Growth and yield response of spider plant (*Cleome gynandra* L.) intercropped at different populations, with cowpea (*Vigna unguiculata* L. Walp)

BY

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DECLARATION

I hereby declare that this research project and ideas are solely of my own effort and has not been submitted for any degree assessment or completion at any institute. All additional information has been acknowledged by references.

Rungano Dickson……………………………….

I hereby the undersigned certify that l have read this research project and it is now ready for evaluation.

Name of supervisor..

Signature…………………………………………………Date……………………………

Name of supervisor……………………………………………………………......................

Signature...Date...

ABSTRACT

Spider plant (*Cleome gynandra*L.) is an important indigenous vegetable in Zimbabwe whose demand is increasing across all social classes due to high nutritional and medicinal qualities. Lack of efficient production technologies is leading to under utilization of its genetic potential hence growing demand cannot be met by current methods used by smallholder farmers. In view of this, a field experiment was carried out at Musena Resettlement area in Chirumanzu District to assess the performance of spider plant under different populations intercropped with cowpeasin the 2014/15cropping season. The field experiment was laid out in a Randomised Complete BlockDesign (RCBD) consisting of seven treatments replicated three times. The treatments were three spider plant sole crops at populations of 37037, 74074 and 111111 plants/ha and sole cowpea at 111111 plants/ha. The other three treatments were intercrops of the three stated spider plant populations to which cowpea was added at 55555 plants/ha. The measurements taken were spider plant height, number of shoots and fresh shoot weight. Grain weight was measured for cowpea and the LER was calculated. There were significant ($p<0.05$) differences in all parameters measured, among the treatments. Spider plant was shortest when intercropped at 74074 plants/ha at five weeks after planting (WAE). Intercrop at 111111 plants/ ha had the highest number of shoots/ha but the fresh shoot yield was statistically similar to intercrop at 74074 plants/ha. The sole crop intercrop at 111111 plants/ha had the highest number of shoots/ha but fresh shoot yield was highest (3.2t/ha) for intercrop at 74074 plants/ha. Cowpea intercropped with spider plant at 111 111 plants/ha had the lowest (1,704t/ha) grain yield compared to intercrop at 74074 plants/ha (2.019t/ha). The highest LER (1.31) was achieved by intercropping spider plant and cowpeas at 74074 and 55 555 plants/ha, respectively. It can be concluded that intercropping spider plant at 74074 results in 31% higher yield compared to sole cropping.

DEDICATIONS

To my departed mother, Angeline and all mothers who bothered to preserve spider plant germplasm against forces of introductions of exotic vegetables and general neglect by research and extension policies. This is one step in recognition of your dream of a healthy food system that remains connected to the local ecosystem and encompasses high nutritional and medicinal values. Rest in peace dear Mother, you could not wait to see this happen.

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ABBREVIATIONS

PROTA-Plant Resources of Tropical Africa

NHI- Nitrogen Harvest Index

BNF- Biological Nitrogen Fixation

LER- Land Equivalent Ratio

ET- Evapo-transpiration

WUE- Water Use Efficiency

RUE- Radiation Use Efficiency

PAR- Photosynthetically Active Radiation

DM- Dry Matter

NUE Nutrient Use Efficiency

AVRDC- Asian Vegetable Research and Development Centre

ATP- Adenosine Triphosphate

RY-Relative Yield

AGRITEX- Agricultural Technical and Extension Services

WAE- Weeks after Emergence

ANOVA- Analysis of Variance

LA- Leaf Area

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CHAPTER ONE

1.0 INTRODUCTION AND JUSTIFICATION

Spider plant (*Cleome gynandra).*L) is a highly polymorphic herb which belongs to the family Cleomaceae (Aparadh*et al.*, 2012). It is common in tropical Africa especially in settled areas or areas that have been settled before (Mnzava and Chigumira, 2004). In Zimbabwe it is known as “Nyeve” in Shona and “Ulude” in Ndebele vernacular languages, respectively. Other names include African cabbage, Spider flower and Cat’s whiskers.

Spider plant is one of the very popular traditional vegetables in Zimbabwe and the rest of East and Southern Africa (PROTA, 2010). The tender leaves, stems and shoots are boiled and eaten fresh or dried as a relish or in stew (Chweya and Mnzava, 1997;Onyango*et al.*, 2013).Nutrition studies show that leaves of spider plant contain beta carotene, ascorbic acid, iron and calcium at levels above normal dietary requirements and protein with high levels of essential amino acids of which Glutamic acid is highest (Chweya and Mnzava, 1997; Kamotho*et al*, 2013). It is suggested that 100g edible portion can supply 100% of daily micronutrient requirement and 40% of protein needs of an individual (Ngetichi*et al.*, 2012; Onyango*et al.*, 2013). This micronutrient richness makes spider plant an important vegetable species for incorporation into existing smallholder cropping systems. Consumption is challenged by the bitter taste caused by condensed tannins which are part of its polyphenolic compound content (Kutsukutsa*et al.*, 2014), but women mix it with amaranth or cowpea leaves to abate bitterness (Mnzava and Chigumira, 2004).

Apart from high nutritional value, spider plant is endowed with a medicinally sound phytochemistry which has been scientifically confirmed (Anbazhagi*et al.*, 2009; Kumari and Jain, 2012; Kutsukutsa*et al.*, 2014). In east and southern African communities, special spider plant meals or recipes are prescribed to cases of blood loss, pregnant mothers for easing child birth, nursing mothers for increasing milk production, treatment of roundworm infestations and epileptic fits among many other common illnesses(Chweya and Mnzava, 1997; Meshra*et al.*, 2011). Insecticidal and insect repellent properties make spider plant an important component of cropping systems for environmental friendly insect control (Ogol and Makatiani, 2007).

Despite being endowed with nutritional, medicinal and economic as well as agro-ecosystem benefits, spider plant still enjoys semi-cultivated status (Masuka*et al*, 2012). Zimbabwean women practice direct seeding of spider plant in the main cereal crop and harvest it during weeding or before mechanical weeding is done between rows of the cereal crop (Maroyi 2011; Mpala*et al.*, 2013). In the process of weeding, they leave a selection of plants intra-row which they allow to set seed for use as planting material in subsequent seasons. The seeds are collected or left to self disburse and regenerate. This is an ancient practice which forms an integral part of indigenous agricultural knowledge systems (Maroyi, 2011; Mpala*et al.*,2013) in Zimbabwe. The practice limits harvests to one or two where weeding is delayed. Moreover, decline in soil fertility, low or non fertilizer use and lack of pest and disease control have been widely blamed for low yields (Mutoro*et al.*, 2012; Ngetichi*et al.*, 2012; Hutchinson, 2011).

