ASSESSMENT OF COWPEA *Vigna unguiculata* (L) Walp. CULTIVARS AGAINST *Alectra vogelii* (Benth) (WITCHWEED) COLLECTED FROM DODOMA, TANZANIA.

BY

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ABSTRACT

Alectra Vogelii (Alectra) (parasitic weed) damages cowpea in the semi-arid areas of Tanzania. Using the petri-dish technique, 14 genotypes from the International Institute of Tropical Agriculture (IITA), Nigeria and four from Tanzania were assessed for ability to stimulate the germination of *Alectra* as a proxy for germination stimulant production using a completely randomized design (CRD) with 4 replications. Overall 5, 6 and 7 genotypes were categorised as low, medium and high germination stimulant producer with germination of *Alectra* ranging from 16.9-27.5, 27.8-34.0 and 35.4-42.7% respectively. Genotypes in each category together with 11 'no spray' genotypes also from IITA were further subjected to *Alectra* in two sets of pot experiments in a CRD with 4 replications to investigate the parasitism of cowpea cultivar by *Alectra* at early growth stages and to evaluate growth and yield variables. Categorization of cultivars into resistant and susceptible to *Alectra* was based on number of tubercles and *Alectra* shoot length at 5 WAS; days to *Alectra* emergence, number of emerged *Alectra/*pot at 9 WAS and grain yield. All local varieties and 12 IITA's genotypes were susceptible to *Alectra* with tubercles counts/plant ranging from 20.8-45.6 compared to 35.5 in check variety Tumaini, long *Alectra* shoots (25.8-38.7mm) compared to 37.8mm in Tumaini. Susceptible cultivars also had low grain yield (0-1.5g/pot) compared to 0.13g/pot in Tumaini, early emergence of *Alectra* shoots (32.3-41.4 days after sowing (DAS) compared to 36 DAS in Tumaini) and high number of emerged *Alectra* shoots/pot (55.5-114.4) compared to 80.9 in Tumaini). For the resistant genotypes IT99K-494-6 and IT98K-205-8 had no *Alectra* shoots while IT97K-829-118, IT98K-628, IT99K-7-21-2-2, IT97K-499-35, IT99K-573-2-1, IT00K-1207, IT97K-568-18, IT98K-131-2, IT99K-573-1-1, IT98K-692 and IT 99K-530-1 had short *Alectra* shoots (3.7-15.1 mm). Resistance genotypes also had 35.4-95.7%

less number of tubercles/plant compared to Tumaini, high grain yield (2.5-9.1g/pot) and less number of emerged *Alectra* shoots/pot by 58.4-99.7% compared to Tumaini.

DECLARATION

I, BASHIR RASHID MAKOKO, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has never been submitted for a degree award in any other University.

_____ _____

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The above declaration confirmed

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Prof. K.P. Sibuga Date
(Supervisor)

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DEDICATION

This dissertation is dedicated to the memory of my late parents, Rashid Makoko Senzia and Amina Makoko.

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LIST OF ABREVIATION AND SYMBOLS

%	percent
µl	micro litre
a. i.	active ingredient
a.m.	ante meridiem (before noon)
ANOVA	analysis of variance
ARI	Agricultural Research Institute
C.V.	coefficient of variation
Ca	calcium
CEC	cation exchange capacity
cm	centimetre
CRD	Competely Randomised Design
Cu	Copper
d.m.	dry matter
DAS	Days after sowing
DAP	Days after planting
e.g.	for example
EC	electrical conductivity
Fe	iron
Fig.	Figure
g	gram
ha	hectare
i.e.	that is
IITA	International Institute of Tropical Agriculture
K	potassium

kg	kilogram
m	metre
M	molar
m. e.	miliequivalent
m.a.s.l.	metre above sea level
Max.	Maximum
Mg	magnesium
mg	milligram
Min.	Minimum
ml	milliliters
mm	millimetre
Mn	manganese
ms/cm	milliseconds/ centimetre
N	nitrogen
Na	sodium
ns	no significant difference
^{o}C	degree Celsius
OC	organic carbon
P	phosphorus
p.m.	post meridiem (after noon)
P<0.05	significant at less than 5 % level
P≤0.05	significant at less or equal to 5 % level
pH	Hydrogen ion concentration
ppm	parts per million
r	correlation coefficient

se	standard error
THSDT	Tukey’s Honest Significant Difference Test
TN	total nitrogen
TOSCI	Tanzania Official Seed Certification Institute
TTC	Triphenyl Tetrazolium Chloride
v/v	volume by volume
WAS	Weeks After Sowing

CHAPTER ONE

1.0INTRODUCTION

1.1 Background information

Alectra vogelii is a yellow witchweed that parasitises mainly grain legumes which include cowpea (*Vigna unguiculata* (L) Walp), bambara groundnut (*Vigna subterranea* (L.) Verdc.), soybean (*Glycine max* (L.) Merr.), mung bean (*Vigna radiata* (L.) Wilczek), groundnut (*Arachis hypogaea* L.) and common bean (*Phaseolus vulgaris L*.) (Bagnall-Oakeley *et al.*, 1991; Elzein and Kroschel, 2003). The parasite has its greatest impact in low-input subsistent farming systems and many farmers' fields have been blighted by *Alectra* and the damage is aggravated by poor nutrient status of the soil and unreliable rainfall (Alonge *et al*., 2001a).

The majority of species in the hemi-parasitic genus *Alectra* of the family Scrophulariaceae are found in tropical Africa and Subtropical Southern Africa within the Guinea-Sudan savanna belt (Singh and Emechebe, 1997). In Tanzania *A. vogelii* is found in Mwanza, Shinyanga, Dodoma, Iringa and Ruvuma Regions, where it has been observed to infest only cowpea resulting in crop yield loss of up to 50% under severe infestation (Mbwaga *et al.*, 2000).

