laid out in a split-plot design with legume planting dates (same time with cassava, two weeks after cassava and four weeks after cassava) as the main plots replicated 3 times and five cropping systems (cassava sole, chickpea sole, cowpea sole, cassava-chickpea and cassava-cowpea) as the subplots. Plant height, number of primary and secondary branches and stem diameter were measured for cassava from 3 months after planting until 10 months after planting. For legumes plant height were taken for growth starting from 8 weeks after planting until physiological maturity. Yield and yield components for cassava such as root weight, root diameter, root length, shoot weight and number of roots was measured at 10 months after planting. Yield and yield components for legumes such as shoot biomass, number of pods per plant, number of seeds per plant,100 seed weight, pod weight, number of pods, grain yield and harvest index were measured at physiological maturity. All data sets were subjected to analyses of variance using Genstat (Version 17), followed by mean separation using Least significant difference (LSD) at 5% probability levels.

The relative planting dates of legumes affected number of roots and root yield during the 1st season in Thohoyandou. The greater root yield was reported when legumes were planted 4 weeks after cassava followed by same time and 2 weeks after cassava respectively in 2014/2015 cropping season in Thohoyandou. The relative planting dates of legumes and

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cropping systems significantly affected the yield and yield components of legumes in Thohoyandou. The highest legume yield and yield components were reported when legumes was planted same time with cassava followed by 2 weeks and four weeks after cassava. The relative planting dates of legumes had no significant effects on yield and yield components of cassava in both cropping seasons. Cropping systems only affected root diameter and root yield in 2014/2015 and shoot weight and root yield in 2015/2016 in Mpumalanga. The highest root yield and yield components was found when cassava was planted alone followed by cassava - Bambara and cassava - cowpea in both seasons in Mpumalanga. Root yield was reduced by 13201 $kgha^{-1}$ in 2014/2015 and 20722 $kgha^{-1}$ in 2015/2016 in Mpumalanga. The overall Land Equivalent Ratio (LER) was higher in intercropping as compared to sole cropping which suggest a positive productivity of cassava – legume intercrop. The relative planting dates of legumes and cropping systems affected the overall productivity of cassava – legume intercrop.

Key words: Cassava, legumes, intercropping, planting dates, productivity.

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CHAPTER 1: INTRODUCTION

1.1 Background Information

Cassava (*Manihot esculenta* Crantz) is a perennial woody shrub grown in different parts of the world especially in the tropical and sub-tropical regions of Africa and Latin America for its edible starchy roots. It is the third largest source of food carbohydrates in the tropics, after rice and Maize (Legese and Gobeze, 2013). The crop is a staple food for more than 800 million people living in developing countries where it is used for different purposes, ranging from direct human consumption, to industrial processing for starch-based products [Burns *et al.*, 2010; Food and Agriculture Organization (FAO), 2013]. Cassava is mostly used for human consumption in Africa, whereas in south India it is a major source of food and industrial starch (Bull *et al.*, 2011). Cassava leaves are rich in proteins and vitamins A and B, and are used commercially as source of feed for livestock (Ngudi *et al.*, 2003).

Cassava is a drought resistant crop which also does well on low nutrient soils. It grows on marginal soils where cereals and other crops do not grow well (Burns *et al.*, 2010). Cassava has been generally cultivated by small-scale farmers as a subsistence crop in a diverse range of agricultural systems (Alves, 2002). Its success as a food security crop in Africa is largely because of its ability and capacity to yield well in drought prone areas and marginal wasteland under poor management where other crops would fail (Legese and Gobeze, 2013). However, cultivation of cassava for several years on the same piece of land usually results in a decline in soil fertility.

Nigeria is the leading producer of cassava in Africa, followed by Democratic Republic of Congo, Tanzania, Mozambique, Ghana, Angola and Madagascar (Yakasai, 2010). Although the production of cassava has been largely significant in many parts of Africa, South Africa still has a very insignificant production of cassava (Ogola *et al.*, 2013). However, there are opportunities for improving cassava production in South Africa, for instance by promoting home consumption of cassava and investing in the industrial processing of cassava. The local landraces, which are produced in small quantities in lowveld areas of Mpumalanga and KwaZulu-Natal, are mainly for human (home) consumption (Ogola and Mathews, 2011). Preliminary findings suggest that cassava may be well adapted to the dry environment of the Limpopo Province due to the high root yields realized without supplemental irrigation and fertilizer additions (Ogola and Mathews

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2011). However, incorporation of cassava, which can grow and yield satisfactorily under dry conditions and nutrient depleted soils, into existing cropping systems in Limpopo and Mpumalanga provinces could be beneficial. However, cassava is a long duration crop that develops slowly during its early growth stages and it takes a long time to mature. Therefore, it may be necessary to introduce short season crops such as legumes that will grow and be harvested before cassava matures. However, there is inadequate information regarding the optimum relative planting time to introduce legumes into cassava cropping systems under specific agro-ecological conditions.

Cassava is usually grown either as a sole crop or an intercrop. Intercropping system is the cultivation of two or more crops on the same piece of land, at the same time leading to more efficient use of environmental resources than the crops grown separately (Dwivedi *et al.,* 2015). Intercropping has been widely practiced due to its economic, ecological and environmental benefits compared to monoculture (Whitmore and Schroder, 2007, Wang *et al.*, 2007, Zhang *et al.*, 2004; Inal *et al.,* 2007). In the humid tropics, cassava is traditionally intercropped with maize (Adeniyan *et al.*, 2014). Cassava/maize intercrop is productive and compatible mainly because maize is a short season crop while cassava is a long duration crop (Ikeorgu, 2002). However, cassava-legume intercrops may be more beneficial because of nitrogen fixation, erosion control, phosphorus solubilisation advantages and nutritional security (Polthanee *et al.,* 2001). Intercropping cassava with legumes may also provide and enhance protein intake and nutritional security of small scale farmers. Identifying suitable relative planting date of legumes, which minimise competition between the two crops, will lead to increased productivity of the cassava-legume cropping system.

Research shows that the cassava yield when intercropped with cowpea varies according to the cowpea genotypes (Polthanee *et al.*, 2001). Cassava intercropping with groundnut also resulted in a positive response of cassava storage root yield and net income as well as decreasing soil erosion over a pure cassava stand (Dung *et al.,* 2005). Ogola *et al.* (2013) reported that cassava - cowpea intercropping resulted in a greater decrease in cassava root yield as compared with chickpea and groundnut intercrop systems which they attributed to greater growth and hence larger leaf canopy of cowpea.

Despite numerous benefits of intercropping, most research has concentrated on developing technologies for growing sole crops with the aim of reducing labour intensive practices.

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However, most smallholder farmers still practice intercropping as a form of crop insurance. Therefore, the complexities of intercropping systems need to be better understood so as to improve their productivity.

1.2 Objectives

1.2.1 Main objective

To evaluate the effect of relative planting dates of legumes on the productivity of cassava-legume intercrops.

1.2.2 The specific objectives of the study were to evaluate the effect of:

- Relative planting date of legumes on growth of cassava and legumes.
- Relative planting dates of legumes on yield and yield components of legumes and cassava.
- Cropping systems on land equivalent ratio of cassava-legume intercrops.

1.3 Hypotheses

- The relative planting date of legumes has an effect on growth of legumes and cassava.
- The relative planting date of legumes has an effect on yield and yield components of legumes and cassava.
- Cropping systems have an effect on land equivalent ratio (LER) of cassava - legume intercrop system.

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CHAPTER 2 LITERATURE REVIEW

2.1 Intercropping system

Intercropping refers to the planting of two or more different crops on the same land area at the same time. Crops are planted on the same land area for time periods ranging from part to their complete growing season (Mousavi and Eskandari, 2011). This increases environmental resource use efficiency compared to when individual crops are grown separately (Dwivedi, *et al.*, 2015). Intercropping is a sustainable agricultural method of controlling insect pests and diseases that is also widely used for enhancing soil fertility and crop yield. Intercropping is practiced by resource constrained farmers as a form of crop security so that if one crop fails the other crop may succeed. In intercropping, there is normally one main crop and one or more added crops, with the main crop being of primary importance for economic or food production reasons (Mousavi and Eskandari, 2011).

There are different types of crop species that can be used in intercropping such as annuals (e.g. cereals and legumes, perennials (e.g. shrubs and trees) or a mixture of annuals and perennials (Lithourgidis *et al.,* 2011). The various types of intercropping can be arranged in different forms of which row, mixed, strip and relay intercropping are the most common (Ofori and Stern, 1987). The most common intercropping system is the cereal-legume intercrop. The most common cereal crops in cereal-legume intercrops are maize (*Zea mays),* millet (*Pennis etum glaucum*) and sorghum (*Sorghum bicolor*). Similarly, beans (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), groundnut (*Arachis hypogaea*), pigeon pea (*Cajanus cajan*) and soybean (*Glycine max*) are some of the most common legume crop species (Tsubo *et al.,* 2003). Selection of compatible crop type and species is key in minimizing competition between crops. Crops should be compatible in terms of spatial arrangement and varying nutrient demand and usage.

Cereal-legume intercropping systems are the most common cropping systems in Southern Africa with maize and common beans being the most common crops (Rusinamhodzi *et al.,* 2012). Cereals and legumes have different canopy growth patterns and rooting systems. Roots of cereals grow to greater depth compared to most of legume crops. Thus the two crop types utilize the available resources such as light, water and nutrients differently (Zaman - Alla *et al.,* 2011). Specific crop types and combinations are dependent on agro-ecology and socio-economic aspects e.g. farmers' preferences. Maize is mostly used for food whereas the legume is used for relish and as a cash crop. Legumes also improve soil fertility through nitrogen

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fixation. Farmers therefore satisfy their food security, reduce fertilizer costs and cash income requirements through cultivation of intercropping systems. The canopy effect in intercropping smothers weeds thus minimizing labour and weeding related costs (Rusinamhodzi *et al.,* 2012). Despite the commonality, most cereal and 'household' legume crops are susceptible to extreme climatic events attributed to climate change. On the contrary, cassava is relatively tolerant to climate risk due to the woody stems and deep tap root, hence cassava-legumes or cereals are a sustainable alternative (Ikeorgu, 2002). Since cassava and maize are both the main crops and thrive under different environmental conditions they can both be intercropped with the short season and beneficial crops such as legumes.

Cassava which is a widely spaced and a long duration crop most of the time is often intercropped with cereals and grain legumes. Success of intercrops in comparison with sole cropping can be determined by a series of agronomic operations interacting between the species. These operations include ultimate density, planting date, resources availability and intercropping models (Mazaheri *et al.*, 2006). Intercropping is mostly practiced by smallholder farmers because they often do not have ready access to markets, thus they produce enough only for domestic subsistence. The type of an intercropping system is determined by the type of soil, climatic condition, economic situation and preferences of the local community (Steiner *et al.,* 1982). Several studies have reported the positive results of cereal - legume intercropping over mono-cropping.

2.2 Benefits of legumes in intercropping systems

Intercropping cassava with legumes is beneficial to farmers since the system provides additional legume crop yield within the same land area during the early growth and development stage of cassava (Legese and Gobeze, 2013). Legumes have been considered to be compatible crops for intercropping with cassava as they supply a considerable amount of nitrogen (N) in low input agro-ecosystems (Fustec *et al.,* 2010). Legumes improve soil fertility through biological nitrogen fixation (BNF), which is the process whereby a symbiotic relationship between legume roots and soil rhizobium result in the formation of nodules which synthesise N (Giller, 2001) and which aid in reducing the use of chemical nitrogen fertilizers (Njoku and Mouneke, 2008). In sustainable agriculture, legumes are used in crop rotation to improve soil fertility and control pests and diseases (Zinsou *et al.,* 2005).

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Inclusion of legumes in intercropping systems improves availability of phosphorus, through the legume-nodulating microorganisms that solubilise inorganic phosphates of low solubility (Peix *et al.*, 2001). They also compensate for food security and income generation while the main crop matures (Pokhrel and Pokhrel, 2013). Grain legumes are important in human nutrition and health as they are a source of protein, essential vitamins (folic acid and vitamin B) and minerals (calcium, zinc, iron); these vitamins and minerals reduce cholesterol and blood sugar (Tosti and Guiducci, 2010). Also, incorporation of legumes residues into livestock feeds low in protein and high in carbohydrates increases the digestibility and feed quality. Moreover, legumes in intercrops are potential sources of plant nutrients that complement or supplement inorganic fertilizers (Ofori and Stern, 1987).This is considered to be a sustainable method for soil fertility improvement amongst resource - constrained farmers. Furthermore, since inorganic fertilizers have shown a negative impact on the environment through nitrate pollution soil acidification, inclusion of legumes in intercropping is a sustainable method of introducing N into lower agro-ecosystems (Fustec *et al.*, 2010).

Legume species commonly used for provision of grain and green manure have the potential to fix 100 - 300 kg Nha^{-1} (Dwivedi *et al.*, 2015). Legumes such as cowpea (*Vigna unguiculata)* when intercropped with cassava could increase land equivalent ratio (LER) compared to sole cropping For example, LER was increased by 50 to 73% when cowpea was intercropped with cassava ((Mutsaers *et al.*, 1993). Cowpea is a drought tolerant crop and the most important edible legume mostly used in the traditional cropping systems in the semi-arid tropics, including Asia, Africa and Central America. Cowpea has relatively higher protein content as compared to other legumes and is mainly used as a source of food among smallholder farmers (Shiringani *et al.*, 2007). In South Africa, cowpea is mostly cultivated amongst smallholder farmers of the Limpopo province and is also a key seed crop throughout Africa. Cowpea could fix about 88kg Nha^{-1} and at least 155kg Nha^{-1} which is sufficient for up to 80 to 90% of its plant total N-requirement (Fatokun *et al.*, 2002). Intercropping cassava with legumes such as cowpea, chickpea and bambara ground may have other beneficial effects such as increased transpiration and a concurrent reduction in direct evaporation (Stewart and Faught, 1984); as well as reduced soil temperature fluctuations and hence soil moisture conservation (Keys and McConnell, 2005).

Chickpea is a drought tolerant crop and is the fourth most commonly cultivated grain legumes globally after soybean, common bean (*Phaseolus vulgaris* L.) and pea (FAOSTAT, 2010). The leading producer of chickpea is India followed by Pakistan, Iran, Australia and Turkey. Several

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physiological and morphological advantages of chickpea allow it to thrive mainly under the drought conditions (Serraj *et al.,* 2004; Toker *et al.,* 2007; Cutforth *et al.*, 2009; Zaman-Allah *et al.,* 2011). It is a source of carbohydrates and high quality vegetable protein, vitamins and minerals. Therefore it has a potential to provide a balanced diet for smallholder famers in legume intercropping systems. Chickpea is also utilized for livestock feed and as a potential industrial input. Chickpea cultivated in intercropping systems could therefore be a sustainable alternative for improving the productivity of the cassava - legume intercrop and achieving a reasonable grain protein yield in arid and semi-arid agro-ecologies of Mpumalanga and Limpopo.

Bambara groundnut is a hardy and drought tolerant crop originating from North Africa [Kadams and Sajo, 1998; Plant Resources of Tropical Africa (PROTA), 2006]. Its drought tolerance potentially endears it for inclusion in climate change adaptation strategies. Nigeria is the main producer of bambara-groundnut in the world producing at least 33 000 tons annually (PROTA, 2006). Legumes such as chickpea, cowpea and bambara groundnut were used for intercropping with cassava in this study because of their drought tolerance and their adaptability to climate change.

2.3 Effect of intercropping on growth of cassava and legumes

Genotype selection plays an important role on the growth and development of both crops involved in the intercropping system.Intercropping of legumes with cassava is highly complementary in terms of growth pattern, canopy development and nutrient demand (Nyi *et al.,* 2014). Legumes provide cassava with Nitrogen through BNF which is required for cassava leaf production.

There is an increasing body of knowledge from research on cassava-legume cropping systems. Cassava-cowpea intercropping did not have a significant effect on cassava plant height (Njoku and Mouneke, 2008). Similarly, Gichangi *et al.* (2006) reported that cassava – legume intercrop had no significant effect on cassava plant height, number of branches and shoots. In contrast, intercropping maize with cassava led to an increase in plant height, stem branching and stem diameter of cassava (Olasantan *et al.,* 1996). Cowpea is a short season crop hence it grows vigorously during the early growth stages; thus it is highly competitive during the early growth

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stages of cassava. Cassava in contrast has a slow growth rate during early growth stages (Amanullah *et al.,* 2007).

Other studies have reported higher crop competition in maize-cowpea intercropping systems which was attributed to increased light interception by maize, thus creating a shading effect on cowpea (Eskandari and Ghanbari, 2009). Therefore, there is a need for staggered intercropping where cowpea is sown earlier followed by maize. The shading effect also leads to benefits in reducing evapo-transpiration and improved soil moisture conservation when compared to sole maize cropping (Ghanbari *et al.,* 2010). Most research has been done on cowpea mixed with cereal but limited research has been conducted with root or root crops. In this study, legumes were mixed with a cassava crop with the aim of increasing productivity of cassava and legume.

2.4 Effect of intercropping on yield and yield components of cassava and legumes

Several authors reported that intercropping cassava with legumes resulted in a decrease in cassava root yield. This was attributed to delayed planting of the cassava crop which was affected by interspecific crop competition. This is worsened by the early vigorously growing legumes which outperform the slow cassava early growth (Ibeauchi *et al.*, 2007; Ogola *et al.*, 2013; Nyi *et al.,* 2014). In contrast, other studies showed that cassava intercropped with legumes gave a positive response of cassava storage root yield compared to sole cropping due to early seeding of the cassava crop compared to the legume crop (Dung *et al.*, 2005; Njoku and Mouneke, 2008). It is clear that the yield in intercropping systems is highly dependent on the compatibility of cultivars in minimising competition and maximising complementarily as well as application of inputs and farm operations (Mutungamiri *et al.*, 2001). Ogola *et al.* (2013) reported that cowpea had a greater leaf canopy than other legumes (chickpea and groundnut) and hence had a greater negative effect of on cassava root yield. Intercropping sustainably improves crop productivity and household income, nutrition and livelihood of the farmers.

Similarly, contrasting results on the effect of cassava-legume intercrops on yield and yield components of legumes have been reported. For example, intercropping with cassava increased yield of haricot bean and mung bean but did not favour cowpea and soybean yield improvement (Legese and Gobeze, 2013). Ennin and Dapaah (2008) revealed a positive legume yield in cassava-legume intercropping system. Also, intercropping reduced the number of soybean pods per plant in the first season and seed yield in the first and second season

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(Mouneke *et al.,* 2007). Intercropping with cassava reduced the number of pods plant, seed weight and grain yield in soybean in two cropping seasons (Mbah and Ogidi, 2012). Soybean is a relatively long season crop compared to cowpea. As a result, competition for resources occurs during flowering and upon initiation of vigorous cassava growth. The decrease in the grain yield of legumes was reported due to intercropping with cassava (Ogola *et al.,* 2013; Ibeawauchi *et al.,* 2007). It is clear from the foregoing that the effect of cassava-legume intercrops on the yield of component crops varies greatly. This variation may be due to a number of factors such as crop genotype, environment and planting time. Therefore, the importance of investigating the productivity of cassava-legume intercrops in diverse environments and varying management practices cannot be overemphasized.

2.5 Effects of intercropping and the relative planting dates of legumes on cassava and legumes Land Equivalent Ratio

Land Equivalent Ratio (LER) is a tool that is widely used to measure the individual crop yield advantage in an intercrop system (Mohammed, 2012). LER shows the efficiency of intercropping systems in using environmental resources compared with sole cropping with the value of unity considered to be the critical value (Lithourgidis *et al.,* 2011). Cassava-legume intercropping led to a greater compared with sole cropping in Mpumalanga (Nelspruit). The greater LER was found in cassava – chickpea (1.50) followed by cassava – groundnut (1.40) and cassava – cowpea (1.30) respectively and all the sole crops (cassava, groundnut, chickpea and cowpea) had LER OF 1.00 (Ogola *et al.,* 2013). Similarly, Legese and Gobeze (2013) reported that LER was greater when cassava was intercropped with legumes. The highest LER was obtained by cassava-haricot bean (1.82) followed by cassava - mung bean (1.62) and cassava-soybean (1.48). Cassava-soybean intercropping showed a positive response in LER during the 2001/2 and 2002/3 growing seasons as compared to sole cropping (Mbah *et al.*, 2008). The highest LER (1.91 and 1.98) was obtained when soybean was sown 4 weeks before cassava in 2001/2 and 2002/3 season respectively. The results are in line with earlier finding with cassava/cowpea intercropping (Okoli *et al.,* 1996). The inclusion of legumes in the cassava /legume system increases land use efficiency and may also improve soil fertility and conserve soil (Harrison *et al.*, 2007). Intercropping and relative planting dates of legumes therefore, could enhance LER compared to sole cropping.

