

**EFFECTS OF SPATIAL ARRANGEMENT OF MAIZE (*Zea mays* [L.])
INTERCROPPED WITH COMMON BEANS (*Phaseolus vulgaris* [L.]) AND
COWPEAS (*Vigna unguiculata* [L.]) ON GROWTH AND YIELD**

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A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of

MASTER OF SCIENCE

in

CROP SCIENCE

of the

UNIVERSITY OF SWAZILAND

June, 2015

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DECLARATION

I, Bongani Lucky Mvubu, hereby declare that the work described in this Thesis is a result of research I carried out during the period of November 2013/2014 to April 2014/2015 at the Malkerns Research Station, Ministry of Agriculture, Swaziland. It is an original work, except where references are made and will not be submitted for the award of any other University.

Signed _____

Bongani Lucky Mvubu

Date _____

DEDICATION

I affectionately dedicate this thesis work to my beloved family. A special gratitude goes to my loving parents Mr. P.M. Mvubu and Mrs. E.S. Mvubu, who provided financial and moral support for my education. Their words of encouragement always echo in my ears. The work is also dedicated to my friends, colleagues and relatives, for their love and support for my education.

ACKNOWLEDGEMENTS

First and foremost let me take this opportunity to thank the Almighty God for giving me strength and wisdom without which I could be nothing. Special thanks go to the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for the financial support for the work and their generous trust in me. To this organisation I am very grateful and may it grow and expand to all African Agriculture Universities. I also extend my sincere gratitude to the late Professor C.K. Ssekabembe for making the grant available to me, may his soul rest in peace. I also want to pass my sincere thanks to Miss Nodumo Dhlamini (RUFORUM Program Manager) for her love and support, making sure that this piece of work comes to completion.

My thanks go to my supervisors, namely Professor O.T. Edje and Dr. D.M. Earnshaw for their excellent guidance, availability, constructive criticism and valuable suggestions without which this study could not be a success. Their advice and guidance contributed to the production of this piece of work and helped me to overcome all types of doubts. Prof, I thank you.

I am indebted to thank Professor H. Mloza-Banda for his technical assistance while writing up this piece of work. My sincere gratitude also goes to Miss Patricia Carmichael for her technical support while carrying out the study at the Malkerns Research Station. I am also grateful to Professor P.E. Zwane for her support and encouragement to carry on this work till the end. Finally, I thank my colleagues and members of staff of the Crop Production Department for their support and encouragement during the execution of the experiment.

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ABSTRACT

Agriculture faces daunting challenges due to increasing population growth and changing food consumption patterns, natural resource scarcity, environmental degradation, climate change, and global economic restructuring. Therefore, it is necessary to adopt improved and sustainable technologies like intercropping in order to guarantee improvements in food productivity and thereby food security. Although intercropping is often recommended to farmers, specific recommendations regarding time of intercropping and spatial arrangements for additive intercropping systems in Swaziland are scarce. A field experiment was conducted at the Malkerns Research Station, of Swaziland during 2013/2014 and 2014/2015 cropping seasons. The general objective of the study was of the improvement of maize-based cropping systems performance through increased productivity of the land on which maize is grown. The specific objectives were to determine the optimum spatial arrangement of maize for intercropping with beans and cowpeas, also to determine the better leguminous crop species for additive intercropping with maize. Treatments in the experiments included: sole maize, 1 plant/hill: sole maize, 2 plants/hill: sole maize, 3 plants/hill: sole beans: sole cowpeas: maize, 1 plant/hill, + beans: maize, 1 plant/hill, + cowpeas: maize, 2 plants/hill, + beans: maize, 2 plants/hill + cowpeas: maize, opposite, 3 plants/hill, + beans: maize, opposite, 3 plants/hill, + cowpeas: sole maize, staggered, 3 plants/hill: maize, staggered, 3 plants/hill, + beans and maize, staggered, 3 plants/hill, + cowpeas. The design of the experiment was a randomised complete block design and treatments were replicated five times within two crop growing seasons. Data collected were on soil test results, meteorological data, data on maize, beans and cowpeas were on morphological, physiological, yield and yield components. Results showed that seed yield in maize was significantly higher (8,435 kg/ha) as a sole crop, and there was a significant difference ($P < 0.01$) in yield between seasons and among treatments. 2013/2014 cropping season had a higher yield of (7,873 kg/ha) compared to 2014/2015 having a yield of (7,695 kg/ha). Maize, 3 plants/hill showed to be the best optimum spatial arrangement for intercropping with beans and cowpeas in terms of growth and seed yield. Beans additively intercropped with maize were observed to be the best leguminous crop species in terms of yield for additive intercropping with maize. Maize, opposite, 3 plants/hill proved to be the desirable maize planting pattern that use resources efficient and results to higher growth rate and seed yield. In all the cropping systems, the land equivalent ratio value was greater than 1.0, indicating that intercropping was more advantageous than sole cropping system. Based on the findings of this study, it is recommended that maize farmers grow maize in association with beans (maize, opposite, 3 plants/hill) in order to obtain higher yields thus improve food production and sustainable crop production adapting to climate change in Swaziland.

Keywords: Additive intercropping, spatial arrangement, staggered planting pattern, sustainable agriculture.

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CHAPTER 1

1.0 INTRODUCTION

1.1 Background and information

Agriculture faces daunting challenges due to increasing population growth and changing food consumption patterns, natural resource scarcity, environmental degradation, climate change and global economic restructuring (National Academic Press, 2010). Agriculture has to address simultaneously three intertwined challenges that are ensuring food security through increased productivity and income, adapting to climate and also contributing to climate change mitigation (FAO, 2010; Foresight, 2011; Beddington *et al.*, 2012). Natural resource scarcity is becoming a major problem in agricultural production for example; the per capita availability of agricultural land in India was 0.5 hectares in 1951 which decreased to 0.15 hectares in 2000 as against the global average of 0.6 hectares (Venkateswarlu, 2012). At the same time, there are unprecedented hopeful changes and opportunities for the future, including a remarkable emergence of innovations in farming practices, systems and technological advances that have generated promising results for improving agricultural sustainability (National Academic Press, 2010).

Self-sustaining, low-input and energy-efficient agricultural systems such as intercropping in the context of sustainable agriculture has always attracted many farmers, researchers and policy makers around the world (Altieri, 1999). Sustainable agriculture is the practice that involves the successful management of agricultural resources to satisfy human needs, while maintaining or enhancing the quality of the environment and conserving natural resources (FAO, 2012). Very recently, there has been a rapidly growing interest in intercropping as a potentially beneficial system of crop production. Growing interest in more sustainable farming has led to increased attention being focused on these complex farming systems, at research level, although many of the practical aspects of introducing intercrops into existing farming system still require investigation (Anil *et al.*, 1998). The reasons for this renewed interest include: possible financial and marketing benefits associated with the utilization of home grown crops, growth complementarity that is reducing the need for input factors such as fertilisers and

pesticides. Another reason for increased interest in cropping systems was the criticisms raised about monocultural cropping systems and the advent of technology capable of drilling and harvesting intercrops more effectively (Anil *et al.*, 1998). Sustainable agriculture is a type of agriculture that is more efficient in use of resources, for the benefit of human and is in balance with the environment (Scherr and McNeely, 2008). Restoring on-farm biodiversity through diversified farming system that mimic nature is considered to be a key strategy for sustainable agriculture (Jackson *et al.*, 2007). Modern agriculture has brought vast increase in productivity to the world's farming systems but it is recognised that much of this may have come at the price of sustainability (Lichfouse *et al.*, 2009). According to Vandermeer *et al.*, (1998), modern farming systems imply the simplification of the structure of the environment over vast areas, replacing natural plant diversity with only a limited number of cultivated plants in extensive areas of arable monocultures. On-farm biodiversity is familiar to traditional farmers particularly in developing countries where traditional farming systems are characterized by their great degree of genetic diversity in the form of mixed cropping and agroforestry patterns, based on numerous varieties of domesticated crop species as well as their wild relatives (Altieri, 1999).

These farming systems offer a means of promoting diversity of diet and income, stability of production, reduced insect and disease incidence, efficient use of labour, intensification of production with limited resources and also maximisation of returns under low levels of technology (Anil *et al.*, 1998; Malezieux *et al.*, 2009). The concept of intercropping comes in as it is also referred to as mixed cropping or polyculture which is the agricultural practice of cultivating two or more crops at the same time in the same piece of land and is an ancient practice still used in much of the developing world (Machado, 2009). In Africa, maize (*Zea mays* L.), sorghum (*Sorghum bicolor* L.), millet (*Penicum* and *Pennisetum* spp.) are grown with pumpkin (*Cucurbita* spp.), cowpeas (*Vigna unguiculata* L.) pigeon peas (*Cajanus cajan* L.) and beans (*Phaseolus* spp.) (Machado, 2009). In an intercropping system, there is normally one main crop and one or more added crop(s), with the main crop being of primary importance for economic or food production reasons. Intercropping increases diversity directly (planned) and indirectly (associated), thereby increasing system complexity an aspect that has been argued to increase ecosystem functioning and resilience (Ehrlich, 1988). Differences in the response of intercrops to climate, soil condition, and diseases have been argued to increase yield stability

(Altieri, 1999) and the complementarity between species may give rise to a more efficient use of available resources and has been argued to keep nutrient cycles more closed (Hauggaard-Nielsen, 2001). Intercropping was thought to be a backward farming system as machines were developed during the green revolution for various single cash crops making intercropping impractical (Machado, 2009). These new modern farming methods were spread to parts of the developing world as high yielding varieties were developed and fertilised to bring about the green revolution that could feed the rapid growing population (Machado, 2009).

In the United States, corn yield increased from 1.9 kg/ha in the 1940s to 9.7 kg/ha in 2008 (Machado, 2009). Intercropping of corn, beans and squash in Mesoamerica is a well-known cropping system where higher yields in the mixture come about due to a complex of interactions among components of the agro-ecosystems (Amador and Gliessman, 1990). Example of such interactions range from the increase presence of beneficial insects due to attractive microclimates and a greater abundance of pollen and nectar sources (Letourneau, 1986), to biologically fixed nitrogen being made available to corn through mycorrhizal fungi connections with roots of beans (Bethlenfalvay *et al.*, 1991). In this study, the interaction effects of site, weather, cropping system, optimum plant arrangements for maize and the different intercropping mixtures were evaluated and they depended upon the relative growth characteristics of the component species and the mechanism of yield improvement. This study was therefore undertaken to determine the feasibility of additive intercropping maize with legumes, with a view of maintaining maize productivity and increasing land productivity.

1.2 Statement of the problem

Maize (*Zea mays* L.) is the third most important cereal crop in the world after wheat and rice and is an important dual purpose crop used in human diet and animal feed (Verheye, 2009). In sub-Saharan Africa, and the Southern Africa, maize is a staple food for an estimated 60 percent of the population and is an important source of carbohydrate, protein, iron, vitamin B and minerals (IITA, 2009). To date, most intercrop studies have focused on issues of yield, economy and food values of crops, basing conclusions on measures of final yield (Connolly *et al.*, 2001). Many of these studies have shown that intercrops may in fact yield more than the average sole crop, be economically sustainable and produce products of superior quality

(Andersen, 2005). Little emphasis has been laid on the understanding of how these benefits accrue over the course of growth, from establishment through the phases of competitive interaction could lead to manipulate intercropping system for greater benefits, whether in terms of crop yield, resource use efficiency, economic benefit or stability (Andersen, 2004). Intercropping is often recommended to farmers, but no specific recommendations regarding time of interplanting and spatial arrangement for additive intercropping systems that the extension staff can take to the farmers (Yiwombe, 1989). This indicates a need for evaluation of these aspects in all crop mixtures. In additive intercropping the main crop population remains unchanged while the intercrop population is incorporated within the main crop. There seems to be little studies on additive mixtures based on maize spatial arrangement, hence a research gap. Some leguminous crops like beans tolerate partial shade and this may also improve their quality but it is not clearly known how much shade different leguminous crops can tolerate when grown in mixture with maize, hence a research gap. Both plant population and spatial arrangement influence the performance of crop mixtures and the effect seems to vary with type of intercrops hence the importance of studying these factors in all these mixtures (Natarajan *et al.*, 1990; Rubaihayo *et al.*, 2003).

1.3 Objectives

1.3.1 General objectives

The general objective of the study was on the improvement of maize-based cropping systems through increased productivity of the land on which maize is grown. Additive intercropping with leguminous crops such as beans and cowpeas is suggested to be one relatively cheap way of doing it.

1.3.2 Specific objectives

The specific objectives are to:

- i. Determine the optimum spatial arrangement of maize for intercropping with beans and cowpeas in terms of seed yield.
- ii. Determine the better leguminous crop species in terms of yield for additive intercropping with maize.
- iii. Identify the desirable maize planting pattern that will use resources efficient and results to higher growth rate and seed yield.

- iv. Determine the optimum population of maize to introduce into legumes in an additive manner.

1.4 Hypothesis

The above objectives were assessed by considering the following hypotheses:

- i. There is an optimum spatial arrangement for maize that will yield significantly ($P < 0.05$) higher and favour beans growth than cowpeas.
- ii. Beans will yield significantly ($P < 0.05$) higher than cowpeas when additively intercropped with maize.
- iii. Maize seed yield will be significantly ($P < 0.05$) higher when maize grown in an opposite pattern than staggering.
- iv. Maize planted in three seeds per planting hill will yield significantly ($P < 0.05$) higher than one or two seeds per hill.

1.5 Significance of the study

Maize is an important food crop throughout eastern and southern Africa and cropping systems that could improve productivity of land on which it is grown are needed. Most research effort done on maize in Swaziland has focused mainly on breeding for biotic and abiotic stress tolerance and improvement in yield (Magagula et al., 1981). There has been inadequate research on the agronomic aspects. The proposed mixture will not only improve land productivity but also diversify the diet and enhance the nutrition of the maize growers in Swaziland. Given the largely starch nature of maize, leguminous crops that are rich in proteins, minerals and vitamins, can improve the diet of all farmers and this is desirable or even required. Economic analysis of the proposed mixtures could reflect a change in the economics of growing maize since the leguminous crops often fetch a higher unit price, depending on time of the season. Since the effect of spatial arrangement on the performance of intercrops varies with different types of intercrops it is imperative that each novel intercropping system be assessed to determine the contribution of this factor to its productivity.

CHAPTER 2

2.0 LITERATURE REVIEW

The current experimental approach for yield improvement in intercropping maize with leguminous crops includes the study of the effects of spatial arrangement of maize (*Zea mays* L.) intercropped with common beans (*Phaseolus vulgaris* L.) and cowpeas (*Vigna unguiculata* L.) on growth and yield. The research information pertaining to maize legumes intercropping systems has been reviewed in this chapter.

2.1 General aspects of intercropping systems

Intercropping is a common feature in traditional farming in many parts of the world, especially among small-scale farmers of tropical Africa and Asia (Ibeawuchi, 2007). According to Adigbo *et al.*, (2013), intercropping describes the forms of cropping systems where total production is achieved through growing two or more crops simultaneously on the same piece of land, such that the growth of some or all the component crops overlap either in space or time and it offers farmers the opportunities to engage nature's principle of diversity on their farms. The rationale behind intercropping is that the different crops planted are unlikely to share the same insect pests and disease causing pathogens, and to conserve the soil (Markevica *et al.*, 2014). It is the practical application of ecological principles such as diversity, crop interaction and other natural regulation mechanisms (Kisetu *et al.*, 2014).

Intercropping has many advantages mainly related to the complementary use of environmental resources by the component crops which results in increased and more stable yields, better nutrient recycling in the soil, better control of weeds, pests and diseases and an increased biodiversity (Malezieux *et al.*, 2009). Cereals and legumes, both for forage and for grain are the most common intercrops. In most parts of Uganda, Malawi and the tropics in general, maize is often intercropped with legumes such as beans, soybeans, pigeon pea or groundnuts and other crops such as banana (Mula and Saxena, 2010). For instance, in Malawi, 77% of the grain legumes are intercropped with maize (Mula and Saxena, 2010). Maize is also intercropped with cassava (*Manihot esculenta*) and pumpkins (*Cucurbita pepo*) in order to maximise land use and to add diversity to the diet. The maize + bean mixture is a predominant cropping system in

most part of Africa and the yield of beans is often reduced considerably when intercropped with a high density of maize (Lithourgidis *et al.*, 2011). In Colombia and other parts of the Andean region of South America, farmers often plant climbing beans and maize in clumps of two to four plants of each crop growing together simultaneously (Piergiovanni and Lucia, 2010) and more than one third of bean production in this region is relay intercropped with maize. Maize is planted first and given enough time to grow alone as it has a long growth period, thus after five months, before it reaches physiological maturity, climbing beans are relay planted in the standing maize (Piergiovanni and Lucia, 2010). Swaziland has two types of land acquisition and ownership, namely modern and traditional land tenure systems. The area in which the traditional land tenure system operates is called the Swazi Nation Land and it covers 56% of the rural land. Agricultural practices in this area are pervasively subsistent in character. It has been estimated that 42.8% of the fields in the Swazi Nation Land are intercropped. Maize is normally the dominant crop here and it is grown intercropped with other cereals, legumes, cucurbits, and other crops (Magagula *et al.*, 1981).

In Nigeria, intercropping maize with cowpea, the most popular legume in the country, is often practised (Alhaji, 1998). In this mixture, due to intercropping, cowpea yield is reduced by about 19% but that of maize may not be reduced and the overall yield advantage of the mixture may be about 48% (Elemo and Olufajo, 1991). In Zimbabwe, the maize and cowpea intercropping system exhibited a higher potential for suppressing *Striga asitica* emergence compared to intercropping with beans or groundnuts especially during the dry seasons (Jewell *et al.*, 1994). In Kenya, both maize and beans are commonly sown in the same hill or the beans are planted between the rows of maize and in this system, competition for moisture, nutrients and light often leads to very low bean yields, often below 250 kg/ha (Nair, 1993).

Sole maize with 90 cm spacing produced 1.57% more number of cobs/plant, 3.74% more number of grains/cob and 1.42% less barren stalk as compared to maize with 60 cm spacing, while maize in association with legumes increased 1.57% to 9.30% cobs/plant and 0.51% to 4.04% grains/cob and decreased barren stalk percentage as much as 3.82% (Kheroar and Patra, 2013). In order to improve the maize + bean intercropping Management of Beneficial Interaction for Legume Intercrops (MBILI), the MBILI system was developed (Mucheru-Muna *et al.*, 2009). It is aimed at improving the yield of beans or other legumes such as cowpeas,

soybeans and groundnuts intercropped with maize. The MBILI system allows more light penetration for the under storey legume component, without changing the plant densities (Tungani *et al.*, 2002). It overcomes the reduction in plant population of some of the intercrops in intercropping systems that farmers often do, by manipulating row arrangement and application of deficient nitrogen and phosphorus in a way that results in higher yields for both intercrops compared to the pure stand

2.2 Crop arrangement in intercropping

Crop arrangement refers to the way the crops are sown in the field. Several methods of intercropping have been a central feature of many tropical agricultural systems for countries. Mixed intercropping involves complete association between crops planted at the same time, while relay cropping involves only partial association in which a second crop is planted into an already standing crop before harvested (Kalisa, 2007). The main advantage of intercropping resides in the reduction of the risk of total crop failure and product diversification, food crops are often planted with cash crop ensuring both subsistence and income for farmers (Graves *et al.*, 2004). Beets (1982) proposed that intercropping can be divided into various cropping arrangements being: mixed cropping, strip, row intercropping, multistoried intercropping and relay intercropping depending on the extent of physical association between the crops.

2.2.1 Strip intercropping

This is the growing of two or more crops in strips wide enough to permit separate crop production using machines but close enough for the crops to interact (Grossman *et al.*, 1982).

2.2.2 Row Intercropping

This is the growing of two or more crops at the same time with at least one crop planted in a well-defined row. Row intercropping is raised by way of additive and replacement series such as sorghum + cowpeas.

i) Additive series: Base crop is raised in full population and in between the rows of the base crop, intercrops are raised at less population level by adjusting or changing crop geometry of the base crop (Chandrasekaran *et al.*, 2010).

ii) Replacement series: By sacrificing certain proportion of population of one component crop, another component crop is introduced, for example, sorghum + cowpea at 2:1 ratio.

2.2.3 Mixed intercropping

Growing two or more crops together in no distinct row arrangement (Rana and Rana 2011).

2.2.4 Relay intercropping

It is the growing of the succeeding crop when the previous crop is at its maturity stage or sowing of the next crop immediately after the harvest of the standing crops. (Chandrasekaran *et al.*, 2010). The planting of succeeding crop may be done before or after flowering, before or after the attainment of reproductive stage before completion of active life cycle that is during senescence of leaves or attainment of physiological maturity of the crop (Chandrasekaran *et al.*, 2010). The relay cropping is primarily done with the objectives (i) to gain time for multiple cropping, (ii) to plant the subsequent crops at their optimum planting date when the current crop harvest is delayed, (iii) to avoid moisture stress in the post-rainy season, and (iv) to avoid labour peaks at the harvest of the first crop and planting of the second crop (Chandrasekaran *et al.*, 2010).

2.2.5 Multistoried intercropping

Growing of two or more crops having different growth habit for example differential rooting pattern and above ground architecture, simultaneously in a piece of land. Multi-level cropping is a system of growing crops of different heights together at the same time on the same piece of land and thus, using land, water and space most efficiently and economically (Chandrasekaran *et al.*, 2010). It is aimed at maximum production per unit area per unit time wherein economic yields of compatible crop species are harvested from different heights. The basement floor is the same for all species and crop yielding floors are increased for more production (Chandrasekaran *et al.*, 2010).

2.3 Importance of intercropping

The demand for food is increasing day by day due to population pressure and practically there is no space of bringing new area under cultivation (FAO, 2012). Therefore, it is becoming necessary to increase the production of food grain by adopting intensive cropping system or by increasing the production per unit area (Fan *et al.*, 2011). Intercropping is an agronomic refinement of the old practice of crop mixtures that in this new system the components, usually two are sown in separate rows, their population ratios are known and can be harvested singly and produce recorded separately (Kumar *et al.*, 2012). Scientific interest in intercropping has developed recently as means of making full use of the entire growing season and optimizing the utilization of environmental resources and thus increasing the total crop production per unit area of land (Place and Meybeck, 2013). Generally, the farmers grow the food grain crops as the main crop and pulses or oilseed as minor crops in the mixture. The food grain crop like sorghum and pearl millet being C₄ plants possess an inherent higher yield potential than legume or pulses (Kumar *et al.*, 2012).

But the present market rates of pulses are two to four times higher than the most of the cereals crop (Kumar *et al.*, 2012). So if a farmer goes with an intercropping practice, he can get additional income from his land and he can boost his family income. Our soil health is deteriorated day by day due to intensive agriculture and food production has received a static position (Maity and Tripathy, 2004). So to improve the soil health and to reduce the use of inorganic fertiliser, a farmer can move toward intercropping practice by adopting a pulse crop as an intercrop (Kerr *et al.*, 2007), as pulses have the capacity to fix atmospheric nitrogen by their symbiotic relationship.

To meet the protein demand of the nation intercropping with pulses is the one of the best option because pulses form an essential component of the vegetarian diet (Kumar *et al.*, 2012). The intake of protein from various foods indicated that out of 53 g protein per day 36 g comes from cereals, 10 g from animal sources and only 7 g from pulses (Kumar *et al.*, 2012). The pulse contribution has shrunk over the last quarter of the century. There is a vast challenge to choose suitable intercrop to get maximum benefit so that a farmer can build up his family to be economically and socially (Kumar *et al.*, 2012). Thus, it is becoming essential to conduct

advanced research and obtain new technologies for improving food security, increasing family income, and better environment for the next crop so that they can be grown successfully.

2.4 Advantages of legume intercropping systems

Cereal-legume intercropping plays an important role in food production worldwide. Interest in multiple cropping and diversification in agro-ecosystems has increased over the last decades (Trenbath, 1993). Intercropping systems that involve cereal-legume are important where traditional farming systems prevail in the tropics (Davis *et al.*, 1986). Some of the benefits for this cropping system are discussed below:

2.4.1. Promotion of biodiversity and stability

Biodiversity is the variability among living organisms both within and between species and also within and between various ecosystems (Ssekabembe, 2010). In general, it encompasses the number of and frequency and variability of all living organisms and the ecosystems in which they occur on the earth (Stocking, 2003). Intercropping is a way to increase the biodiversity of the farming system. More diversity in the farming system means more stability, resulting in risk spreading and reduced pest and disease incidence. The diversity of living organisms in the soil enriches the activities in the soil responsible for maintaining soil fertility and increasing crop productivity (Hillel and Rosenzweig, 2005). The myriad of microbes in the soil help to decompose crop residues as well as xenobiotic toxic materials, converting some of them into nutrients utilisable in crop cultivation and enhancement of soil physical conditions (Hillel and Rosenzweig, 2005). A high diversity of plants also supports a higher diversity of pollinators (Hillel and Rosenzweig, 2005).

2.4.2. Increasing production and higher yield per unit land area

Higher yield in terms of total biomass and grain production per unit area in a given season without the use of costly inputs under intercropping system is attributed to better use of growth resources namely, light, nutrients and moisture (Sivakumar and Virmani, 1980). Ghanbari and Lee, (2002) reported that dry matter production in wheat and beans intercrops had been more than pure cropping. Odhiambo and Ariga, (2001) working with maize and beans intercrop in different ratios found that production increased due to reduced competition between species

compared competition within species. Intercropping has a role in improvement of farm incomes. For instance, in Kenya, coffee is stumped to 20-30 cm height, it is intercropped with a variety of crops that increase biodiversity thus the intercrops reduces loss of income while waiting for the coffee shoots to regrow (Ssekabembe, 2010). Intercropping enables farmers to be able to cope with price variability and sometimes, the market price may be more favourable for one crop in a particular season than for others (Glucroft *et al.*, 2012). Farmers may be able to benefit from good prices and may suffer less due to poor prices for particular crops if they grow several types of crops.

2.4.3 Improvement of soil fertility and increase in nitrogen

An important reason for intercropping is on the improvement and maintenance of soil fertility. This is reached when a cereal crop (such as maize or sorghum) or a tuber crop (like cassava) is grown in association with pulses (bean, peas). Rhizobium bacteria are able to have a symbiotic relationship with plants of leguminosea family, and thereby can fix atmospheric nitrogen and hence make it available for plants uptake (Eskandari *et al.*, 2009). Deep rooted pulses like pigeon pea, also take up nutrients from deeper soil layers, there by recycling nutrients leached from the surface. After the intercrop is harvested, decaying roots and fallen leaves provide nitrogen and other nutrient for the next crop resulting to less needs for external nitrogen addition (Borin and Frankow-Lindberg, 2005). Soil structure may improve if plants with various root depth and structures are grown. Deep roots penetrate far into the soil breaking up hardpans and utilise moisture and nutrients from deeper down in the soil profile (Zimbabwe Symposium, 2013).

Shallow roots bind the soil at the surface and thereby help to reduce erosion. Shallow roots also help to aerate the soil and add humus as they decompose. Yield advantages in intercropping systems are mainly because of differential use of growth resources by the component crops (Lithourgidis *et al.*, 2011). Therefore the combined yields of two crops grown as intercrops can be higher than the yield of the same crop grown as pure stand (Wolfswinkel, 2003). Higher grain yields, greater land use efficiency per unit land area and improvement of soil fertility through the addition of fixed nitrogen by legumes and excretion from legumes have been achieved (Ofori and Stern, 1987). In addition, the green parts and roots of intercrops decompose

and release nitrogen into the soil where it is made available to other crops. Vesterager *et al.*, (2008) found maize and cowpea intercropping beneficial on nitrogen poor soils. Maize-cowpea intercropping increases the amount of nitrogen, phosphorus and potassium contents compared to mono crop of maize (Dahmardeh *et al.*, 2010).

2.4.4. Improvement of forage quality and manure

The crop residue of the pulses crop can also be used as fodder, by cutting and carrying them to the animal, or by letting the animals graze the residues in the field (Kumar *et al.*, 2012). The nutrients in the crop residue can be recycled when manure is used to fertilize the crops. Animal manure improves soil fertility through supply of nutrients and soil structure, as it increases the amount of humus in the soil. It should be spread evenly over the field, even when the manure is left on the field during grazing or collected from the stable and applied later.

2.4.5 Soil cover and reduction in soil erosion

Through intercropping, farmers can maintain a wide variety of plants for a longer duration in the field, and such vegetative cover reduces rain drop impact. Sole maize can maintain 30% vegetative soil cover and that of maize + velvet beans can cover about 60% of the soil, which reduces the erosion hazard to one-sixth of that in a maize monocrop (Ssekabembe, 2003). This is accomplished through control of soil erosion in the following manner: Better and more continuous vegetation cover in the landscape that intercepts rainfall reducing its ability to erode and promotion of better water infiltration channels left after decay of different roots systems (Stocking, 2002). Pulses in an intercropping system do not only provide only a source of nitrogen and other nutrients to the associated crop but, also increase the amount of humus in the soil, due to decaying crop remains thus reducing soil susceptibility to soil erosion (Stocking, 2002). Water losses, soil erosion and leaching of nutrients are also reduced in intercropping system, due to improved soil structure and better soil cover, especially when creeping pulses crops are used (Wolfswinkel, 2003). In relay intercropping, the pulse crop is planted sometimes after the main crop and continues growing after the harvest of main crop thus result in more efficient use of soil water and prevents leaching and erosion, as the soil is still covered after the harvest of main crop (Wolfswinkel, 2003). In maize-cowpea intercropping, cowpeas act as best cover crop and reduces soil erosion (Kariaga, 2004). Reddy and Reddi (2007) mentioned taller crops act as wind barrier for short crops. In brinjal-groundnut intercropping, pod mass of brinjal

in monocropping was low due to absence of intercrop which leads to high water evaporation in soil surface (Prashaanth *et al.*, 2009). A row of maize in a field with a shorter crop reduces wind speed above the shorter crops and thus desiccation (Beets, 1990).

2.4.6. Reduce risk of crop failure and improve food security

Farmers reduce crop cultivation risks by growing many types of crops as an insurance against crop failure and avoidance of total economic loss (Gyasi *et al.*, 2003). For example, in one experiment at the Makerere University, maize which is not drought resistant failed to mature while Napier grass (*Pennisetum purpureum*) intercropped with it gave sufficient commercial yield (Ssekabembe and Sabiiti, 2001). Small scale farmers in the tropics have long used crop diversity to minimise risks of crop failure (Tumuhairwe and Nkwiine, 2003). This happens when several crops differ in the way they respond to environmental stresses such as drought, the risk for crop failure is spread over the different crops as they have different periods and patterns of growth, and are affected by different diseases (Tumuhairwe and Nkwiine, 2003). If one of the crops fail due to pest or diseases attack, there is still a harvest from other crops as reduced concentration of the pests' favoured host in diverse agro-ecosystems (Sharrock and Frison, 2004). This increases food security. In good season the yield of two crops grown on the same field as an intercrop is often higher than the yield of the same crop grown separately. Besides supporting food security a diversity of crops supports a more balanced diet (Gyasi, 2002).

Intercropping provides a more diverse diet to relish the staple crop for example, intercrops such as beans and cowpeas improves the nutrition of farmers and their families by supplying proteins, vitamins and minerals while cereals supply carbohydrates (Stocking, 2002). A continuous supply of food throughout the season can be ensured through use of a diversity of crop types and varieties which differ in ecological requirements and maturity periods (Frison *et al.*, 2014). In general, biodiversity is also a source of the variety of goods and services for the benefit of the society both nationally and globally.

2.4.7 Less weed infestation

Intercropping may sometimes be used as a strategy for weed control in some crop mixtures which are able to achieve earlier and greater soil cover which suppresses weeds. For increasing

land use efficiency and weed suppression, intercropping plays a pivotal role (Banik *et al.*, 2006). Presence of weeds in wheat severely affects the grain yield and biological yield of wheat (Khan and Marwat, 2006) therefore intercropping is one option for reducing weed problems through non-chemical methods (Vandermeer, 1989). Olasantan (2001) found that intercropping cassava with a high density planting of okra (50,000) plants per hectare) reduced weed growth by 25-45% due to increased shading. In an intercropping system weeds are more easily controlled. For example in maize bean intercrop, the bean covers the soil, preventing some weeds to grow. Intercropping offers effective weed suppression, pest and disease control, and use of soil resources under organic farming systems (Bulson *et al.*, 1997). Weed growth suppression is an explanation of intercropping yield advantage, which can be applied to diminish herbicide use in agriculture (Poggio, 2005). At adequate density of crops, the yield of uniformly distributed crop plants can be optimized by suppressing weeds (Weiner *et al.*, 2001). Intercropping is encouraged throughout the world as higher number of effective nodules under intercropping system over pure stand of legume is an indication that more atmospheric nitrogen fixation in the crop mixture (Maingi *et al.*, 2001). Maize-pumpkin and maize-bean intercropping reduced weed biomass by 50-66% when established at a density of 12,300 and 222,000 plants ha⁻¹ for beans (Mashingaidze, 2004).

2.4.8 Microclimate

Intercropping between high and low canopy crops is a common practice in tropical agriculture and to improve light interception and hence yields of the shorter crops requires that they be planted between sufficiently wider rows of the taller crops. Intercropping creates microclimate that favours the lower plant growth (Azam-Ali *et al.*, 1990). Jiao *et al.* (2008) found that maize-groundnut intercropping enhanced the efficient utilization of strong light by maize and weak light by groundnut leading to yield advantages. When the intercrop provides a good soil cover, soil temperature will stay relatively low thus prevent burning of the organic matter in the soil and loss of nutrients (Wolfswinkel, 2003). Intercropping practice could modify the microclimate by reducing light intensity, air temperature, desiccating wind and other climatic components. For example, tomato intercropped with grain sorghum, as the shade crop yielded more than pure stand tomato with little loss of sorghum yield and the Land Equivalent Ratio of the tomato + sorghum intercrop ranged from 2.58 to 2.99 (Kamel *et al.*, 2004). Poor foliage development, dropping of blossom, poor fruit set, breakage of leaves and branches, fall over of

plants in irrigation furrow and high dust coverage on the leaves cause poor plant development and reduce fruit yield in the Rift Valley (Lemma, 2002). However, in a study at Melkassa (in Ethiopia), wind protected tomato plants with strip intercropping of maize and sorghum plants gave higher yield (7.4 t/ha) compared to unprotected ones (5.7 t/ha) (Lemma, 2002).

2.4.9 Disease and pest infestation

Maize is susceptible to many insects (Drinwater *et al.*, 2002). It is generally believed that one component crop of an intercropping system may act as a barrier or buffer against the spread of pests and pathogen and intercropping maize-cowpea reduces the stem borer (Henrik and Peeter, 1997). Maize leafhopper (*Dalbus maindis* L.) was reduced under intercropping reported by Power (1990). Pino *et al.*, (1994) working on maize intercropped with tomato, found that pests and diseases were less in tomato-maize intercropping. Soybean and groundnut are more effective in suppressing termite attack than common beans (Sekamatte *et al.*, 2003). Umarajini and Seran (2008) reported incidence of white fly and leaf hopper were lower in brinjal groundnut intercropping compared to monocropping. Singh and Adjeigbe (2002) reported that monocropping needs more chemical to control pests and diseases than intercropping. Although intercropping does not always reduce pest or pathogen, but most reports have pointed to reduced populations of pests and diseases in the intercropping (Fujita *et al.*, 1992). In a review by Francis (1989) on intercropping, in 53% of the intercropped experiments pests were reduced while in 18% pests were increased in the pure cropping. Increasing pests can be due to several reasons, such as the second crop is a host for pests in intercropping, or increasing the shade in canopy, provides favourable conditions for pests and pathogens activity. In addition plant residues can be as a source for pathogens inoculated (Anil *et al.*, 1998). More species diversity in agricultural ecosystems can limit the plant pathogenic spread. Intercropping systems increase biodiversity like the natural ecosystems. This increase in diversity reduces pests damage and diseases (Anil *et al.*, 1998).

2.5 Importance of beans

Beans (*Phaseolus vulgaris*) are the most important and most widely grown grain legume food crop for direct human consumption in the world (Broughton *et al.*, 2003). Total production

exceeds 23 million metric tonnes (MT) of which 7 million MT are produced in Latin America and Africa (Broughton *et al.*, 2003). About 75-90% of beans in East Africa and the tropics in general, are grown in mixed stands (Keswani and Ndunguru, 1980). Up to 80% of the beans in Latin America are planted in mixture with maize and other crops (Lithourgidis *et al.*, 2011). Common bean is the most important source of protein, carbohydrates and valuable micronutrients for more than 300 million people in the tropics (CGIAR, 2012). They supplement the diets based mainly on starchy foods such as root crops and cereals. The protein content of beans is about 20-25% and beans are rich in amino acids, lysine and tryptophan that are deficient in maize. Generally, in sub-Saharan Africa beans are the second most important source of dietary protein and third most important source of calories to more than 100 million people both in rural and urban areas (Kirkby, 2005). Beans provide more than 22% and 11% of the daily needs of protein and energy, respectively in sub-Saharan Africa (David *et al.*, 2000).

2.6 Importance of cowpeas

In general, cowpea is the third most important grain legume in the world, after common beans and groundnuts (Mugambi, 2013). The crop is grown for its grain, immature pods, leaves and fodder (haulms). Cowpea has a high nutritional value and both leaves and grain are important sources of quality protein (El Naim *et al.*, 2012). The green tender leaves are used as a vegetable and the seed as pulses especially in arid and semi-arid areas (El Naim *et al.*, 2012). In eastern and northern Uganda, cowpea leaves provide vegetable sauce to off-set early season famine and the grain is sold for cash (Isubikalu *et al.*, 2000). Cowpea is a major source of vegetable protein for both humans and livestock in developing countries especially in Africa and Asia (Oppong-Konadu *et al.*, 2005).

Cowpea dry grain contains 23-38% protein, 1-3% fat, 56.9% carbohydrates, 3.9% fiber, 3.6% ash, 0.74% thiamine, 0.42% riboflavin and 2.8% niacin (Cruz *et al.*, 2014). It is estimated that cowpea supplies about 40% of the daily protein requirements to most of the people in Nigeria (Kamai *et al.*, 2014). Cowpea is important for its ability to maintain soil fertility through its ability to fix nitrogen and rapid establishment, which is associated with soil erosion reduction and reduction in soil temperature, and lowering of weed pressure (Nabhan *et al.*, 1999). Intercropping of maize and cowpea is especially beneficial on nitrogen poor soils (Vesterager

et al., 2008). As cowpeas obtain the majority of their nitrogen from the atmosphere, they do not compete with maize for nitrogen in the soil therefore maize yield is not significantly affected by intercropping with cowpeas according to a study done by Vesterager *et al.* (2008). In West Africa, where cowpea is the most important legume, the most important intercrops with cowpea are millet and sorghum especially in the drier regions of northern Guinea, Sudan and the Sahel (Dudge *et al.*, 2009). The yield of cowpea is greatly reduced when it is introduced late in the maize + cowpea mixture and this is because of the shading effect from the already established maize plants (Addo-Quaye *et al.*, 2011).