1.2 Problem statement

Cowpea is one of the most widely adapted, versatile, and nutritious grain legume. The crop is grown in warm to hot regions of the world (Ehlers and Hall, 1997). Most of the highlands (above 1 500 m) in Tanzania grow common beans as a source of plant protein, while the lowlands (below 900 m) and coastal areas grow cowpea. About 50-60% of the country consists of Semi-arid areas where cowpeas but not common beans can be grown

(Price *et al.*, 1982). According to Singh *et al.* (2001), the estimated area under cowpea production in Tanzania is 145 000 ha and the yield is apparently low (317 kg/ha), compared to world average estimated at 4.2 t/ha.

Multiple field infestations by *A. vogelii* during the crop season, and its dormancy mechanisms and mode of parasitism, make 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 the small-scale farmer (Singh *et al.*, 1993). Therefore significant efforts have been put into the identification of natural sources of genetic resistance within cowpea cultivars and to the selection and breeding of improved lines as a more effective and economic means of control.

1.3 Justification of the study

Although no absolute resistance to *Striga* has been found in cereals, several sources of true resistance to *Striga gesnerioides* and *Alectra* has been identified in cowpea (Lane *et al.*, 1991a). A number of cowpea lines from The Nigeria-based International Institute of Tropical Agriculture (IITA) breeding program and other sources have been identified as having resistance to *A. vogelii* in several countries in Africa (Singh and Emechebe, 1991). However, a number of strains of the parasite exist; different sources of resistance may therefore be required for different areas. There is also a clear variation in the host range of *A. vogelii* in different regions of Africa (Parker and Riches, 1993). For example, among some populations which are able to attack both cowpea and bambara, differential attack is seen of at least one selection of each crop which is resistant in other areas. For these reasons there is a need to screen resistant cowpea cultivars against locally adapted *Alectra vogelii* strains.

1.4 Objectives

1.4.1 General objective

The overall objective of this work was to identify cowpea cultivars that are resistant and/or tolerant to *Alectra vogelii* biotypes found in Dodoma, Tanzania for the purpose of increasing cowpea yield.

1.4.2 Specific objectives

The specific objectives of this study were:

i) To identify cowpea cultivars producing low levels of *A. vogelii* germination stimulant.

ii) To evaluate growth and yield variables of selected cowpea genotypes (from IITA and varieties grown in Tanzania) for resistance and/or tolerance to *Alectra vogelii.*

iii) To investigate the parasitism of selected cowpea cultivars by *Alectra vogelii* and levels of resistance.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Botanical description

Alectra vogelii belongs to the family Scrophulariaceae and it grows up to 30-45 cm tall, often as a single stem, but sometimes branched from near to ground level. The stems and leaves are hairy. The shape of the leaves, particularly the extent of toothing along the edge of the lamina, 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 plants with five or six sharp teeth have been collected. Flowers appear singly on a short stem in the axils of upper leaves or bracts and they are bell-shaped when open. The petals are pale yellow and the flowers wither and remain covering the developing seed capsule at maturity (Plant Protection Compendium, 2004).

2.2 Biology and physiology of *A. vogelii*

2.2.1 The seeds, dispersal and germination conditions

Alectra vogelii seeds are tiny and are dispersed over long distance by wind, water and animals (Singh and Emechebe, 1997). Each capsule produces 2,000 to 3,000 seeds, and with as many as 200 to 350 capsules some 400,000 to 600,000 seeds may be produced by a single plant (Botha, 1946; Visser, 1978; cited by Parker and Riches, 1993). Riches, (1989) reported that *Alectra seeds*, will only germinate when exposed to synthetic germination stimulant or natural stimulants present normally in the root exudates of many host or non-host plants. Radicles elongate, showing a chemotropic response to concentration gradient of root exudates (Singh and Emechebe, 1997). *A. Vogelii* has no after- ripening requirement, and seed taken from mature dry capsules will germinate immediately,

following exposure to a suitable germination stimulant at a suitable temperature (Parker and Riches, 1993).

2.2.2 Conditioning, penetration and development of *A. vogelii*

Alectra vogelii seeds need to be conditioned, a treatment which sensitizes the seeds prior to germination by exposing them to a water-saturated atmosphere for some time. *Alectra* species requires a very short period of conditioning, thus will germinate within five days of adding a suitable stimulant to even dry unconditioned seed incubated at 28°C or 30°C (Visser and Johnson, 1982; Riches, 1989). However prolonged periods of conditioning do not appear to induce a wet dormancy of *A. vogelii*, for at least up to 40 days (Botha, 1948), cited by Parker and Riches, (1993). Studies by (Müller *et al.*, 1992) showed that *Alectra vogelii* seeds were sensitive to germination after 4-5 days and after 10-11 days of conditioning at the low concentration.

Radicle growth occurs largely at the root meristem during the germination of the seeds resulting in seedlings with elongated radicles. These grow to a maximum of 3 mm and need to penetrate a compatible host root within 8 to 10 days to survive (Okonkwo and Raghavan, 1982). The root cap of the *A. vogelii* is lost during post-germination growth of the radicle in host root exudates. This makes the radicular apex to be adapted to penetrate the host root. Once in contact with host roots, the radicular apex develops numerous hairs, which attach to host roots. The new host cells, together with growing *Alectra* tissues form a large haustorium uniting the parasite with tissue in the host's stele (Singh and Emechebe, 1997). The haustorium draws water; mineral nutrients and carbohydrates from the host (Elzein and Kroschel, 2003). *A. vogelii* emerges above ground four weeks after its radicle has penetrated a cowpea root. The first flowers are produced some two weeks later.

