ASSESSMENT OF COMMON BEAN (*PHASEOLUS VULGARIS* L.) VARIETAL TOLERANCE TO ANGULAR LEAF SPOT DISEASE *(PHAEOISARIOPSIS GRISEOLA)*.

A PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE HONOURS IN AGRICULTURE AND NATURAL RESOURCES.

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DECLARATION

I…………………………………………..do hereby declare that this work is my original work undertaken at Africa University, Mutare, Zimbabwe in partial fulfillment of the requirements for the degree of Bachelor of Science Honours in Agriculture and Natural Resources and has not been submitted nor is being currently submitted to any university for the award of any other degree.

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ABSTRACT

Angular Leaf Spot disease of common bean is of importance in both tropical and temperate regions. Angular leaf spot (ALS) caused by *Phaeoisariopsis griseola* (Sacc.) Ferraris, is one of the most damaging and widely distributed diseases of common bean, causing yield losses as high as 80%. Beans are a source of income for many rural communities in Zimbabwe; therefore, effective disease control measures should be taken to ensure high yields. A field experiment was conducted to evaluate angular leaf spot tolerance in five different common bean cultivars namely Ex-Rico, Bonus, PAN 148, White Kidney and Carioca. A Randomized Complete Block Design was used. There were three replications and five treatments (five common bean varieties). The land was ploughed first and a pre-emergence herbicide, Gramoxone was applied and planting was done on the 28th of January 2012. Compound D fertilizer was applied at a rate of 350kg/ha during planting. Readings on disease incidence and disease severity were taken for four consecutive weeks starting from nine weeks after emergence. For disease severity, the area under disease progress curve was analyzed using Minitab version 15. The results showed that the variety Carioca was the most susceptible to ALS whilst variety Ex-Rico was the most tolerant to ALS. Carioca had the highest area under the disease progress curve and Ex-rico had the lowest area under the disease progress curve. It is recommended that farmers use tolerant common bean varieties such as Ex-rico and Bonus in order to have high yields. Integrated Disease Management where cultural, biological and chemical control methods are used to control crop diseases is also encouraged to farmers. In cases where susceptible varieties such as Carioca are used, fungicides such as Chlorothalonil (Bravo 500) should be used to control ALS.

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DEDICATION

I dedicate this project to my precious mom, family and Africa University at large. Thank you so much mom for your support when I felt some things were insurmountable. I draw my strength from you. To my late Father, the Honourable MP, Rufaro Zonde Gwanzura, I wish you were here to see me achieve something big in life but nevertheless, I salute you because you are my source of inspiration.

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"The grace of God cannot lead you where the will of God cannot protect you"

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

CHAPTER ONE

1.0 INTRODUCTION

Angular leaf spot disease (ALS), caused by the fungus *Phaeoisariopsis griseola* is an important disease of beans in both tropical and temperate regions. It is the most destructive foliar disease in common beans causing lesions on leaves, pods, branches and petioles that result in severe defoliation. It can be a problem when warm moist conditions accompany abundant inoculum from infected plant residues or contaminated seed (Hall, 1991). All above the ground parts are susceptible. Leaf lesions appear as gray or brown irregular spots having a chlorotic halo. After approximately 9 days, lesions turn brown and necrotic and assume an angular shape characteristic of this disease. Spores are produced on a compact erect sometimes fused spore stalk. These are found on the lower surface of the trifoliate leaves. Pod lesions are reddish brown, circular spots, usually surrounded by a darker colored border. Primary inoculum comes from seed or infested residue. Infection and disease occur at 16.1–27.8 degrees celcius with an optimum at 23.9 degrees celcius. (Hall, 1991)

Planting disease free certified seed and rotating with 2–3 years between bean crops is the best cultural practice of controlling Angular Leaf Spot. Approved fungicides should be applied when the disease first appears and conditions are favorable for disease development. Resistant cultivars should also be used. Angular Leaf Spot causes reduction of yield, net photosynthetic rate, and stomatal conductance. Plants infected with the fungus usually exhibit a reduced photosynthetic rate (Lucas, 1998). Abnormalities in form and function of chloroplasts of diseased tissues are commonly associated with a decline in photosynthetic phosphorylation, photochemical reactions and carbon dioxide assimilation (Lope and Berger 2007). These reductions are frequently associated with reductions in chlorophyll content, decrease in mesophyll conductance or increase in leaf saccharide content. The leaf area of plants is reduced due to the defoliation of leaves ((Monda *et al*, 2001)

1.1 STATEMENT OF THE PROBLEM

There are many factors that are limiting bean production in Zimbabwe. These include; Lack of appropriate skills and knowledge on agronomic practices that optimize yields; lack of well adapted cultivars with resistance to diseases and insect pests; Lack of irrigation facilities and poor water management practices and poor produce marketing channels that act as a disincentive for farmers to grow beans. Diseases pose a major problem in the production of beans for small holder farmers and even commercial farmers. Major diseases affecting bean varieties are mainly viral diseases, fungal diseases and bacterial diseases. One of the diseases affecting beans in Zimbabwe and East Africa is Angular leaf Spot caused by the fungus *Phaeoisariopsis griseola* (Allen et al, 1996). This disease has been reported in more than 70 countries, including Mexico and the United States. The disease affects foliage and bean pods and is highly destructive in areas where warm, moist conditions are accompanied by abundant inoculum from infested plant residues and contaminated seed. Leaf lesions appear as brown irregular spots that may be bordered by a chlorotic halo. The lesions become necrotic and assume the characteristic angular shape. The lesions coalesce leading to premature abscission of leaves. On primary leaves, lesions are circular. Pod lesions are oval to circular greasy brown spots, usually surrounded by a dark colored border. Levels of seed-borne infection ranging from 0.5-38% have been detected on seed lots from the Zimbabwean Highveld (Manyangarirwa *et al* 2002)