Mongi *et al.* (1976) found that cowpeas planted 3 weeks after maize had significantly reduced yields and therefore recommended planting cowpeas simultaneously with maize. Intercropping of maize and cowpeas is more economical than sole maize when phosphorus fertiliser is not applied as compared to application of 30 or 60 kg P/ha (Mongi *et al.*, 1976). Sole cowpea is more seriously damaged by insect pests reducing yield significantly although not all pests of cowpea are controlled through intercropping, neither do all intercropping systems control pests. Nampala *et al.* (2002) found that aphids and thrips populations were significantly reduced in the cowpea + sorghum intercrop but were higher in the cowpea + green gram mixture.

2.7 The effects of intercropping on plant interactions

2.7.1 Below-ground interactions

The pattern and spatial extension of root growth displayed by a given crop is highly species and cultivar dependent. However, cereals generally have much greater rooting densities than legumes (Ani *et al.*, 1998). This difference has often led to the conclusion that cereals are the most competitive with respect to the uptake of nutrients from the rhizosphere (Hauggaard-Nielsen *et al.*, 2001). Differences in root systems, particularly rooting depth, lateral root spread, and root density, have been found to affect competition for water (Haynes, 1980). Haynes concluded that proper management of root systems can minimize root competition for water. As plants begin to mature, the uptake of both nutrients and water declines. In intercropping, shallow rooted primary crops of an intercropping system may force companion crops to develop deeper rooting systems that explore the soil matrix more extensively than their monoculture counterparts (Fisher, 1976). Such root avoidance may assist in developing root

systems that use soil to a greater depth (Trenbath, 1974). However, as a result of the varying strategies of plant species to further extend their rhizosphere through the development of root hairs and indirectly through mycorrhiza association (Hinsinger, 1998) this pattern may not be conclusive. For example, Li *et al.*, (1991) showed that phosphorous could be obtained from a distance of up to 12 cm by the hyphae of mycorrhizal fungi associated with white clover. Katayama *et al.*, (1995) showed that pigeon pea developed a deeper rooting in response to competition from companion crops.

2.7.2 Above-ground interactions

Light, water, mineral nutrients, oxygen, and carbon dioxide are all required for plant growth (Trenbath, 1976). Competition occurs when two plants vie for the same nutritional and water requirements in the same space one of the plants usually receives less than it requires. Overlapping in space and time, the growth of two or more often results in decreased yields of both crops due to competition for limited essential resources (Wanki *et al.*, 1982).

2.8 Utilisation of growth resources for enhanced productivity

In intercropping the available resources needed for plant growth and development such as light, water and nutrients are utilized more efficiently by the crops as compared to sole or pure stand of a crop (Qayyam *et al.*, 2011). Thus it is believed that efficient utilization of resources results in yield advantages.

2.8.1 Light use efficiency

Light is the visible portion of the electromagnetic radiation from the sun and is used to provide the energy for photosynthesis (Ssekabembe, 2010). Light is one of the important growth factors affecting the yield of crops. Unlike other resources, light is instantaneously available and has to be instantaneously intercepted, if it is to be used for photosynthesis (Ssekabembe, 2010). A fraction of light is intercepted by leaves and absorbed, some is transmitted through the canopy, while the rest is reflected or redirected. It has been suggested that light transmission through the canopy is affected by row orientation in addition to plant population density (Jaya *et al.*, 2001). The reflectivity of the leaf surface influences the proportion of intercepted radiation that is absorbed and that is transmitted through the canopy (Ssekabembe, 2010). The rate of dry matter (DM) production and crop growth are usually directly proportional to the amount of

light intercepted by the leaf blades or crop canopy and this is influenced by leaf area index (Ong *et al.*, 1996). This is particularly during the early growth stages. Within certain limits, dry matter (DM) production and crop yield can be increased by maximising the amount of photosynthetically active radiation intercepted by the crop canopy (Miah *et al.*, 2003). Low availability of light for a component crop in mixtures reduces the photosynthetic rate and crop growth rate, finally leading to drastic reduction in grain and straw yields of component crops. Willey (1979) emphasized that, light was the most important factor when better temporal use of resources was achieved due to the better distribution of leaf area over time. At ICRISAT, measurement of light interception showed that intercropping did not intercept more light energy than sole cropping, but this energy was more efficiently converted into dry matter (Reddy *et al.*, 2007).

In South Africa, Tsubo and walker (2005) measured photosynthetically active radiation above and beneath a maize-bean intercrop canopy in both north-south and east west rows, in which they observed that the intercropping was equivalent in growth efficiency of maize to the sole cropping whereas, beans had greater radiation use efficiency in intercropping than in sole cropping. This might explain the intercrop yield advantage. Light interception and light use efficiency are powerful concepts for characterizing the resource capture and use efficiency of cropping systems, including intercrops. Improved productivity can result from either greater interception of solar radiation, higher light use efficiency, or a combination of the two (Willey, 1990). Light interception as a result of mixing two species and growing them together instead of alone is sometimes increased, either as a result of a lengthening of the period of soil coverage (temporal advantage), or as a result of a more complete soil cover (spatial advantage) (Keating and Carberry, 1993). When total crop densities are higher in intercrops, they can intercept more light especially early in the growing season. Intercrops composed of non-synchronous patterns of canopy development and different maturation times can display a greater amount of leaf area over the course of the growing season and intercept more total light energy than monocultures. Carandang (1980) thought that intercrops allow maximum utilization of sunlight by increasing light interception by 30-40%.

2.8.2 Moisture use efficiency

With limited water supply, each unit of water ought to be used support production of as much dry matter (yield) as possible (Ssekabembe, 2010). The ratio of dry matter produced to water transpired is known as the water use ratio or water use efficiency (WUE) (Byrd and May, 2000). For instance, the WUE for maize and sorghum (*Sorghum bicolor*) is about 3.0 and 9.0 g dry matter (DM) kg⁻¹, respectively (Mortlock, 2009). In Kenya, maize + bean intercropping proved advantageous in a wet season but not so in a dry season (Fisher, 1977). Intercrops have been identified to conserve water largely because of early high leaf area index and higher leaf area (Ogindo and Walker, 2005). Morris and Garrity (1993) mentioned that water extraction by intercrops differs from water extraction by sole crops only slightly higher by about 7 per cent.

Barhom (2001) reported that water use efficiency was the highest under soybean-maize intercropping compared with monocropping maize and monocropping soybean. Tsubo *et al.*, (2005) reported that soybean-maize intercropping was the best combination system during water scarcity periods. The amount of water transpired by a crop depends on the leaf area or leaf area index, which is responsible for losing the water to the atmosphere but also for light interception. Evaporation depends on the water deficits in the environment or the evaporative demand of the environment. In other words, relative humidity determines the ability of the atmosphere to accept moisture, which constitutes its evaporative demand. The water use efficiency response by intercrops to increased levels of seasonably available water differs from the response by sole crops (Ssekabembe, 2010). Variation in plant density also affects the water use efficiency.

2.9 Land equivalent ratio (LER)

One way of assessing the benefits of growing two or more crops together is to measure productivity using the Land Equivalent Ratio (LER). According to Willey (1979), the most generally useful single index for expressing the yield advantages is probably the Land Equivalent Ratio defined as the relative land area under sole crop that is required to produce the yields achieved in intercropping. Assessment of land return is made from the yield of pure stands and from each separate crop within the mixture. The calculated figure is called the Land Equivalent Ratio (LER), intercrop yields are divided into pure stand yields for each crop in the intercropping system and the two figures added together (Sullivan, 2003). Yield advantages

from intercropping, as compared to sole cropping are often attributed to mutual complementary effects of component crops, such as better use of available resources. Land Equivalent Ratio gives an indication of magnitude of sole cropping required to produce the same yield on a unit of intercropped land. Land Equivalent Ratio concept has got some short comings, particularly when used to compare the productivity of an intercrop and sole crop (Thobatsi, 2009). The major problem is that the computation of Land Equivalent Ratio needs maximum yields of sole crop obtained at optimum plant densities (Willey, 1979). LER compares the yields from growing two or more crops with yields from growing the same crop in monocultures or pure stand. As an index of combined yield, LER provides a quantitative evaluation of the yield advantage due to intercropping (Willey, 1979). Although component crops may give varying yields, the estimate of relative yields with sole crops at optimum or recommended densities as references gives comparable scales for both components crops allowing comparisons of various crop combinations (Ofori and Stern, 1987). Chetty and Reddy (1984) proposed that LER could be used either as an index of biological efficiency to evaluate the effects of various agronomic variables for example fertility levels, densities, comparison of cultivar performance and relative time of sowing on an intercrop system in a locality or as an index of productivity across geographic locations to compare a variety of intercrop systems.

2.10 Economic aspects of intercropping systems

Economic returns obtained from the systems such as intercropping or sole cropping depend mainly on the component crops, their yield and price prevailing during that period of study. Intercropping has been identified as a promising system that results in an effective use of land and other resources (Remison, 1982), efficient utilization of water and soil nutrients (Sharma *et al.*, 1993) and reduction in the cost of production. Yield advantages from intercropping as compared to sole cropping are often attributed to mutual complementary effects of component crops, such as better total use of available resources. Generally, monoculture legumes have higher yield compared to an intercropping system. However, in most cases, land productivity, measured by Land Equivalent Ratio (LER), clearly shows the advantage of mixed cropping of cereals and legumes (Mandal *et al.*, 1990). Depending on component crops, yield advantages may vary considerably due to several factors, including differences in plant architecture, rooting patterns, competitive advantages and potential nitrogen fixing capacity of the legume.

These, in turn, determine the optimum density, time of sowing and amount of nitrogen fertilizer. The need for simultaneous production of different food crops and or cash crops can also encourage intercropping. Intercropping has gained wide acceptability among farmers in tropical countries because of its economic advantages (Adeniyi, 2007) resulting from the symbiotic association of legumes intercropped with other crops (Ahmed and Gunasema, 1979). Intercropping involving legumes has been found to be most useful and cost effective cropping system (Bryan and Materu, 1987).

2.11 Spatial arrangement

Spatial arrangement defines the pattern of distribution of plants over the ground, which determines the shape of the ground area available to the plant (Willey, 1979). Crop arrangement is important because it determines the efficiency with which solar radiation and space is utilized (Nayak *et al.*, 1996). When plants are grown together in a community, they will affect each other and the degree of influence depends on the planting pattern which results in interference that affect the extent to which the population must be increased to have a yield advantage (Willey, 1979). The way the plants are laid in the field also influences the growth, development and yield of the individual plants as well as the crop as a whole (Beet, 1982). Spatial arrangement of component crops is one of the most important management factors that determine whether an intercropping system can be advantageous or not.

It is the systematic apportioning of the farm area or any growing surface for crop production. In intercropping, the intercrop can be planted in any of the following ways: (1) within the rows of the main crop, (2) between the rows of the main crop, and (3) in replacement series (Abellanosa and Pava, 1987). Single row planting of the intercrop can also be done between the rows of the maincrop. For example, peanut can be dibbled between two adjacent rows of maize. This system of planting arrangement is likewise common in coconut farms where fruit trees like durian, lanzones and mangosteen are grown in single rows between coconuts. In replacement series, one or more rows that are intended for the maincrop are replaced with the intercrop (Abellanosa and Pava, 1987). For example, a 3:2 maize + common bean intercrop means that for every 4 rows that are intended for sole maize, only 3 rows are planted to maize and one row may be substituted with 2 rows of common bean. Another practice is in strip

intercropping, for example the simultaneous growing of 6 rows maize and 12 rows soybean in alternating strips thus resulting to multiple row arrangement.

2.12 Additive intercropping model

Additive intercropping is a cropping system in which one crop is sown with 100% of its recommended population in pure stand (base crop) and another crop known as intercrop is introduced into the base crop by adjusting or changing geometry (Vandermeer, 1989). The population of intercrop can be less than its recommended population in pure stand land equivalent ratio. Additive series is more efficient than replacement series in intercropping system. In an additive intercrop, plants of one component crop species are sown in addition to the normal population of a sole crop (Connolly et al., 2001). Here, the population and usually the spatial arrangement of one crop are fixed whilst varying the population of the intercrop (Vandermeer, 1989).

2.13 Architecture and morphology of cowpeas

Cowpea is grown both as a sole crop and in mixture with maize, sorghum, cassava, pigeon pea, soybeans, millet, yam and sunflower. Sorghum is the most common intercrop with cowpea. Fox and Young (1982) described cowpea as an annual herb reaching heights of up to 80 cm with a strong taproot and many spreading lateral roots in the surface soil. Growth forms vary and many are erect, trailing, climbing, or bushy, usually indeterminate growers under favourable conditions. It is tolerant to heat and drought conditions. Cowpea is sensitive to frost and germinates rapidly at temperatures above 20°C; colder temperatures slow germination. Cowpea is well adapted to a wide range of soils and conditions and this attributes makes it suitable for intercropping. Cowpea have an advantage of greater separation of the leaves that improves interception of solar radiation in the intercropping systems. A better understanding of both the morphological, physiological and biochemical mechanisms involved in plant response to water deficit could therefore help improve cowpea productivity in dry land areas (Blum and Ebercon, 1981). Different mechanisms may make a drought tolerant plant. It may be by drought avoidance or drought tolerance (Blum and Ebercon, 1981). Drought avoidance is the ability of a plant to escape periods of drought, particularly during the most sensitive periods of its development (Visser, 1994). Drought tolerance is the ability of the plant to endure

or withstand a dry period by maintaining a favourable internal water balance under drought conditions. Cowpeas canopy architecture is bushy and the leaves are dense, minimising air circulation which results to build up of fungal diseases (Visser, 1994).. Cowpeas rooting system extracts resources at the same zone to that of maize rooting system, thus competes for resources. The lateral braches of cowpeas spread apart and covers the rows in an intercropping system, thus creating allopathic effects to the main crop like maize, thus making it not suitable for intercropping with maize.

2.14 Architecture and morphology of beans

Common bean (*Phaseolus vulgaris* L.) is a major grain legume consumed worldwide for its edible seeds and pods. It is a highly polymorphic warm-season, annual herbaceous (Ecoport, 2013). It has a taproot with many adventitious roots (Ecoport, 2013). The stems are slender and pubescent. They are many-branched in bushy types. In twinning types, the stems are prostrate for most of their length and rise toward the end (Ecoport, 2013). The leaves, borne on long green petioles, are green and trifoliate. Leaflets are 6-15 cm long and 3-11 cm broad. The inflorescences are axillary or terminal, 15-35 cm long racemes. The flowers are arranged in pairs or solitary along the rachis, white to purple and typically papilionaceous (Wortmann, 2006). Once pollinated, each flower give rise to one pod. Pods are slender, green, yellow, black or purple in colour, sometimes striped. They can be cylindrical or flat, straight or curved, 1-1.5 cm wide and up to 20 cm in length (Wortmann, 2006). The pods may contain 4 to 12 seeds. Beans are particularly because of their early maturity and reduced cultivation requirements, therefore they do not compete much with maize for resources. Common beans architecture is not dense compared to cowpeas, therefore allows air circulation and minimises the development of fungal diseases associated with damp places. Beans rooting system is not competitive to that of maize plants, thus makes beans suitable for intercropping with maize.

CHAPTER 3

3.0 MATERIALS AND METHODS

A field experiment was conducted at the Malkerns Research Station of Swaziland, Ministry of Agriculture during the 2013/2014 and 2014/2015 growing season to determine the optimum spatial arrangement of maize intercropped in additive manner with beans and cowpeas. The material used and techniques employed during the course of experimentation are described in this section.

3.1 General description

3.1.1 Experimental site

The Malkerns Research Station, Malkerns is situated in the Upper-Middleveld agro-ecological zone of Swaziland. The research station is about 4km from the Faculty of Agriculture and Consumer Sciences, University of Swaziland. Malkerns Research Station is 740m above sea level, latitude 26.55°S and longitude 31.15°E. The site has an annual rainfall of 800-1000 mm; and annual mean temperature ranging from 7.3°C to 26.6°C. (Edje and Ossom, 2009). The annual rainfall of this site is well distributed from October to February with low coefficient of variation (Edje and Ossom, 2009). The mean monthly meteorological data on rainfall, temperature and relative humidity during the period of experimentation were collected.

3.1.2 Experimental site history, soil characteristics and soil sampling

The previous crop growing season 2011/2012, cowpeas were grown in the experimental site plot and during the crop growing season 2012/2013 common beans had been grown. The soil of the experimental site belongs to an Oxisol (M-set) of the Malkerns series (Murdoch, 1968). A composite soil sample was collected from 0 to 30 cm depth in experimental plots before planting and analysed for physical and chemical properties. Soil samples were taken across the experimental area in a zig zag pattern throughout the field. An auger was used to collect representations of soil samples from different locations in the field and then mixed together for analysis.

3.1.3 Determination of exchangeable calcium, magnesium and potassium in the soil

Method proposed by Lanyon and Heald (1982) was used to quantify the above bases. The method consists of taking 10g of soil, weighed and placed in a 250 ml erlenmeyer flask and 90 ml of ammonium acetate added. The flasks were placed on a shaker and shaken for 10 minutes. The content of the flasks was allowed to settle and then filtered through Whatman No. 42 filter paper into 100 ml volumetric flasks. The contents of the flasks were made to a volume with the extracting solution. An Atomic Absorption Spectrophotometer (model AA 200) at the appropriate wavelength for each element was used to measure the amounts of calcium and magnesium extracts in the soil. Potassium was measured using the Jenway Flame Photometer (model PFP7). The nutrient content of the elements was expressed in cmol kg^{-1} .

3.1.4 Determination of soil pH

The method outlined by McLean (1982) was used in the determination of the pH of the soil samples from Malkerns experimental site. Duplicate of 10 g soil samples were weighed into 50 ml beakers and 20 ml of 0.01M CaCl_2 added. Then the mixtures were swirled for 5 minutes with a glass rod and allowed to equilibrate for 30 minutes before taking the pH. Before determination of the soil pH, the pH metre was standardized, by first taking the temperature of the solution and set the temperature compensation dial at the experimental temperature. The electrodes were washed with distilled water, wipe off the water with filter paper and introduced to a pH 7.00 buffer. The electrodes were then washed again and a pH 4.00 buffer solution used. This was repeated until constant readings at pH 4.00 and pH 7.00 were recorded. The pH was measured with a Hanna pH metre and expressed as pH in CaCl_2 . The soil pH in water was determined and expressed as pH in H_2O

3.1.5 Determination of phosphorus in the soil

The ammonium molybdate blue method outlined by Olsen and Sommers (1982) was followed in the determination of phosphorus in the soil samples from the Malkerns experimental site. Duplicates of 2 g of dry soil were weighed and placed in 50 ml centrifuge tubes and 20 ml of Bray-1 solution added. The centrifuge tubes were mounted on a mechanical shaker and shaken for 5 minutes. The contents of the centrifuge tubes were centrifuged for 10 minutes on a Kubota centrifuge (model 2010). The supernatant solution was filtered through No.42 Whatman filter paper into 50-ml volumetric flasks. Phosphorus in the extracts was measured using a Biochrom

Spectrophotometer (model Libra S12) at a wavelength of 730 nm. The amount of phosphorus in the extracts was expressed in mgkg^{-1} soil.

3.1.6 Determination of exchangeable aluminium (Al)

In the determination of exchangeable Al, the method outlined by Barnhisel and Berstch (1982) was used. Duplicate of 5g samples were weighed into 250 ml erlenmeyer flasks and 50 ml of 1N KCl solution added. The contents of the flasks were shaken on a mechanical shaker for 30 minutes. After shaking the solution, the content was allowed to settle and then filtered through Whatman No. 42 filter paper into 50 ml volumetric flasks. The content of Al in the extracts was measured by titration against a 0.01 M NaOH solution. The content of Al in the extracts was expressed in cmolckg^{-1} .

3.2 Experimental details

3.2.1 Treatment details

Treatments consisted of sole crops and different spatial arrangements of maize grown in association with common beans (*Phaseolus vulgaris* L.) and cowpeas (*Vigna unguiculata* L.). The spatial arrangement consisted of maize intercropped with one row of beans or cowpeas with maize within a row in which its spacing is varied from 25, 50 and 75 cm and the number of seeds per hill increased. This also applied to treatments where maize was planted in an opposite and staggered planting arrangement as indicated in Table 1. The treatments were two legumes grown separately at adjusted crop spacing (such as 90 x 10 spacing) on pure stand and then a mix stand where a maize row was additively intercropped into the legumes.

Table 1. Treatment code and treatment description of the experiment.

Treatment code	Treatment description
T:1	Sole maize, 1 plant/hill
T:2	Sole maize, 2 plants/hill
T:3	Sole maize, 3 plants/hill
T:4	Sole beans
T:5	Sole cowpeas
T:6	Maize, 1 plant/hill, + beans
T:7	Maize, 1 plant/hill, + cowpeas
T:8	Maize, 2 plants/hill, + beans
T:9	Maize, 2 plants/hill + cowpeas
T:10	Maize, opposite, 3 plants/hill, + beans
T:11	Maize, opposite, 3 plants/hill, + cowpeas
T:12	Sole Maize, staggered, 3 plants/hill
T:13	Maize, staggered, 3 plants/hill, + beans
T:14	Maize, staggered, 3 plants/hill, + cowpeas

3.2.2 Skeletal ANOVA Table

Table 2. Skeletal ANOVA Table for maize additively intercropped with beans and cowpeas

Source of variation	Degree of freedom
Replication	(R-1) (5 -1)= 4
Cropping system	(CS-1) (14 - 1)= 13
Season	(Y-1) (2 -1)= 1
CS x Y	(CS x Y) (14 x 2)= 28
Error	T- (R + T + Y) (70-(5 + 14 + 2)=49
Total	T-1 (70-1)= 69

3.2.3 Design and layout

The experiment was conducted on a randomised complete block design to eliminate the effect of a heterogeneous factors in the field. It is a random experiment, because the experimental units are randomly assigned to each block. It is complete, because each treatment is included in every block. The experiment was consist of five replicates in a single factor arrangement having 14 treatments as shown on Table 2 which were grown in two seasons, 2013/2014 and 2014/2015 (Appendix 196).

3.2.4 Plot size

Net plot size consisted of 6 m length and 5.4 m width having 6 rows, each 6 m long with an inter-row spacing of 0.9 m. Intra-row spacing was 10 cm for legumes and 25 cm, 50 cm, 75 cm for maize, respectively, according to spatial arrangement.

3.2.5 Genotypes

The maize cultivar used in the study was PAN 53 from Pannar. This is a white, dent-type medium maturity variety which takes about 140-150 days to maturity. It has a high yielding potential, good tolerance to grey leaf spots and to maize streak mottle virus, good tolerance to northern corn spot and phesopharia and, also good tolerance to both stalk and root lodging. The cultivar also has a semi-erectophile leaf architecture, which makes it suitable for intercropping. Determinant type of beans were used and the variety was Limpopo speckled sugar bean seed which takes 100 days to physiological maturity with a minimum germination percentage of 80% - 99% and purity. The type of cowpeas used were determinate and the variety used was Glenda, lot no-A/AG/PDB/14, germination percentage of 90% -100%.

3.3 Cultural operations

3.3.1 Land preparation

The experimental land was ploughed after the harvest of previous crop. Three tonnes per hactor of dolomitic lime was spread on the surface of the soil followed by a single disc harrowing to mix the lime with the soil and crush clods to prepare a fine seed bed.

3.3.2 Fertiliser application

The recommended basal dose of fertiliser in the Middleveld of Swaziland for pure stand plots of maize is 400 kg/ha of a compound fertiliser (2:3:2: (22) and 216 g/row were applied to maize in monoculture or in association with legumes. For beans, (250 kg/ha) that is 135 g/row was applied and for cowpeas (200 kg/ha) that is 108 g/row was applied in the form of 2:3:2 (22) (Edje and Ossom, 2009). In the case of maize, the remaining dose of nitrogen (100 kg/ha) that is 193 g/row was applied as a side dressing at 40 days after planting (knee height) (Edje and Ossom, 2009) using limestone ammonium nitrate (28% nitrogen) as a nitrogen source.

3.3.3 Seeds and sowing

Healthy seeds of maize, (*Zea mays* L.) PAN 53 from Pannar, beans (*Phaseolus vulgaris* L.) Limpopo speckled sugar bean seed and cowpeas (*Vigna unguiculata* L.) Glenda were selected for sowing. Rows were opened using hand hoes with the help of markers to obtain the required spacing for sowing both maize and legumes. The seeds were planted by hand, one seed per hill in 25 cm intra-row spacing, two seeds per hill in a 50 cm intra-row spacing of maize and 3 seeds per hill in 75 cm intra-row spacing. Planting depth of maize varied from 5 to 10 cm, depending on the soil type. As a rule, planting was shallower in heavier soils than in sandy soils. For the legume intercrops, one seed was planted at 10 cm intra-row spacing. During seedling emergence, cutworm bait was applied to prevent cutworms from damaging plant roots.

3.3.4 Gap filling

Gap filling operations were done ten days after planting to maintain the required plant population. This was due to birds' damage during seedling emergence. The gaps were filled by drilling a hill and then inserting a seed into the hill. The hills were then covered with soil and the surface pressed by stepping onto it to increase seed soil contact. Old maize grain was spread all over the gross plot borders as a delaying tactic for birds.

3.3.5 Plot maintenance

Two hand weeding were carried out during the growing season at 30 and 60 days after planting. Supplementary irrigation was applied through sprinkler irrigation based on soil moisture content. Pests and diseases were controlled after their visibilities were noted through field assessments and frequent detection using pests and disease scoring (Table 3 and 4). Stalk borer granules were applied in the whorl of the maize to control stalk borer in maize. Fastac and bravo 1.4 l/ha were used to control fusarium wilt, beans rust in beans and cowpeas at 30 ml/20 l of water. To control black aphids in cowpeas, decis was applied at a rate of 30 ml/20 l water.

3.3.6 Harvesting

Crops were harvested on different dates according to their maturity periods, maize, common beans and cowpeas. The cobs and pods were hand-picked and placed in sacks for final yield determination.

3.4 Data collection

Growth parameters in the experimental site were collected until physiological maturity of the crop was reached and data on maize and legumes collected include: morphological, physiological, as well as grain yield and yield components.

3.4.1 Seedling emergence count

Emergence and establishment occurs when the seedlings (plumule) come out of the soil surface, followed by survival and formation of a new plant. The stage at which the seedling emerges out of the soil is critical and is called the weaned seedling stage. To facilitate success of the weaned seedling stage farmers must plant seeds at an appropriate depth. Seedling emergence count was determined every day until all seedlings had emerged. A seedling was said to have emerged if the plumule was visible above ground for maize and legumes. Seedling emergence percentage was calculated using the formula according to (Hartmann *et al.*, 1990).

$$\text{Seedling emergence} = \frac{\text{Total number of emerged seedlings} \times 100}{\text{Number of seeds planted}}$$

3.4.2 Maize and legumes growth parameters

Five plants from each plot were selected randomly and tagged for recording various growth and yield attributes. For growth analysis studies, four destructive sampling was carried out at various intervals and at harvest. Data were collected at 2, 4, 6, 8, 10 for legumes and 12 weeks after planting for maize.

3.4.3 Plant height

Height is the distance to which anything rises above that on which it stands; the measure upward from a surface, as the ground. Plant height has been used as a basis for interpretation of characteristics such as growth, vigor and competition.

3.4.3.1 Maize

For maize, the plant height was determined by measuring the height of maize from the base of the plant to the fully opened top leaf sheath of the last leaf of the plant, using a 5 m tape measure every two weeks interval starting from 2 weeks after planting (WAP) up to 12 WAP. After

tasseling of the maize, the plant height was measured up to the base of the tassel (collar of flag leaf). In field experiment, 5 plants were randomly selected in the two middle rows from each field plot for measuring the height of the plant at different stages of the growth. After recording the height of five plants, an average was worked out to get a representative plant height from each plot.

3.4.3.2 Legume plant height

For the legumes intercrops, plant height was determined from the net plot by measuring height of five plants from ground level to the tip of the plant growing point using a calibrated stake.

3.4.4 Leaf area (cm²)

3.4.4.1 Maize

Leaf area was measured by following the formula, length x breadth x factor as illustrated by Edje and Ossom, (2009). The length of each leaf was measured along the midrib and the width was taken along the widest part of the leaf. Since the leaf shape is not constant, a factor is used to correct this and the factor is 0.75 for maize. This was carried out by selecting 5 plants randomly and average was worked out.

3.4.4.2 Legumes

In beans and cowpeas, leaf area was determined according to the method by Edje and Ossom, (2009). Leaf area was measured by following the formula, length x breadth x factor (2.88 for beans) and (2.70) for cowpeas. This was carried out by selecting 5 plants randomly and average was worked out and the product expressed in cm² per plant.

3.4.5 Leaf area index (LAI)

Leaf area index (LAI) is an important index of crop growth. It is a measure of the leafiness of the crop canopy which is a ratio of the total leaf area in the crop canopy to the land area on which the crop stands. The following formula was used to calculate the leaf area index from five randomly selected plants in two middle rows.

$$\text{L.A.I} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Land area from which plants were obtained (cm}^2\text{)}}$$

3.4.5.1 Leaf area index in maize

Leaf area index in maize was determined directly by measuring the leaf area of each sample plot by dividing it with the plot land surface (Edge and Ossom, 2009). The land area was the crop spacing multiplied by the number of plants from which the leaf area was measured. For example in maize, randomly 5 plants x 0.9m (inter-row spacing) x 0.25 m (intra-row spacing) was used. The following formula was used to calculate the leaf area index.

$$\text{L.A.I} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Land area from which plants were obtained (cm}^2\text{)}}$$

3.4.5.2 Leaf area index in legumes

For the legumes, leaf area index was determined by measuring the leaf area per each sample plot and dividing it by the plot land surface using 5 randomly selected plants x 0.9 m (inter-row spacing) x 0.10 m for intra-row spacing in the experiment.

3.4.6 Cob height (cm)

The cob height in maize (from the soil level to the node at which the cob is attached) was measured from five randomly selected plants within 2 middle rows in all maize plots when plants had fully developed cob. Five plants were measured per plot and values averaged to obtain the mean.

3.4.7 Dry matter determination (DMD)

Dry matter refers to the material (tissues) remaining after the removal of water, that is the moisture content of tissues still present. Determination of DMD is a relatively simple and quick process that can be easily done on a farming operation. The most common way that moisture is determined is through the evaporation of water from the plant, using an oven, leaving only the dry contents behind.

3.4.7.1 Maize DMD

In the experiment, five randomly selected maize plants from the second end rows per plot were selected for destructive sampling and taken to the laboratory for dry matter determination. This procedure was done at 2 weeks interval that is at 60, 80, 100 and 120 days after planting. In maize, the sampled plants were separated into leaf (including leaf sheath), stems, cobs with husk and tassels and their fresh masses were determined before drying. The stems from sample

plants were chopped into 10 cm sets to facilitate drying. Sub sampling was done and sub samples were placed in labelled bags and oven dried with hot air at 100°C to a constant mass for 72 hours after which the dry matter was determined. Dry mass was then recorded separately at each stage for calculating dry matter accumulation in different parts and total dry matter production expressed in grams per plant. The following calculation was carried to determine the dry matter content of the plant.

$$DM = \frac{\text{Fresh mass} - \text{Dry mass}}{\text{Dry mass}} \times 100$$

3.4.7.1 Legumes

In both beans and cowpeas, five randomly selected maize plants from the second end rows per plot were selected for destructive sampling and taken to the laboratory for dry matter determination. This procedure was done at 2 weeks interval that is at 40, 60, 80 and 100 days after planting. For legumes; leaves, stems and pods were separated and their mass computed separately. Samples were placed in labelled bags and then oven dried with hot air at 100°C to reach a constant mass for 72 hours after which the dry matter was determined. Dry mass was then recorded separately at each stage for calculating dry matter accumulation in different parts and total dry matter production expressed in grams per plant.

3.5 Maize yield components

Partitioning is the allocation of plant tissues to different plant parts including the organs of the plant that can be harvested. This has a central role in determining yield potential. The products of photosynthesis (photo-assimilates) in the leaves and other green parts of the plant are divided into roots, shoots (stems) and grains or tubers. Sink size and activity and management factors (such as pruning and topping) are among the factors that influence partitioning of assimilates.

3.5.1 Number of seeds per cob

Number of seeds per cob was counted and recorded. The number of seeds was averaged and taken as the mean number of seeds per cob.

3.5.2 Shelling percentage %

After husk removal and grain shelling, the shelling percentage was determined and expressed as the ratio of the mass of shelled grains to the mass of unshelled. This ratio was obtained by

mass of seeds/mass of cob without husk. The ratio was then multiplied by 100 to obtain the shelling percentage.

3.5.3 100-seed fresh mass (g)

The seeds from cobs harvested within the middle row were shelled and impurities removed. Hundred seeds were selected randomly out of each treatment from the entire shelled row seeds and their mass weight were taken, averaged and expressed in grams/plant.

3.5.4 100-seed dry mass (g)

For seed dry mass determination, hundred seeds were selected randomly from the entire shelled row seeds. The seeds fresh mass were taken and then oven dried at 100°C to a constant mass for 48 hours. Their mass was recorded, averaged and expressed in grams per plant.

3.5.5 Maize seed yield

At physiological maturity, cobs from each net plot were harvested. Cobs were separated, air-dried, shelled, cleaned and weighed. Seed yield was expressed in kg/ha.

3.5.6 Stover yield

After the harvest of cobs in each net plot, stover yield was recorded after complete sun drying. Net plot stover yield was calculated and expressed as stover yield in kg/ha.

3.5.7 Harvest index

Harvest index is the ratio of economical yield (grain) to total aboveground biomass. It measures the success in partitioning photosynthates to harvestable product. In the experiment, harvest index was calculated by using the formula given by Donald (1962).

$$\text{Harvest index} = \frac{\text{Unit mass (harvested, usable yield) (kg/ha)}}{\text{Total biomass usually above ground yield (kg/ha)}}$$

3.5.8 Seed yield (kg/ha) at 12.5% moisture content

The final yield in kg/ha was expressed from knowledge of the 100 seed mass or single seed mass and the area from which this harvest was obtained. This was determined from the harvested row area (5.4 m²). By proportion, this yield component was then used to determine yield in kg/ha.

Seed yield was calculated using the following:

$$\text{Seed yield kg/ha} = \frac{\text{Seed yield/plot} \times 10 \text{ (conversion factor)} \times \text{dry matter at weighing}}{87.5\% \text{ (predetermined dry matter)} \times (5.4 \text{ m}^2) \text{ row area}}$$

Dry matter of actual moisture content (MC) = fresh mass of 100 seeds minus dry mass of 100 seeds, all divided by the fresh mass.

Dry matter of adjusted MC = 100% - constant moisture adjusted to (12.5%).

3.6 Determination of components and yield in legumes

When legumes reach physiological maturity, the pods harden and become dry. Harvesting was done in one row for both beans and cowpeas. At harvesting, data collection were on haulm mass, number of pods/plant, pods mass, seed mass after shelling, mass of fresh and dry 100seeds and total grain yield (kg/ha).

3.6.1 Number of pods per plant

In legumes, pods develop on nodes soon after the crop has flowered. In each of the treatments, the pods were counted to observe their variation with changes in spatial arrangement in an additive intercropping. The number of pods per plant was counted then a mean calculated.

3.6.2 Dry mass of 100 seeds

After shelling and impurities removal, fresh mass of 100 seeds was obtained from randomly selected seeds in each net plot and hence for all treatments. Then the 100 seeds were oven dried at 100°C for 48 hours to obtain a dry mass.

3.6.3 Shelling percentage

The shelling percentage was expressed as the ratio of the mass of shelled seeds to the mass of unshelled. This ratio was obtained by weighing the pods with seeds and then threshing them and weighing the actual threshed grains. The ratio was then multiplied by 100 to obtain the shelling percentage.

The following formula was used to calculate shelling %.

$$\text{Shelling\%} = \frac{\text{Crop seed mass (g)} \times 100}{\text{Mass of seed before shelling (g)}}$$

3.6.4 Harvest index

Harvest index is the measure of a plant's ability to partition its photosynthates into seed production. It is the ratio of the harvested or edible dry mass to the total above ground dry mass

of the crop at harvest time. In the experiment, harvest index was determined at the end of the harvesting period for each treatment. The harvest index was determined using the following formula:

$$\text{Harvest index} = \frac{\text{Crop seed mass (g)} \times 100}{\text{Total above ground biomass (g)}}$$

3.6.5 Dry mass (g) of 100 seeds

The mass of 100 seeds was determined after shelling the legumes for each treatment whereby 100 seeds were counted out of each treatment. The mass of the seeds were taken and then the seeds were oven dried to constant mass at 70 °C for 72 hours.

3.6.6 Seed yield (kg/ha) at 10% moisture content

The mass of 100 seeds was determined by weighing seed from the net plot (32.4 m²) and expressed at 10 % moisture content using the following formula. Seed yield was calculated using the following:

$$\text{Seed yield kg/ha} = \frac{\text{Seed yield/plot} \times 10 (\text{conversion factor}) \times \text{dry matter at weighing}}{90 \% (\text{predetermined dry matter}) \times (5.4 \text{ m}^2) \text{ row area}}$$

Dry matter of actual moisture content (MC) is = fresh mass of 100 seeds minus dry mass of 100 seeds, all divided by the fresh mass.

Dry matter of adjusted MC = 100% - constant moisture adjusted to (10%).

3.7 Assessment of efficiency of intercropping system

3.7.1 Land equivalent ratio (LER)

Land equivalent ratio is defined as the relative land area under sole crop that is required to produce yields achieved in intercropping. LER values greater than 1 indicate advantage of intercropping over monoculture. The LER was worked out by using the following formula given by Willey (1979).

$$\text{LER} = (Y_{ab}/Y_{aa}) + (Y_{ba}/Y_{bb})$$

Where,

Y_{aa} and Y_{bb} are yields as sole crops

Y_{ab} and Y_{ba} are yields in intercrops

$$\text{LER} = \frac{\text{Intercrop maize}}{\text{Sole maize}} + \frac{\text{intercrop legume}}{\text{sole legume}}$$

3.7.2 Relative crowding coefficient (RCC)

This is the measure of relative dominance of one component crop over the other in an intercropping system (Gosh, 2004). If the product of the two coefficients; $K = (K_{ab} K_{ba})$ is greater than 1, then there is a yield advantage whereas if k obtained in the system equals to 1, there is no yield advantage, and if K in the system is less than 1, there is a yield disadvantage.

$$K_{ab} = Y_{ab} Z_{ba} / (Y_{aa} - Y_{ab}) Z_{ab} \text{ and } K_{ba} = Y_{ba} Z_{ab} / (Y_{bb} - Y_{ba}) Z_{ba}$$

Where K_{ab} – the relative crowding coefficient for species a in polyculture with species b;

K_{ba} – the relative crowding coefficient for species b in polyculture with species a;

Y_{ab} – yield of species a in polyculture with species b;

Y_{aa} – yield of species a in monoculture;

Y_{ab} – yield of species a in polyculture with species b;

Y_{bb} – yield of species b in monoculture;

Y_{ba} – yield of species b in polyculture with species a;

Z_{ab} – ratio (%) of species a to species b in polyculture;

Z_{ba} – ratio (%) of species b to species a in polyculture.