2.3 Ecology of *A. vogelii*

Environmental requirements of *A. vogelii* mirror those of its major hosts in Sub-Saharan Africa. Such environments are found in semi-arid areas, below 1500 m altitude. These areas normally receive a mean annual rainfall of 520-1 000 mm, have a mean annual temperature of 19-26ºC and mean maximum temperature of 29-38 ºC. The parasite is most commonly found in areas of mono-modal rainfall with a long dry season as in Botswana or the Guinea savannah of West Africa, and in bimodal rainfall areas in North-West and coastal Tanzania. Host crops are largely associated with free-draining sands and sandy-loams that are normally acidic and infertile (Miller *et al.*, 1989; Plant Protection Compendium, 2004). In contrary, (Johnson, 1970; Duke, 1981) reported that Cowpea is tolerant of a wide range of soil textures from sands to heavy, well-drained clays. It also adapts to a wide range of pH, but prefers slightly acid to slightly alkaline soils and in general are less tolerant to alkaline conditions.

2.4 Control of *Alectra vogelii* in cowpea

2.4.1 Cultural and mechanical control methods

Late planting is reported to reduce infestation of cowpea by *A. vogelii* in Kenya (Bagnall-Oakeley *et al.*, 1991). However, this practice could be very risky where the length of the growing season is unpredictable. In contrast, Alonge *et al*. (2001b) reported a reduction of grain yield of susceptible varieties due to *Alectra* infestation regardless of time of planting. Timely destruction of crop residues can reduce the *A. vogelii* seed bank. It was observed in Botswana, for example, that *A. vogelii* continued to emerge and seed as long as host roots remained after harvest (Parker and Riches, 1993). However given the fact that cowpea and cereals are grown as mixed crops by many farmers and cowpea is harvested a number of

weeks earlier than cereals, post-harvest cultivation to destroy cowpea roots cannot be done on time.

Trap crops are crops whose roots stimulate parasite germination but do not allow attachment and parasite development. Riches, (1989) mentioned sunflower, bambara groundnut and millet as potential trap crops of *A. vogelii* in cowpea. Riches, (1989) further reported that two consecutive seasons of trap-cropping with bambara or millet reduced the *A. vogelii* population in the following cowpea crop by 79% and 68% respectively, of that following two seasons of fallow. However, this is only feasible when parasite population is low. Catch – crops are normal hosts, which can stimulate germination and carry the parasite to maturity. Catch crops can be planted as early as possible in the season and then ploughed after parasite attachment when there is still sufficient time to plant a susceptible crop to maturity. However Lagoke *et al.* (1991) noted that with the prevailing erratic rainfall, it is very unlikely that farmers would be prepared to sacrifice part of the season to grow catch crops without any return.

2.4.2 Fertilizer use

Observation in Botswana showed that neither single superphosphate nor ammonium nitrate at recommended levels for cowpea affected the infestation level of *A. vogelii* on cowpea when applied to the current crop or as a residual treatment (Parker and Riches, 1993). In Nigeria, parasite emergence and the number of plants affected was reduced following an application of 60 kg ha^{-1} N, but cowpea yield was depressed (Maganin *et al.*, 1992). In any case, adding fertilizer N may not be a practical control option because most traditional farmers seldom use nitrogenous fertilizers on cowpea (Singh and Emechebe, 1997).

2.4.3 Chemical control

During the last two decades, some chemicals have become available for parasitic weed control (Garcia-Torres, 1998). However, lack of application technology and marginal crop selectivity particularly in mixed crop situations, limit the successful usage of herbicides in developing countries. Berner *et al.* (1994) reported that soaking cowpea seeds in an aqueous solution of imazaquine at a concentration of 3.6 mg a.i./ml for 5 minutes before planting in pots greatly reduced *Striga* and *Alectra* infection. However, the chemical was somewhat toxic to cowpea plants.

2.5 Germination stimulants

Control of parasitic weeds by this technique involves stimulation of parasite seed germination in the absence of a host. In the United States, ethylene gas has been used to stimulate *Striga asiatica* seed germination in the absence of hosts and to eradicate the parasite from farmers' fields. The technique has been tested at research level in Africa. Results achieved in Kenya indicated only 50-60 percent reduction of the seed bank However, in some parts of Africa ethylene was found to be more effective than trap crops in reducing the *Striga* seed bank. Thus, its use in heavily infested areas are likely to be highly economical (Egley *et al.*, 1990; cited by Elzein and Kroschel, 2003).

Some natural substances that stimulate *A. vogelii* seed germination have been identified including *alectrol*, isolated from cowpea root exudates (Müller *et al.*, 1992; Plant Protection Compendium, 2004). The compound is chemically very similar to strigol isolated from cotton root exudates and it was termed alectrol because of its high germination activity of seeds of *A. vogelii*. Alectrol is more active than strigol in stimulating seeds of *A. vogelii* and *Striga gesnerioides*. Cowpea has been found to produce

at least four different germination stimulants with different chromatographic behaviour (Müller *et al.*, 1992). However alectrol is the most active compound in the root exudates of cowpea plants. There are reports of possible effects of strigol and it's analogous as regulator in germination/nongermination equilibrium (Müller *et al*., 1992).