The agronomy of spider plant is underdeveloped due to past neglect such that optimum plant population, intercropping technologies, optimum nutrient requirements and post harvest technologies are not readily available to farmers (Onyango*et al.*,2013). This has limited the ability of women to maximise productivity in their entitled small pieces of land so as to meet the rising demand which they have created in urban, retail and cross boarder markets (Mnzava and Chigumira, 2004; Mpala*et al.*,2013). Creating space for monocropping is a big challenge because cereals occupy most of the available land in smallholder farming systems leaving little for legumes and vegetables which are often regarded as women's crops.

Intercropping, which involves growing of two or more crop species together on the same piece of land at the same timein the same growing season such that components interact in time and spacedepending on design(Perksen and Golumser, 2013).This practiceis associated with increased production per unit area and is a sustainable option which has not been widely investigated for spider plant. Spider plant and cowpea form a non-nitrogen fixing and nitrogen fixing legume combination which needs to be tested for productivity, for the benefit of smallholder growers especially women who produce most of the legumes and vegetables.

Cowpea is considered the most widely intercropped pulse in semi-arid tropics (Yirzagla,2013) especially with cereals and vegetables in Nigeria and Niger (Egbe and Egbo, 2011). It is known to have the capacity to fix up to 100% of its nitrogen requirement hence can possibly reduce competition for soil mineral N to the benefit of spider plant (Lindemann and Glover, 1996; Kouyate*et al.*, 2012). Its nitrogen harvest index (NHI) is low such that a large portion of nitrogen from biological nitrogen fixation (BNF) remains in residue to enrich the soil and it has potential to transfer part of fixed nitrogen to spider plant (Rusinamhodzi, 2006).Other important attributes of cowpea include the ability to protect soil from erosion, tolerate drought and heat, smother weeds, and reduce evapotranspiration through canopy cover and increase water and light use efficiency of the intercropping system (Dube *et al.*, 2014).In this study, a field experiment was carried out to determine the growth and yield response of spider plant intercropped with cowpea under rain fed conditions.

1.1 **Broad Objective**

To assess the growth and yield performance of spider plantintercropped with cowpea.

1.2 **Specific Objectives**

1.2.1 To determine the effect of intercropping spider plant at different populations,with cow pea on the height and number of spider plant shoots.

1.2.2 To assess the effect of intercropping spider plant at different populations,with cowpea on marketable fresh shoot yield of spider plant.

1.2.3 To evaluate the effect of intercropping spider plant at different populations,with cowpea on cowpea grain yield.

1.2.4 To establish the effect of intercropping spider plant at different populations,with cowpea on Land Equivalent Ratios (LER).

1.3 Hypotheses

1.3.1 Intercropping spider plantat different populations, with cowpea has a significant effect on the height and number of spider plant shoots

1.3.2 Intercropping spider plantat different populations,with cowpea has a significant effect on marketable fresh shoot yield of spider plant.

1.3.3 Intercropping spider plantat different populations,with cowpea has a significant effect on cowpea grain yield.

1.3.4 Intercropping spider plantat different populations, with cowpea affects LER of intercrops.

CHAPTER TWO

2.0 LITERARURE REVIEW

2.1 Definition, scope and benefits of intercropping

Intercropping involves the cultivation of two or more crop species together at the same time in the same field during the same growing season (Perksen and Golumser, 2013). It is important to note that intercropping results in competition between different crop species (interspecific competition) which needs to be effectively managed for the success of the system. Critical management aspects include component species selection, density manipulations and a good understanding of both root and shoot interaction of component crops.

Choice of intercropping systems depends on soil, climate, and economic objectives of the farmingcommunity (Matusso*et al*., 2014). The benefits of intercropping depend on response of components to the environment and their interaction in space and time. The choice of component species is therefore central to the planning phase. The most common combinations are legume-non legume or nitrogen fixing and non nitrogen fixing components. This is because of the importance attached by smallholder farmers to the reduction of dependence on mineral nitrogen fertilizers which are expensiveand difficult to access (Manenji, 2011). Biological nitrogen Fixation (BNF) contributes part of nitrogen requirement for the subsequent crop resulting in reduced production costs which makes legume-non legume intercropping systems more economic and productive.Nitrogen is considered to be the most essential nutrient that limits production in most tropical cropping systems (Egbe and Egbo, 2011).

Apart from BNF the legume component canopy and density prevent runoff and erosion of soil and nutrients as well as eutrophication of water bodies (Matusso*et al.*, 2014) by avoiding soil pore sealing effect of rain drops resulting in increased infiltration. The legume canopy reduces radiation that reaches the soil surface which results in reduced evapotranspiration (ET) (Dube *et al.*,2014) and allows for high water use efficiency (WUE) in intercropping systems. On the other hand radiation use efficiency (RUE) is also high given less radiation reaching the soil surface (Dube *et al.*, 2014). The component densities need to be effectively moderated to avoid fast moisture depletion associated with excessively high plant densities.

Smallholder farmers especially those located in marginal areas of Zimbabwe, need to intercrop since these areas are associated with declining soil fertility and farmers have the need to access diverse food, reduce fertilizer expenses and accessibility challenges as well as losses due to crop failure (Manenji, 2011; Dube *et al.*, 2014). The intercrop yield provides an option for compensating for losses and on the other hand yields are often higher than sole cropping (Metuzals, 2014).This is in addition to protection of the soil, increased agro-biodiversity and food diversity for smallholder farm families. Yield stability of the intercropping systemdepends on component differences in resilience to environmental stresses such that high yields can be achieved even in drier areas (Dube *et al.*, 2014) and total crop failure is avoided.

2.2 Intercropping practices

Pulses and cereals are widely intercropped especially in Africa, Asia and SouthAmerica (Metuzals, 2014). This practice is the domain of smallholder farmers who need to maximise productivity in their small pieces of land to meet diverse food needs and avoid low incomes associated with sole cropping (Oseni, 2010; Metuzals, 2014). These farmers consider intercropping as a viable option for land use efficiency with high productivity per unit of land (Matusso*et al.*, 2014). In China, one third of cropped land is said to be intercropped and accounts for 50% of total grain produced (Perksen and Golumser, 2013). While 70% of world cowpea is produced in central and West Africa, the production system is basically cereal-cowpea intercropping though cowpea is also intercropped with vegetables. Cowpea was found to be the most common component of intercropping systems in semi-arid tropics (Yirzagla, 2013). In Africa, especially Nigeria, 60-70% of cropped land is intercropped with cowpea (Mohammed *et al*., 2006) but in Zimbabwe it is at a small scale because smallholder farmers are investing in maize even where it does not do well (Manenji, 2011; Dube*et al.*, 2014). Generally, intercropping practice in Zimbabwe has suffered from effects of aggressive promotion of sole crops especially maize and cash crops through master farmer schemes and the drive for commercialization. This policy has resulted in underdevelopmentof intercropping technology. Moreover, research has been associated with the notion that intercropping is complex to manage (Perksen and Golumser, 2013).