1.2 JUSTIFICATION

The project looks at how Angular leaf Spot can be controlled in the production of beans to ensure high yields through the use of bean varieties that are tolerant to the disease. Most small-seeded cultivars are resistant to ALS whereas most large seeded speckled and kidney type cultivars are susceptible. The use of healthy bean seed is important. Crop rotation can reduce the amount of viable inoculum in soils. Tolerant cultivars include Teebus, PAN 185, PAN 123, PAN 116 and Mkhuzi, MCM 5001 and Iris. Fungicides such as Chlorothalonil (Bravo 500) and Benomyl (Benlate) should be applied as foliar sprays when the disease is first noticed. Debris from previous crops must be ploughed under months prior to planting a new crop to afford residue decomposition. Crop rotation is also a method of controlling ALS but it should be done with crops that are not susceptible to the fungi. Crop rotation can reduce the amount of viable inoculum in soils. Weed control, proper fertilization and good water management are also other methods of controlling Angular leaf Spot. The use of resistant or tolerant varieties is a cheap and a long term solution in controlling Angular Leaf Spot than using chemicals as they are expensive and cannot be afforded by smallholder farmers. This study was therefore conducted with the main objective of identifying ALS tolerant bean varieties among five bean cultivars namely PAN 148, Ex-rico, bonus, Carioca and White Kidney.

1.3 OBJECTIVES AND HYPOTHESIS

1.3.1 Specific Objective

-To find an ALS tolerant variety among the commonly grown bean varieties which are White Kidney, Carioca, PAN 148, Ex- rico and Bonus.

1.3.2 Hypothesis

The selected bean varieties have different levels of tolerance to angular leaf spot.

CHAPTER TWO

LITERATURE REVIEW

2.1 Status of Bean Production in Zimbabwe

Common Bean *(Phaseolus vulgaris* L.) belongs to the plant family Fabaceae or Leguminosae and is also known as French bean, haricot bean, dry bean, navy bean, sugar bean or string bean in many regions. *Phaseolus vulgaris* is a pulse crop hence a major source of protein. Common bean is an annual legume with considerable variation in growth habit, vegetative characters, flower colour, flower size, shape and colour of pods and seed. Plant types vary from the climbing to erect/bush cultivars. In Africa, the climbing types are predominantly grown in East Africa. In Zimbabwe, common bean is mainly grown by smallholder farmers for the dried pulse that is cooked and eaten as relish. Farmers grow common bean because bean is a relatively low-cost high protein (22%) food source for communities with limited access to animal protein. Bean has a short growing cycle and is useful as a catch crop in several cropping systems and it efficiently utilizes residual soil fertility and hence is useful in soil fertility management. Moreso, bean is a source of cash income for many rural communities in Zimbabwe. Bean production in the smallholder sector is characterized by low yields averaging about 500 to 700 kg/ha under dryland conditions in Zimbabwe. In normal situations, bean varieties produce an average yield of 1tonne per hectare and 3tonnes per hectare on a high yield basis (Seed-Co, 2002). Factors limiting bean productivity include among others lack of appropriate skills and knowledge on agronomic practices that optimize yields, lack of well adapted cultivars with resistance to diseases and insect pests, lack of irrigation facilities and poor water management practices and poor produce marketing channels that act as a disincentive for farmers to grow beans.

2.2 Nutritional Value of Beans

Common bean (*Phaseolus vulgaris* L.) is the most important food legume consumed worldwide. Beans provide an important source of protein (22%), vitamins (foliate), and minerals (Ca, Cu, Fe, Mg, Mn, and Zn) for human diets, especially in developing countries. In first-world countries the nutritional benefits and contribution of beans to healthy human diets is recognized by non-profit organizations targeting human aliments like cancer, diabetes and heart disease. Annual production, including both dry and snap bean, exceeds 21 million metric tons (MT), which represents more than half of the world's total food legume production. A majority of the bean production occurs under low input agriculture on small-scale farms in developing countries. Although largely grown for subsistence, mainly by women, approximately 40 percent of production is marketed at a market value of UD$ 452 million (Allen *et al*, 1996). In recent years, the crop production trend has not kept pace with the annual growth rate (estimated above 2 percent) in population in some countries due to a number of biotic, abiotic and socio-economic constraints.