High concentration of Strigol or alectrol has been found to repeatedly inhibit germination of *Alectra* seeds. Cowpea seedlings of up to 18 days old have been found to produce large quantities of stimulants for *A. vogelii* than older plants and stimulants for *A. vogelii* are mainly produced at the root elongation zone (Müller *et al.,* 1993; Emechebe and Ahonsi, 2003). Cowpea is a genuine host for *Alectra vogelii* and *Striga gesnerioides* (Visser, 1975) and a false host for *Striga asiatica, Striga hermonthica* and *Orobanche aegyptiaca*. Thus, cowpea can be grown as trap crops to reduce soil seed bank of *Striga* species and *O. aegyptiaca*. Natural stimulants are not used as weed-control agents because their stability under soil conditions is limited and their complicated structures make their syntheses lengthy and uneconomic (Bagnall-Oakeley *et al.*, 1991; Mangnus *et al.,* 1992). Synthetic analogues of alectrol, including GR7 and GR24 are in world wide use to induce germination of parasitic weed seeds under laboratory conditions but have not been extended to use under field conditions.

2.6 Mechanism and genetic of resistance in cowpea

Resistant according to Somani (1989) is a characterstic of a host plant such that it is capable of suppressing or retarding the development of a pathogen or other injurios factor. Tolerance on the other hand (Somani, 1989) is a term used to describe the ability of the host plant to withstand unrestricted and extensive colonization by a parasite organism or virus without symptom development.

Resistance to *Striga* in sorghum is due to low stimulant production (Ramaiah *et al*., 1990). According to Heller and Wegmann, (2000), the mechanism 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 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*. (1991a, b) identified at least two mechanisms of resistance of cowpea 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, including those resistant to *A. vogelii* and *S. gesnerioides,* induced high germination percentages of *A. vogelii* and *S. gesnerioides* seeds (>70%). In the first mechanism, host tissue around invading *Striga* radicles became 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.*, 1991b). Lane *et al*. (1993) later showed that the same was true for varieties B 301 and 58-57.

The second mechanism for resistance inhibits development of parasite tubercles and stems. For example, on variety B 301, *Alectra* and *Striga* radicles penetrated host roots and formed small tubercles (Lane *et al.*, 1991a; 1993). However, these tubercles failed to develop beyond 1-2 mm in diameter and stem development was severely restricted. Atokple *et al*. (1995) reported similar observations on variety B 301. A*lectra* resistant variety B359 grown in pot formed tubercles that were 2-3 mm in diameter and stem growth was severely reduced (20-30 mm long) after 10 weeks. The hypersensitive response has been proposed as a mechanism of cowpea resistance to *S. gesnerioides* and

A. vogelii based on localized host root necrosis at the site of parasite penetration (Lane *et al.*, 1993).

The root exudates of the leguminous crop also contain inhibitory substances which prevent the post-germination elongation of *A. vogelii* radicles (Parker and Riches, 1993). This effectively prevents the penetration of cowpea roots. However the actual physiological or biochemical basis of resistance in cowpea to *A. vogelii* and *S. gesnerioides* is yet to be determined (Parker and Riches, 1993).

Genetics of resistance to *Striga* and *Alectra* in cowpea genotype B 301 according to Singh *et al*. (1993), is conditioned by a single dominant gene and duplicate dominant genes respectively. These genes are nonallelic and independent of each other. Atokple *et al*. (1995), established that moderately *Alectra* resistant cultivar, IT 81D-994 is controlled by a single major gene and the duplicate dominant genes in B 301 against *Alectra* are nonallelic to a single gene in IT 81D-994. According to Parker and Riches (1993), this implies that the single dominant resistance gene to *Striga* and a major resistance gene to *Alectra* as in IT 81D-994 are relatively easy to transfer. However, since new varieties are build with a single resistant gene, a new *Striga* or *Alectra* strain may arise which can overcome its stability in the field. Parker and Riches (1993) however noted that, the opportunity of parasitic weeds to form flowers and seeds in resistant varieties is low. There is therefore no risk of more virulent strains to build up where the resistant types are grown. On the other hand, the resulting resistance, which might be based on a combination of several resistance mechanisms, is more likely to last longer than resistances that are based on a single gene (Rubiales *et al.*, 2006).

2.7 Effect of *A. vogelii* on host and associated crop losses

Affected cowpea plants may appear wilted even before the parasite emerges aboveground. According to Singh and Emechebe (1997), plants infected by *A. vogelii* have symptoms that are similar to those of plants infected by *Striga gesnerioides*, but less drastic. The common symptoms of *Striga* infection are interveinal chlorosis, general stunting, smaller leaves, reduced number of flowers and pods. In the previous studies (Singh *et al.*, 1993), susceptible cowpea plants showed leaf chlorisis, stunted growth and partial defoliation. In cases of severe infection, straw-coloured necrotic spots develop on the lamina, followed by complete desiccation of the leaves (Emechebe *et al.*, 1991). Complete plant wilting under acute moisture deficit has been reported by Mugabe (1983). Delayed flowering, reduced number of flowers and pods all contribute to yield loss but the extent of loss depends on the susceptibility of the cultivar (Parker and Riches, 1993). In Kenya, total crop loss was reported in the 1980s in Embu District due to *A. vogelii* infestation. *A. vogelii* infection alters dry matter partitioning by increasing the proportion of root d.m. (Bagnall-Oakeley *et al.*, 1991; Rambakudzibga *et al.*, 2002). Further, Rambakudzibga *et al.* (2002) reported that total cowpea dry matter production remains unchanged as a result of *Alectra* infection, i.e. total combined plant dry matter calculated as the contribution of the individual plant tissues in the host–parasite association (cowpea roots, stems, leaves and pods and *A. vogelii* shoots). There is therefore no dry matter loss from the host: parasite association. Photosynthetic activity of *A.vogelii* is apparently only half that of a host leaf on a per gram dry mass basis. The parasite is therefore at least partly dependent on its host for photosynthates and by so doing it induces the formation of lateral roots of the host plant (Doerr *et al.*, 1977; cited by Rambakudzibga *et al.*, 2002).