Generally the density of component crops depends on intercropping practice. The most common practice is the additive type where the plant population of the other component is fixed at its optimum rate and the other component crop is added at a lower population than optimum (Yirzagla, 2013). Smallholder farmers practisethis system throughout the tropics and subtropics probably because of the need to get more of the staple food crop than the added component. The other option practised is the replacement type in which plant populations of both components are reduced below optimum up to densities that do not promote negative effects of interspecific competition which are detrimental to the yield (Sullivan, 1998). The basis for development of various intercropping types within the above models is the need to reduce interspecific competition for growth resources. The critical task is to come up with ideal densities that promote complementary effects through manipulation of spatial arrangements or densities. There is intense competition when component crops are intercropped at their optimum populations or when population of one component is increased while the other one is fixed (Morgado and Willey, 2008), hence densities can be adjusted in favour of the more desired component crop. Mixed intercropping is where component crops are planted haphazardly at the same time. Strip intercropping involves planting component crops in individual strips but close enough to interact. In this case it is possible to give adequate management attention to component crops as individuals. Row intercropping is when intercrops are planted in distinct rows or at least one component in rows, either simultaneously or at different times (Sullivan, 1998). When planting of the second component is done into an established crop, it becomes relay intercropping. In this case planting time separates interaction in space and in time such that peak nutrient demand is at different times and as main crop senesces it is less competitive for light, nutrients and water to the advantage of the added component crop. .

2.3 Intercropping of spider plant and cowpea

The purpose of intercropping is to increase crop productivity and diversity per unit area of land and meet smallholder farm family food security and income needs. An intercropping system needs to account for declining soil fertility (Rusinamhodzi, 2006). It is most important that intercrop combinations result in high WUE, RUE, and nutrient use efficiency(NUE) for the system to achieve the above purposes (Oseni, 2010; Matusso*et al.*, 2014). High RUE, WUE and NUE have been associated with the higher yields of components than sole cropping such that sole cropping may need more land to achieve yield levels of intercropping systems (Matusso*et al*, 2014; Dube *et al.*, 2014). The key productivity issue is the ability of components to reduce competition, intercept photosynthetically active radiation (PAR) and efficiently convert it into dry matter (DM) all of which depend on soil nutrient concentration. Basic compatibility factors to consider are growth habit or pattern, canopy architecture, root systems, densities as well as water and nutrient demand at various phenological stages

(Perksen and Golumser, 2013). Components need to be compatible in many of the above aspects so that competition is reduced and NUE is increased.

Studies centred on productivity of spider plant as an intercrop are limited with respect to this review. One case of intercropping with maize recorded yield reductions greater than 50% but Land Equivalent Ratios (LER) were all greater than one (Abukutsa-Onyango, 2007). Selection of crops to intercrop with spider plant needs to be done carefully given that it requires high radiation and does not grow well under shade (Chweya and Mnzava, 1997) which possibly influenced above results.Plant population of spider plant varies with production and harvesting methods or practices giving a range of 33 333-500 000 plants/ha (AVRDC, 2003; Fusire, 2008; Mbugua et al., 2008; Mavengahama, 2013). Under field conditions populations are not standardised in Zimbabwe but a range of 33333-100000 plant3/ha has been tested in East Africa and South Africa (AVRDC, 2003;Mavengahama, 2013). Optimum plant population for rain fed production is critical for higher yields hence needs to be specified for the benefit of smallholder farmers because it also specifies yields, seed rates, and fertilizer rates which also have to be optimum. Existing populations need further evaluation to establish optimum for various production and harvesting systems. Specifications of optimum populations are also required for intercropping technologies in order to diversify options for farmers.

Women have access to small pieces of land that require maximum utilization and are major producers, preservers and traders in spider plant, cowpea as well as other vegetables and legumes (Mpala*et al.*, 2013).Spider plant and cowpea are both legumes but differ in that cowpea is nitrogen fixing while spider plant is non nitrogen fixing and has high affinity for nitrogen as shown by its association with high organic matter soils especially around homesteads with high nitrogen levels. Combining the two in an intercropping system results in inter-specific competition that can drive cowpea to rely more on BNF nitrogen than soil mineral nitrogen leading to a separation of nitrogen sources.Spider plant can possibly benefit from a combination of soil mineral nitrogen and nitrogen transfer from cowpea provided densities and row arrangements allow for root interaction. Cowpea BNF nitrogen is directly transferred through root exudation of soluble nitrogen compounds, leaf leachates and decomposition of nodules (Rhizodeposition) provided densities allow root interaction (Rusinamhodzi, 2006; Matusso*et al.*, 2014). The subsequent crop indirectly benefits through cowpea biomass decomposition and mineralization of nitrogen. In the reviewed experiments, cowpea transferred 3.6% of BNF nitrogen to cotton component (Rusinamhodzi, 2006) and 24.9% BNF nitrogen to maize in a maize-cowpea intercrop combination (Matusso*et al.*, 2014) through rhizodeposition. It is however, suggested that most intercropping systems do not show significant transfer except where soil mineral nitrogen is severely limited (Rusinamhodzi, 2006; Matusso*et al.*, 2014).

2.4 Cowpea and BNF contribution to intercropping systems

The major significance of cowpea in cropping systems is its ability to add nitrogen to the system through BNF. BNF is a process of changing atmospheric nitrogen to biologically usable ammonium ion in the nodule of a nitrogen fixing legume which is then absorbed by the plant (Lindemann and Glover, 1996). The nodule must host bacteria of the *Rhizobium* spp. which have the nitrogenase enzyme necessary for BNF. In this relationship cowpea supplies energy and gets ammonium ion for use in return. Cowpea nodulates freely in Zimbabwean soils which is an important attribute for saving cost of nitrogen fertilizer or inoculants for smallholder farmers. The only challengethey would face is the availability of high yielding varieties rather than mineral nitrogen fertilizer.Rhizobial inoculation has been attempted in tropical Brazil but free nodulation gave similar results as inoculated and mineral nitrogen fertilized cowpea (Martins *et al.*, 2003; Martins da Costa, 2014). It is critical to ensure that cowpea has a quick and vigorous start for successful nodulation and enhanced BNF (Balasubramanian and Nnadi, 1976) by providing starter nitrogen and phosphorus.

BNF must be a component of any intercropping system to ensure that supply of nitrogen is increased to offset intensity of interspecific competition for the nutrient. Choice of cowpea variety is based on knowledge of its performance in cereal based intercropping systems and the low nitrogen harvest index (NHI). NHI is the proportion of BNF nitrogen that is part of the grain at harvest (Rusinamhodzi, 2006; Metuzals, 2014) and determines the proportion of BNF nitrogen remaining in vegetative residue. Cowpea has been observed to have the ability to fix 90% or even 100% of its nitrogen requirement (Lindemann and Glover, 1996; Kouyate*et al.*, 2012). BNF is lowest during pod filling when most assimilates are channelled to grain development or when nitrate is high in cowpea root zone (Kimiti and Odee, 2013; Matusso *et al.*, 2014). Quantification studies for cowpea BNF nitrogen are still limited but available literature gives the BNF nitrogen potential of 100-300kg N/ha compared to 100-260kg N/ha for soya (Matusso *et al.*, 2014).

