GROWTH AND YIELD RESPONSE OF SELECTED COWPEA GENOTYPES TO *Alectra vogelii* (Benth) INFESTATION IN DODOMA, TANZANIA

BY

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ABSTRACT

The effects of *Alectra vogelii* was assessed by introducing cowpea genotypes that are resistant and/or tolerant under field conditions of Chamwino District in Dodoma. Specifically, the research aimed at assessing the effects of *A. vogelii* on shoot and root growth characteristics of cowpea and determining its effects on cowpea yield. Randomized complete block design (RCBD) with three replications was used. The experiment was set up at ARI-Hombolo and cowpea shoot biomass, root biomass, plant height and yield component data obtained were subjected to analysis of variance (ANOVA) using MSTAT-C computer statistical package. Tukey's honestly significant different test was used to compare treatment means. At 9 Week After Sowing Tumaini variety, genotypes IT 99K 205-8 and IT 99K 628 had significantly ($P<0.05$) low shoots biomass in gram/plant 15.6 g, 12.4 g and 14.2 g, respectively compared to IT 99K 494-6, IT 99K 7-21-2-2 and IT 97K 568-18 which had 18.9 g, 18.4 g and 17.1 g, respectively. Cowpea plant height of the local landrace (34.1 cm), IT 99K 628 (33.3 cm) and IT 99K 530-1 (38.5 cm) differed significantly ($P<0.05$) with the resistant genotypes IT 99K 494-6 (47.6 cm), IT 99k 7-21-2-2 (54.1 cm) and IT 97K 568-18 (63.2 cm) at 9 WAS. The local landrace (664.3 kg/ha), IT 99K 628 (944.0 kg/ha) and IT 99K 573-1-1 (1128.0 kg/ha) had significantly ($P<0.05$) low yield compared to the resistant genotypes IT 99K 494-6 (2141.0 kg/ha), IT 99K 7-21-2-2 (1536.0 kg/ha) and IT 97K 568-18 (2302.0 kg/ha). The seed weight per plant of the local landrace (10.0 g) and IT 99K 628 (16.1 g) differed significantly ($P<0.05$) from IT 99K 7-21-2-2 (23.4 g) and IT 97K 568-18 (23.2 g). Finally the findings revealed that, genotypes IT 99K 494-6, IT 99k 7-21-2-2 and IT 97K 568-18 are resistant and all others are susceptible to *A.vogelii* strain of Dodoma.

DECLARATION

I, Marcel Thomas Mtei, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my original work and that it has neither been submitted nor being concurrently submitted for degree award in any other Institution.

25.10.2011

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Prof. Sibuga K. P. **Date**

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LIST OF ABBREVIATIONS AND SYMBOLS

%	=	Percent
AHAS	=	Acetohydroxy Acid Synthase
ALS	=	Acetolactate Synthase
ANOVA	=	Analysis of Variance
ARI	=	Agriculture Research Institute
CEC	=	Cation exchange capacity
CV	=	Coefficient of variation
DALDO	=	District agriculture and livestock development officer
DED	=	District Executive Director
EPSPS	=	Enolpyruvylshikimate-3-Phosphate Synthase
et al	=	and others
FARTH	=	*Fusarium arthrosporiodies*
FAO	=	Food and Agriculture Organization
Fig.	=	Figure
FOXY	=	*Fusarium oxysporium*
g	=	gram
ha	=	hectare
i.e.	=	that is
IITA	=	International Institute of Tropical Agriculture
Kg	=	Kilogram
LAI	=	Leaf Area Index
Max	=	Maximum
Min	=	Minimum

mm	=	millimeter
°C	=	degree celsius
p.m.	=	Past meridiem
P≤ 0.05	=	Significant at less or equal to 5% level
pH	=	Hydrogen ion concentration
RCBD	=	Randomized complete block design
RH	=	Relative humudity
Se±	=	Standard error
TSC	=	Total Soluble Carbohydrate
THSDT	=	Tukey's honestly significant difference test
WAS	=	Weeks after sowing

CHAPTER ONE

1.0 INTRODUCTION

Cowpea (*Vigna unguiculata* [L.] Walp.) is a crop of major importance to nutrition of poor rural households in drier and sub-humid regions of Eastern and Southern Africa, where diets tend to comprise mainly on starchy foods such as millet, sorghum, maize and cassava (Myaka and Kabissa, 1993). Being a drought tolerant and warm weather crop, cowpea is well adapted to the drier regions of the tropics where other food legumes do not perform well. In Tanzania, cowpea is grown on the highlands (above 1500 m), lowlands (below 900 m) and coastal areas. The crop has also the unique ability to fix atmospheric nitrogen through its nodules and it grows well even in the soils with more than 85% sand and with less than 0.2% organic matter and low levels of phosphorus (Myaka and Kabissa, 1993).

According to Parker and Riches (1993), cowpea is a major host of *Alectra vogelii* (Benth), a parasite which is always associated with the cultivation of leguminous crops. It is a common parasite in semi-arid savannah areas of sub-Saharan Africa. Singh and Emechebe (1991) reported that, *A. vogelii* cause substantial damage to cowpea; and it is difficult to control by conventional methods. Apart from cowpea, other common hosts of *A. vogelii* include Bambara groundnuts (*Vigna subterranean* (L.) Verdc.), common bean (*Phaseolus vulgaris* L.), soybean (*Glycine max* (L.) Merr.), mung bean (*Vigna radiate* (L.) Wilczek), and tepary bean (*Phaseolus acutifolius* A. Gray) (Elzein and Kroschel, 2003). There have been occasional reports of infestation of chickpea (*Cicer arietinum* L.) and runner bean (*Phaseolus occineus* L.) by *A. vogelii* (Mbwaga *et al.*, 2007).

Alectra vogelii is widespread in Tanzania particularly in Mwanza, Shinyanga, Dodoma, Iringa and Ruvuma regions (Mbwaga *et al.*, 2007). According to Chamwino district (2007), the average cowpea yield is 0.3 t/ha which is extremely low compared to the world average which is estimated at 4.2 t/ha (Singh *et al.*, 1982, as cited in Mbwaga *et al.*, 2007). The use of late maturing cultivars, low plant density and insect damage are widely recognized as important constraints to improved cowpea production under on-farm conditions (Chamwino district, 2007). Less well appreciated is the growing importance of *A. vogelii*, which attaches itself to the roots of cowpea plants and interferes with the plants' ability to obtain water and nutrients (Singh and Emechebe, 1991). The released improved cowpea cultivars in Tanzania (Vuli-1, Vuli-2, Tumaini and Fahari) are especially susceptible to *A. vogelii*. Infestation with *A. vogelii* might lead up to 50% yield reductions (Mbwaga *et al.*, 2007). Field infestation by *A. vogelii*, its dormancy mechanism and mode of parasitism, render control measures such as crop rotation, constant weeding, pre- and post-emergence herbicides and suicidal germination by trap crops stimulants, either ineffective or too expensive for a small scale farmer (Singh *et al.*, 1993).

There have been efforts to identify natural sources of genetic resistance within cowpea cultivars through selection and breeding of improved lines, which is more effective and economic means of control (Lane *et al.*, 1991). A number of cowpea lines from the Nigerian-based International Institute of Tropical Agriculture (IITA) breeding program and other sources have been developed combining diverse plant type, different maturity periods, and resistance to several diseases, insect pests, and *A. vogelii* weeds, and possessing other good agronomic traits in several African

countries (Singh and Amechebe, 1992). Based on the data of the screen house experiments (Makoko, 2007); 13 IITA cowpea genotypes were identified as resistant to *A. vogelii* strains from Dodoma, Tanzania. Furthermore Makoko's study concluded that, variation in *Alectra* emergence and grain yields in the screen house experiment among cultivars that showed resistance should be supplemented with field observation.

The general purpose of this study was to quantify the effects of *A. vogelii* on the different phases of cowpea life cycle and the consequent influence on the production of grains by introducing cowpea genotypes under field conditions of Chamwino District in Dodoma.

The specific objectives were:

i. To assess the effects of *Alectra vogelii* on shoot and root growth characteristics of cowpeas under natural field infestation.

ii. To determine the effects of *Alectra vogelii* on cowpea yield under field conditions of Chamwino district.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Socio-geographical Description of Cowpea Production

Cowpea is the most important food legume grown in the tropical Savanna zones of Africa. Although indigenous to south eastern Africa, cowpea has spread worldwide and is extensively cultivated and consumed in many parts of Asia, South and Central America, the Caribbean, the United States, the Middle East and southern Europe. Cowpea is an ideal crop for the semiarid regions of the tropics, where other food legumes may not perform well and is a preferred staple food in many regions of Africa (Cisse and Hall, 2005). The total worldwide production of cowpea is estimated at 3.3 million tons of dry grain of which 64% is produced in Africa (FAO, 2001 as cited in Cisse and Hall, 2005).

The released improved cowpea cultivars in Tanzania (Vuli-1, Vuli-2, Tumaini and Fahari) are especially susceptible to *A. vogelii*. Infestation with *A. vogelii* might lead up to 50% yield reductions (Mbwaga *et al.*, 2007). The average cowpea yield in Chamwino district is 0.3t/ha (Chamwino district, 2007) which is extremely low compared to the world average which is estimated at 4.2t/ha (Mbwaga *et al.*, 2007). Over the last two decades, the International Institute of Tropical Agriculture (IITA) has made significant advances in improving the productivity of cowpea in sub-Saharan Africa. A number of varieties have been developed combining diverse plant type, different maturity periods, and resistance to several diseases, insect pests, and parasitic weeds, and possessing other good agronomic traits (Singh *et al.*, 1993). The low yield reported from Chamwino district is a driving force that led into a need to

test IITA materials in Tanzania particularly Chamwino district council as the materials has made significant advances in improving the productivity of cowpea in Sub-Saharan Africa (Singh *et al.*, 1993).

2.2 *Alectra Vogelii*

According to CAB International, (2005) *Alectra vogelii* plant grows up to between 30-45 cm tall, often as a single stem (1.5 cm long and 0.3 cm wide) but sometimes branching from near soil level. As with other *Alectra* species the stem is bright orange below the ground.

2.2.1 Leaves and flowers

The leaves are 3.5 cm long and 1.3 cm wide and are conspicuously hairy (Parker and Riches, 1993). The leaf shape varies considerably. In parts of West Africa, leaf margins are almost entire, in central and southern Africa they may have two to five widely spaced teeth along each edge while in Kenya the plants with five or six sharp teeth, each up to 3 mm long, have been collected. Flowers appear singly on a short stem in the axils of upper leaves or bracts. Up to 10 flowers may open one day on individual plants depending on the extent of branch development and age. The buds are enclosed in a densely hairy calyx whose five lobs each have a triangular tip with an obtuse apex. The corolla, which is formed of five petals and fused into a tube for the bottom half, is bell shaped when open and it measures 0.6 to 1 cm in diameter, which is somewhat longer than calyx. Petals are generally pale yellow and may or may not have three deep red veins. Both flower forms can be found in the same stand of *A. vogelii*. After flowering the corolla withers and remains covering the

developing globuse seed capsule which eventually swells to approximately 5 mm in diameter (Parker and Riches, 1993).

2.2.2 The seeds

The seeds of *A vogelii* are tiny and produced through capsule (Singh and Emechebe, 1997). Each capsule produces 2000 to 3000 seeds; and as many as 200 to 350 capsules, which produce between four and six hundred thousands seeds by a single plant (Parker and Riches, 1993). The seeds are light and therefore can be transferred over a long distance by wind, water and animals (Makoko, 2007).