Several strategies have been developed for the control of *A.vogelii*, from chemical control to cultural practices, but all without unequivocal success. Exploiting host-plant resistance in combination with cultural practices will confer to the principles of parasitic weed control three major outcomes which include reduction of seed number in the soil, prevention of new seed production and prevention of movement or transfer of seeds to non-infested areas. Efforts towards breeding for resistance against *A. vogelii* have been done for many years. However, the mechanism of resistance as to whether is due to presence of an inhibitor or absence of substrate or combination of both is not known.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Sources of *Alectra* seed and cowpea genotypes

Seeds of *A. vogelii* were collected from parasitized cowpea plants (cultivar unknown) in Dodoma three months prior to the commencement of the Laboratory experiment. *A. vogelii* seeds used in the second set of experiments were collected from the same location two weeks before establishing the experiments. *Alectra vogelii* plants with mature capsules were pulled out as completely as possible and placed in paper bags. Cowpea genotypes were supplied by IITA, Nigeria and local varieties by Ilonga Research Institute, Tanzania. This includes 14 genotypes into which *Striga gesnerioides* and/or *Alectra* resistant genes have been incorporated and eleven 'no spray' cowpea genotypes and four local varieties (Table 1).

3.2 Location

Laboratory experiments were carried out at Tanzania Official Seed Certification Institute (TOSCI) and screen house experiments at Sokoine University of Agriculture (SUA). Both TOSCI and SUA are located in Morogoro region, Tanzania, 525 m.a.s.l., latitude 6°45" South and Longitude 37°40" East.

Table 1: Cowpea genotypes evaluated

Descriptor/local name	Source	Status	Significant characteristic	Seed coat colour	100 seed weight (g)
1. IT 99k- 573-2-1	IITA	Breeding line	*Alectra* Resistant	White	23.7***
2. IT 97k-390-2	IITA	Breeding line	*Alectra* Resistant + no spray	Reddish	15.9**
3. IT 00k-835-45	IITA	Breeding line	*Alectra* Resistant	White	12.2*
4. IT 99k-494-6	IITA	Breeding line	*Alectra* Resistant + no spray	Orange	19.3**
5. IT 93k-452-1	IITA	Breeding line	*Alectra* Resistant + no spray	Yellowish-white	17.7**
6. IT 98k-628	IITA	Breeding line	*Alectra* Resistant	White	16.8**
7. IT 00k-1207	IITA	Breeding line	*Alectra* Resistant	Yellowish-white	16.4**
8. IT 99k-7-21-2-2	IITA	Breeding line	*Alectra* Resistant	White	22.5***
9. IT 99k-529-1	IITA	Breeding line	*Alectra* Resistant	Brown	22.6***
10. IT 98k-692	IITA	Breeding line	*Alectra* Resistant	Orange	19.8**
11. IT 97k-499-35	IITA	Breeding line	*Alectra* Resistant	White	18.6**
12. IT 99k-573-1-1	IITA	Breeding line	*Alectra* Resistant	White	23.8***
13. IT 03k-378-4	IITA	Breeding line	*Alectra* Resistant	Yellowish-white	23.9***
14. IT 97k-829-118	IITA	Breeding line	*Alectra* Resistant	orange	16.1**
15.Fahari(TVx1948-1F)	Tanzania	Variety		Light brown	13.9*
16.Tumaini(TVx 9-11D)	Tanzania	Variety		Light brown	12.7*
17. Vuli I (IT 82D-889)	Tanzania	Variety		Reddish	11.6*
18. Vuli II	Tanzania	Variety		Orange	12.8*
19. IT 98K-506-1	IITA	Breeding line	No spray#	White	19.7**
20. IT 98K-131-2	IITA	Breeding line	No spray	Orange	20.9***
21. IT 96D-610	IITA	Breeding line	No spray	Light brown	19.2**
22. IT 99K-530-1	IITA	Breeding line	No spray	Yellowish-white	16.4**
23. IT 98K-555-1	IITA	Breeding line	No spray	Light brown	17.8**
24. IT 98K-205-8	IITA	Breeding line	No spray	White	16.3**
25. IT 00K-1148	IITA	Breeding line	No spray	Light brown	16.4**
26. IT 90K-277-2	IITA	Breeding line	No spray	White	19.0**
27. IT 97K-1042-3	IITA	Breeding line	No spray	Reddish	17.7**
28. IT 98K-1111-1	IITA	Breeding line	No spray	White	17.5**
29. 97K-568-18	IITA	Breeding line	No spray	Orange	20.2***

- Breeding line = A plant or variety still under breeding process.
- Variety = A group of plants within a species or subspecies which share similar characteristics but differ in respect of those characteristics from other groups or varieties within the species.
- Cultivar (cv.) = An inclusive term for lines, varieties, hybrids, or selections of crops. Each cultivar is distinct from other cultivars of the same species (Stoskopf, 1981).
- Grain size; * = Small (10-15g/100 seeds); ** = Medium (15.1-20g/100 seeds); *** = Large (20.1-25g/100seeds).
- "No spray" = Cowpea genotypes bred for resistance to insects and pests.

3.3 Threshing and cleaning of *Alectra vogelii* seeds

Harvested *Alectra* plants were dried for 14 days while still in paper bags. Threshing was done by crushing the capsules gently between fingers. After threshing, the material was

screened by passing it through sieves of 600; 250 and 125 micron openings. Seeds collected on 125 micron openings were used in the laboratory and screen house experiments. The seeds were stored at room temperature which averaged 26 ^{0}C in paper envelopes.