2.3 Production Constraints

Among the abiotic constraints, drought is the major and common across the Eastern and Southern Africa. Drought can be caused by inadequate total rainfall, erratic rainfall distribution, long dry spells and delayed onset and/or early cessation of rains. With global climatic change threatening to exacerbate the drought problem in some parts, rapid population growth and the increasing cost of livestock products, the food and nutritional insecurity in Sub-Saharan Africa is feared to increase. This has forced researchers from National Agricultural Research systems (NARS) together with the Centro International de Agricultura Tropical (CIAT), to step up their research effort on common bean, which is, strategic in alleviating malnutrition. The intention is to increase yields and stability of the crop in drought prone areas so as to minimize the risks of food insecurity as well as increase surplus for sale. Beans produced by these resource-poor farmers are more vulnerable to attack by disease and insect pests and to abiotic stresses including drought and low soil fertility. High input farmers have more resources to combat these stresses through the use of pesticides, fertilizers, and irrigation (Waller and Bridge, 2000)

Utilization of such inputs, however, can seriously reduce profitability and threaten the environment, and many pests are not effectively controlled with chemicals. Thus, across farming systems, biotic and abiotic stresses continue to represent the major constraints on subsistence production and economic yield of common bean. Development of cultivars with improved resistance to biotic and abiotic stresses is a primary goal of bean breeding programs throughout the world. Cultivars with improved stress resistance can reduce reliance on pesticides in high input systems, avert risk of yield loss from pests in low- and high-input systems, and enable more stable bean production across diverse and adverse environments (low precipitation, high humidity, etc.) and poor soil conditions (low fertility, hillsides, etc.), (Liebenberg and Pretorius, 1997).

Common bean is an important source of protein for many households in Kenya, but its production has not kept pace with demand. In 2007, production was about 417,000 metric tons while demand was estimated at 500,000 metric ton. The supply deficit is attributed to the severity of biophysical stresses (such as climatic variability, insect pests and diseases; declined soil fertility) that maintain productivity at less than 25% of potential yield. The National Agricultural Research Institute of Kenya in partnership with Centro Internacional de Agricultura Tropical (CIAT) has been conducting researches to produce common bean germplasm that is well adapted to the environment.

Bean is highly susceptible to frost and is grown as a rainfed crop in areas with an average annual rainfall ranging from 500 mm to 1000 mm. Planting beans in cool, wet soils results in slow germination and poor seedling emergence. These conditions can also result in seed rot and seedling diseases. The best time of production in Zimbabwe is from January to April, a period with sunshine and sufficient rainfall especially during pod filling. Beans are sensitive to cool overcast conditions early in the season and during pod filling. Adequate soil moisture during the entire growing season is essential for maximum yield and quality but the most critical period is during pod filling. In frost free areas beans can be grown under irrigation in winter. Bean production is possible in most parts of Zimbabwe provided the minimum temperature is not lower than 10^0C at seedling emergence and the maximum temperature does not exceed 30^0C at flowering. The optimum temperature range is 16^0C to 24^0C. Temperatures above 35^0C cause flower and pod drop and seeds to split. Excessive rain causes flower drop and raises the incidence of fungal diseases (Venge, 1992).

2.4 Soil Fertility Requirements

A wide range of soils which include loamy sands, sandy loams or sandy clay are suitable but most bean cultivars prefer heavy textured soils with clay content greater than 15%. The crop is sensitive to soil acidity and farmers must apply lime if soil pH is less than 5.3 ($CaCl_2$). Bean prefers a soil pH range of 5.0 to 6.6 and grows poorly on soils with a pH higher than 6.5 ($CaCl_2$). At a pH below 5.3, manganese toxicity causes stunting, chlorosis and leaf puckering. At a pH above 6.8, manganese deficiency causes stunted growth and leaf chlorosis. Bean is also sensitive to high concentrations of aluminium, boron and sodium. Farmers must avoid planting sugar beans in fields with shallow top soil, poorly drained areas or fields prone to erosion. Soils forming a surface crust prevent seedling emergence and may require a light irrigation or light harrowing to improve seedling emergence (Schwartz *et al*, 2004)

2.5 Angular Leaf Spot

Angular Leaf Spot (ALS), caused by the fungus *Phaeoisariopsis griseola*, is a serious disease of Common bean. This disease has been reported in more than 70 countries, including Mexico and the United States. In Brazil the disease was considered a minor nuisance at first but is now one of the most economically important diseases of dry beans. The pathogen can infect common, Lima, scarlet runner, tepary, black gram, adzuki beans and cowpea, and has been observed on peas. ALS affects foliage and bean pods and is highly destructive in areas where warm, moist conditions are accompanied by abundant inoculum from infested plant residues and contaminated seed. Leaf lesions appear as brown irregular spots that may be bordered by a chlorotic halo. The lesions become necrotic and assume the characteristic angular shape. The lesions coalesce leading to premature abscission of leaves. On primary leaves, lesions are circular. Pod lesions are oval to circular greasy brown spots, usually surrounded by a dark coloured border (Hall, 1991). Levels of seed-borne infection ranging from 0.5-38% have been detected on seed lots from the Zimbabwean Highveld (Manyangarirwa *et al*, 2002). For the management of ALS, The use of healthy bean seed is important. Most small-seeded cultivars are resistant to ALS whereas most large seeded speckled and kidney type cultivars are susceptible. Debris from previous crops must be ploughed under months prior to planting a new crop to afford residue decomposition. Crop rotation can reduce the amount of viable inoculum in soils. Tolerant cultivars include MCM 5001, PAN 116, PAN 118, PAN 139, PAN 148 and Iris. Fungicides such as Chlorothalonil (Bravo 500) and Benomyl (Benlate) should be applied as foliar sprays when the disease is first noticed (ACIA, 2002). Angular leaf Spot occurs in most producing bean areas worldwide but is primarily a disease of the tropics and subtropics. Reported yield losses range from 10-50% in the Northern U.S and up to 80% in tropical and subtropical countries (Barrros *et al* 1958).