The BNF capacity depends on access and ability to intercept PAR (Matusso*et al*, 2014; Metuzals, 2014). Cowpea of the determinate type have erect leaf canopy consistent with efficient PAR interception. Other factors that affect BNF are crop densities (competition), cropping system, and soil nutrient concentrations (Kouyate *et al.*, 2012; Matusso *et al.*, 2014) as well as moisture, acidity, and temperature extremes (Metuzals, 2014). BNF efficiency of cowpea increases with increasing competition for soil mineral nitrogen associated with higher crop densities and interspecific competition in intercropping systems (Rusinamhodzi, 2006) up to a certain optimum. Cowpea BNF N is partitioned generally into leaves, peduncles, stems, pods, roots and nodules (Douglas and Weaver, 1989).

2.5 Potential below ground spider plant/cowpea interactions

Nutrient use efficiency (NUE) is another important consideration which is centred on rooting or nutrient extraction depth. Component crops of different rooting depths lead to efficient utilization of nutrients in the available soil profile especially deep-shallow rooted and long - short duration crop combinations (Dube, *et al*, 2014). Competition is reduced and the deeper rooted component brings leached nutrients to the upper profile through biomass decomposition where residue is incorporated. Intercropping spider plant and cowpea leads to increased nutrient scavenging in the soil profile and both crops may recycle important nutrients like phosphorous (P) and leached nitrogen. Both spider plant and cowpea have taproots that go deep but the lateral roots of spider plant are fewer and largely found in the topsoil some within the top 3 cm (Chweya and Mnzava, 1997). This implies that it is dependent on nutrients in a shallow volume of soil. It is unclear whether the taproot can also absorb nutrients when top soil gets dry. Cowpea has the ability to access water and nutrients from as deep as 80 cm because of a deep root system (Itan *et al*., 1992).

2.6Canopy and Radiation Use Efficiency (RUE)

RUE depends on spatial arrangements and canopy architecture. Components should include high and low canopy crops to increase PAR interception which is critical for DM production and BNF efficiency (Matusso *et al.*, 2014). Care needs to be taken to avoid excess shading because it reduces BNF intensification which depends on PAR interception through energy compounds produced by the legume (Egbe and Egbo, 2011; Perksen and Golumser, 2013). Conversion of PAR to DM is critical for high RUE, competitive abilities of component species, their densities, spatial arrangements, and time of planting and soil nutrient concentration status of soil need to be considered (Perksen and Golumser, 2013).

The intensificationof BNF depends on competition for nitrogenfrom the main crop hence is decreased when intercrop population is increased on a fixed main crop population becausethe main crop becomes weak.This may depress yield where competition centres on soil mineral nitrogen because BNF is not immediately intensified(Rusinamhodzi, 2006). Manipulation of component densities should be possible in order to come up with optimum densities that achieve the highest resource use efficiency and productivity per unit area and time. High competition for PAR and nutrients especially Phosphorusleads to low BNF rate (Metuzals, 2014). Spider plant is diheliotropic (leaves move following the sun) hence it is able to track radiation all day which associates it with high light intake and high transpiration rates. Cow employs paraheliotropic leaf movements to control transpiration in which leaves position themselves parallel to the sun's rays (Itan*etal*.,1992). This results in a cool leaf with reduced transpiration rates. The trifoliate nature of leaves for both component crops can allow improved penetration of radiation into the canopy.

2.7Component interaction as influenced soil nutrient status.

Available land and location influences availability of important nutrients like Phosphorus which is an essential component of energy compounds (ATP) that drive BNF. Phosphorus is often unavailable at pH extremes (fixed in insoluble compounds) and the ideal pH is 6-7. The legume has to compete aggressively for Phosphorus if too limited because BNF is energy intensive (Metuzals, 2014). In high nitrogen or High organic matter soils the non legume or non nitrogen fixing legume needs to be an aggressive nitrogen utilizer in order to force the nitrogen fixing legume to intensify and rely on BNF (Perksen and Golumser, 2013; Matusso et al,2014; Metuzals, 2014).

Under marginal lands of very low nitrogen status, the legume needs to be highly BNF efficient to allow non legume to benefit from soil mineral nitrogen and direct nitrogen transfer through rhizodeposition. Spider plant and cowpea are considered naturally selected to survive in marginal environments and are easily produced under low input technology (Mbugua *et al.*, 2008; Seeiso and Materechera, 2011; Mpala *et al*,2013).

Spider plant and cow pea are a good match under the circumstances of declining soil fertility in marginal areas inhabited by smallholder farmers. Cowpea is endowed with the capacity to improve soil available Phosphorus by solubilizing that which is fixed in iron oxide and aluminium oxides by way of root organic acid exudation and membrane bound phosphatase enzyme (Mahamane, 2008). The oxidation of BNF produced ammonium has been associated with rhizosphere acidification(proton release) which release Phosphorus fixed at extremely alkaline conditions. Lateral root spread is very critical because it determines size of sorption zone of which less mobile nutrients like Phosphorus require a larger sorption zone for crop plants to access it more efficiently. This ability to access Phosphorus coupled with BNF makes cowpea an important component for reducing interspecific competition for growth resources in intercropping systems.

2.8 Agro-ecosystem interactions in spider plant/cowpea intercropping

Components like spider plant can repel diamond back moth and red spider mite, combining it with susceptible crops needs to be considered so that intercropping remains economic and sustainable. A number of experiments with spider plant as a companion crop have been carried out for example in Cutflower rose(*Rosa hybrida*), spider plant significantly reduced red spider mite(*Tetranychus urticae*) populations when planted within rows or around the perimeter of a bed (Nyalala and Grout, 2007). In Kenya it was companion cropped with cabbage and kale and significant reduction in populations of diamond back moth larvae was recorded (Ogol and Makatiani, 2007). The same happened with flower thrips in French bean and tomato (Slue, 2009). Thrips are an important insect pest of cowpea which can potentially be repelled by presence of spider plant. Insect pests may have difficulty in identifying host between spider plant and cowpea (Rusinamhodzi, 2006). More over cowpeaflowers have extra floral nectaries which attract bees, predatory wasps, lady bird beetles and ants (Valenzuela and Smith, 2002) into the cropping system. These insects are important for pollination (bees) and the rest for regulation of pest populations. Cowpeaestablishes a quick canopy that suppresses weeds and is more efficient in this than other legumes (Lawson *et al*.,2013). Experiments show that there was suppressed germination of *Striga* species in cereal-cowpea intercropping systems.