3.4 Assessment of viability of *A. vogelii* seeds

Alectra seeds were assessed for viability before being used in the experiments, to determine the quality of a given seed lot and to ensure the use of seed material with a high quality. Viable seeds according to Kroschel (2001) are defined as those seeds, which are capable of producing normal seedlings in a germination test under favourable conditions, after dormancy has been broken. The assessment was done using 2, 3, 5-triphenyl tetrazolium chloride (TTC) using procedure described by Kroschel (2001).

3.4.1 Preparation of 2, 3, 5-triphenyl tetrazolium chloride

One g of TTC salt was dissolved in 100 ml of water. After mixing, the container with the solution was covered entirely in aluminium foil to exclude light as this solution deteriorates rapidly in light. The solution was then used freshly and excess was refrigerated for future use.

3.4.2 Viability of *A. vogelii* seed test procedure

The methodology of Kroschel (2001) was followed and is briefly described hereunder: *Alectra* seeds were surface sterilized using Sodium hypochlorite (NaOCL) by immersing the seeds in 1% NaOCL solution for one minute. In order to ensure full surface contact of solution on the seeds, the flask containing the seed was sealed and then shacked followed by washing the seeds thoroughly with water through a filter paper. Seeds were then put in

a small glass tube and 5 ml of freshly prepared 1% solution of TTC added. The tube was closed to prevent evaporation and placed in a dark incubator adjusted at 33°C for 8 days. After the incubation period, excess TTC-solution was filtered through a filter paper placed in a funnel. Afterwards 5 ml of water was added, shaked well and samples of seeds plus water were sucked with a pipette and dropped on a petri dish lined with filter paper and evaluated for viability under a dissecting microscope (20x). Viability was assessed based on the colour of the endosperm as descibed by Kroschel, (2001) and Berner *et al.,* (1997). *Alectra* seeds with red, reddish and pink endosperm were considered to be viable. Seeds with entirely white and black endosperm were considered to be non-viable.

3.5 Assessment of germination of *A. vogelii* seeds

Prior to commencement of the laboratory and screen house experiments, the seeds of *A. vogelii* were assessed for germination ability. The test was done using artificial stimulant GR24 (3-[(2,5-Dihydro-3-methy l-2-oxo-5-furanyl) oxymethylene]- 3, 3a,4, 8b-tetrahydroindeno-[1,2-b]furan-2-one), an analogue of the natural stimulant (alectrol) produced by cowpea roots.

3.5.1 Test procedure for determination of germination percent of *A. vogelii* seeds

3.5.1.1 Preconditioning of *Alectra* seeds (Prior to exposure to stimulant)

Alectra seed germination test was conducted according to method described by Kroschel (2001). Small disks (5 mm-diameter) were cut from Whatman glass microfibre (Whatman GF/A) filter papers. *Alectra* seeds were sprinkled on each disk. The disks were then placed on two layers of 9 cm diameter filter papers in a 9 cm diameter petri dish. Each petri dish was moistened with 5.0 ml sterile distilled water. The petri dishes were then sealed with

parafilm and wrapped with aluminum foil to prevent water losses and exclude light and then incubated in a dark incubator at 33 ºC for 5 days.

3.5.1.2 Stimulation of germination

Ten mg of GR24 was dissolved in 10 ml of acetone. The mixture was diluted to 1:1000 with sterile distilled water to stabilize the solution. Five ml of the germination stimulant prepared above was added to individual petri dishes containing two layers of filter paper (Whatman GF/A). Preconditioned seeds were then placed in these petri dishes. The petri dishes were then sealed with parafilm and wrapped with aluminum foil to prevent water losses and exclude light and incubated in the dark at 30 ºC for three days. Seed germination evaluation was done under a low power (x20) dissecting microscope. *Alectra* seeds were scored as germinated if the root tip (radicle) had protruded through the seed coat. Germinated seeds were calculated as the percentage of the total.

3.6 Laboratory experiment

Objective: To identify cowpea cultivars producing low levels of *A. vogelii* germination stimulant

3.6.1 Experimental procedure and treatments applied

A laboratory experiment was carried out using the cut root assay technique as described by Berner *et al.* (1997).

3.6.1.1 Sterilization of growing media and growing of cowpea cultivar seedlings

Pure construction quality sand was sterilized by heating on a metal pan using fire woods for one hour. The sand was turned frequently during heating to ensure uniform sterilization. The media was left to cool down over night before filling in pots for planting.

Seedlings of the cowpea cultivars tested were grown in sterilized sand in small plastic pots measuring 10.5 cm top diameter and 8 cm deep. Eight seeds of same cultivar were seeded per pot in a screen house. These plants were watered daily with distilled water and were grown for 18 days, after which they were removed gently from the pots and the roots washed free of sand with sterile distilled water.

3.6.1.2 Sterilization and conditioning of *Alectra* seeds

Alectra vogelii seeds were surface disinfected for one minute in an aqueous 1% NaOCL (Sodium hypochlorite) solution. The seeds were then washed with sterile distilled water and placed on 5mm diameter glass-fiber filter paper disks. Approximately 20-50 *A.vogelii* seeds were placed on each disk, and placed on two moistened (with 5.0ml of sterile distilled water) Whatman No. 1 filter papers in a sterilized petri dish (60 disks/petri dish). The petri dishes were then sealed with parafilm and wrapped with aluminum foil to prevent water losses and exclude light and then incubated in a dark incubator at 33 ^{o}C for 5 days for the purpose of preconditioning the seeds. This time coincided with 18 days growth period of the test plants above.