2.2.3 Germination condition

Parker and Riches (1993) reported that, seeds of *A vogelii* may remain viable in the soil for up to 12 years. The seeds germinate when exposed to synthetic germination stimulants present normally in the root exudates of many host or non-host plants (Riches, 1989). According to Parker and Riches (1993) there is no an after-ripening requirement for *A vogelii* seeds to germinate. The seed is taken from mature dry capsules and germinates immediately following exposure to suitable germination stimulant at a suitable temperature. Some natural substances which stimulate *A vogelii* seed germination have been identified including alectrol, which was isolated from cowpea root exudates (CAB International, 2005; Müller *et al.*, 1992). The compound was termed alectrol because of its high germination rate of seeds of *Alectra vogelii.*

2.2.4 Penetration and development of *Alectra vogelii*

Alectra vogelii seed requires a very short period of conditioning and thus germinates within five days of adding a suitable stimulant to even dry unconditioned seed incubated at 28 ^{0}C or 30 ^{0}C (Riches 1989; Visser and Johnson. 1982). The growth occurs largely at the root meristem during the germination of the seeds resulting into seedling with elongated radicles, which grow to a maximum of 3 mm and penetrate the host root within 8 to 10 days to survive (Okonkwo and Ravaghan. 1982). The radicle's apex develops numerous hairs. which attach to host roots. The new host cells together with growing *Alectra* tissue (haustorium) draws water. mineral nutrients and carbohydrates from the host (Elzein and Kroschel. 2003). *A. vogelii* emerges above the ground four weeks after its radicle has penetrated cowpea root and the first flower is produced two weeks later.

2.3 Effect of *Alectra vogelii* on Cowpea Production

Cowpea varieties with complete resistance to *Alectra* stimulate germination and permit attachment of radicles to their roots but the haustorium development is inhibited (Singh and Amachebe, 1997). The initial attachment of germinating *Alectra* to resistant cowpea roots causes a shock to the hosts and reduces the growth of the host plant even though further development of the weed is checked. In a set of 23 resistant cowpea varieties planted in pots infested with *Alectra vogelii* seeds as well as in pots without *Alectra* seeds; the resistant varieties did not show any *Alectra* emergence, while in nine susceptible cowpea varieties planted in infested and non-infested pots following same procedure showed severe infestation (Singh and Amachebe, 1991).

2.4 Managing *Alectra vogelii* in Cowpea Production

There are several control methods for parasitic weeds (Parker and Riches 1993; Kroschel, 2001; Joel *et al.*, 2006). A range of parasitic weed management practices have been developed and these can be broadly classified under the general themes of chemical, cultural, physical, biological and host-plant resistance.

2.4.1 Cultural and physical control methods

2.4.1.1 Crop rotation, trap and catch crops

Rotating susceptible crops with crops that are non-hosts to *Alectra* particularly false hosts has been adapted to reduce *Alectra* soil seed levels (Radi, 2007). A wide range of rotations can be effective in reducing *Alectra* numbers and increasing yields in a subsequent cereal crop (Odhiambo and Ransom, 1994; Sauerborn *et al.*, 2000; Oswald and Ransom, 2001). According to Riches (1989) "trap crops" are crops whose roots stimulate parasite germination but do not allow root attachment and parasite development. Examples of trap crops for *A. vogelii* are sunflower, bambara groundnut and millet.

Lagoke *et al.*, (1991) defined Catch-crops as susceptible species which are ploughed in or harvested after parasite attachment but before emergence and seed production of the parasitic plant. A catch-crop of a cultivar of cowpea suitable for use as fodder has been recommended in South Africa (Oswald and Ransom, 2001). Catch crops are normal hosts, which can stimulate germination and carry the parasite to maturity (Riches, 1989). The crops can be planted as early as possible in the season and then plaughed after parasite attachment when there is still sufficient time to plant a

susceptible crop to maturity (Sauerborn *et al.*, 2000). *A. vogelii* would be cut and the roots destroyed by ploughing when about two months old and when emerging (CAB International, 2005).

In a season of good rainfall, a quick-maturing crop of sunflower could then be grown with cowpea planted again in the following season (Riches, 1989). As Parker and Riches (1993) observed in Botswana, grain or fodder cultivars of pearl millet and bambara are not attacked by the local biotype of the parasite but they are potent stimulators of *A. vogelii* germination. Pearl millet and Bambara can be used in a rotation to cause suicidal germination of the parasite and hence reduce the number of seeds in the soil (Parker and Riches, 1993). Crop rotations can be used to reduce *Alectra* infestation by growing cereals or other grass crops for several years consecutively, exhausting the soil seed bank (Dawson, 1987). However the Fields infested by *A vogelii* are difficult to clean, because of the large amount of seeds produced and the dormancy mechanisms that enable them to stay in the soil for several years (Singh and Emechebe, 1992). It is apparent that no single method can adequately control them and therefore a number of integrated methods are required for effective control (Parker and Riches, 1993).

2.4.1.2 Soil solarization

Exploitation of sunlight to reach high temperatures (55 °C) under clear polyethylene mulch covering the soil for several weeks (Katan and deVay, 1991) is another approach to achieve destruction of the *A vogelii* weed soil seed bank. Soil solarization was successfully applied in the Middle East for crops such as tomato,

eggplant, faba beans, cowpeas, lentil, and carrot (Jacobsohn *et al.*, 1980: Abu-Irmaileh, 1991) to control different types of parasitic weeds.

2.4.1.3 Hand –pulling

Hand pulling and destruction of emerging stems before flowering may be useful, where infestations are limited to the extent of preventing seed production and an expansion of the area infested. However, Beck (1987) observed that, hand pulling did not directly improve the yield of an infested bambara crop and is likely to be the same for other susceptible species, as the majority of damage occurs before the parasite emerges above the ground. Prompt ploughing of crop residues after harvest will prevent continued seed production as host plants continue to grow on residual moisture (CAB International, 2005). Hand pulling is effective especially in fields with a relatively low infestation (Radi, 2007). Removing mature *Alectra* plants from an infested field will reduce the amount of seeds. Verkleij and Kuiper (2000) reported that, removing *A. vogelii* through hand-pulling is more effective method because less damage is caused by the parasite underground.

2.4.2 Chemical control

Alectra vogelii is predominantly a pest for crops grown by resource-poor small-holder farmers who rarely have the financial resource to access herbicides. Also as reported by Gressel *et al.* (2004) there are some difficulties in using chemicals such as; Lack of application technology, chemical damage to the host, continuous parasite seed germination throughout the season, marginal crop selectivity, environmental pollution, low persistence, and availability. Damage by chemical persistence and

availability is another major constraint that limits the successful usage of herbicides for parasitic weed control (Radi, 2007). Little attention has therefore been given to the development of chemical control. However some herbicides can be used to control *A vogelii* weeds.

2.4.2.1 Herbicides

The potential for controlling the weed by treating cowpea seed with the herbicide imazaquin before planting has been demonstrated but this practice has not been commercialized (Berner *et al.*, 1993). Some herbicides have become available for *A. vogelii* weed control (Garcia-Torres, 1998), although few of the herbicides are able to selectively control *A. vogelii* weeds (Goldwasser and Kleifeld, 2004; Gressel *et al.*, 2004). Two concepts are considered for chemical control of *A. vogelii*: foliar herbicide application (Mesa-García and García-Torres, 1985) and soil herbicide application (Radi, 2007). For *A. vogelii* control, glyphosate (an inhibitor of 5-enolpyruvylshikimate-3-phosphate synthase or EPSPS), imidazolinones, and sulfonylureas (inhibitors of acetolactate synthase, ALS) have been recommended (Garcia-Torres and Lopez-Granados, 1991).

Other groups of herbicidal compounds including, sulfonylurea, imidazolinone, and other ALS inhibitors or acetohydroxy acid synthase (AHAS) inhibitors (Garcia-Torres, 1998) have shown promising results in broomrape control. Selective *Alectra* control was achieved by carefully applying some of these herbicides at low rates on non-engineered crops (Kleifeld *et al.*, 1998), depending mainly on the application method. The herbicides fluridone [1-methyl-3-phenyl-5-(3-trifluoromethyl-phenyl)-4-(1-H)-pyridinone] and orflurazon [4-chloro-5-methylamino-2-(3-trifluoro

methylphenyl) pyridazi n-3-one], inhibitors of carotenoid biosynthesis. were shown to induce GA-like effects on the conditioning and germination of *A. vogelii* (Radi. 2007).

Accordingly, soil application of carotenoid biosynthesis inhibitors could potentially be a control method (Sang *et al.*, 2004), that promote seed conditioning of *Alectra* and other root parasites, and enhance the activity of germination stimulants to induce more effective suicidal germination.

2.4.2.2 Fumigation

Fumigation with methyl bromide has been reported to offer effective control of *Alectra* seeds in soil (Jacobsohn 1994; Goldwasser *et al.*, 1995; Warren. 2005). However, Methyl bromide use is being phased out by international agreement to protect the global environment (McDonald. 2002). Other fumigants have been tested as possible substitutes for methyl bromide, but are much less effective and more expensive (Foy *et al.*, 1989; McDonald. 2002; Goldwasser and Kleifeld. 2004). Therefore. the use of this method is not highly recommended because some fumigants are expensive, labor intensive, and extremely environmentally hazardous.

2.4.3 Biological control

This technique utilizes living organisms to suppress or reduce parasitic weeds. Considerable attention and efforts have been made in biological control, but until recently, the control of *Alectra vogelii* in the field using insects or fungi as bio-control agents has failed (Kroschel *et al.*, 1999) as cited in Radi (2007). The results indicate that the bio-control agents in most cases do not provide the level of control

desired by farmers. Many insects (*Eulocastra argentisparsa* Hampson, *Smicronyx* spp., *Ophiomyia strigalis* Spencer, *Phytomyza orobanchia* Kalt) have been collected on *Striga* and *Alectra* in India and Africa, but most are not specific for these parasitic plant species (Klein and Kroschel, 2002). Recently, fungal isolates were reported to be promising bio-control agents for the control of *Alectra* and *Striga*. Approximately 30 fungal genera are reported to occur on *Alectra* spp (Klein and Kroschel, 2002). *Fusarium* isolates were most prominently associated with diseased *Alectra* and *Striga* (Radi, 2007).

The *Fusarium* isolate exclusively attacks *Alectra spp* and susceptible biotypes of *O. aegyptiaca* (Bedi, 1994). On the other hand, other *Fusarium* isolates [*Fusarium oxysporum* (FOXY) and *F. arthrosporiodies* (FARTH)] attack *Alectra spp*. and *Orobanche ramosa* (Amsellem *et al.*, 2001). It is reported that, *Fusarium oxysporum* Schlect (isolate PSM 197) could also be a potential mycoherbicide for controlling *Striga* spp (Marley *et al.*, 2005). Novel approaches were recently developed to increase control by fungi, i.e., by a "multiple-pathogen strategy." In this strategy, two or more pathogens are combined and applied before or after parasite emergence. Some applied fungal mixtures caused a significant reduction of the number of emerging *O. cumana* (Charudattan, 2001).

A combined treatment of the herbicide benzothiadiazole with the pathogen *F. oxysporum* f. sp. *orthoceras* successfully controlled *Alectra vogelii* and reduced parasite emergence up to 100% (Radi, 2007). Other techniques such as formulation or encapsulation of fungal propagules in a solid matrix to prevent rapid desiccation

or microbial competition have been developed (Radi. 2007). A successful example of granular formulation called "Pesta" showed high efficacy in controlling *S. hermonthica* and *O. cumana* in the greenhouse (Elzein. 2003). Another approach is the engineering of hypervirulence genes into weed-specific pathogens. e.g., genes that encode enzymes that degrade metabolites involved in parasite defense mechanisms such as phytoalexines, or coding for enhanced virulence by the production of fungal toxins (Gressel, 1992; Gressel *et al.*, 2004).