2.9 Resilience of spider plant to environmental stresses

Below 60% of available moisture, spider plant leaf expansion and inter node elongation start to decline (citation). Experiments have shown that leaf area can drop fivefold, dry matter by 45% and transpiration decrease significantly under declining moisture status of soil (Masinde *et al.*, 2005; Masinde *et al.*, 2007). Kumar *et al.*, (2003) observed that spider plant responded to initiated moisture stress in four days and reached critical water potential in nine days. Spider plant reduces leaf area development as a means to control transpiration rate which is high due to diheliotropic leaf movements. The reduction of leaf area and stomatal closure constitute a reduction in radiation interception, gaseous exchange and ultimately dry matter and biomass production. Leaf quality is affected through leaf size, moisture content, and nitrate accumulation (Masinde*et al.*, 2007).

Spider plant flowers or bolts prematurely under environmental stresses such as nutritional, biotic and moisture stress even at the seedling stage or around 4-6 weeks of emergence (Chweya and Mnzava, 1997; Mavengahama, 2013). Premature flowering reduces fresh shoot yield (Mavengahama, 2013) because photo-assimilates are directed to reproductive organs at the expense of vegetative regeneration. Removing the reproductive organs is an agronomic practice to rejuvenate and sustain vegetative growth for longer periods and increase fresh leaf or shoot yield (Fusire, 2008).Deflowering studies have shown that the practice increases branches, leaf and shoots/plant but reduces the height of spider plant (Chweya and Mnzava, 1997; Mavengahama, 2013). Factors responsible for premature flowering need further study because their effects may not be the same in severity or flowering may be a response to a combination of factors.

Cowpea tolerates drought, heat, and to some extent acid soils which make it an important legume for dry environments (N_2Africa, 2014). Cowpea has been noted to be more drought tolerant than most legumes (Chandiposha *et al*, 2013).The mechanism of drought tolerance consists of deep root system, stomatal closure, paraheliotropy and leaf shed (Itan*et al*.,1992). Only moisture deficit in soil at adepth of80 cm and beyond can cause crop failure in cowpea (Itan *et al*., 1992). Such attributes can be associated with a crop adapted to the vagaries of climate variability and change, especially the bushy and determinate CBC1 and CBC2 varieties that can give a crop in 60-90 days (N_2Africa, 2014). CBC2 has a potential yield of 4.0t/ha and seed weight of 44g/100 seeds and matures in 85 days from planting.

2.10 Productivity measurement in intercropping systems: Land Equivalent Ratio approach.

The yield of each intercrop component is first related to yield of sole crop to give the Relative Yield (RY). Relative Yields are then added to give the Land Equivalent Ratio (LER)

$$RY = \frac{\text{Intercrop yield}}{\text{Sole crop yield}}$$

$$LER = \frac{\text{Intercrop yield cropA}}{\text{Solecrop yield cropA}} + \frac{\text{Intercrop yield cropB}}{\text{Solecrop yield cropB}}$$

LER > 1 means intercrops yield higher than growing them as sole crops and LER < 1 means yield of intercrops is less than that of components sole cropped. Results of many intercropping experiments show that cotton-cowpea combination had LER as high as 1.7 (Rusinamhodzi, 2006), maize-cowpea under conservation farming 2.86 (Dube *et al* 2014), and sorghum-cowpea 1.38 (Mohammed *et al.*, 2006). The yield advantage in these cases ranges 27% to 186% showing a potential of doubling the sole crop yields.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site location and description

The field experiment was carried out at Musena resettlement area in Chirumanzu District in the Midlands province of Zimbabwe from 18th December 2014 to March 2015. Musena resettlement area is 60km west of Mvuma near the border with Mashonaland West province and is located 19º28´ S and 30º53´E. The altitude of the site is1406m above sea level.

It is in Agro-ecological Region III which receives annual rainfall of 650-800mm. The rainy season extends from November to March but the start and termination is unpredictable. This period is associated with high temperatures ranging 18-22^{o}C (Mugandani *et al.*, 2012) and high light intensity. Winter is an extended cool period often with occasional frost in August. Midseason droughts are a common feature of the region. Both cowpea and spider plant grow well in this area during summer. The field experiment was conducted on soil belonging to the 5G series under Fersiallitic Group of the Kaolinitic Order. These soils are moderately leached and have appreciable amounts of sesqui-oxides of iron and aluminium and are of moderate inherent fertility (Nyamapfene, 1991).

3.2 Experimental Design and Treatments

A Randomised Complete Block Design (RCBD) consisting of seven treatments replicated three times was used in the field experiment. Slope was used as the blocking factor to account for nutrient and moisture gradient. Treatments were randomly allocated to plots. Spider plant was treated as the main crop whose population was maintained at three levels 37 037, 74074 and 111 111 plants/ha. Row spacing was maintained at 90 cm for both sole and intercropped spider plant while intra-row was 30 cm, 15 cm and 10 cm for the respective populations. Cowpea was then planted between spider plant rows at an inter-row spacing of 45 cm. The population of sole cowpea was fixed at 111 111 plants/ha with an inter-row spacing of 45 cm and intra-row spacing of 20 cm. Treatments consisted of three pure stands of spider plant at the given populations, one cowpea pure stand and three intercrops as illustrated in Table 3.1. The experiment was laid out in three blocks each consisting of seven plots each measuring 4.8m x 3.6m. The plots were separated by 0.5m pathways between them and 1m pathways between blocks. Each intercropped plot consisted of five single rows of spider plant alternated with four single rows of cowpea. The two component crops were planted on the same date. A 5m wide boarder crop of cowpea was planted around the experimental plot to act as a guard crop.

Table 3.1Treatments used in the field experiment

Treatment	**Spider plant population (Plants /ha)**	**Cowpea population (Plants / ha)**
1	37037	nil
2	74074	nil
3	111111	nil
4	Nil	111111
5	37037	55555
6	74074	55555
7	111111	55555

3.3 Agronomic Management of the Field Experiment

The land was ploughed to a depthof 250mm in late November 2014. Clods were broken to a fine tilth using hoes. The experimental plot was measured outusing a 50m measuringtapeand each corner marked with a peg before squaring using the diagonal method. Treatment plots were marked out in three defined blocks each separated by a 1m pathway. Plot size was 4.8m x 3.6m separated by a pathway of 0.5m. Planting rows were then marked out in each of the twenty one plots at uniform spacing of 90 cm for sole spider plant and 45cm for sole cow pea and intercropped plots. Small furrows of 5 cm depth were opened using a small hoe. Maize Fert (N_7:P_{14}:K_7) was applied in rows at the rate of 200kg/ha for both crops. The fertilizer was placed at a depth of 5 cm and wascovered before cowpea was planted at a depth of 3 cm and spider was drilled at a depth of 1.5 cm. Planting commenced on the 18th of December 2014, in a soil near field capacity. Seed of spider plant variety Green stem was drilled at a depth of 1.5 cm and covered with moist soil. Cowpea variety CBC2 was planted on specific stations at an in- row spacing of 20 cm and 2 pips were planted per station. No nitrogen top dressing was done to both crops. First weeding was done two weeks after emergence (WAE) and the second at six WAE and thereafter canopy cover suppressed the weeds. Thinning was carried out in the third week of emergence to bring spider plant to the desired populations as per treatment. A graduated metre rule was used to achieve the specified intra-row spacing for each treatment. No disease occurrence was registered for both crops. The Hurrican bug (*Bagrada hilaris*) in spider plant and Aphids (*Aphis craccivora*) in cowpeawere the insect pests encountered and these were successfully controlled by applying dimethoate 40EC.