2.6 Symptoms of Angular Leaf Spot Disease

All aerial plant parts, including leaves, petioles, seeds, branches, stems and pods can be infected, but symptoms are most recognizable on leaves. Lesions are most characteristic on leaves 8-12 days after infection. The leaf lesions initially appear as gray or brown irregular spots that may be bordered by a chlorotic halo. By 9 days, the lesions become necrotic and assume the angular shape characteristic of the disease. Lesions on leaves usually appear as brown spots with a tan or silvery centre that are initially confined to tissue between major veins, which gives it an angular appearance. On some varieties a yellow halo occasionally surrounds lesions and eventually the entire leaflet becomes yellow before senescing. Lesions can be observed on the underside of the leaf and appear slightly more pale than those on the upper surface of the leaflet. A close look at lesions on the underside of a leaflet with a magnifying lens will reveal tiny dark tufts (synnemata producing conidia) protruding from lesions especially in humid conditions. These dark gray to black spores and spore structures form on the lower surface of infected leaves (Hall, 1991, Liebenberg and Pretorius, 1997).

Black synemmata and conidia are produced in lesions on the lower surface of the trifoliolate leaves. Lesions may also appear as gray or brown angular spot 0.38 to 0.64 centimetres in diameter surrounded by a yellow border (Hall, 1991). Leaf drop may occur if lesions develop on leaves. The lesions on pods are roughly circular, and reddish brown with sharply defined borders, sometimes coalescing until much of the pod is affected. These dark tufts are a collection of stalks (conidiophores) that produce spores, which are wind-blown or rain-splashed to other healthy tissue. Lesions on stems and petioles appear dark brown and elongated. Lesions on pods are circular, black and sunken, and look similar to anthracnose). Yield reduction caused by ALS is due mainly to reduction in photosynthetic area; however, this fungal pathogen can also reduce quality by causing lesions on pods. (Cardona and Walker, 1956)

2.7 Biology of ALS Disease

The fungus survives on infested crop debris, and in humid conditions produces asexual spores (conidia) which are dispersed by wind or water Studies indicate *P. griseola* can survive Ontario winters in infested bean residue left on the soil surface; however, the pathogen does not survive very long when infested bean debris is buried in soil and decomposes. The pathogen can also survive between seasons on infested seed, which is one pathway of introduction into fields. Spores from lesions on stems, leaves and pods, as well as on crop debris, only develop after continuous high humidity or wet conditions for 24-48 hours. Spores produced on infested debris or seed are rain-splashed and/or wind-blown onto healthy tissue after planting. When spores land on susceptible bean tissue, they germinate and infect through natural pores (stomata), that is in the presence of moisture. The fungus then produces specialized thick-walled bodies (it is these which are later capable of surviving adverse conditions). Disease develops rapidly during periods of warm temperatures (24ºC) but can occur over a range of moderate to warm temperatures (16ºC-28ºC) when accompanied by wet weather or high humidity alternating with dry, windy conditions (Barros *et al*, 1958).

In Ontario, ALS tends to develop and spread quickly during late summer on late seeded snap bean crops when day temperatures are warm and night temperatures become cool resulting in dew formation on plants. However, significant disease development and yield loss can also occur on earlier seeded crops if moderate temperatures coincide with prolonged periods of wet weather. Leaf lesions, which are grey to brown, are typically angular in shape because their expansion is limited by the veins. In contrast, a particularly virulent form of this fungus (occurring in Tanzania) was found to produce circular lesions on leaves; furthermore the spore-bearing structures developed on both surfaces of the leaf, rather than only on the underside as in the common form. (Snowdon 1991). Spore development is favoured by periods of high humidity, whereas spore dispersal is at its most efficient in a dry atmosphere (Cardona and Walker 1956). Since in turn, infection is favoured by cool, moist conditions, and disease development is most rapid during warm spells, epidemics occur only after alternating periods of different types of weather perhaps aggravated by injudicious use of irrigation. Severe attacks result in defoliation. Even in mild outbreaks, lesions may form on stems and leaf stalks, and also on pods, which become unmarketable. In addition to substantial losses I yield, seed may be shriveled and of generally poor quality. Furthermore, seeds directly beneath pod lesions may become infected. Although angular leaf spot is essentially a field disease, blemished pods may be encountered in the market. Angular Leaf Spot is caused by *Phaeoisariopsis griseola*. Ferraris, an imperfect fungus belonging to the Monilioles, family Stilbaceae. Conidiophores are produced in groups (synnemata) of eight to forty and bear conidia that are gray, slightly curved and 3-8 by 43-68 micro metres, with one to six septa. Sporulation occurs at 16-26ºC. The pathogen exhibits pathogenic variability, and 14 pathotypes have been identified worldwide. It infects numerous crops, including common bean, lima bean, scarlet runner bean, tepary bean, black gram, pea and cowpea. The fungus overwinters mostly in infected bean debris but sometimes in seed. Most spread is by wind-blown spores (Bergamin *et al*, 1997)

2.8 Factors Favouring Disease Spread

Humid conditions favour disease development. The pathogen survives in infected seed or infected plant debris. Infections may start the following season as volunteer from infected seeds. Spores are then spread by wind and/ or rain. Disease development occurs at 15.6-27.8ºC, with an optimum temperature of 23.9ºC. Symptoms appear on lower leaves after flowering and as plants approach maturity. Fluctuating daily temperatures and moisture extremes favour spore production and movement. Several field and snap beans are resistant.