2.4.4 Host plant resistance

Generally, parasitic weeds derive their water, nutrients and photosynthates from the host plants, having produced a strong demand on the host roots. Although *Alectra* infestation is considered less dramatic than that of *Striga*, a total yield loss is not uncommon in fields heavily infested by this parasite, when susceptible varieties of cowpea are planted (Lagoke *et al.*, 1996; Lagoke. 1989; Emechebe *et al.*, 1983) as cited in Alonge *et al.* (2001a).

The best long-term strategy for limiting damage by parasitic weeds is the development of resistant varieties (Cubero and Hernández, 1991; Ejeta *et al.*, 1991), but conventional breeding has yielded few varieties with stable resistance (Rubiales. 2003). According to Singh and Amachebe (1991), the mechanisms of resistance to *Striga* in cereals include avoidance, presence of growth inhibitors and mechanical barriers e.g. lignification. In cowpea, Atokple *et al.* (1995) suggested that, the production of active germination stimulants and the defense mechanism are two major factors that play an important role in the response of cowpea to parasitic weeds. In contrast, Parker and Riches (1993) noted from several studies that

resistance of cowpea to parasitic weeds was not associated with low stimulant production. Furthermore Lane *et al.* (1991) and Lane and Bailey (1991), identified at least two mechanisms of cowpea resistance *to S. gesnerioides* and *Alectra*. Neither of these mechanisms depends on reduced parasite germination; and the mechanisms of resistance are apparently similar for both parasites. Cowpea cultivars evaluated include those resistant to *A. vogelii* and *S. gesnerioides* seeds. In the first mechanism, the host tissue around the invading *Striga* radicals becomes necrotic in association with the early death of the parasite and lack of tubercles formation. This was expressed in variety 58-57 (Lane *et al.*, 1991). Lane *et al.* (1993) later reported similar results for varieties B301 and 58-57.

Improved cowpea cultivars with resistance to *Alectra vogelii*, the related parasitic weed *Striga gesnerioides*, and several insect pests and fungal diseases have been developed in West Africa. These include the cultivars IT90K-76-6 and IT90K-82-2 which have been released for commercial production in Nigeria (Singh, 2000). However, these are not resistant to biotypes of *A. vogelii* from southern Africa (Riches, 2002).

The Botswana landrace accession B359 has been shown to be resistant to samples of the parasite from Botswana, Malawi, and Kenya therefore, this accession could be used as a parent for breeding improved cultivars for East and southern Africa (Riches *et al.*, 1992). Potentially, useful levels of resistance have also been demonstrated in germplasm of bambara (Riches *et al.*, 1992) and cultivars of soyabean (Alonge *et al.*, 2001b) but multi-location testing is needed to confirm the value of these lines in the field.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Source of Cowpea Genotypes

Twelve cowpea genotypes of which 10 described as resistant to *Alectra vogelii* (Makoko, 2007) were used in the study. One improved variety (Tumaini) and a local landrace "Nandala" obtained from farmers around Hombolo village were used as standard and local checks, respectively. Both Tumaini and the landrace collected from farmers are known to be susceptible to *Alectra vogelii* (Table 1).

Table 1: Selected cowpea genotypes

S/NO	GENOTYPES	SOURCE	STATUS	SEED COLOUR	100 SEED WEIGHT (g)
1	IT 99k-494-6	IITA	*Alectra* Resistant	Orange	12.3
2	IT 98k-628	IITA	*Alectra* Resistant	White	15.8
3	IT 99k-7-21-2-2	IITA	*Alectra* Resistant	White	17.6
4	IT 98k-205-8	IITA	*Alectra* Resistant	White	15
5	IT 99k-573-2-1	IITA	*Alectra* Resistant	White	15.5
6	IT 00k-1207	IITA	*Alectra* Resistant	Yellowish white	12.1
7	IT 97k-568-18	IITA	*Alectra* Resistant	Orange	15.9
8	IT 98k-131-2	IITA	*Alectra* Resistant	Orange	18.5
9	IT 99k-573-1-1	IITA	*Alectra* Resistant	White	17.7
10	IT 99k-530-1	IITA	*Alectra* Resistant	Yellowish white	14.4
11	Tumaini (standard check)	ARI, Ilonga	Susceptible check	Light brown	12.7
12	Nandala (local check)	Hombolo	Susceptible check	Light brown	13.9

According to Parlevliet and Zadoks (1993) the term susceptible refers to the situation by which a living organism is easily influenced or affected by a harmful environmental agent while resistant is the capacity of an organism or tissue to withstand the effect of a harmful environmental agent. Tolerant on the other hand is the ability of an organism to partially withstand or endure an adverse environmental condition.

3.2 Location and Duration

An on-station experiment was conducted at Agricultural Research Institute – Hombolo, Dodoma in Central Tanzania. The station lies between latitudes $5^0 45'$ and 8^0 South and between longitudes 35.57^0 and 37^0 East at an altitude of 1020 m above sea level. The duration of the experiment was 5 months from December 2009 to April 2010.

3.3 Effect of *Alectra vogelli* on Shoot and Root Growth Characteristics

Ten cowpea genotypes and a local variety (Tumaini) were planted. The local landrace and Tumaini ware used as checks. A single field experiment was set up to address the two specific objectives namely (i) to assess the effects of *Alectra vogelii* on shoot and root growth characteristics of cowpeas under natural field infestation and (ii) to determine the effects of *Alectra vogelii* on cowpea yield under field conditions of Chamwino district. Randomized complete block design (RCBD) with three replications was used.

3.3.1 Soil analysis

Soil samples from the experimental plot were collected by using a spring type of Auger. The samples were taken at a depth of 15 cm in the field by walking along a W-shaped path taking 12 samples which were bulked and put in a labeled polythene bag. After the first sampling, the auger was thoroughly washed to avoid contamination between successive vertical samples. Then the samples were taken to the laboratory and analyzed according to the standard routine soil analysis (London, 1991). The parameters analyzed from the laboratory involves physical

characteristics (soil texture, bulk density, particle size, etc), and chemical characteristics (CEC, soil pH, exchangeable bases, etc).

3.3.2 Planting and Crop Management

Land preparation was done by clearing the bush using slashes and hand hoe; and tillage was done using an ox-plough. Cowpeas were planted at a spacing of 20 cm between plants and 50 cm between rows (Fig. 1). One cowpea seed was planted in each hole and after ten days gap filling was done to maintain one plant per hill. Each plot of 17.6 m^2 was planted with 176 cowpea plants (0.1 x 10^6 plants/ha) consisting of 8 rows (Fig. 1), which comprised guard, sampling and harvesting rows. Two weeks after sowing all weeds that emerged were pulled by hand.

To control insect pests (Aphids), Profenos 720 g/l was applied at a recommended rate of 0.72 kg a-i/ha. One litre of the insecticide covered one hectare of leguminous plants. Therefore, 63.4 ml of the chemical was applied to cover the experimental plot area of 633.6 m^2. This practice was done after mixing 25 ml of insecticide in a sprayer loaded with 15 liters of water. Metalaxy 40 g/kg + mancozeb 640 g/kg was applied at the recommended rate of 2.5 kg a-i/ha. To spray in the whole experimental plot, 45 g of fungicide was mixed in a sprayer loaded with 15 litres of water to control powdery mildew disease. Spraying of these pesticides was done two weeks after sowing and the process was repeated during flower formation.

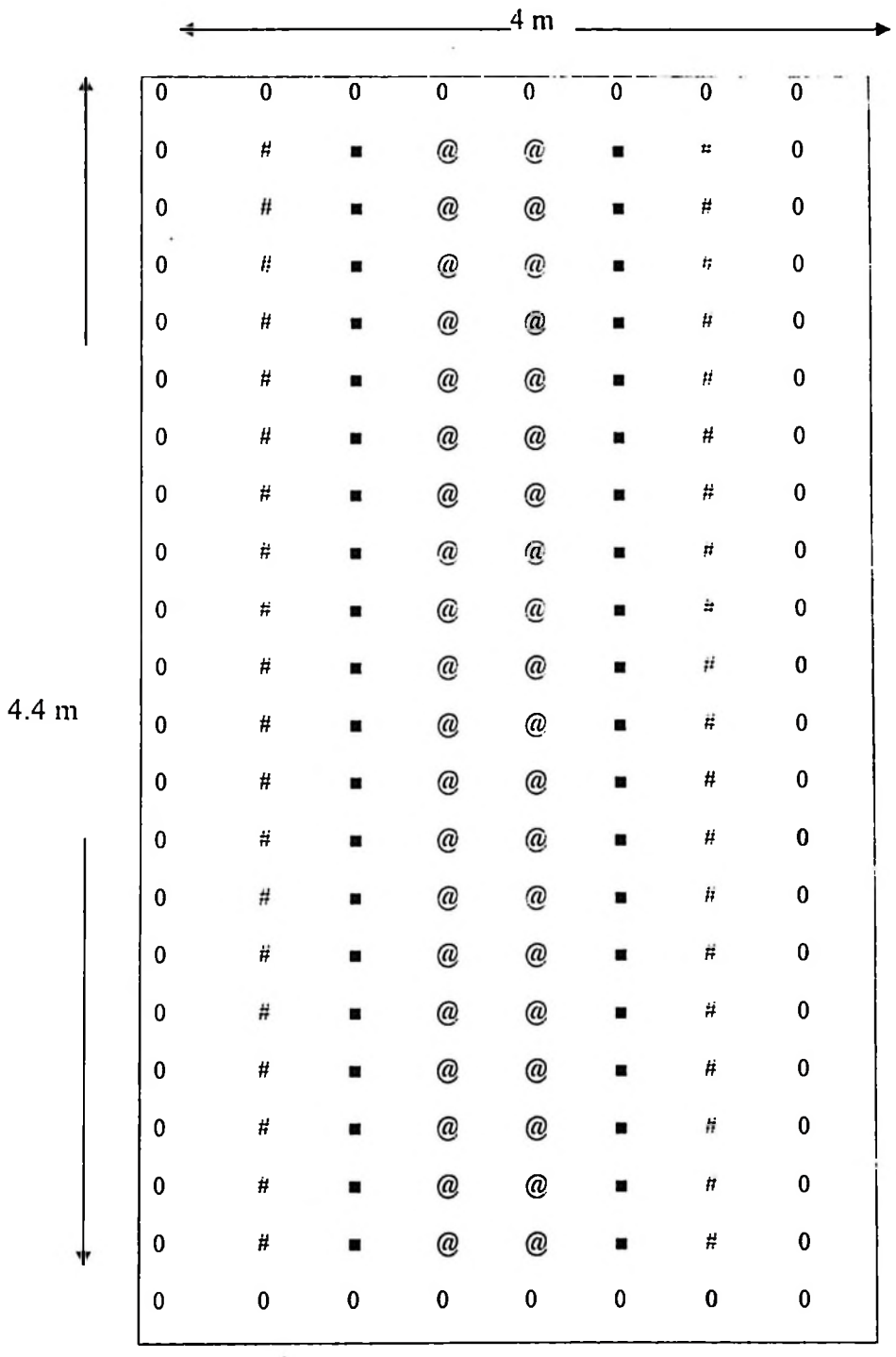

Figure 1:: Single plot appearance

Key: 0 = Outer guard rows
■ = Inner guard rows
= Rows used for destructive sampling
@ = Harvest rows