Where X_{ab} is the sown proportion of ‘a’ in mixture of ‘b’ and X_{ba} the sown proportion of ‘b’ in mixture of ‘a’.

3.7.3 Light transmission ratio (LTR)

The light transmission by the canopies of sole maize, sole intercrops and intercropping system was determined using lux meter (Yoshida *et al.*, 1972). The light intensity above canopy (I_0) and at the ground level (I) was recorded between 12:30 and 1:00 pm and then averaged for the system based on row proportions. Light transmission ratio was calculated by the following formula.

$$\text{LTR (\%)} = I/I_0 \times 100$$

Where,

I = Light intensity received at the ground level

I_0 = Light intensity received at the top of crop canopy

3.7.4 Light absorption

Light absorption (%) was calculated by the following formula.

$$\text{Light absorption (\%)} = 100 - \text{LTR (\%)}$$

3.8 Moisture retention

The soil moisture content was measured every week from the sixth till the twelfth week after planting. Soil samples taken from 6 - 30 cm at 6 – 12 weeks after planting were placed in air tight moisture containers. The samples were weighed and dried in a hot air oven at 105°C for about 24 hours to a constant mass. The available soil moisture was calculated using the formula by (Reddi and Reddy, 2000).

$$\text{Moisture content of soil (\%)} = \frac{WS_1 - WS_2}{WS_2} \times 100$$

Where,

WS₁ = Wet mass of soil sample (g)

WS₂ = Oven dry mass of soil sample (g)

3.9 Scoring for disease, pests and lodging

3.9.1 Disease scoring

The disease scoring was done at every 4, 6 and 8 weeks after planting. The scoring was done as shown in Table 3. The number of infested plants was counted and scored using the score as shown below in Table 3.

Table 3. Disease rating score.

Disease rating score	Description
1	Complete absence of disease
2	Sparse disease coverage
3	Intermediate disease coverage
4	Severe disease coverage
5	Complete disease coverage

Source: Edje and Ossom (2009).

3.9.2 Insect pest rating

The use of crop varieties which are resistant to insects is extremely beneficial since they offer both short and long-term benefits. The short-term benefit of plant resistance is that it limits pest damage, while economic threshold values are often not reached. Insect scoring was done at 6 and 8 weeks after planting for maize and legumes. The number of infested plants was counted and scored using the score as shown in Table 4.

Table 4. Insect rating score.

Insect rating score	Description
1	Complete absence of insect pests
2	Sparse insect coverage
3	Intermediate insect coverage
4	Severe insect coverage
5	Complete insect coverage

Source: Edje and Ossom (2009).

3.9.3 Lodging score

Lodging of plants has a financial implication for the producer because a number of ears, pods may be laying on the soil, making it uneconomical to be picked up by hand thus resulting to yield losses. Good progress in breeding for lodging resistance in crops has been made with cultivars showing less lodging, but differences among cultivars still occur. Lodging scoring was done at 6, 8, and 10 weeks after planting. The score in Table 5 was used.

Table 5. Lodging score.

Lodging score	Description
1	Upright
2	Semi-upright
3	Semi-prostrate
4	Prostrate
5	Completely prostrate

Source: Edje and Ossom (2009).

3.10 Statistical analysis and interpretation of data

Data obtained was statistically analysed following the procedure described by Steel and Torrie (1980). MSTAT-C computer software package was used to determine the analysis of variance (ANOVA) and calculate the least significance difference test (LSD) and to separate the significant mean values. The analysis and interpretation of data was done using the Fisher's method of analysis of variance technique as described by Gomez and Gomez (1984). The level of significance used in "F" and "t" test was $P=0.05$. Critical difference values were calculated wherever the F test was significant.

3.11 Correlation coefficients

Correlation coefficient was determined in all the parameters for both maize and legumes at ($P < 0.05$, $P < 0.01$). A determination of correlation (R^2) was determined using the formula $R^2 = r^2 \times 100$. This was between plant morphological, physiological as well as yield and yield components. Data were computed and presented in a matrix form. Simple correlation coefficients (r) were worked out between entries.

CHAPTER 4

4.0 RESULTS

4.1 Overview of results presentation

This chapter covers meteorological data, soil test results and data on maize (morphological, physiological, as well as seed yield and yield components). Similar results on legumes are presented.

4.2 Soil physio-chemical properties before planting

The soil physio-chemical properties are shown in Tables 6 and 7 for season 2013/2014 and 2014/2015, respectively. The site was sandy loam in texture. The pH of the soil was low (3.9) compared to what maize, beans and cowpeas require for optimum growth, hence why lime was applied. The data show that the soil is acid in reaction and has high exchangeable Al (1.15). The contents of the exchangeable cations Calcium (Ca), Magnesium (Mg), are below the sufficiency level which is 0.3 me/100g for Potassium (K), 20 mg/kg for Phosphorus (P) thus a response to application of this elements is expected. This soil has a toxic level of Al and thus nutrient uptake by plant roots may be inhibited. In season 2014/2015, the site was slightly above the data obtained in 2013/2014 in all the nutrient elements measured, as well as in base saturation. The soil acidity was; however, lower in 2014/2015 compared to 2013/2014 due to lime application in 2013/2014.

Table 6. Properties of soil before planting (2013/2014).

pH		Exchangeable cations (cmolc/kg)					Exchangeable acidity (meq/100g)
H ₂ O	CaCl ₂	Al	Ca	Mg	K	P	
3.91	3.66	0.42	0.29	0.95	0.01	1.25	1.15

Table 7. Properties of soil before planting (2014/2015).

pH		Exchangeable cations (cmolc/kg)					Exchangeable acidity (meq/100g)
H ₂ O	CaCl ₂	Al	Ca	Mg	K	P	
4.51	4.30	0.20	0.47	1.65	1.21	2.25	0.15

4.3 Meteorological data

The average monthly minimum and maximum temperatures of the experimental site are presented in Table 8 for 2013/2014 and Table 9 for 2014/2015 cropping seasons. There was little variation in temperature between the months in either 2013/2014 or 2014/2015. In 2013/2014, the average rainfall during planting in November was higher (16.0 mm) compared to 2014/2015 (8.0 mm). Temperature was at maximum 27.7 °C in January 2015 and at minimum 13.6 °C in November, 2014. The highest mean wind speed was received in November 2014 (570 m/s). In January 2015, the highest soil temperature was observed being 27.3 °C and the lowest was obtained in 19.6 in November 2013 (Malkerns Research Station, Meteorology Department).

Table 8. Meteorological data at Malkerns Research Station (2013/2014).

Month	Mean rainfall (mm)	Temperature °C		Wind m/s	Soil temperature °C (at 30 cm depth)
		Max	Min		
November 2013	16.0	22.5	13.6	550	19.7
December 2013	13.8	24.4	15.3	520	20.5
January 2014	9.2	26.3	20.7	517	27.3
February 2014	18.7	26.8	17.2	490	24.6
March 2014	14.8	25.7	16.4	485	23.0
Mean/Total	72.5	25.1	16.6	512	23.0

Table 9. Meteorological data at Malkerns Research Station (2014/2015).

Month	Mean rainfall (mm)	Temperature °C		Wind m/s	Soil temperature °C (at 30 cm depth)
		Max	Min		
November 2014	8.0	24.5	15.6	570	22.1
December 2014	13.5	26.4	17.3	537	23.8
January 2015	8.5	27.7	18.7	505	26.2
February 2015	7.5	27.6	18.2	500	26.2
March 2015	2.2	28.3	17.2	550	26.2
Mean/Total	47.6	26.9	17.4	532	24.9

4.4 Data on maize

Spatial arrangement of maize for intercropping with beans and cowpeas results on maize included: morphological, physiological, seed yield and yield components.

4.4.1 Maize emergence count (%)

Seedling emergence was uniform in all treatments and there was no significant difference between treatments in both seasons (Table 10). Significant difference ($P < 0.05$) was only observed between treatments in season 2013/2014. Emergence count percentage in 2013/2014 was (88.2 %) and in 2014/2015 was (92.3 %) and showed a significant different ($P < 0.05$). The highest emergence percentage was (94.6%) obtained in maize, 2 plants/hill + beans in 2014/2015. Between plant mixtures, maize, 1 plant/hill + cowpeas had the highest mean emergence percentage (92.9 %) among treatments in both seasons.

Table 10. Maize emergence count % in sole maize, maize-beans association and maize-cowpea association.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	84.6a	90.1a	87.4a
Sole maize, 2 plants/hill	91.2b	90.8a	91.0a
Sole maize, 3 plants/hill	85.2a	91.9a	88.5a
Maize, 1 plant/hill, + beans	83.2a	89.4a	86.3a
Maize, 1 plant/hill, + cowpeas	91.8b	93.9a	92.9a
Maize, 2 plants/hill, + beans	86.9a	94.6a	90.8a
Maize, 2 plants/hill + cowpeas	91.6b	93.8a	92.7a
Maize, opposite, 3 plants, + beans	90.1b	92.5a	91.3a
Maize, opposite, 3 plants, + cowpeas	88.9a	92.6a	90.7a
Sole maize, staggered, 3 plants	85.3a	92.9a	89.1a
Maize, staggered, 3 plants, + beans	87.6a	93.6a	90.6a
Maize, staggered, 3 plants, + cowpeas	92.1b	91.5a	91.8a
Mean	88.2a	92.3a	90.3a
Significance	*	NS	NS

C.V. (%) = 4.9%

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T interaction
S E $\pm$	0.5680	1.3914	1.9677

NS = Not significant; * = Significant at $P < 0.05$

4.4.2 Maize plant height at 6, 8 and 10 weeks after planting (WAP)

4.4.2.1 Plant height at six WAP

There was increase in plant height with progression in the number of weeks after planting with the highest plant height of (76.2 cm) obtained from sole maize at six weeks after planting (Table 11). Maize plant height was significantly different ($P < 0.05$) between seasons with a mean height of 59.3 cm and 71.1 cm for the 2013/2014 and 2014/2015, respectively. Sole maize was the only cropping system with the highest plant height of 67.6 cm among treatments. Staggering planting pattern had the highest plant height among spatial arrangements 65.2 cm. Maize-cowpea mixture had the highest plant height compared to maize-beans mixture.

Table 11. Maize plant height in sole maize, maize-beans association and maize-cowpea association at six weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	59.1a	76.2d	67.6e
Sole maize, 2 plants/hill	58.5a	66.2a	62.3a
Sole maize, 3 plants/hill	59.5a	72.7c	66.1d
Maize, 1 plant/hill, + beans	59.5a	73.5c	66.5d
Maize, 1 plant/hill, + cowpeas	59.1a	71.3c	65.2c
Maize, 2 plants/hill, + beans	59.2a	72.0c	65.6c
Maize, 2 plants/hill + cowpeas	59.4a	71.2c	65.3c
Maize, opposite, 3 plants, + beans	59.1a	69.9b	64.5b
Maize, opposite, 3 plants, + cowpeas	59.8a	70.1c	65.0c
Sole maize, staggered, 3 plants	59.3a	70.3c	64.8b
Maize, staggered, 3 plants, + beans	59.4a	69.9b	64.6b
Maize, staggered, 3 plants, + cowpeas	59.7a	70.6c	65.1c
Mean	59.3a	71.1c	65.2c
Significance	NS	*	*

C.V. (%) = 4.6 %

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T interaction
S E $\pm$	0.3937	0.9643	1.3637

NS = Not significant; * = Significant at $P < 0.05$

4.4.2.2 Plant height at eight weeks after planting

Plant height of maize at eight WAP showed an increase and there was no significance difference between treatments at eight weeks after planting. The second cropping season (2014/2015) had the highest mean plant height of (130.1 cm) in maize, while that of first season (2013/2014) was (109.2 cm) making a difference of 19.1 % from the second season. (Table 12). Plant height between seasons was significantly different ($P < 0.05$). Sole maize, staggered, 3 plants/hill had the highest mean plant height (120.7 cm) among the planting arrangements.

Table 12. Maize plant height in sole maize, maize-beans association and maize-cowpea association at eight weeks after planting (cm).

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant hill	109.1a	129.7a	119.4a
Sole maize, 2 plants/hill	108.5a	129.7a	119.1a
Sole maize, 3 plants/hill	109.2a	130.9a	120.1a
Maize, 1 plant/hill, + beans	108.2a	129.0a	118.6a
Maize, 1 plant/hill, + cowpeas	109.0a	131.0a	120.0a
Maize, 2 plants/hill, + beans	109.2a	131.8a	120.5a
Maize, 2 plants/hill + cowpeas	109.5a	128.8a	119.1a
Maize, opposite, 3 plants, + beans	108.9a	131.3a	120.1a
Maize, opposite, 3 plants, + cowpeas	109.8a	133.0a	121.4a
Sole maize, staggered, 3 plants	109.6a	131.8a	120.7a
Maize, staggered, 3 plants, + beans	109.4a	129.2a	119.3a
Maize, staggered, 3 plants, + cowpeas	109.7a	124.7a	117.3a
Mean	109.2a	130.1a	119.7a
Significance	NS	NS	NS

C.V. (%) = 4.6 %

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T interaction
S E $\pm$	0.4040	0.9896	1.3994

NS = Not significant

4.4.2.3 Plant height at 10 weeks after planting

The second cropping season 2014/2015 had the highest mean plant height (218.4 cm) compared to the first season (170.1 cm) with a percentage difference of 22.2%. Among the cropping systems, maize, 2 plants/hill + cowpeas had the highest plant height (225.9 cm) in 2014/2015 and the least (160.5) was obtained from maize, 2 plants/hill + cowpeas in 2013/2014 (Table 13). Among the planting patterns, maize, opposite, 3 plants/hill, + cowpeas had the highest plant height of (199.3 cm). Plant height between seasons was significantly different ($P < 0.01$). There was an increase in plant height as the weeks after planting increased and there was no significance difference between treatments at 10 weeks after planting.

Table 13. Maize plant height in sole maize, maize-beans association and maize-cowpea association at 10 weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	169.5a	211.7a	190.6a
Sole maize, 2 plants/hill	169.2a	214.2a	191.7a
Sole maize, 3 plants/hill	170.8a	216.8a	193.8a
Maize, 1 plant/hill, + beans	170.7a	216.5a	193.6a
Maize, 1 plant/hill, + cowpeas	170.0a	218.2a	194.1a
Maize, 2 plants/hill, + beans	170.6a	218.8a	194.7a
Maize, 2 plants hill + cowpeas	160.5a	225.9a	193.2a
Maize, opposite, 3 plants, + beans	171.3a	221.6a	196.5a
Maize, opposite, 3 plants, + cowpeas	171.9a	226.6a	199.3a
Sole maize, staggered, 3 plants	171.2a	210.8a	191.1a
Maize, staggered, 3 plants, + beans	172.0a	225.0a	198.5a
Maize, staggered, 3 plants, + cowpeas	172.4a	214.5a	193.4a
Mean	170.1a	218.4a	194.2a
Significance	NS	NS	NS

C.V. (%) = 6.0 %

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T interaction
S E $\pm$	1.508	3.695	5.225

NS = Not significant

4.4.3 Maize leaves dry matter mass (g)

4.4.3.1 Maize leaves dry matter mass at 10 weeks after planting

Maize, 2 plants/hill+ beans spatial arrangement had the highest leaves dry matter (676.9 g) at 10 weeks after planting in 2014/2015 season. The least dry matter of (297.1 g) was obtained in maize, 2 plants/hill + cowpeas cropping mixture (Table 14). Interaction between season 2013/2014 and 2014/2015 showed a significant difference ($P < 0.05$), with a percentage difference of 39.4 %. 2013/2014 had the highest mean leaves dry matter 589.7 g compared to 357.5 g for 2014/2015. Maize-beans mixture had the highest leaves dry matter (676.9 g) among cropping mixtures. There was no significant difference among treatments in both seasons.

Table 14. Maize leaves dry matter mass in sole maize, maize-dry beans association, maize-cowpea association in percentage, at 10 weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	550.0b	467.0c	508.5c
Sole maize, 2 plants/hill	673.9c	283.7a	478.8b
Sole maize, 3 plants/hill	717.6d	462.8c	590.2c
Maize, 1 plant/hill, + beans	530.2b	276.9a	403.6b
Maize, 1 plant/hill, + cowpeas	797.7d	350.9b	573.9c
Maize, 2 plants/hill, + beans	848.9e	504.9d	676.9d
Maize, 2 plants/hill + cowpeas	361.1a	233.1a	297.1a
Maize, opposite, 3 plants, + beans	417.3a	312.2b	364.8a
Maize, opposite, 3 plants, + cowpeas	379.7a	263.6a	321.7a
Sole maize, staggered, 3 plants	563.9b	419.2c	491.6b
Maize, staggered, 3 plants, + beans	705.8d	320.1b	512.9c
Maize, staggered, 3 plants, + cowpeas	530.0b	395.8b	462.9b
Mean	589.7	357.5	432.6
Significance	*	*	*

C.V. (%) = 10.3 %

Mean values within the same column followed by a different letter are significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T interaction
S E $\pm$	1.0378	2.5420	3.5949

NS = Not significant; * = Significant at $P < 0.05$

4.4.3.2 Maize leaves dry matter mass at 12 weeks after planting

Sole maize, 2 plants/hill showed the highest mean leaves dry matter 551.6 g at 12 weeks after planting. The least dry matter of 431.4 g was observed in maize, opposite, 3 plants, + cowpeas cropping mixture and planting pattern. Leaves dry matter between treatments and seasons at 12 weeks after planting showed a significance difference ($P < 0.05$) (Table 15). There was a significant difference ($P < 0.05$) in leaves dry matter at 12 weeks after planting between 2013/2014 and 2014/2015. Maize-cowpeas cropping mixture had the highest leaves dry matter 513.6 g.

Table 15. Maize leaves dry matter in sole maize, maize-dry beans association and maize-cowpea association, at 12 weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	536.1b	432.0b	484.1a
Sole maize, 2 plants/hill	654.9c	448.2b	551.6b
Sole maize, 3 plants/hill	554.2b	328.1a	441.2a
Maize, 1 plant/hill, + beans	456.3a	446.8b	451.6a
Maize, 1 plant/hill, + cowpeas	522.3b	358.8a	440.6a
Maize, 2 plants/hill, + beans	536.7b	366.1a	451.4a
Maize, 2 plants + cowpeas	498.2a	396.4a	447.3a
Maize, opposite, 3 plants, + beans	444.6a	424.6b	434.6a
Maize, opposite, 3 plants, + cowpeas	532.5b	330.2a	431.4a
Sole maize, staggered, 3 plants	596.3b	446.4b	521.4b
Maize, staggered, 3 plants, + beans	474.5a	412.3b	443.4a
Maize, staggered, 3 plants, + cowpeas	652.7c	374.5a	513.6b
Mean	538.3	397.0	467.7
Significance	*	*	*

C.V. (%) = 9.7 %

Mean values within the same column followed by the different letter are significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T interaction
S E $\pm$	1.0511	2.5747	3.6412

NS = Not significant; * = Significant at $P < 0.05$

4.4.4 Maize stems dry matter mass (g)

4.4.4.1 Maize stems dry matter mass at 10 weeks after planting

Maize, 2 plants/hill + cowpeas mixture, showed the highest mean stems dry matter (747.3 g) at 10 weeks after planting. The least dry matter of (489.4 g) was observed in sole maize, cropping system at 10 weeks after planting. There was a significant difference ($P < 0.05$) between treatments, between seasons and between crop mixtures in stem dry matter at 10 weeks after planting (Table 16). A percentage difference of 51.9 % between seasons in stem dry matter was observed.

Table 16. Maize stems dry matter mass in sole maize, maize-dry beans association, maize-cowpea association, at 10 weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	624.0b	354.8a	489.4a
Sole maize, 2 plants/hill	752.3c	456.0b	604.2b
Sole maize, 3 plants/hill	814.5d	572.4c	693.5b
Maize, 1 plant/hill, + beans	540.6a	694.4d	617.5b
Maize, 1 plant/hill, + cowpeas	656.3b	558.0c	607.2b
Maize, 2 plants/hill, + beans	622.3b	610.5d	616.4b
Maize, 2 plants/hill + cowpeas	758.2c	736.3e	747.3c
Maize, opposite, 3 plants, + beans	766.6c	452.7b	609.7b
Maize, opposite, 3 plants, + cowpeas	770.8c	632.1d	701.5c
Sole maize, staggered, 3 plants	690.0b	628.7d	659.4b
Maize, staggered, 3 plants, + beans	810.3d	580.0c	695.2b
Maize, staggered, 3 plants, + cowpeas	696.3b	546.1c	621.2b
Mean	708.5	341.1	638.5
Significance	*	*	*

C.V. (%) = 6.4 %

Mean values within the same column followed by a different letter are significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T interaction
S E $\pm$	0.7182	1.7592	2.4878

NS = Not significant* = Significant at $P < 0.05$

4.4.4.2 Maize stems dry matter mass at 12 weeks after planting

Maize, opposite, 3 plants, + beans showed the highest stems dry matter (590.2 g) at 12 weeks after planting between treatments. The least dry matter of (475.3 g) was observed in maize, 1 plant/hill, + cowpeas cropping mixture at 12 weeks after planting (Table 17). At 12 weeks after planting, stems dry matter showed a significant difference ($P < 0.05$) between spatial arrangements and cropping mixtures. There was a significant difference between seasons and the percentage difference between seasons was 19.3 %.

Table 17. Maize stems dry matter mass in sole maize, maize-dry beans association, and maize-cowpea association, at 12 weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	532.4a	506.8c	519.6b
Sole maize, 2 plants/hill	600.3b	476.4b	538.4b
Sole maize, 3 plants/hill	720.1c	462.8b	591.5b
Maize, 1 plant/hill, + beans	566.3a	484.3b	525.3b
Maize, 1 plant/hill, + cowpeas	556.2a	394.4a	475.3a
Maize, 2 plants/hill, + beans	680.0b	480.2b	580.1b
Maize, 2 plants/hill + cowpeas	684.1b	558.2c	621.2c
Maize, opposite, 3 plants, + beans	624.1b	556.3c	590.2b
Maize, opposite, 3 plants, + cowpeas	606.6b	560.7c	583.7b
Sole maize, staggered, 3 plants	584.2a	520.3c	552.3b
Maize, staggered, 3 plants, + beans	522.2a	440.3b	481.3a
Maize, staggered, 3 plants, + cowpeas	570.1a	406.9b	488.5a
Mean	603.7	487.3	545.6

Significance

C.V. (%) = 10.4 %

Mean values within the same column followed by a different letter are significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T interaction
S E $\pm$	1.0424	2.5533	3.6109

NS = Not significant

4.4.5 Maize Cob height (cm)

4.4.5.1 Maize cob height (cm) at 10 weeks after planting

The highest mean cob height (113.2 cm) was obtained from maize-beans association in the opposite spatial arrangement, 3 plants/hill, + beans while the least cob height mean (103.9 cm) was obtained from sole maize staggered, 3 plants/hill. Significance difference ($P < 0.01$) for the treatments was observed at 10 weeks after planting between seasons respectively having a percentage difference of 15.3 % (Tables 18).

Table 18. Maize cob height (cm) in sole maize, maize-dry beans association, maize-cowpea association, at 10 weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	114.0a	94.6a	104.3a
Sole maize, 2 plants/hill	113.0a	97.9a	105.5a
Sole maize, 3 plants/hill	114.9a	94.9a	104.9a
Maize, 1 plant/hill, + beans	118.8a	102.7a	110.8a
Maize, 1 plant/hill, + cowpeas	105.3a	98.4a	101.9a
Maize, 2 plants/hill, + beans	120.7a	100.7a	110.7a
Maize, 2 plants/hill + cowpeas	108.6a	105.1a	106.9a
Maize, opposite, 3 plants, + beans	123.2a	103.1a	113.2a
Maize, opposite, 3 plants, + cowpeas	122.9a	95.2a	109.1a
Sole maize, staggered, 3 plants	104.9a	103.3a	103.9a
Maize, staggered, 3 plants, + beans	117.2a	103.2a	110.2a
Maize, staggered, 3 plants, + cowpeas	117.1a	96.2a	106.7a
Mean	116.5a	98.7a	107.6a
Significance	NS	NS	NS

C.V. (%) = 8.6 %

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T interaction
S E $\pm$	1.1978	2.9339	4.1492

NS = Not significant

4.4.5.2 Maize cob height (cm) at 12 weeks after planting

The highest mean cob height (124.4 cm) was obtained from maize-beans association in the opposite spatial arrangement, 3 plants/hill, + beans while the least cob height mean (116.5 cm) was obtained from maize staggered, 3 plants/hill, + cowpeas. Significance difference ($P < 0.01$) for the treatments was observed at 12 weeks after planting between seasons respectively having a percentage difference of 14.2 % (Tables 19).

Table 19. Maize cob height (cm) in sole maize, maize-dry beans association, maize-cowpea association, at 12 weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	122.6a	111.7a	117.2a
Sole maize, 2 plants/hill	130.6a	108.2a	119.4a
Sole maize, 3 plants/hill	127.5a	111.1a	119.3a
Maize, 1 plant/hill, + beans	132.4a	114.3a	123.3a
Maize, 1 plant/hill, + cowpeas	126.2a	113.9a	120.1a
Maize, 2 plants/hill, + beans	133.8a	114.4a	124.1a
Maize, 2 plants/hill + cowpeas	124.2a	119.8a	122.0a
Maize, opposite, 3 plants, + beans	136.4a	112.4a	124.4a
Maize, opposite, 3 plants, + cowpeas	134.1a	110.1a	122.1a
Sole maize, staggered, 3 plants	129.5a	107.1a	118.3a
Maize, staggered, 3 plants, + beans	127.1a	109.7a	118.4a
Maize, staggered, 3 plants, + cowpeas	130.7a	102.3a	116.5a
Mean	129.6a	111.2a	120.4a
Significance	NS	NS	NS

C.V. (%) = 7.8 %

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T interaction
S E $\pm$	1.2182	2.9840	4.2200

NS = Not significant

4.4.6 Maize cob dry matter mass (g)

4.4.6.1 Maize cob dry matter mass at 10 weeks after planting

In Table 20, range in season one was from 266.3 g to 458.9 g while that in season two was from 178.3 g to 352.1 g. From the mean difference of season one and two 368.2 g and 283.2 g, respectively, with a difference of 23.1 %. Maize, 2 plants/hill, + beans cropping mixture showed the highest mean cob dry matter of (405.5 g) at 10 weeks after planting. Mean cob dry matter was significantly different ($P < 0.05$) between 2013/2014 and 2014/2015 growing seasons. The least cob dry matter of (222.3 g) was observed in sole maize, 2 plants/hill at 10 weeks after planting (Table 20).

Table 20. Cob dry matter mass in sole maize, maize-dry beans association, maize-cowpea association, at 10 weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	282.0a	204.4b	243.2a
Sole maize, 2 plants/hill	266.3a	178.3a	222.3a
Sole maize, 3 plants/hill	418.5c	300.5c	359.5b
Maize, 1 plant/hill, + beans	408.8c	294.7b	351.8b
Maize, 1 plant/hill, + cowpeas	412.3c	330.4c	371.4b
Maize, 2 plants/hill, + beans	458.9c	352.1c	405.5c
Maize, 2 plants/hill + cowpeas	328.5b	336.0c	332.3b
Maize, opposite, 3 plants, + beans	448.6c	246.8b	347.7b
Maize, opposite, 3 plants, + cowpeas	364.5b	308.4c	336.5b
Sole maize, staggered, 3 plants	308.5b	280.5b	294.5a
Maize, staggered, 3 plants, + beans	418.6c	354.2c	386.4b
Maize, staggered, 3 plants, + cowpeas	302.6b	212.7b	257.7a
Mean	368.2	283.2	325.7

Significance

C.V. (%) = 19.5 %

Mean values within the same column followed a different letter are significantly different at LSD P < 0.05

Parameter	Season (S)	Treatment (T)	S x T interaction
S E ±	1.6789	4.1124	5.8158

NS = Not significant

4.4.6.2 Maize cob dry matter mass at 12 weeks after planting

Table 21 shows cob dry matter at 12 weeks after planting. 2014/2015 cropping season had the highest mean cob dry matter of 368.8 g at 12 weeks after planting. Maize, 2 plants/hill + beans had the highest mean cob dry matter of 405.4 g between cropping systems. In Table 21, range in season one was from 266.0 g to 458.6 g while that in season two was from 178.3 g to 352.2 g.

Table 21. Cob dry matter mass in sole maize, maize-dry beans association, maize-cowpea association, at 12 weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	282.1a	204.1b	243.1b
Sole maize, 2 plants/hill	266.0a	178.3a	222.2a
Sole maize, 3 plants/hill	418.5c	300.4c	359.5b
Maize, 1 plant/hill, + beans	408.7c	294.6b	351.7b
Maize, 1 plant/hill, + cowpeas	412.3c	330.9c	371.6b
Maize, 2 plants/hill, + beans	458.6c	352.2c	405.4c
Maize, 2 plants/hill + cowpeas	336.6b	328.0c	332.3b
Maize, opposite, 3 plants, + beans	448.3c	246.8b	347.6b
Maize, opposite, 3 plants, + cowpeas	364.7b	308.1c	336.4b
Sole maize, staggered, 3 plants	308.2b	280.3b	294.3a
Maize, staggered, 3 plants, + beans	418.3c	354.5c	386.4b
Maize, staggered, 3 plants, + cowpeas	302.8b	212.7b	257.8a
Mean	368.8	282.5	325.7
Significance	*	*	*

C.V. (%) = 18.2 %

Mean values within the same column followed by a different letter are significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T interaction
S E $\pm$	1.7045	4.1753	5.9047

NS = Not significant; * = Significant at $P < 0.05$

4.4.7 Maize tassels dry matter mass (g)

4.4.7.1 Maize tassels dry matter mass at 10 weeks after planting

Maize, 2 plants hill+ cowpeas cropping system in 2013/2014 season had the highest tassel dry matter of 112.3 g at 10 weeks after planting. Mean tassel dry matter was significantly different ($P < 0.05$) between 2013/2014 and 2014/2015 season with a percentage difference of 17.4 %. The least mean dry matter mass was (74.4 g), observed in sole maize, 3 plants/hill cropping system. 2013/2014 cropping season had the highest mean tassel dry matter mass 98.0 g and 80.9 g for 2014/2015 season. Season one ranges from 76.2 g to 112.3 g while season two ranges from 73.2 g to 105.3 g (Table 22).

Table 22. Maize tassel dry matter mass in sole maize, maize-beans association, and maize-cowpea association, at 10 weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	88.1b	64.6a	76.4a
Sole maize, 2 plants/hill	96.4c	86.5c	91.5c
Sole maize, 3 plants/hill	76.2a	72.3b	74.3a
Maize, 1 plant/hill, + beans	112.3d	86.5c	99.4c
Maize, 1 plant/hill, + cowpeas	98.4c	76.7b	87.6b
Maize, 2 plants/hill, + beans	100.3d	90.6d	95.5c
Maize, 2 plants hill+ cowpeas	112.3d	98.3d	105.3d
Maize, opposite, 3 plants, + beans	106.5d	74.3b	90.4c
Maize, opposite, 3 plants, + cowpeas	84.1b	72.4b	78.3a
Sole Maize, staggered, 3 plants	102.1d	80.9c	91.5c
Maize, staggered, 3 plants, + beans	100.6d	86.6c	93.6c
Maize, staggered, 3 plants, + cowpeas	98.8c	80.7c	89.8b
Mean	98.0	80.9	89.5
Significance	*	*	*

C.V. (%) = 10.4 %

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T interaction
S E $\pm$	1.0424	2.5533	3.6109

NS = Not significant

4.4.7.2 Maize tassels dry matter mass at 12 weeks after planting

Table 23 shows tassels dry matter mass at 12 weeks after planting. 2013/2014 cropping season had the highest mean tassel dry matter mass of 91.1 g while season 2014/2015 had the least tassel dry matter of 78.9 g. Sole maize, 1 plants/hill had the highest mean tassel dry matter mass 104.4 g among treatments. In Table 23, range in season one was from 76.9 g to 108.0 g while that in season two was from 61.6 g to 100.8 g. Mean differences of season one was 91.1 g and season two 78.9 g, having a difference percentage of 13.4 %.

Table 23. Maize tassel dry matter mass in sole maize, maize-beans association, and maize-cowpea association, at 12 weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	108.0d	100.8e	104.4e
Sole maize, 2 plants/hill	96.8c	84.4c	90.6d
Sole maize, 3 plants/hill	80.5b	74.4b	77.5b
Maize, 1 plant/hill, + beans	86.9b	64.9a	75.9b
Maize, 1 plant/hill, + cowpeas	76.5a	66.7a	71.6b
Maize, 2 plants/hill, + beans	100.3d	92.1d	96.2d
Maize, 2 plants hill+ cowpeas	90.5c	68.7a	79.6b
Maize, opposite, 3 plants/hill, + beans	84.4b	76.0b	80.2c
Maize, opposite, 3 plants, + cowpeas	106.9d	88.9c	97.9d
Sole Maize, staggered, 3 plants	84.5b	76.8b	80.7c
Maize, staggered, 3 plants, + beans	100.7d	91.2d	95.9d
Maize, staggered, 3 plants, + cowpeas	76.9a	61.6a	69.3a
Mean	91.1	78.9	84.9
Significance	*	*	*

C.V. (%) = 16.4 %

Mean values within the same column followed by a different letter are significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T interaction
S E $\pm$	1.2314	3.0164	4.2658

NS = Not significant; * = Significant at $P < 0.05$

4.4.8 Cob length (cm)

The highest mean cob length (19.4 cm) was recorded in maize, 2 plants hill + cowpeas and the least was obtained 17.7 cm in maize, 1 plant/hill, + beans and sole maize, staggered, 3 plants. There was no significant different in the maize cob length in all the treatments (Table 24). Maize-cowpea mixture had the highest cob length among treatments. Cob length in season 2013/2014 ranges from 17.2 cm to 18.8 cm and season 2014/2015 ranges from 18.2 cm to 20.4 cm.

Table 24. Maize cob length in sole maize, maize-dry beans association, maize-cowpea association.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	17.2a	18.6a	17.9a
Sole maize, 2 plants/hill	17.6a	18.4a	18.0a
Sole maize, 3 plants/hill	17.5a	19.2a	18.3a
Maize, 1 plant/hill, + beans	17.0a	18.4a	17.7a
Maize, 1 plant/hill, + cowpeas	18.5a	17.0a	17.8a
Maize, 2 plants/hill, + beans	17.7a	18.4a	18.0a
Maize, 2 plants hill+ cowpeas	18.8a	20.0a	19.4a
Maize, opposite, 3 plants, + beans	17.9a	19.6a	18.7a
Maize, opposite, 3 plants, + cowpeas	17.4a	20.0a	18.7a
Sole Maize, staggered, 3 plants	17.3a	18.2a	17.7a
Maize, staggered, 3 plants, + beans	17.8a	20.4a	19.1a
Maize, staggered, 3 plants, + cowpeas	17.2a	19.0a	18.1a
Mean	17.7a	18.9a	18.3a
Significance	NS	NS	NS

C.V. (%) = 8.6%

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	1.1978	2.9339	4.1492

NS = not significant

4.4.9 Cob diameter (cm)

The highest mean cob diameter (4.7 cm) in the two seasons was recorded in maize, 1 plant/hill, + beans. However, within each season, season one had 4.9 cm obtained by treatment maize, 1 plant/hill + cowpeas while season two it was 4.8 cm obtained by treatment maize, 2 plants/hill + beans. There was no significant different ($P < 0.05$) in the maize cob diameter in all the treatments (Table 25).

Table 25. Maize cob diameter (cm) in sole maize, maize-dry beans association, maize-cowpea association.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	4.6a	4.5a	4.6a
Sole maize, 2 plants/hill	4.8a	4.6a	4.7a
Sole maize, 3 plants/hill	4.5a	4.7a	4.6a
Maize, 1 plant/hill, + beans	4.7a	4.5a	4.6a
Maize, 1 plant/hill, + cowpeas	4.9a	4.5a	4.7a
Maize, 2 plants/hill, + beans	4.4a	4.8a	4.6a
Maize, 2 plants/hill, + cowpeas	4.5a	4.6a	4.6a
Maize, opposite, 3 plants, + beans	4.5a	4.7a	4.6a
Maize, opposite, 3 plants, + cowpeas	4.6a	4.5a	4.6a
Sole maize, staggered, 3 plants	4.3a	4.6a	4.5a
Maize, staggered, 3 plants, + beans	4.7a	4.6a	4.6a
Maize, staggered, 3 plants, + cowpeas	4.4a	4.7a	4.5a
Mean	4.6a	4.6a	4.6a
Significance	NS	NS	NS

C.V. (%) = 5.8%

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	0.0342	0.0838	0.1185

NS = not significant

4.4.10 Number of seeds/cob

Number of seeds/cob was significantly different ($P < 0.05$) in all treatments (Table 26). The highest mean number of seeds (630) was obtained in maize grown in association with beans. 2013/2014 cropping season had the highest number of seeds (612) compared to 2014/2015 season.

Table 26. Maize seed count in sole maize, maize-dry beans association, and maize-cowpea association.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	563.2a	617.6c	590.4b
Sole maize, 2 plants/hill	631.6c	553.2a	592.4b
Sole maize, 3 plants/hill	643.4c	528.6a	586.0b
Maize, 1 plant/hill, + beans	645.6c	614.6c	630.1d
Maize, 1 plant/hill, + cowpeas	546.4a	570.4b	558.4a
Maize, 2 plants/hill, + beans	598.4b	622.0c	610.2c
Maize, 2 plants/hill + cowpeas	593.2b	610.8c	602.0c
Maize, opposite, 3 plants, + beans	646.4c	615.0c	630.7d
Maize, opposite, 3 plants, + cowpeas	646.0c	574.4b	610.2c
Sole maize, staggered, 3 plants	570.0b	611.2c	590.6b
Maize, staggered, 3 plants, + beans	631.8c	583.6c	607.7c
Maize, staggered, 3 plants, + cowpeas	636.8c	535.2a	586.0b
Mean	612.7c	586.4b	599.6b
Significance	*	*	*

C.V. (%) = 16.1 %

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	12.472	30.550	43.204

NS = not significant; * = significant at $P < 0.05$

4.4.11 100 seeds dry mass in grams

100 seeds dry mass was not significantly different in all treatments and between 2013/2014 and 2014/2015 crops growing season. The highest seeds dry mass (35.8 g) was obtained in maize grown in association with beans (Table 27).