Sources of primary inoculum include contaminated seed and infested plant residue. In both cases, spores produced in seed or other host tissue are disseminated to leaves by wind, rain, splash or both. The conidia germinate on the leaf surface, and hyphae penetrate through stomata and grow between cells in the leaf parenchyma. By nine days, the pathogen extensively colonizes necrotic lesions. After nine to twelve days, stomata develop in substomatal cavities, and sporulation occurs during periods of high humidity. These spores cause secondary spread of the disease. Infection and disease occur at 16-28ºC and develop maximally at 24ºC. Symptoms in the field are generally observed soon after flowering or as plants approach maturity. Most crop losses result from premature defoliation. Seed contamination may be external or internal. External contamination in red kidney beans is associated with fungal development in the hilum area only, whereas in other beans the fungal development can be in the hilum and other areas of the seed coat. Levels of seed infection differ among bean cultivars. The viability of P. griseola in seed decreases over time (Schwartz *et al*, 2004).

2.9 Management of Angular Leaf Spot

Although it appears not to be very prevalent, seed transmission can be responsible for introducing the disease to new areas. Seed treatment may therefore be advisable. Pathogen free seed that has been treated with an effective fungicide should be planted. Certified seed of varieties resistant to prevalent races of Angular leaf Spot should be planted. Cultural practices are of much greater significance in reducing the extent of disease. Infested crop debris should be destroyed or thoroughly ploughed into the soil after harvest, and beans should be rotated with non host crops for at least two years as this significantly reduces survival of fungal pathogen. Volunteer beans should be eliminated the following season. Crop rotation should be practised where possible with a break of two years between bean crops to permit decomposition of infested residue (Barros *et al*, 1958)

Good drainage is advantageous. Chemical treatment should also be used. Fungicides that prevent or reduce Angular Leaf Spot infection are effective if applied early in the epidemic and coverage is thorough. Fungicide sprays may be used during the growing season especially the early bloom (10-30%) flowering when environmental conditions are conducive for disease. Fungicides should be applied as foliar sprays when the disease is first detected and if environmental conditions are favourable for disease spread. Consider applying a second fungicide application seven days later at late bloom (50%-70% flowering) if environmental conditions favouring infection and disease development occur between early bloom and late bloom, or are predicted after late bloom. Different bean cultivars vary considerably in their susceptibility to angular leaf spot. Resistant cultivars are available, and breeding work continues, for example, crosses are made with scarlet runner bean which is highly resistant. The least susceptible varieties should be grown particularly in fields with a history of ALS, to reduce disease impact on the quantity and quality of yield (Bassanezi *et al*, 2000).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The research on ALS tolerance on bean varieties was conducted on the Africa University Farm. The Africa University research block is located at the university farm along Nyanga Road in Old Mutare which is in Natural Region II. Africa University Farm has about 60 Ha of arable land. The average annual temperature is 19ºC. The coldest month is July with minimum temperatures of 8.5ºC and maximum being 20.5ºC. The latitude for Mutare is 18.97 South and the longitude is 32.670 East. The annual rainfall is 818mm. Rain falls mostly in the months December to February although heavy showers are possible before and after this period. The soils at the Africa University Farm research block are Sandy Clay loam (SCL) in terms of the texture that is well drained and suited for bean production. The soil has an average pH of 5.1 (Africa University Agricultural Advisory Services, 2012).

3.2 Experimental Design

Varieties tested were Carioca, White kidney, Ex-rico, Bonus and PAN 148. PAN varieties are known in literature to be tolerant to ALS hence; PAN 148 was used as the control. The five varieties used are in different bean classes. PAN 148 is under the red speckled beans which are the most preferred in Zimbabwe because of the large grown size, good taste and good resistance to shattering. Bonus is a new introduction in the red speckled types. White kidney forms a small proportion of bean types grown in Zimbabwe and they are sensitive to high temperatures during flowering. Due to their disease resistance and adaptability, they are recommended for the cool, high rainfall areas where high yields can be obtained. Ex-Rico falls under small white navy beans. These are small, white seeded cultivars and yield well under good growing conditions. Large scale farmers and smallholder farmers, particularly in irrigation schemes, grow navy beans on contract with canning companies. Carioca has a high yield potential and tolerant to low soil phosphorus but has good resistance to Bean Common mosaic Potyvirus.

3.3 EXPERIMENTAL UNITS AND MANAGEMENT

In the experiment, there were three replications and five treatments (bean varieties). A Randomized Complete Block Design was used as shown in plate 3.1. The land was ploughed first a week before planting then a pre emergence-herbicide; gramoxone was applied two days before planting for weed suppression. The objective of land preparation was to form a deep, friable seedbed and to bury previous crop residues and weed seeds. After land preparation, the plots were marked. For field beans, the plots were 2m (width) x 3m (length) with 4 rows per plot. The inter-row spacing was 45cm and in-row spacing depended on the bean varieties with PAN 148, Bonus, White Kidney and Carioca having an in-row spacing of 10cm and Ex-Rico had an in-row spacing of 7.5cm. Holes were established using hoes. After making holes, a size 30 cup was used to place Compound D fertilizer in the holes at a rate of 350kg/Ha. Two seeds of beans were placed in each hole. The beans were planted and irrigated on the same day for about six hours using sprinkler irrigation. Planting was done on 28 January 2012 and on 18 February there was gap-filling in all the plots. Weeding was done fortnightly to reduce competition of weeds and the bean crop.