3.6.1.3 Preparation of root cuttings and inoculation procedure

Petri dishes lined with two layers of filter paper (Whatman GF/A) were moistened with 5.0 ml of sterile distilled water and then the disks with preconditioned *Alectra* seeds were placed around an aluminum foil ring (2 cm in diameter and 1.5 cm deep), centered in the petri dish. The disks were arranged on 4 lines forming a cross radiating from the central aluminum foil ring (Fig.2). Each line had 5 disks, with the first disk in each line touching the central ring and subsequent disks touching.

Roots of the cowpea cultivars seedlings were cut into approximately 1-cm-long pieces using a sharp surgical blade, and 1.0 g of root pieces were weighed and placed into central aluminum foil ring around which the disks with *A.vogelii* seeds had been placed. The weighed pieces of roots were placed immediately into the aluminum foil ring and 300 µl of sterile distilled water was pipetted over the root pieces to help diffuse the root exudates across the filter paper. In the negative controls, 300 µl of sterile distilled water was substituted for the root pieces while 300 µl of 10mg/l GR24 was pipetted in the positive controls. The petri dishes were then sealed with parafilm and wrapped in aluminium foil. The root pieces, controls, and parasite seeds were then incubated together at 30^{o}C for 5 days.

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Figure 1: Petri dish setup for testing cowpea cultivars in stimulating *A. vogelii* seed germination.

3.6.2 Experimental design

The experiment was a split plot in a completely randomized design (CRD) with each petri dish representing an experimental unit. Cut plant-roots of each cowpea cultivar represented the main plots and sub-plots were distance of glass fiber disk from the germination stimulant. A row of five glass-fiber disks in each petri dish was one replication, making a total of four replications per cultivar.

3.6.3 Data collection

Germination on each disk was checked on the 4^{th} day after incubation. The proportional of germinated *Alectra* seeds, out of the number of seeds on each disk in each of the petri dishes was determined by counting under a low power (x20) dissecting microscope. The confirmatory trial to check for consistence of results was conducted using the same protocol as for the first trial.

3.6.4 Data analysis and treatment means comparison

Germination percentage data obtained was transformed using arcsine before subjected to analysis of variance (ANOVA) (Gomez and Gomez, 1984). Statistical analysis was done using MSTAT-C computer statistical package (Michigan State University, 1991), and significant means separated using Tukey's test for comparison at $P \leq 0.05$. The statistical model used was:

$$\mathbf{Y_{ij} = \mu + A_i + a_i + B_j + (AB)_{ij} + e_{ij}}$$

Where: $\mathbf{Y_{ij}}$ = response, $\boldsymbol{\mu}$ = general effect, $\mathbf{A_i}$ = main factor treatment effect, **Bj** = sub factor treatment effect, A_i = main factor error, $\mathbf{(AB)_{ij}}$ = Main factor and sub factor interaction and $\mathbf{e_{ij}}$ = experimental random error.

3.7 Screen house pot experiments

Objective: **Evaluate growth and yield variables of cowpea genotypes for resistance/ tolerance to *Alectra vogelii***

The 18 cowpea cultivars tested in the laboratory were categorized into high, medium and low stimulant producers and evaluated in separate screen house experiments. The first set of screen house experiments was carried out from January to March, 2007 and repeated May to August, 2007. Eleven other cowpea lines from IITA described as “no spray” were included in the repeated experiments. Two locally grown cowpea cultivars (Vuli I and Tumaini) were included as checks in all experiments. The two were selection based on their low and high stimulant production characteristic in the laboratory experiments, respectively. Experimental procedures applied were according to Kroschel (2001) presented hereunder in summary form.

3.7.1 Growth medium, inoculation and filling the pots

Alectra free sandy loam soil (collected from SUA Horticulture Unit) and construction quality sand mixed at a ratio of 2:1 (v/v), respectively, was used as growth medium. Four-litre capacity pots (20 cm top diameter and 20 cm height) were partly filled with the medium. Similar medium required to fill the middle 11 cm portion of the pots was thoroughly mixed with 0.12 g of *A. vogelii* seeds (0.06 g of *Alectra* seed/Kg of soil). The top 2.0 cm of the pot was filled with uninfected soil (Fig. 2). Uninfected controls filled with similar soils were also included.

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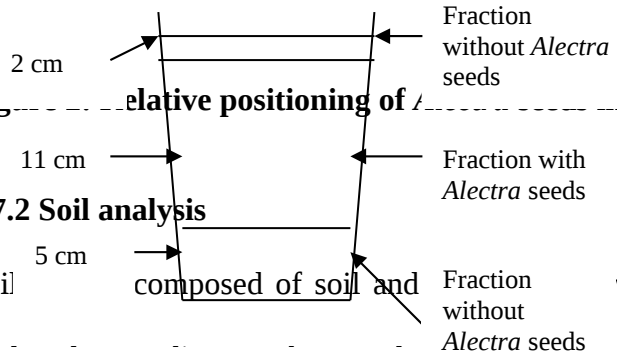

Figure 3: Relative positioning of *Alectra* seeds in pots filled with growth medium

3.7.2 Soil analysis

Soil composed of soil and which was used in the experiment was analysis available in the laboratories (Landon, 1991). Analysis was based on physical (particle size analysis) and chemical characteristics as shown in Table 2.