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2.6 Effects of relative planting dates of legumes on growth of cassava and legumes

Manipulation of planting time potentially regulates nutrient, moisture and light resource competition during the growth and development of associated crops. Early seeding of crops in the season increases the chances of attaining higher yields compared to late seeding. Early seeding is associated with maximising on moisture, nutrients and radiation. In contrast, in late seeding moisture levels and nutrient levels deplete as the season progresses. Delay in sowing of component crops decreases the length of vegetative and reproductive growth stages (Mojaddam and Noori, 2015). Ambe (1993) realised that early and late seeding reduces the risk of cassava mosaic virus, bacterial blight and leaf spot diseases. The risk is greater during peak rainfall periods where growth coincides with increased disease susceptibility.

Cassava in cassava based intercropping systems is mainly affected by the light shading effect. Late seeding a component crop into an already cultivated cassava crop stand therefore increases risk of light competition (Caballero *et al.*, 1995; Carr *et al.,* 2004). If cassava is planted earlier than the intercrop, shading and competition for other growth factors may affect crop growth and development of the late seeded crop. It has been reported that the optimum growth of maize and cowpea plant height was greatly affected by planting dates (Mukungu, 2002). Component crops when intercropped usually compete with each other for growth resources such as light, nutrients and water. To minimize this competition and increase production, appropriate cultural practices such as relative planting time should be adopted (Leihner, 2002). This study evaluated the effects of relative planting dates of legumes to maximize the growth of cassava and legumes.

2.7 Effects of relative planting dates of legumes on yield and yield components of cassava and legumes

The relative planting time of both crop components has biological and physiological implications in intercropping systems. Cassava does not cause significant competition at the beginning of the growing season but it does not tolerate competition either. Cassava yield could be significantly decreased if the legumes are planted earlier than cassava. Early vigorous unimpeded legume growth and development leads to weak cassava crop unable to compete for light, water and nutrients. The relative planting time of component crops in an intercropping system has been shown to affect the productivity of the intercropping system. The relative planting time of component crops could affect the yields of component crops due to the interspecific competition between the main crop and the component crops (Addo-Quaye *et al.,*

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2011). Common bean had the least yield reduction when inter-planted at 9 months with beans reaching up to 50% yield loss as a sole crop. A study on maize, cowpea and soybean revealed that incorporation of legumes during early growth stages of the maize could be advantageous to the component crops (Allen and Obura, 1983). Soybean grain yield was increased when soybean was planted four weeks before cassava in two cropping seasons than when sown two weeks before, same time and two or four weeks after cassava (Mbah *et al.,* 2008). In contrast the highest fresh root yield in cassava was observed when soybean was sown four weeks after cassava (Mbah *et al.,* 2008).

Similarly, all the cassava cultivars had higher yield when cowpea was planted 4 weeks after cassava than when it was planted 2 weeks before cassava (Harrison *et al.,* 2007). In contrast, Nyi *et al.* (2014) reported that cassava planting time did not have an effect on both grain and biomass yields of groundnut in the Democratic Republic of Congo.

When cassava is planted as a sole crop, it does not use the available resources efficiently during its early stages because of its slow initial development (Gichangi *et al.*, 2000). Leihner (2002) also stated that the root yields of cassava can be significantly reduced if the crop intercropped with it is planted earlier than cassava due to the strong interspecific competition for the growth resources at a time when cassava is still a weak competitor. Hence cassava can be planted at same time or not later than two weeks after the legumes without affecting the cassava root yield in cassava-legume intercrop (Nyi *et al.*, 2014). Therefore there is a need to incorporate the legume crop in the cassava-legume intercrop at least 4 weeks after seeding cassava to minimise cassava yield losses.

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CHAPTER 3: MATERIALS AND METHODS

3.1 Study site

The field experiment was conducted at two sites (University of Mpumalanga and University of Venda) during two consecutive seasons (2015/2016 and 2016/2017). The University of Venda is situated in Thohoyandou (22°58′S and 30°26′E and 596 m above the sea level). Daily temperatures in Thohoyandou vary from about 25°C to 40°C in summer and between 22°C and 26°C in winter (M'marete, 2003; Tadross *et al.,* 2006). The site is characterised by deep, well drained clay soil (Soil classification group, 1991) and annual rainfall of approximately 500 mm that falls predominantly in summer. Rainfall is highly seasonal with 95% occurring between October and March, often with mid-season dry spell during critical growth periods (FAO, 2009). The University of Mpumalanga is situated in Nelspruit (25°45′S and 30°97´E and 660 m above the sea level). The site is characterised by sandy loam soils and annual rainfall of approximately 620 mm that falls predominantly in summer. It has average minimum and maximum temperatures of 6.5°C and 28°C respectively (Soil classification group, 1991).

3.2 Experimental design

The experiment was laid out in a split-plot design, with planting dates as the main plots replicated three times and five cropping systems as the subplots. The three planting dates were legumes planted same time with cassava; legumes sown two weeks after cassava and legumes sown four weeks after cassava. The five cropping systems at University of Venda were cowpea sole, chickpea sole, cassava sole, cassava + cowpea and cassava + chickpea. The cropping systems at University of Mpumalanga were cowpea sole, bambara sole, cassava sole, cassava + cowpea and cassava + bambara. This gave a total of 15 intercropping treatment combinations in each experiment. In the intercropped plots, chickpea, bambara groundnut and cowpea were planted in two 6 m rows between the two rows of cassava. The corresponding sole crops were planted in four rows. The total area was 10 m x 6 m (60 m^2) and the spacing between the rows for legumes was 30 cm and the intra row spacing was 10 cm. Cassava was planted at 1 m x 1 m spacing, in both sole and intercrop system. Two rows of cassava were planted in both sole and mixed cropping system (Figure 3.1).

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Figure 3.1: Cassava - legumes intercrop at Thohoyandou

3.3 Cultural practices

The grass and debris were cleared before setting up the experiment to obtain fine seedbeds. There was no fertilizer application and the crops were rainfed. Weeding was done manually whenever necessary using a hand hoe. Cassava cuttings were planted manually with hands on the flat slope. Legumes were planted manually with hands. All the cassava stands were planted during the first planting dates of both sites and seasons. The first planting date of both seasons in Thohoyandou was 5 December 2014 and 30 November 2015, respectively.

3.4 Measurements

The following parameters were measured: plant height, number of branches per plant, stem diameter, proportion of intercepted radiation, number of pods per plant, 100 seed weight, dry and fresh biomass, pod weight, total seed yield, cassava root yield, harvest index and LER. Harvesting of legumes was done manually by hand at physiological maturity and cassava was harvested manually by hand hoe at 10 months after planting in both sites. Five plants from each

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plot were selected and tagged with wool. Measurements such as plant height, stem diameter, primary and secondary branches were taken from the tagged plants every time when collecting data. 10 plants were harvested at physiological maturity for legumes and four cassava plants were harvested at 10 months after planting.

3.4.1 Plant height

Cassava Plant height (cm) was determined monthly from 1 month after planting (2014/2015) and 3 months after planting (2015/2016) until 10 months after planting from the five tagged plants in Thohoyandou. In Nelspruit plant height for cassava were taken at 3, 5 and 10 months after planting only during the second season. For the legumes plant height was determined fortnightly from 8 weeks after planting until physiological maturity from the five tagged plants by measuring the distance from the base of the plant to the apex of the plant or to the leaf, that is, the plant's highest point using a tape measure (Figure 3.2).



Figure 3.2: Measuring cowpea plant height at Thohoyandou

3.4.2 Primary and Secondary branches

Number of primary branches was determined fortnightly starting from 8 weeks after planting until physiological maturity for legumes and for cassava from 1 (2014/2015) and 3 (2015/2016)

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months after planting until 10 months after planting in Thohoyandou respectively by counting the number of branches sprouted from the main stem. Secondary branches was measured by counting the number of branches sprouted from the primary branches from 3 (2015/2016) and 4 (2014/2015) months after planting until 10 months after planting respectively in Thohoyandou. In Nelspruit the number of primary and secondary branches was measured at 5 and 10 months after planting during the second season (2015/2016).

3.4.3 Stem diameter

Stem diameter was taken only for cassava. Stem diameter was measured using a digital calliper (Model: 16 ER). The calliper was calibrated to 0.00 mm before measuring. The reading of stem diameter was estimated from the average measurements taken at 0.1 m above the ground. Stem diameter was measured from the five tagged cassava plants per plot and the average were taken after. Stem diameter was measured during the second season for both sites from 5 months until 10 months after planting in Thohoyandou and at 3, 5 and 10 months after planting in Nelspruit..

3.4.4 Intercepted radiation

The proportion of radiation intercepted by the crops was measured using Accu PAR, model LP-80 ceptometer (Decogan Devices Ltd, Pullman/USA). On each measurement date, the ceptometer was used to measure photosynthetically active radiation (PAR) above (Pa) and below (Pb) the canopy. The Ceptometer readings were taken at 3, 5 and 10 months after planting only in Thohoyandou during 2nd season (2015/2016) by placing the ceptometer perpendicular to the rows. The proportion of the intercepted radiation was calculated as the difference between the radiation measured above the leaf canopy and the radiation measured below the leaf canopy. The proportion PAR intercepted by the canopy was obtained as:

$$\alpha = 1 - (P_a / P_b) \quad \ldots\ldots 1$$

Where: α = is the proportion of the intercepted radiation

P_a = is the photosynthetically active radiation (PAR) above the canopy

P_b= is the photosynthetically active radiation (PAR) below the canopy (Ogola, 2015).

3.4.5 Yield and yield components for legumes

Yield and yield components were determined at physiological maturity from 10 sampled plants in the two inner middle rows per experimental unit. For the intercropped legumes 10 plants were

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selected randomly from the area of 1.2m^2 in the middle of the two rows. Ten (10) plants were randomly selected from the two middle rows of 4 rows from legumes sole cropping by leaving 2m in both sites of 6m **(Figure 3.3)**. The number of pods per plant was counted manually after separating the pods from the shoot and then the pod weight was measured. The number of seeds per plant was determined after shelling the total pods per plant. Four sets of 100 seeds were randomly selected and counted from the 10 sampled plants and weighed to get the weight of 100 seeds weight. The shoots of the sampled plants were weighed to get the fresh biomass and then oven dried for 48 hours at 65°C to get the dry biomass which was used with the grain yield to calculate harvest index. The total seeds were air dried, weighed and grain yield was determined. Harvest index was determined by using the ratio of grain yield to biomass using equation 2 below:

Harvest index (%) = seed dry weight (kg)/Total above ground biomass (kg) x100..... 2 (Pypers *et al.*, 2011)



Figure 3.3: Harvesting of chickpea at maturity

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3.4.6 Cassava yield and yield components

Four cassava plants were harvested at 10 months after planting for determination of yield and yield components. Four plants were selected at the middle of two rows of cassava. Root diameter and root length were determined by randomly selecting four marketable roots from each plot. Root diameter was measured using a digital Vanier caliper (in mm) by measuring the basal end of each root (**Figure 3.5**). Root length (in cm) was measured using 5 m measuring tape by subjecting the tape from the bottom to the apex of each root. Cassava total root yield was determined by weighing the roots from four sampled plants per plot (**Figure 3.4**). Cassava fresh shoot biomass was measured by weighing the shoots of the 4 sampled plants from each plot. The number of roots per plant was determined by manually counting the number of roots per plant from the four selected plants.



Figure 3.4: Measuring root weight.

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Figure 3.5: Measuring root diameter

3.4.4 LER for cassava and legumes

PLER (Partial Land Equivalent Ratio) was determined by dividing the intercropped yield of cassava by yield of cassava sole, whereas that of legumes were calculated as intercropped yield of legumes divided by yield of legume sole. The overall LER were determined by simply adding the sum PLER of cassava and PLER of legumes.

Land equivalent ratio was calculated using equation 3 below:

$$LER = L_A + L_B = Y_A/S_A + Y_B/S_B \quad \ldots\ldots 3$$

Where L_A and L_B are PLERs for individual crop yields, Y_A and Y_B are Individual crop yields in inter-cropping and S_A and S_B are their corresponding yields as sole crops. If LER >1 means that intercropping is more productive than sole cropping; LER < 1 indicates sole cropping was more productive, while LER = 1 shows no significant difference between intercropping and sole cropping (Legese and Gobeze, 2013).

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3.5 Weather

The weather station broke down and the weather data for both seasons were obtained from Makwarela station located 2 km away from Thohoyandou. Rainfall (mm), maximum and minimum air temperatures (°C), solar radiation (MJ $m^{-2}d^{-1}$), evapotranspiration (mm), and relative humidity (%), were calculated from the recorded data of daily weather condition during the experiments **(Table 3.1** and **Figure 3.6).** In Mpumalanga weather data was not collected due to logistical problems.

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Table 3.1: Summary of weather data during 2014/2015 and 2015/2016 cropping seasons in Thohoyandou

Year/Month	Mean Temp (°C)	Solar Radiation (MJ $m^{-2}D^{-1}$)	Total Rainfall (mm)	Total Epan (mm)	Relative Humidity (%)
2014/2015 cropping season					
Dec-14	23.81	21.05	320.04	134.23	72.52
Jan-15	24.48	25.98	55.62	163.37	70.93
Feb-15	24.87	21.17	49.77	123.48	68.62
Mar-15	23.71	19.69	53.84	126.17	66.14
Apr-15	21.25	14.62	35.06	85.8	73.97
May-15	20.15	14.84	0	92.07	62.43
Jun-15	16.32	12.48	1.01	69.3	61.06
Jul-15	17.36	13.05	0.76	81.22	58.97
Aug-15	19.13	15.22	1.52	91.5	55.74
Sep-15	20.4	16.07	102.86	101.99	64.67
Oct-15	23.57	20.97	22.1	132	58.94
Mean/Total	21.37	17.74	642.58	1201.13	64.91
2015/2016 cropping season					
Nov-15	24.60	22.43	52.83	143.1	53.06
Dec-15	27.37	22.85	105.67	153.4	57.30
Jan-16	25.67	20.57	80.52	137.64	61.29
Feb-16	26.14	20.22	102.87	124.99	63.02
Mar-16	24.43	16.89	296.16	107.57	71.99
Apr-16	22.42	15.26	0.75	92.4	68.01
May-16	17.60	12.85	55.11	74.09	71.45
Jun-16	16.91	11.95	7.61	72.3	68.32
Jul-16	16.08	11.59	9.65	69.44	62.69
Aug-16	18.30	16.94	3.81	70.2	54.45
Sep-16	21.67	16.29	20.82	110.05	56.45
Mean/Total	21.92	17.07	710.67	1155	62.55

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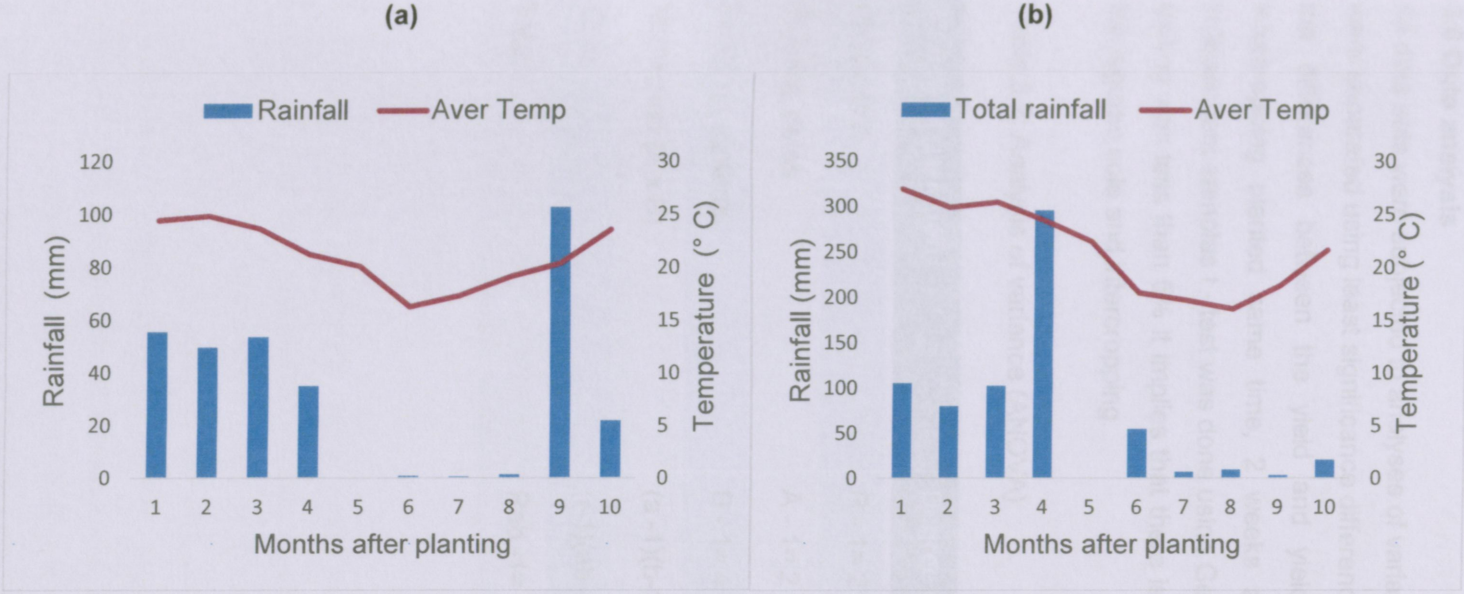


Figure 3.6 Monthly rainfall and average monthly temperature after planting during a) 2014/2015 b) 2015/2016 cropping seasons in Thohoyandou

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3.6 Data analysis

All data sets were subjected to analyses of variance (ANOVA) using Genstat Version 17. Means were separated using least significance difference (LSD) at 5% probability level. To test whether the differences between the yield and yield components of legume sole and legume intercropping planted same time, 2 weeks and 4 weeks after cassava were significant independent samples t - test was done using Genstat version 17. If the P - value found after the testing was less than 5% it implies that there is a significant difference between the means of the legume sole and intercropping.

Table 3.2: Analysis of variance (ANOVA)

Source of variation	Degree of freedom
Replication	R - 1= 2
Planting dates	A - 1= 2
Cropping systems	B - 1= 4
Interaction (A x B)	(a -1)(b-1)= 8
Error	(r-1)(ab -1)= 28
Total	Rab -1= 44

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CHAPTER 4:

4. EFFECTS OF RELATIVE PLANTING DATES OF LEGUMES ON YIELD, YIELD COMPONENTS AND LAND EQUIVALENT RATIO OF CASSAVA

4.1 Introduction

Cassava-based farming systems are particularly prevalent as cassava is one of the major staple foods widely grown in most sub-Saharan Africa countries. Cassava-legume intercrop is a common practice among the small - holder farmers in West Africa. Yield in intercropping systems could be greatly improved by agronomic measures, plant densities, and arrangement of crops, the relative planting dates, genotype and the type cultivar of the component crop. In intercropping legumes and other long season crops like maize and cassava, yield is usually high in intercropping than in the sole crop. Yield advantages resulting from intercropping may be due to component crops having different durations or growth patterns, hence making major demands on resources at different times thereby resulting in better temporal use of growth resources (Mbah and Muoneke, 2007).

The success of intercropping depends on the consideration of several aspects before and after planting; planting pattern and compatibility of the crops play a major role in intercropping systems. When mixed crops are planted at different times, resource utilization improves and competition for available resources reduces (Andrews, 1972). Cassava yield can be greatly reduced by early competition and light seems to be the most critical factor followed by water and nutrients (Thung, 1978).

Light competition is the most critical when the component crops are given an advantage in planting time and it overgrows cassava. In contrast when cassava is planted earlier it also affects the yield of component crops such as legumes. Generally higher LER is found in intercropping than in sole cropping systems. Land equivalent ratio is a tool used to measure the yield potential of intercropping compared to mono-cropping. Other researchers reported that the yield and yield components of cassava and legumes of an intercrop system will vary with component species as well as environment (Ogola *et al.,* 2013). However, the time of introducing an intercrop such as legumes continues to be a problem. Hence this study intended to evaluate the effect of appropriate relative planting date of incorporating legumes in cassava – legume intercrop to improve the yield, yield components and PLER of cassava.

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4.2 Materials and method

A summary of the materials and method used in the study is presented here as the major detailed description is described in chapter 3. The field experiment was conducted at two sites, the University of Mpumalanga and University of Venda. The experiment was laid out in a split-plot design, with planting dates (legumes same time with cassava, 2 weeks after cassava and 4 weeks after cassava) as the main plots and cropping systems (cowpea sole, chickpea sole, cassava sole, cassava - chickpea and cassava - cowpea) as the subplots in Thohoyandou, giving total of 15 treatments. In Mpumalanga cropping systems was cowpea sole, Bambara sole, cassava sole, cassava - Bambara and cassava – cowpea. The combination of the main plots and the subplots gave the total of 15 treatments. The total area planted was 10m x 6 m (60 m^2) and the spacing between the rows for legumes was 30 cm and the intra row spacing was 10 cm. Cassava was planted at 1m x 1m spacing.