3.3.3 Data collected to assess the effects of *Alectra vogelii* on Shoot and Root Growth Characteristics of Cowpea under Natural Field Infestation

The following data were recorded from cowpea plants at 5, 6, 7, 8 and 9 weeks after sowing:-

i. Plant height. Three plants were sampled from harvesting rows by taking first plant at the beginning of the row, second plant close to the center and third plant at the end of the row. The plants were measured from the ground level to the tip of the longest leaf and recorded in cm.

ii. The number of leaves per plant. The leaves were counted from three plant samples by sampling one plant at the beginning of the harvesting row, second at the center and third plant just close to the end of the harvesting row. After recording calculations were done to obtain averages.

iii. The number of branches per plant. These were also recorded from three plant samples as explained above.

iv. Leaf Area Index (LAI). Three leaves were taken from three different cowpea plants within the destructive sampling rows. The sample collected was placed in a well labeled envelop and taken to the lab for LAI measurements. This was determined by using a computer program leaf area measurement version 1.3 (Askew, 2003) at ARI, Hombolo laboratory.

v. Shoot dry matter weight: Three plant samples were uprooted from destructive sampling row at each plot. The first plant was sampled after the guard plant just at the beginning of the row and the second plant followed after leaving two plants and the same was done for the third plant sample. The samples were separated from roots and the shoot (combined stems,

petioles, leaves and pods) and put into well labeled envelop. and then dried in an oven at 60 ^{0}c up to constant weight.

vi. Root length: After being separated from shoots. root lengths were measured in cm by considering the longest root.

vii. Root dry matter weight: The roots were put into the envelopes and oven dried at 60 ^{0}c up to constant weight. Then weight was recorded after 48 hours.

viii. Shoot to root ratio of cowpea plants. Each plant's shoot weight was divided by its respective root weight to determine the shoot to root ratio.

3.4 Data Collected to Determine the Effects of *Alectra vogelii* on Cowpea Yield under Field Conditions of Chamwino District.

The following data were collected:-

3.4.1 On *Alectra vogelli*

Alectra vogelii plants were sampled from a fixed quadrant of 1 m^2 in the center of harvest rows, then data were collected as follows:-

i. *Alectra* emergence: Days to *Alectra* appearance were recorded by considering the number of days after sowing to the first emergence of *Alectra* plants.

ii. Number of shoots: The number of *Alectra* shoots per cowpea plant were collected at 7, 8 and 9 weeks after sowing to assess the host support for *Alectra* growth

iii. Flowering: The number of days to first flowering was recorded from days of *Alectra* emergence to the first flowering of *Alectra* plants.

iv. Biomass of *Alectra* plants: - At crop harvest. all *Alectra* shoots from the 1 m^2 area were cut and oven dried at 60 °C for 48 hours and then weighed.

3.4.2 On cowpea plants

The data were collected from two rows at the centre of the plot which were designated as harvest rows. These rows contained 44 plants including two guard plants at the beginning and two guard plants at the end. But in each plot only 20 plants were used for data collection leaving 4 plants at the end of rows which were left as guard plants. There was an experience of severe plants death in each plot due to drought condition happened in February 2010. The numbers of plants were reduced to 26 plants per plot at one plot planted with cowpea genotype IT 00K 1207. Therefore according to the reason above. 20 plants in each plot i.e. 10 plants in each harvest row were used for data collection.

i. Number of plants at harvest: The total number of plants at harvest was counted from harvest rows just before pod harvesting, leaving plants in the guard rows and four guard plants at the end of the rows.

ii. Days to flowering: Days to first flower were recorded during the appearance of the first flower from harvesting rows in each plot leaving guard plants in the entire row.

iii. Pods per plant: The number of pods per plant was done during harvest from ten randomly sampled cowpea plants and their average calculated. The sampling was done in the rows marked as harvesting rows by taking third plant from the beginning of the row and continuing with other plants leaving every other plant.

iv. Pod length: At harvest, ten pods in each plant from three different plants sampled in each plot were measured and their average calculated.

v. Number of seeds per pod: Seeds were counted from ten pods sampled from three different plants collected at random in each plot at harvest and average was recorded.

vi. Weight of 100 seeds: After shelling 100 grain were counted from a shelled sample harvested in each plot.

vii. Shoot biomass: Shoots fresh weight was obtained as average of 20 plants after harvesting and shelling of all grain from pods. All 20 plant samples were put into a plastic bag and weighed by using a spring balance and recorded.

viii. Pod weight: The mature pods from 20 plants harvested in the harvest rows were picked, dried and weighed before shelling.

ix. Grain yield:- After shelling pods from 20 plants harvested in the harvest rows total grain weight in kg/ha was determined.

x. Harvest index and shelling % were determined using the following:-

$$\text{Harvest index} = \frac{\text{Weight of grain (g)}}{\text{Weight of grain + shoots (g)}} \quad \text{.....(i)}$$

$$\text{Shelling \%} = \frac{\text{Total weight of grains (g)} \times 100}{\text{Weight of unshelled pods (g)}} \quad \text{.....(ii)}$$

3.5 Host Damage Severity

At an area of 2 m^2 in each plot cowpea plants samples that were infested with *Alectra vogelii* were assessed on host damage severity. These data were collected

during harvesting time. The *Alectra* rating scale of 1-9 adopted from Berner *et al.* (1993) was used with some modification as shown below.

1 = Normal cowpea growth; no visible symptoms.

2 = Scattered, small and vague, whitish/yellowish leaf blotches visible, otherwise normal plant growth.

3 = Blotching easily noticeable. Mild wilting. Only trace of scorching on leaves.

4 = Extensive blotching and mild wilting. Only trace of leaf scorching. Slightly but noticeable stunting and reduction in pod size and number.

5 = Extensive blotching and wilting. Leaf scorching on small portion of the leaf area. Moderate stunting and reduction in pod size and number.

6 = Extensive scorching. Leaf scorching covering about a third of the leaf area. Reduction in plant height, stem diameter, pod size and number.

7 = Extensive scorching turning brown and necrotic. About one third of the plant's surface is scorched. About 30% reduction in height. Noticeable reduction in stem diameter and in pod size. Some stems breaking.

8 = Scorching on most of the leaf area. Stunting, height reduction by more than 30%. Stems look thin and weak; many are broken.

9 = Virtually all leaf area are scorched; 50% reduction in height; most stems collapsing; no useful pod formed; plant dead or nearly dead.

3.6 Weather Data

Temperature, rainfall and relative humidity data were obtained from Hombolo meteorological station between November 2009 and May 2010.

3.7 Data Analysis

The data obtained excluding weather data were subjected to analysis of variance (ANOVA) using MSTAT-C computer statistical package (Michigan State University, 1993). Tukey's Honestly Significant Difference Test (THSDT) was used to compare treatment means because it is suitable for experiments with a large number of treatments (> 10).

The statistical model was:- $X_{ij} = \mu + T_i + B_j + e_{ij}$; .....(iii)

Where: μ = Overall mean, T_i = Treatments effects of treatments I = 1, 2, ... t, B_j = Block effects of blocks j = 1, 2, ... b and e_{ij} = Random error peculiar to each observation in the i^{th} treatment and j^{th} block.

CHAPTER FOUR

4.0 RESULTS

4.1 Soil Characterization

Soil samples collected from experimental plots at Hombolo were analysed at the SUA soil science laboratory while adhering to standard routine soil analysis procedures (London, 1991). The results for soil analysis are summarized in Table 2.

Table 2: Physico-chemical characteristics of soils from Hombolo

No.	Parameter	Determined Value	Standard value	Comments
1	PH in water 1:2.5	6.4	6.6-7.3	Medium
2	Organic carbon (%)	0.55	1.26-2.5	Very low
3	Total N (%)	0.05	0.21-0.5	Very low
4	Particle size			
	Clay (%)	21.0		
	Silt (%)	3.2		
	Sand (%)	75.8		
5	Texture class			Sand clay loam
6	CEC (Cmol (+)Kg+)	16.4	17.1-25	Low
7	Available Phosphorus (mg/kg)	3.9	7-20	Low
8	Exchangeable bases			
	Calcium	5.4	4.4-7.3	Medium
	Magnesium	0.9	0.5-2.7	Medium
	Potassium	0.15	0.5-7.5	Low
	Sodium	1.2	0.1-2	Medium

Whereas the results of the soil showed moderate levels of macronutrient elements (P, K and Ca), but the total N was very low (Table 2). The pH value was medium and according to the observed distribution of particle size and reported trends, the soil texture class is **sand clay loam** (London, 1991). In general the soils were infertile indicating the need for fertilization.

4.2 Weather Condition

The experimental site is within the central agro ecological zone which experiences only one rain season. In Hombolo, rains normally start towards the end of November and ends in April, the rest of the year is dry. The total average annual rainfall is 573.1 mm. Mean monthly rainfall distribution, mean monthly temperature and mean monthly RH at Hombolo for the period November 2009 to May 2010 are shown in Table 3.

Table 3: Monthly means of some weather parameters

Month/Year	Rainfall (mm)	Temperature (^{o}c)		3PM RH (°o)
		Max	Min	
Nov. 2009	16.2	31.12	13.6	042
Dec. 2009	17.3	31.5	20.3	043
Jan. 2010	12.9	28.5	20.0	055
Feb. 2010	8.9	30.3	20.4	048
Mar. 2010	27.4	30.9	20.2	049
Apr. 2010	7.7	30.3	19.6	047
May 2010	3.0	28.7	18.5	074

The data in Table 3 were recorded from Hombolo meteorological station and showed that, the highest precipitation (27.4 mm) was in March while in other months especially February and May the precipitation was relatively low at 8.9 mm and 3 mm respectively.

Cowpea plants were planted on 15 January 2010, on this date rainfall was received. Two days after sowing the plants germinated and emerged from the ground and the germination percentage was averaged at 87%. Low amount of rainfall observed in February resulted to drought that caused death to cowpea plants in some of the experimental plots described in section 3.4.2. The maximum temperatures were

experienced in November and December with 31.1 ^{0}C and 31.5 ^{0}C, respectively. The highest percentage of relative humidity was observed in May while the lowest percentage was observed in November. During cowpea growing period, the rate of humidity did not vary much from January to April.

4.3 Effects of *Alectra vogelii* on Shoot and Root Growth Characteristics of Cowpea

4.3.1 Dry shoot biomass

There were no significant differences (P> 0.05) in the dry shoot weight between the genotypes tested throughout the sampling period. However, genotypes IT 99K 494-6 (18.9 g), IT 99K 7-21-2-2 (18.4 g) and IT 99K 573-2-1 (18.3 g) had relatively higher shoot dry weight compared to genotypes IT 98K 205-8 (12.4 g) and IT 99K 628 (14.2 g) at 9 WAS (Fig. 2).