Table 27. Maize seeds dry mass (g) in sole maize, maize-dry beans association, and maize-cowpea association.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	36.6a	33.2a	34.9a
Sole maize, 2 plants/hill	34.4a	34.0a	34.2a
Sole maize, 3 plants/hill	35.8a	34.2a	35.0a
Maize, 1 plant/hill, + beans	37.2a	34.4a	35.8a
Maize, 1 plant/hill, + cowpeas	36.2a	34.4a	35.3a
Maize, 2 plants/hill, + beans	36.0a	35.2a	35.6a
Maize, 2 plants/hill + cowpeas	36.8a	34.4a	35.6a
Maize, opposite, 3 plants, + beans	34.4a	33.2a	33.8a
Maize, opposite, 3 plants, + cowpeas	34.8a	32.8a	33.8a
Sole maize, staggered, 3 plants	33.8a	33.6a	33.7a
Maize, staggered, 3 plants, + beans	37.4a	36.0a	36.7a
Maize, staggered, 3 plants, + cowpeas	36.8a	33.6a	35.2a
Mean	35.7a	34.2a	34.9a
Significance	NS	NS	NS

C.V. (%) = 7.8 %

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	0.3520	0.8622	1.2193

NS = not significant

4.4.12 Shelling percentage (%)

The highest maize shelling percentage was (84.8%) recorded in maize grown at a staggering arrangement in association with cowpeas followed closely by maize grown at an opposite arrangement in association with cowpeas (84.3%) (Table 28). The lowest percentage were obtained (75.0%) from maize grown in association with cowpeas. There was no significant difference in the maize shelling percentage in all the treatments both in 2013/2014 and 2014/2015 seasons. Maize-cowpea mixture had the highest shelling percentage.

Table 28. Maize shelling percentage in sole maize, maize-dry beans association, maize-cowpea association.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	87.6a	69.1a	78.3a
Sole maize, 2 plants/hill	80.4a	73.8a	77.1a
Sole maize, 3 plants/hill	85.7a	79.2a	82.5a
Maize, 1 plant/hill, + beans	74.0a	76.1a	75.0a
Maize, 1 plant/hill, + cowpeas	83.3a	81.2a	82.2a
Maize, 2 plants/hill, + beans	77.9a	74.5a	76.2a
Maize, 2 plants/hill, + cowpeas	79.5a	77.8a	78.7a
Maize, opposite, 3 plants, + beans	80.7a	80.1a	80.4a
Maize, opposite, 3 plants, + cowpeas	77.9a	90.7a	84.3a
Sole maize, staggered, 3 plants	86.0a	76.8a	81.4a
Maize, staggered, 3 plants, + beans	75.4a	78.1a	76.8a
Maize, staggered, 3 plants, + cowpeas	88.0a	81.6a	84.8a
Mean	81.4a	78.2a	79.8a
Significance	NS	NS	NS

C.V. (%) = 12.4 %

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (Y)	Treatment (S)	S x T
S E $\pm$	1.2743	3.1214	4.4143

NS = not significant

4.4.13 Harvest index

There was no significant difference in the maize harvest index ($P < 0.05$) in all the treatments recorded in Table 29. The highest harvest index was 40.5 recorded in maize grown in a staggering arrangement with beans while the lowest (37.9) was obtained from sole maize.

Table 29. Maize harvest index in sole maize, maize-dry beans association, maize-cowpea association.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	37.0a	38.7a	37.9a
Sole maize, 2 plants/hill	37.8a	42.1a	39.9a
Sole maize, 3 plants/hill	37.5a	40.7a	39.1a
Maize, 1 plant/hill, + beans	38.3a	40.2a	39.2a
Maize, 1 plant/hill, + cowpeas	37.2a	40.9a	39.1a
Maize, 2 plants/hill, + beans	38.1a	41.1a	39.6a
Maize, 2 plants/hill, + cowpeas	38.5a	41.8a	40.2a
Maize, opposite, 3 plants, + beans	38.3a	38.3a	38.3a
Maize, opposite, 3 plants, + cowpeas	38.3a	39.6a	38.9a
Sole maize, staggered, 3 plants	39.2a	41.2a	40.2a
Maize, staggered, 3 plants, + beans	41.1a	39.9a	40.5a
Maize, staggered, 3 plants, + cowpeas	38.9a	40.4a	39.6a
Mean	38.4a	40.4a	39.4a
Significance	NS	NS	NS

C.V. (%) = 7.1 %

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	0.3617	0.8860	1.2530

NS = not significant

4.4.14 Seed yield (kg/ha)

The highest mean seed yield of 8,435 kg/ha was recorded in sole maize, 1 plant/hill followed by 8,253 kg/ha for maize, 2 plants/hill + cowpeas and the lowest being 7,143 kg/ha obtained from sole maize, 2 plants/hill. There was a significant difference in maize seed yield ($P < 0.01$) between seasons in all the treatments (Table 30). 2013/2014 cropping season had the highest mean seed yield 7,873 kg/ha compared to 7,695 kg/ha for 2014/2015 with a difference of 178 kg/ha. Maize-cowpeas cropping mixture had the highest seed yield of 8,253 kg/ha in maize, 2 plants/hill + cowpeas. Sole maize, 1 plant/hill had the highest yield of 9,386 kg/ha among cropping mixtures in 2013/2014 and maize, 2 plants/hill + cowpeas 8,379 kg/ha had the highest yield among cropping mixture arrangement. Maize, opposite, 3 plants, + beans had the highest seed yield 7,845 kg/ha among planting patterns.

Table 30. Seed yield (kg/ha) in sole maize, maize-dry beans association and maize-cowpea association.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	9,386g	7,484d	8,435i
Sole maize, 2 plants/hill	7,226a	7,059a	7,143a
Sole maize, 3 plants/hill	8,264e	7,856f	8,060g
Maize, 1 plant/hill, + beans	7,950d	7,561e	7,755d
Maize, 1 plant/hill, + cowpeas	7,969d	7,849f	7,909f
Maize, 2 plants/hill, + beans	7,902d	7,878f	7,890e
Maize, 2 plants/hill + cowpeas	8,379f	8,127g	8,253h
Maize, opposite, 3 plants, + beans	8,370f	7,375c	7,845e
Maize, opposite, 3 plants, + cowpeas	7,520c	7,331c	7,426b
Sole maize, staggered, 3 plants	7,486b	7,358c	7,422b
Maize, staggered, 3 plants, + beans	7,920d	7,398d	7,659c
Maize, staggered, 3 plants, + cowpeas	7,965d	7,264b	7,614c
Mean	7,873	7,695	7,784
Significance	**	**	**

C.V. (%) = 15.0 %

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	151.0746	370.0556	523.3376

NS = not significant; * = significant at $P < 0.05$; ** = significant at $P < 0.01$

4.4.15 Stover yield (kg/ha)

Stover yield showed a significant difference ($P < 0.01$) in all the treatments. The highest mean stover yield was 7,701 kg/ha recorded in maize, opposite, 3 plants, + beans and the lowest 6,353 kg/ha) was obtained from sole maize, 2 plants/hill. Cropping systems between seasons had a significant difference ($P < 0.01$) (Table 31). Maize-beans mixture had the highest stover yield among treatments. Stover yield ranges from 6,398 kg/ha to 7,836 kg/ha for 2013/2014 and ranges from 6,033 kg/ha to 7,536 kg/ha for 2014/2015.

Table 31. Stover yield in sole maize, maize-dry beans association and maize-cowpea association.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	7,270e	6,726e	6,998e
Sole maize, 2 plants/hill	6,398a	6,309b	6,353b
Sole maize, 3 plants/hill	7,799h	7,316i	7,558i
Maize, 1 plant/hill, + beans	7,224e	6,835f	7,029f
Maize, 1 plant/hill, + cowpeas	7,394f	6,754e	7,074f
Maize, 2 plants/hill, + beans	7,166d	6,033a	6,599a
Maize, 2 plants/hill + cowpeas	7,258e	7,205h	7,231g
Maize, opposite, 3 plants, + beans	7,836i	7,536j	7,701j
Maize, opposite, 3 plants, + cowpeas	7,607g	7,091g	7,349h
Sole maize, staggered, 3 plants	6,778b	6,601d	6,689c
Maize, staggered, 3 plants, + beans	7,613g	7,064g	7,338h
Maize, staggered, 3 plants, + cowpeas	7,099c	6,410c	6,755d
Mean	7,143	6,969	7,056
Significance	**	**	**

C.V. (%) = 23.5 %

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	149.6915	366.6678	518.5465

NS = not significant; * = significant at $P < 0.05$; ** = significant at $P < 0.01$

4.5 Beans growth parameters

This section covers objective number two which determines the better leguminous crop species for additive intercropping with maize.

4.5.1 Beans emergence count percentage

The results for emergence count are presented in Figure 1. Seeds emergence was rapid and almost uniform, assisted by rainfall. The seeds emergence was essentially complete in 8 days after sowing. There was no significant difference in emergence count among the treatments. The lowest emergence count was observed from sole beans which was 84.6.1 % season 2014/2015 and the highest was observed in maize, 2 plants/hill + beans 93.7 % in 2014/2015. Interaction between treatments and seasons showed a significant difference.

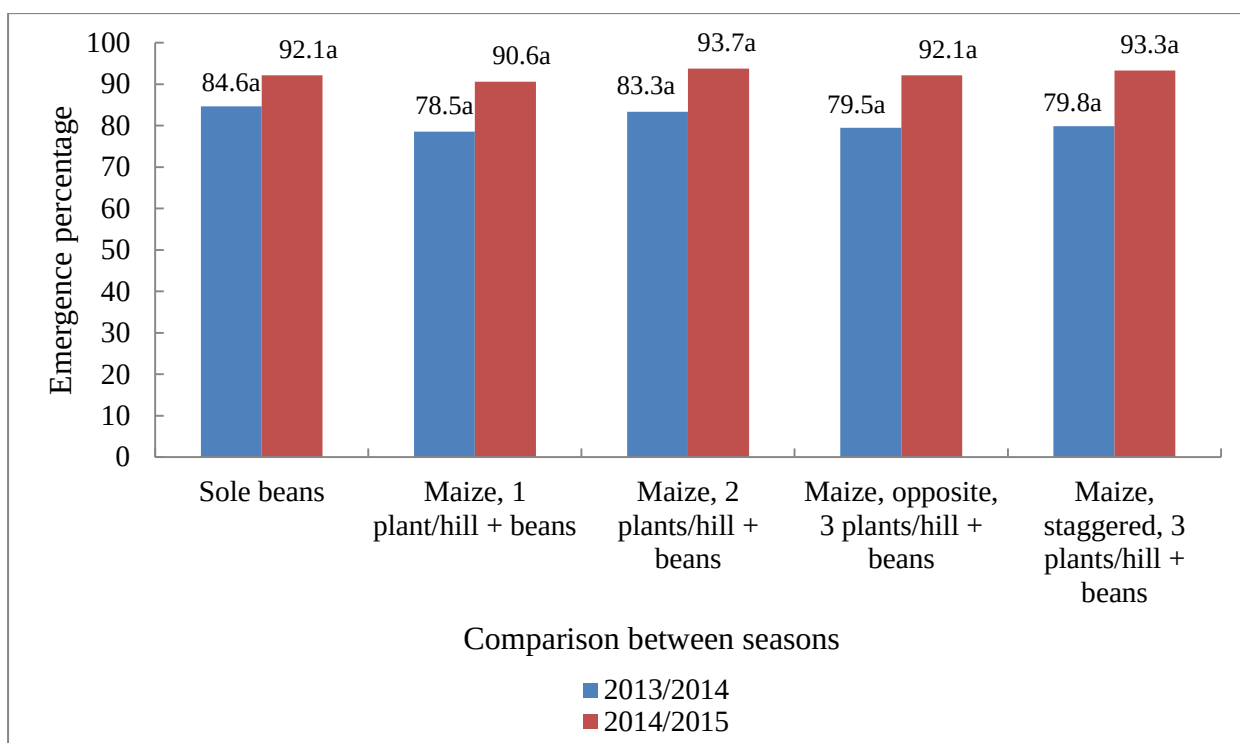


Figure 1. Comparison between treatments and seasons in dry beans emergence percentage grown as sole and maize-beans association

4.5.2 Beans plant height (cm) at 10 weeks after planting

Dry beans plant height was not significantly different for all the treatments at 2, 4, 6, 8 and 10 weeks after planting. There was an increase in plant height with increase in number of weeks after planting with the highest mean plant height of (46.6 cm) obtained from sole beans in 2013/2014 season and the least (40.6 cm) from maize, 1 plant/hill + beans. Comparison between seasons showed no significant difference (Figure 2).

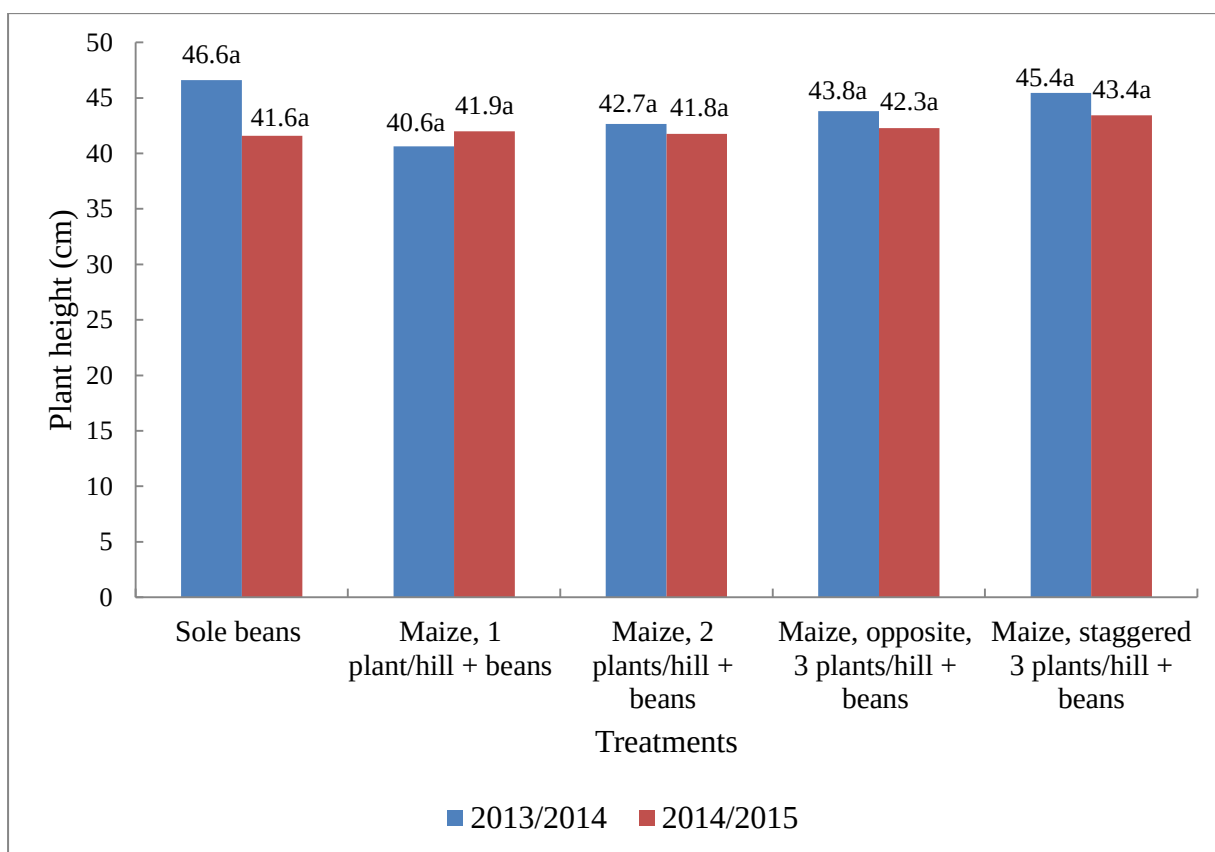


Figure 2. Dry beans plant height (cm) in sole beans and maize-dry beans association at 10 weeks after planting.

4.5.7 Beans ground cover within row (%) at 10 weeks after planting

In Table 32, range in season one was from 94.0 % to 100 % while that in season two was from 76.0 % to 88.0 %. From the mean differences of season one 98.4 % and two 81.6 %, respectively, having a difference percentage of 17.1 %. Maize, 1 plant/hill, + beans recorded the least ground cover with a mean ground cover of (85.0 %) between treatments at 10 weeks after planting. Maize, opposite, 3 plants, + beans recorded the highest mean ground cover within rows (94.0 %) at 10 weeks after planting. There was a significant difference ($P < 0.05$) between treatments and between season 2013/2014 and season 2014/2015. The opposite planting pattern had the highest ground cover (94.0 %) among spatial arrangements.

Table 32. Ground cover percentage within row in sole beans and maize-beans association at 10 weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole beans	100.0b	84.0b	92.0b
Maize, 1 plant/hill, + beans	94.0a	76.0a	85.0a
Maize, 2 plants/hill, + beans	100.0b	84.0b	92.0b
Maize, opposite, 3 plants, + beans	100.0b	88.0b	94.0b
Maize, staggered, 3 plants, + beans	98.0b	76.0a	87.0a
Mean	98.4b	81.6b	90.0b
Significance	*	*	*

C.V. (%) = 5.2 %

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	0.9309	1.4720	2.0817

NS = not significant; * = significant at $P < 0.05$

4.5.8 Beans ground cover between rows (%) at 10 weeks after planting

There was a significant difference ($P < 0.05$) among treatments and between seasons. Maize, staggered, 3 plants, + beans arrangement recorded the least ground cover (80.0 %) at 10 weeks after planting. Maize, opposite, 3 plants, + beans arrangement and sole beans recorded the highest ground cover between rows of (85.0 %). In Table 33, range in season one was from 94.0 % to 98.0 % while that in season two was from 68.0 % to 74.0 %. From the mean differences season one having 94.8 % and two 71.6 %, respectively, the difference percentage was 24.5 %.

Table 33. Ground cover percentage between row in sole beans and maize-beans association at 10 weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole beans	98.0d	72.0b	85.0a
Maize, 1 plant/hill, + beans	94.0b	74.0c	84.0a
Maize, 2 plants/hill,+ beans	96.0c	68.0a	82.0a
Maize, opposite, 3 plants, + beans	96.0c	74.0c	85.0a
Maize, staggered, 3 plants, + beans	90.0a	70.0b	80.0a
Mean	94.8b	71.6b	83.2a
Significance	*	*	NS

C.V. (%) = 7.7 %

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	1.2875	2.0358	2.8790

NS = not significant; * = significant at $P < 0.05$

4.5.10 Beans pod length (cm)

Figure 3 shows the length of dry beans pods after harvesting in centimeters. There was no significant difference between pods length in season (2013/2014) and season (2014/2015). Numerically, maximum pod length (13.5 cm) was noted in sole beans, thus the data suggests that pod length is affected by canopy cover and increases in sole crops compared to intercropping due to pod exposure to the sun. The highest pod length was observed in sole beans in both crop growing seasons.

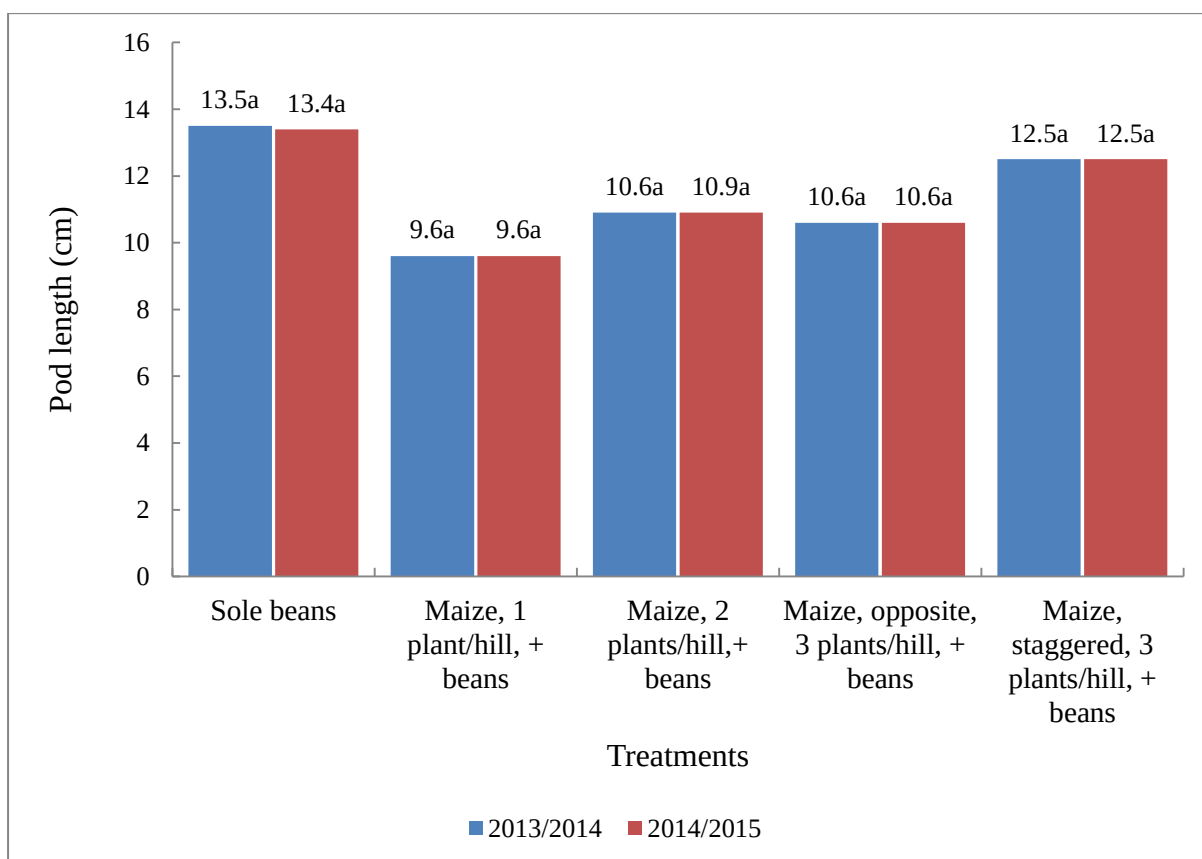


Figure 3. Dry beans pod length (cm) in sole beans and maize-beans in association in 2013/2014 and 2014/2015.

4.5.11 Beans number of pods/plant

There was a significance difference ($P < 0.05$) in the number of pods among the treatments and between seasons. Beans grown in association with maize (maize grown in a staggering arrangement) showed the highest number of pods (8.4) in season 2013/2014. The cropping system that had the lowest number of bean pods was maize, 2 plants/hill + beans (4.7) (Figure 4).

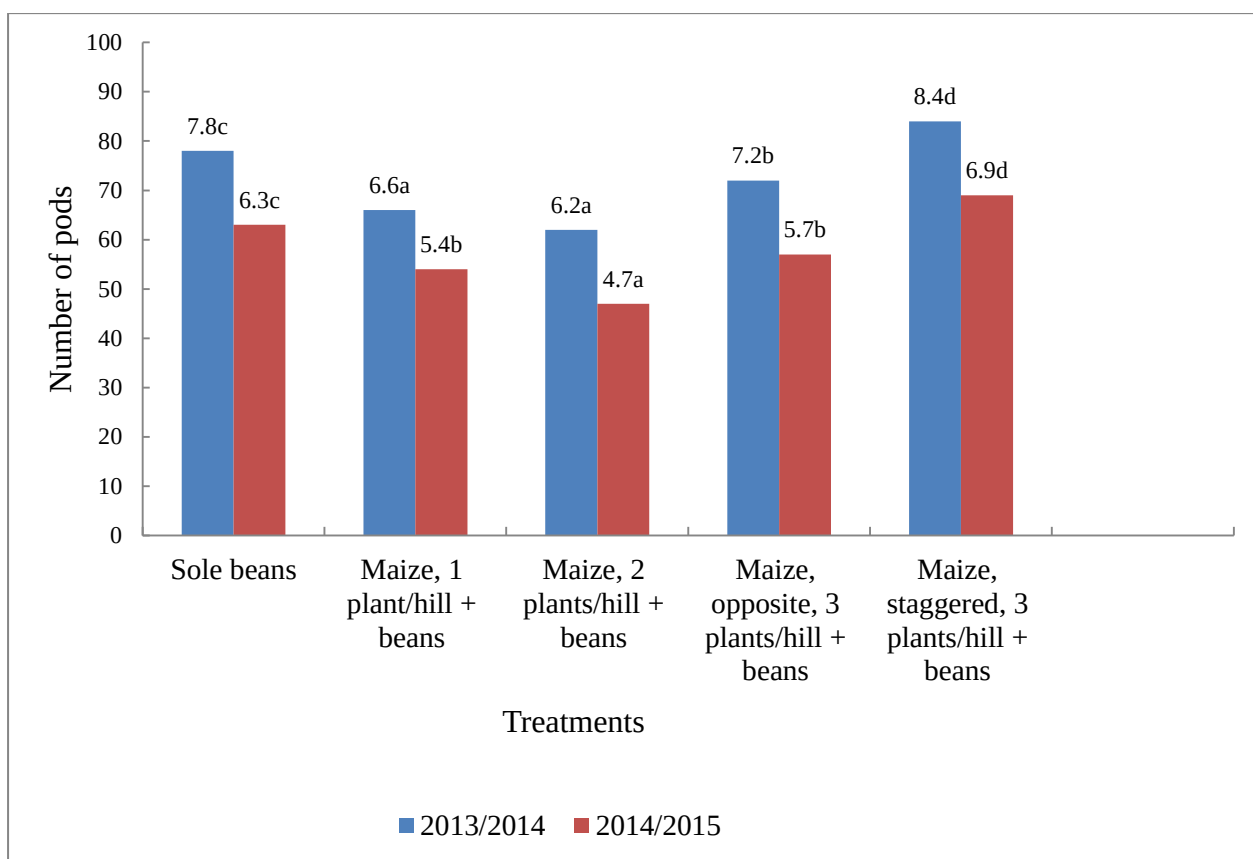


Figure 4. Number of pods/plant in sole beans and maize-bean association in 2013/2014 and 2014/2015.

4.5.12 Beans 100 seeds dry mass (g)

Sole beans in season 2013/2014 had the highest seed mass (50.9 g) followed by maize-beans association (maize grown in a staggering arrangement) (47.7 g). There was a significant difference ($P < 0.05$) among treatments for 100 seeds dry mass (Figure 5). Among the planting arrangements, staggering had the highest seed dry mass 47.7 g in 2013/2014 and 41.2 in 2014/2015. Season 2013/2014 had the highest seed dry mass compared to season 2014/2015.

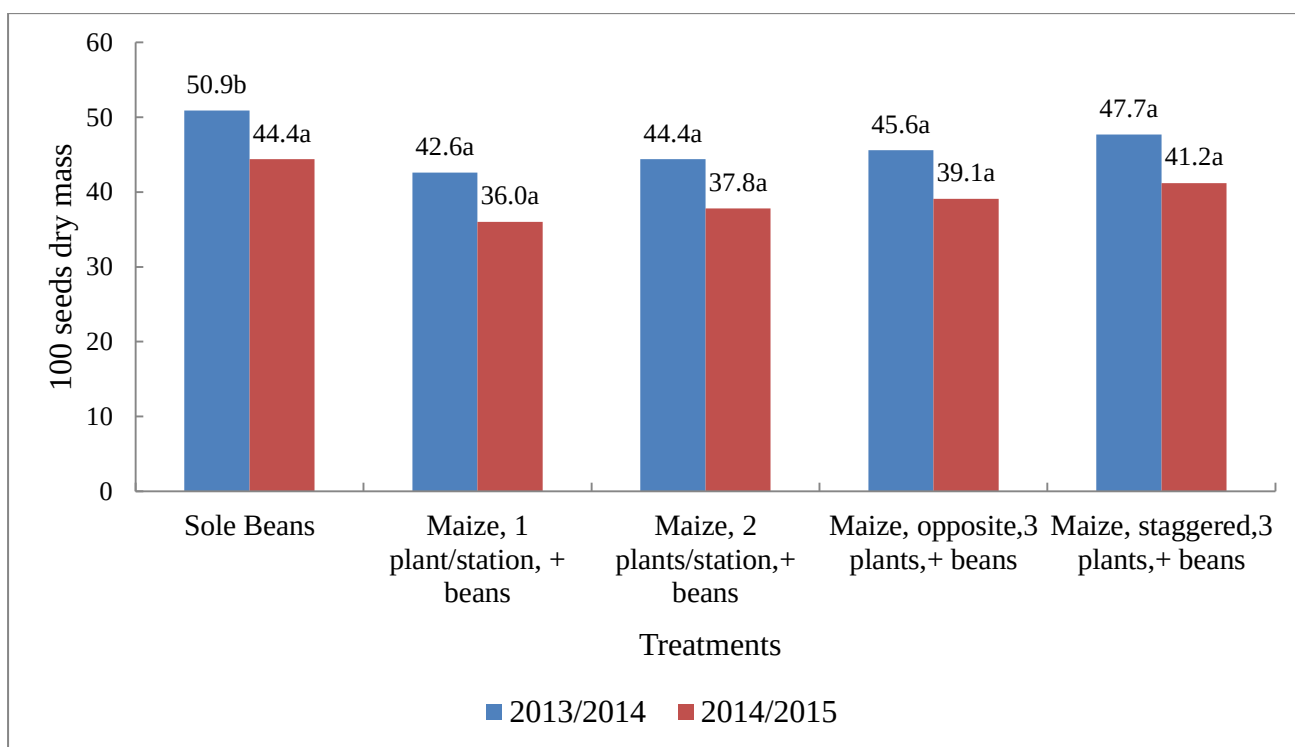


Figure 5. Comparison between seasons in 100 seed dry mass in sole beans and maize-beans association.

4.5.16 Beans shelling percentage (%)

The shelling percentage results are presented in Figure 7. There was no significance difference in the treatments studied in their shelling percentage between the two crop growing seasons 2013/2014 and 2014/2015. However, season 2014/2015 had the highest shelling percentage (82.3%) in maize grown at 50 cm spacing in association with beans, followed by sole dry beans (82.2%).

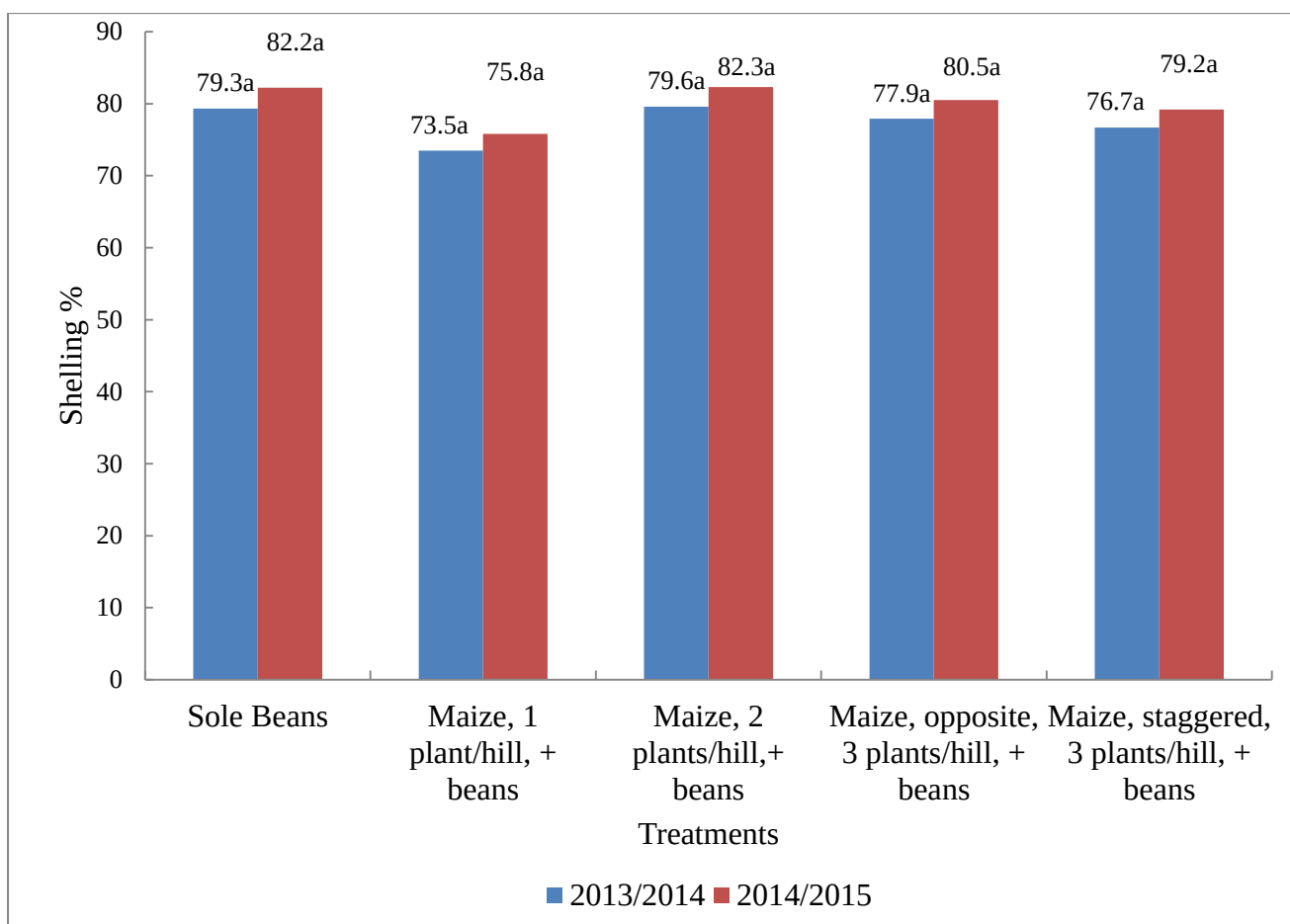


Figure 6. Comparison between seasons and cropping pattern in beans shelling percentage for sole beans and maize-beans association.

4.5.17 Beans harvest index

Data on harvest index also showed that there was no significant response in relation to various cropping systems and spatial arrangement in the experiment between the two seasons (2013/2014 and 2014/2014) (Table 34). There was no significant difference in the beans harvest index in all the treatments between season 2013/2014 and 2014/2015, respectively.

Table 34. Harvest index for sole beans and maize-beans in association.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole beans	0.822a	0.618a	0.696a
Maize, 1 plant/hill, + beans	0.758a	0.576a	0.683a
Maize, 2 plants/hill, + beans	0.824a	0.568a	0.717a
Maize, opposite, 3 plants, + beans	0.804a	0.582a	0.684a
Maize, staggered, 3 plants, + beans	0.790a	0.580a	0.681a
Mean	0.800a	0.585a	0.692a
Significance	NS	NS	NS

C.V. (%) = 8.4 %

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	0.0117	0.0185	0.0261

NS = not significant

4.5.18 Beans seed yield (kg/ha)

Results on bean seed yield (Figure 8) shows that in relation to the two crop growing seasons (2013/2014 and 2014/2015), yield among treatments were significantly different ($P < 0.05$). Maximum yield (611 kg/ha) was obtained in sole beans cropping system in 2013/2014 followed by beans grown in association with maize (maize grown in a staggering arrangement) (573 kg/ha). 2013/2014 seed yield was high 555.4 kg/ha compared to 2014/2015 having a seed yield of 258.2 kg/ha. The percentage difference between the two seasons was 53.5 %. Season one seed yield range from 511 kg/ha to 611 kg/ha and season two ranges from 243 kg/ha to 264 kg/ha.

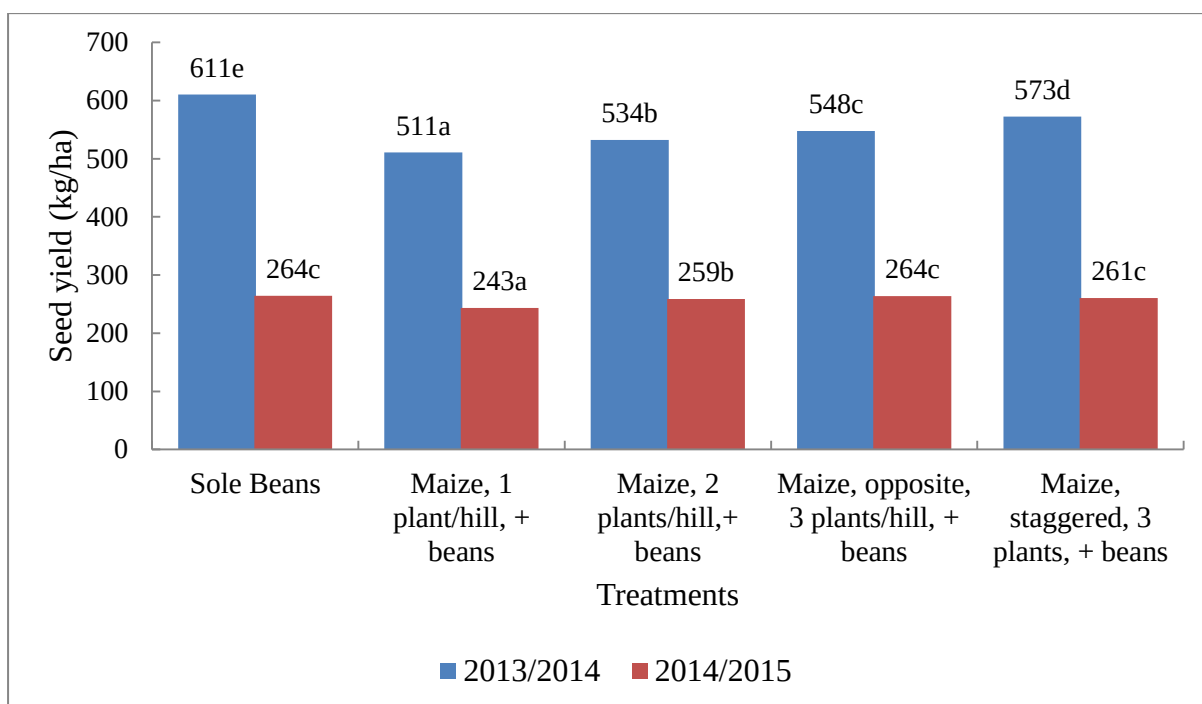


Figure 7. Comparison between seasons and cropping systems in seed yield for sole beans and maize-beans in association.

4.6 Cowpeas parameters

This section also covers specific objective number two which determines the better leguminous crop species for additive intercropping with maize. Cowpeas growth, seed yield and yield components are presented in this section.

4.6.1 Emergence percentage (%)

The results for emergence count in cowpeas are presented in Table 35. There was no significant difference in emergence count among the treatments and between the seasons. 2014/2015 emergence percentage was high being 94.3 % compared to 2013/2014 having an emergence percentage of 89.1 %. The percentage difference between the two seasons was 5.5 %. Season one emergence percentage ranges from 88.5 % to 90.1 % and season two ranges from 93.6 % to 94.8 %.