Plate 3.1 Trial set up with the bean plots

3.4 DATA COLLECTION AND ANALYSIS

Data collection started on the 5th of April 2012 when the disease started showing and it was sixty eight days (9 weeks) after planting and it was done on weekly basis for four continuous weeks. The five common bean varieties were evaluated for disease incidence and disease severity. Disease incidence is the relative proportion of the number of diseased plants in relation to the total units examined and it is expressed as a percentage and transformed before statistical analyses. Disease severity is the proportion of area of amount of plant tissue that is diseased relative to healthy tissue. Disease severity was scored on a scale from 1-9 with 1=no disease and 9=severe. The scale is internationally acceptable and published. For disease severity, the Area Under Disease Progress Curve (cm^2) was calculated and subjected to ANOVA using the statistical package Minitab Version 15. The bean cultivars have known different yield potentials and the design of the trial did not cater for the evaluation of the effect of disease on yields and hence no data on yields was collected for analysis of variance.

CHAPTER FOUR

4.0 RESULTS

4.1 Confirmation of *Phaeoisariopsis griseola*

Phaeoisariopsis griseola was positively confirmed through the characteristic angular leaf lesions as shown in plate 4.1, and also the greasy soaked pod lesions as shown in plate 4.2. Samples of diseased leaves were viewed under a stereo microscope to see the synnemata sporulating underneath the leaves. Slides were prepared to view the spores under a compound microscope to confirm the pathogen.

Plate 4.1 Characteristic angular lesions on the cultivar White kidney caused by the fungus *Phaeoisariopsis griseola*

Plate 4.2 Characteristic greasy soaked lesions on pods of the cultivar Carioca caused by *Phaeoisariopsis griseola*

4.2 Disease Incidence

Disease Incidence was recorded from 5 to 26 April 2012 as it is when the disease started showing. A week before readings were taken, the disease incidence was still at zero. As shown in the graph below, Carioca was the most susceptible variety to angular leaf spot as it started with a disease incidence of 81.37% at week 1 and reached 100% at week 4. Ex-Rico is the most tolerant variety to angular leaf spot as it started with a disease incidence of 31.82% and reached 37.80% which is less than 50% at week 4.

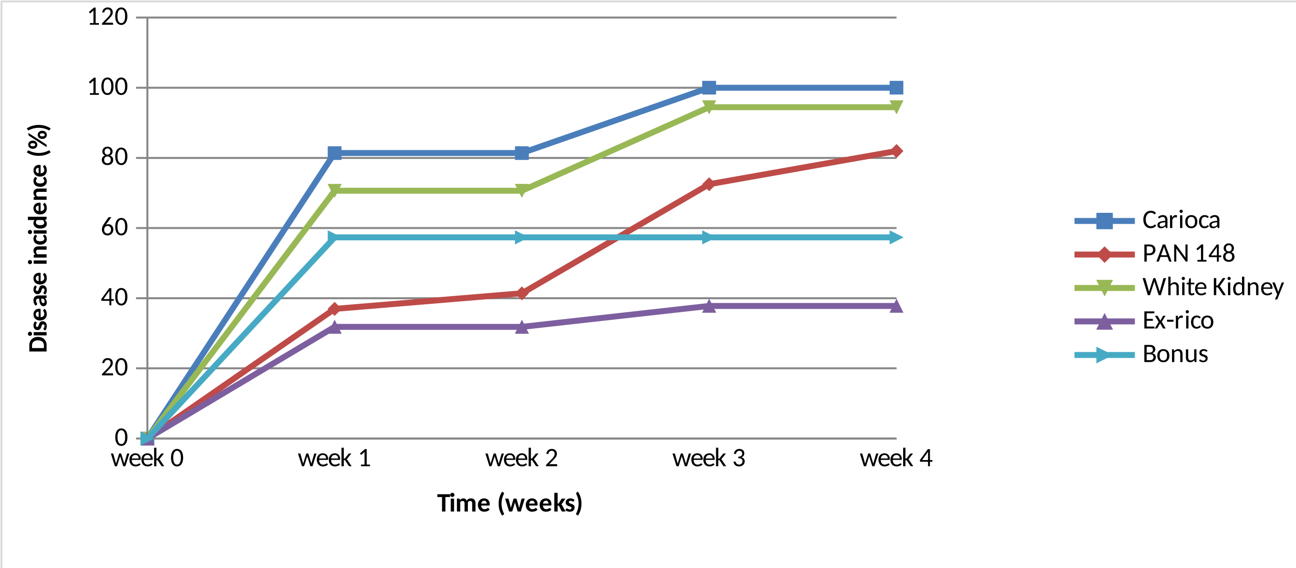

Figure 4.1 Pattern of disease incidence on the five bean cultivars evaluated over four consecutive weeks from 9 weeks after crop emergence.

4.3 Disease Severity

All the means followed by the same letter in the columns are not significantly different at P<0.05 using Fisher's conversion. This is shown in table 4.1.