There were no fertilizers and irrigation applied in the experiment. The yield and yield components such as number of roots root diameter, root length, shoot weight and root yield were measured for cassava at 10 months after planting. Four plants were selected at the middle of two rows of cassava. Four marketable cassava roots were selected from the four sampled plants to measure the above mentioned parameters. Data was analyzed using Genstat version 17.

4.3 Results

4.3.1 Number of roots per plant

The relative planting dates of legumes had a significant effect on the number of roots per plant in Thohoyandou in 2014/2015, but not in 2015/2016 cropping season **(Table 4.1).** In contrast, the relative planting dates of legumes did not affect the number of roots in both seasons (2014/2015 and 2015/2016) in Mpumalanga **(Table 4.2).** Cassava had the highest number of roots when legumes were planted four weeks after cassava followed by same time and two weeks after cassava in Thohoyandou (2014/2015).

Cropping systems had a significant effect on number of roots per plant in Thohoyandou in both cropping seasons **(Table 4.1).** In 2014/2015 the highest number of roots was recorded when cassava was planted alone followed by cassava - cowpea and cassava - chickpea. In contrast, the highest number of roots per plant was found when cassava was intercropped with chickpea

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followed by cassava sole and cassava - cowpea in 2015/2016 in Thohoyandou. Cropping systems did not affect number of roots in Mpumalanga both seasons **(Table 4.2).** The interaction between the relative planting dates of legumes and cropping systems affected number of roots per plant in 2015/2016 in Thohoyandou. The number of roots per plant was higher when chickpea was planted same time with cassava followed by 4 weeks and 2 weeks after cassava in cassava – chickpea. In contrast, the highest number of roots was found when cowpea was planted 4 weeks after cassava followed by 2 weeks after cassava and same time respectively **(Figure 4.1).**

4.3.2 Root length

Relative planting dates of legumes had no significant effect on root length in both seasons and locations (**Table 4.1 and 4.2).** However, the interaction between the legume relative planting dates and cropping systems affected root length in Thohoyandou in 2014/2015 **(Table 4.1).** When cassava was intercropped with cowpea the highest root length was found when cowpea was planted four weeks after cassava followed by 2 weeks after cassava similarly cassava - chickpea it was higher when chickpea was planted 4 weeks after cassava but there was no difference between same time and 2WAC **(Figure 4.2)**.

Cropping systems had a significant effect on root length in 2014/2015, but did not affect root length in 2015/2016 at Thohoyandou **(Table 4.1).** The highest root length was reported when cassava was planted alone followed by cassava - chickpea and cassava -cowpea in 2014/2015 cropping season. Cropping systems did not have a significant effect on root length in both seasons in Mpumalanga.

4.3.3 Root diameter

The relative planting dates and cropping systems did not affect root diameter in both seasons at Thohoyandou **(Table 4.1).** Similarly, the relative planting dates of legumes did not have a significant effect on root diameter in both cropping seasons in Mpumalanga **(Table 4.2).** In contrast, the effect of cropping systems on root diameter was significant in 2014/2015 but not in 2015/2016 in Mpumalanga **(Table 4.2).** Greater root diameter was found when cassava was intercropped with bambara followed by cassava sole and cassava – cowpea, respectively **(Table 4.2)**.

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4.3.4 Shoot weight

The effect of the relative planting dates of legumes and cropping systems on cassava shoot weight was not significant in Thohoyandou in 2014/2015 **(Table 4.1).** Similarly, the relative planting dates of legumes had no significant effect on shoot weight in 2014/2015 and 2015/2016 in Mpumalanga **(Table 4.2).** In contrast the interaction between planting date and cropping system affected shoot weight in 2015/2016; in cassava - cowpea, shoot weight was higher when cowpea was planted 4 weeks after cassava followed by same time, and with cassava - chickpea shoot weight was higher when chickpea was planted same time with cassava followed by 4 weeks after cassava **(Figure 4.3).** Cropping systems had a significant effect on shoot weight in Mpumalanga 2015/2016 but not in in 2014/2015 **(Table 4.2)**. The highest shoot weight was found when cassava was planted alone followed by cassava - bambara and cassava - cowpea in 2015/2016 **(Table 4.2).**

4.3.5 Root yield

The relative planting dates of legumes had a significant on cassava root yield in 2014/2015 but not in 2015/2016 cropping season in Thohoyandou **(Table 4.1)**. The interaction between the relative planting dates of legumes and cropping systems also affected root yield in Thohoyandou in both seasons. During the first season the lowest root yield was obtained when cowpea was planted same time with cassava, and with cassava - chickpea intercrop it was found when chickpea was planted 4 weeks after cassava. In 2015/2016 the highest root yield was found when legumes was planted four weeks after cassava in both cropping systems followed by 2 weeks and same time with cassava – cowpea but with cassava – chickpea the highest root yield was found when chickpea was planted 4 weeks after cassava followed by same time and two weeks after cassava **(Figure 4.3 a and b)**. In contrast the relative planting dates of legumes did not affect cassava root yield in Mpumalanga in both seasons.

The effect of cropping system on root yield was significant in both seasons and locations **(Table 4.1 and 4.2)**. Cropping systems had a significant effect on root yield in both seasons at Thohoyandou. The highest root yield was found when cassava was planted alone followed by cassava - chickpea and cassava cowpea 2014/2015 cropping season **(Table 4.1)**. In contrast, the highest root yield was reported when cassava was intercropped with chickpea followed by cassava sole and cassava - cowpea in 2015/2016. Similarly cropping systems had a significant effect on root yield in Mpumalanga in both seasons. The highest root yield was reported when

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cassava was planted alone followed by cassava - bambara and cassava cowpea, respectively in Mpumalanga in both seasons **(Table 4.2).**

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Table 4.1: Effects of relative planting dates of legumes and cropping systems on yield and yield components of cassava at Thohoyandou.

YEARS	2014/2015					2015/2016				
TREATMENT	Roots/ plant	Root length (cm)	Root diameter (mm)	Shoot weight (kg/ha)	Root yield (kg/ha)	Root/ plant	Root length (cm)	Root diameter (mm)	Shoot weight (kg/ha)	Root yield (kg/ha)
Legumes planting date										
1 (Same time with cassava	8.7[a]	39.19	39.89	91765	47752[b]	9.93	45.60	36.29	70372	72087
2 (two weeks after cassava	6.17[b]	37.22	38.91	40025	27050[a]	8.75	45.01	35.88	53168	59416
3 (four weeks after cassava	9.63[a]	42.20	43.67	70294	68500[c]	9.04	47.53	35.77	71135	62583
LSD	2.43	8.97	10.27	15605.50	19459.60	1.32	15.19	6.96	23804.90	35291.60
CROPPING SYSTEMS										
Cassava-cowpea	7.44[a]	36.06	39.73	95422	37030[a]	7.72[a]	42.72	37.59	57685	58701[a]
Cassava-chickpea	7.30[a]	39.19	39.76	82751	45108[a]	10.97[b]	46.44	35.74	75129	77867[b]
Cassava sole	10.07[b]	43.84	42.42	96325	61155[b]	9.45[ab]	42.08	34.79	65149	61953[a]
LSD	2.45	4.12	6.53	13416.40	15396.20	1.28	11.03	4.38	17845.10	16153.80
PD	*	**ns**	**ns**	**ns**	*	**ns**	**ns**	**ns**	**ns**	**ns**
CS	*	**	**ns**	**ns**	*	**	**ns**	**ns**	**ns**	*
PD*CS	**ns**	*	**ns**	**ns**	*	*	**ns**	**ns**	*	*
CV %	24.2	4.3	4.3	21.9	30	13.3	7.2	**3.7**	10.2	21.2

*= Significant at 5%; **ns** = not significant;**= significant at 1%; **PD** = planting date, **CS**=cropping system, **LER** = land equivalent ratio

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Table 4.2: Effects of relative planting dates of legumes and cropping systems on yield and yield components of cassava in Nelspruit.

YEARS	2014/2015					2015/2016				
TREATMENT	Roots/plant	Root length(cm)	Root diameter (mm)	Shoot weight (kg/ha)	Root yield (kg/ha)	Roots/ plant	Root length (cm)	Root diameter (mm)	Shoot weight (kg/ha)	Root yield (kg/ha)
Legumes planting date										
1 (Same time with cassava	5.04	24.02	29.30	13135	18630	6.83	48	39.20	40054	48665
2 (two weeks after cassava	5.19	27.11	32.60	15029	17405	3.78	34.90	32.50	21389	23056
3 (four weeks after cassava	4.64	24.24	29.80	12472	14277	4.17	31.50	27	19223	16779
LSD	0.78	4.14	17.88	2275.60	10315.50	4.00	32.44	19.98	35519.70	47393.50
CROPPING SYSTEMS										
Cassava-cowpea	4.07	23.70	24.08[a]	9139	8008[a]	4.56	39.20	35	22167[a]	22000[a]
Cassava-bambara	4.69	26.56	34.80[b]	15500	21090[b]	4.42	32.50	31.50	22778 [a]	23778[a]
Cassava sole	6.11	25.06	32.76[b]	15995	21209[b]	5.81	27	32.10	35722 [b]	42722[b]
LSD	0.86	2.6	8.45	2791.20	5084.80	2.08	14.30	10.93	10665.70	16259.50
PD	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
CS	**ns**	**ns**	*	**ns**	*	**ns**	**ns**	**ns**	*	*
PD*CS	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
CV %	4.6	6	2.7	24.6	28	15	1.8	5.8	14.8	3.4

*= Significant at 5%; **ns** = not significant;**= significant at 1%; **PD** = planting date, **CS**=cropping system, **LER** = land equivalent ratio

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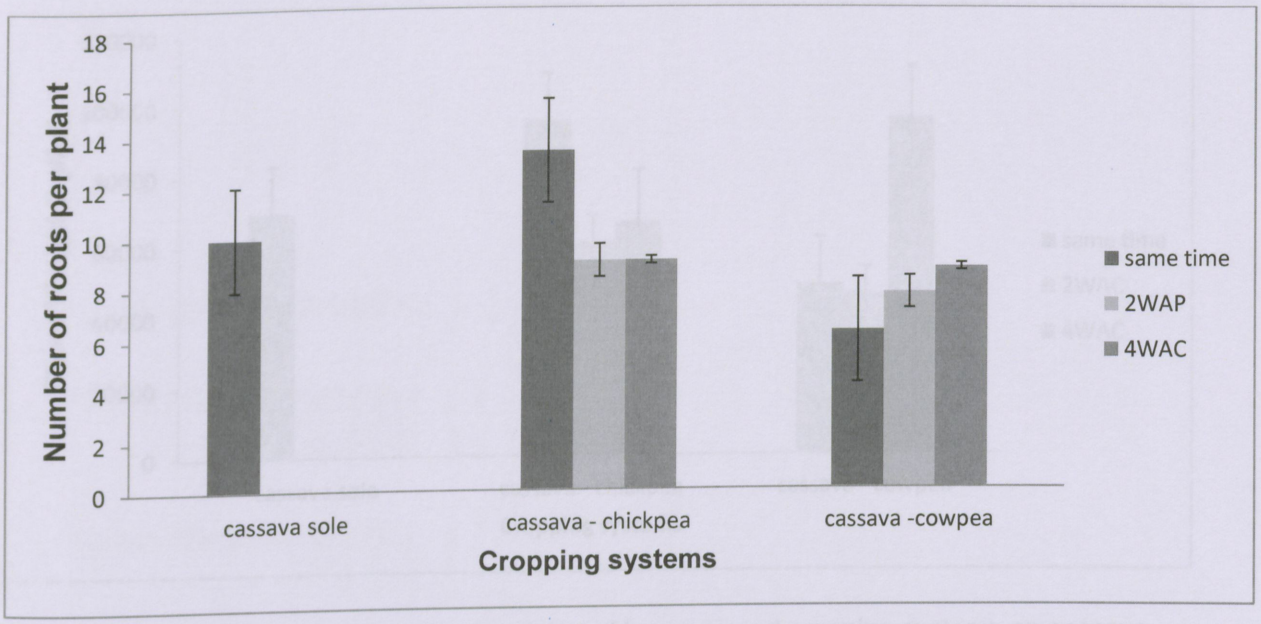


Figure 4.1: Effects of the relative planting dates of legumes and cropping systems on number of roots in 2015/2016 at Thohoyandou

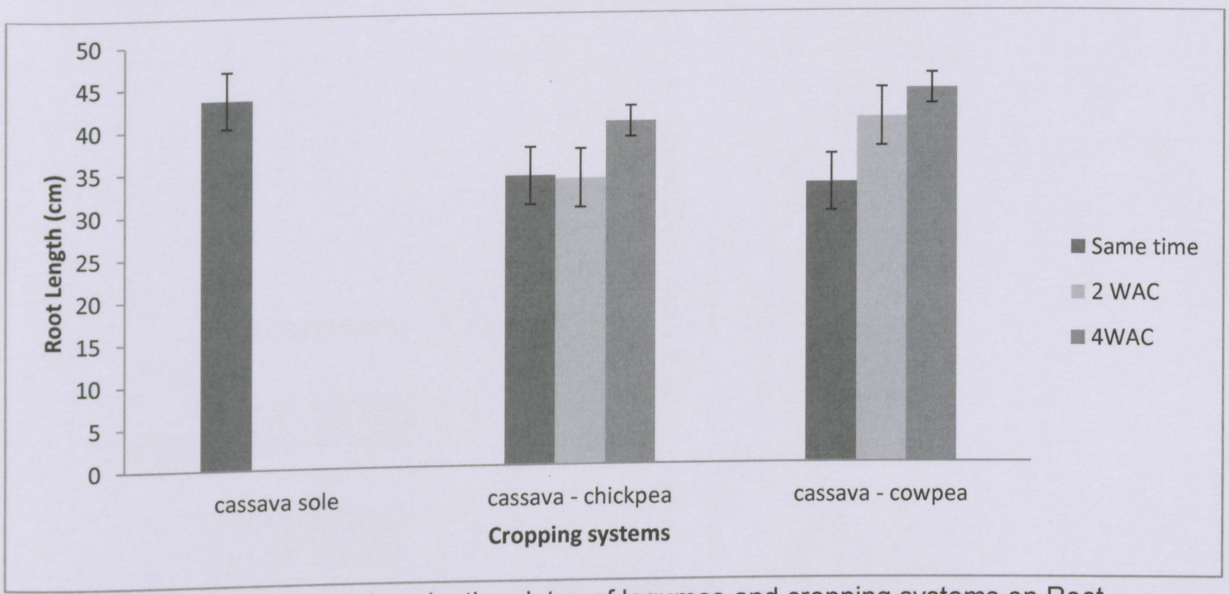


Figure 4.2: Effects of the relative planting dates of legumes and cropping systems on Root length in 2014/2015 in Thohoyandou.

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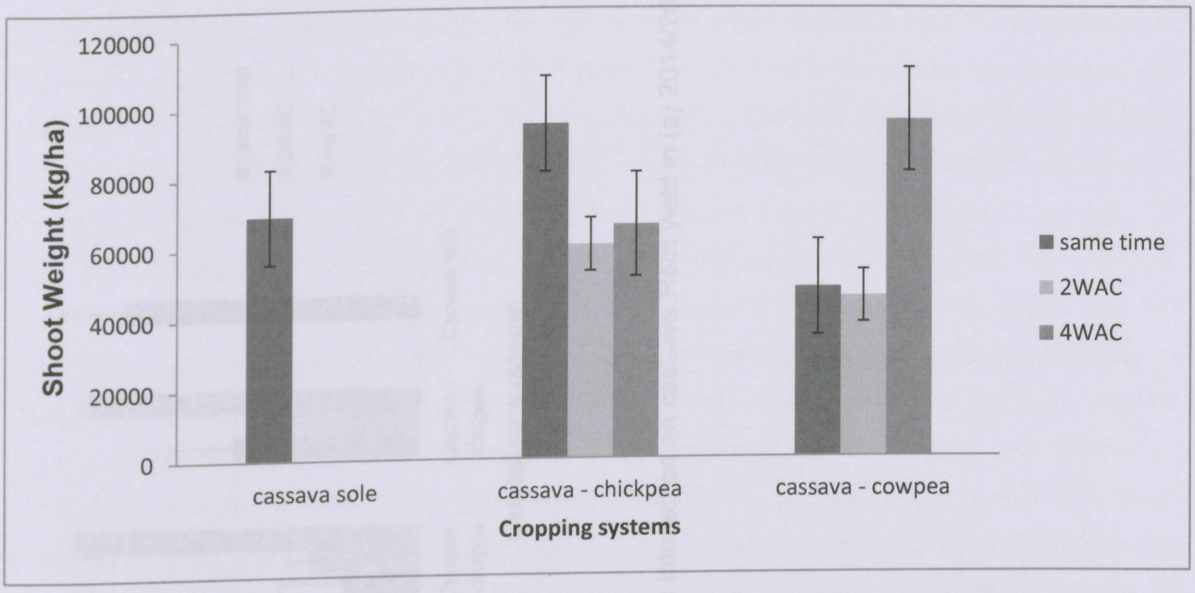


Figure 4.3: Effects of the relative planting dates of legumes and cropping systems on cassava shoot weight in 2015/2016 in Thohoyandou

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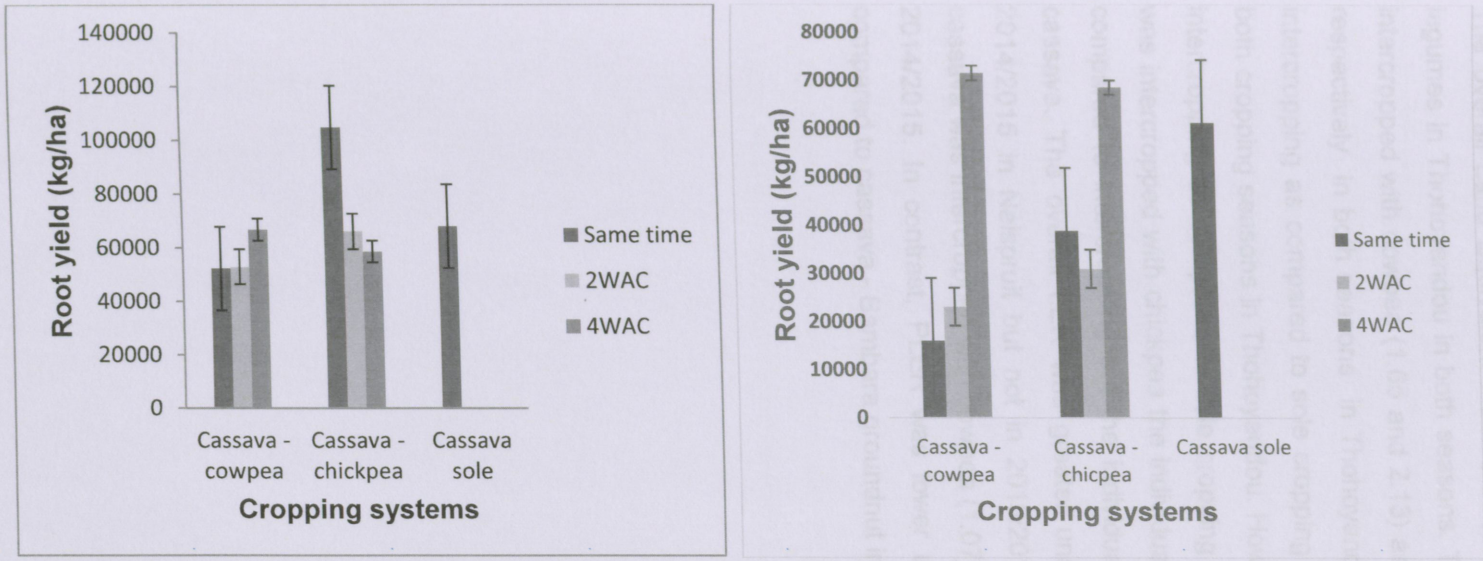


Figure 4.4: Effects of the relative planting dates of legumes and cropping systems interaction on cassava Root yield in (a) 2014/2015 (b) 2015/2016 at Thohoyandou

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4.4.6 Land equivalent ratio

The overall Land Equivalent Ratio (LER) was greater when cassava was intercropped with legumes in Thohoyandou in both seasons. The highest LER was recorded when cassava was intercropped with cowpea (1.65 and 2.13) as compared to cassava - chickpea (1.25 and 1.26) respectively in both seasons in Thohoyandou. The individual yield for cassava was lower in intercropping as compared to sole cropping when cassava was intercropped with cowpea for both cropping seasons in Thohoyandou. However, the individual yield for cowpea was higher in intercropping as compared to sole cropping in both seasons in Thohoyandou. When cassava was intercropped with chickpea the individual yield for cassava was higher in sole cropping as compared to intercropping but the individual yield for chickpea was lower than the one for cassava. The overall LER was greater under the intercropping of cassava and legume in 2014/2015 in Nelspruit but not in 2015/2016. The highest partial LER was reported when cassava was intercropped with cowpea (1.07) as compared to cassava - Bambara groundnut in 2014/2015. In contrast, PLER was lower under cassava - cowpea (0.51) intercropping as compared to cassava - Bambara groundnut in 2015/2016 in Nelspruit **(Table 4. 4).**

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Table 4.3: Effects of relative planting dates of legumes on land equivalent ratio of cassava-legume intercrop.