Table 35. Emergence percentage for sole cowpeas and maize-cowpeas in association.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole cowpeas	88.7a	94.7a	91.7a
Maize, 1 plant/hill, + cowpeas	88.8a	93.6a	91.2a
Maize, 2 plants/hill,+ cowpeas	89.7a	94.8a	92.2a
Maize, opposite, 3 plants, + cowpeas	90.1a	93.6a	91.9a
Maize, staggered, 3 plants, + cowpeas	88.5a	94.8a	91.6a
Mean	89.1a	94.3a	91.0a
Significance	NS	NS	NS

C.V. (%) = 4.3%

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	0.7917	1.2518	1.7704

NS = not significant

4.6.2 Cowpeas plant height (cm) at 10 weeks after planting

Cowpeas plant height was not significantly different for the treatments at 2, 4, 6, 8 and 10 weeks after planting. However, there was an increase in plant height with increase in weeks after planting, with the highest plant mean height of 64.8 cm at 10 weeks after planting. This was obtained from sole cowpeas (Table 36). Season 2013/2014 plant height ranges from 61.8 cm to 68.0 cm and season 2014/2015 ranges from 61.4 to 61.8 cm. The percentage difference between the two seasons was 5.7 %.

Table 36. Plant height for sole cowpeas and maize-cowpeas in association at 10 weeks after planting

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole cowpeas	68.0a	61.6a	64.8a
Maize, 1 plant/hill, + cowpeas	61.8a	61.4a	61.6a
Maize, 2 plants/hill,+ cowpeas	65.0a	61.4a	63.1a
Maize, opposite, 3 plants, + cowpeas	65.4a	61.5a	63.5a
Maize, staggered, 3 plants, + cowpeas	66.0a	61.8a	63.9a
Mean	65.2a	61.5a	63.4a
Significance	NS	NS	NS

C.V. (%) = 2.5%

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	0.3202	0.5064	0.7161

NS = not significant

4.6.3 Cowpeas ground cover (%) within row at 10 weeks after planting

There was no significant difference between crop mixtures and between spatial arrangements. Maize intercropped with cowpeas in a staggering planting pattern recorded the highest ground cover (90.0 %) at 10 weeks after planting (Table 37). Season 2013/2014 had the highest ground cover within row (88.4 %) while 2014/2015 had a ground cover of 85.6 %. The percentage difference between seasons was 3.2 %. Figure 8 shows cowpeas total ground cover within rows at 10 weeks after planting.

Table 37. Cowpeas ground cover percentage within rows for sole cowpeas and maize-cowpeas in association at 10 weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole cowpeas	88.0a	86.0a	87.0a
Maize, 1 plant/hill, + cowpeas	90.0a	78.0a	84.0a
Maize, 2 plants/hill,+ cowpeas	90.0a	88.0a	89.0a
Maize, opposite, 3 plants, + cowpeas	84.0a	86.0a	85.0a
Maize, staggered, 3 plants, + cowpeas	90.0a	90.0a	90.0a
Mean	88.4a	85.6a	87.0a
Significance	NS	NS	NS

C.V. (%) = 8.1%

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	1.4063	2.2236	3.1447

NS = not significant



Figure 8. Cowpeas ground cover at 10 weeks after planting, 2013/2014.

4.6.4 Cowpeas ground cover (%) between row at 10 weeks after planting

A significant difference ($P < 0.05$) between treatments was observed in cowpeas ground cover between rows (Table 38). Cowpeas grown in association with maize in a staggered arrangement recorded the highest mean ground cover of 98.0 % at 10 weeks after planting and maize-cowpea association (maize, opposite, 3 plants, + cowpeas) recorded the least mean ground cover 85.0 % at 10 weeks after planting. 2013/2014 had a mean ground cover between

row of 93.6 % while 2014/2015 had a mean ground cover of 88.8 %. The percentage difference between seasons was 4.8 %.

Table 38. Ground cover between rows for sole cowpeas and maize-cowpeas in association at 10 weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole cowpeas	100.0c	96.0b	98.0c
Maize, 1 plant/hill, + cowpeas	88.0a	84.0a	86.0a
Maize, 2 plants/hill, + cowpeas	90.0a	80.0a	85.0a
Maize, opposite, 3 plants, + cowpeas	90.0b	88.0a	89.0b
Maize, staggered, 3 plants, + cowpeas	100.0c	96.0b	98.0c
Mean	93.6a	88.8b	91.0b
Significance	*	*	*

C.V. (%) = 4.8%

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	0.8769	1.3864	1.9607

NS = not significant; * = significant at $P < 0.05$

4.6.6 Cowpeas number of pods

The results revealed that the mean maximum number of pods per plant 16 was obtained in season 2013/2014 while season 2014/2015 had the lowest 12.9. There was no significant difference between seasons. The number of pods/plant was significantly affected by the cropping seasons. (16.2). (Figure 9). Sole cowpeas had the highest number of pods per plant 16.2 among treatments.

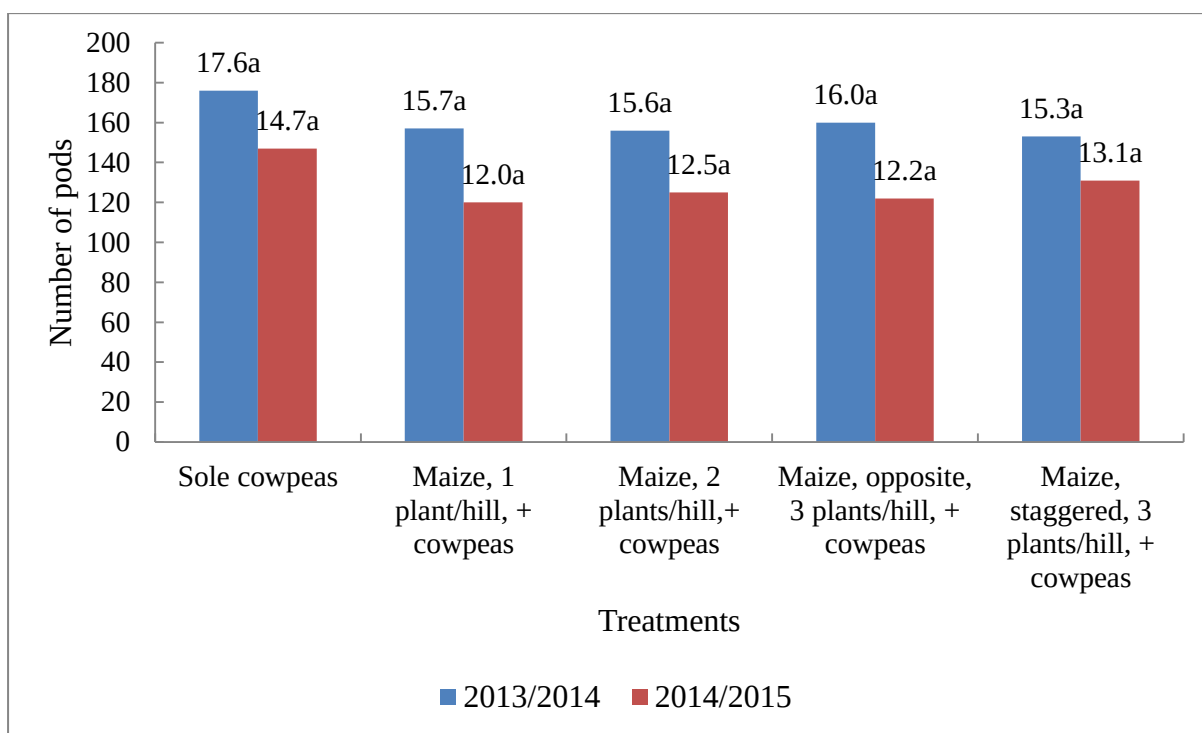


Figure 9. Cowpeas number of pods in sole cowpeas and maize-cowpeas association.

4.6.7 Cowpeas harvest index

Data on the harvest index shows cowpeas response to various treatments and seasons (Table 39). There was no significant difference observed among cropping mixtures and planting arrangements. The highest cowpeas mean harvest index was obtained in sole cowpeas 0.37. Season 2013/2014 had the highest mean harvest index 0.50 while season 2014/2015 had the least harvest index of 0.17. Among the planting patterns, staggered had the highest mean harvest index of 0.35. Season 2013/2014 harvest index ranges from 0.37 to 0.57 while season 2014/2015 ranges from 0.16 to 0.20, respectively and the percentage difference between seasons is 66.4 %.

Table 39. Cowpeas harvest index for sole cowpeas and maize-cowpea in association.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole cowpeas	0.58a	0.16a	0.37a
Maize, 1 plant/hill, + cowpeas	0.48a	0.17a	0.33a
Maize, 2 plants/hill, + cowpeas	0.52a	0.16a	0.34a
Maize, opposite, 3 plants, + cowpeas	0.37a	0.20a	0.28a
Maize, staggered, 3 plants, + cowpeas	0.56a	0.16a	0.36a
Mean	0.50a	0.17a	0.33a
Significance	NS	NS	NS

C.V. (%) = 27.5%

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	0.0184	0.0291	0.0412

NS = not significant

4.6.8 Cowpeas 100 seeds dry mass (g)

The results on 100 seeds dry mass showed that there was no significant difference between treatments and cropping seasons (Figure 10). Season 2013/2014 sole cowpeas had the highest seed mass of 16.3 g followed by maize, opposite, 3 plants/hill + cowpeas having 15.7 g while the lowest 12.5 g was obtained in season 2014/2015, maize, 1 plant/hill = cowpeas treatment. Season 2014/2015 had a slight decrease in seed dry mass ranging from 15.5 g to 14.2 g.

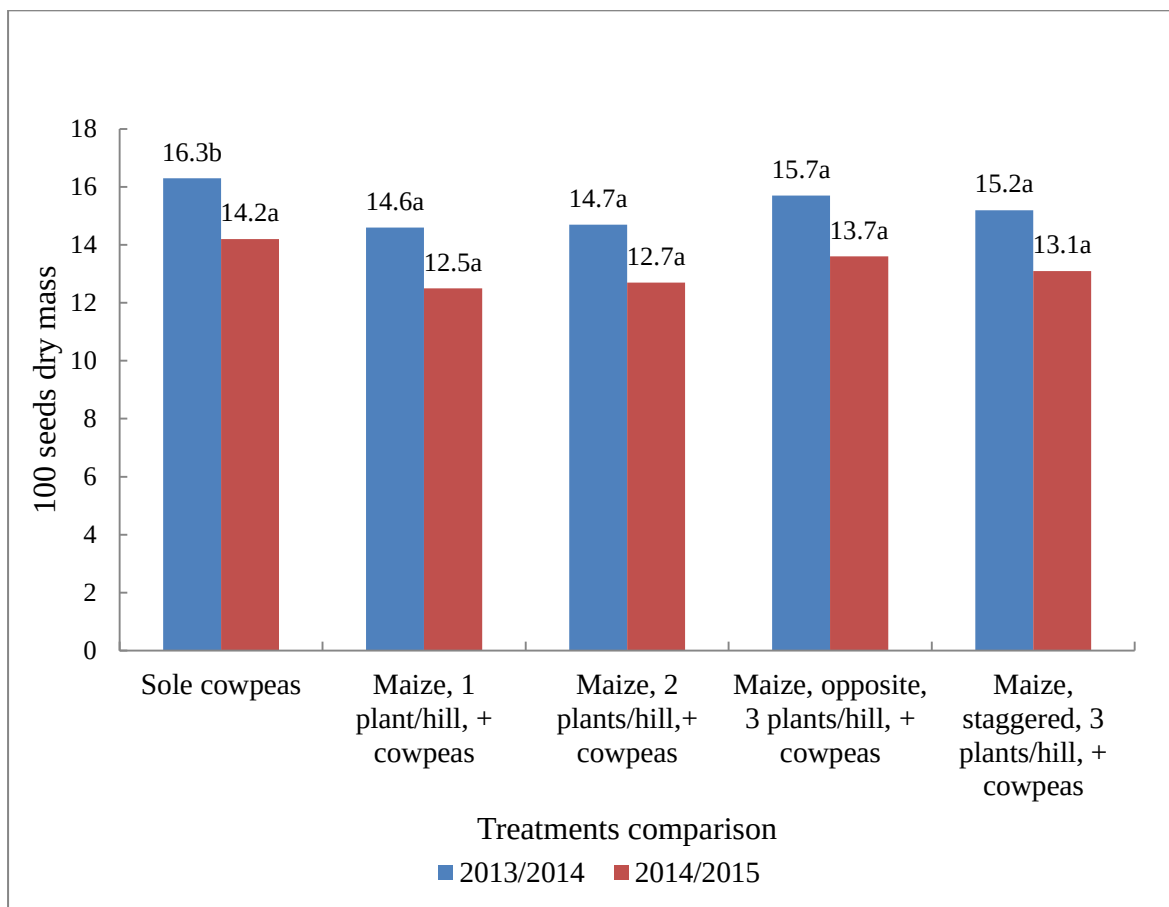


Figure 10. Cowpeas 100 seeds dry mass comparison between growing seasons and cropping pattern.

4.6.9 Cowpeas shelling percentage

Sole cowpea had the highest shelling percentage (57.3 %) followed by cowpeas grown in association with maize (maize, staggered, 3 plants/hill + cowpeas) (55.9%). There was no significant difference between the shelling percentages of sole cowpeas and maize-cowpeas mixtures (Figure 11). However, there was a significant difference ($P < 0.05$) between seasons. Season 2013/2014 had a mean shelling percentage of 49.9% while season 2014/2015 had a mean shelling percentage of 24.5 %.

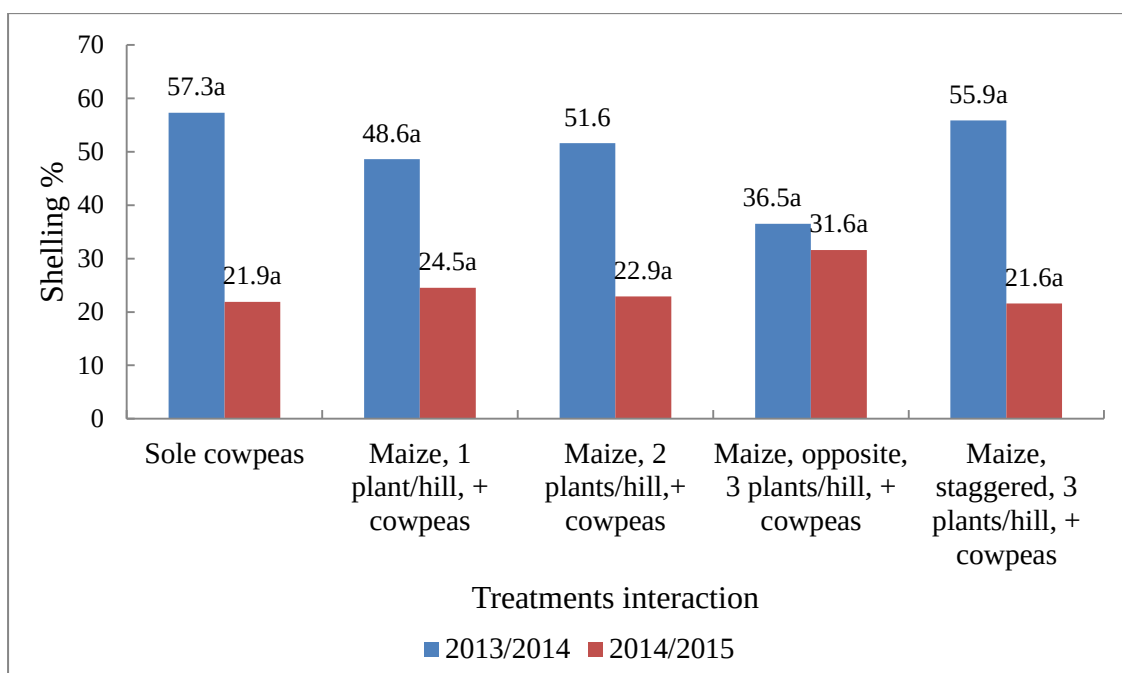


Figure 11. Cowpeas shelling percentage comparison between seasons and cropping pattern.

4.6.10 Cowpeas seed yield (kg/ha)

Results pertaining cowpeas seed yield Figure 13 shows the relation between cowpea seed yield in the two crop growing seasons 2013/2014 and 2014/2015. Yield among seasons were significant different ($P < 0.05$) while treatments within each season were not significantly different. Higher yield of 656 kg/ha was obtained in sole cowpeas treatment followed by cowpeas grown in association with maize (maize grown in an opposite arrangement) 645 kg/ha for season 2013/2014. The lowest seed yield 174 kg/ha was obtained in season 2014/2015 under the treatment maize, opposite, 3 plants/hill + cowpeas. The mean seed yield for season 2013/2014 was 626.8 kg/ha while season 2014/2015 obtained 230.4 kg/ha. In season 2013/2014, cowpeas seed yield ranged from 602 kg/ha to 656 kg/ha while season 2014/2015 ranged from 174 kg/ha to 284 kg/ha. The mean percentage difference in seed yield between seasons was 63.2 %.

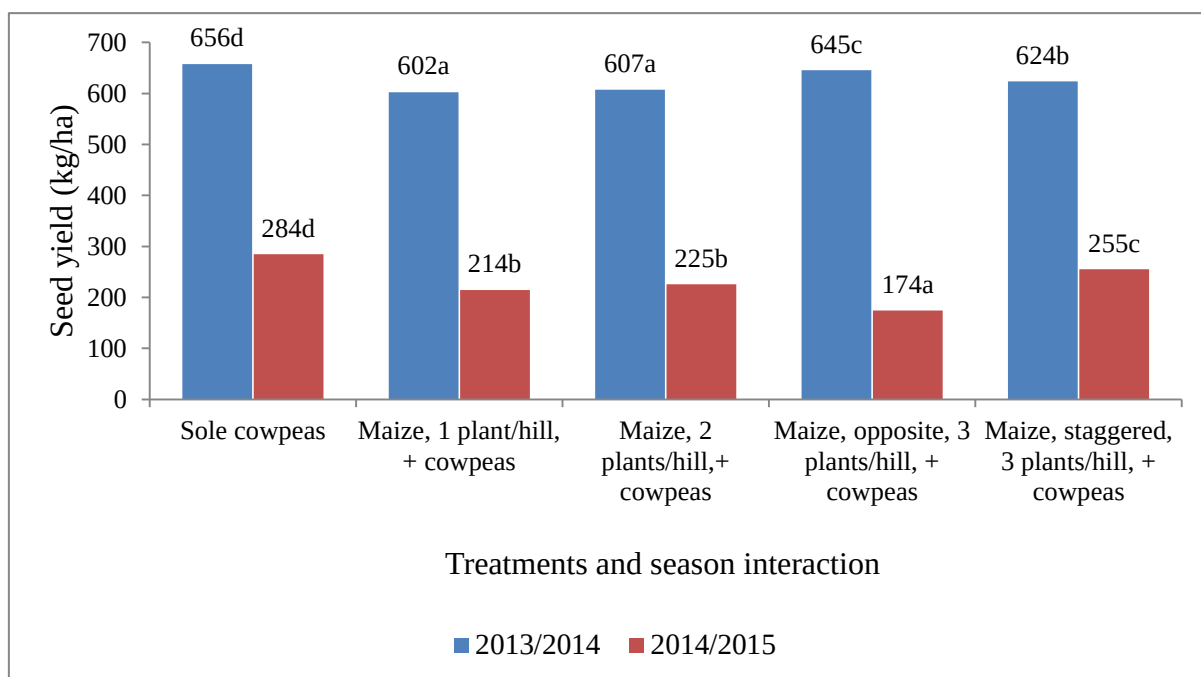


Figure 12. Cowpeas seed yield as compared between seasons and cropping pattern.

4.7 Utilisation of growth resources for enhanced productivity

This section covers objective number three which aims at identifying the desirable maize planting pattern and spatial arrangement that will use resources efficient and results to higher growth rate and seed yield.

4.7.1 Moisture use efficiency

4.7.1.1 Soil moisture retention (mm) at 8 and 10 weeks after planting

The data on moisture retention includes moisture retention within sole maize rows, sole beans, cowpeas rows, crop mixtures and cropping pattern. There was no significant difference among the treatments in moisture retention between maize and legumes rows at 8 and 10 weeks after planting for season 2013/2014 and season 2014/2015. Maize, 1 plant/hill + cowpeas measured the highest mean moisture retention of 22.0 mm in season 2013/2014 and measured 19.7 mm in season 2014/2015 (Table 40). Season 2013/2014 measured 20.4 mm mean moisture retention while season 2014/2015 measured 19.4 mm mean moisture retention. Season one moisture retention ranges from 19.5 mm to 22.0 mm while season two ranges from 18.2 mm to 19.7 mm. Maize-cowpeas mixture had the highest moisture retention among cropping mixtures.

Table 40. Soil moisture retention (mm) at eight and ten weeks after planting.

Cropping system	Soil moisture retention (mm) (weeks after planting)					
	8	10	Mean	8	10	Mean
	2013/2014			2014/2015		
Sole maize, 1 plant/hill	20.3	19.8	20.1	17.7	19.9	18.8
Sole maize, 2 plants/hill	20.3	19.5	19.9	17.6	19.6	18.6
Sole maize, 3 plants/hill	20.0	18.9	19.5	17.4	19.0	18.2
Sole beans	20.4	19.6	20.0	17.8	19.5	18.7
Sole cowpeas	21.4	19.6	20.5	18.8	19.3	19.1
Maize, 1 plant/hill, + beans	20.4	18.7	19.6	17.6	19.5	18.6
Maize, 1 plant/hill, + cowpeas	23.3	20.7	22.0	18.8	20.6	19.7
Maize, 2 plants/hill, + beans	20.7	19.7	20.2	17.5	19.8	18.7
Maize, 2 plants/hill + cowpeas	20.7	20.3	20.5	18.8	20.0	19.4
Maize, opposite, 3 plants + beans	20.7	19.2	20.0	17.7	19.6	18.7
Maize, opposite, 3 plants + cowpeas	21.5	19.4	20.5	19.0	20.4	19.7
Sole Maize, staggered, 3 plants/hill	21.0	19.9	20.5	17.8	19.9	18.9
Maize, staggered, 3 plants + beans	20.4	18.7	19.6	17.7	20.5	19.1
Maize, staggered, 3 plants + cowpeas	20.0	20.0	20.0	19.0	19.9	19.5
Mean	21.5	19.5	20.4	18.5	20.2	19.4
Significance	NS	NS	NS	NS	NS	NS

C.V. (%) = 6.35%

LSD = 6.2

Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	0.1574	0.4165	0.5890

NS = not significant

4.7.2 Light use efficiency

4.7.2.1 Light transmission ratio at 8, 9 and 10 weeks after planting

Light transmission ratio had a significant difference among treatment. A fraction of light was intercepted by leaves and absorbed, some was transmitted through the canopy, while the rest was reflected. The reflectivity of the leaf surface influences the proportion of intercepted radiation that is absorbed and that is transmitted through the canopy. Highest light transmitted was at the 10th week after planting as shown in Tables 41. There was no significant difference among treatments and spatial arrangements for light transmission. Season 2013/2014 had a mean light transmission ratio of 47.2 while season 2014/2015 measured had a mean light transmission ratio of 25.7. Season one mean light transmission ranges from 37.0 mm to 57.6

while season two ranges from 16.9 to 36.7. Sole cowpeas had the highest light transmission ratio of 57.6 among cropping mixtures. Difference in percentage among seasons was 45.6 %. Light absorption was observed at eight to ten weeks after planting in Table 42. Season 2014/2015 had the highest light absorption percentage of 68.9 %. Sole intercrops (beans and cowpeas) had the highest light absorption percentage in both seasons.

Table 41. Light transition ratio at 8, 9 and 10 weeks after planting.

Cropping system	Light transmission ratio, weeks after planting							
	8	9	10	Mean	8	9	10	Mean
	2013/2014				2014/2015			
Sole maize, 1 plant/hill	55.6	43.8	24.1	41.2	31.6	23.4	23.5	26.2
Sole maize,2 plants/hill	56.7	55.7	37.7	50.0	26.7	19.1	20.1	21.9
Sole maize, 3 plants/hill	49.6	46.1	43.6	46.4	31.6	35.4	33.9	33.6
Sole beans	66.3	70.8	30.4	55.8	39.5	43.8	26.7	36.7
Sole cowpeas	73.1	62.5	37.3	57.6	45.4	33.6	26.8	35.3
Maize, 1 plant/hill, + beans	63.7	64.0	23.4	50.7	20.1	27.3	29.8	25.7
Maize, 1 plant/hill, + cowpeas	49.3	37.1	24.7	37.0	23.8	24.6	24.9	24.4
Maize, 2 plants/hill,+ beans	56.0	55.7	27.4	46.4	26.8	22.4	19.4	22.9
Maize, 2 plants/hill + cowpeas	65.2	41.8	30.2	45.7	19.7	18.5	12.6	16.9
Maize, opposite, 3 plants, + beans	56.0	56.4	27.6	46.7	27.3	21.2	10.6	19.7
Maize, opposite, 3 plants + cowpeas	54.6	38.2	25.6	39.5	40.1	35.8	28.7	34.9
Sole Maize, staggered, 3 plants	54.4	39.8	31.0	41.7	21.9	15.9	16.1	17.9
Maize, staggered, 3 plants, + beans	65.1	46.9	30.3	47.4	28.3	22.5	22.6	24.5
Maize, staggered, 3 plants, + cowpeas	59.3	56.2	27.7	47.7	20.6	26.1	11.2	19.3
Mean	55.7	43.9	24.2	47.2	31.7	23.4	23.5	25.7
Significance	NS	NS	NS	NS	NS	NS	NS	NS
C.V. (%) = 34.6%								
Parameter	Season (S)		Treatment (T)		S x T			
S E ±	0.0208		0.0550		0.0778			
NS = not significant								

Table 42. Light absorption percentage at 8, 9 and 10 weeks after planting.

Cropping system	Light absorption %, weeks after planting							
	8 2013/2014	9 2013/2014	10 2013/2014	Mean 2013/2014	8 2014/2015	9 2014/2015	10 2014/2015	Mean 2014/2015
Sole maize, 1 plant/hill	44.4	75.8	86.1	68.8	68.3	76.6	76.4	73.8
Sole maize, 2 plants/hill	43.3	62.2	88.7	64.7	73.2	80.9	79.8	77.9
Sole maize, 3 plants/hill	50.3	56.4	87.9	64.9	68.3	64.6	66.1	66.3
Sole beans	33.6	69.6	86.2	63.1	78.1	84.1	83.8	82.0
Sole cowpeas	45.3	74.3	90.7	70.1	80.2	81.5	87.3	83.0
Maize, 1 plant/hill, + beans	36.2	76.5	89.6	67.4	79.8	72.7	90.2	80.9
Maize, 1 plant/hill, + cowpeas	50.6	75.2	87.2	71.0	76.2	75.3	75.0	75.5
Maize, 2 plants/hill, + beans	44.0	72.6	84.9	67.2	54.6	66.4	73.1	64.7
Maize, 2 plants/hill + cowpeas	34.7	69.8	87.5	64.0	73.1	77.6	80.6	77.1
Maize, opposite, 3 plants, + beans	44.0	72.4	88.1	68.2	72.7	78.8	89.4	80.3
Maize, opposite, 3 plants + cowpeas	26.9	62.7	84.4	58.0	59.9	64.2	71.3	65.1
Sole Maize, staggered, 3 plants	45.5	69.0	88.8	67.8	60.5	56.2	73.3	63.3
Maize, staggered, 3 plants, + beans	34.9	69.6	84.8	63.1	71.7	77.4	77.4	75.5
Maize, staggered, 3 plants, + cowpeas	40.6	72.3	88.1	67.0	79.4	73.9	88.8	80.7
Mean	44.5	75.9	86.2	66.1	68.4	76.6	76.4	68.9

C.V. (%) = 51.9%

LSD = 13.1

Parameter	Season (s)	Treatment (T)	S x T
S E $\pm$	0.0235	0.0622	0.0880

NS = not significant

4.8 Efficiency of intercropping

4.8.1 Land equivalent ratio (LER) for beans

In all the cropping systems, the LER value (Table 43) were greater than 1.0, indicating that intercropping was more advantageous than sole cropping system. LER was calculated based on yield of sole maize at an intra-row spacing of 25 cm, 50 cm, 75 cm and also the staggered planting pattern. Season 2013/2014 had the highest LER of 2.15 while season 2014/2015 had the least of 1.80. LER calculated from sole maize yield at a spacing of 25 cm resulted to higher LER among the cropping mixture and planting patterns. Maize, opposite, 3 plants/hill, + beans had the highest mean LER of 2.73. The higher the intra-row plant spacing the lower the LER among the crop mixtures.

Table 43. Land equivalent ratio for maize grown in association with beans.

Cropping system	Land equivalent ratio		Mean
	2013/2014	2014/2015	
Sole maize at 25 cm			
Maize, 1 plant/hill, + beans	2.14	1.82	1.82
Maize, 2 plants/hill,+ beans	1.98	1.81	1.11
Maize, opposite, 3 plants/hill, + beans	2.37	2.01	2.73
Maize, staggered, 3 plants/hill, + beans	2.22	2.02	2.42
Sole maize yield at 50 cm			
Maize, 1 plant/hill, + beans	1.89	1.79	1.99
Maize, 2 plants/hill,+ beans	1.77	1.78	1.76
Maize, opposite, 3 plants/hill, + beans	2.09	1.98	1.98
Maize, staggered, 3 plants/hill, + beans	1.97	1.99	1.95
Sole maize yield at 75 cm			
Maize, 1 plant/hill, + beans	1.83	1.65	1.10
Maize, 2 plants/hill,+ beans	1.72	1.65	1.79
Maize, opposite, 3 plants/hill, + beans	2.02	1.82	1.82
Maize, staggered, 3 plants/hill, + beans	1.91	1.84	1.98
Sole maize yield staggered			
Maize, 1 plant, + beans	1.88	1.69	1.10
Maize, 2 plants,+ beans	1.76	1.69	1.83
Maize, opposite, 3 plants/hill, + beans	2.07	1.87	1.87
Maize, staggered, 3 plants/hill, + beans	1.95	1.89	1.10
Mean	2.15	1.80	1.15

4.8.2 Land equivalent ratio (LER) for cowpeas

Table 44 shows that the LER value were greater than 1.0, indicating that intercropping was more advantageous than sole cropping system in all the cropping mixture. LER was calculated based on yield of sole maize at an intra-row spacing of 25 cm, 50 cm, 75 cm and also the staggered planting pattern. Season 2013/2014 had the highest LER of 2.0 while season 2014/2015 had the least of 1.83. LER calculated from sole maize yield at a spacing of 25 cm resulted to higher LER among the cropping mixture and planting patterns. Maize, 2 plants/hill, + cowpeas had the highest mean LER of 2.11. The closer the maize planting spacing, the higher the LER.

Table 44. Land equivalent ratio for maize grown in association with cowpeas.

Cropping system	Land equivalent ratio		
	2013/2014	2014/2015	Mean
Sole maize yield at 25 cm			
Maize, 1 plant/hill, + cowpeas	2.07	2.08	2.08
Maize, 2 plants/hill,+ cowpeas	2.14	2.08	2.11
Maize, opposite, 3 plants/hill, + cowpeas	2.05	1.85	1.95
Maize, staggered, 3 plants/hill, + cowpeas	2.09	2.17	2.13
Sole maize yield at 50 cm			
Maize, 1 plant/hill, + cowpeas	2.04	1.81	1.93
Maize, 2 plants/hill,+ cowpeas	2.11	1.81	1.96
Maize, opposite, 3 plants/hill, + cowpeas	2.02	1.59	1.81
Maize, staggered, 3 plants/hill, + cowpeas	2.06	1.91	1.99
Sole maize yield at 75 cm			
Maize, 1 plant/hill, + cowpeas	1.87	1.74	1.81
Maize, 2 plants/hill,+ cowpeas	1.94	1.75	1.85
Maize, opposite, 3 plants/hill, + cowpeas	1.87	1.54	1.71
Maize, staggered, 3 plants/hill, + cowpeas	1.90	1.85	1.86
Sole maize yield staggered			
Maize, 1 plant/hill, + cowpeas	1.92	1.79	1.86
Maize, 2 plants/hill,+ cowpeas	1.98	1.79	1.89
Maize, opposite, 3 plants/hill, + cowpeas	1.91	1.58	1.75
Maize, staggered, 3 plants/hill, + cowpeas	1.95	1.89	1.92
Mean	2.0	1.83	1.91

4.8.3 Relative crowding coefficient (RCC)

4.8.3.1 Relative crowding coefficient (RCC) for beans

Table 45 shows the Relative crowding coefficient of maize grown in association with beans. When the product of the two coefficients; $K = (K_{ab} K_{ba})$ is greater than 1, there is a yield advantage whereas if K obtained in the system equals to 1, there is no yield advantage, and if K in the system is less than 1, there is a yield disadvantage. RCC was calculated based on sole maize planted at an intra-row spacing of 25 cm, 50 cm, 75 cm and staggered planting pattern. Among the cropping mixtures, there was no significance difference observed. Maize, opposite, 3 plants/hill, + beans had the highest RCC in both planting seasons. Spacing between plants affects the RCC and results to yield disadvantage.

Table 45. Relative crowding coefficient for maize grown in association with beans.

Cropping system	Relative crowding coefficient		Mean
	2013/2014	2014/2015	
Sole maize yield at 25 cm			
Maize, 1 plant/hill, + beans	1.14	0.84	0.99
Maize, 2 plants/hill,+ beans	0.99	0.83	0.91
Maize, opposite, 3 plants/hill, + beans	1.39	1.02	1.21
Maize, staggered, 3 plants/hill, + beans	0.99	1.04	1.02
Sole maize yield at 50 cm			
Maize, 1 plant/hill, + beans	0.90	0.82	0.86
Maize, 2 plants/hill,+ beans	0.81	0.74	0.78
Maize, opposite, 3 plants/hill, + beans	1.03	0.99	1.01
Maize, staggered, 3 plants/hill, + beans	1.02	0.92	0.97
Sole maize yield at 75 cm			
Maize, 1 plant/hill, + beans	0.85	0.83	0.84
Maize, 2 plants/hill,+ beans	0.74	0.69	0.72
Maize, opposite, 3 plants/hill, + beans	1.03	0.85	0.94
Maize, staggered, 3 plants/hill, + beans	0.92	0.87	0.90
Sole maize yield staggered			
Maize, 1 plant/hill, + beans	0.85	0.76	0.81
Maize, 2 plants/hill,+ beans	0.74	0.76	0.75
Maize, opposite, 3 plants/hill, + beans	1.03	0.85	0.94
Maize, staggered, 3 plants/hill, + beans	0.92	0.95	0.94
Mean	0.95	0.87	0.97

4.8.3.2 Relative crowding coefficient (RCC) for cowpeas

Table 46 shows the Relative crowding coefficient of maize grown in association with cowpeas. RCC was calculated based on sole maize planted at an intra-row spacing of 25 cm, 50 cm, 75 cm and staggered planting pattern. Among the cropping mixtures, there was no significance difference observed. Maize, 2 plants/hill, + cowpeas had the highest RCC in both planting seasons. Spacing between plants affects the RCC and results to yield a disadvantage and this can be seen in season 2013/2014 at 25 and 50 cm intra-row spacing, the RCC was greater than one, but as the intra-row spacing is increased, the RCC decreases.

Table 46. Relative crowding coefficient for maize grown in association with cowpeas.

Cropping system	Relative crowding coefficient		Mean
	2013/2014	2014/2015	
Sole maize yield at 25 cm			
Maize, 1 plant/hill, + cowpeas	1.08	1.01	1.05
Maize, 2 plants/hill,+ cowpeas	1.12	1.16	1.14
Maize, opposite, 3 plants/hill, + cowpeas	1.07	0.76	0.92
Maize, staggered, 3 plants/hill, + cowpeas	1.15	1.03	1.09
Sole maize yield at 50 cm			
Maize, 1 plant/hill, + cowpeas	1.12	0.82	0.97
Maize, 2 plants/hill,+ cowpeas	1.09	0.92	1.01
Maize, opposite, 3 plants/hill, + cowpeas	1.05	0.80	0.93
Maize, staggered, 3 plants/hill, + cowpeas	1.05	0.61	0.83
Sole maize yield at 75 cm			
Maize, 1 plant/hill, + cowpeas	0.92	0.86	0.89
Maize, 2 plants/hill,+ cowpeas	0.96	0.76	0.86
Maize, opposite, 3 plants/hill, + cowpeas	0.89	0.75	0.82
Maize, staggered, 3 plants/hill, + cowpeas	0.89	0.57	0.73
Sole maize yield at 75 cm			
Maize, 1 plant/hill, + cowpeas	0.93	0.98	0.96
Maize, 2 plants/hill,+ cowpeas	0.97	0.90	0.94
Maize, opposite, 3 plants/hill, + cowpeas	1.00	0.80	0.90
Maize, staggered, 3 plants/hill, + cowpeas	0.94	0.79	0.87
Mean	1.01	0.85	0.93

4.9 Correlation matrix

4.9.1 Correlation matrix for maize

There was a significant correlation between cob length and husk mass at ($P < 0.05$). A determination of correlation (R^2) recorded was 26.3%. This would imply that a 26.3% increase in the cob length might have contributed to the differences in husk mass. There was a significant correlation between the number of seeds and the cob length at ($P < 0.01$). A determination of correlation (R^2) = 90.3% was recorded, respectively. This would imply that 90.3% increase in the number of seeds might have contributed to the differences in cob length. There was a significant correlation between the mass of cob without husk and the husk mass ($P < 0.01$). A determination of correlation (R^2) = 56.3% was recorded, respectively. This would imply that

56.3% increase in the mass of cob without husk might have contributed to the differences in husk mass (Appendix 193).

4.9.2 Correlation matrix for beans

There was a significant correlation between number of seeds and pod length at ($P < 0.05$). A determination of correlation (R^2) = 61.8% was recorded. This would imply that a 61.8% increase in the number of seeds might have contributed to the differences in pod length. There was a significant correlation between the seed moisture content and the harvest index at ($P < 0.05$). A determination of correlation (R^2) = 46.4% was recorded. This would imply that a 46.4% increase in seed moisture content might have contributed to the differences in the harvest index (Appendix 194).

4.9.3 Correlation matrix for cowpeas

There was a significant correlation between the seed mass and the number of pods at ($P < 0.05$) and determination of correlation (R^2) = 46.4% was recorded. This would imply that a 46.4% increase in seed mass might have contributed to the number of pods. There was a significant correlation between 100 seeds dry mass and the number of pods at ($P < 0.05$). A determination of correlation (R^2) = 24.5% was recorded. This would imply that a 24.5% increase in 100 seed mass might have contributed to the differences in the number of pods per plant. There was a significant correlation between 100 seeds dry mass and seed mass at ($P < 0.05$). A determination of correlation (R^2) = 52.4% was recorded. This would imply that a 52.4% increase in 100 seed mass might have contributed to the differences in the seed mass.

There was a significant correlation between the harvest index and shelling percentage at ($P < 0.01$). A determination of correlation (R^2) = 52.4% was recorded. This would imply that a 96.0% increase in harvest index might have contributed to the differences in the shelling percentage. There was a significant correlation between seed moisture content and mass of pods before shelling at ($P < 0.05$). A determination of correlation (R^2) = 75.9% was recorded. This would imply that a 75.9% increase in seed moisture might have contributed to the differences in the mass of pods before shelling. There was a significant correlation between seed yield and 100 seeds dry mass at ($P < 0.05$). A determination of correlation (R^2) = 54.9%

was recorded. This would imply that a 54.9% increase in seed yield might have contributed to the differences in 100 seeds dry mass (Appendix 195).