Harvesting of tender shoots with five leaves of spider plant including the apical bud was done commencing at five WAE and thereafter pickings were done every seven days for six weeks. At five WAE spider plant had begun to flower hence harvesting involved deflowering to extend the vegetative phase. Cowpea grain was harvested when fully mature and this was at10 WAE. At this stage pods had turned brown and dry. The pods were allowed to sundry further to 12-13% moisture content.

3.4 Data Collection and Analysis

For the purpose of taking measurements, one row of each crop was discarded on each side of a treatment plot and 90 cm from each end leaving a net plot of 5.4m^2. The net plot consisted of three rows of spider plant and two of cow pea, where 8 plants of each crop were randomly selected and tagged for taking height measurements. Plant height was measured using a graduated metre rule at five WAE just before the firstharvest. Height was measured from the base of the plant to the tip of the main shoot. Physical counting of shoots per plot was done at 6 WAE seven days after the first harvest and converted to shoots per hectare. Yield was measured in terms of weight of marketable shoot and five leaves per plot for spider plant and grain weight/plot at 12-13% moisture content for cowpea which was then converted to weight/hectare. A digital scaleSF-400 was used to measure weight in the field immediately after harvesting spider plant. Analysis of Variance (ANOVA) was done using Gen Stat 14th version and means were separated using LSD test at 5% level of significance.Count data were transformed using the square root method. Relative Yields (RY) were calculated for each crop and then added to give Land Equivalent Ratio (LER) as described in Section 2.10

CHAPTER FOUR

4.0 RESULTS

4.1Effect of intercropping spider plant at different plant populations with cowpea on spider plant height at five WAE.

Significant differences ($p<0.05$) were observed among treatments. Sole crop at 74 074 plants/ha was significantly ($p<0.05$) taller than its intercrop (Table 4.1). Among intercrops, height of intercrop at 74 074/ha was statistically ($p<0.05$) shorter than intercrop at 111 111plants/ha but statistically similar to intercrop at 37037 plants/ha. Across treatments, the height of intercrop at 111plants /ha was statistically similar to all sole crop treatments (Table 4.1).

Table 4.1Effect of intercropping spider plant at different populations levels with cowpea on spider plant height at 5 WAE in cm.

Cropping system	Mean height (cm)
Intercrop (74 074 +55 555)	34.54^{a}
Intercrop (37 037 +55 555)	38.17^{ab}
Sole crop (37 037)	43.76^{bc}
Intercrop (111 111 +55 555)	46.75^{c}
Sole crop (111 111)	49.21^{c}
Sole crop (74 074)	50.46^{c}
CV %	9.400
LSD	7.478
Pvalue	0.004

*Means with the same letters are not significantly different and numbers in brackets are population combinations of spider plant and cowpea or sole crop populations.

4.2Effect of intercropping spider plant at different populations with cowpea on number of spider plant shoots.

Sole crop at 111 111/ha had statistically ($p<0.001$) the highest number of shoots/ha.While sole crop at 74074 plants/ha had statistically ($p<0.001$) lower number of shoots/ha than sole crop at 111 111plants/ha,   number of shoots/ha was significantly higher ($p<0.001$) than that of sole crop at 37037 plants/ha (Table 4.2). Generally spider plant shoots/ha increased with increasing population from 37037 to 111 111 plants/ha among sole crops. Among intercrops, intercrop at 111 111 plants/ha had significantly ($p<0.001$) higher number of shoots /hathan intercrops at 37037 and 74074 plants/ha.Sole spider plant had higher number of shoots/ha than that intercropped with cowpea. Across treatments, sole crop at 37037 plants/ha had number of shoots/ha statistically similar to intercrop at 111111 plants/ha.

Table 2.2 2 Effect of intercropping spider plant and cowpea on the number of spider plant shoots

Cropping system	Mean number of shoots/ha
Intercrop (37 037 +55 555)	756.8[a]
Intercrop (74 074 +55 555)	846.7[b]
Sole crop (37 037)	943.9[c]
Intercrop (111 111+55 555)	1003.1[c]
Sole crop (74 074)	1094.4[d]
Sole crop (111 111)	1262.8[e]
CV%	4.20
LSD	75.29
Pvalue	<0.001

*Means with the same letters are not significantly different and numbers in brackets are population combinations of spider plant and cowpea or sole crop populations.

4.3Effect of intercropping spider plant at different populations with cowpea on fresh shoot yield of spider plant

Significant differences (p<0.001) were observed among treatments. Sole crop at 74074 plants/ha had significantly (p<0.001) the highest fresh shoot yield among them (Table 4.3). All spider plant sole crops performed better than their intercrops. Intercrop at 74074 plants/ha hadstatistically(p<0.001) higher fresh shoot yield than intercrop at 37037 plants/ha among intercrops though statistically similar to intercrop at 111111 plants/ha (Table 4.3). Intercrop at 37037 plants/ha had statistically (p<0.001) lower fresh shoot yield than the rest of the treatments. Generally fresh shoot yield increased from sole crop at 37037 to 74074 plants/ha then at 111111 plants/ha it regressed to levels statistically similar to that for 37037 plants/ha (Table 4.3). Intercrop at 74074 plants/ha had significantly ($p<0.001$) higher fresh shoot yield than intercrop at37037 plants/ha but statistically similar to intercrop at 111111 plants/ha.

Table 4.3Effect of intercropping spider plant with cowpea at different populations on fresh shoot yield of spider plant.

Cropping system	Fresh shoot yield (t/ha)
Intercrop (37037 +55555)	1.299[a]
Intercrop (111111 +55555)	1.610[b]
Intercrop (74074 +55555)	1.889[b]
Sole crop (37037)	2.826[c]
Sole crop (111111)	2.831[c]
Sole crop (74074)	3.213[d]
CV %	6.900
LSD	0.2847
Pvalue	<0.001

*Means with the same letters are not significantly different and numbers in brackets are population combinations of spider plant and cowpea or sole crop populations.

4.4Effect of intercropping spider plant at different populations on cowpea grain yield

Cowpea grain yield for sole crop was significantly (p<0.001) the highest compared to intercrops at 37037, 74074 and 111 111 plants/ha (Table 4.4). Intercrop at 37037 plants/ha grain yield was statistically similar to intercrops at 74074 and 111 111 plants/ha but intercrop at 74074 plants/ha grain yield was significantly (p<0.001) higher than intercrop at 111 111 plants/ha. Generally cowpea grain yield increased with increasing spider plant up to 74074 plants/ha then decreased at the highest population of 111 111 plants/ha.

Table4.4Effect of intercropping spider plant at different populations with cowpea on cowpea grain yield.