LOCATION	YEARS	2014/2015			2015/2016		
Thohoyandou	TREATMENT	$PLER_C$	$PLER_L$	TOTAL LER	$PLER_C$	$PLER_L$	TOTAL LER
	CROPPING SYSTEMS						
	Cassava-Cowpea	0.61	1.04	1.65	0.95	1.18	2.13
	Cassava-Chickpea	0.74	0.51	1.25	1.26	-	1.26
Nelspruit	Cassava -cowpea	0.38	1.07	1.45	0.51	-	0.51
	Cassava -Bambara	0.99	1.02	2.01	0.56	0.59	1.15

*= Significant at 5%; **ns** = not significant;**= significant at 1%; **PD** = planting date, **CS**=cropping system, **LER** = total land equivalent ratio, $PLER_C$ = Partial land equivalent ratio for individual cassava, $PLER_L$ = land equivalent ratio for individual legumes.

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4.5 Discussion

The relative planting dates of legumes had a significant effect on cassava root yield in 2014/2015 but not in 2015/2016 cropping season in Thohoyandou. The highest root yield was found when legumes were planted four weeks after cassava followed by same time and two weeks after cassava in 2014/2015. This was associated with cassava yield components such as number of roots, root length and root diameter which were also higher when legumes were planted four weeks after cassava followed by same time and two weeks after cassava respectively. It is highly that the cassava crop had a lesser competition for growth resources such as water, light and nutrients when legumes were planted 4 weeks after cassava. This could have contributed to greater yield and yield components of cassava when legumes were planted 4 weeks after cassava. In 2014/2015 cropping season there was no enough rainfall as compared to 2015/2016. The total rainfall was lower by 10 % in 2014/2015. These might have contributed to the greater competition in 2014/2015 compared with 2015/2016 cropping season. Since there was no enough rainfall the competition for resources such as water, solar radiation and nutrients was higher amongst the component crops

The results are in agreement with the ones reported by Mbha *et al.,* (2008) who found the greater fresh root yield when soybean was sown 4 weeks after cassava. Similarly, Nyi *et al.,* (2014) found that cassava storage root yield significantly decreased when cassava was planted 3 weeks after the groundnuts as compared to same time with groundnuts. This shows that legumes should not be planted before cassava to improve cassava yield.

Cropping systems affected fresh root yield in both seasons and locations. Root yield were generally greater when cassava was grown as a sole crop compared with intercropping at both locations. Similarly, the highest number of roots, root diameter and root length were found in sole crop compared to intercropping. It is highly that the competition for growth resources such as light and water could have contributed to the lower root yield and yield components in intercropping.

Also, there was variation in root yield amongst the intercropping systems. In 2014/2015 the highest root yield was found when cassava was planted alone followed by cassava - chickpea and cassava - cowpea. The lower root yield in cassava – cowpea, was associated with lower yield components such as number of roots, was probably due to the greater competition through cowpea growth habit and larger canopy as compared to other legumes. This is comparable with

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earlier findings by Ogola *et al.,* (2013) that there was greater reduction of cassava root yield in cassava - cowpea compared to cassava chickpea and cassava - groundnuts. Similarly, significantly greater cassava root yield in sole cropping compared to intercropping have been reported (Taah *et al.,* 2017; Prabhakar and Nair, 1996).

The highest root yield was reported when cassava was intercropped with chickpea followed by cassava sole and cassava - cowpea in 2015/2016. The reduced competition for growth resources such as light, water and nutrients in cassava – chickpea as compared to cassava - cowpea might have contributed to the higher root yield in cassava – chickpea. In the 2nd season of the study the growth of the earlier planted legumes especially chickpea was poor and delayed due to low rainfall, that may also be the reason for the increased yield in cassava - chickpea than the sole crop. This probably let to the lower inter – specific competition for growth resources such as light, water and nutrients due to the absence and delayed growth of chickpea. In contrast, Collins *et al.,* (2015) found highest root yield in cassava - cowpea followed by cassava sole and cassava - soybean. In this study the highest root yield was reported when cassava was planted alone followed by cassava - bambara and cassava cowpea at Mpumalanga in both seasons. The larger root yield including number of roots realized in sole cropping may be due to the greater growth resources utilization efficiency of the sole planted crops, which promote the higher number of roots, root diameter and root length as compared to the one found in intercrop. Mbah *et al.,* 2008 reported similar results where cassava sole crop gave the highest number of roots in both seasons studied.

The overall LER was higher in intercropping as compared to sole crop suggesting the greater productivity of the intercropped system as compared to the sole cropping despite the reduction in yield of component crops in the intercropping system. The results are comparable to the earlier findings by Ogola *et al.,* (2013), Dapaah *et al.,* (2003), and Ennin and Dapaah, (2008). Cassava - cowpea led to a greater LER as compared to cassava - chickpea and cassava - bambara groundnuts probably due to larger canopy and the growth habit of cowpea which make it a better competitor for growth resources as compared to other legumes (Ogola *et al.,* 2013). In a review Amanullah *et al.,* (2007) reported the higher LER by many researchers in cassava – cowpea combination.

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4.6 Conclusion

The relative planting dates of legumes and cropping systems influenced the overall yield and yield components of cassava. The results show that legumes should be planted four weeks after cassava to improve the yield of cassava. Although the cassava – chickpea gave the higher cassava root yield, however in terms of cropping systems cassava should be intercropped with cowpea to improve the overall productivity of the system. Cropping systems increased the overall LER and the yield of intercropping was higher than the yield of the sole crop.

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CHAPTER 5:

5. EFFECTS OF RELATIVE PLANTING DATES OF LEGUMES ON YIELD AND YIELD COMPONENTS OF LEGUMES

5.1 Introduction

Legumes play a huge role in contributing to food security, income generation, and sustainability of environment for millions of small-scale farmers in sub - Saharan Africa (Tarawali *et al.*, 2003). Grain legumes are the major source of protein in human's food and animal feed. They play a major role in improving soil fertility, control weeds and also reduce pest and disease incidence in intercropping systems. The ability of legumes to fix biological nitrogen gives them a potential effect of improving soil fertility and that could be useful in improving their own yield in intercropping. Therefore legumes are commonly used in intercrop systems by smallholder farmers. In most farming systems legumes are usually used for intercropping with cereals and other field crops such as cassava to improve land yield (Gbaraneh *et al.*, 2004

Because of the interspecific competition for growth resources, the time of incorporating legumes relative to cassava is an important management practice for intercropping systems in improving yield of each component crops. The relative planting dates of the component crop could have an effect on the yields of the component crops due to interspecific competition for growth resources such as light, water and nutrients. These effects may be negative or positive depending on nature of the crop and the time of incorporating that component crop (legumes) relative to the main crop (cassava). To get high productivity, the relative planting dates have a significant impact on legumes yield (Azadi *et al.*, 2013). The optimal relative planting dates depend on the location and sometimes differ from genotype to genotype (Azadi *et al.*, 2013). Therefore the objective of this study was to evaluate the effect of planting dates of legumes on yield and yield components of legumes.

5.2 Materials and methods

The field experiment was conducted at two sites (Thohoyandou and Nelspruit). The design of the experiment was a split plot consisting of. 3 relative planting dates which were legumes planted same time with cassava, 2 weeks and 4 weeks after cassava as the main plots and 5 cropping systems (cowpea sole, chickpea sole, cassava sole, cassava - chickpea and cassava - cowpea) as subplots. The combination of the relative planting dates of legumes and cropping systems gave the total of 15 treatment. The total experimental area was 60 m^2 with 30 cm inter -

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row spacing and 10 cm intra - row spacing for all the legumes. Yield and yield components such as shoot biomass, number of pods, pod weight, 100 seed weight, and grain yield and harvest index were measured from the ten sampled plants at physiological maturity. Ten plants were selected randomly in the middle of the two rows in intercropped legumes and from the two middle rows of 4 rows from legumes in sole cropping. Land Equivalent ratio was calculated after measuring the yield of both cassava and legume. There was no yield of cowpea at 4 weeks after cassava in both sites during the first season because of the late planting and low rainfall (55.62 mm) which affected the podding and seeding of cowpeas. The yield and yield components on the table of results is represented by a dash (-).

5.3 Results

5.3.1 Yield and yield components for cowpea

5.3.1.1 Shoot biomass

The relative planting dates of legumes and cropping systems did not have a significant effect on cowpea shoot biomass in both cropping seasons in Thohoyandou **(Table 5.1)**. In contrast, the effect of the relative planting dates of legumes on shoot biomass of cowpea was significant in Mpumalanga in 2014/2015 cropping season **(Table 5.2)**. The highest shoot biomass was found when cowpea was planted same time with cassava (**Table 5.2)**. Cropping systems did not have a significant effect on shoot biomass in 2014/2015 at Mpumalanga. There was no significant difference between the shoot biomass of cowpea sole and cowpea intercrop when cowpea was planted same time and two weeks after cassava in both seasons and sites **(Table 5.3).**

5.3.1.2 Number of pods per plant

The effects of the relative planting dates of legumes on the number of pods per plant of cowpea was significant in 2014/2015 but not in 2015/2016 in Thohoyandou. The highest number of pods was found when cowpea was planted same time with cassava followed by two weeks in 2014/2015 (**Table 5.1**). Cropping system did not affect the number of pods per plant at both sites **(Table 5.1 and 5.2)**. There was no significant difference between the number of pods per plant for cowpea sole and cowpea intercrop when cowpea was planted same time and two weeks after cassava in both seasons and sites **(Table 5.3)**.

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5.3.1.3 Pod weight

The relative planting dates of legumes had a significant effect on cowpea pod weight in 2014/2015 but not in 2015/2016 at Thohoyandou. Cowpea pod weight was higher when cowpea was planted same time with cassava followed by two weeks after cassava in 2014/2015 **(Table 5.1)**. In 2014/2015 at Mpumalanga the relative planting dates of legumes had a highly significant effect on cowpea pod weight; the highest pod weight was found when cowpea was planted same time followed by two weeks after cassava in (**Table 5.2)**. Cropping systems did not affect pod weight of cowpea in both seasons and sites. Pod weight for cowpea sole and cowpea intercrop were not significantly different when cowpea was planted same time with cassava and 2 weeks after cassava in both seasons and sites **(Table 5.3)**.

5.3.1.4 100 seed weight

The relative planting dates of legumes affected ($P<0.01$) 100 seed weight of cowpea in 2014/2015 but not in 2015/2016 in Thohoyandou **(Table 5.1)**; the highest 100 seed weight was reported when cowpea was planted same time followed by two weeks after cassava (**Table 5.2**). Similarly, the relative planting dates of legumes affected ($P<0.001$) cowpea 100 seed weight in 2014/2015 in Mpumalanga. The highest 100 seed weight was found when cowpea was planted two weeks after cassava followed by same time with cassava respectively (**Table 5.2**). The effect of cropping systems on 100 seed weight was not significant in both seasons and sites **(Table 5.1 and 5.2).** The was no significant different between 100 seed weight for cowpea sole and cowpea intercrop when cowpea was planted same, 2 weeks and 4 weeks after cassava in both season and sites **(Table 5.3 and 5.4)**.

5.3.1.5 Grain yield

Cowpea grain yield was significantly affected by the relative planting dates of legumes in 2014/2015 but not in 2015/2016in Thohoyandou. The highest cowpea grain yield was reported when cowpea was planted same time with cassava followed by two weeks after cassava (**Table 5.1**). Similarly, the relative planting dates of legumes affected cowpea grain yield in 2014/2015 at Mpumalanga. The cowpea grain yield was higher when cowpea was planted same time with cassava (**Table 5.2**). Cropping systems did not have a significant effect on the cowpea grain yield in both seasons and sites **(Table 5.2)**. The was no significant different between grain yield for cowpea sole and cowpea intercrop when cowpea was planted same, 2 weeks and 4 weeks after cassava in both season and sites **(Table 5.3 and 5.4)**.

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5.3.1.6 Harvest index (%)

Harvest index was significantly affected by the relative planting dates of legumes in 2014/2015 but not in 2015/2016 in Thohoyandou. The highest harvest index was reported when cowpea was planted same time with cassava followed by two weeks after cassava in both seasons respectively (**Table 5.1**). The relative planting dates of legumes had a significant effect on the cowpea harvest index in 2014/2015 at Mpumalanga (**Table 5.2**).

Harvest index was not significantly affected by the cropping system in both seasons in Thohoyandou. In contrast cropping systems had a significant effect on cowpea harvest index in 2015/2016 cropping season. The highest harvest index was reported when cowpea was planted alone as compared to cassava – cowpea (**Table 5.1**). Cowpea harvest index was not significantly affected by the cropping systems in 2014/2015 at Mpumalanga **(Table 5.2)**. Harvest index for cowpea sole planted same time and two weeks after cassava was not significantly different to cowpea intercropped same time with cassava and 2 weeks after cassava in both season and sites **(Table 5.3 and 5.4)**.

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Table 5.1. Effects of relative planting dates of legumes and cropping systems on yield and yield components of cowpea at Thohoyandou

YEARS	TREATMENT	Shoot biomass (kg/ha)	No of pods per plant	Pod weight (kg/ha)	100 seed weight (g)	Grain yield (kg/ha)	Harvest index (kg/ha)
2014/2015	Legumes planting date						
	1 (Same time with cassava	3962.44	8.64[b]	2916.08[b]	15.08[b]	1617.84[b]	24.37
	2 (two weeks after cassava	2066.38	2.38[a]	457.79[a]	8.69[a]	163.56[a]	18.97
	3 (four weeks after cassava	476.62	–	–	–	–	–
	LSD	3594.25	4.3	1336.07	10.08	869.7	16.96
	CROPPING SYSTEMS						
	Cassava-cowpea	2551.46	4.66	1566.8	9.49	815.62	22.66
	Cowpea sole	2509.9	4.69	1410.12	9.27	785.24	26.56
	LSD	617.95	1.44	498.43	0.29	103.47	7.6
	PD	ns	**	**	**	**	**
	CS	ns	ns	ns	ns	ns	ns
	PD*CS	ns	ns	ns	ns	ns	ns
	CV %	48.1	39.4	24.5	16.5	37.5	47.3
2015/2016	Legumes planting date						
	1 (Same time with cassava	2753.25	8.14	3225.76	13.94	2098.5	35.82
	2 (two weeks after cassava	2681.09	5.63	2456.83	14.17	1434.53	28.02
	3 (four weeks after cassava	6223.31	5.53	2461.77	11.91	1169.19	15.94
	LSD	3073.3	3.67	1579.45	2.3	1318.31	16.31
	CROPPING SYSTEMS						
	Cassava-cowpea	4313.77	7.56	3105.19	13.3	1813.26	26.52
	Cowpea sole	2985.84	6.01	2533.9	13.63	1539.33	30.45
	LSD	2113.83	2.64	1228.37	1.31	828.65	6.71
	PD	ns	ns	ns	ns	ns	ns
	CS	ns	ns	ns	ns	ns	ns
	PD*CS	ns	ns	ns	ns	ns	ns
	CV %	24.4	18.7	16.5	2.3	21.2	22.2

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Table 5.2: Effect of relative planting dates of legumes and cropping systems on yield and yield components of cowpea (*Vigna uguiculata*) in 2014/2015 Nelspruit

TREATMENT	Shoot biomass (kg/ha)	No of pods /plant	Pod weight (kg/ha)	100 seed weight (g)	Grain yield (kg/ha)	Harvest index (%)
LEGUMES PLANTING DATE						
1(Same time with cassava	7879[b]	3.39[b]	1138[b]	12.16[a]	725.5[b]	8.03
2(two weeks after cassava	4344[a]	2.6[a]	207[a]	13.15[b]	629.3[a]	14.34[b]
3(four weeks after cassava	1780[a]	_	_	_	_	_
LSD	2710.30	0.81	191.0	0.97	121.11	3.58
CROPPING SYSTEMS						
Cowpea sole	4625	2	454	8.5	436.4	7.29
Cassava-cowpea	4711	1.99	443	8.38	466.9	7.63
LSD	862.0	0.36	77.9	0.86	67.58	3.11
PD	**	***	***	***	***	**
CS	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
PD*CS	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
CV %	5.8	12.5	12.8	1.6	9.7	12.0

= Significant at 1%; **ns = not significant;***= highly significant at < 0.001; **PD** = planting date, **CS**=cropping system, _ = no yield/yield component

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Table 5.3 Comparison of the means of yield and yield components of cowpea sole and cowpea intercropped with cassava same time, 2 weeks and 4 weeks after cassava using T-test at Thohoyandou

YEARS	Cropping systems	No of pods/ plant	100 seed weight (g)	Pod weight (kg/ha)	Shoot biomass (kg/ha)	Grain yield (kg/ha)	Harvest Index (%)
2014/2015	Cowpea sole same time	8.6	14.49	2711	4051	1548	49.62
	Cassava - cowpea same time	8.73	15.79	3149	3891	1698	48.21
	T - value	-0.04	-1.4	-0.51	0.08	-0.27	0.23
	P-value	0.97	0.32	0.64	0.94	0.80	0.83
	cowpea sole 2WAC	2.37	9.02	444	1708	193.4	24.12
	Cassava - cowpea 2WAC	2.4	8.38	474.8	1650	134.6	13.87
	T - value	-0.03	0.1	-0.1	0.06	0.39	0.68
	P - value	0.98	0.92	0.93	0.96	0.71	0.53
	Cowpea sole 4WAC	_	_	_	694.9	_	_
	Cassava - cowpea 4WAC	_	_	_	259.9	_	_
	T - value	_	_	_	3.97	_	_
	P - value	_	_	_	0.017	_	_
2015/2016	Cowpea sole same time	8	13.94	3347	2070	2248	40.76
	Cassava - cowpea same time	8.33	13.94	3117	3390	1963	31.1
	T - value	-0.14	0	0.26	-1.31	0.49	1.6
	P - value	0.90	0.49	0.81	0.32	0.65	0.19
	Cowpea sole 2WAC	5.07	13.51	2095	2146	1219	28.07
	Cassava -cowpea 2WAC	6.2	12.81	2820	3211	1651	27.99
	T - value	-0.95	0.83	-1.22	-1.42	-0.95	-0.02
	P - value	0.39	0.45	0.29	0.23	0.40	0.99
	Cowpea sole 4WAC	3.93	12.32	1853	5421	832	16.96
	Cassava - cowpea 4WAC	7.13	11.51	3072	7020	1507	14.93
	T - value	-1.6	0.75	-1.26	-0.63	-0.34	0.17
	P - value	0.25	0.49	0.28	0.57	0.49	0.87

_ = no yield

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Table 5.4 Comparison of the means of yield and yield components of cowpea sole and cowpea intercropped with cassava same time, 2 weeks and 4 weeks after cassava using T-test in Nelspruit

Cropping systems for T comparison	No of pods/ plant	100 seed weight (g)	Pod weight (kg/ha)	Shoot biomass (kg/ha)	Grain yield (kg/ha)	Harvest index (%)
Cowpea sole same time	3.4	11.99	1150	8056	7333	7.96
Cassava - cowpea same time	3.37	12.38	1126	7703	7178	8.11
T - value	0.07	-0.97	0.17	0.41	0.71	-1.03
P - value	0.95	0.43	0.87	0.70	0.87	0.36
Cowpea sole 2WAC	2.6	13.51	212	4000	575.8	13.91
Cassava -cowpea 2WAC	2.6	12.81	201.9	4689	682.9	14.78
T - value	0	0.83	0.44	-0.89	-1.99	-0.25
P - value	1.00	0.45	0.70	0.42	0.12	0.81
Cowpea sole 4WAC	_	_	_	1819	_	_
Cassava - cowpea 4WAC	_	_	_	1080	_	_
T - value	_	_	_	0.41	_	_
P - value	_	_	_	0.55	_	_

_ = no yield

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5.3.2 Yield and yield components of chickpea

5.3.2.1 Shoot biomass

Neither the relative planting of legumes nor the cropping system affected the shoot biomass of chickpea in 2014/2015 at Thohoyandou (**Table 5.5**).