Table 4.1 Disease severity as evaluated using the area under disease progress curves (AUDPC cm^2) for the five bean cultivars

Cultivar	AUDPC± standard error
Bonus	32.440 ± 4.393 a
White Kidney	55.227 ± 1.445 b c
Carioca	65.000 ± 1.427 c
Ex-rico	30.480± 5.311 a
PAN 148	46.520± 8.440 b

CHAPTER FIVE

5.0 Discussion

The results of the trial show that Ex-rico is the most tolerant common bean variety to angular leaf spot whilst Carioca is the most susceptible variety. Disease incidence and disease severity vary significantly among the five common bean varieties In Fig 4.1 on disease incidence, the figures started from zero because data was collected sixty eight days after planting (DAP) as the symptoms of angular leaf spot were not yet showing. Disease incidence is dynamic and changes with time that is why for the four common bean varieties it started with a low percentage and got high as the weeks went by except for Bonus where the disease incidence was constant throughout. Carioca was again the variety with the highest area under the disease progress curve (cm^2) showing that it is more susceptible to angular leaf spot (Table 4.1). White kidney comes after carioca then PAN 148, Bonus and finally Ex-rico being the variety with the smallest area under the disease progress curve and is the most tolerant variety to angular leaf spot (Table 4.1). In Table 4.1, all means followed by the same letter in the column are not significantly different at $P< 0.05$ using the Fisher's conversion. In this case, Ex-rico and Bonus are almost the same in terms of their tolerance to angular leaf spot but are however significantly different to PAN 148. White kidney is not significantly different from PAN 148 and Carioca whereas PAN 148 is significantly different from Carioca.

Cultivar choice depends on its suitability to soil and climatic conditions. For common bean varieties to be tolerant to angular leaf spot, the beans should be grown in conducive conditions suitable for bean production. Farmers should grow common beans during the best time of production from January to April in Zimbabwe, a period with sunshine and sufficient rainfall especially during pod filling as this will help in attaining high yields through controlling diseases. Minimum temperatures should not be lower than 10ºC and rainfall should range from 500mm to 1000mm. The soils should not be wet and cool as this results in slow germination, poor seedling germination, seed rot and seedling diseases. A wide range of soils which include loamy sands, sandy loams or sandy clay are suitable but most bean cultivars prefer heavy textured soils with clay content greater than 15% (Seed-co, 2002).

Agronomic attributes of selected bean varieties in Zimbabwe (Liebenberg *et al*, 2007) reveal that Ex-Rico has a good disease tolerance especially tolerance to angular leaf spot. Ex-Rico yields well under good growing conditions. Large scale farmers and smallholder farmers particularly in irrigation schemes, grow navy type beans like Ex-Rico on contract with canning companies (Manyangarirwa et al, 2002). PAN 148 is under the red speckled beans which are the sugar types and sugar types are generally susceptible to ALS and rust. Examples of susceptible varieties are PAN 148 and PAN 159. PAN 148 requires chemical control against angular leaf spot. PANNER varieties like PAN 116, PAN 118 and PAN 139 are the most tolerant common bean varieties to angular leaf spot compared to PAN 148 which is highly susceptible to angular leaf spot as brought out in the trial.

Bonus is a red speckled common bean variety which is susceptible to angular leaf spot and requires chemical control (Liebenberg *et al*, 2007). This is in contrast to the results which came out in the trial where bonus is actually the second tolerant variety after ex-rico. This might be due to the fact that the soil at Africa University Farm is well drained and suited for bean production. The soil pH for beans ranges from 5.0-6.6 and the pH for the soil at AU Farm is about 5.1 which is suitable for bean production. Carioca varieties are generally tolerant to low soil phosphorous and have a high yield potential. Mkhuzi carioca has a high yield potential and is widely adapted, with resistance to several diseases and is recommended for the high rainfall regions like Mazowe, Banket, Harare, Marondera, Chipinge and Chinhoyi where it does well. Conversely, in the trial, Carioca turned out to be the most susceptible variety to angular leaf spot. It could be due to the shortage of enough water as the annual rainfall for Mutare is about 818mm only.

White kidney forms a small proportion of bean types grown in Zimbabwe (Seed-co, 2002). White kidney beans are sensitive to high temperatures during flowering and this might be one of the reasons why White kidney was the second most susceptible variety after Carioca. Rainfall was not consistent because in January the total amount of rainfall was 93mm and it went down to 38mm in February. In March, total rainfall was 82mm which went down to 24mm in April. Due to their disease resistance and adaptability, White kidney beans are recommended for the cool, high rainfall areas where even high yields can be obtained.

The fungus causing ALS survives in humid conditions and produces asexual spores (conidia) which can be dispersed by wind or water (Hall, 1991). Beans are sensitive to cool overcast conditions early in the season and during pod filling (Barros *et al*, 1958) and as a result, this might have caused fungal development in the bean varieties as rainfall was a bit high in January and March having 93mm and 82mm respectively. In short, excessive rain raises the incidence of fungal diseases especially angular leaf spot (Schwartz *et al*, 2004). For Mutare, 93mm per month is a bit high as the annual rainfall is 818mm which is about 68mm per month.