CHAPTER 5

5.0 DISCUSSION

The growth and yield of crops is governed by soil and weather conditions apart from management practices. Crop performance under given environmental conditions is also depended on nature and composition of cropping system. Intercropping not only alters the conditions available for the pure crop by competition, but also influences the complementarity of one species over other. These requires thorough understanding before development of an intercropping system for recommendation. The results obtained in the experiment conducted under rainfed conditions to study the effects of spatial arrangement for maize intercropped with beans and cowpeas on growth and yield are discussed in this chapter and they cover the soil test results, meteorological data, morphological and physiological data as well as seed yield and yield components for maize and legumes. Efficiency of intercropping is also discussed in this chapter.

5.1 Soil physio-chemical properties

The sandy loam texture of the soil might have resulted to the uniform plant emergence. This type of soil allows air circulation thus supply for oxygen to the seed, free movement of water within the soil, thus all contributing to the uniform seedling emergence. From the results obtained in the study, Ca, Mg, K and P content increased after the application of lime in the soil. Lime application is important because it improves the soil pH, making nutrient more available to plants roots and also improves the soil structure. This was observed from the study as the pH increased from 3.91 in season one to 4.51 in season two as a result of lime application. Neutralisation reactions may explain the decrease in exchangeable Al^{3+} after lime application. The increase in soil pH with lime application might be due to the neutralization of H^+ and Al^{3+} ions. The liming material used supplies calcium, an essential plant nutrient, and other essential nutrient, potassium, magnesium. Liming promotes better soil structure thus increase microbial action, partly to increased crop residues from higher crop yields and partly to chemical effects of decreasing hydrogen ion concentration and increasing calcium and magnesium ion concentrations. This might be due to the chemical reaction taking place in the soil resulting to the release of soil nutrients. Liming also increase the community of microorganisms which are

responsible for the release of nitrogen to the soil in legumes root nodes. Soil acidity is the major problem in most agricultural soils especially in the Middleveld and Highveld of Swaziland (Dr. G.N. Shongwe, University of Swaziland, personal communication, October, 2013). The recommended rate of agricultural lime that farmers should use in the Highveld and Middleveld ecological zones of Swaziland is 3 tonnes/ha of dolomitic lime every after 3 seasons. The nutrient content of the soil were not good, therefore the results indicate a need for the application of compound fertiliser N.P.K (2:3:2[22]). A response of fertiliser application by plants was observed as the crops foliage became green and a rapid growth was noticed. According to Mulongo (2004), poor soil fertility, phosphorus deficiency and high soil mineral nitrogen can negatively affect nitrogen fixation by the legumes. The increase in yield might be due to lime application to the soil which releases nutrients to the soil and make them available to plant roots.

5.2 Meteorological data

Crop growth is mainly dependent on the environmental factors. Fluctuations in weather conditions greatly influence the growth, development and thereby yield potential of the crop. The total rainfall received in the 2013/2014 crop growing season was 950 mm and for 2014/2015 cropping season was 712.4 mm indicating a percentage difference of 25.0 %. The rainfall was well distributed during the crop growth period, but the quantity of rainfall was less than the average. However, dry spell prevailed in the third month (January) after sowing of crops which persisted for three weeks up to the first week of February. In order to establish requisite crop stand, several severe irrigation was scheduled during the dry spell although the temperatures were very high exceeding 30 °C.

The rainfall received during February was quite sufficient for proper grain filling and development. The variation in rainfall received had an effect on growth and yield of the crops although it was sufficient for the growth of maize and legumes for additive intercropping as they did not suffer much from moisture stress. The lower maize yield in the second season compared to the first season may be explained by water deficits, high temperatures that results to increased evapotranspiration rate experienced during critical periods such as the flowering and grain filling in the second season. Storm damage in the second season could also explain

the yield differences between the two seasons. The yield reduction in the maize, 1 plant/station, + legumes was much greater due to the relative drier 2014/2015 season. The highest total rainfall was 29.7 mm received in December 2014 and the least 23.9 mm was received in March 2015. Mean maximum temperature experienced during the cropping season was 28.3 °C in March 2015 and a mean minimum monthly temperature was 22.5 °C experienced in November 2013. The mean maximum and minimum temperatures were ideal for the growth of maize and legumes having an ideal temperature for growth ranging between 17.5 °C – 27 °C (Anonymous, 2007). Maize and legumes are warm weather crops requiring a minimum of 15 °C for growth. Soil temperature was high in January in both seasons, this might be due to the fact that January experienced dry spell resulting to increased soil temperature. Temperature, rainfall have an effect on the growth and yield of crops. There were no outbreaks of pests and diseases during entire crop growing season. However, precautionary measures were taken up to control pests and diseases.

5.3 Data on maize

Discussion on maize includes emergence percentage, plant height, lodging, dry matter determination and cob height. The data also included mass of stover, cob mass of all seeds, harvest index, shelling percentage, mass of 100-dry seeds and seed yield.

5.3.1 Emergence count

Seedling emergence was uniform in all the treatments probably because the necessary conditions needed for seed germination were favourable. Rainfall, fine soil tilt and temperature facilitated early and uniform seedling emergence since this factors are a necessity for emergence. Season 2014/2015 had a higher mean emergence percentage of 92.3 % which might be attributed to higher soil temperature of 22.1 °C and an environmental temperature of 24.5 °C experienced in November during germination. Such temperatures are important for breaking seed dormancy and optimal function of metabolic enzymes responsible for seed germination. Rainfall supplied the seeds with moisture which metabolically activate the cells (cotyledon) for their successful germination. Season 2013/2014 had a mean emergence percentage of 88.2 % which might be attributed to minimum air temperature of 13.6 °C in November and soil temperature of 19.7 °C. This factors might have contributed to the lower emergence percentage

in season 2013/2014. If emergence ends up not being 100%, then gap filling, as was done in the experiment, in order to have the desired plant population per treatment. The lack of a significant treatment effect on plant populations indicates that seedling emergence was not influenced neither by the cropping mixture nor by cropping pattern.

5.3.2 Plant height (cm)

Maize plant height was significantly different ($P < 0.05$) between season 2013/2014 and 2014/2015 and between weeks after planting, respectively. This might be attributed by the availability of moisture, high temperatures which facilitate plant rapid growth and establishment. Higher air temperatures encourages rapid growth in crops as it catalise growth hormones in crops. Season 2014/2015 had a high plant height in all the weeks compared to season 2013/2014. This might be due to the fact that the soil mineral content had improved as a result of lime application in the 2013/2014 season, thus making the soil nutrients to be more available for plant growth. Another factor contributing to the difference in plant height might be light transmission and absorption by plants. The experimental site is characterised by well light interception, no light barrier around. The opposite planting pattern and sole maize recorded the highest plant height between week 6, 8 and 10 in all the treatments and in both seasons. Maize-cowpeas mixtures recorded the highest maize plant height compared to maize-beans mixtures. This might be attributed by the fact that cowpeas covers the soil and preserve moisture which might have been used by the maize resulting to high plant height.

In a study by Vilakati (2010), maize intercropped with cowpeas had a higher plant height compared to maize grown in monoculture. In contrary, an experiment conducted at Potchefstroom having two crop growing seasons 2005/2006 and 2006/2007, reported a mean maize height of 223.45 cm during the 2005/2006 season and during the 2006/2007 season, maize monocrop had the tallest plants 226.13 compared to maize intercropped with legumes. In other results, Thwala and Ossom (2004) did not find any significant differences between maize monocrop and intercropped with cowpeas. They concluded that maize-cowpeas intercropping does not have any effect on maize plant height. Taller maize cultivars provide a better advantage of trapping more solar radiation than the intercropped legumes, which is very critical for the growth and development of the crop (Thwala and Ossom, 2004). A study

conducted by Silwana and Lucas (2002) found that sole maize plant was taller than maize which was intercropped with beans.

5.3.3 Maize lodging

Significant score level ($P < 0.05$) of (4.1) was observed in 2014/2015 season compared to 1.0 in 2013/2014 season at five weeks after planting. This high difference could be due to hail storm damage experienced in the fifth week after planting resulting to all maize plants lodging (being prostrate) in the field. However, between treatments there were no significance differences for lodging score at five weeks after planting for both seasons (2013/2014 and 2014/2015), as shown in appendix 196. The wind speed in November and December 2014 at which the hailstorm was experienced mostly, measured 570 m/s and 537 m/s respectively. This might have contributed to the reduction in maize yield in season 2014/2015 since lodging interferes with water and nutrient uptake resulting in reduced translocation of nutrients as well as photo-assimilates for grain-filling. Lodging also reduces grain quality in terms of reducing specific weight of grains, increasing number of small grains and increasing the proportion of grains with more than 11.5 % protein. Hailstones split leaves of crops and affect leaf area and, hence photosynthesis, ultimately affecting yield and quality of produce.

5.3.4 Maize leaves dry matter mass (g)

Leaves dry matter mass was high in season 2013/2014 in all the weeks after planting. The results for the two crop growing seasons indicates that maize-beans (maize grown in a staggered pattern) cropping system accumulates more dry matter than the other cropping systems. This is due to efficient use of resources as the space between plants is increased, the availability of moisture obtained from beans ground cover. Availability of moisture, nutrients, and light also contributed to leaves dry matter accumulation. Leaf area index and plant height exposed the leaves to light, thus light for photosynthesis was captured and resulted to dry matter accumulation. The second season 2014/2015 had a lower leaves dry matter which might be attributed to a slight increase in temperatures and reduction in rainfall. Hailstones damages experienced at five weeks after planting might have affected leaf dry matter in the second season. Dry matter accumulation in leaf revealed significant variations due to intercropping

systems at all the growth stages. Maize, staggered + beans recorded significantly higher dry matter accumulation in leaf 83.3 % 10 WAP and 88.9 % 12 WAP.

5.3.5 Stems dry matter mass (g)

Stems dry matter mass recorded the highest in maize, staggered, 3 plants/hill + cowpeas followed by sole maize in a 25 cm spatial arrangement. Season 2013/2015 measured the highest stems dry matter both at 10 and 12 weeks after planting compared to season 2014/2015. This could be attributed by moisture availability and light interception in the crop mixture. Cowpea ground cover retains moisture in the soil thus contribute to the total moisture required for photosynthesis which results to photoassimilate. A decline in stem dry matter in season 2014/2015 might be due to lodging and hailstones damage. Photoassimilate stored on the maize stem was converted to usable forms of energy to supplement the energy damaged through hailstones in leaves.

5.3.6 Cob height, length and diameter (cm)

In both 2013/2014 and 2014/2015 seasons, maize, opposite, 3 plants/hill, + beans produced the highest cob height. This can be attributed to the availability of moisture returned by the beans as they cover the soil. Beans offers less competition to maize compared to cowpeas which covers the ground totally and extend their branches to the maize rows resulting to maize lower leaf senescence therefore a reduction in cob height. The cowpeas ground cover competes with maize for nutrients and resources like moisture therefore end up being a weed. Maize, 2 plants/hill + cowpeas cropping mixture produced the longest cob length of 19.4 cm and this might be attributed to the availability of moisture and nutrients obtained from the complementarity effect of the two crops in mixture. Maize grown in association with cowpeas produced the highest cob diameter. Maize cob height varies according to maize variety, time of seed emergence and environmental conditions such as soil characteristics (Andrade and Abbate, 2005). The effect of intercropping on cob diameter of maize was significant in 2013/2014 but not in 2014/2015. Presumamable this could be attributed to and observation by Fisher (1978) that maize effectively competes in association with legumes than in monoculture thus results to efficient use of resources.

5.3.7 Number of seeds per cob and 100 seeds dry mass (g)

Intercropping and crop arrangement significantly affected the number of seeds/cob per plant in both 2013/2014 and 2014/2015. In both seasons, the number of seeds/cob produced by maize grown in association with beans (maize, opposite, 3 plants/hill + beans) was significantly higher than those obtained by any of the intercrop arrangements. This could be a result of crop mixture complementarity effects. Also beans add nitrogen to the soil which might have been used by maize plants for grain filling. Intercropping and crop arrangement had no significant effect on dry seed mass for both crop growing seasons. In 2013/2014, maize, staggered, 3 plants/hill + beans produced significantly higher 100-seed dry mass than any of the arrangements. Staggering allows air circulation within crop rows, ease light penetration down the canopy which might in turn contribute to the allocation of assimilates in the seed, resulting to higher seed mass.

5.3.8 Maize shelling percentage

Intercropping maize with legumes significantly affected its harvest index both in 2013/2014 and 2014/2015 crop growing seasons. In both seasons, the sole maize staggered at 75 cm produced significantly slight higher harvest index than any of the intercrop arrangements. The shelling percentage of maize was the highest when maize was grown in monoculture than those intercropped with legumes (Matsebula, 2010). Intercropping and crop arrangement had no significant effect on shelling percentage of maize in 2013/2014 and 2014/2015. In 2014/2015, the shelling percentage obtained by maize grown in a staggering arrangement in association with cowpeas was higher than the values obtained at any crop arrangement but not significantly different to sole maize staggered.

5.3.9 Maize seed yield

2013/2014 cropping season had the highest mean seed yield of 7,873 kg/ha compared to 7,695 kg/ha of 2014/2015. This can be attributed to the fact that 2013/2014 had high mean rainfall of 72.5 mm that was evenly distributed throughout the growing season compared to 2014/2015. This might be also due to the fact that 2014/2015, maize was affected by hailstorm which had an influence in partitioning of assimilates. Cropping systems influenced the grain yield of maize significantly. The higher grain yield in sole maize and maize, opposite, 3 plants/hill may be attributed to higher cob length. These superior values of yield parameters in sole crop of

maize at sole cropping system could be attributed to a competition free environment, which resulted in higher leaf area, higher leaf area index and higher dry matter accumulation which contributed to an increase in yield. It is a well-known fact that the persistence of the assimilatory surface area is a prerequisite for prolonged photosynthetic activity and ultimate crop productivity, therefore the hailstones damage might have an impact on the photosynthetic activity in season 2014/2015. Intercropping and crop arrangement had a significant effect on seed yield of maize in 2013/2014 and 2014/2015. In 2013/2014, sole maize, maize grown in association with beans in an opposite pattern produced significantly the highest seed yield than any of the intercrop arrangements. Odhiambo and Ariga, (2001) working with maize and beans intercrop in different ratios found that production increased due to reduced competition between species compared competition within species. There was a significant difference in maize seed yield ($P < 0.01$) in all the treatments and between seasons. The highest seed yield of 8,435 kg/ha was recorded in sole maize and followed by maize, 2 plants/hill, + cowpeas 8,235 kg/ha cropping mixture and lastly maize, opposite, 3 plants/hill + beans being 7,872 kg/ha obtained from the cropping pattern (Table 33).

This is attributed to the space between maize plants and the complementarity effect the two crops have. Cowpeas and beans act as a cover crop between the maize rows, thus moisture is preserved. This is quantified by the fact that the moisture content between rows in cowpeas was slight higher than beans. Barhom (2001) reported that water use efficiency was the highest under soybean-maize intercropping compared with monocropping maize and monocropping soybean and this was the same with maize-cowpeas. Beans are important for their ability to maintain soil fertility through their ability to fix nitrogen and rapid establishment, which is associated with soil erosion reduction and reduction in soil temperature and lowering of weed pressure thus resulting to increased grain yield in maize. This might have attributed to higher yields experienced in this cropping mixture. As beans obtain the majority of their nitrogen from the atmosphere, they do not compete with maize for nitrogen in the soil therefore maize yield was not significantly affected by intercropping with beans according to a study done by Vesterager *et al.* (2008) and the same was true to the study conducted.

5.3.10 Maize stover yield

Stover yield of maize varied significantly due to inclusion of legumes and showed a significant difference ($P < 0.01$) in all the treatments. The highest mean stover yield was 7,701 kg/ha recorded in maize, opposite, 3 plants, + beans and the lowest 6,353 kg/ha) was obtained from sole maize, 2 plants/hill. These results are in contrary with the findings of Biru Amedie *et al.* (2004) who found that noticed higher stover yield of maize in sole crop as compared to intercropping with legumes. The difference in stover yields were due to difference in plant height and dry matter accumulation in leaf and stem at harvest. The lowest stover yield of maize in sole maize could be attributed to lower plant height and lower dry matter accumulation in leaf and stem at harvest. A difference in stover yield between seasons (7,143 kg/ha) for 2013/2014 and (6,969 kg/ha) for 2014/2015 could be attributed to the variation in weather conditions between the two seasons. 2014/2015 experienced hailstones damage which greatly had an impact on the translocation of photoassimilate from foliage, stems for grain filling.

5.4 Data on legumes intercropping

Objective number two was aimed at determining the better leguminous crop species in terms of yield for additive intercropping with maize and results pertaining legumes growth and yield are discussed in this section.

5.4.1 Legumes plant height (cm)

Plant height, increased as the number of days from planting increased. This is due to the availability of moisture, light, and nutrients supplied to the plants. In both beans and cowpeas, grown in association with maize staggered, there was an increase in plant height between seasons. This was made possible due to the fact that maize staggering arrangement allowing light to penetrate the canopy down to the legumes, therefore legumes leaves are able to capture solar radiation and use it for photosynthates production. The space between maize plants allows air circulation and exchange of gases. The shading effects of intercrops by the maize leaves helps lowers the impact of the scorching sun experienced during the dry spell of January, thus contribute to the growth of legumes. Maize plants also acts as a wind break to the intercrops thus prevents excess evapotranspiration by making the environment conducive. Therefore, planting pattern has an impact on legumes plant height in intercropping. Above ground

temperatures for maize photosynthesis and root temperatures for root growth and germination of maize have different requirements and effects to intercrops. Soil temperatures and related air temperatures may therefore influence growth and development differently, although effect on root temperature requirements is appreciably less when shade involved.

5.4.2 Legumes lodging

In beans, there was no significance of difference ($P < 0.05$) in the lodging score among treatments (Appendices 197 and 198). The highest lodging score 4.2 was observed in season two at 5 weeks after planting due to hail storm damage. Season 2013/2014 had the lowest lodging score while season 2014/2015 had the highest score 4.2 indicating that plants were prostrate. In cowpeas, lodging score was high at five weeks after planting in season 2014/2015 compared to season 2013/2014 (Appendices 199 and 200) due to hail storm damage experienced at week five. Treatments were not significantly different at five weeks after planting and between seasons. Season 2013/2014 had the lowest lodging score 1.2 while season 2014/2015 had the highest score 3.9 indicating that plants were prostrate. An increase in lodging score might be attributed to hailstone damage experienced at week five. Heavy rainfall also resulted to water logging making plant roots not to be firm on the soil. The wind speed 531 m/s at five week after planting season 2014/2015 was high resulting to plants to be prostrate.

5.4.3 Legumes ground cover %

Both beans and cowpeas ground cover increased as the number of weeks after planting increased in both seasons. Ground cover was significantly different to the cropping systems and crop arrangements. Ground cover within rows was high in maize, opposite + beans 94.0 % followed by sole beans 92.0 % and between rows in beans, ground cover was high in maize, opposite, + beans 85.0 % and sole beans 85.0 %. This could be attributed by the complementarity effect the two crops have. Maize provide shading to the beans making a cooler microclimate that favours beans growth. In cowpeas, ground cover within rows recorded highest in maize, staggered + cowpeas 90.0% and between rows ground cover recorded highest in maize, staggered and sole cowpeas 98.0%. This could be attributed by the complementarity

effect the two crops have and the availability of resources. Increase in number of leaves and canopy architecture helped preserve moisture and suppress weeds. Cropping mixture and cropping pattern has an effect on ground cover. Mashingaidze (2004) reported that maize-bean intercropping reduced weeds biomass by 50-66 % when established at a density of 222,000 plants/ha.

5.4.4 Number of pods per plant in beans and cowpeas

Among the intercrop arrangements, the number of pods per plant obtained in beans were statistically different in both crop growing season 2013/2014 and 2014/2015. Maize, staggered, 3 plants/hill produced the highest number of seeds per pod in both seasons in beans. The effect of intercropping and crop arrangement on percentage sterile pods was also significant in 2014/2015. Dense shading in beans results to poor pod initiation thus results to a decrease in the number of pods per plant. Addo-Quaye *et al.* (2011) reported that the growth and yield of bean was reduced when intercropped with maize due to dense shading effects.

The number of pods per plant in cowpeas was significantly higher in sole cowpeas in both crop growing seasons. The length and diameter of the pods, number of pods per plot and per plant, and seeds per pod in the sole cowpea outperformed those in the cowpea-maize intercrop. The sole cowpea produced many pods per plot (16.2) and this was higher than the intercrops. In each of the seasons, the highest numbers of pods were produced by the sole crop. According to Alhaji (2008), maize leaves form canopy and barricades light from reaching the cowpea leaves and this reduced the ability of cowpea to make more food for the formation of flowers and pods. When maize plants were at high density, they caused reduction in the growth and development attributes of cowpea due to the effects of canopy and as a result grain yield of cowpea was low compared with sole crops when cowpea is was intercropped with maize. This observation was attributed to the inter-specific competition and depressive effect of maize crop on the counter legume crop. A research done by Iderawumi and Friday (2013) also showed that sole cowpea plants produced significantly higher number of harvested pods per plant than those which were intercropped with maize.

Alhaji (2008) found that the number of pods, pod mass and seed yield was significantly reduced when cowpea was intercropped with maize. Lemlem (2013) reported that intercropping affect pod length and cowpea in monocrop had the longest pod length but this was significantly reduced under intercropping. These findings suggest that the number of pods obtained per plot was attributed to the number of cowpea plants which were many in the sole plot compared with that in the intercrop due to shading effects from the maize. In addition, there was flower abortion in the intercrop due to moisture stress which reduced the final number of pods obtained in a plot especially season 2014/2015.

5.4.5 100 seed dry mass in beans and cowpeas

Beans mean dry mass recorded highest in sole beans being 47.7 g followed by staggered planting pattern being 44.5 g. Season 2013/2014 had a high dry mass compared to season 2014/2015. With adequate moisture during seed development, seed size might be expected to compensate for pod number. Sole beans high dry mass indicates that proportionately more photosynthates went to seed production and less to vegetative production. Water stress can reduce seed mass and pod fills this however this contributed to the beans dry seed mass in season 2014/2015 which experienced a dry spell in January 2015.

In cowpeas, crop mixture and crop pattern both significantly affected 100 seed dry mass in 2013/2014 and 2014/2015 cropping seasons. The results on cowpeas indicated that the highest 100 seed dry mass was obtained by the sole crops 15.3 g in both seasons followed by the opposite cropping pattern 14.6 g. The heavy seed mass was due to favourable temperatures, high rainfall, and the absence of diseases throughout the experiment. A reduction in the cowpeas seed dry mass in the second season can be contributed to hailstones damage and moisture stress experienced during January 2015. When photosynthesis assimilates is translocated from vegetative organs to the other parts, seed mass will be enhanced considerably. As seeds are a major source of assimilate, they moves to the seeds and in conclusion larger seeds were produced in sole cowpea as the plot is exposed to sunlight, no canopy shading from maize. Data regarding 100 seed dry mass enunciated that it was significantly influenced by different cropping mixture.

5.4.6 Shelling percentage

The effect of intercropping on shelling percentage of beans and cowpeas was significant between the two seasons. The sole beans and cowpeas produced significantly higher shelling percentage than the intercrop arrangements in both seasons. Maize, opposite, 3 plants/hill + legumes, produced the highest shelling percentage among the planting patterns in both seasons. This could be attributed to the favourable temperatures, high rainfall and the absence of diseases which all result to the production of more seeds per pod, and heavier mean seed mass.

5.4.7 Beans and cowpea seed yield (kg/ha)

The seed yield obtained at cropping system and crop arrangement were statistically significant. Intercropping and crop arrangement differently affected seed yield in both beans and cowpeas in 2013/2014 and 2014/2015. In 2013/2014, the sole beans and cowpeas produced significantly higher seed yield than the rest of the intercropping arrangement, while seed yields obtained among the different intercrop arrangements were not significantly different. In 2014/2015, seed yield obtained by the sole crop was statistically higher than that of the intercrop arrangements. Similarly, seed yield differences among all the intercrop arrangements were also significant. High seed yield in sole beans and cowpeas could be attributed to the absence of competition experienced in crop mixtures. In sole crops, light penetration and utilization is high due to the absence of above ground canopy cover from maize and this results to higher yields.

5.5 Data on Moisture Retention

5.5.1 Moisture retention within legume row (mm)

Maize-cowpeas association measured the highest moisture (21.6 mm) content due to high rainfall received at this time while sole maize measured the least (17.4 mm) moisture content at 9 weeks after planting. Sole maize leaf canopy was slow in establishing the ground cover and the fact that maize is erect contributes to less moisture retention. On the contrary soil moisture content in the soil was increased dramatically in the sole crop of cowpea due to low evapotranspiration potential for growth period (Dahmardeh *et al.*, 2010). Moisture measurements taken at different maize stages indicated higher moisture retention in maize/legume compared to sole maize alone and bare land (Tauelli *et al.*, 2003). Soil moisture

content in the soil was reduced dramatically in the sole crop of maize due to high evapotranspiration potential (Dahmardeh *et al.*, 2010). Reddy and Reddi (2007) mentioned that taller crops act as wind barrier for short crops. A row of maize in a field with a shorter crop reduces wind speed above the shorter crops and thus desiccation (Beets, 1990). In an intercropping system weeds are more easily controlled for example in maize bean intercrop, the bean covers the soil, preventing weeds to grow. Intercrops have been identified to conserve water largely because of early high leaf area index and higher leaf area (Ogindo and Walker, 2005). Cowpea provided better soil cover compared to sole maize, so water evaporation at soil surface was low and soil moisture high compared to sole maize. Distribution of root systems among species and cropping system influenced the water content down the soil profile.

5.6 Light use efficiency

Light transmission ratio was high in sole cowpeas with a mean of 57.6 % and the light absorption was 76.6 % in both seasons. This could be attributed to the availability of solar radiation throughout the season. In sole crops, there is no competition for light in the crops and shading of leaves from above canopy. In the intercropping system, light use efficiency was high among intercrops. The rate of dry matter (DM) production and crop growth are usually directly proportional to the amount of light intercepted by the leaf blades or crop canopy and this is influenced by leaf area index (Ong *et al.*, 1996). Low availability of light for a component crop in mixtures reduces the photosynthetic rate and crop growth rate, finally leading to drastic reduction in grain and straw yields of component crops. In South Africa, Tsubo and walker (2002) measured photosynthetically active radiation above and beneath a maize-bean intercrop canopy in both north-south and east west rows, they observed that intercropping was equivalent in growth efficiency of maize to the sole cropping whereas, beans had greater radiation use efficiency in intercropping than in sole cropping. At ICRISAT, measurement of light interception showed that intercropping did not intercept more light energy than sole cropping, but this energy was more efficiently converted into dry matter (Reddy *et al.*, 2007).

5.7 Land equivalent ratio (LER)

LER was high in maize, opposite, 3 plants/hill + beans 2.73 and also maize, 2 plants/hill + cowpeas 2.11 among the cropping mixtures and cropping patterns. The effect of season and the comparison of season by cropping system and spatial arrangement on seed yield of maize significantly affected the LER. The land equivalent ratio exceeded unity in most intercropping systems and spatial arrangement in the experiment indicating an advantage of intercropping compared to the sole cropping. Higher LER in intercropping treatments indicated yield advantage over monocropping due to better land utilization LER values were greater than 1.0 in all intercropping systems with different planting patterns which indicated yield advantage of intercropping over sole cropping of maize. When LER is greater than 1.0, the intercropping favours the growth and yield of the species. In contrast, when LER is lower than 1.0, the intercropping negatively affects the growth and yield of plants grown in mixtures. So intercropping showed an advantage over sole cropping at all two harvesting seasons; in general there was a trend for LER values to decrease with an increase in optimum spatial arrangement. Thus, it can be suggested that complementary facilitation dominates over competitive interference. Facilitative root interactions are most likely to be of importance in nutrient poor soils and low input agro-ecosystems due to critical interspecific competition or facilitation for plant growth factors.

Because of the spatial and temporal differences in the growth factors and different crop species, intercropped plants could better utilize nutrients from soils compared with monocropped plants. The highest LER obtained from this study was 2.73 in in maize, opposite, 3 plants/hill + beans. These LERs appear high, but other researchers have reported similar LERs. For example research done by Ibrahim Hamza (2008) working on yield performance of cowpea varieties under sole and intercropping with maize at Bauchi, Nigeria, obtained a LER of 2.29. Also Dahmardeh *et al.* (2007) working on the role of intercropping maize and cowpea on yield and soil properties reported LERs of 2.31 and 2.57 in years one and two, respectively.

CHAPTER 6

6.0 CONCLUSIONS

From the data presented, analysed, and discussed, the following conclusions can be drawn:

Based on the growth and yield parameters collected during the two crop growing seasons (2013/2014 and 2014/2015), it was observed that growing maize with beans (maize grown in an opposite arrangement, 3 plants/hill) results to efficient use of resources than sole crops thus higher yields. These suggest that selecting intercrops that are best adapted to the growing environment would have the most positive effect on the companion crop by minimizing competition thus yield higher. From the above statement, it can be concluded that there are opportunities for improving the productivity of maize-based cropping systems through increased productivity of the land on which maize is grown. It was also noted that, maize, 3 plants/hill showed to be the best optimum spatial arrangement for intercropping with beans and cowpeas in terms of growth and seed yield. In the intercrop experiment, beans additively intercropped with maize were observed to be the best leguminous crop species in terms of yield for additive intercropping with maize. Maize, opposite, 3 plants/hill proved to be the desirable maize planting pattern that use resources efficient and results to higher growth rate and seed yield. Intercropping compared to sole cropping is the best cropping system, because at this system light interception, soil moisture, soil temperature and yield were higher compared to sole crops in maize. Microclimatic variation in intercropping system have caused favourable environmental conditions, ready for growth and higher yield compared to sole crops. The cowpea-maize intercropping exploited more stored water than a sole maize crop; the beneficial effects of the intercropping (reduced evaporation and crop transpiration) appeared to greatly compensate the interception and uptake losses near the cowpea canopy. It is evident from the results, that cowpea and cowpea-maize intercropping are more effective in improving soil water retention compared to sole maize. Significantly higher Light Transmission Ratio (LTR) was obtained in sole crop treatments of maize. The land equivalent ratio exceeded unity in most intercropping systems and spatial arrangement in the experiment indicating an advantage of intercropping compared to the sole cropping. The LER analysis further showed that the best intercropping advantage occurred in maize, staggered, 3 plants/hill, + cowpeas. Results from the calculated RCC presented indicates that the species has produced more yield.

CHAPTER 7

7.0 RECOMMENDATIONS

- i. Based on the findings of this study, it is recommended that maize farmers grow maize in association with beans because:
 - The optimum spatial arrangement for maize, yields significantly higher and favour beans growth than cowpeas.
 - Beans yield significantly higher than cowpeas when additively intercropped with maize and fetch a higher market price.
 - Maize seed yield will be significantly higher when maize grown in an opposite planting pattern than staggering thus improve food production and sustainable crop production adapting to climate change.
 - Maize planted in three seeds per planting hill will yield significantly higher than one or two seeds per hill even in the farmer's field thus ascertain food security.
- ii. Farmers should also adopt the intercropping pattern preferably the opposite, 3 maize plants/hill technique for yield advantage. However, more research is needed to further understand the associated additional benefits to enhance the benefits of intercropping achieved in this study.
- iii. This experiment needs to be investigated on-farm and under different Agro-ecological zones of Swaziland to validate the findings of this study.
- iv. Further research is needed to check maize-beans intercropping's performance as dual purpose crops under on-farm and multi-location trials.

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APPENDICES

Appendix 1. ANOVA table for maize emergence count

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
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1	Replication	4	338.917	84.729	4.3768	0.0028
2	Factor A	11	459.440	41.767	2.1576	0.0235
4	Factor B	1	496.093	496.093	25.6265	0.0000
6	AB	11	237.784	21.617	1.1166	0.3576
-7	Error	92	1780.991	19.359		
Total		119	3313.225			
Coefficient of Variation: 4.87%						

Appendix 2. ANOVA table for maize plant height 2WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	13.777	3.444	6.3556	0.0001
2	Factor A	11	2.923	0.266	0.4903	
4	Factor B	1	1920.320	1920.320	3543.4334	0.0000
6	AB	11	5.355	0.487	0.8982	
-7	Error	92	49.858	0.542		
Total		119	1992.233			
Coefficient of Variation: 5.54%						

Appendix 3. ANOVA table for maize plant height 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	26.837	6.709	1.2374	0.3006
2	Factor A	11	91.571	8.325	1.5353	0.1323
4	Factor B	1	106.974	106.974	19.7291	0.0000
6	AB	11	92.465	8.406	1.5503	0.1273
-7	Error	92	498.839	5.422		
Total		119	816.686			
Coefficient of Variation: 7.71%						

Appendix 4. ANOVA table for maize plant height 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	26.665	6.666	0.7169	
2	Factor A	11	178.168	16.197	1.7418	0.0763
4	Factor B	1	4231.657	4231.657	455.0726	0.0000
6	AB	11	147.724	13.429	1.4442	0.1669
-7	Error	92	855.495	9.299		
Total		119	5439.708			
Coefficient of Variation: 4.67%						

Appendix 5. ANOVA table for maize plant height 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	71.530	17.882	1.8262	0.1305
2	Factor A	11	132.017	12.002	1.2256	0.2816
4	Factor B	1	13129.391	13129.391	1340.7950	0.0000
6	AB	11	130.848	11.895	1.2148	0.2886
-7	Error	92	900.886	9.792		
Total		119	14364.672			
Coefficient of Variation: 2.62%						

Appendix 6. ANOVA table for maize plant height 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1074.384	268.596	1.9677	0.1060
2	Factor A	11	808.077	73.462	0.5382	
4	Factor B	1	70117.171	70117.171	513.6614	0.0000
6	AB	11	1333.236	121.203	0.8879	
-7	Error	92	12558.429	136.505		
Total		119	85891.297			
Coefficient of Variation: 6.02%						

Appendix 7. ANOVA table for maize plant height 12WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	3169.792	792.448	6.4573	0.0001
2	Factor A	11	4564.100	414.918	3.3810	0.0006
4	Factor B	1	36749.999	36749.999	299.4613	0.0000
6	AB	11	1.508	0.137	0.0011	
-7	Error	92	11290.272	122.720		
Total		119	55775.673			
Coefficient of Variation: 5.15%						

Appendix 8. ANOVA table for maize leaf length 2WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	8.456	2.114	0.8502	
2	Factor A	11	35.287	3.208	1.2902	0.2426
4	Factor B	1	0.217	0.217	0.0872	
6	AB	11	26.508	2.410	0.9692	
-7	Error	92	228.752	2.486		
Total		119	299.220			
Coefficient of Variation: 16.24%						

Appendix 9. ANOVA table for maize leaf length 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	139.130	34.783	2.5470	0.0446
2	Factor A	11	159.604	14.509	1.0625	0.4001
4	Factor B	1	857.071	857.071	62.7596	0.0000
6	AB	11	142.514	12.956	0.9487	
-7	Error	92	1256.390	13.656		
Total		119	2554.709			
Coefficient of Variation: 16.80%						

Appendix 10. ANOVA table for maize leaf length 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	83.828	20.957	0.6094	
2	Factor A	11	379.949	34.541	1.0045	0.4488
4	Factor B	1	2915.603	2915.603	84.7869	0.0000
6	AB	11	460.413	41.856	1.2172	0.2870
-7	Error	92	3163.644	34.387		
Total		119	7003.436			
Coefficient of Variation: 13.20%						

Appendix 11. ANOVA table for maize leaf length 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	90.321	22.580	0.6820	
2	Factor A	11	422.807	38.437	1.1609	0.3251
4	Factor B	1	22249.636	22249.636	672.0164	0.0000
6	AB	11	438.535	39.867	1.2041	0.2955
-7	Error	92	3046.007	33.109		
Total		119	26247.306			
Coefficient of Variation: 6.73%						

Appendix 12. ANOVA table for maize leaf length 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	151.521	37.880	0.6543	
2	Factor A	11	900.415	81.856	1.4139	0.1800
4	Factor B	1	8949.315	8949.315	154.5798	0.0000
6	AB	11	502.105	45.646	0.7884	
-7	Error	92	5326.291	57.894		
Total		119	15829.646			
Coefficient of Variation: 6.82%						

Appendix 13. ANOVA table for maize leaf length 12WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	435.974	108.994	1.6993	0.1569
2	Factor A	11	724.623	65.875	1.0270	0.4295
4	Factor B	1	57347.525	57347.525	894.0899	0.0000
6	AB	11	623.653	56.696	0.8839	
-7	Error	92	5900.941	64.141		
Total		119	65032.716			
Coefficient of Variation: 6.93%						

Appendix 14. ANOVA table for maize leaf width 2WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	8.472	2.118	5.5622	0.0005
2	Factor A	11	3.535	0.321	0.8440	
4	Factor B	1	5.808	5.808	15.2528	0.0002
6	AB	11	3.330	0.303	0.7950	
-7	Error	92	35.032	0.381		
Total		119	56.177			
Coefficient of Variation: 18.12%						

Appendix 15. ANOVA table for maize leaf width 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	5.894	1.473	4.2112	0.0036
2	Factor A	11	4.289	0.390	1.1143	0.3594
4	Factor B	1	11.907	11.907	34.0304	0.0000
6	AB	11	3.855	0.350	1.0016	0.4513
-7	Error	92	32.190	0.350		
Total		119	58.135			

Coefficient of Variation: 10.51%

Appendix 16. ANOVA table for maize leaf width 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	9.511	2.378	5.2944	0.0007
2	Factor A	11	4.279	0.389	0.8662	
4	Factor B	1	31.930	31.930	71.0980	0.0000
6	AB	11	3.961	0.360	0.8018	
-7	Error	92	41.317	0.449		
Total		119	90.998			

Coefficient of Variation: 9.12%

Appendix 17. ANOVA table for maize leaf width 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	7.918	1.980	3.7050	0.0077
2	Factor A	11	7.275	0.661	1.2379	0.2738
4	Factor B	1	411.848	411.848	770.8438	0.0000
6	AB	11	6.827	0.621	1.1617	0.3246
-7	Error	92	49.154	0.534		
Total		119	483.023			

Coefficient of Variation: 7.63%

Appendix 18. ANOVA table for maize leaf width 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.906	0.227	0.5304	
2	Factor A	11	5.557	0.505	1.1825	0.3101
4	Factor B	1	388.080	388.080	908.4447	0.0000
6	AB	11	2.490	0.226	0.5298	
-7	Error	92	39.302	0.427		
Total		119	436.335			

Coefficient of Variation: 5.79%

Appendix 19. ANOVA table for maize leaf width 12WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1.261	0.315	0.5160	
2	Factor A	11	7.230	0.657	1.0757	0.3894
4	Factor B	1	672.607	672.607	1100.7738	0.0000
6	AB	11	7.270	0.661	1.0817	0.3847
-7	Error	92	56.215	0.611		
Total		119	744.583			
Coefficient of Variation: 6.80%						