5.3.2.2 Number of pods per plant

Number of pods per plant was significantly affected by the relative planting dates of legume in 2014/2015 cropping season in Thohoyandou **(Table 5.5)**. The highest number of pods was realized when chickpea was planted simultaneously with cassava followed by two weeks and four weeks after cassava **(Table 5.5)**. Similarly, cropping systems affected number of pods in 2014/2015 in Thohoyandou. Greater number of pods was found when chickpea was planted sole as compared to cassava - chickpea (**Table 5.5**). There were significant differences between the number of pods per plant for chickpea sole and chickpea intercrop when chickpea was planted same time with cassava but at 2 weeks and 4 weeks after cassava in 2014/15 in Thohoyandou **(Table 5.6)**. Relative planting dates of legumes and cropping systems did not affect pod weight in 2014/2015 in Thohoyandou **(Table 5.5).**

5.3.2.3 100 seed weight

Relative planting dates of legumes and cropping systems did not affect chickpea 100 seed weight in 2014/2015 in Thohoyandou **(Table 5.5)**. There was no significant difference between 100 seed weight of chickpea sole and chickpea intercrop when chickpea was planted same time, 2 and 4 weeks after cassava in 2014/2015 in Thohoyandou **(Table 5.6)**.

5.3.2.4 Grain yield

Chickpea grain yield was significantly affected by both the relative planting dates of legumes and the cropping systems in 2014/2015 cropping season in Thohoyandou **(Table 5.5)**. The highest grain yield of chickpea was obtained when chickpea was planted same time with cassava followed by 2 weeks and 4 weeks after cassava, respectively. Moreover, greater yield was reported in chickpea sole as compared to intercropping. The grain yield of chickpea sole was significantly different to the grain yield of chickpea intercrop when chickpea was planted same time, 2 and 4 weeks after cassava in 2014/2015 in Thohoyandou (**Table 5.6**).

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5.3.2.5 Harvest index

Neither relative planting dates of legumes nor the cropping system affected harvest index in Thohoyandou **(Table 5.5)**. The was a significant difference between the chickpea sole and chickpea intercrop when chickpea was planted 2 and 4 weeks after cassava. In contrast, there were no significant difference between the chickpea sole planted same time and chickpea intercrop planted same time with cassava in 2014/2015 in Thohoyandou **(Table 5.6)**.

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Table 5.5: Effect of relative planting dates of legumes and cropping systems on yield and yield components of chickpea (*Cicer arietinum*) at University of Venda Thohoyandou

TREATMENT	Shoot biomass (kg/ha)	No of pods per plant	Pod weight (kg/ha)	100 seed weight (g)	Grain yield (kg/ha)	Harvest index (%)
LEGUMES PLANTING DATE						
1 (Same time with cassava)	6011.46	17.07^{c}	1278.41	22.27	742.50^{b}	7.42
2 (two weeks after cassava)	1174.09	13.11^{b}	1762.98	21.9	602.72^{b}	5.61
3(four weeks after cassava)	625.09	3.13^{a}	343.03	13.25	131.31^{a}	1.63
LSD	11661.48	10.49	1496.79	14.56	205.19	7.00
CROPPING SYSTEMS						
Chickpea sole	9983.11	14.96^{b}	1323.07	19.72	718.60^{c}	7.55
Cassava-chickpea	9590.15	9.69^{a}	995.33	19.86	368.40^{a}	3.26
LSD	1251.13	2.64	522.59	3.99	19.83	6.83
PD	**ns**	*	**ns**	**ns**	**	**ns**
CS	**ns**	**	**ns**	**ns**	***	**ns**
PD*CS	**ns**	**ns**	**ns**	**ns**	*	**ns**
CV %	7.6	8.4	24.5	15.8	4.1	37.3

=** Significant at 5%; **ns** = not significant;*=** significant at 1%; **PD** = planting date, **CS**=cropping system

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Table 5.6 Comparison of the means of yield and yield components of chickpea sole and chickpea intercropped with cassava same time, 2 weeks and 4 weeks after cassava using T-test at Thohoyandou

Cropping systems	No of pods/ plant	100 seed weight (g)	Pod weight (kg/ha)	Shoot biomass (kg/ha)	Grain yield (kg/ha)	Harvest index (%)
Chickpea sole same time	20.77	21.65	1192	10900	964.7	33.67
Cassava - Chickpea same time	13.53	23.03	1367	1211	526.8	20.5
T - value	4.97	-0.58	-0.25	0.97	9.24	0.69
P - value	0.008	0.923	0.817	0.435	<0.001	0.56
Chickpea sole 2WAC	14.97	22.88	2044	1003	795.9	25.93
Cassava - chickpea 2WAC	11.27	20.93	1482	1353	410.1	15.64
T - value	0.65	0.86	0.94	-1.22	3.49	3.99
P - value	0.549	0.436	0.399	0.289	0.025	0.016
chickpea sole 4WAC	5.57	12.76	643.9	1008	245.1	14.96
Cassava - chickpea 4WAC	0.7	13.75	46.4	250.1	18.1	6.14
T - value	1.63	-0.1	6.53	5.11	6	4.76
P - value	0.244	0.923	0.22	0.035	0.026	0.009

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5.3.3. Yield and yield components of bambara groundnuts

5.3.3.1 Shoot biomass

Shoot biomass of Bambara was significantly affected (P<0.001) by the relative planting dates of legumes in 2014/2015 in Nelspruit. However the relative planting dates of legumes did not affect Bambara shoot biomass in 2015/2016 cropping season. The highest shoot biomass was reported when Bambara was planted same time with cassava followed by two week and four weeks after cassava. Cropping systems had a significant effect on shoot biomass in both seasons at Mpumalanga. The highest shoot biomass was found when Bambara was planted as a sole crop compared to cassava - Bambara in both seasons **(Table 5.7)** There was no significant differences between the shoot biomass of Bambara sole and Bambara intercrop when Bambara was planted same time with cassava, 2 and 4 weeks after cassava in both seasons in Mpumalanga **(Table 5.8)**.

5.3.3.2 Number of pods per plant

The relative planting dates of legumes had significant effect on the number of pods per plant in 2014/2015 but not in 2015/2016. The highest Bambara pod number was found when Bambara was planted same time followed by two weeks and four weeks after cassava in Nelspruit in 2014/2015. Cropping systems showed no significant effect on the number of pods in 2014/2015 cropping season in Mpumalanga. In contrast, number of pods per plant was significantly affected by cropping systems in 2015/2016. In 2015/2016 cropping season, the highest number of pods was found in Bambara sole compared to cassava - Bambara **(Table 5.7).** The number of pods per plant for Bambara sole was not significantly different to the number of pods for Bambara intercrop when it was planted same time with cassava, 2 and 4 weeks after cassava in both seasons in Mpumalanga **(Table 5.8)**.

The relative planting dates of legumes showed a significant effect on Bambara pod weight in 2014/2015 at Mpumalanga. However Bambara pod weight was not significantly affected by the relative planting dates of legumes in 2015/2016 at Mpumalanga. The highest pod weight was found when Bambara was planted same time followed by two weeks and four weeks after cassava in both seasons **(Table 5.7)**. Bambara pod weight was not significantly affected by cropping systems in 2014/2015. In contrast, cropping systems had a significant effect on Bambara pod weight in 2015/2016; the highest Bambara pod weight was found when Bambara was planted alone as compared to cassava - Bambara **(Table 5.7)**. There were no significant

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difference among the pod weight of Bambara sole and Bambara intercrop when Bambara was planted same time with cassava, 2 and 4 weeks after cassava in both seasons in Mpumalanga **(Table 5.8)**.

5.3.3.3 100 seed weight

The relative planting dates of legumes had a significant effect on Bambara 100 seed weight in 2014/2015 at Mpumalanga; but the relative planting dates of legumes had no significant effect on Bambara 100 seed weigh in 2015/2016. In 2014/2015 the highest 100 seed weight was found when Bambara was planted same time followed by two weeks and four weeks after cassava. Bambara 100 seed weight was not significantly affected by cropping systems in both seasons **(Table 5.7)**. There was no significant difference among 100 seed weight for Bambara sole and Bambara intercrop when Bambara was planted same time, 2 weeks and 4 weeks after cassava in both seasons in Mpumalanga **(Table 5.8)**.

5.3.3.4 Grain yield

Grain yield for Bambara was significantly affected by the relative planting dates of legumes in 2014/2015 but not in 2015/2016. The highest grain yield was reported when Bambara was planted same time followed by two weeks and four weeks after cassava in 2014/2015. Cropping systems had no significant effect on Bambara grain yield in 2014/2015 in Mpumalanga. However, cropping systems affected ($P < 0.05$) grain yield in 2015/2016 cropping season. The highest Bambara grain yield was found when Bambara was grown as a sole crop as compared to cassava - Bambara in 2015/2016 at Mpumalanga **(Table 5.7).** Grain yield for Bambara sole and Bambara intercrop when Bambara was planted same time and 2 weeks and 4 weeks after cassava were not significantly different in both seasons in Nelspruit **(Table 5.8)**.

5.3.3.5 Harvest index

The relative planting dates of legumes had a significant effect on Bambara harvest index in both seasons. The highest harvest index was found when Bambara was planted same time with cassava followed by two weeks and four weeks after cassava in 2014/2015 at Mpumalanga. However, in 2015/2016 the highest harvest index was found when Bambara was planted two weeks after cassava followed by same time and four weeks after cassava. Cropping systems did not affect harvest index in both seasons at Mpumalanga **(Table 5.7)**. There was no significant difference among Harvest index for Bambara sole and Bambara intercrop when

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Bambara was planted same time, 2 weeks and 4 weeks after cassava in both seasons in Nelspruit **(Table 5.8)**.

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Table 5.7: Effects of the relative planting dates of legumes and cropping systems on the yield and yield components of Bambara groundnut in Nelspruit.

YEARS	TREATMENT	Shoot biomass (kg/ha)	No of pods / plant	Pod weight (kg/ha)	100 seed weight (g)	Grain yield (kg/ha)	Harvest index (%)
2014/2015	**Legumes planting date**						
	1 (Same time with cassava	4578^{b}	38.3^{b}	2685^{c}	34.8^{b}	4133^{b}	53.7 b
	2 (two weeks after cassava	864^{a}	7.9^{a}	229^{b}	17.8^{ab}	496^{a}	41.2 b
	3 (four weeks after cassava	578^{a}	1.8^{a}	38^{a}	5.5^{a}	11^{a}	1.2 a
	LSD	359.1	17.86	1718.4	21.44	2782.6	28.39
	CROPPING SYSTEMS						
	Cassava - bambara	1698^{a}	18.2	1056	15.7	1563	30.4
	Bambara sole	2315^{b}	13.8	911	23.1	1530	33.7
	LSD	612.8	11.4	1103.9	15.19	756.5	34.74
	PD	***	*	*	*	*	*
	CS	*	**ns**	**ns**	**ns**	**ns**	**ns**
	PD*CS	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
	CV %	14.7	23.8	45	10.6	47.4	29.5
2015/2016	**Legumes planting date**						
	1 (Same time with cassava	4358	17.5	2691	32.6	1890	21.14
	2 (two weeks after cassava	3428	15.29	2595	32.1	1905	26.45
	3 (four weeks after cassava	2635	7.36	1452	66.5	971	13.23
	LSD	6244.5	27.26	3894.9	95.27	2598.1	40.04
	CROPPING SYSTEMS						
	Cassava-bambara	3445^{a}	6.44^{a}	1008	40.7	686^{a}	15.92
	Bambara sole	3824^{b}	13.93^{b}	1778	41.6	1168^{b}	20.63
	LSD	328.6	7.18	1687.6	89.01	1229.5	13.56
	PD	**ns**	**ns**	**ns**	**ns**	**ns**	*
	CS	**	*	**ns**	**ns**	*	**ns**
	PD*CS	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
	CV %	39.7	22.5	16.5	53.1	16.1	33.8

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Table 5.8 Comparison of the means of yield and yield components of Bambara sole and Bambara intercropped with cassava same time, 2 weeks and 4 weeks after cassava using T-test

YEARS	cropping systems	No of pods/ plant	100 seed weight (g)	Pod weight (kg/ha)	Shoot biomass (kg/ha)	Grain yield (kg/ha)	Harvest index (%)
2014/2015	Bambara sole same time	41.13	36.15	2360	4595	3977	54.71
	Cassava - Bambara same time	35.47	33.47	3010	4264	4290	52.62
	T -value	0.42	0.33	-0.45	1.28	0.13	0.11
	P - value	0.694	0.755	0.675	0.270	0.900	0.920
	Bambara sole 2WAC	9.73	22.05	320.6	1152.6	591.6	43.95
	Cassava -Bambara 2WAC	6	13.58	136.7	574.3	400.2	38.54
	T -value	0.84	0.79	1.97	2.33	0.15	0.18
	P - value	0.448	0.475	0.120	0.232	0.635	0.869
	Bambara sole 4WAC	32.76	11	54	898.4	22	2.38
	Cassava - Bambara 4WAC	0	0	0.22	256.7	0	0
	T -value	1.09	-1	1	1.5	1	1
	P - value	0.337	0.573	0.424	0.080	0.374	0.374
2015/2016	Bambara sole same time	12.07	33	2030	2900	1312	27.5
	Cassava - Bambara same time	14.93	27.11	1760	3415	1298	21.63
	T -value	-0.41	0.58	-0.24	-0.94	0.02	0.44
	P - value	0.703	0.592	0.697	0.402	0.986	0.724
	Bambara sole 2WAC	28.73	41.52	4696	5470	3288	34.77
	Cassava -Bambara 2WAC	18.2	30.99	2282	5666	1564	22.75
	T -value	1.56	2.09	2.09	-0.07	2.38	1.51
	P - value	0.194	0.105	0.316	0.944	0.076	0.450
	Bambara sole 4WAC	1.33	84.32	250.7	2485	203.3	6.78
	Cassava - Bambara 4WAC	0.33	35.17	20.9	1786	14.4	0.74
	T -value	2.26	0.75	1.74	1.86	1.93	0.17
	P - value	0.147	0.493	0.966	0.137	0.192	0.168

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5.4 Discussion

Cowpea grain yield was significantly affected by the relative planting dates of legumes in 2014/2015 but not 2015/2016 at both sites. Nonetheless, the highest cowpea grain yield was reported when cowpea was planted same time with cassava followed by two weeks and four weeks after cassava in both seasons and sites. The yield components of cowpea such as number of pods per plant, biomass, number of seeds per plant, 100 seed weight, and pod weight and harvest index followed a similar pattern. This is possibly because cassava at the early growth stage was still a weak competitor and cowpea had a lesser competition for the growth resources at that stage. Udealor (2002) similarly reported reduced cowpea grain yield when cowpea was planted four weeks after cassava and concluded that the later the incorporation of legumes in cassava - legume intercrop, the greater was the shading effect of the well - established cassava. Cropping systems did not affect cowpea grain yield in both seasons at both sites. Although the results shows that the relative planting dates of legumes significantly affected the cowpea yield and yield components, the t- tests analysis was also done to compare the means of the cowpea sole yield and yield components and cowpea intercrop at 2 weeks after cassava in both seasons and sites. The results showed no significant difference between the means of cowpea sole and cowpea intercrop at 2 weeks after cassava. Thus the yield and yield components of cowpea at 2 weeks after cassava seems to be reduced by the late planting date not the relative planting date of cowpea. Mathews and Saxena (2005) reported that late planting of the long to short seasoned crops in drought prone areas of South Africa in December could result in smaller canopy and lower yields.

The effects of the relative planting dates of legumes and cropping systems affected chickpea grain yield. The chickpea grain yield was higher when chickpea was planted same time followed by two weeks and four weeks after cassava, respectively. Similarly, chickpea yield components such as number of pods, pod weight, number of seeds, 100 seed weight, harvest index and biomass of chickpea were higher when chickpea was planted simultaneously with cassava. The reduced yield when chickpea was planted later (4WAC) was probably due to the reduced interception and transmission of radiation in the lower canopy associated with the shading leaf canopy of cassava resulting in etiolated growth and poor pod setting.

Also, the highest grain yield was reported when chickpea was planted alone as compared to cassava - chickpea. These findings are comparable to an earlier report of Ogola *et al.* (2013) who found that chickpea grain yield was highly reduced in cassava - legume intercrop as

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compared to cassava - cowpea and chickpea sole. The poor chickpea growth in intercropping as compared to sole during the first season probably led to a reduced chickpea grain yield. These results show that chickpea was a poor competitor for growth resources as compared to cowpea in this study. Also, Jandaghi (2005) reported that the highest yield was obtained from chickpea monoculture followed by barley-chickpea intercropping. The lower yield in intercropping could be due to the competition for nutrients, moisture and space (Adeniyani *et al.*, 2007). The partial LER for chickpea was higher (0.51) in sole cropping as compared to intercropping (Table 4.3). The t – test results revealed that there was a significant difference between the grain yield of chickpea sole and chickpea intercrop at same time, 2 weeks and four weeks after cassava in 2014/2015 in Thohoyandou, This suggests that the reduced grain yield at 2 and 4 weeks after cassava was due to the relative planting dates of chickpea not the late planting of chickpea.

Bambara grain yield was significantly affected by the relative planting dates of legumes in 2014/2015 but not in 2015/2016. The highest grain yield was reported when Bambara was planted same time followed by two weeks and four weeks after cassava in 2014/2015 at Mpumalanga. This was probably due to the lesser competition for the growth resources such as light, water and nutrients while cassava was still a weak competitor. Bambara yield components such as number of pods, number of seed, pod weight and 100 seed weight influenced the higher Bambara grain yield when followed the same pattern. Bambara shoot biomass was significantly was significantly affected by the cropping systems in both seasons and number of pods per plant in 2015/2016 but not all other yield and yield components of Bambara groundnut. The highest shoot biomass and number of pods per plant was found in sole bambara as compared to Bambara intercropping. This might be the absence of competition for resources in sole Bambara as compared to cassava - Bambara. The results are in line with the one of Mas - ud *et al.*, (2016) who obtained greater grain yield in sole groundnut as compared to intercropping.

The overall land equivalent ratio was higher under intercropping as compared to the sole cropping in Thohoyandou 2014/2015 **(Table 4.3)**. The results are in line with the report of Mutsaers *et al.*, (1993) who reported that intercropping cassava with legumes such as cowpea could increase land equivalent ratio as compared to pure cassava. Land equivalent ratio was higher when cassava was intercropped with cowpea as compared to cassava - chickpea in both seasons (2014/2015 and 2015/2016) in Thohoyandou. This was probably due to the higher yield

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of cowpea under intercropping as compared to chickpea and Bambara groundnut. Yield advantages resulted from intercropping because the component crops had different durations and growth patterns, hence, made major demands on resources at different times, which led to better temporal use of growth resources (Mbah and Muoneke, 2007). The t- test results showed that there was no significant difference among the yield and yield components of Bambara sole and Bambara intercrop at same time, 2 weeks and 4 weeks after cassava in both seasons in Mpumalanga. This suggest that the decreased yield at 2 weeks and 4 weeks after cassava was probably due to the late planting of Bambara not the relative planting date of Bambara.

5.5 Conclusion

The relative planting dates of legumes and cropping systems increased the overall productivity of the system. Cowpea grain yield was higher under intercropping as compared to mono cropping, however, chickpea and Bambara groundnut grain yield were lower under intercropping as compared to sole cropping. The results of this study shows that legumes should be planted same time with cassava improve the yield of legumes.

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CHAPTER 6:

6. EFFECTS OF RELATIVE PLANTING DATES OF LEGUMES AND CROPPING SYSTEMS ON GROWTH OF CASSAVA

6.1 Introduction

Cassava intercropping is a common practice in Sub- Saharan Africa. Cassava is an important root crop often found in intercropping with other staples (e.g. legumes) for resource poor households providing food and income for over 700 million people in the tropics (FAO, 1999). Grain legumes are beneficial in intercropping with cassava due to their potential effect on growth pattern, canopy development and nutrients demand through their biological nitrogen fixation. Besides the mentioned benefits legumes grown in intercropping sustain the other nutrients through the return and residue breakdown (decomposition). The relative planting time of the component crops is important in intercropping because of the competition for growth resources amongst the mixed crops. Delayed growth of cassava was found in the cassava – groundnut intercrop due to the interspecific competition of resources such as light and nutrients (Nyi *et al.*, 2014).

Planting of a component crop before, simultaneously or later than cassava has both biological and practical implications. The biological implication may be the fact that cassava does not compete much at the early stage of its growth cycle, although it does not tolerate too much competition either (Leihner, 2002). Therefore, to improve the growth of cassava the component crop such as legumes should be planted later than cassava to avoid the interspecific competition for growth resources. The objective of this study was to assess the effect of the relative planting date of legumes on growth of cassava.

6.2 Materials and method

In this chapter only the summary of the materials and methods used for the growth parameters measured for cassava will be explained. For the detailed description refer to chapter 3. The study was conducted at Thohoyandou and Nelspruit in the consecutive growing seasons of 2014/2015 and 2015/2016. The experiment was laid out in a split - plot design, with relative planting dates of legumes (same time, 2 weeks after and 4 weeks after cassava) as the main plots and cropping systems (cassava sole, chickpea sole, cowpea sole, cassava - cowpea and cassava – chickpea) as the subplots. The combination of the main plots and the subplots gave a

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total of 15 treatments. The total area planted was 10m x 6 m (60 m^2) and the spacing for cassava was 1m x 1m spacing. For the legumes the spacing between the plants was 10cm and between the rows was 30cm.There were no fertilizers and irrigation applied in the experiment.