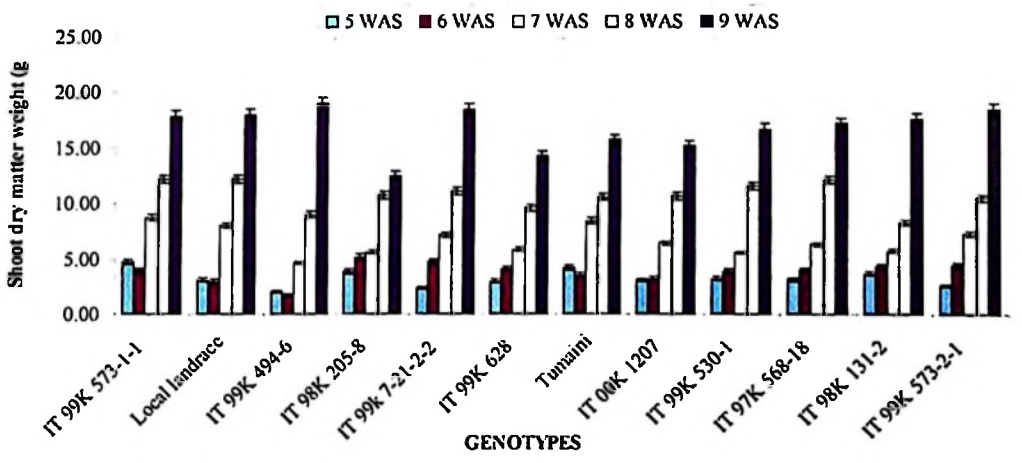

Figure 2: Shoots biomass in tested cowpea genotypes

4.3.2 Root biomass

The cowpea's roots biomass of the genotype tested showed no significant differences ($P > 0.05$) at early growth stages up to sixth week after sowing (Fig. 3). From the seventh week, genotype IT 99K 7-21-2-2 (3.6 g) differed significantly ($P>0.05$) from the standard check Tumaini (1.3 g) in root dry weight. The results (Fig. 3) indicated that the local landrace, IT 99K 573-1-1 and IT 99K 628 genotypes which also showed symptoms of *Alectra* damage (Table 6) had relatively lower root biomass from five to nine WAS compared to the other genotypes. The differences in root dry weights for IT 97K 568-18, IT 98K 131-2 and IT 99K 573-2-1 were not significantly different ($P>0.05$) either at 5 and 6 WAS or at 8 and 9 WAS.

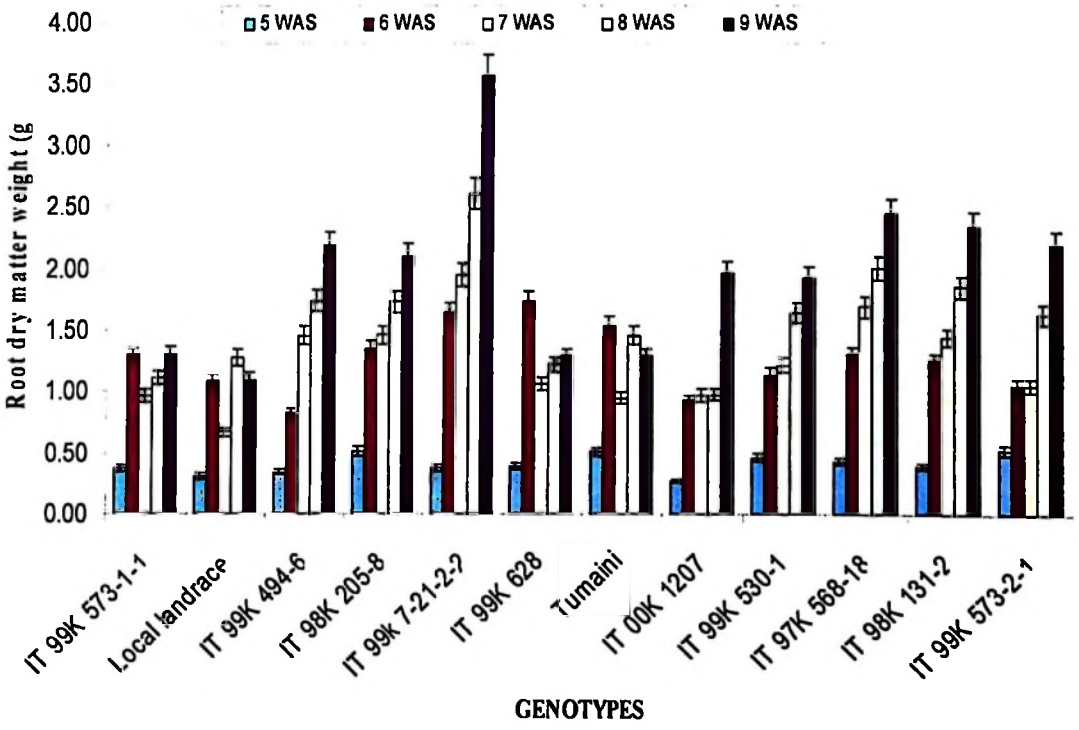

Figure 3: Cowpea root biomass

4.3.3 Cowpea genotypes shoot to root ratio.

The shoot to root ratio for the local landrace was low (0.12) compared to the genotype IT 99K 494-6 (0.3) as observed at 7 WAS (Table 4). At 9 WAS the local landraces differed significantly ($P \leq 0.05$) with all tested genotypes. No significant difference ($P>0.05$) was observed between genotype IT 99K 573-1-1 and the standard check variety Tumaini at 9 WAS since both of them showed similar levels of symptoms of *Alectra* damage (Table 6).

Table 4: Shoot to root ratios

GENOTYPES	Weeks after sowing				
	5	6	7	8	9
IT 99K 573-1-1	0.1a	0.3a	0.17ab	0.1a	0.09bc
IT 99K 494-6	0.2a	0.5a	0.30a	0.2a	0.13abc
IT 98K 205-8	0.1a	0.2a	0.25ab	0.2a	0.17ab
IT 99K 7-21-2-2	0.3a	0.3a	0.27ab	0.3a	0.20a
IT 99K 628	0.1a	0.6a	0.18ab	0.1a	0.11abc
IT 00K 1207	0.1a	0.3a	0.20ab	0.1a	0.08bc
IT 99K 530-1	0.1a	0.3a	0.23ab	0.2a	0.14abc
IT 97K 568-18	0.1a	0.3a	0.26ab	0.2a	0.12abc
IT 98K 131-2	0.1a	0.3a	0.17ab	0.2a	0.15abc
IT 99K 573-2-1	0.2a	0.2a	0.21ab	0.2a	0.14abc
Local (control)	0.1a	0.4a	0.12b	0.1a	0.06c
Tumaini (control)	0.1a	0.5a	0.16ab	0.1a	0.12bc
Mean	0.2	0.4	0.23	0.2	0.16
S.E (±)	0.1	0.1	0.1	0.1	0.1
CV (%)	73.4	51.6	35.6	36.5	27.9

Means followed by the same letter (s) within the column do not differ significantly at $P \leq 0.05$ according to Tukey's Honestly Significant Difference Test

4.3.4 Number of leaves per plant

There were no significant variations ($P \leq 0.05$) on the number of leaves per plant throughout the sampling period (Table 5) except at 9 WAS when genotype IT 99K 494-6 had higher number of leaves (42) compared to the genotype IT 98K 205-8 (23). No significant differences were observed at 7 WAS between genotype IT 99K

7-21-2-2 (15), IT 99K 628 (14), Tumaini, IT 00K 1207 (15) and IT 99K 530-1(15) but they all differed significantly (P<0.05) from the local landrace (23) and IT 97K 568-18 (22) which had high number of leaves per plant (Table 5).

Table 5: Number of leaves per plant

GENOTYPES	Weeks after sowing				
	5	6	7	8	9
IT 99K 573-1-1	9.7a	17.3a	17ab	22a	31ab
IT 99K 494-6	11.0a	21.7a	18ab	18a	42a
IT 98K 205-8	10.3a	17.0a	17ab	22a	23b
IT 99K 7-21-2-2	10.7a	16.3a	15b	15a	34ab
IT 99K 628	9.3a	15.7a	14b	19a	30ab
IT 00K 1207	9.0a	17.7a	15b	15a	30ab
IT 99K 530-1	10.3a	19.0a	15b	18a	37ab
IT 97K 568-18	11.0a	22.3a	22a	22a	41ab
IT 98K 131-2	9.7a	21.7a	18ab	14a	28ab
IT 99K 573-2-1	10.3a	18.3a	19ab	15a	33ab
Local landrace	12.3a	22.3a	23a	23a	35ab
Tumaini (control)	11.3a	16.3a	15b	17a	25ab
Mean	10.4	13.5	17.4	19.0	32.8
S.E (±)	0.7	1.5	1.0	2.7	3.6
CV (%)	11.7	19.8	13.3	24.5	19.1

Means followed by the same letter (s) within the column do not differ significantly at $P \leq 0.05$ according to Tukey's Honestly Significant Difference Test

4.3.5 Plant height

Although there were no significant differences ($P \leq 0.05$) observed in plant height during early growth period, cowpea genotypes IT 99K 494-6 (30.3 cm), IT 99k 7-21-2-2 (30.6 cm) and IT 97K 568-18 (29.9 cm) showed significant increase (P>0.05) in plant height compared to the local landrace (20.2 cm), Tumaini (26.6 cm), IT 99K 628 (22.3 cm) and IT 00K 1207 (24.9 cm) at 9 WAS (Fig. 4). Throughout the sampling period, genotypes IT 99K 573-1-1 and IT 99K 494-6 increased in plant height while the control genotypes (local landrace and Tumaini) decreased in plant height from the seventh week after sowing onwards.

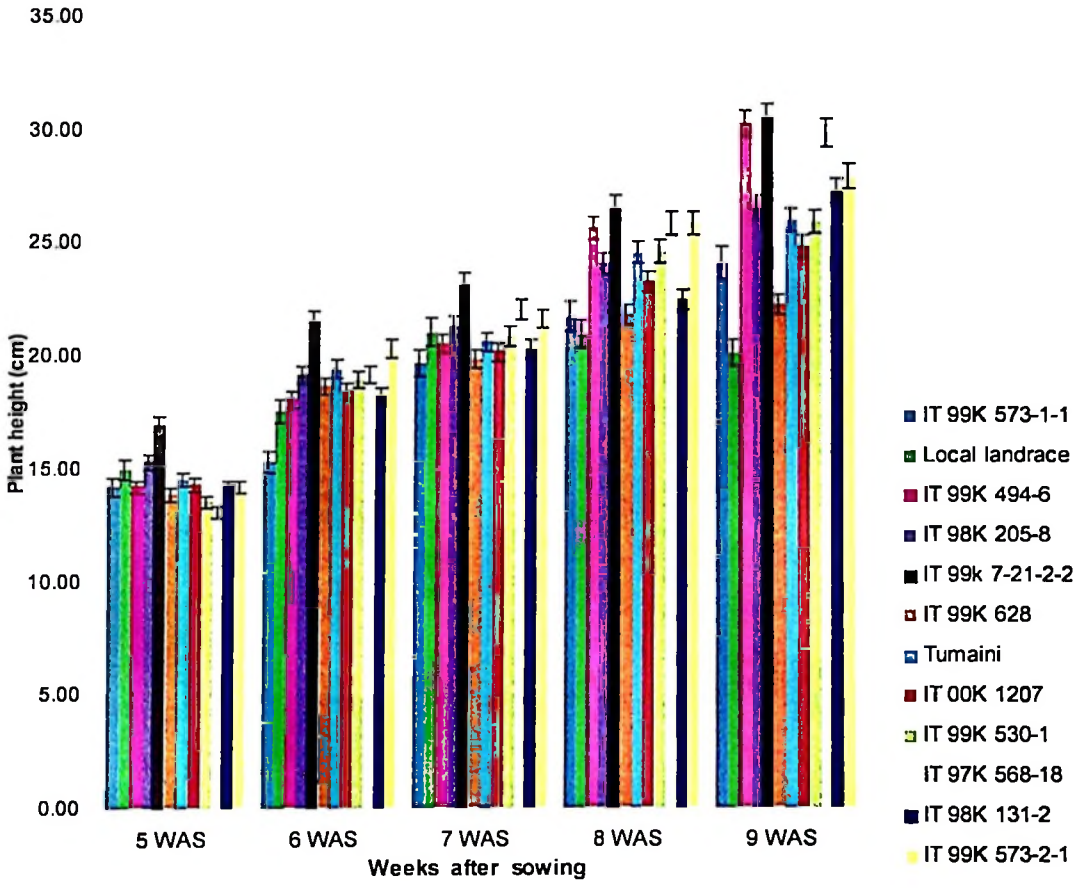

Figure 4: Plant height over the growing period

4.4 Effects of *Alectra vogelii* on Yield and Yield Components

4.4.1 Days to cowpea flowering, maturity and damage severity of *Alectra vogelii*

Results on days to cowpea flowering, physiological maturity, *Alectra* syndrome score and cowpea shoots biomass at harvest are presented in Table 6. The genotypes IT 99K 628 and IT 99K 530-1 flowered earlier which differed significantly (P>0.05) from the local landrace, Tumaini, genotypes IT 00K 1207, IT 97K 568-18, 98K 131-2 and 99K 573-2-1 that flowered late (Table 6). Also there were no significant difference (P>0.05) observed on the days to physiological maturity (Table 6). However, there were significant difference (P<0.05) on fresh shoots biomass at

harvest to the genotype IT 99K 494-6 that had large shoots biomass compared to the genotypes IT 99K 573-1-1 and IT 628 99K 628.