Cropping system	Grain yield t/ha
Intercrop (111111 + 55555)	1.704[a]
Intercrop (37037 + 55555)	1.833[ab]
Intercrop (74074 + 55555)	2.019[b]
Sole crop (111111)	2.815[c]
CV %	5,300
LSD	0.221
Pvalue	<0.001

*Means with the same letters are not significantly different and numbers in brackets are population combinations of spider plant and cowpea or sole crop populations.

4.5Effect of intercropping spider plant at different populations with cowpea on LER

The highest LER was recorded for a combination of spider plant at 74074 plants/ha and 55555 plants/ha cowpea (Table 4.5). The lowest LER was recorded at 37037 plants/ha combined with the same cowpea population. The intercropping advantages were 11%, 31% and 18% for intercrops with 37 037, 111 111 and 74 074 plants /ha of spider plant, respectively. All intercrops had LER greater than unity though for intercrop at 37037 plants/ha, spider plant contributed less than in the other two levels. Generally LER increased with increasing population up to 74074 plants /ha then declined.

Table 4. 5 Effect of intercropping spider plant at different populations with cowpea onLER

Cropping system	RY Spider plant	RY Cowpea	LER
Intercrop (37037+55555)	0.46	0.65	1.11
Intercrop (111111 +55555)	0.57	0.61	1.18
Intercrop (74074 +55555)	0.59	0.72	1.31

CHAPTER FIVE

5.0 DISCUSSION

5.1Effect of intercropping spider plant at different populations with cowpea on height of spider plant at five WAE

The shortest spider plant height recorded for intercrop at 74074 plants /ha could suggest that there was more intensive root based inter-specific competition for water and nutrients

Because if it was more shoot based then height should have significantly increased. Nitrogen and moisture are likely to be the limiting factors in this case because they are associated with cell elongation, expansion and ultimately shoot growth (Masinde et al., 2007). Studies also show that increasing population of the added component increases inter-specific competition and the intensity of effects on the main crop. (Perksen and Golumser, 2013; Matusso *et al.,* 2014).

Intercrop at 37037 plants/ha resulted in the population of cowpea exceeding that of spider plant resulting in inter-specific competition effects similar to intercropping at 74074 plants/ha. This could be as a result of cowpea having higher root density in the top soil than spider plant enabling it to remove more water and nutrients against spider plantunder prevailing moisture limited conditions (Appendix 5). In a related study , Morgado and Willey (2008) found that intercropping maize at 20000 with beans at 30000 plants/ha had lower inter-specific competition than at 20000 plus 90000bean plants/ha where maize biomass decreased. This confirms that inter-specific competition is controlled by the added component population up to a balanced point beyond which growth begins to decrease. Xiao *et al.* (2006) also suggests that beyond the critical limit, height begins to decrease as population increases. Shading maynot have been very strong because of simultaneous planting of the component crops andBNF may not have been fully established at five WAE such that nitrogen mighthave been the most limiting among other nutrients because of associated depletion with increase in height of spider plant or ingrowth (Masinde *et al*., 2007).

5.2Effect of intercropping spider plant at different populations with cowpea on number of spider plant shoots at 6WAE

Intercrop at 37037 plants/ha had the lowest number of shoots/ha. The result shows that the number of shoots/ha increased with increasing population of spider plant. Sole crop at 111 111plants/haoutperformed intercrop at the same population probably due toabsence of competitive ability differencesin the sole crop. The result suggests that the number of shoots increased due to effect of number of plants/unit area than number of shoots/plant. Addition of a fixed cowpea population into the specified populations of spider plant could have resulted in competitive ability differences. This may have increased inter-specific competition for water and nutrients resulting in significant reduction in number of shoots /ha in intercrops compared to sole crops. At 6WAE, BNF may not have been well established, such that competition for nitrogen may have been more intense among intercrops. The increasing trend in number of shoots as population increases, suggests that number of shoots/ha strongly depends on density rather than shoots/ plant. This is in line with findings by AVRDC-The World vegetable centre (2003) who observed that shoots increase with increasing populations in vegetables.Results are further confirmed by Law-Ogbomo and Ajayi (2009) in an experiment with*Amaranthus cruentus* populations at 62500 and 111 111 plants/ha and found that the population of 111 111 plants/ha had a higher leaf and shoot production rate than 62500plants/ha at the same level of nutrition.

5.3Effect of intercropping spider plant at different populations with cowpea on fresh shoot yield of spider plant (t/ha)

Sole spider plant at 74074 plants/hahad the highest fresh shoot yield of 3.213t/ha while intercrop at 37037 plants/ha had the lowest (1.299t/ha). The resultssuggest that spider plant performed best as sole crop in terms of fresh shoot yield than when intercropped with cowpea.This could be a as a result of differences inintensity between intra-specific and inter-specific competition.

Despite having the highest number of shoots/ha sole spider plant at 111 111 plants/ ha had a fresh shoot yield lower than sole spider plant at 74074 plants/ha. This could have resulted from the effect of population that resulted in competition which reduced leaf size and mass.Chweya (1982) recorded higher fresh leaf weight, number of leaves and branches/plant at a lower population of 21489 plants/ha than at 42978 plants/ha in sole crop of kale *(Brassica oleracea var acephala)*.Maseko (2014) carriedout a study of *Cochorus olitirious* and *Amaranthus cruentus*as sole crops in South Africa and recorded better quality leaf and shoots at 50000 than at 100000 plants/ha where yield was highest. It is therefore possible that quality maybe lowered at higher populations by effects of competition.The lowest fresh shoot yield recorded for intercrop at 37037 plants/ha can be attributed to intense inter-specific competition due to increased root mass of cowpea because of having a higher population (55 555 plants/ha) than spider plant. Legwaila *et al.* (2014) increased population of cowpea in a maize-cowpea system andestablishedthat root depth, density and root lateral spread were determinants of competition intensity.

5.4Effect of intercropping spider plant and cowpea at different populations on cowpea grain yield (t/ha)

Intercropping cowpea with spider plant at 111 111 plants/ha gave the lowest (1.704t/ha) cowpea grain yield due to combined effect of low population and competition which may have reduced the number of pods per unit area. Sole cowpea had the highest (2.815t/ha) grain yield due to high population which may have resulted in high number of pods per unit area. Cowpea was added to spider plant populations at 50% of its sole crop population suggesting that the effect of population difference may have been much stronger when sole cowpea is compared to intercropped cowpea.

While intercrop at spider plant population of 111 111 plants/ha had the lowest, the grain yield was 61% of sole cowpea grain yield. This suggests that the yield difference was density based than higher grain weight. Intercrop at 111 111 plants/ha had significantly lower grain yield than at 74074 plants/ha possibly due to negative effects of inter -specific competition and progressively declining water at densities higher than the critical limit in a water deficit environment. Cowpea therefore, performed best as a sole crop than when intercropped with spider plant may be because of higher population. Intercropped cowpea could have efficiently used growth resources especially light, moisture and nutrients such that grain yield could have increased significantly compared to sole crop yield. Rana and Rana (2011) made an indication that light interception increases by 30-40% in intercropping systems and the taller component would take in more light than shorter component. In this case cowpea was shorter but was never shaded off at the top of the canopy because planting was simultaneous and spider plant leaf area was reduced every seven days through harvesting of shoots.