Farmers should always try to minimize the incidence of ALS. Several control measures can be taken to ensure that bean is protected from *Phaeoisariopsis griseola.* The trial demonstrated that tolerant common bean cultivars such as Ex-rico and Bonus have low disease incidence and severity. The advantage of host plant resistance is that once the technology has been developed, it is packaged in seed which is easier to disseminate and deploy, and does not require any additional or specialized handling on the part of the farmers (Mahuku *et al*., 2009). The greatest setback to development and deployment of resistant bean varieties is the high pathogenic variability occurring in *P. griseola* that renders varieties that are resistant in one location or year susceptible in another (Mahuku, *et al*., 2002a). Crop rotation is important in common bean production because bean is sensitive to the effects of preceding crops. Common bean should not be planted in the same field more than once in a year nor should the crop be followed by soyabean, tobacco or cotton in a rotation (Seed-co, 2002). Farmers are encouraged to grow cereals such as maize, sorghum, wheat, and small grains immediately after sugar beans. Crop rotation does not only help in controlling angular leaf spot through reducing the amount of viable inoculum in the soil but the other benefits it brings are that it improves fertilizer utilization efficiency, reduces pod yield loss and improves weed control efficiency. If susceptible cultivars are used, effective fungicides such as Chlorothalonil (Bravo 500) and Benomyl (Benlate) should be applied as foliar sprays when the disease is first noticed (ACIA, 2002). Smallholder farmers should try to implement Integrated Disease Management through the combined use of tolerant varieties, disease free seeds, varietal mixtures, fungicides, crop rotation and proper field sanitation (Barros *et al*, 1958).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study demonstrated that tolerant common bean cultivars to ALS have low disease incidence and severity hence they may yield more than susceptible cultivars. Farmers should also grow common beans during the best time of production from January to April in Zimbabwe, a period with sunshine and sufficient rainfall especially during pod filling as this will help in attaining high yields through controlling diseases. For common bean varieties to be tolerant to angular leaf spot, the beans should be grown in conducive conditions suitable for bean production. The best way farmers can manage angular leaf spot is to use resistant and tolerant varieties because the advantage of host plant resistance is that once the technology has been developed, it is packaged in seed which is easier to disseminate and deploy, and does not require any additional or specialized handling on the part of the farmers (Mahuku *et al*, 2009). However, the greatest setback to development and deployment of resistant bean varieties is the high pathogenic variability occurring in P.*griseola* that renders varieties that are resistant in one location or year susceptible in another (Mahuku *et al*, 2002a)

6.2 Recommendations

- It is recommended that a viable and cost effective Integrated Disease Management be developed especially for smallholder farmers. Components of IDM should include use of tolerant and resistant varieties, disease free seeds, varietal mixtures, fungicides, crop rotation and proper field sanitation.

- The use of healthy bean seed is important. The use of resistant and tolerant varieties like Ex-Rico and Bonus is pivotal to any effective, economical and environmentally friendly strategy of managing ALS especially for small-scale farmers.

- In cases where susceptible cultivars are used, effective fungicides such as Chlorothalonil (Bravo 500) and Benomyl (Benlate) should be applied as foliar sprays when the disease is first noticed.

-Farmers should grow bean cultivars that are best suited for the prevailing climate and soil conditions.

CHAPTER SEVEN

7.0 REFERENCES

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APPENDICES

Appendix 1: Weekly disease incidence on the five common bean varieties.

Weeks	Carioca	PAN 148	White Kidney	Ex-Rico	Bonus
1	81.37%	36.94%	70.61%	31.82%	57.33%
2	81.37%	41.38%	70.61%	31.82%	57.33%
3	100%	72.48%	94.44%	37.80%	57.33%
4	100%	81.94%	94.44%	37.80%	57.33%

Appendix 2: Weekly records of disease severity on the five common bean varieties.

Time	Carioca			PAN 148			W. Kidney			Ex-Rico			Bonus		
weeks	rep 1	rep 2	rep 3	rep 1	rep 2	rep 3	rep 1	rep 2	rep 3	rep 1	rep 2	rep 3	rep 1	rep 2	rep 3
week 1	3.4	5.4	4.2	1.8	2.6	3.4	2.6	3.4	4.2	2.2	2.6	1.8	2.6	3	2.2
week 2	3.8	5.8	5.4	2.2	3.8	3.4	3.4	3.8	4.2	2.2	3	2.2	2.6	3	2.6
week 3	6.6	7	5.8	4.2	5	3.8	5.8	5.8	5	2.2	3	2.6	2.6	3	2.6
week 4	7.8	7.8	6.6	5	7.4	5	5.8	5.8	5.4	2.6	3.8	2.6	2.6	3.8	3

Appendix 3: ANOVA output on the disease severity of the five common bean varieties

```
Source     DF        SS        MS        F        P
C1          4    2613.4     653.3    26.59    0.000
Error      10     245.7      24.6
Total      14    2859.1
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev ----+---------+---------+---------+--
1           3    30.480     5.311  (---*----)
2           3    55.227     1.445                  (---*---)
3           3    65.000     1.427                        (---*----)
4           3    32.440     4.393   (----*---)
5           3    46.520     8.440            (---*---)
                                   ----+---------+---------+---------+--
Pooled StDev =    4.957               30        45        60        75
Fisher's pairwise comparisons
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Appendix 4: Key used for scoring disease severity.

Angular leaf spot severity is based on the percentage of leaf area or the area of pod infected using a standardized CIAT scale of 1 to 9. The description and the diagram of this scale can be found in CIAT book. In the field, disease severity can be evaluated at the flowering stage (R6) and at pod filling stage (R9). In the greenhouse, the lesions may not sporulate as in the field. Therefore, the percentage of leaf area covered by the lesions is considered. The scale used is as follows:

1= No visible symptoms of the disease.

2= Less than 2% of leaf area affected by the lesions.

5= 5% of leaf area affected by the lesions.

7= 10% of leaf area affected by the lesions.

9= More than 25% of leaf area affected by the lesions.

Appendix 5

Rainfall pattern during period of study.