Table 6: Number of days to cowpea flowering, maturity and *Alectra* syndrome score

GENOTYPES	No. of days to cowpea flowering	Days to harvesting	Fresh Shoots weight (kg/ha)	Syndrome score
IT 99K 573-1-1	36.0abc	74.67a	1340.3b	3
IT 99K 494-6	36.0abc	77.00a	2688.0a	1
IT 98K 205-8	35.7abc	74.67a	1328.3b	2
IT 99k 7-21-2-2	36.7ab	77.00a	1764.7ab	1
IT 99K 628	35.0bc	74.67a	1327.7b	5
IT 00K 1207	37.3a	77.00a	1524.2ab	2
IT 99K 530-1	34.7c	74.67a	1709.0ab	2
IT 97K 568-18	37.0a	74.67a	2454.5ab	1
IT 98K 131-2	37.3a	72.33a	1707.6ab	2
IT 99K 573-2-1	37.3a	77.00a	1810.8ab	1
Local landrace (control)	37.0a	77.00a	1653.6ab	6
Tumaini (control)	37.3a	70.00a	1531.4ab	4
Mean	36.4	75.1	1736.1	2.5
S.E (±)	0.4	1.5	248.2	0.4
CV (%)	1.8	3.5	24.8	

Means followed by the same letter (s) within the column do not differ significantly at $P \leq 0.05$ according to Tukey's Honestly Significant Difference Test; Syndrome score 1= Normal cowpea growth and 6 = Extensive scorching

Under field conditions of Dodoma, the 12 cowpea genotypes showed responses ranging from complete resistance to susceptibility to *Alectra* damage (Table 6). The local landrace and genotype IT 99K 628 were significantly (P>0.05) highly susceptible to *Alectra* while genotypes IT 99K 494-6, IT 99k 7-21-2-2, IT 97K 568-18 and IT 99K 573-2-1 were resistant as there were no visible symptoms of *Alectra* damage. There were no significant differences (P> 0.05) observed between genotypes tested on the number of pods per plant and pod length during harvesting period (Table 7). However, the results (Table 7) indicate that Tumaini variety

produced a significantly (P > 0.05) higher number of seeds per pod compared to genotypes IT 99K 494-6 and IT 99K 573-1-1. The local landrace had significantly (P ≤ 0.05) low seed weight (expressed as 100 seed weight) compared to genotype IT 99K 7-21-2-2 and this was also reflected in grain yield per hectare. There were no significant differences (P> 0.05) of pod weight in all genotypes tested.

Table 7: Effect of *Alectra* damage on yield and yield components

GENOTYPES	No of seeds/pod	Pod weight (kg/ha)	Grain yield (kg/ha)	Shelling percentage (%)	Harvest index (%)	100 seed wt (g)
IT 99K 573-1-1	10.6b	1266.9	1128.0abc	88.9a	0.84a	20.4ab
IT 99K 494-6	10.8b	2426.4	2141.0ab	88.18a	0.80a	17.3ab
IT 98K 205-8	11.4ab	1231.1	1172.0abc	95.2a	0.88a	15.9ab
IT 99k 7-21-2-2	11.0ab	1657.5	1536.0abc	92.7a	0.87a	23.4a
IT 99K 628	11.1ab	1193.1	944.0bc	78.9ab	0.71ab	16.1ab
IT 00K 1207	11.7ab	1604.9	1283.7abc	80.2ab	0.86a	14.2ab
IT 99K 530-1	12.0ab	1580.7	1378.0abc	88.8a	0.81a	15.7ab
IT 97K 568-18	12.0ab	2373.0	2302a	96.9a	0.93a	21.2ab
IT 98K 131-2	12.1ab	1469.4	1257.1abc	82.2ab	0.71ab	19.5ab
IT 99K 573-2-1	10.9ab	1547.8	1364.4abc	84.9ab	0.72ab	18.1ab
Local landrace	13.0ab	1197.6	664.3c	57.5b	0.40b	10.8b
Tumaini	14.4a	1482.8	1333.3abc	87.9ab	0.85a	13.5ab
Mean	11.8	1585.4	1375.2	85.2	0.78	17.2
S.E (±)	0.7	256.1	260.3	5.9	7.2	2.2
CV (%)	10.3	27.9	32.8	12.1	15.9	21.9

Means followed by the same letter (s) within the column do not differ significantly at P ≤ 0.05 according to Tukey's Honestly Significant Difference Test.

Further, the local landrace had significantly (P< 0.05) low shelling percentage and harvest index compared to genotypes IT 99K 494-6, IT 99k 7-21-2-2, and IT 97K 568-18. It has also been observed in shelling percentage of genotypes IT 99K 573-2-1 and the standard check Tumaini which did not differ significantly from *Alectra* resistant genotypes. The genotype IT 97K 568-18 had higher yield (2302 kg/ha) compared to the genotype IT 99K 628 (944 kg/ha) and the local landrace (664.3 kg/ha) Table 7. Also the genotype IT 99K 494-6 yielded higher than the local landrace (Table 7). No significant difference (P> 0.05) observed between the

genotypes IT 99K 573-2-1, IT 98K 205-8, IT 99k 7-21-2-2, IT 00K 1207, IT 99K 530-1, 98K 131-2, IT 99K 573-2-1 and the local variety (Tumaini) on yield in kg/ha.

4.5 Growth Variables for *Alectra vogelii*

4.5.1 Days to *Alectra* appearance

There was no *Alectra* infestation observed in the genotypes IT 99K 494-6, IT 99K 7-21-2-2 and IT 97K 568-18 throughout cowpea growth period. Also no significant differences ($P< 0.05$) observed on the days to *Alectra* appearance in all infested genotypes, Tumaini and the local landrace (Fig. 5).

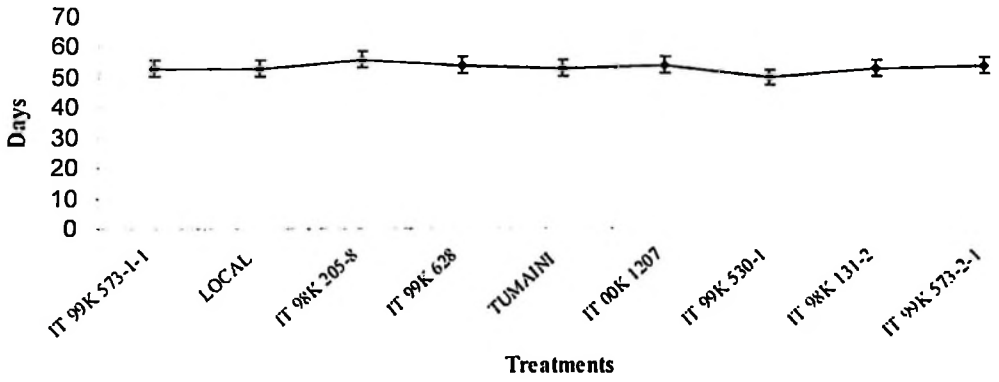

Figure 5: Number of days to *Alectra vogelii* appearance

4.5.2 The number of *Alectra* shoots per cowpea plant

The local landrace (7) and the genotypes IT 99K 628 (7), IT 99K 530-1 (8) and IT 99K 573-2-1 (8) were highly infested with *Alectra* as observed to host a large number of *Alectra* plants compared to genotypes IT 99K 573-1-1 (0), IT 98K 205-8 (0), IT 00K 1207 (0) and IT 98K 131-2 (0) that did not show any signs of *Alectra* infestation (Fig 6).

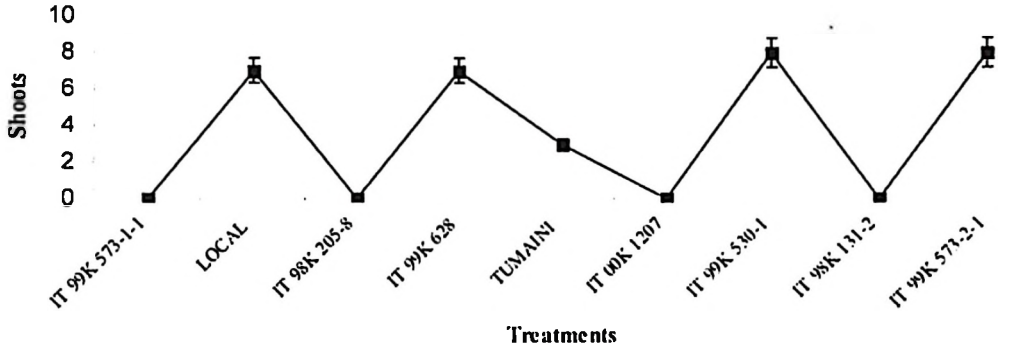

Figure 6: The number of *Alectra* shoots per cowpea plant

4.5.3 Days to *Alectra* flowering

No significant differences ($P<0.05$) on the days to *Alectra* flowering in all cowpea genotypes tested (Fig. 7). *Alectra* plants that infested genotypes IT 99K 628, IT 99K 530-1 and IT 99K 573-2-1 flowered on the 12th days after emergence and those infested the local landraces, Tumaini and other IITA genotypes flowered 13 days after emergence.