5.5 Effect of intercropping spider plant at different populations with cowpea on LER

LER increased with increase in spider plant population up to 74074 plants/ha then decreased at 111 111plants/ha.This suggests thatintercropping at 74074 plants/ha gave the highest yield advantage (31%).The lowest yield advantage of 11% wasfrom the combination with the lowest population of 37037 plants/ha. Morgado and Willey (2008) found that LER increased with increasing population of maize from 20000 to 40000 plants/ha with maize contributing higher partial LER depending on level of bean population added.It can be suggested that a population of 74074 plants/ha could be the critical level to intercrop with cowpea at 55555 plants/ha at which LER was highest. The sole crops require 1.31 ha to achieve the intercrop yield levelaccording to the results of this experiment. Fresh shoot harvest may have given cowpea a competitive advantage over spider plant which was subjected to harvesting stress.On the other hand cowpea was highly competitive may be because of a dynamic response to both inter-specific competition and moisture deficit. At 111 111 and 74074 plants/ha spider plant yield was depressed by 43 and 41% respectively. Under moisture deficit cowpeaemploys paraheliotropy, increase roots that grow deeper and roots can grow even beyond flowering stage (Itan et al., 1992). In the prevailing dry environmentcowpea may have been capable of following moisture dynamics in the soil profile.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

On the basis of the results of this field experiment, it can be concluded that intercropping spider plant at 74074 plants/ha with cowpea at 55 555 plants/ha gave the highest LER and a yield advantage of 31%. Intercropping depressed height of spider plant at lower populations.The number of shoots increased with increase in spider plant population regardless of cropping system. Among the three sole spider plant populations, 74074 plants/ha gave the highest fresh shoot yield.Intercropping spider plant and cowpea at the three populations gave LER greater than one.

6.2 Recommendations

Given the results of the field experiment, it is recommended that smallholder farmers can adopt the intercropping of spider plant at 74074 plants/ha with cowpea at 55555 plants/ha to get the highest yield advantage of 31%. Smallholder farmers focussing more on market demand than yield advantage may adopt sole cropping of spider plant at 74074 plants/ha which gave the highest yield (3.213t/ha) under rain fed conditions compared to 37037 and 111 111 plants/ha.

For further research, the field experiment may be repeated over seasons to verify the effect of environment including all Agro-ecological Regions of Zimbabwe. Other intercropping populations (between 74 074 and 111 111 for spider plant and between 55 555 and 111 111) for cowpea could also be tested to improve validity of the results obtained in this study.

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APPENDICES

Appendix 1ANOVA table for the effects of intercropping spider plant at different populations with cowpea on number of spider plant shoots

Variate: number of shoots/ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	2	55478.	27739.	16.19	
Replication.*Units* stratum					
Treatment	5	487107.	97421.	56.88	<.001
Residual	10	17128.	1713.		
Total	17	559713.			

Appendix 2 ANOVA table for the effects of intercropping spider plant at different populations with cowpea on spider plant height

Variate: Height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	2	220.75	110.38	6.53	
Replication.*Units* stratum					
Treatment	5	599.32	119.86	7.09	0.004
Residual	10	168.95	16.90		
Total	17	989.02			

Appendix 3 ANOVA table for the effects of intercropping spider plant at different populations on spider plant fresh shoot yield

Variate: Yield_t_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	2	2.20500	1.10250	45.03	
Replication.*Units* stratum					
Treatment	5	9.10853	1.82171	74.40	<001
Residual	10	0.24485	0.02449		
Total	17	11.55838			

Appendix 4 ANOVA table for the effect of intercropping spider plant at different populations on cowpea grain yield

Variate: Grain_yield_t_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	2	0.01904	0.00952	0.78	
Replication.*Units* stratum					
Treatment	3	2.23745	0.74582	60.99	<.001
Residual	6	0.07337	0.01223		
Total	11	2.32986			

Appendix 5Rainfall distribution for the experimental period

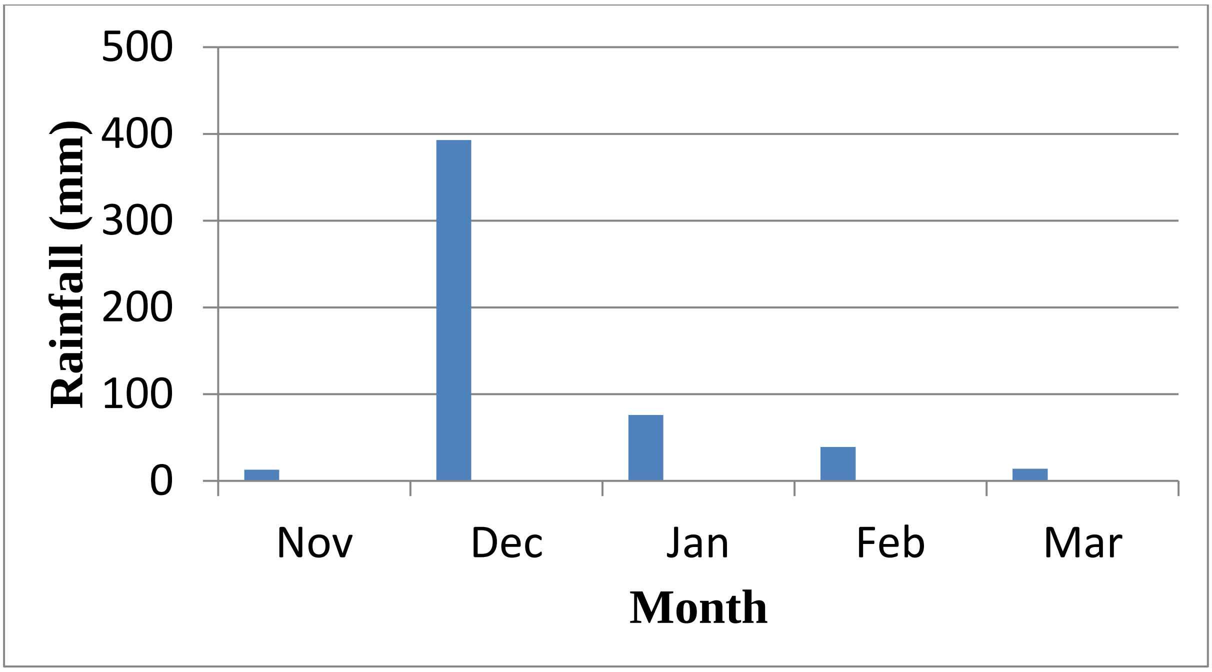

Fig **1. Rainfall distribution for the experimental period**