Plant height stem diameter, number of primary and secondary branches was taken on a monthly basis starting from 3 months after planting in the 1st season at Thohoyandou and 5 months after planting in the 2nd season at Thohoyandou until at 10 months after planting. In Mpumalanga growth parameters such as plant height (cm), stem diameter (mm) and primary and secondary branches were only collected in the 2nd season at 3, 5 and 10 months after planting.

6.3 Results

6.3.1 Plant height

The relative planting dates of legumes did not affect cassava plant height in both seasons in Thohoyandou **(Figure 6.1a and b)**. However, the relative planting dates of legumes showed a significant ($P<0.05$ and $P<0.01$) effect on cassava plant height at 5 and 10 months after planting in Mpumalanga 2nd season. The highest plant height in Nelspruit was found when legumes were planted 2 weeks after cassava followed by same time and four weeks after cassava **(Figure 6.1c).** Plant height increases with the months after planting in both seasons and sites.

Cropping systems significantly ($P< 0, 05$) affected cassava plant height at 4 months after planting but not at all other measurement dates at Thohoyandou in 2014/15. The highest plant height was reported when cassava was planted as a sole followed by cassava - cowpea and cassava - chickpea **(Figure 6.2a and b).** Cassava plant height in Mpumalanga 2nd season was not significantly affected by the cropping systems at 5 and 10 months after planting **(Figure 6.2c).**

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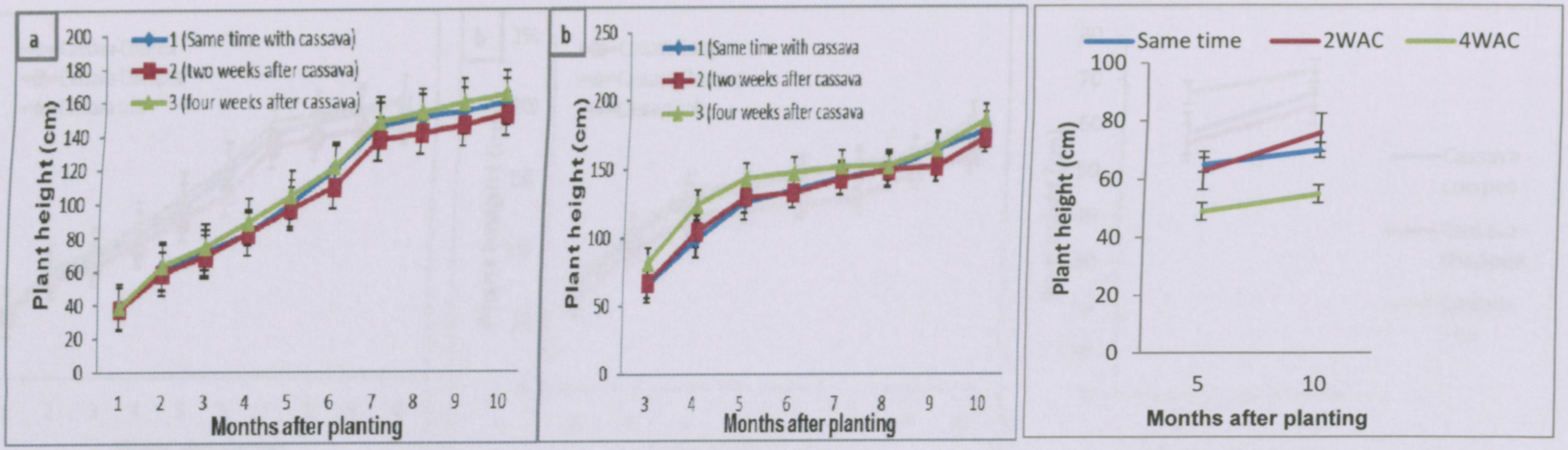


Figure 6.1: Effects of relative planting dates of legumes on cassava plant height in (a) Thohoyandou in 2014/2015 season (b). Thohoyandou 2015/2016 and (c) Nelspruit in 2015/2016 season

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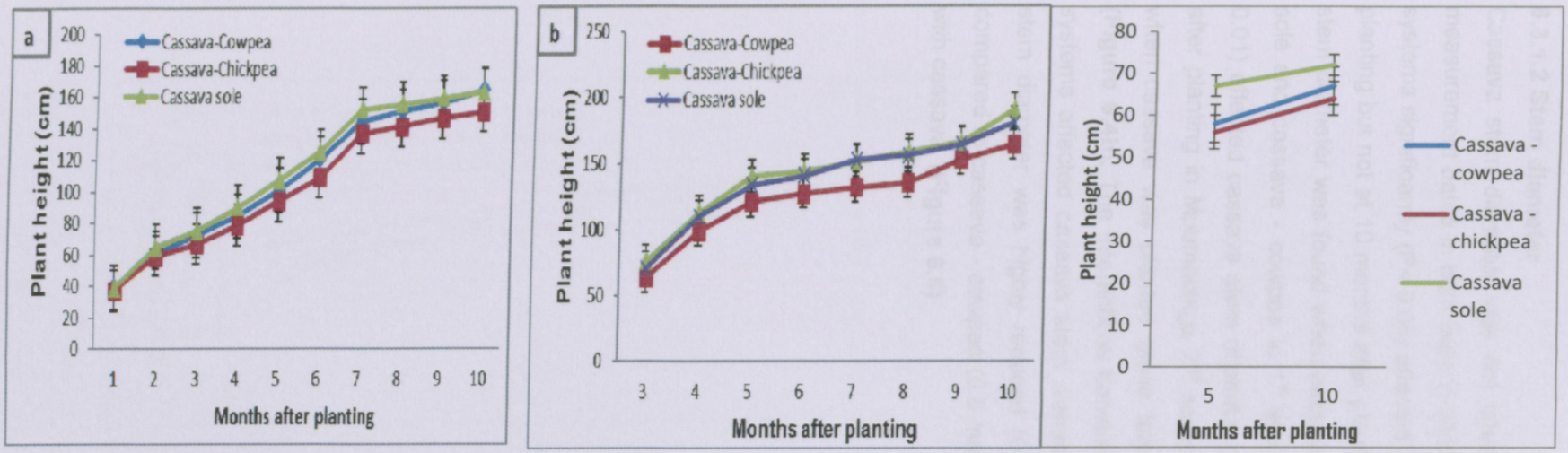


Figure 6.2: Effects of cropping systems on cassava plant height in (a) Thohoyandou 2014/2015 season (b) Thohoyandou 2015/2016 season and (c) Nelspruit in 2015/2016 season

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6.3.1.2 Stem diameter

Cassava stem diameter was not affected by the relative planting dates of legumes at all measurement dates in both sites in 2015/2016 cropping season **(Figure 6.3a and b)**. Cropping systems significantly (P< 0.05) affected cassava stem diameter at 5, 6, 7, 8, and 9 months after planting but not at 10 months after planting in 2015/2016 in Thohoyandou. The largest cassava stem diameter was found when cassava was intercropped with chickpea followed by cassava sole and cassava - cowpea in 1st season **(Figure 6.4a).** Cropping systems significantly (P< 0.01) affected cassava stem diameter at 3 months after planting but not at 5 and 10 months after planting in Mpumalanga 2nd season. The highest cassava stem diameter was observed when cassava was planted alone followed by cassava - cowpea and cassava - Bambara **(Figure 6.4b).** The interactions between the relative planting dates of legumes and cropping systems affected cassava stem diameter in Mpumalanga 2nd season **(Figure 6.5)**. Cassava stem diameter was highly reduced (0.31 mm) when chickpea was planted same time as compared to cassava - cowpea (0.8 mm) stem diameter when cowpea was planted same time with cassava. **(Figure 6.5)**.

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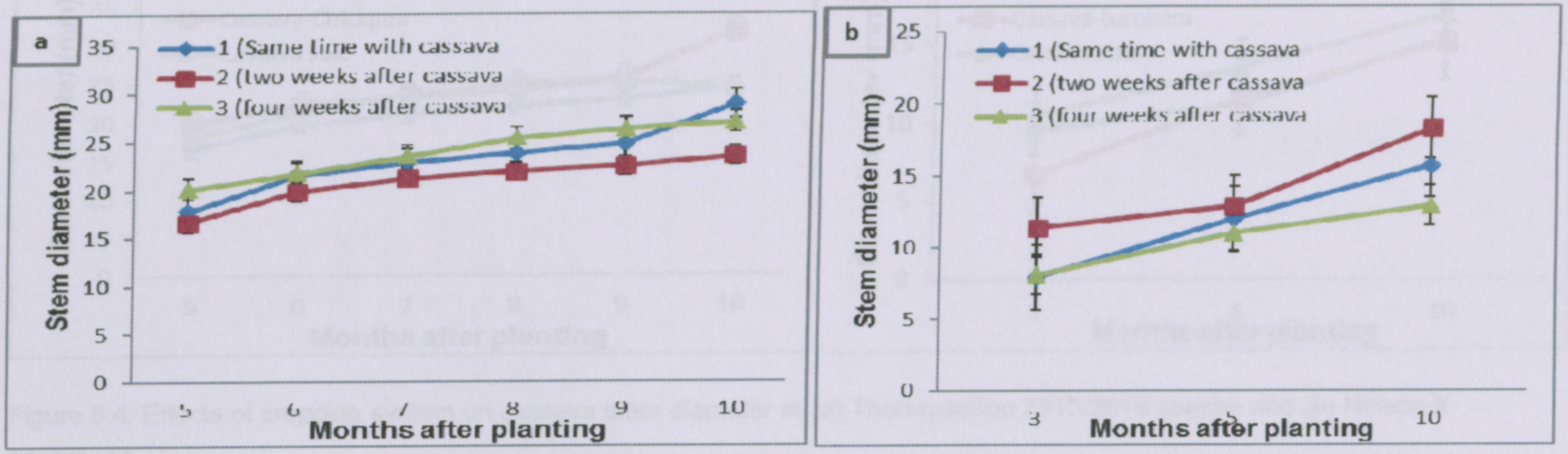


Figure 6.3: Effects of the relative planting dates of legumes on cassava stem diameter at (a) Thohoyandou in 2015/2016 season and (b) Nelspruit in 2015/2016 season.

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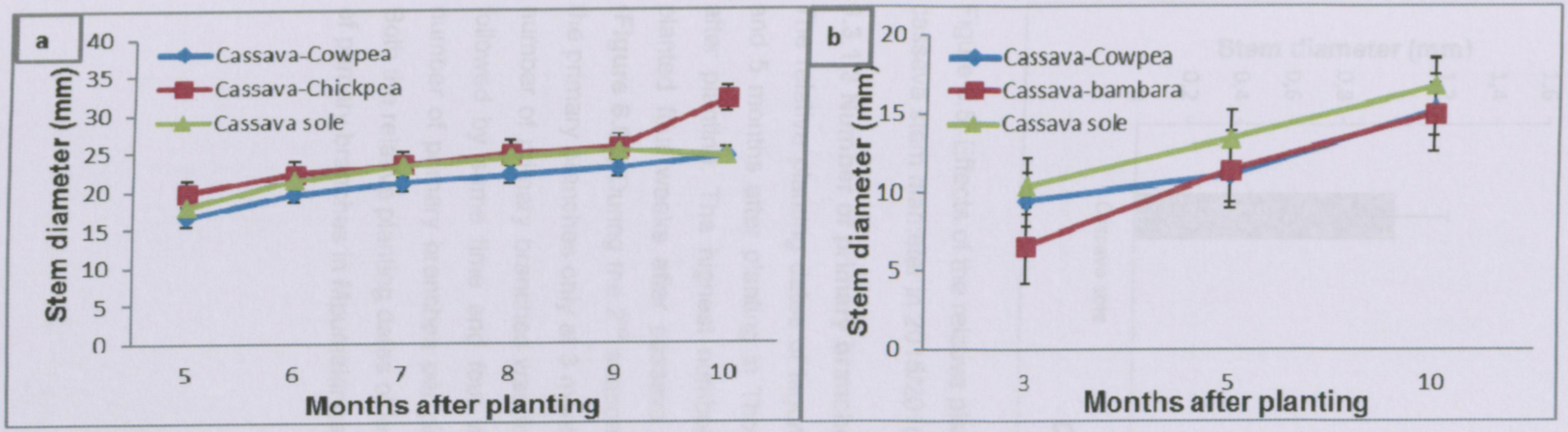


Figure 6.4: Effects of cropping system on cassava stem diameter at (a) Thohoyandou 2015/2016 season and (b) Nelspruit 2015/2016 season

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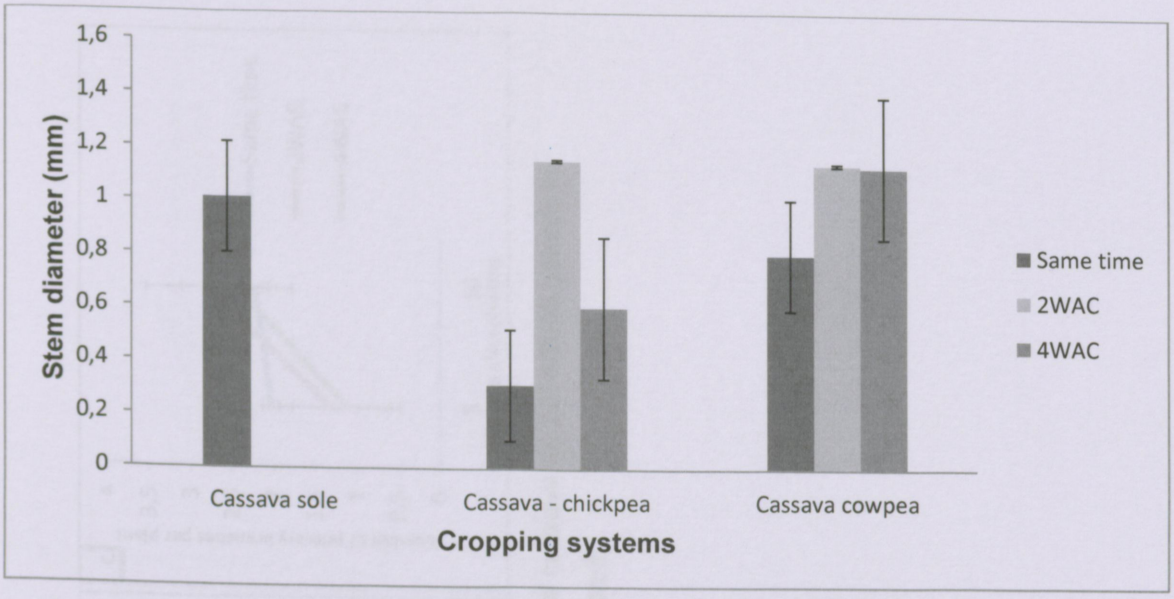


Figure 6.5: Effects of the relative planting dates of legumes and cropping systems interaction on cassava stem diameter in 2015/2016 in Nelspruit

6.3.1.3 Number of primary branches per plant

The relative planting dates of legumes significantly affected number of primary branches at 4 and 5 months after planting in Thohoyandou first season but not at 3,6,7,8,9 and 10 months after planting. The highest number of primary branches were reported when legumes was planted four weeks after cassava followed by 2 weeks after and same time with cassava **(Figure 6.6a)** During the 2nd season the relative planting dates of legumes significantly affected the primary branches only at 3 months after planting in Thohoyandou **(Figure 6.6b).**The highest number of primary branches was found when legumes were planted two weeks after cassava followed by same time and four weeks after cassava. Cropping systems did not affect the number of primary branches per plant in Thohoyandou in both seasons **(Figure 6.7a and b)**. Both the relative planting dates of legumes and cropping systems did not affect cassava number of primary branches in Mpumalanga in 2015/2016 **(Figure 6.6c and 6.7c)**.

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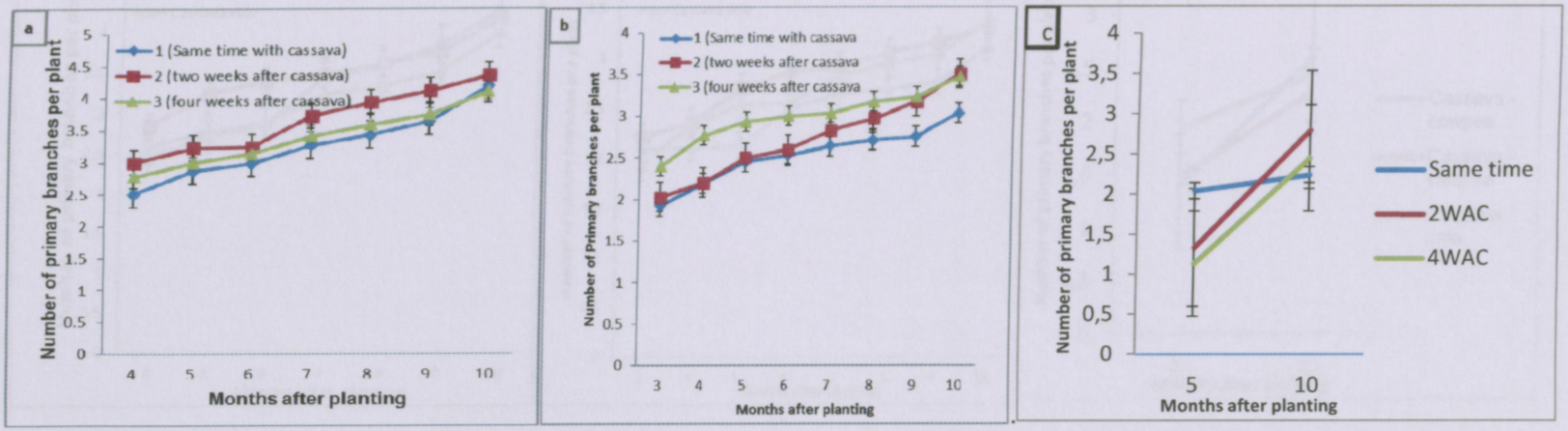


Figure 6.6 Effects of the relative planting dates of legumes on the primary branching of cassava (a) 2014/2015 season in Thohoyandou; (b) 2015/2016 season in Thohoyandou. (c) 2015/2016 season in Nelspruit

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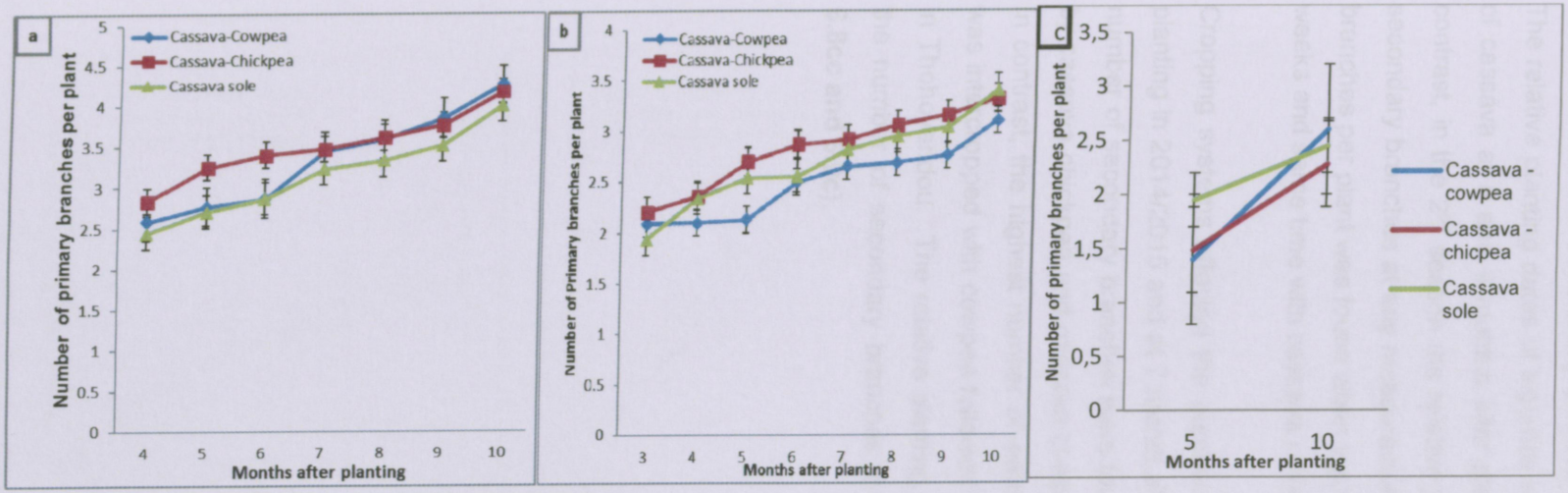


Figure 6.7: Effects of cropping systems on the primary branches of cassava (a) 2014/2015 season in Thohoyandou. (b) 2015/2016 season in Thohoyandou. (c) 2015/2016 season in Nelspruit

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6.3.1.4 Number of secondary branches per plant

The relative planting dates of legumes significantly affected the number of secondary branches of cassava at 8 and 9 months after planting in Thohoyandou in 2014/2015 **(Figure 6.8a)**. In contrast, in the 2nd season the relative planting dates of legumes did not affect the number of secondary branches at any measurement date **(Figure 6.8b).**The highest number of secondary branches per plant was found when legumes were planted 4 weeks after cassava followed by 2 weeks and same time with cassava in the 1st season.