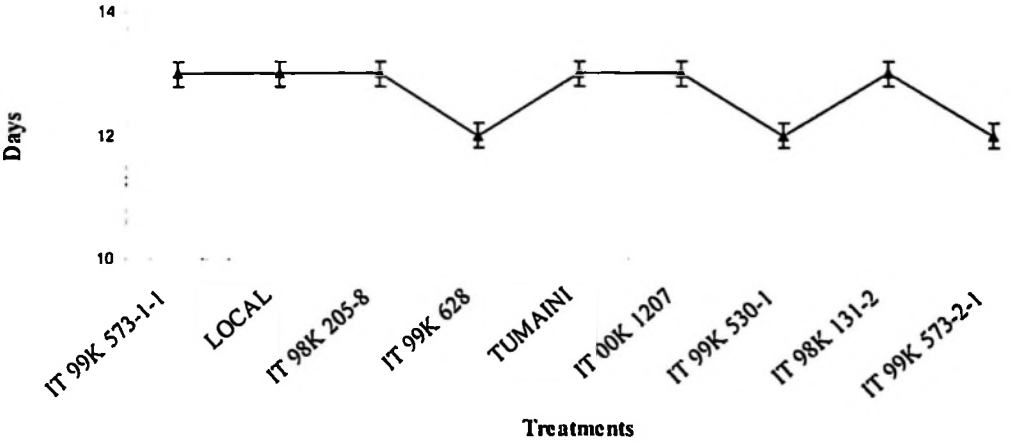

Figure 7: The number of days to *Alectra* flowering

4.5.4 *Alectra* shoot biomass

Alectra plants that infested the local landraces, genotype IT 99K 628, IT 99K 530-1 and IT 99K 573-2-1 had significantly (P>0.05) higher shoots biomass compared to the plants that infested the standard check variety (Tumaini) and other genotypes tested (Fig. 8).

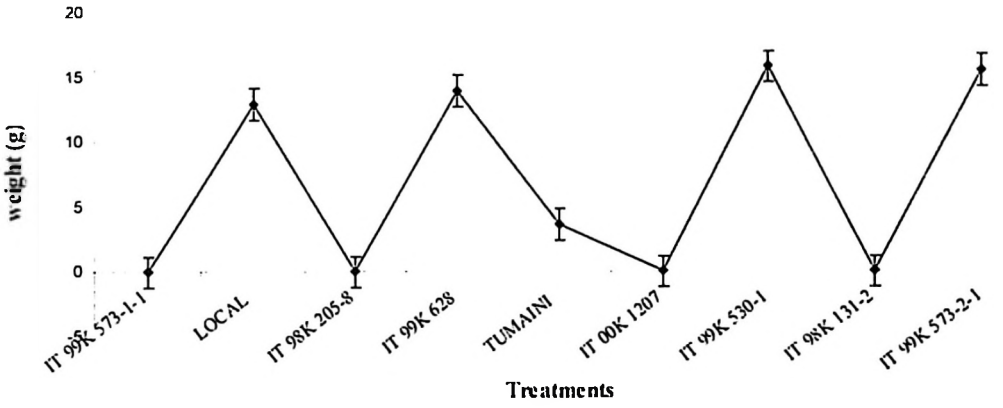

Figure 8: *Alectra* shoot Biomass

4.6 Correlation Matrix of Yield Components of Cowpea and *Alectra* Damage yndrome

The correlation matrix of cowpea yield components and *Alectra* damage syndrome is shown in Table 8. There were highly significant positive correlations relating grain yield to 100 seed weight, Pod weight, shelling percentage and harvest index. On the contrary there was significant inverse relationship between grain yield and *Alectra* damage syndrome (Table 8). Furthermore independent variables (100 seed weight, shelling percentage, pod weight and harvest index were positively correlated; but negatively correlated to the *Alectra* damage syndrome.

Table 8: Correlation matrix between yield components and *Alectra* syndrome of cowpea

	100 Seeds weight	Pod weight	Shelling percentage	Harvest index	*Alectra* syndrome
100 Seeds weight	-				
Pod weight	0.274***				
Shelling (%)	0.417**	0.333*			
Harvest index	0.418**	0.405*	0.914***		
Alectra syndrome	-0.460**	-0.500**	-0.635***	-0.591***	
Grain yield	0.371*	0.948***	0.604***	0.624**	-0.616***

Correlation between *Alectra* syndrome and yield components (P<0.05)*; (P<0.01)**; (P<0.001)***

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effects of *Alectra vogelii* on Cowpea Growth Variables

The genotypes IT 99K 494-6, IT 99K 7-21-2-2 and IT 99K 573-2-1 which showed no symptoms of *Alectra* damage (Table 6) had relative high shoots biomass at the ninth week after sowing compared to susceptible Tumaini variety and genotype IT 99K 205-8 (Fig. 2). The trend in shoot biomass reported here is in agreement with earlier results by Alonge *et al.* (2001a) who noted that the effect of *Alectra* infestation on cowpea shoot growth was more apparent between 7 and 9 weeks after sowing (WAS), a period of flower initiation and the first phase of pod development. The rate of assimilation may depend on the sink-activity since there has to be a balance between production and consumption of assimilates implying that, under high sink-activity due to parasite infestation, the rate of photosynthesis will surpass sink-activity (Borg and Van Ast, 1991).

Results from the field also revealed that, the genotype IT 99K 7-21-2-2 at 7 and 9 WAS allocated more biomass to the roots compared to the local variety (Tumaini), the local landraces and genotype IT 99K 628 (Fig. 3). This result is similar with that of Lagoke *et al.* (1991), who reported increased root dry matter production of most cowpea varieties at 5 and 7 week after planting (WAP). However, at 9 WAP in every trial, a minimum of 8 varieties had their root dry matter production reduced due to *Alectra* inoculation. The reduction in the root growth of most cowpea varieties in this study could also be attributed firstly to inadequacy of phosphorus as shown in Table 2. From studies in the laboratory, Caspa (1997) reported that *Alectra* infestation reduced phosphorus and iron content of cowpea varieties TVX 3236 and

SAMPEA 7 root at 7 and 9 WAP. Phosphorus has been reported to stimulate root and plant growth, as well as influence the general efficiency of the *Rhizobium* legume symbiosis (Robinson *et al.*, 1981).

The shoot to root ratio of the local landrace was low compared to the genotypes IT 99K 494-6 as observed at 7 WAS (Table 4), this results are similar to those observed in the case of root biomass (Fig. 3). Rambakudzibga *et al.* (2002) similarly noted that *Alectra vogelii* infection did not decrease cowpea biomass production, but significantly altered biomass partitioning by increasing the proportion of root biomass. These results imply that genotypes which succumbed to *Alectra* damage allocated more dry matter (Photosynthates) to the roots and hence increased the rate of nutrient uptake to cater for the loss due to *Alectra* competition. Low shoot to root ratios in parasitic weeds have also been reported in other studies (Both, 1948; Press, 1995). In these studies it was shown that apart from nutrient competition between parasite and host plant, the reduced rate of photosynthesis and reduced levels of growth hormones in the host plants were also contributing factors. The work of Alonge *et al.* (2001a), showed that *Alectra* infestation reduced root elongation, root to shoot ratio and leaf area of most cowpea varieties at vegetative growth stages.

Variations on the number of leaves per plant were observed at 9 WAS when genotype IT 99K 494-6 differed significantly ($P>0.05$) from genotype IT 98K 205-8 (Table 5). This result is consistent with the report of Alonge *et al.* (2001a) who noted that *Alectra* infestation generally, reduced the leaf area of most of the cowpea varieties and also similar trend in the number of leaves per plant between resistance and highly susceptible cowpea varieties have been reported by Makoko (2007). The

observed trend in the number of leaves per plant in this study can be explained in terms of leaves nutritional importance of the genotypes used. In Africa, humans consume the young cowpea leaves as they are rich in nutrients and fibre, therefore, though cowpea genotypes such as local landrace and genotype IT 99K 628 had similar number of leaves with resistant genotypes such as IT 99K 494-6, IT 99k 7-21-2-2, IT 97K 568-18 and IT 99K 573-2-1 the former would not serve this purpose as the leaves were extensive blotched and scorched which subsequently turned brown and necrotic.

Cowpea genotypes IT 99K 494-6, IT 99k 7-21-2-2 and IT 97K 568-18 which were not affected by *Alectra* damage (Table 6) showed an increase in plant height compared to the Local landrace, Tumaini, IT 99K 628, IT 00K 1207, IT 99K 573-2-1 and IT 99K 530-1 (Fig. 4). This trend implies that *Alectra* susceptible cowpea genotypes stimulated plant height during early growth stages but were severely affected at later growth stages. The rate of assimilation (photosynthesis) may depend on the sink-activity/availability since there has to be a balance between production and consumption of assimilates (Borg and Van Ast, 1991). Stimulation of susceptible cultivars to increase in Plant height at early stages and resistance cultivars at a later growth stage suggest that the system works in favour of the host plant when the infestation of *Alectra* is low or when the sink demand is low (Graves *et al.*, 1992).

5.2 Effects of *Alectra vogelii* on Cowpea Yield

Non significant differences observed in the number of pods and pod length in this work is in contrast to the results reported by Makoko (2007) who noted that *Alectra* susceptible cowpea cultivars such as Tumain had very few pods and sometimes. under severe *Alectra* infestation did not form pods at all. The trend observed in this work implied that the effect due to *Alectra* infestation that began at 7 WAS (Fig. 5) under Dodoma soil conditions did not occur during flowering. which started at 5 WAS (Table 6) and pod initiation of most genotype tested. It was indicated earlier (Kropf *et al.*, 1992) that the relative emergence time is a critical factor next to weed density.

The current study reveals that genotypes IT 99K 573-1-1 and IT 99K 628 were succumbed to *Alectra* damage under field conditions which is in contrast to Makoko's (2007) report. These results can be due to the fact that under field conditions the cowpeas were exposed to other biotic and abiotic factors which have an effect on the plants' ability to withstand *A.vogelii* damage as opposed to the screen house. Examples of biotic factors that could affect cowpea plants include aphids and powdery mildew disease which were observed two week after sowing before they were controlled by Profenos 720 g/l applied at the rate of 0.72 kg a-i/ha and metalaxy 40 g/kg + mancozeb 640 g/kg applied at the rate of 2.5 kg a-i/ha, respectively. Abiotic factors that were experienced include temperature. humidity and drought (Table 3). The drought condition occurred in February 2010 caused severe plant death in some experimental plots. Hence the numbers of plants were reduced from 40 plants (Fig. 1) to 26 and 28 plants in the plots planted with cowpea genotypes IT 00K 1207 and IT 99K 628 respectively.

Earlier reports by Parker and Riches (1993) indicated that cowpea genotypes from different sources react differently to A. *vogelii* strains from different areas; Riches *et al.* (1992) also showed that, there was a host preference among various *Alectra* strains. Hence, the results observed in this study to a large extent, could be attributed to a variation of *Alectra* strains between Nigeria and Tanzania. These results suggest that IITA cowpea genotypes IT 99K 494-6, IT 99k 7-21-2-2, IT 97K 568-18 and IT 99K 573-2-1 could form a selection pool of cowpea genotypes that could be used under Dodoma conditions to ensure reduced risk resulting from *A. vogelii* infestation.

Tumaini variety had high number of seeds per pod (Table 7) and low root biomass (Fig. 3) as unlike other varieties which had high root biomass that resulted into high shoot vegetative growth (Fig. 4) than pods grain filling (Table 7). However, this phenomenon is in contrast with the observation of Alonge *et al.* (2001b) who noted that *Alectra* infestation resulted in higher reduction of grain yield, yield components and grain total soluble carbohydrate (TSC) content in most of the late than early planted cowpea varieties. The high seed number per pod shown by *Alectra* damaged genotypes were then, however, offset by relatively small grain size and low shelling and harvest indices.

The observed low harvest index in *Alectra* damaged genotypes is an indication that with similar number of pods per plant, resistant genotypes allocated more resources to the seeds rather than shoots. This implies that, in *Alectra* infected genotypes, more resources were needed to support photosynthesis to cater for increased sink demand due to the parasite. In other studies where several leguminous crops

including cowpea were used. Kabambe *et al.* (2008) reported similarly significant ($P < 0.05$) reduction in plant dry mass, grain weight, and pod number due to *Alectra* infection.