Appendix 20. ANOVA table for maize leaf area 2WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	932.931	233.233	3.5178	0.0102
2	Factor A	11	778.236	70.749	1.0671	0.3963
4	Factor B	1	498.169	498.169	7.5137	0.0074
6	AB	11	680.076	61.825	0.9325	
-7	Error	92	6099.709	66.301		
Total		119	8989.121			
Coefficient of Variation: 28.84%						

Appendix 21. ANOVA table for maize leaf area 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	3976.423	994.106	3.4845	0.0107
2	Factor A	11	5700.875	518.261	1.8166	0.0621
4	Factor B	1	3075.469	3075.469	10.7800	0.0015
6	AB	11	5383.542	489.413	1.7155	0.0820
-7	Error	92	26246.957	285.293		
Total		119	44383.265			
Coefficient of Variation: 18.56%						

Appendix 22. ANOVA table for maize leaf area 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	12007.021	3001.755	1.9818	0.1038
2	Factor A	11	12329.895	1120.900	0.7400	
4	Factor B	1	233244.919	233244.919	153.9906	0.0000
6	AB	11	18744.521	1704.047	1.1250	0.3513
-7	Error	92	139349.648	1514.670		
Total		119	415676.004			
Coefficient of Variation: 15.88%						

Appendix 23. ANOVA table for maize leaf area 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	60666.379	15166.595	3.9112	0.0056
2	Factor A	11	32042.112	2912.919	0.7512	
4	Factor B	1	132129.394	132129.394	34.0735	0.0000
6	AB	11	55158.601	5014.418	1.2931	0.2409
-7	Error	92	356755.408	3877.776		
Total		119	636751.895			
Coefficient of Variation: 13.84%						

Appendix 24. ANOVA table for maize leaf area 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	15807.393	3951.848	0.6025	
2	Factor A	11	145391.358	13217.396	2.0150	0.0355
4	Factor B	1	58392.808	58392.808	8.9022	0.0036
6	AB	11	62989.589	5726.326	0.8730	
-7	Error	92	603461.206	6559.361		
Total		119	886042.354			

Coefficient of Variation: 11.44%

Appendix 25.ANOVA table for maize leaf area 12WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	33020.740	8255.185	1.0667	0.3776
2	Factor A	11	143816.793	13074.254	1.6894	0.0880
4	Factor B	1	1190281.804	1190281.804	153.7994	0.0000
6	AB	11	108220.537	9838.231	1.2712	0.2536
-7	Error	92	712004.872	7739.183		
Total		119	2187344.746			

Coefficient of Variation: 11.87%

Appendix 26.ANOVA table for maize leaf area index 2WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.000	0.000	3.3808	0.0126
2	Factor A	11	0.000	0.000	1.1317	0.3463
4	Factor B	1	0.001	0.001	1670.5666	0.0000
6	AB	11	0.000	0.000	1.0070	0.4466
-7	Error	92	0.000	0.000		
Total		119	0.001			

Coefficient of Variation: 14.35%

Appendix 27.ANOVA table for maize leaf area index 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.000	0.000	3.5027	0.0104
2	Factor A	11	0.000	0.000	1.0787	0.3870
4	Factor B	1	0.009	0.009	1785.8829	0.0000
6	AB	11	0.000	0.000	0.8809	
-7	Error	92	0.000	0.000		
Total		119	0.009			

Coefficient of Variation: 12.90%
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Appendix 28.ANOVA table for maize leaf area index 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.000	0.000	3.3718	0.0127
2	Factor A	11	0.000	0.000	1.0201	0.4354
4	Factor B	1	0.102	0.102	3373.5195	0.0000
6	AB	11	0.000	0.000	0.3623	
-7	Error	92	0.003	0.000		
Total		119	0.106			

Coefficient of Variation: 11.73%
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Appendix 29. ANOVA table for maize leaf area index 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.000	0.000	0.9301	
2	Factor A	11	0.001	0.000	1.7612	0.0724
4	Factor B	1	0.139	0.139	3225.5082	0.0000
6	AB	11	0.001	0.000	1.3659	0.2025
-7	Error	92	0.004	0.000		
Total		119	0.145			

Coefficient of Variation: 9.28%
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Appendix 30.ANOVA table for maize leaf area index 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.020	0.005	0.8518	
2	Factor A	11	0.052	0.005	0.8028	
4	Factor B	1	0.024	0.024	4.1772	0.0438
6	AB	11	0.058	0.005	0.9054	
-7	Error	92	0.539	0.006		

Total	119	0.694
Coefficient of Variation: 77.70%		

Appendix 31.ANOVA table for maize leaf area index 12WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.000	0.000	0.7683	
2	Factor A	11	0.000	0.000	0.5703	
4	Factor B	1	0.116	0.116	1561.9411	0.0000
6	AB	11	0.001	0.000	0.7648	
-7	Error	92	0.007	0.000		
Total		119	0.125			
Coefficient of Variation: 9.75%						

Appendix 32.ANOVA table for maize lodging score 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1.450	0.363	4.3032	0.0031
2	Factor A	11	1.100	0.100	1.1871	0.3070
4	Factor B	1	288.300	288.300	3422.4000	0.0000
6	AB	11	1.100	0.100	1.1871	0.3070
-7	Error	92	7.750	0.084		
Total		119	299.700			
Coefficient of Variation: 11.38%						

Appendix 33. ANOVA table for maize lodging score 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.333	0.083	0.4340	
2	Factor A	11	1.100	0.100	0.5208	
4	Factor B	1	2.133	2.133	11.1094	0.0012
6	AB	11	1.267	0.115	0.5997	
-7	Error	92	17.667	0.192		

Total	119	22.500
Coefficient of Variation: 35.06%		

Appendix 34.ANOVA table for maize lodging score 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.000	0.000	0.0000	
2	Factor A	11	0.000	0.000	0.0000	
4	Factor B	1	0.000	0.000	0.0000	
6	AB	11	0.000	0.000	0.0000	
-7	Error	92	0.000	0.000		
Total		119	0.000			
Coefficient of Variation: 0.00%						

Appendix 35.ANOVA table for maize insect rating score 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1.383	0.346	1.4321	0.2296
2	Factor A	11	2.625	0.239	0.9882	
4	Factor B	1	1.008	1.008	4.1755	0.0439
6	AB	11	2.692	0.245	1.0133	0.4412
-7	Error	92	22.217	0.241		
Total		119	29.925			
Coefficient of Variation: 32.22%						

Appendix 36.ANOVA table for maize insect rating score 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1.117	0.279	2.6523	0.0380
2	Factor A	11	1.067	0.097	0.9213	
4	Factor B	1	0.533	0.533	5.0671	0.0268
6	AB	11	1.467	0.133	1.2668	0.2562

-7	Error	92	9.683	0.105		
	Total	119	13.867			
Coefficient of Variation: 28.63%						

Appendix 37. ANOVA table for maize leaves dry matter 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	919.819	229.955	1.5959	0.1821
2	Factor A	11	4960.335	450.940	3.1295	0.0013
4	Factor B	1	10367.643	10367.643	71.9501	0.0000
6	AB	11	298.831	27.166	0.1885	
-7	Error	92	13256.729	144.095		
	Total	119	29803.356			
Coefficient of Variation: 18.96%						

Appendix 38. ANOVA table for maize leaves dry matter 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	23.971	5.993	0.1581	
2	Factor A	11	1385.948	125.995	3.3244	0.0007
4	Factor B	1	2076.672	2076.672	54.7924	0.0000
6	AB	11	356.240	32.385	0.8545	
-7	Error	92	3486.865	37.901		
	Total	119	7329.695			
Coefficient of Variation: 7.35%						

Appendix 39. ANOVA table for maize leaves dry matter 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	975.660	243.915	3.7749	0.0069
2	Factor A	11	1415.830	128.712	1.9920	0.0379
4	Factor B	1	2631.565	2631.565	40.7264	0.0000
6	AB	11	27.015	2.456	0.0380	

-7	Error	92	5944.648	64.616		
	Total	119	10994.719			
Coefficient of Variation: 10.27%						

Appendix 40.ANOVA table for maize leaves dry matter 12WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1058.798	264.699	3.9929	0.0049
2	Factor A	11	1323.420	120.311	1.8149	0.0624
4	Factor B	1	1102.314	1102.314	16.6280	0.0001
6	AB	11	37.561	3.415	0.0515	
-7	Error	92	6098.906	66.292		
	Total	119	9620.999			
Coefficient of Variation: 9.65%						

Appendix 41.ANOVA table for maize stems dry matter 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	309.434	77.359	1.0208	0.4009
2	Factor A	11	907.862	82.533	1.0891	0.3788
4	Factor B	1	4898.574	4898.574	64.6403	0.0000
6	AB	11	1244.733	113.158	1.4932	0.1474
-7	Error	92	6971.950	75.782		
	Total	119	14332.553			
Coefficient of Variation: 14.52%						

Appendix 42.ANOVA table for maize stems dry matter 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	273.195	68.299	1.2181	0.3086
2	Factor A	11	376.849	34.259	0.6110	

4	Factor B	1	1946.490	1946.490	34.7159	0.0000
6	AB	11	504.434	45.858	0.8179	
-7	Error	92	5158.357	56.069		
Total		119	8259.326			
Coefficient of Variation: 9.77%						

Appendix 43. ANOVA table for maize stems dry matter 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	50.691	12.673	0.4095	
2	Factor A	11	777.975	70.725	2.2854	0.0161
4	Factor B	1	362.616	362.616	11.7174	0.0009
6	AB	11	229.492	20.863	0.6742	
-7	Error	92	2847.102	30.947		
Total		119	4267.875			
Coefficient of Variation: 6.39%						

Appendix 44. ANOVA table for maize stems dry matter 12WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1244.416	311.104	4.7720	0.0015
2	Factor A	11	1683.445	153.040	2.3475	0.0134
4	Factor B	1	301.150	301.150	4.6193	0.0342
6	AB	11	20.763	1.888	0.0290	
-7	Error	92	5997.816	65.194		
Total		119	9247.590			
Coefficient of Variation: 10.72%						

Appendix 45. ANOVA table for maize cob height 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1895.932	473.983	5.5063	0.0005
2	Factor A	11	1020.464	92.769	1.0777	0.3878

4	Factor B	1	9521.405	9521.405	110.6110	0.0000
6	AB	11	1002.359	91.124	1.0586	0.4032
-7	Error	92	7919.369	86.080		
Total		119	21359.528			
Coefficient of Variation: 8.62%						

Appendix 46.ANOVA table for maize cob height 12WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	963.940	240.985	2.7064	0.0350
2	Factor A	11	800.542	72.777	0.8173	
4	Factor B	1	10083.334	10083.334	113.2428	0.0000
6	AB	11	1224.113	111.283	1.2498	0.2665
-7	Error	92	8191.838	89.042		
Total		119	21263.766			
Coefficient of Variation: 7.83%						

Appendix 47.ANOVA table for maize cob dry matter 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	5183.811	1295.953	7.6631	0.0000
2	Factor A	11	3390.771	308.252	1.8227	0.0611
4	Factor B	1	2019.578	2019.578	11.9420	0.0008
6	AB	11	714.309	64.937	0.3840	
-7	Error	92	15558.574	169.115		
Total		119	26867.044			
Coefficient of Variation: 19.50%						

Appendix 48. ANOVA table for maize cob dry matter 12WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	7495.186	1873.796	10.7486	0.0000
2	Factor A	11	1307.458	118.860	0.6818	

4	Factor B	1	2154.175	2154.175	12.3570	0.0007
6	AB	11	1634.548	148.595	0.8524	
-7	Error	92	16038.259	174.329		
Total		119	28629.625			
Coefficient of Variation: 18.19%						

Appendix 49. Tassels dry matter 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	785.669	196.417	1.5420	0.1966
2	Factor A	11	4172.621	379.329	2.9780	0.0020
4	Factor B	1	1446.574	1446.574	11.3565	0.0011
6	AB	11	740.679	67.334	0.5286	
-7	Error	92	11718.773	127.378		
Total		119	18864.317			
Coefficient of Variation: 22.66%						

Appendix 50. ANOVA table for maize tassels dry matter 12WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1307.982	326.996	3.5939	0.0091
2	Factor A	11	3677.954	334.359	3.6748	0.0002
4	Factor B	1	898.119	898.119	9.8708	0.0023
6	AB	11	514.949	46.814	0.5145	
-7	Error	92	8370.821	90.987		
Total		119	14769.826			
Coefficient of Variation: 16.39%						

Appendix 51. ANOVA table for maize cob + husk mass

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	238954.117	59738.529	1.7341	0.1492

2	Factor A	11	776380.825	70580.075	2.0488	0.0322
4	Factor B	1	444205.008	444205.008	12.8944	0.0005
6	AB	11	296224.892	26929.536	0.7817	
-7	Error	92	3169343.483	34449.386		
Total		119	4925108.325			

Coefficient of Variation: 11.90%

Appendix 52.ANOVA table for maize husk mass

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	626310.133	156577.533	116.6307	0.0000
2	Factor A	11	23304.000	2118.545	1.5781	0.1184
4	Factor B	1	90750.000	90750.000	67.5974	0.0000
6	AB	11	0.000	0.000	0.0000	
-7	Error	92	123510.667	1342.507		
Total		119	863874.800			

Coefficient of Variation: 13.23%

Appendix 53.ANOVA table for maize cob length

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	32.671	8.168	2.8342	0.0288
2	Factor A	11	35.504	3.228	1.1200	0.3550
4	Factor B	1	48.514	48.514	16.8345	0.0001
6	AB	11	31.611	2.874	0.9972	
-7	Error	92	265.129	2.882		
Total		119	413.429			

Coefficient of Variation: 9.28%

Appendix 54.ANOVA table for maize cob diameter

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
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1	Replication	4	0.727	0.182	2.5886	0.0418
2	Factor A	11	0.477	0.043	0.6171	
4	Factor B	1	0.033	0.033	0.4747	
6	AB	11	1.537	0.140	1.9892	0.0382
-7	Error	92	6.461	0.070		
Total		119	9.235			
Coefficient of Variation: 5.77%						

Appendix 55.ANOVA table for maize number of seeds

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	65638.133	16409.533	1.7582	0.1440
2	Factor A	11	44783.692	4071.245	0.4362	
4	Factor B	1	20829.675	20829.675	2.2318	0.1386
6	AB	11	92031.425	8366.493	0.8964	
-7	Error	92	858650.667	9333.159		
Total		119	1081933.592			
Coefficient of Variation: 16.11%						

Appendix 56.ANOVA table for maize number of rows

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	4.867	1.217	1.1291	0.3477
2	Factor A	11	15.300	1.391	1.2908	0.2422
4	Factor B	1	14.700	14.700	13.6422	0.0004
6	AB	11	9.700	0.882	0.8184	
-7	Error	92	99.133	1.078		
Total		119	143.700			
Coefficient of Variation: 6.90%						

Appendix 57. ANOVA table for maize mass of cob without husk

K	Degrees of Freedom	Sum of Squares	Mean Square	F
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Value	Source	Freedom	Squares	Square	Value	Prob
1	Replication	4	237402.667	59350.667	2.0028	0.1006
2	Factor A	11	362281.892	32934.717	1.1114	0.3616
4	Factor B	1	164354.117	164354.117	5.5462	0.0206
6	AB	11	246454.492	22404.954	0.7561	
-7	Error	92	2726309.333	29633.797		
Total		119	3736802.500			
Coefficient of Variation: 11.69%						

Appendix 58.ANOVA table for maize mass of all seeds shelled

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	2462242.967	615560.742	0.7570	
2	Factor A	11	9042435.492	822039.590	1.0109	0.4432
4	Factor B	1	79516.008	79516.008	0.0978	
6	AB	11	8899463.692	809042.154	0.9949	
-7	Error	92	74813519.433	813190.429		
Total		119	95297177.592			
Coefficient of Variation: 72.35%						

Appendix 59.ANOVA table for maize fresh mass 100 seeds

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	178.133	44.533	4.3592	0.0028
2	Factor A	11	67.067	6.097	0.5968	
4	Factor B	1	1687.500	1687.500	165.1830	0.0000
6	AB	11	54.900	4.991	0.4885	
-7	Error	92	939.867	10.216		
Total		119	2927.467			
Coefficient of Variation: 5.82%						

Appendix 60.ANOVA table for maize dry mass 100 seeds

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	72.533	18.133	2.4395	0.0524
2	Factor A	11	95.867	8.715	1.1724	0.3170
4	Factor B	1	70.533	70.533	9.4888	0.0027
6	AB	11	47.067	4.279	0.5756	
-7	Error	92	683.867	7.433		
Total		119	969.867			
Coefficient of Variation: 7.80%						

Appendix 61.ANOVA table for maize shelling %

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	356.066	89.016	0.9137	
2	Factor A	11	1165.469	105.952	1.0875	0.3801
4	Factor B	1	298.621	298.621	3.0650	0.0833
6	AB	11	1585.648	144.150	1.4795	0.1526
-7	Error	92	8963.455	97.429		
Total		119	12369.258			
Coefficient of Variation: 12.37%						

Appendix 62.ANOVA table for maize moisture %

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	61.916	15.479	0.5023	
2	Factor A	11	298.742	27.158	0.8813	
4	Factor B	1	630.208	630.208	20.4500	0.0000
6	AB	11	174.998	15.909	0.5162	
-7	Error	92	2835.164	30.817		
Total		119	4001.028			
Coefficient of Variation: 15.47%						

Appendix 63.ANOVA table for beans emergence percentage

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
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1	Replication	4	100.419	25.105	1.0951	0.3738
2	Factor A	4	114.027	28.507	1.2435	0.3101
4	Factor B	1	1570.241	1570.241	68.4942	0.0000
6	AB	4	56.337	14.084	0.6144	
-7	Error	36	825.305	22.925		
Total		49	2666.329			
Coefficient of Variation: 5.52%						

Appendix 64.ANOVA table for beans plant height 2WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	15.439	3.860	2.8656	0.0369
2	Factor A	4	7.937	1.984	1.4731	0.2307
4	Factor B	1	44.180	44.180	32.8007	0.0000
6	AB	4	6.100	1.525	1.1322	0.3568
-7	Error	36	48.489	1.347		
Total		49	122.145			
Coefficient of Variation: 12.82%						

Appendix 65.ANOVA table for beans plant height 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	8.335	2.084	2.2648	0.0813
2	Factor A	4	15.959	3.990	4.3365	0.0058
4	Factor B	1	25.490	25.490	27.7053	0.0000
6	AB	4	14.853	3.713	4.0361	0.0083
-7	Error	36	33.121	0.920		
Total		49	97.758			
Coefficient of Variation: 5.28%						

Appendix 66.ANOVA table for beans plant height 6WAP

K	Degrees of Freedom	Sum of Squares	Mean Square	F
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Value	Source	Freedom	Squares	Square	Value	Prob
1	Replication	4	40.867	10.217	5.1547	0.0022
2	Factor A	4	75.603	18.901	9.5360	0.0000
4	Factor B	1	8.161	8.161	4.1174	0.0499
6	AB	4	48.689	12.172	6.1413	0.0007
-7	Error	36	71.353	1.982		
Total		49	244.673			
Coefficient of Variation: 4.47%						

Appendix 67.ANOVA table for beans plant height 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	45.233	11.308	7.0555	0.0003
2	Factor A	4	67.467	16.867	10.5236	0.0000
4	Factor B	1	8.989	8.989	5.6083	0.0234
6	AB	4	48.473	12.118	7.5609	0.0002
-7	Error	36	57.699	1.603		
Total		49	227.861			
Coefficient of Variation: 3.19%						

Appendix 68.ANOVA table for beans plant height 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	41.501	10.375	6.3330	0.0006
2	Factor A	4	67.135	16.784	10.2446	0.0000
4	Factor B	1	32.967	32.967	20.1228	0.0001
6	AB	4	52.525	13.131	8.0151	0.0001
-7	Error	36	58.979	1.638		
Total		49	253.107			
Coefficient of Variation: 2.98%						

Appendix 69.ANOVA table for beans leaf length 2WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.333	0.083	1.0933	0.3746
2	Factor A	4	1.635	0.409	5.3656	0.0017
4	Factor B	1	0.769	0.769	10.0907	0.0031
6	AB	4	0.323	0.081	1.0605	0.3901
-7	Error	36	2.743	0.076		
Total		49	5.803			
Coefficient of Variation: 7.57%						

Appendix 70.ANOVA table for beans leaf length 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.227	0.057	1.8990	0.1318
2	Factor A	4	3.193	0.798	26.6891	0.0000
4	Factor B	1	0.010	0.010	0.3276	
6	AB	4	0.017	0.004	0.1438	
-7	Error	36	1.077	0.030		
Total		49	4.524			
Coefficient of Variation: 2.86%						

Appendix 71.ANOVA table for beans leaf length 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.339	0.085	2.7892	0.0408
2	Factor A	4	1.683	0.421	13.8540	0.0000
4	Factor B	1	45.697	45.697	1504.8338	0.0000
6	AB	4	0.321	0.080	2.6443	0.0493
-7	Error	36	1.093	0.030		
Total		49	49.133			
Coefficient of Variation: 2.12%						

Appendix 72.ANOVA table for beans leaf length 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.240	0.060	1.1699	0.3403
2	Factor A	4	1.917	0.479	9.3334	0.0000
4	Factor B	1	22.378	22.378	435.8137	0.0000
6	AB	4	0.358	0.090	1.7440	0.1618
-7	Error	36	1.849	0.051		
Total		49	26.742			
Coefficient of Variation: 2.41%						

Appendix 73.ANOVA table for beans leaf length 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.256	0.064	1.2299	0.3154
2	Factor A	4	1.649	0.412	7.9079	0.0001
4	Factor B	1	14.418	14.418	276.5688	0.0000
6	AB	4	0.507	0.127	2.4296	0.0654
-7	Error	36	1.877	0.052		
Total		49	18.707			
Coefficient of Variation: 2.23%						

Appendix 74.ANOVA table for beans leaf width 2WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1.063	0.266	2.6034	0.0520
2	Factor A	4	0.283	0.071	0.6929	
4	Factor B	1	26.165	26.165	256.2771	0.0000
6	AB	4	0.317	0.079	0.7760	
-7	Error	36	3.676	0.102		
Total		49	31.504			
Coefficient of Variation: 8.35%						

Appendix 75.ANOVA table for beans leaf width 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.150	0.038	0.7822	
2	Factor A	4	0.526	0.131	2.7428	0.0433
4	Factor B	1	0.051	0.051	1.0679	0.3083
6	AB	4	0.047	0.012	0.2440	
-7	Error	36	1.726	0.048		
Total		49	2.500			
Coefficient of Variation: 4.12%						

Appendix 76.ANOVA table for beans leaf width 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.183	0.046	0.8566	
2	Factor A	4	0.409	0.102	1.9133	0.1294
4	Factor B	1	55.968	55.968	1046.7867	0.0000
6	AB	4	0.103	0.026	0.4807	
-7	Error	36	1.925	0.053		
Total		49	58.588			
Coefficient of Variation: 3.04%						

Appendix 77.ANOVA table for beans leaf width 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.550	0.138	2.1281	0.0974
2	Factor A	4	0.224	0.056	0.8667	
4	Factor B	1	3.976	3.976	61.5405	0.0000
6	AB	4	0.049	0.012	0.1888	
-7	Error	36	2.326	0.065		
Total		49	7.125			
Coefficient of Variation: 2.93%						

Appendix 78.ANOVA table for beans leaf width 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.543	0.136	2.1472	0.0949
2	Factor A	4	0.207	0.052	0.8190	
4	Factor B	1	0.952	0.952	15.0559	0.0004
6	AB	4	0.061	0.015	0.2403	
-7	Error	36	2.277	0.063		
Total		49	4.040			
Coefficient of Variation: 2.64%						

Appendix 79.ANOVA table for beans leaf area 2WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	170.230	42.557	1.2823	0.2951
2	Factor A	4	228.362	57.090	1.7202	0.1669
4	Factor B	1	3994.392	3994.392	120.3579	0.0000
6	AB	4	199.267	49.817	1.5011	0.2224
-7	Error	36	1194.754	33.188		
Total		49	5787.005			
Coefficient of Variation: 14.22%						

Appendix 80.ANOVA table for beans leaf area 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	36.017	9.004	0.2905	
2	Factor A	4	1147.389	286.847	9.2557	0.0000
4	Factor B	1	18.362	18.362	0.5925	
6	AB	4	27.141	6.785	0.2189	
-7	Error	36	1115.695	30.992		
Total		49	2344.604			
Coefficient of Variation: 6.00%						

Appendix 81.ANOVA table for beans leaf area 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	57.293	14.323	0.2133	
2	Factor A	4	947.621	236.905	3.5274	0.0158
4	Factor B	1	106463.439	106463.439	1585.1977	0.0000
6	AB	4	685.757	171.439	2.5527	0.0556
-7	Error	36	2417.795	67.161		
Total		49	110571.906			
Coefficient of Variation: 4.49%						

Appendix 82.ANOVA table for beans leaf area 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	780.282	195.071	1.9799	0.1185
2	Factor A	4	1888.914	472.229	4.7930	0.0033
4	Factor B	1	28929.748	28929.748	293.6279	0.0000
6	AB	4	364.437	91.109	0.9247	
-7	Error	36	3546.907	98.525		
Total		49	35510.288			
Coefficient of Variation: 4.22%						

Appendix 83.ANOVA table for beans leaf area 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	534.618	133.654	0.9067	
2	Factor A	4	392.507	98.127	0.6657	
4	Factor B	1	1345.767	1345.767	9.1292	0.0046
6	AB	4	620.923	155.231	1.0530	0.3938
-7	Error	36	5306.865	147.413		
Total		49	8200.679			
Coefficient of Variation: 3.99%						

Appendix 84.ANOVA table for beans leaf area index 2WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.000	0.000	0.2924	
2	Factor A	4	0.000	0.000	2.6165	0.0511
4	Factor B	1	0.000	0.000	132.7961	0.0000
6	AB	4	0.000	0.000	3.4890	0.0166
-7	Error	36	0.000	0.000		
Total		49	0.000			
Coefficient of Variation: 13.69%						

Appendix 85.ANOVA table for beans leaf area index 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.000	0.000	0.6987	
2	Factor A	4	0.000	0.000	3.3160	0.0206
4	Factor B	1	0.000	0.000	0.1637	
6	AB	4	0.000	0.000	1.9254	0.1273
-7	Error	36	0.000	0.000		
Total		49	0.000			
Coefficient of Variation: 6.79%						

Appendix 86.ANOVA table for beans leaf area index 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.000	0.000	1.2265	0.3168
2	Factor A	4	0.000	0.000	4.3704	0.0055
4	Factor B	1	0.006	0.006	698.7854	0.0000
6	AB	4	0.000	0.000	0.1672	
-7	Error	36	0.000	0.000		
Total		49	0.006			
Coefficient of Variation: 7.04%						

Appendix 87.ANOVA table for beans leaf area index 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.000	0.000	2.4248	0.0658
2	Factor A	4	0.000	0.000	0.5431	
4	Factor B	1	0.001	0.001	221.8302	0.0000
6	AB	4	0.000	0.000	0.5966	
-7	Error	36	0.000	0.000		
Total		49	0.002			
Coefficient of Variation: 4.87%						

Appendix 88.ANOVA table for beans leaf area index 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.000	0.000	0.8131	
2	Factor A	4	0.000	0.000	1.0283	0.4060
4	Factor B	1	0.062	0.062	7400.3594	0.0000
6	AB	4	0.000	0.000	0.1464	
-7	Error	36	0.000	0.000		
Total		49	0.062			
Coefficient of Variation: 2.84%						

Appendix 89.ANOVA table for beans ground cover within rows4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1348.000	337.000	9.6901	0.0000
2	Factor A	4	508.000	127.000	3.6518	0.0135
4	Factor B	1	18.000	18.000	0.5176	
6	AB	4	532.000	133.000	3.8243	0.0109
-7	Error	36	1252.000	34.778		
Total		49	3658.000			
Coefficient of Variation: 12.34%						

Appendix 90.ANOVA table for beans ground cover within rows6WAP

K	Degrees of	Sum of	Mean	F
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Value	Source	Freedom	Squares	Square	Value	Prob
1	Replication	4	512.000	128.000	4.3969	0.0054
2	Factor A	4	92.000	23.000	0.7901	
4	Factor B	1	882.000	882.000	30.2977	0.0000
6	AB	4	348.000	87.000	2.9885	0.0315
-7	Error	36	1048.000	29.111		
Total		49	2882.000			
Coefficient of Variation: 7.64%						

Appendix 91.ANOVA table for beans ground cover within rows 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	68.000	17.000	0.5604	
2	Factor A	4	208.000	52.000	1.7143	0.1682
4	Factor B	1	6050.000	6050.000	199.4505	0.0000
6	AB	4	160.000	40.000	1.3187	0.2816
-7	Error	36	1092.000	30.333		
Total		49	7578.000			
Coefficient of Variation: 7.46%						

Appendix 92.ANOVA table for beans ground cover within rows10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	180.000	45.000	2.0769	0.1042
2	Factor A	4	580.000	145.000	6.6923	0.0004
4	Factor B	1	3528.000	3528.000	162.8308	0.0000
6	AB	4	132.000	33.000	1.5231	0.2161
-7	Error	36	780.000	21.667		
Total		49	5200.000			
Coefficient of Variation: 5.17%						

Appendix 93.ANOVA table for beans ground cover between rows 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	48.000	12.000	0.4355	
2	Factor A	4	68.000	17.000	0.6169	
4	Factor B	1	1152.000	1152.000	41.8065	0.0000
6	AB	4	68.000	17.000	0.6169	
-7	Error	36	992.000	27.556		
Total		49	2328.000			
Coefficient of Variation: 13.53%						

Appendix 94.ANOVA table for beans ground cover between rows6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	252.000	63.000	1.2141	0.3218
2	Factor A	4	212.000	53.000	1.0214	0.4094
4	Factor B	1	162.000	162.000	3.1221	0.0857
6	AB	4	68.000	17.000	0.3276	
-7	Error	36	1868.000	51.889		
Total		49	2562.000			
Coefficient of Variation: 9.92%						

Appendix 95.ANOVA table for beans ground cover between rows 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	668.000	167.000	5.1297	0.0022
2	Factor A	4	428.000	107.000	3.2867	0.0214
4	Factor B	1	9248.000	9248.000	284.0683	0.0000
6	AB	4	452.000	113.000	3.4710	0.0169
-7	Error	36	1172.000	32.556		
Total		49	11968.000			
Coefficient of Variation: 8.06%						

Appendix 96.ANOVA table for beans ground cover between rows 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	348.000	87.000	2.0992	0.1012
2	Factor A	4	188.000	47.000	1.1340	0.3560
4	Factor B	1	6728.000	6728.000	162.3378	0.0000
6	AB	4	132.000	33.000	0.7962	
-7	Error	36	1492.000	41.444		
Total		49	8888.000			
Coefficient of Variation: 7.74%						

Appendix 97.ANOVA table for beans lodging score 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.080	0.020	1.0000	0.4203
2	Factor A	4	0.080	0.020	1.0000	0.4203
4	Factor B	1	52.020	52.020	2601.0000	0.0000
6	AB	4	0.080	0.020	1.0000	
-7	Error	36	0.720	0.020		
Total		49	52.980			
Coefficient of Variation: 4.68%						

Appendix 98.ANOVA table for beans lodging score 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.080	0.020	1.0000	0.4203
2	Factor A	4	0.080	0.020	1.0000	0.4203
4	Factor B	1	13.520	13.520	676.0000	0.0000
6	AB	4	0.080	0.020	1.0000	
-7	Error	36	0.720	0.020		
Total		49	14.480			
Coefficient of Variation: 5.61%						

Appendix 99.ANOVA table for beans lodging score 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.000	0.000	0.0000	
2	Factor A	4	1.000	0.250	2.2500	0.0829
4	Factor B	1	4.500	4.500	40.5000	0.0000
6	AB	4	1.000	0.250	2.2500	0.0829
-7	Error	36	4.000	0.111		
Total		49	10.500			
Coefficient of Variation: 10.10%						

Appendix 100.ANOVA table for beans disease rating score 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.400	0.100	1.2857	0.2938
2	Factor A	4	0.400	0.100	1.2857	0.2938
4	Factor B	1	0.500	0.500	6.4286	0.0157
6	AB	4	0.400	0.100	1.2857	0.2938
-7	Error	36	2.800	0.078		
Total		49	4.500			
Coefficient of Variation: 13.28%						

Appendix 101.ANOVA table for beans disease rating score 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.880	0.220	0.9519	
2	Factor A	4	1.080	0.270	1.1683	0.3410
4	Factor B	1	0.500	0.500	2.1635	0.1500
6	AB	4	1.000	0.250	1.0817	0.3800
-7	Error	36	8.320	0.231		
Total		49	11.780			
Coefficient of Variation: 20.20%						

Appendix 102.ANOVA table for beans disease rating score 8WAP

Value	K Source	Degrees of Freedom	Sum of Squares	Mean Square	Mean Value	F Prob
1	Replication	4	0.320	0.080	0.5902	
2	Factor A	4	0.120	0.030	0.2213	
4	Factor B	1	21.780	21.780	160.6721	0.0000
6	AB	4	0.120	0.030	0.2213	
-7	Error	36	4.880	0.136		
Total		49	27.220			
Coefficient of Variation: 13.84%						

Appendix 103.ANOVA table for beans insect rating score 4WAP

Value	K Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.000	0.000	0.0000	
2	Factor A	4	0.000	0.000	0.0000	
4	Factor B	1	0.000	0.000	0.0000	
6	AB	4	0.000	0.000	0.0000	
-7	Error	36	0.000	0.000		
Total		49	0.000			
Coefficient of Variation: 0.00%						

Appendix 104.ANOVA table for beans insect rating score 6WAP

Value	K Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1.320	0.330	1.3687	0.2641
2	Factor A	4	0.720	0.180	0.7465	
4	Factor B	1	0.320	0.320	1.3272	0.2569
6	AB	4	0.480	0.120	0.4977	
-7	Error	36	8.680	0.241		
Total		49	11.520			
Coefficient of Variation: 20.81%						

Appendix 105.ANOVA table for beans pod length

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	23.541	5.885	5.5446	0.0014
2	Factor A	4	93.989	23.497	22.1375	0.0000
4	Factor B	1	0.000	0.000	0.0000	
6	AB	4	-0.000	-0.000	-0.0000	
-7	Error	36	38.211	1.061		
Total		49	155.741			
Coefficient of Variation: 9.02%						

Appendix 106.ANOVA table for beans number of seeds

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1985.120	496.280	25.2460	0.0000
2	Factor A	4	2881.120	720.280	36.6410	0.0000
4	Factor B	1	1250.000	1250.000	63.5881	0.0000
6	AB	4	0.000	0.000	0.0000	
-7	Error	36	707.680	19.658		
Total		49	6823.920			
Coefficient of Variation: 6.43%						

Appendix 107.ANOVA table for beans number of pods

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	38.000	9.500	0.1356	
2	Factor A	4	2978.000	744.500	10.6273	0.0000
4	Factor B	1	2592.000	2592.000	36.9992	0.0000
6	AB	4	18.000	4.500	0.0642	
-7	Error	36	2522.000	70.056		
Total		49	8148.000			
Coefficient of Variation: 12.84%						

Appendix 108.ANOVA table for beans mass of plants with pods

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	32088.700	8022.175	1.2961	0.2899
2	Factor A	4	60256.354	15064.088	2.4338	0.0650
4	Factor B	1	16538380.432	16538380.432	2672.0385	0.0000
6	AB	4	0.005	0.001	0.0000	
-7	Error	36	222819.281	6189.424		
Total		49	16853544.772			
Coefficient of Variation: 3.22%						

Appendix 109.ANOVA table for beans mass of pods before shelling

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	53621.155	13405.289	2.3805	0.0697
2	Factor A	4	78377.752	19594.438	3.4796	0.0168
4	Factor B	1	77973.005	77973.005	13.8465	0.0007
6	AB	4	0.002	0.001	0.0000	
-7	Error	36	202724.528	5631.237		
Total		49	412696.442			
Coefficient of Variation: 4.82%						

Appendix 110.ANOVA table for beans shells mass

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	7279.019	1819.755	18.2791	0.0000
2	Factor A	4	1402.843	350.711	3.5228	0.0159
4	Factor B	1	64132.137	64132.137	644.1966	0.0000
6	AB	4	5.059	1.265	0.0127	
-7	Error	36	3583.932	99.554		
Total		49	76402.990			
Coefficient of Variation: 4.24%						

Appendix 111.ANOVA table for beans seed mass

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	92941.698	23235.425	20.1924	0.0000
2	Factor A	4	8284.393	2071.098	1.7999	0.1503
4	Factor B	1	8646.131	8646.131	7.5138	0.0095
6	AB	4	799.999	200.000	0.1738	
-7	Error	36	41425.345	1150.704		
Total		49	152097.566			
Coefficient of Variation: 2.78%						

Appendix 112.ANOVA table for beans fresh mass 100 seeds

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	57.511	14.378	2.7063	0.0455
2	Factor A	4	486.415	121.604	22.8892	0.0000
4	Factor B	1	712.909	712.909	134.1895	0.0000
6	AB	4	0.005	0.001	0.0002	
-7	Error	36	191.257	5.313		
Total		49	1448.097			
Coefficient of Variation: 3.85%						

Appendix 113.ANOVA table for beans dry mass 100 seeds

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	29.840	7.460	0.6631	
2	Factor A	4	410.222	102.555	9.1157	0.0000
4	Factor B	1	529.426	529.426	47.0582	0.0000
6	AB	4	0.001	0.000	0.0000	
-7	Error	36	405.016	11.250		
Total		49	1374.505			
Coefficient of Variation: 7.81%						

Appendix 114.ANOVA table for beans shelling %

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	820.821	205.205	9.0331	0.0000
2	Factor A	4	263.195	65.799	2.8964	0.0355
4	Factor B	1	83.722	83.722	3.6854	0.0628
6	AB	4	0.417	0.104	0.0046	
-7	Error	36	817.815	22.717		
Total		49	1985.970			
Coefficient of Variation: 6.06%						

Appendix 115.ANOVA table for beans harvest index

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.009	0.002	0.6641	
2	Factor A	4	0.015	0.004	1.0801	0.3808
4	Factor B	1	0.577	0.577	168.9497	0.0000
6	AB	4	0.007	0.002	0.5428	
-7	Error	36	0.123	0.003		
Total		49	0.731			
Coefficient of Variation: 8.44%						

Appendix 116.ANOVA table for beans moisture content %

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	161.254	40.314	3.9652	0.0091
2	Factor A	4	48.686	12.171	1.1972	0.3288
4	Factor B	1	4659.986	4659.986	458.3467	0.0000
6	AB	4	29.049	7.262	0.7143	
-7	Error	36	366.010	10.167		
Total		49	5264.985			
Coefficient of Variation: 11.35%						