Cropping systems affected the number of secondary branches of cassava at 5 months after planting in 2014/2015 and at 7 month after planting in 2015/2016 in Thohoyandou. The highest number of secondary branches were found when cassava was planted as a sole crop followed by cassava chickpea and cassava cowpea in 2014/2015 in Thohoyandou (**Figure 6.9a and b).** In contrast, the highest number of secondary branches per plant was reported when cassava was intercropped with cowpea followed by cassava sole and cassava – chickpea in 2015/2016 in Thohoyandou. The relative planting dates of legumes and cropping systems did not affect the number of secondary branches in Mpumalanga in 2015/2016 cropping season **(Figure 6.8cc and 6.9c)**.

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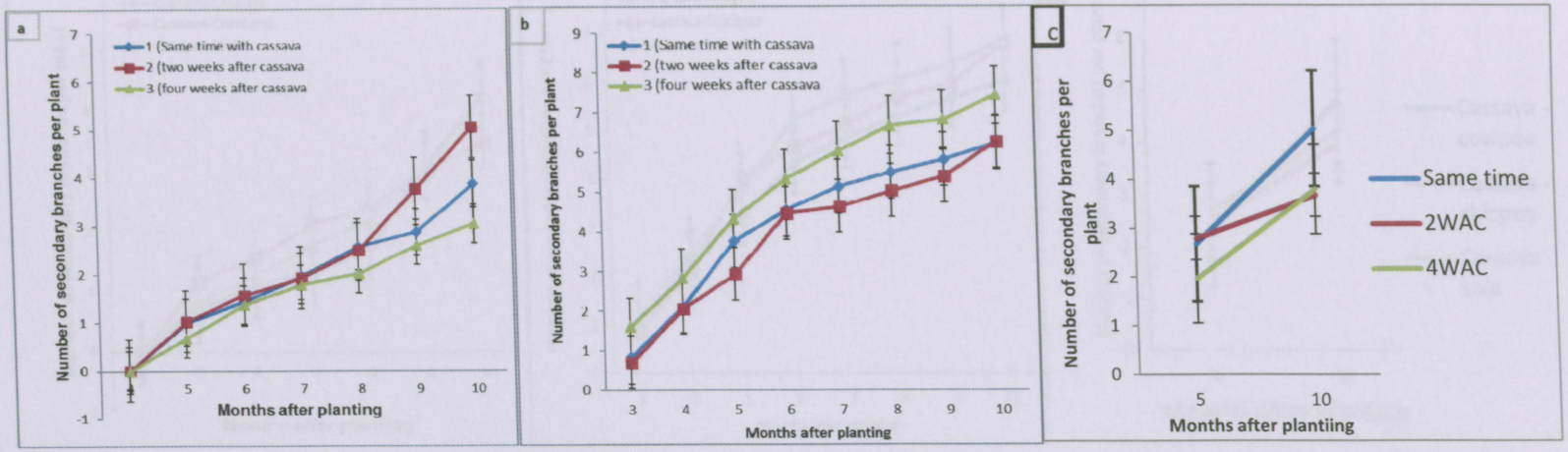


Figure 6.8: Effects of the relative planting dates of legumes on secondary branching of cassava (a) 2014/2015 season in Thohoyandou (b) 2015/2016 season Thohoyandou. (c) 2015/2016 season in Nelspruit.

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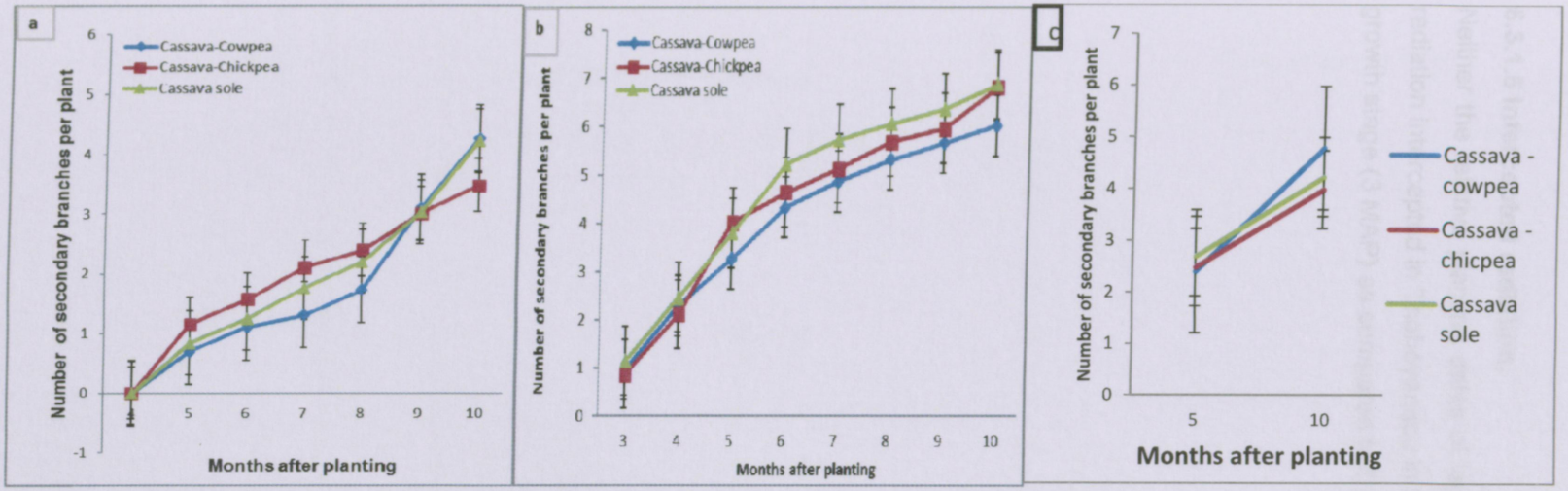


Figure 6.9: Effects of cropping systems on the secondary branches of cassava in (a) 2014/2015 season in Thohoyandou (b) 2015/2016 season in Thohoyandou (c) 2015/2016 season in Nelspruit.

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6.3.1.5 Intercepted radiation.

Neither the relative planting dates of legumes nor cropping systems affected the proportion of radiation intercepted in Thohoyandou in 2015/2016. Cassava intercepted more radiation at early growth stage (3 MAP) as compared to 5 MAP and 10 MAP **(Figure 6.10 and 6.11).**

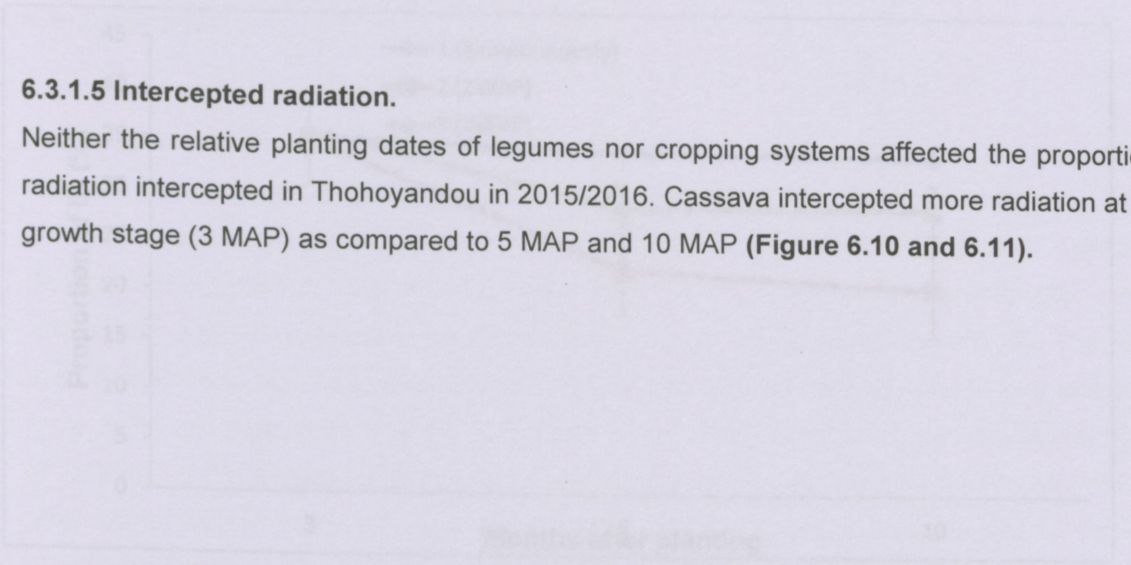


Figure 6.10: Effects of relative planting of legumes on cassava intercepted radiation in 2015/2016 in Thohoyandou

Figure 6.11: Effects of cropping systems on cassava intercepted radiation in 2015/2016 in Thohoyandou

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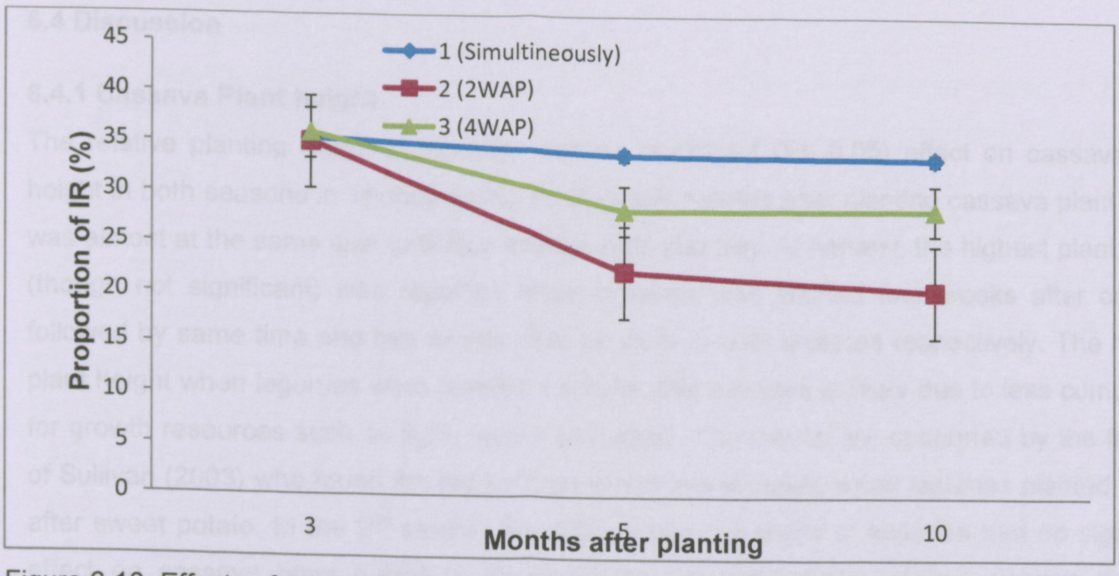


Figure 6.10: Effects of relative planting of legumes on cassava intercepted radiation in 2015/2016 in Thohoyandou

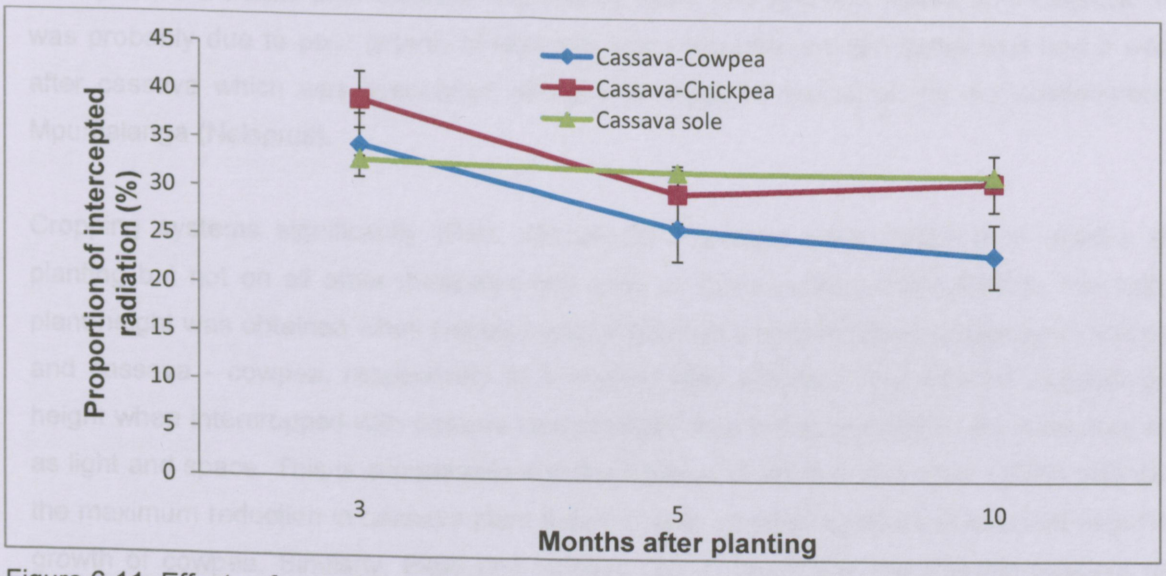


Figure 6.11: Effects of cropping systems on cassava intercepted radiation in 2015/2016 in Thohoyandou

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6.4 Discussion

6.4.1 Cassava Plant height

The relative planting dates of legumes had no significant (P≤ 0.05) effect on cassava plant height in both seasons in Thohoyandou. At the early months after planting cassava plant height was almost at the same size until four months after planting. At harvest, the highest plant height (though not significant) was reported when legumes was planted four weeks after cassava followed by same time and two weeks after cassava in both seasons respectively. The highest plant height when legumes were planted 4 weeks after cassava is likely due to less competition for growth resources such as light, space and water. The results are supported by the findings of Sullivan (2003) who found the reduced growth of sweet potato when legumes planted 9 days after sweet potato. In the 2nd season the relative planting dates of legumes had no significant effect on cassava plant height in Thohoyandou. In contrast the relative planting dates of legumes showed a significant effect on cassava plant height at 5 and 10 months after planting in Mpumalanga 2nd season. The highest plant height in Mpumalanga was found when legumes were planted 2 weeks after cassava followed by same time and four weeks after cassava. This was probably due to poor growth of legumes when legumes planted same time and 2 weeks after cassava which was associated with the shortage of rainfall at the dry environment of Mpumalanga (Nelspruit).

Cropping systems significantly (P≤0, 05) affected cassava plant height at 4 months after planting but not on all other measurements date in Thohoyandou in 2014/2015. The highest plant height was obtained when cassava was planted as a sole followed by cassava - chickpea and cassava - cowpea, respectively at 4 months after planting. The reduced cassava plant height when intercropped with cowpea was probably due to the competition for resources such as light and space. This is comparable with the findings of Ammanullah *et al.* (2007) who found the maximum reduction in cassava plant height due to smothering effect of luxuriant vegetative growth of cowpea. Similarly, Ekpo and Ndaeyo (2011) found that the shortest cassava plant height was obtained from the sole crop compared to intercropping in 2008 and 2009 cropping seasons. Njoku and Mouneke, (2008) and Amanullah *et al.*, (2007) also reported the highest cassava plant height in sole cropping as compared to intercropping in cassava - cowpea intercrop.

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6.4.2 Stem diameter

Cassava stem diameter was not significantly affected by the relative planting dates of legumes at 5, 6, 7, 8, 9 and 10 MAP in 2015/2016 in Thohoyandou. In Mpumalanga 2nd season the relative planting of legumes showed no significant effect on cassava stem diameter at 3, 5 and 10 MAP. The results are comparable with the findings of Nyi *et al.* (2014) who reported that the relative planting dates of groundnut had no significant effect on cassava stem yield in both seasons. Cropping systems significantly ($P< 0.05$) affected cassava stem diameter at 5, 6, 7, 8, and 9 months after planting but not at 10 months after planting in 2015/2016 in Thohoyandou. The largest cassava stem diameter was found when cassava was intercropped with chickpea followed by cassava sole and cassava - cowpea in Thohoyandou. In contrast, Nyi *et al.,* (2014) found that cassava stem yield was not significantly affected by cropping systems. This was probably due to the lesser competition for resources such as light, water and nutrients when cassava was planted as a sole and intercropped with chickpea as compared to cassava - cowpea. Cropping systems significantly ($P< 0.01$) affected cassava stem diameter at 3 months but not at 5 and 10 months after planting after planting in Mpumalanga 2nd season. The highest cassava stem diameter was revealed when cassava was planted alone followed by cassava - cowpea and cassava - Bambara in Mpumalanga 2nd season. The higher stem diameter when cassava was planted as a sole was probably due to the lesser competition for growth resources such as light, water and nutrients as compared to intercropped cassava.

6.4.3 Number of primary branches per plant

The relative planting dates of legumes significantly affected number of primary branches at 4 and 5 months after planting but not at 3, 6,7,8,9 and 10 months after planting in Thohoyandou first season. The highest number of primary branches was reported when legumes were planted four weeks after cassava followed by 2 weeks after and same time with cassava. These may be due to the lesser inter - specific competition of the component crops for growth resources encountered by cassava while it was still a weak competitor. During the 2nd season the relative planting dates of legumes significantly affected the primary branches at 3, 4, 5, 6, 7, 8, 9 and 10 after planting in Thohoyandou. The highest primary branches were found when legumes planted two weeks after cassava followed by same time and four weeks after cassava. The higher number of primary branches at 2 weeks after cassava was probably due to lesser competition for growth resources such as light and nutrients, since there was a growth delay for legumes during the 2nd season. Cropping systems showed no significant difference on number of primary branches per plant in Thohoyandou in both seasons.

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6.4.4 Number of secondary branches per plant

The relative planting dates of legumes significantly affected the number of secondary branches of cassava at 8 and 9 but not at 3, 4, 6, 7 and 10 months after planting in 2014/2015 in Thohoyandou. In 2015/2016 relative planting dates of legumes did not affect number of secondary branches of cassava at all measurement dates. The highest number of secondary branches was found when legumes were planted 4 weeks after cassava followed by 2 weeks and same time with cassava in the 1st season. When legumes was planted 4 weeks after cassava they gave cassava a chance to be well established without competing with legumes for growth resources hence, the greater number of secondary branches was obtained when legumes planted 4 weeks after cassava.

Cropping systems affected the number of secondary branches of cassava at 5 months after planting in Thohoyandou 1st season and at 7 months after planting during the 2nd season. The highest secondary branches were found when cassava was planted as a sole crop followed by cassava chickpea and cassava cowpea at Thohoyandou 1st season. The reduced number of secondary branches in cassava - cowpea could be attributed to the competitive ability of cowpea over cassava as compared to chickpea crop due to larger leaf canopy and greater growth habit (Ogola *et al.*, 2013).

6.4.5 Intercepted radiation

Neither the relative planting dates of legumes nor the cropping systems affected proportion of radiation intercepted by cassava in Thohoyandou 2016. Cassava intercepted more radiation it was planted same time with legumes followed by 4 weeks and 2 weeks respectively. The delay of legumes germination due to shortage of rainfall during the first relative planting date may have contributed to the higher radiation intercepted by cassava when it was planted same time with cassava. This is because cassava was faced to lesser growth resources competition during its early growth stages until it reaches the point where it starch to growth faster with more shoot and larger leaf canopy. Moreover cassava intercepted more radiation when it was planted alone followed by cassava - chickpea and cassava - cowpea. Cassava intercepted more radiation at early growth stage (3 MAP) as compared to 5 MAP and 10 MAP. It has been observed that cassava intercepted less light towards the end of its growth cycle (Hillock and Thresh, 2001). The lesser radiation intercepted by cassava in intercropping was due to the higher competition of the component crops (legumes) for the growth resources (Ogola and Mathews, 2011).

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6.5 Conclusion

The relative planting dates of legume and cropping systems greatly affected growth of cassava. Cassava growth was increased when legumes planted 4 weeks after cassava and it was also greater under sole cropping as compared to intercropping. However, the effect on growth of cassava depends on the type of legumes and the relative planting date of legumes. Therefore the incorporation of legumes at the appropriate relative planting date such as 4 weeks after cassava could enhance the overall growth of cassava in both sites.