In Tanzania, yield losses of up to 50% have been reported (Mbwaga *et al.*, 2000 as sited by Kabambe *et al.*, 2008). Yield losses of comparable magnitude due to *Alectra* infestation have been reported including a total crop loss in parts of Kenya and in Botswana (Bagnall- Oakley *et al.*, 1991). Losses in susceptible cultivars of 80 – 100% have been reported (Riches, 1989). The low grain yield of *Alectra* damaged genotypes observed in this study could be attributed to the reduced root and shoot growth exhibited by susceptible genotypes during vegetative growth. Although the reduction in host photosynthetic capacity probably contributes to lower host productivity, it was noted that it is the dependence of these parasites on the host for carbon which is the major factor leading to reduced grain yield (Riches, 2002).

On the other hand, non *Alectra* damaged genotype IT 99K 573-2-1 produced significantly low grain yield compared to that of *Alectra* damaged genotypes. Such observation has also been reported in *Alectra* resistant genotype B301, IT90K-76 and IT90K-59 (Alonge *et al.*, 2001b). The authors attributed this trend to the low root development which resulted in low nitrogen and nutrients uptake. In relation to the fact that *Alectra* seed contains some toxic chemicals which might be leaked into the soil and affect the root growth without showing physical damage in the crop shoots. The results also indicated that higher number of *Alectra* (Fig. 6) had increased photoynthate allocation to *Alectra* plant (Fig. 9) than cowpea crop

development and *Alectra* biomass increased compared to crop performance. The results observed in this work is contrary to that of Van Ast *et al.* (2005) who reported a non-linear relationship between *Striga hermonthica* biomass and grain production in sorghum that, reducing *Striga* infection will not automatically result in an increased sorghum yield.

5.3 *Alectra vogelii* Growth Variables

In this study, *Alectra* infestation started at 7 WAS whereby the local landrace and the genotype IT 99K 628 were highly infested with *Alectra* as they hosted large amount of *Alectra* plants (7 *Alectra* plants and 7 *Alectra* plants, respectively) compared to genotypes IT 98K 205-8 and IT 00K 1207 (Fig. 6). The higher number of *Alectra* plants has resulted into low root biomass (Fig. 3) in the genotype IT 99K 628 and the local landrace compared to other genotypes. It has also been noted in Table 7 that, the highly infested local landraces and genotype IT 99K 628 had low grain yield 664.3 kg/ha and 944 kg/ha, respectively compared to the less infested genotypes IT 98K 205-8 and IT 00K 1207 that had the yield of 1172 kg/ha and 1283.7 kg/ha, respectively. The reduction in grain yield due to high *Alectra* shoots per plant was also reported by Lagoke *et al.* (1991) from a field experiment and Makoko (2007) from screen house experiments.

At 10 weeks after sowing the *Alectra* plants that infested the local landraces, genotype IT 99K 628, IT 99K 530-1 and IT 99K 573-2-1 had significantly ($P>0.05$) higher shoots biomass compared to the plants that infested the standard check variety (Tumaini) and other IITA genotypes (Fig. 8). Similar results were reported in sorghum infestation by *Striga hermonthica* (Van Ast *et al.*, 2005). The low *Alectra*

biomass to other cowpea genotypes could be due to death of *Alectra* plants that was observed at 10 WAS. Similar observation was reported by Alonge *et al.* (2001a) on heavily infested cowpea varieties. The authors attributed this to the intraspecific competition for the host nutrient and water.

As observed from Table 8 *Alectra* syndrome showed highly negative correlation with shelling percentage (r = -0.635, P = 0.000), harvest index (r = -0.591, P = 0.000) and weight of grains (r = -0.616, P = 0.000). This implies that as the *Alectra* plants increased parasitic relationship with cowpea plants, more photosynthate was allocated to *Alectra* rather than cowpea crop development, which eventually results into reduced grain weight and pod filling. Reduced grain weight and other yield components due to *Alectra* infestation have been reported by Mugabe (1983) and Mbwaga, *et al.* (2007).

Conclusively, this study showed that, in most of the cowpea varieties *Alectra* infestation tended to stimulate the root and shoot growth at 5 WAS depending on the degree of infestation but reduced it at 9 WAS. The plant height, shoots and roots biomass, yields and yield components of cowpeas were generally reduced by *Alectra* infestation. Finally the results confirmed that genotypes IT 99K 494-6, IT 99k 7-21-2-2, IT 97K 568-18 and IT 99K 573-2-1 are resistant to *A.vogelii* strain of Dodoma soils (Tables 6, 7 and 8).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Based on the results of this study, it is concluded that;

(i) Cowpea genotypes IT 99K 494-6, IT 99K 7-21-2-2 and IT 97K 568-18 are resistant to *A.vogelii* strain of Dodoma when grown under field conditions. These genotypes showed normal growth without any symptoms of *Alectra* damage. On the other hand, genotypes IT 99K 573-1-1, IT 98K 205-8, IT 00K 1207, IT 99K 530-1, IT 98K 131-2, IT 99K 573-2-1, IT 99K 628, local landrace and Tumaini are susceptible to *Alectra* damage under similar conditions.

(ii) *Alectra* infestation interfered with crop productivity through resource allocation between shoot and roots. Most *Alectra* damaged genotypes had narrow shoot to root ratio: IT 99K 573-1-1 (0.17), IT 99K 628 (0.18), Tumaini (0.16) and local landrace (0.12) compared to resistant genotypes IT 99K 494-6 (0.30), IT 99K 7-21-2-2 (0.27) and IT 97K 568-18 (0.26) at 7 WAS (Table 4). This resulted into reduced plant height after infestation e.g. the local landrace (34.1 cm), IT 99K 628 (33.3 cm) and IT 99K 530-1 (38.5 cm) compared to resistant genotypes IT 99K 494-6 (47.6 cm), IT 99k 7-21-2-2 (54.1 cm) and IT 97K 568-18 (63.2 cm) at 9 WAS (Fig 5).

(iii) Consistently, seed weight, shelling percentage and harvest index of the susceptible local landrace (10.0g, 57.5% and 0.4) and genotype IT 99K 628 (16.1g, 78.9% and 0.71), respectively were low compared to resistant

genotypes IT 99K 7-21-2-2 (23.4 g, 92.7% and 0.87) and IT 97K 568-18 (23.2 g, 96.9% and 0.94). In general these figures give an indication that *Alectra* damage had an effect on grain yield as they affect resource allocation within the crop.

(iv) At early *Alectra* growth stages, most of the assimilates are available for crop growth, hence breeding for early maturity cowpea genotypes will facilitate avoidance of peak *Alectra* photosynthate demand thus reducing the impact of the weed on crop growth.

6.2 Recommendations

(i) Genotypes IT 99K 494-6, IT 99k 7-21-2-2, and IT 97K 568-18, which exhibited *Alectra* resistance and high grain yield under field conditions can be used to constitute a genetic pool for further evaluation to enhance cowpea productivity under Dodoma conditions.

(ii) In this study the local landrace was highly susceptible to *Alectra vogelii* therefore; continuous use of local cowpea seeds for production should be avoided so as to reduce increase in *Alectra* seed bank in the soil. More over farmers should be advised to use the improved cowpea varieties that are resistant and/or tolerant to *A. vogelii.*

(iii) *Alectra* infestation was much more severe in late planted crops. Further work is needed to investigate the effect of planting time of the genotypes tested in this study so as to have clear understanding of the host parasite behavior under Dodoma conditions

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APPENDICES

Appendix 1: Sum mary of analysis of variance (ANOVA) for variable analyzed in the effect of *A. vogelii* on cowpea shoot and root growth characteristics at 5 and 6 WAS

Variables analysed	MS for factor A	MS for Error	F-value	Probability value
Number of leaves per plant	28.750	2.614	1.7692ns	0.1227
Number of branches per plant	20.2	1.838	6.1176***	0.0002
Shoots biomass	19.07	1.734	1.6544ns	0.152
Roots biomass	0.217	0.02	0.893ns	-
Plant height	109.274	9.934	4.0503**	0.0025
Leaf area index	19.88	1.808	3.6114**	0.005
Roots length	32.14	2.922	0.7876ns	-
At 6 Week after sowing				
Number of leaves per plant	112.306	10.210	1.4236ns	0.2309
Number of branches per plant	6.75	0.614	0.567ns	-
Shoots biomass	27.398	2.491	1.2196ns	0.3312
Roots biomass	2.530	0.230	2.1364ns	0.0624
Plant height	229.526	20.866	4.6724***	0.0010
Leaf area index	22.683	2.062	2.5505*	0.0296
Roots length	75.775	6.889	0.8207ns	-

MS = Mean square, A = Cowpea cultivars *, ** and *** = significant at 5%, 1% and 0.1% levels respectively, ns = non significant.

Appendix 2: Summary of analysis of variance (ANOVA) for variable analyzed in the effect of *A. vogelii* on cowpea shoot and root growth characteristics at 7, 8 and 9 WAS

Variables analysed at 7 WAS	MS for factor A	MS for Error	F-value	Probability value
Number of leaves per plant	233.417	21.220	3.9285**	0.0031
Number of branches per plant	7.639	0.694	0.604ns	-
Shoots biomass	54.083	4.917	0.7518ns	-
Roots biomass	4.35	0.395	3.0554**	0.01
Plant height	148.569	13.506	3.9272**	0.003
Leaf area index	41.792	3.799	2.0645ns	0.0712
Roots length	33.137	3.012	0.8861ns	-
At 8 Week after sowing				
Number of leaves per plant	264.306	24.028	1.1142	0.3961
Number of branches per plant	3.639	0.331	0.5622ns	-
Shoots biomass	52.244	4.749	0.5474ns	-
Roots biomass	6.504	0.591	3.5709**	0.0053
Plant height	294.935	26.812	3.8790**	0.0033
Leaf area index	43.622	3.966	3.1116**	0.01
Roots length	117.305	10.664	2.1568ns	0.0602
At 9 Week after sowing				
Number of leaves per plant	1092.333	99.303	2.5443*	0.0300
Number of branches per plant	2.556	0.232	0.4402ns	-
Shoots biomass	126.368	11.488	0.4787ns	-
Roots biomass	15.436	1.403	5.5286***	0.0003
Plant height	2340.782	212.798	3.7273**	0.0042
Leaf area index	60.318	5.483	4.6575***	0.001
Roots length	337.958	30.723	3.1536**	0.0105

MS = Mean square, A = Cowpea cultivars *, ** and *** = significant at 5%, 1% and 0.1% levels respectively, ns = non significant.

Appendix 3: Summary of analysis of variance (ANOVA) for variable analyzed in the effect of *A. vogelii* on cowpea yield component

Variables analysed	MS for factor A	MS for Error	F-value	Probability value
Days to cowpea flowering	30.222	2.747	6.5150	0.0001
Days to harvesting	157.889	14.354	2.0714	0.0703
No of seeds/pod	39.774	3.616	2.4477	0.0356
100 seed weight (g)	418.515	38.047	2.7050	0.0226
Pod weight in (kg/ha)	5670928.711	515538.974	2.6193	0.0262
Shoots weight in (kg/ha)	6039940.607	549085.510	2.9712	0.0143
Grain weight in (kg/ha)	6865052.001	624095.636	3.0705	0.0121
Shelling percentage (%)	3535.593	321.418	3.0482	0.0125
Harvest index (%)	6426.908	584.264	3.7803	0.0038
Alectra syndrome score	96.222	8.747	4.6248	0.0011

MS = Mean square, A = Cowpea cultivars *, ** and *** = significant at 5%, 1% and 0.1% levels respectively, ns = non significant