Appendix 117.ANOVA table for beans dry mass

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	319.851	79.963	6.6401	0.0004
2	Factor A	4	94.615	23.654	1.9642	0.1209
4	Factor B	1	5050.125	5050.125	419.3593	0.0000
6	AB	4	11.014	2.753	0.2286	
-7	Error	36	433.529	12.042		
Total		49	5909.134			
Coefficient of Variation: 4.80%						

Appendix 118.ANOVA table for beans seed yield

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	7437.425	1859.356	1.9722	0.1197
2	Factor A	4	20466.145	5116.536	5.4270	0.0016
4	Factor B	1	1100801.529	1100801.529	1167.5965	0.0000
6	AB	4	10592.678	2648.169	2.8089	0.0398
-7	Error	36	33940.540	942.793		
Total		49	1173238.317			
Coefficient of Variation: 7.55%						

Appendix 119.ANOVA table for cowpeas emergence count

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	23.235	5.809	0.3707	
2	Factor A	4	5.432	1.358	0.0867	
4	Factor B	1	331.068	331.068	21.1266	0.0001
6	AB	4	12.016	3.004	0.1917	
-7	Error	36	564.145	15.671		
Total		49	935.897			
Coefficient of Variation: 4.31%						

Appendix 120.ANOVA table for cowpeas plant height 2WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	24.120	6.030	15.1339	0.0000
2	Factor A	4	11.608	2.902	7.2833	0.0002
4	Factor B	1	10.397	10.397	26.0935	0.0000
6	AB	4	0.011	0.003	0.0070	
-7	Error	36	14.344	0.398		
Total		49	60.480			
Coefficient of Variation: 6.26%						

Appendix 121.ANOVA table for cowpeas plant height 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	6.392	1.598	1.5711	0.2030
2	Factor A	4	7.546	1.887	1.8548	0.1398
4	Factor B	1	450.000	450.000	442.4296	0.0000
6	AB	4	1.706	0.426	0.4193	
-7	Error	36	36.616	1.017		
Total		49	502.260			
Coefficient of Variation: 5.17%						

Appendix 122.ANOVA table for cowpeas plant height 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	3.675	0.919	0.2575	
2	Factor A	4	16.549	4.137	1.1594	0.3448
4	Factor B	1	76.385	76.385	21.4068	0.0000
6	AB	4	13.539	3.385	0.9486	
-7	Error	36	128.457	3.568		
Total		49	238.605			
Coefficient of Variation: 5.31%						

Appendix 123.ANOVA table for cowpeas plant height 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	29.612	7.403	3.1653	0.0250
2	Factor A	4	65.246	16.311	6.9744	0.0003
4	Factor B	1	235.445	235.445	100.6701	0.0000
6	AB	4	47.206	11.802	5.0460	0.0025
-7	Error	36	84.196	2.339		
Total		49	461.705			
Coefficient of Variation: 2.96%						

Appendix 124.ANOVA table for cowpeas plant height 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	34.978	8.744	3.4106	0.0183
2	Factor A	4	56.240	14.060	5.4837	0.0015
4	Factor B	1	172.980	172.980	67.4664	0.0000
6	AB	4	45.760	11.440	4.4619	0.0050
-7	Error	36	92.302	2.564		
Total		49	402.260			
Coefficient of Variation: 2.53%						

Appendix 125.ANOVA table for cowpeas leaf length 2WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.156	0.039	0.6524	
2	Factor A	4	0.312	0.078	1.3048	0.2867
4	Factor B	1	9.074	9.074	151.7922	0.0000
6	AB	4	0.011	0.003	0.0468	
-7	Error	36	2.152	0.060		
Total		49	11.705			
Coefficient of Variation: 7.57%						

Appendix 126.ANOVA table for cowpea's leaf length 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.146	0.036	0.4320	
2	Factor A	4	0.356	0.089	1.0533	0.3937
4	Factor B	1	53.665	53.665	635.0864	0.0000
6	AB	4	0.131	0.033	0.3882	
-7	Error	36	3.042	0.085		
Total		49	57.340			
Coefficient of Variation: 5.55%						

Appendix 127.ANOVA table for cowpeas leaf length 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.059	0.015	0.2090	
2	Factor A	4	0.805	0.201	2.8432	0.0380
4	Factor B	1	3.328	3.328	47.0085	0.0000
6	AB	4	0.311	0.078	1.0975	0.3727
-7	Error	36	2.549	0.071		
Total		49	7.052			
Coefficient of Variation: 3.47%						

Appendix 128.ANOVA table for cowpeas leaf length 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.143	0.036	0.4885	
2	Factor A	4	0.578	0.145	1.9753	0.1192
4	Factor B	1	3.759	3.759	51.3619	0.0000
6	AB	4	0.155	0.039	0.5284	
-7	Error	36	2.635	0.073		
Total		49	7.270			
Coefficient of Variation: 2.98%						

Appendix 129.ANOVA table for cowpeas leaf length 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.133	0.033	0.5931	
2	Factor A	4	0.300	0.075	1.3445	0.2724
4	Factor B	1	3.798	3.798	67.9809	0.0000
6	AB	4	0.431	0.108	1.9292	0.1267
-7	Error	36	2.011	0.056		
Total		49	6.673			
Coefficient of Variation: 2.38%						

Appendix 130.ANOVA table for cowpeas leaf width 2WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.186	0.046	0.7588	
2	Factor A	4	0.177	0.044	0.7250	
4	Factor B	1	0.211	0.211	3.4520	0.0714
6	AB	4	0.015	0.004	0.0600	
-7	Error	36	2.203	0.061		
Total		49	2.792			
Coefficient of Variation: 8.97%						

Appendix 131.ANOVA table for cowpeas leaf width 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.102	0.026	0.3825	
2	Factor A	4	0.165	0.041	0.6183	
4	Factor B	1	51.491	51.491	771.3514	0.0000
6	AB	4	0.065	0.016	0.2450	
-7	Error	36	2.403	0.067		
Total		49	54.227			
Coefficient of Variation: 5.95%						

Appendix 132.ANOVA table for cowpeas leaf width 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.098	0.024	0.4264	
2	Factor A	4	0.399	0.100	1.7427	0.1620
4	Factor B	1	51.248	51.248	895.9178	0.0000
6	AB	4	0.218	0.055	0.9528	
-7	Error	36	2.059	0.057		
Total		49	54.021			
Coefficient of Variation: 4.04%						

Appendix 133.ANOVA table for cowpeas leaf width 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.156	0.039	0.7237	
2	Factor A	4	0.521	0.130	2.4208	0.0661
4	Factor B	1	4.842	4.842	90.0698	0.0000
6	AB	4	0.117	0.029	0.5441	
-7	Error	36	1.935	0.054		
Total		49	7.571			
Coefficient of Variation: 2.86%						

Appendix 134.ANOVA table for cowpeas leaf width 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.275	0.069	1.0584	0.3912
2	Factor A	4	0.476	0.119	1.8316	0.1441
4	Factor B	1	2.808	2.808	43.1999	0.0000
6	AB	4	0.161	0.040	0.6180	
-7	Error	36	2.340	0.065		
Total		49	6.061			
Coefficient of Variation: 2.78%						

Appendix 135.ANOVA table for cowpeas leaf area 2WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	33.207	8.302	0.6398	
2	Factor A	4	58.939	14.735	1.1355	0.3553
4	Factor B	1	683.021	683.021	52.6362	0.0000
6	AB	4	22.987	5.747	0.4429	
-7	Error	36	467.145	12.976		
Total		49	1265.299			
Coefficient of Variation: 14.88%						

Appendix 136.ANOVA table for cowpeas leaf area 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	79.307	19.827	0.5249	
2	Factor A	4	77.323	19.331	0.5118	
4	Factor B	1	34779.393	34779.393	920.7359	0.0000
6	AB	4	174.825	43.706	1.1571	0.3459
-7	Error	36	1359.845	37.773		
Total		49	36470.693			
Coefficient of Variation: 9.53%						

Appendix 137.ANOVA table for cowpeas leaf area 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	254.013	63.503	1.0418	0.3993
2	Factor A	4	1164.887	291.222	4.7777	0.0034
4	Factor B	1	31305.024	31305.024	513.5762	0.0000
6	AB	4	260.095	65.024	1.0667	0.3871
-7	Error	36	2194.379	60.955		
Total		49	35178.398			
Coefficient of Variation: 6.34%						

Appendix 138.ANOVA table for cowpeas leaf area 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	580.480	145.120	1.0851	0.3784
2	Factor A	4	1603.880	400.970	2.9981	0.0311
4	Factor B	1	8064.500	8064.500	60.2988	0.0000
6	AB	4	623.000	155.750	1.1646	0.3426
-7	Error	36	4814.720	133.742		
Total		49	15686.580			
Coefficient of Variation: 5.82%						

Appendix 139.ANOVA table for cowpeas leaf area 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	441.651	110.413	0.6756	
2	Factor A	4	1228.979	307.245	1.8799	0.1352
4	Factor B	1	419.921	419.921	2.5694	0.1177
6	AB	4	329.683	82.421	0.5043	
-7	Error	36	5883.610	163.434		
Total		49	8303.843			
Coefficient of Variation: 5.53%						

Appendix 140.ANOVA table for cowpeas leaf area index 2WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.000	0.000	0.9856	
2	Factor A	4	0.000	0.000	0.3182	
4	Factor B	1	0.000	0.000	49.6794	0.0000
6	AB	4	0.000	0.000	0.0797	
-7	Error	36	0.000	0.000		
Total		49	0.000			
Coefficient of Variation: 15.94%						

Appendix 141.ANOVA table for cowpeas leaf area index 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.003	0.001	1.0115	0.4144
2	Factor A	4	0.003	0.001	1.0180	0.4111
4	Factor B	1	0.004	0.004	7.0129	0.0119
6	AB	4	0.002	0.001	0.9752	
-7	Error	36	0.023	0.001		
Total		49	0.035			
Coefficient of Variation: 140.26%						

Appendix 142.ANOVA table for cowpeas leaf area index 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.003	0.001	1.0308	0.4047
2	Factor A	4	0.004	0.001	1.1399	0.3534
4	Factor B	1	0.000	0.000	0.1721	
6	AB	4	0.003	0.001	1.0039	0.4183
-7	Error	36	0.028	0.001		
Total		49	0.038			
Coefficient of Variation: 88.85%						

Appendix 143.ANOVA table for cowpeas leaf area index 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.016	0.004	1.0155	0.4124
2	Factor A	4	0.017	0.004	1.0617	0.3896
4	Factor B	1	0.002	0.002	0.4290	
6	AB	4	0.015	0.004	0.9438	
-7	Error	36	0.143	0.004		
Total		49	0.193			
Coefficient of Variation: 118.70%						

Appendix 144.ANOVA table for cowpeas leaf area index 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
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1	Replication	4	0.000	0.000	0.4491	
2	Factor A	4	0.000	0.000	1.2549	0.3056
4	Factor B	1	0.000	0.000	19.6585	0.0001
6	AB	4	0.000	0.000	0.3943	
-7	Error	36	0.000	0.000		
Total		49	0.001			
Coefficient of Variation: 5.87%						

Appendix 145.ANOVA table for cowpeas ground cover within rows 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	52.000	13.000	0.3023	
2	Factor A	4	92.000	23.000	0.5349	
4	Factor B	1	800.000	800.000	18.6047	0.0001
6	AB	4	100.000	25.000	0.5814	
-7	Error	36	1548.000	43.000		
Total		49	2592.000			
Coefficient of Variation: 22.15%						

Appendix 146.ANOVA table for cowpeas ground cover within rows 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	388.000	97.000	1.6077	0.1935
2	Factor A	4	28.000	7.000	0.1160	
4	Factor B	1	50.000	50.000	0.8287	
6	AB	4	380.000	95.000	1.5746	0.2021
-7	Error	36	2172.000	60.333		
Total		49	3018.000			
Coefficient of Variation: 13.92%						

Appendix 147.ANOVA table for cowpeas ground cover within rows 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	348.000	87.000	1.4420	0.2402
2	Factor A	4	28.000	7.000	0.1160	
4	Factor B	1	50.000	50.000	0.8287	
6	AB	4	380.000	95.000	1.5746	0.2021
-7	Error	36	2172.000	60.333		
Total		49	2978.000			
Coefficient of Variation: 11.73%						

Appendix 148.ANOVA table for cowpeas ground cover within rows 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	220.000	55.000	1.1124	0.3658
2	Factor A	4	260.000	65.000	1.3146	0.2831
4	Factor B	1	50.000	50.000	1.0112	0.3213
6	AB	4	340.000	85.000	1.7191	0.1671
-7	Error	36	1780.000	49.444		
Total		49	2650.000			
Coefficient of Variation: 8.08%						

Appendix 149.ANOVA table for cowpeas ground cover between rows 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1468.000	367.000	5.3883	0.0017
2	Factor A	4	148.000	37.000	0.5432	
4	Factor B	1	1922.000	1922.000	28.2186	0.0000
6	AB	4	68.000	17.000	0.2496	
-7	Error	36	2452.000	68.111		
Total		49	6058.000			
Coefficient of Variation: 25.63%						

Appendix 150.ANOVA table for cowpeas ground cover between rows 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	328.000	82.000	3.5481	0.0154
2	Factor A	4	608.000	152.000	6.5769	0.0004
4	Factor B	1	338.000	338.000	14.6250	0.0005
6	AB	4	192.000	48.000	2.0769	0.1042
-7	Error	36	832.000	23.111		
Total		49	2298.000			
Coefficient of Variation: 8.04%						

Appendix 151.ANOVA table for cowpeas ground cover between rows 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	52.000	13.000	0.2806	
2	Factor A	4	752.000	188.000	4.0576	0.0081
4	Factor B	1	72.000	72.000	1.5540	0.2206
6	AB	4	128.000	32.000	0.6906	
-7	Error	36	1668.000	46.333		
Total		49	2672.000			
Coefficient of Variation: 9.51%						

Appendix 152.ANOVA table for cowpeas ground cover between rows 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	28.000	7.000	0.3642	
2	Factor A	4	1628.000	407.000	21.1734	0.0000
4	Factor B	1	8.000	8.000	0.4162	
6	AB	4	372.000	93.000	4.8382	0.0032
-7	Error	36	692.000	19.222		
Total		49	2728.000			
Coefficient of Variation: 4.81%						

Appendix 153.ANOVA table for cowpeas lodging score 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1.520	0.380	2.4085	0.0672
2	Factor A	4	2.120	0.530	3.3592	0.0195
4	Factor B	1	87.120	87.120	552.1690	0.0000
6	AB	4	1.880	0.470	2.9789	0.0319
-7	Error	36	5.680	0.158		
Total		49	98.320			
Coefficient of Variation: 15.52%						

Appendix 154. ANOVA table for cowpeas lodging score 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.280	0.070	0.2490	
2	Factor A	4	1.280	0.320	1.1383	0.3541
4	Factor B	1	16.820	16.820	59.8340	0.0000
6	AB	4	0.480	0.120	0.4269	
-7	Error	36	10.120	0.281		
Total		49	28.980			
Coefficient of Variation: 26.78%						

Appendix 155. ANOVA table for cowpeas lodging score 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.200	0.050	0.1698	
2	Factor A	4	0.600	0.150	0.5094	
4	Factor B	1	0.000	0.000	0.0000	
6	AB	4	0.600	0.150	0.5094	
-7	Error	36	10.600	0.294		
Total		49	12.000			
Coefficient of Variation: 22.61%						

Appendix 156. ANOVA table for cowpeas disease score 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.520	0.130	1.0935	0.3745
2	Factor A	4	0.320	0.080	0.6729	
4	Factor B	1	11.520	11.520	96.8972	0.0000
6	AB	4	0.880	0.220	1.8505	0.1406
-7	Error	36	4.280	0.119		
Total		49	17.520			
Coefficient of Variation: 21.02%						

Appendix 157.ANOVA table for cowpeas disease score 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.880	0.220	1.0532	0.3937
2	Factor A	4	0.880	0.220	1.0532	0.3937
4	Factor B	1	2.420	2.420	11.5851	0.0016
6	AB	4	0.880	0.220	1.0532	0.3937
-7	Error	36	7.520	0.209		
Total		49	12.580			
Coefficient of Variation: 25.68%						

Appendix 158.ANOVA table for cowpeas disease score 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.280	0.070	0.2593	
2	Factor A	4	1.680	0.420	1.5556	0.2072
4	Factor B	1	0.020	0.020	0.0741	
6	AB	4	0.480	0.120	0.4444	
-7	Error	36	9.720	0.270		
Total		49	12.180			
Coefficient of Variation: 21.47%						

Appendix 159.ANOVA table for cowpeas insect rating score 4WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.720	0.180	0.8437	
2	Factor A	4	0.120	0.030	0.1406	
4	Factor B	1	0.500	0.500	2.3437	0.1345
6	AB	4	0.600	0.150	0.7031	
-7	Error	36	7.680	0.213		
Total		49	9.620			
Coefficient of Variation: 36.66%						

Appendix 160.ANOVA table for cowpeas insect rating score 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	22.080	5.520	0.6031	
2	Factor A	4	35.880	8.970	0.9800	
4	Factor B	1	25.920	25.920	2.8318	0.1011
6	AB	4	37.080	9.270	1.0127	0.4138
-7	Error	36	329.520	9.153		
Total		49	450.480			
Coefficient of Variation: 120.06%						

Appendix 161.ANOVA table for cowpeas mass of plant with pods

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	554853.174	138713.294	1.7415	0.1623
2	Factor A	4	1280012.159	320003.040	4.0176	0.0085
4	Factor B	1	1074929.998	1074929.998	13.4956	0.0008
6	AB	4	20869.520	5217.380	0.0655	
-7	Error	36	2867416.414	79650.456		
Total		49	5798081.265			
Coefficient of Variation: 15.08%						

Appendix 162.ANOVA table for cowpeas mass of pods before shelling

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	195336.638	48834.159	1.1856	0.3337
2	Factor A	4	309750.692	77437.673	1.8800	0.1352
4	Factor B	1	10740870.811	10740870.811	260.7604	0.0000
6	AB	4	298396.870	74599.218	1.8111	0.1481
-7	Error	36	1482860.491	41190.569		
Total		49	13027215.501			
Coefficient of Variation: 14.58%						

Appendix 163.ANOVA table for cowpeas number of pods

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1928.720	482.180	2.2571	0.0821
2	Factor A	4	3711.520	927.880	4.3435	0.0057
4	Factor B	1	12261.780	12261.780	57.3988	0.0000
6	AB	4	412.320	103.080	0.4825	
-7	Error	36	7690.480	213.624		
Total		49	26004.820			
Coefficient of Variation: 10.08%						

Appendix 164.ANOVA table for cowpeas seed mass

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	188549.887	47137.472	1.1719	0.3395
2	Factor A	4	301356.732	75339.183	1.8730	0.1364
4	Factor B	1	13553925.166	13553925.166	336.9658	0.0000
6	AB	4	294748.385	73687.096	1.8319	0.1440
-7	Error	36	1448044.174	40223.449		
Total		49	15786624.343			
Coefficient of Variation: 13.85%						

Appendix 165.ANOVA table for cowpeas seeds fresh mass

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	12.685	3.171	2.5811	0.0536
2	Factor A	4	14.205	3.551	2.8903	0.0358
4	Factor B	1	35.786	35.786	29.1262	0.0000
6	AB	4	0.279	0.070	0.0568	
-7	Error	36	44.231	1.229		
Total		49	107.186			
Coefficient of Variation: 6.40%						

Appendix 166.ANOVA table for cowpeas seeds dry mass

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	16.627	4.157	4.7385	0.0036
2	Factor A	4	18.531	4.633	5.2811	0.0019
4	Factor B	1	54.497	54.497	62.1227	0.0000
6	AB	4	0.007	0.002	0.0021	
-7	Error	36	31.581	0.877		
Total		49	121.243			
Coefficient of Variation: 6.58%						

Appendix 167.ANOVA table for cowpeas shelling %

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	109.915	27.479	0.2785	
2	Factor A	4	185.753	46.438	0.4707	
4	Factor B	1	8095.009	8095.009	82.0547	0.0000
6	AB	4	1525.561	381.390	3.8659	0.0103
-7	Error	36	3551.537	98.654		
Total		49	13467.776			
Coefficient of Variation: 26.65%						

Appendix 168.ANOVA table for cowpeas harvest index

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.017	0.004	0.5119	
2	Factor A	4	0.042	0.010	1.2354	0.3132
4	Factor B	1	1.381	1.381	162.6274	0.0000
6	AB	4	0.105	0.026	3.0853	0.0278
-7	Error	36	0.306	0.008		
Total		49	1.851			
Coefficient of Variation: 27.57%						

Appendix 169.ANOVA table for cowpeas moisture %

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	38.205	9.551	1.8363	0.1432
2	Factor A	4	53.749	13.437	2.5834	0.0534
4	Factor B	1	5218.333	5218.333	1003.2532	0.0000
6	AB	4	13.829	3.457	0.6647	
-7	Error	36	187.251	5.201		
Total		49	5511.367			
Coefficient of Variation: 13.20%						

Appendix 170.ANOVA table for cowpeas dry mass

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	31.783	7.946	1.1846	0.3341
2	Factor A	4	90.265	22.566	3.3644	0.0194
4	Factor B	1	4859.008	4859.008	724.4304	0.0000
6	AB	4	30.975	7.744	1.1545	0.3470
-7	Error	36	241.465	6.707		
Total		49	5253.496			
Coefficient of Variation: 3.12%						

Appendix 171.ANOVA table for cowpeas seed yield

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	14535.653	3633.913	1.3229	0.2801
2	Factor A	4	28421.712	7105.428	2.5868	0.0532
4	Factor B	1	1965589.290	1965589.290	715.5809	0.0000
6	AB	4	17968.628	4492.157	1.6354	0.1866
-7	Error	36	98886.396	2746.844		
Total		49	2125401.678			
Coefficient of Variation: 12.22%						

Appendix 172. ANOVA table for maize net plot seed mass

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	47210434751.367	11802608687.842		0.8912
2	Factor A	11	142554165907.092	12959469627.917		0.9785
4	Factor B	1	27743924897.008	27743924897.008		2.0949
0.1512	AB	11	139292432647.092	12662948422.463		0.9562
-7	Error	92	1218417522241.433	13243668720.016		
Total		119	1575218480443.991			
Coefficient of Variation: 93.01%						

Appendix 173. ANOVA table for maize seed yield

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	4452435.783	1113108.946	0.8128	
2	Factor A	11	14653064.567	1332096.779	0.9728	
4	Factor B	1	951588.300	951588.300	0.6949	
6	AB	11	13948492.300	1268044.755	0.9260	
-7	Error	92	125985835.417	1369411.255		
Total		119	159991416.367			
Coefficient of Variation: 15.03%						

Appendix 174. ANOVA table for maize stover

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	248216561.348	62054140.337	3.3894	0.0124
2	Factor A	11	379552992.979	34504817.544	1.8847	0.0514
4	Factor B	1	262510.437	262510.437	0.0143	
6	AB	11	101351724.550	9213793.141	0.5033	
-7	Error	92	1684357313.602	18308231.670		
Total		119	2413741102.916			
Coefficient of Variation: 23.50%						

Appendix 175. ANOVA table for maize harvest index

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	108.772	27.193	3.4639	0.0111
2	Factor A	11	69.557	6.323	0.8055	
4	Factor B	1	128.133	128.133	16.3221	0.0001
6	AB	11	68.009	6.183	0.7876	
-7	Error	92	722.228	7.850		
Total		119	1096.699			
Coefficient of Variation: 7.11%						

Appendix 176. ANOVA table for soil moisture percentage 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	3.197	0.799	0.4608	
2	Factor A	13	35.401	2.723	1.5699	0.1051
4	Factor B	1	1577.186	1577.186	909.2585	0.0000
6	AB	13	42.459	3.266	1.8829	0.0399
-7	Error	108	187.335	1.735		
Total		139	1845.578			
Coefficient of Variation: 6.35%						

Appendix 177. ANOVA table for soil moisture percentage 7WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	13.364	3.341	1.5973	0.1803
2	Factor A	13	33.308	2.562	1.2249	0.2718
4	Factor B	1	197.778	197.778	94.5537	0.0000
6	AB	13	44.480	3.422	1.6358	0.0863
-7	Error	108	225.904	2.092		
Total		139	514.834			
Coefficient of Variation: 7.39%						

Appendix 178. ANOVA table for soil moisture percentage 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	9.502	2.376	1.4664	0.2175
2	Factor A	13	41.593	3.199	1.9750	0.0296
4	Factor B	1	721.860	721.860	445.5886	0.0000
6	AB	13	31.807	2.447	1.5103	0.1251
-7	Error	108	174.962	1.620		
Total		139	979.724			
Coefficient of Variation: 6.71%						

Appendix 179. ANOVA table for soil moisture 9WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	4.185	1.046	0.6334	
2	Factor A	13	51.743	3.980	2.4101	0.0068
4	Factor B	1	3531.973	3531.973	2138.6216	0.0000
6	AB	13	27.230	2.095	1.2683	0.2434
-7	Error	108	178.364	1.652		
Total		139	3793.494			
Coefficient of Variation: 7.10%						

Appendix 180. ANOVA table for soil moisture percentage 10WAP

K	Degrees of Freedom	Sum of Squares	Mean Square	F
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Value	Source	Freedom	Squares	Square	Value	Prob
1	Replication	4	4.978	1.244	0.6760	
2	Factor A	13	25.033	1.926	1.0460	0.4140
4	Factor B	1	2359.965	2359.965	1281.9547	0.0000
6	AB	13	30.753	2.366	1.2850	0.2330
-7	Error	108	198.818	1.841		
Total		139	2619.547			
Coefficient of Variation: 6.83%						

Appendix 181. ANOVA table for soil moisture percentage11WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	7.123	1.781	0.8650	
2	Factor A	13	16.517	1.271	0.6171	
4	Factor B	1	1.761	1.761	0.8552	
6	AB	13	29.024	2.233	1.0844	0.3801
-7	Error	108	222.353	2.059		
Total		139	276.778			
Coefficient of Variation: 8.60%						

Appendix 182. ANOVA table for soil moisture percentage 12WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	5.283	1.321	0.7002	
2	Factor A	13	32.955	2.535	1.3438	0.1994
4	Factor B	1	281.984	281.984	149.4831	0.0000
6	AB	13	23.008	1.770	0.9382	
-7	Error	108	203.730	1.886		
Total		139	546.960			
Coefficient of Variation: 9.55%						

Appendix 183. ANOVA table for light reaching canopy 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	6.092	1.523	14.2826	0.0000
2	Factor A	13	1.600	0.123	1.1540	0.3234
4	Factor B	1	0.093	0.093	0.8681	
6	AB	13	0.639	0.049	0.4613	
-7	Error	108	11.516	0.107		
Total		139	19.940			
Coefficient of Variation: 25.09%						

Appendix 184. ANOVA table for light reaching canopy 7WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	11.030	2.758	22.2761	0.0000
2	Factor A	13	2.052	0.158	1.2749	0.2392
4	Factor B	1	3.210	3.210	25.9328	0.0000
6	AB	13	0.618	0.048	0.3838	
-7	Error	108	13.370	0.124		
Total		139	30.280			
Coefficient of Variation: 29.29%						

Appendix 185. ANOVA table for light reaching canopy 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	15.128	3.782	45.1199	0.0000
2	Factor A	13	1.243	0.096	1.1409	0.3336
4	Factor B	1	0.492	0.492	5.8707	0.0171
6	AB	13	1.397	0.107	1.2820	0.2349
-7	Error	108	9.052	0.084		
Total		139	27.312			
Coefficient of Variation: 23.47%						

Appendix 186. ANOVA table for light reaching canopy 9WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	8.625	2.156	18.4193	0.0000
2	Factor A	13	2.285	0.176	1.5018	0.1282
4	Factor B	1	0.023	0.023	0.1977	
6	AB	13	0.815	0.063	0.5354	
-7	Error	108	12.643	0.117		
Total		139	24.391			
Coefficient of Variation: 26.61%						

Appendix 187. ANOVA table for light reaching canopy 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	10.344	2.586	24.8029	0.0000
2	Factor A	13	1.838	0.141	1.3563	0.1928
4	Factor B	1	0.360	0.360	3.4536	0.0658
6	AB	13	1.339	0.103	0.9879	
-7	Error	108	11.260	0.104		
Total		139	25.141			
Coefficient of Variation: 24.42%						

Appendix 188. ANOVA table for light reaching canopy 11WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	16.249	4.062	38.7462	0.0000
2	Factor A	13	0.849	0.065	0.6232	
4	Factor B	1	2.633	2.633	25.1152	0.0000
6	AB	13	1.011	0.078	0.7417	
-7	Error	108	11.323	0.105		
Total		139	32.065			
Coefficient of Variation: 28.30%						

Appendix 189. ANOVA table for light reaching canopy 12WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	2.467	0.617	5.8252	0.0003
2	Factor A	13	0.553	0.043	0.4021	
4	Factor B	1	0.743	0.743	7.0198	0.0093
6	AB	13	0.731	0.056	0.5311	
-7	Error	108	11.433	0.106		
Total		139	15.927			
Coefficient of Variation: 34.10%						

Appendix 190. ANOVA table for light reaching the ground 6WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.903	0.226	6.3903	0.0001
2	Factor A	13	0.702	0.054	1.5279	0.1189
4	Factor B	1	1.558	1.558	44.0917	0.0000
6	AB	13	0.296	0.023	0.6439	
-7	Error	108	3.817	0.035		
Total		139	7.276			
Coefficient of Variation: 24.78%						

Appendix 191. ANOVA table for light reaching the ground 7WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.720	0.180	5.3593	0.0006
2	Factor A	13	1.062	0.082	2.4327	0.0063
4	Factor B	1	0.559	0.559	16.6556	0.0001
6	AB	13	0.451	0.035	1.0328	0.4259
-7	Error	108	3.628	0.034		
Total		139	6.420			
Coefficient of Variation: 30.70%						

Appendix 192. ANOVA table for light reaching the ground 8WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.683	0.171	5.6407	0.0004
2	Factor A	13	0.729	0.056	1.8524	0.0440
4	Factor B	1	0.418	0.418	13.8136	0.0003
6	AB	13	0.484	0.037	1.2310	0.2677
-7	Error	108	3.268	0.030		
Total		139	5.582			
Coefficient of Variation: 34.55%						

Appendix 193. ANOVA table for light reaching the ground 9WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.678	0.170	4.3798	0.0025
2	Factor A	13	0.458	0.035	0.9094	
4	Factor B	1	0.559	0.559	14.4460	0.0002
6	AB	13	0.514	0.040	1.0210	0.4368
-7	Error	108	4.182	0.039		
Total		139	6.392			
Coefficient of Variation: 51.86%						

Appendix 194. ANOVA table for light reaching the ground 10WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.850	0.212	6.6092	0.0001
2	Factor A	13	0.973	0.075	2.3289	0.0090
4	Factor B	1	0.361	0.361	11.2348	0.0011
6	AB	13	0.166	0.013	0.3964	
-7	Error	108	3.471	0.032		
Total		139	5.821			
Coefficient of Variation: 48.00%						

Appendix 194. ANOVA table for light reaching the ground 11WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.705	0.176	5.6788	0.0003
2	Factor A	13	0.700	0.054	1.7364	0.0634
4	Factor B	1	0.361	0.361	11.6414	0.0009
6	AB	13	0.649	0.050	1.6091	0.0935
-7	Error	108	3.350	0.031		
Total		139	5.765			
Coefficient of Variation: 60.04%						

Appendix 195. ANOVA table for light reaching the ground 12WAP

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.371	0.093	3.6749	0.0076
2	Factor A	13	0.660	0.051	2.0139	0.0260
4	Factor B	1	0.187	0.187	7.4267	0.0075
6	AB	13	0.288	0.022	0.8775	
-7	Error	108	2.723	0.025		
Total		139	4.228			
Coefficient of Variation: 81.55%						

Appendix 196. Field layout

501	502	503	504	505	506	507	508	509	510	511	512	513	514
(2)	(1)	(9)	(8)	(3)	(10)	(5)	(11)	(7)	(4)	(13)	(12)	(14)	(6)
414	413	412	411	410	409	408	407	406	405	404	403	402	401
(3)	(1)	(10)	(11)	(13)	(4)	(8)	(7)	(14)	(9)	(12)	(6)	(2)	(5)
301	302	303	304	305	306	307	308	309	310	311	312	313	314
(1)	(5)	(13)	(10)	(14)	(11)	(6)	(9)	(7)	(4)	(3)	(8)	(12)	(2)

214	213	212	211	210	209	208	207	206	205	204	203	202	201
(9)	(11)	(4)	(13)	(14)	(6)	(10)	(5)	(12)	(1)	(3)	(7)	(8)	(2)
101	102	103	104	105	106	107	108	109	110	111	112	113	114
(5)	(11)	(12)	(8)	(1)	(3)	(9)	(10)	(4)	(2)	(6)	(7)	(13)	(14)

Appendix 197. Correlation matrix for maize

Parameters	Cob + husk mass	Husk mass	Cob length	Cob diameter	Number of seeds	Number of rows	Mass of cobs without husk	Mass of all seeds shelled	Dry mass 100 seeds	Shelling %
Cob + husk mass										
Husk mass	0.205ns									
Cob length	0.107ns	0.513*								
Cob diameter	0.011ns	0.319ns	0.165 ns							
Number of seeds	- 0.200ns	- 0.010ns	0.950**	0.144 ns						
Number of rows	0.122ns	-0.109 ns	0.174 ns	-0.145 ns	-0.072 ns					
Mass of cobs without husk	0.245ns	0.75**	0.143 ns	0.055 ns	0.233 ns	0.134 ns				
Mass of all seeds shelled	0.256ns	0.303ns	0.074 ns	0.150 ns	0.238 ns	-0.017 ns	0.162 ns			
Dry mass 100 seeds	- 0.022ns	0.192ns	0.113 ns	0.179 ns	0.020 ns	-0.236 ns	-0.011 ns	0.141 ns	0.141 ns	
Shelling %	- 0.009ns	0.162ns	-0.040 ns	0.001 ns	-0.105 ns	0.065 ns	0.069 ns	0.132 ns	0.132 ns	-0.027 ns
Seed yield	0.183ns	0.099ns	0.299ns	0.179ns	0.183ns	0.184ns	0.179ns	0.269ns	0.253ns	0.179ns

Appendix 198. Correlation matrix for beans

Parameters	Pod length	Number of seeds	Number of pods	Shelling %	Harvest index	Moisture content	Dry mass
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Pod length							
Number of seeds	0.786*						
Number of pods	0.455ns	0.339 ns					
Shelling %	0.332 ns	0.284 ns	-0.074 ns				
Harvest index	0.234 ns	0.135 ns	-0.385 ns	0.309 ns			
Moisture content	-0.097 ns	-0.166 ns	-0.428 ns	0.229 ns	0.681*		
Dry mass	0.113 ns	0.180 ns	0.445 ns	-0.123 ns	-0.588 ns	-0.939 ns	
Seed yield	0.317 ns	0.341 ns	0.495 ns	0.079 ns	-0.418 ns	-0.712 ns	0.758*

Appendix 199. Correlation matrix for cowpeas

Parameters	Mass of pods before shelling	Number of pods	Seed mass	100 seeds fresh mass	100 seeds dry mass	Shelling %	Harvest index	Moisture content	Dry mass
Mass of pods before shelling									
Number of pods	-0.546 ns								
Seed mass	-0.797 ns	0.681*							
100 seeds fresh mass	0.683*	-0.332 ns	-0.360 ns						
100 seeds dry mass	-0.445 ns	0.495*	0.724*	0.182 ns					
Shelling %	0.608*	-0.376 ns	0.525 ns	0.478 ns	-0.494 ns				
Harvest index	0.743*	-0.445 ns	-0.633 ns	0.529 ns	-0.551 ns	0.980**			
Moisture content	0.871**	-0.675 ns	-0.893 ns	0.531 ns	-0.712 ns	0.756*	0.844*		
Dry mass	-0.872 ns	0.678*	0.894	-0.533 ns	0.710*	-0.753 ns	-0.842 ns	-1.000 ns	
Seed yield	-0.840 ns	0.689*	0.991**	-0.415 ns	0.741*	-0.614 ns	-0.717 ns	-0.941 ns	0.942*

Appendix 200. Maize lodging score at five weeks after planting

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole maize, 1 plant/hill	1.0a	3.8b	2.4a
Sole maize, 2 plants/hill	1.0a	4.0a	2.5a

Sole maize, 3 plants/hill	1.0a	4.4a	2.7a
Maize, 1 plant/hill, + beans	1.0a	4.0a	2.5a
Maize, 1 plant/hill, + cowpeas	1.0a	4.0a	2.5a
Maize, 2 plants/hill, + beans	1.0a	4.0a	2.5a
Maize, 2 plants/hill + cowpeas	1.0a	4.0a	2.5a
Maize, opposite, 3 plants, + beans	1.0a	4.0a	2.6a
Maize, opposite, 3 plants, + cowpeas	1.0a	4.0a	2.5a
Sole maize, staggered, 3 plants	1.0a	4.0a	2.5a
Maize, staggered, 3 plants, + beans	1.0a	4.0a	2.7a
Maize, staggered, 3 plants, + cowpeas	1.0a	4.0a	2.7a
Mean	1.0a	4.1a	2.6a
Significance	NS	NS	NS
C.V. (%) = 11.4 %			
Parameter	Season (S)	Treatment (T)	S x T interaction
S E ±	0.0375	0.0918	0.1298

NS = Not significant

Appendix 201. Lodging maize and beans after a hail storm damage at five weeks after planting 2014/2015.



Appendix 202. Lodging score in sole beans and maize-beans association at five weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole beans	2.0a	4.2a	3.1a
Maize, 1 plant/hill, + beans	2.0a	4.0a	3.0a
Maize, 2 plants/hill, + beans	2.0a	4.0a	3.0a

Maize, opposite, 3 plants, + beans	2.0a	4.0a	3.0a
Maize, staggered, 3 plants, + beans	2.0a	4.0a	3.0a
Mean	2.0a	4.0a	3.0a
Significance	NS	NS	NS
C.V. (%) = 4.7 %			
Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	0.0283	0.0447	0.0632

NS = not significant

Appendix 203. Dry beans lodging after a hail storm damage at five weeks after planting, 2014/2015.



Appendix 204. Lodging score for sole cowpeas and maize-cowpea in association at five weeks after planting.

Treatment code	Season		Mean
	2013/2014	2014/2015	
Sole cowpeas	1.0a	4.2a	2.6a
Maize, 1 plant/hill, + cowpeas	1.2a	3.2a	2.2a
Maize, 2 plants/hill,+ cowpeas	1.4a	4.0a	2.7a

Maize, opposite, 3 plants, + cowpeas	1.2a	3.8a	2.5a
Maize, staggered, 3 plants, + cowpeas	1.4a	4.2a	2.8a
Mean	1.2a	3.9a	2.6a
Significance	NS	NS	NS
C.V. (%) = 4.3%			
Parameter	Season (S)	Treatment (T)	S x T
S E $\pm$	0.0794	0.1256	0.1776
NS = not significant			