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CHAPTER 7:

7 EFFECTS OF RELATIVE PLANTING DATES OF LEGUMES AND CROPPING SYSTEMS ON PLANT HEIGHT OF LEGUMES

7.1 Introduction

The relative planting time of the component crops is important in intercropping because of the competition for growth resources amongst the mixed crops (Jalilian *et al.,* 2017). The architecture and the height of canopy as well as the land utilization and the aerial environment of the plants contribute to the competitiveness and performance of the component crops in intercropping (Mbah and Ogidi (2012). Moreover, the light penetration into the plant is diminished through interception and absorption by leaves and other parts of the shoot systems. Difference in time of planting may relate to different climatic conditions (rainfall, temperature and photoperiod). Intercropping cassava with legumes at different times is practiced to avoid a complete crop failure due to unpredictable rainfall patterns as results of climatic changes.

Legumes intercropping can greatly increase biomass production in intercropping system without necessarily compromising cassava biomass yield (Borin and Frankon - Lindberg, 2005). The objective was to evaluate the relative planting date legumes such as cowpea, chickpea and Bambara ground nuts on the plant height of legumes..

7.2 Materials and method

In this chapter only the summary of the materials and methods used for the growth parameters measured for legumes will be explained. The detailed methodology was discussed in chapter 3. The study was conducted at Thohoyandou (University of Venda) and Nelspruit (University of Mpumalanga) in the consecutive growing seasons 2014/2015 and 2015/2016. The experiment was laid out in a split-plot design, with planting dates (legumes same time with cassava, 2 weeks and 4 weeks after cassava) as the main plots and cropping systems (cassava sole, cowpea sole, chickpea sole, cassava - chickpea and cassava - cowpea) as the subplots. The combination of the main plots and the subplots gave a total of 15 treatments. The total area planted was 10m x 6 m (60 m^2) and the spacing between the rows for legumes was 30 cm and the intra row spacing was 10 cm. The area was cleared free of grass and debris before

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preparing a seedbed. There were no fertilizers and irrigation applied in the experiment, however the crops was irrigated immediately after planting only for a week for germination.

The legumes plant height was taken at 8 and 16 weeks planting in 2014/2015 cropping season and weeks after planting and at 8, 11,12,13 and 16 weeks after planting in 2015/2016 in Thohoyandou. However in Mpumalanga the growth parameters for legumes (Bambara and cowpea) were not measured in both seasons due to logistical reason.

7.3 Results

7.3.1 Cowpea

The relative planting dates of legumes had no significant effect on cowpea plant height in both seasons in Thohoyandou **(Figure 7.1 a and b)**. Cropping systems did not affect cowpea plant height at 8 and 16 weeks after planting in both seasons in Thohoyandou. However cropping systems significantly ($P \leq 0.01$) affected cowpea plant height at 11 weeks after planting (WAP) in 2015/2016. The highest cowpea plant height was obtained in intercropping as compared to cowpea sole in both seasons (**Figure 7.2 a and b).** The interaction of relative planting dates of legumes and cropping systems significantly affected cowpea plant height at 11 weeks after planting (WAP) in Thohoyandou 2nd season; the cowpea plant height was higher in intercropped cowpea as compared to cowpea sole when cowpea was planted same time and 2 weeks after cassava **(Figure 7.3).**

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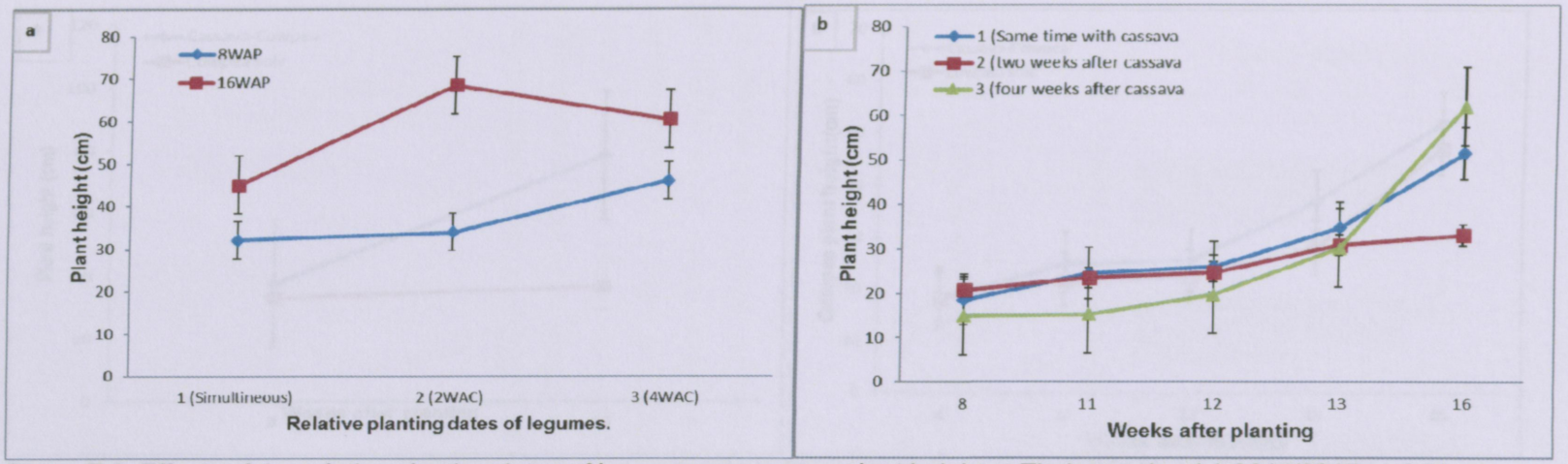


Figure 7.1: Effects of the relative planting dates of legumes on cowpea plant height at Thohoyandou (a) 2014/2015 and (b) 2015/2016 seasons.

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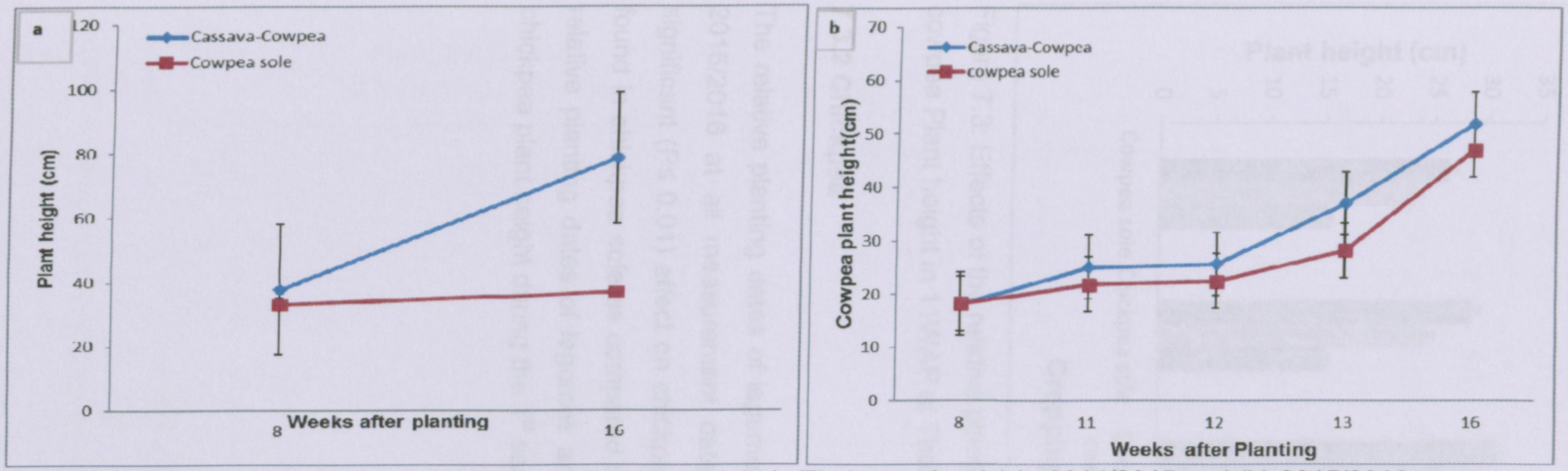


Figure 7.2: Effects of cropping systems on cowpea plant height in Thohoyandou (a) in 2014/2015 and (b) 2015/2016 seasons

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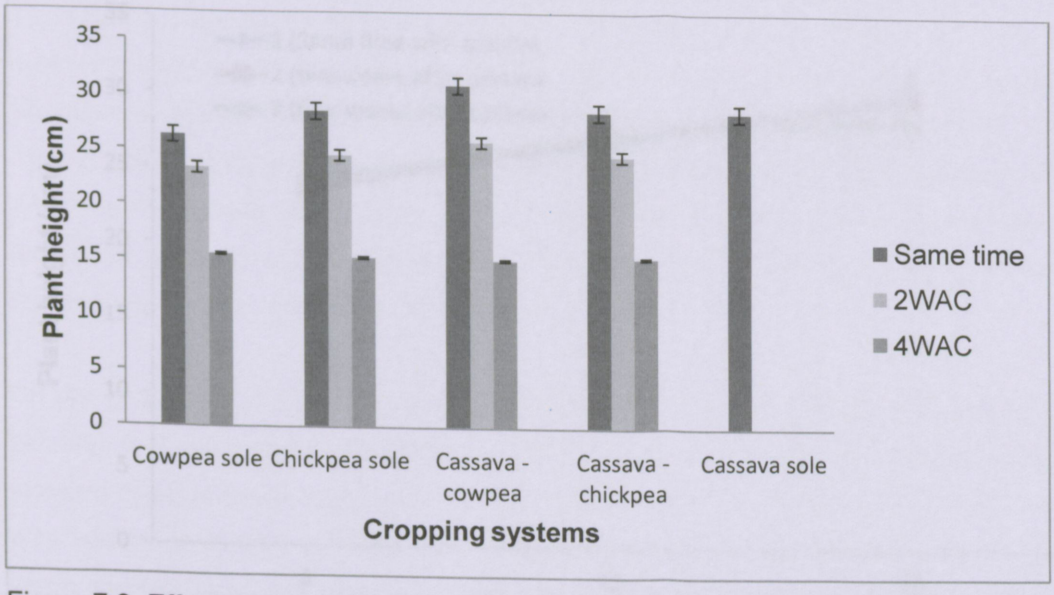


Figure 7.3: Effects of the relative planting dates of legumes and cropping systems interaction on cowpea Plant height in 11WAP at Thohoyandou.

7.3.2 Chickpea

The relative planting dates of legumes did not affect chickpea plant height in Thohoyandou in 2015/2016 at all measurement dates **(Figure 7.4)**. However cropping systems showed a significant (P≤ 0.01) effect on chickpea plant height at 16 WAP. The greater plant height was found in chickpea sole as compared to cassava - chickpea **(Figure 7.5)**. The interaction of the relative planting dates of legumes and cropping systems showed a significant (P ≤ 0.05) on chickpea plant height during the 1st season in Thohoyandou.

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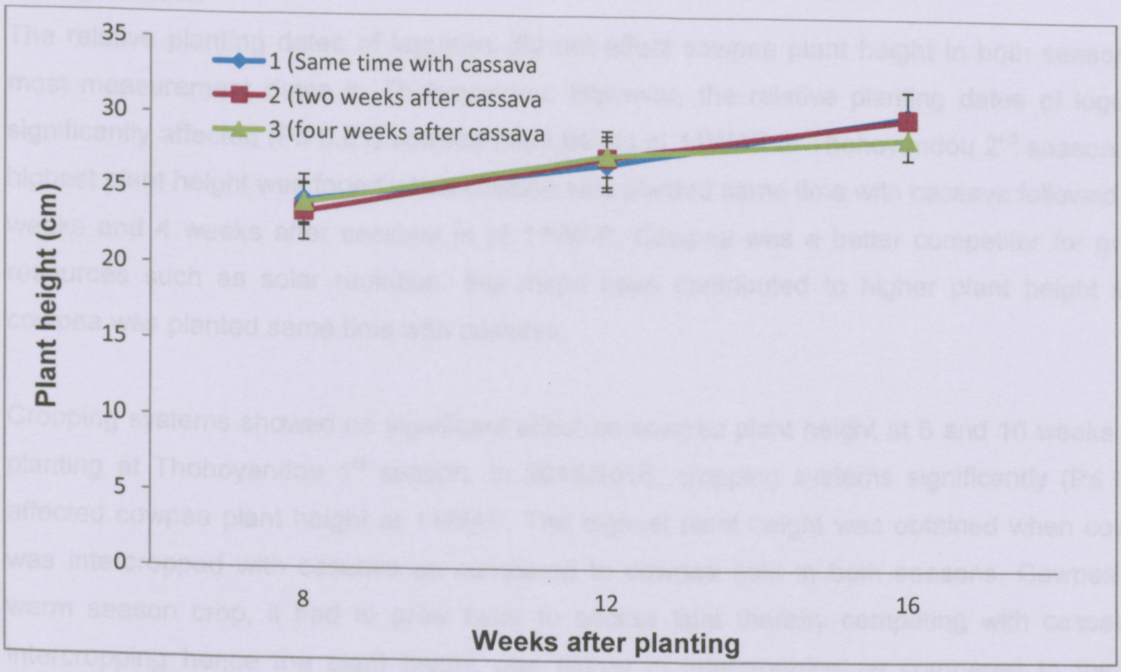


Figure 7.4: Effects of the relative planting dates of legumes on chickpea plant height in 2015/2016 in Thohoyandou.

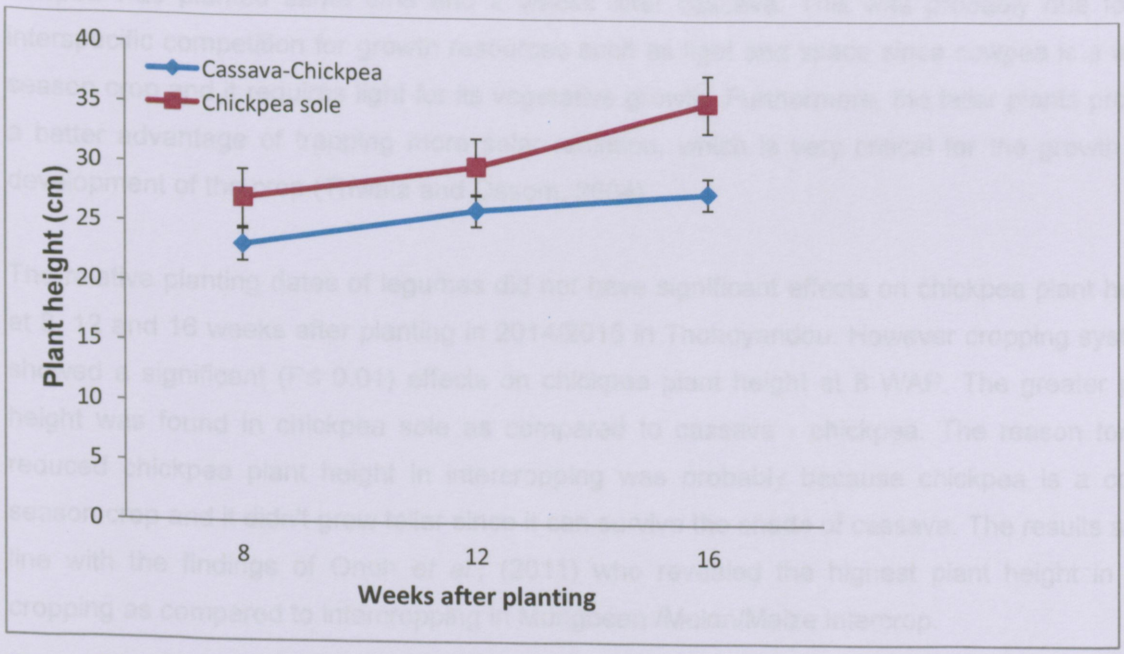


Figure 7.5: Effect of cropping systems on chickpea plant height in 2015/2016 in Thohoyandou.

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7.4 Discussion

The relative planting dates of legumes did not affect cowpea plant height in both seasons at most measurement dates in Thohoyandou. However, the relative planting dates of legumes significantly affected (P≤ 0.01) cowpea plant height at 11WAP in Thohoyandou 2nd season. The highest plant height was found when cowpea was planted same time with cassava followed by 2 weeks and 4 weeks after cassava in at 11WAP. Cowpea was a better competitor for growth resources such as solar radiation, this might have contributed to higher plant height when cowpea was planted same time with cassava.

Cropping systems showed no significant effect on cowpea plant height at 8 and 16 weeks after planting at Thohoyandou 1st season. In 2015/2016, cropping systems significantly (P≤ 0.01) affected cowpea plant height at 11WAP. The highest plant height was obtained when cowpea was intercropped with cassava as compared to cowpea sole in both seasons. Cowpea is a warm season crop, it had to grow taller to access light thereby competing with cassava in intercropping hence the plant height was higher in intercropping as compared to the sole cropping. The interaction of relative planting dates of legumes and cropping systems significantly affected cowpea plant height at 11 weeks after planting (WAP) in Thohoyandou 2nd season. The highest plant height was found in intercropping as compared to sole crop when cowpea was planted same time and 2 weeks after cassava. This was probably due to the interspecific competition for growth resources such as light and space since cowpea is a warm season crop and it requires light for its vegetative growth. Furthermore, the taller plants provide a better advantage of trapping more solar radiation, which is very critical for the growth and development of the crop (Thwala and Ossom, 2004).

The relative planting dates of legumes did not have significant effects on chickpea plant height at 8, 12 and 16 weeks after planting in 2014/2015 in Thohoyandou. However cropping systems showed a significant (P≤ 0.01) effects on chickpea plant height at 8 WAP. The greater plant height was found in chickpea sole as compared to cassava - chickpea. The reason for the reduced chickpea plant height in intercropping was probably because chickpea is a cooler season crop and it didn't grow taller since it can survive the shade of cassava. The results are in line with the findings of Onuh *et al.,* (2011) who revealed the highest plant height in sole cropping as compared to intercropping in Mungbean /Melon/Maize intercrop.

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7.5 Conclusion

The results of this study demonstrate that the relative planting dates of legumes and cropping systems positively affected the legumes plant height in both seasons. The legumes plant height was increased when legumes were planted same time with cassava, especially cowpea. Therefore the incorporation of legumes to the cassava should not be at two weeks of later than two weeks after cassava.

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CHAPTER 8:

8 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

8.1 Summary

8.1.1 Performance of Cassava

Cassava achieved the highest growth, yield and yield components when legumes was planted 4 weeks after cassava in 2014/2015 in Thohoyandou. In 2015/2016 the same parameters were higher when legumes was planted same time with cassava probably due to late germination of the legumes due to water stress. The greater yield was found in sole cropping as compared to intercropping in both seasons and sites. The greater cassava yield and yield components was obtained in Thohoyandou as compared to Nelspruit. This was probably due to different environmental conditions, soil types and Temperatures. The overall results shows that the manipulation of the relative planting dates of legumes and cropping systems have a high potential in improving the productivity of cassava.

8.1.2 Performance of Legumes

Legumes gave greater growth, yield and yield components when they were planted same time with cassava in both sites and seasons. Furthermore the highest growth, yield and yield components was obtained in sole cropping as compared to intercropping in cassava - chickpea, cassava - bambara but not in cassava - cowpea. Cowpea growth, yield and yield components was greater in intercropping as compared to sole cropping in both sites and seasons. This was probably due to competition for light and other growth resources in intercropping as compared to sole cropping.

8.2 Conclusion and recommendations

The relative planting dates of legumes and cropping systems affected the overall productivity of cassava - legume intercrop. However, after the t-test the results of this study suggest that planting date itself played a major role and should be considered in future studies. The problem of changing climate which causes the rainfall shortage shows a need for early planting of legumes at both sites. The results of this study showed the greater LER in cassava - cowpea when compared to other legumes but drastically reduced the yield of cassava. In further studies the optimum relative planting date of incorporating cowpea to cassava without affecting both of

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them negatively should be evaluated. It is also recommended that other cowpea varieties could be used to check their response in intercropping with cassava. Further studies should therefore at least be established earlier at more locations.

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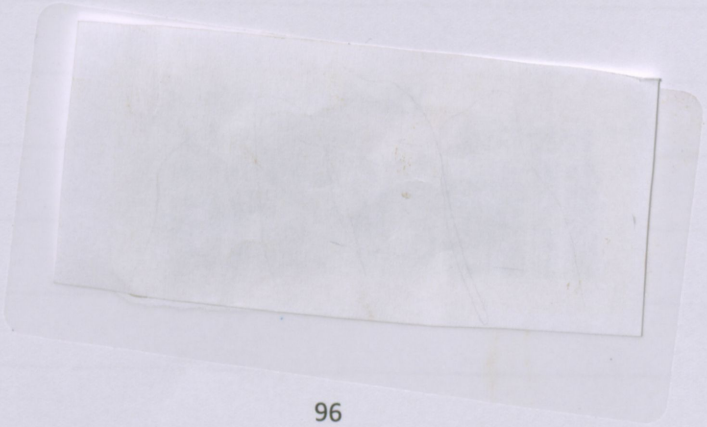
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