Table 2: Physical and chemical characteristics for pot experiments soil

Determination	Measured value (Quantity)		Rating	
	Sample1	**Sample 2**	**Sample 1**	**Sample 2**
pH in 1:2.5 H_2O	7.1	6.16	High	medium
EC(MS/cm)	0.19		Low	
Particle size				
Clay (%)	28.6	24.9		
Silt (%)	2.0	8.3		
Sand (%)	69.4	66.8		
Textural class			Sandy clay loam	Sandy clay loam
Cu (ppm)	0.66	0.93	Low	Low
Zn (ppm)	0.77	0.95	Low	Low
Mn (ppm)	22.29	26.09	Low	low
Fe (mg/Kg)	13.98	42.58	Medium	Medium
(%) TN	0.07	0.10	Low	Medium
(%) OC	1.00	0.96	Low	Low
Available P (ppm)	36.30	46.73	High	Medium
CEC (m.e./100g)	13.8	14.40	Medium	Medium
Exchangeable Bases (m.e./100g)				
Ca^{2+}	6.14	3.68	Medium	Low
Mg^{2+}	2.25	2.21	Medium	Medium
K+	0.30	0.44	Medium	Medium
Na+	0.38	0.50	Medium	Medium

Sample 1: For the first set of screen house experiments.
Sample 2: For the second set of screen house experiments.

3.7.3 Experimental design and treatments

Each cowpea cultivar comprised two sets of treatments where one was inoculated with *Alectra* seeds while the other one was uninoculated. Pots were arranged in 2^2 factorial experiments in a complete random design, replicated four times. Factors were cowpea varieties and *Alectra* seed levels (with *Alectra* seeds and without *Alectra* seeds).

3.7.4 Planting and crop management

Inoculating the soil was followed by pre-conditioning of *Alectra* seeds by watering the soil in the pots to field capacity daily for five days. Pots without *Alectra* seeds (controls) also received the same amount of water for the same period. After pre-conditioning of *Alectra*

seeds, four cowpea seeds of the test entry were planted per pot. The experimental pots were subsequently watered to field capacity throughout the period of the trials. At 10 days after sowing (DAS) cowpea plants were thinned to two per pot. Weeds other than *A. vogelii* were removed by hand pulling as they emerged.

Cowpea plants were sprayed with Karate at the product rate of (0.5L/ha) to control insects and Mancozed (maneb/zinc complex) at 2.5 kg/ha to control fungal diseases. These chemicals were applied at 6 WAS on experiment one and at 4 and 7 WAS on repeated experiments.

Table 3: Details of the chemicals applied in this study

Trade name	Formulation	Active ingredient
Karate	Emulsifiable concentrate	Lambda cyhalothrin (50g/L)
Dithane M-45	Wettable powder	Mancozed (maneb/zinc complex) (80%).

3.7.5 Data collected

3.7.5.1 On *Alectra vogelii*

Data to asses the host support for *Alectra* growth were recorded as narrated below.

i. Days to *Alectra* appearance in each pot:- Number of DAS to first emergence of *Alectra* per pot.

ii. Number of *Alectra* plants per pot:- Number of *Alectra* plants that emerged were recorded at weekly interval from six weeks after sowing to maturity of cowpea plants.

iii. Number of days to first flowering of *Alectra* plants:- The day the first flower was formed on *Alectra* plants in each pot were recorded.

iv. Number of *Alectra* plants with flowers:- *Alectra* plants that flowered were counted at the end of the experiments. This variable was recorded for second season experiments and in the experiment involving no spray cultivars only.

v. Number of dead *Alectra* plants:- *Alectra* plants that were dead in each pot were counted and recorded at weekly interval from 6 WAS.

vi. Number of unemerged *Alectra* plants: - At the end of the trial, the soil was washed off the plant roots after submerging each pot in a 20-liter bucket of water for about 5 minutes. The number of unemerged *Alectra* shoots per pot was counted and recorded.

vii. Biomass of *Alectra* plants on each pot:- At crop harvesting time, all emerged *Alectra* plants were harvested, combined with unemerged ones and oven dried together at 70^{o}C for 48 hours before weighing.

viii. *Alectra* vigour ratings:- *Aletra* were rated for their vigour at harvest using *Striga* rating scale adopted from Berner *et al.*, (1993), as narrated below (with some modifications):-

0 = No emerged *Alectra* plant
1 = Average height of *Alectra* plants <5 cm.
2 = Average height 5-10 cm.
3 = Average height 10-15 cm
4 = Average height 15-21 cm.
5 = Average height >21cm.

3.7.5.2 On Cowpea plants

(i) Plant height at 5, 6, 7, 8 and 9 weeks after seeding: - This was measured using a tape measure as the distance from the ground level to the tip of the tallest leaf when leaves are full extended. Average height of the two plants per pot was recorded in cm.

(ii) Date to onset of flowers in each treatment: - Number of DAS to formation of first flower per pot.

(iii) Number of leaves per pot: Number of leaves was counted at 8 WAS and average number of leaves per plant calculated.

(iv) Date to physiological maturity:- This was judged based on maturity of pods i.e. when 80% of pods per pot changed to straw colour.

(v) Number of pods per pot:- Number of mature pods in each pot were counted at harvesting time (Some cowpea cultivars continued to form flowers and set new pods after the first ones matured but these were ignored).

(vi) Length of pods per pot:- All harvested pods were measured in cm and the average length of pods per pot calculated.

(vii) Dry weight of cowpea plants:- Cowpea plants were separated into root and shoot (combined stems, petioles, leaves and pods when present) at ground level using a knife and each part was put into labeled envelopes, then dried in an oven as indicated above.

(viii) Root to shoot ratio of cowpea plants:- Dry weights of plant roots in each pot was divided by their respective shoot weights to determine the root to shoot ratio.

(ix) Grain yield and yield components:- The mature pods of cowpea plants in each pot were picked, counted, dried and weighed before shelling. After shelling total grain weight per pot was determined (Data is based on two plants per pot because both

plants in each pot in all experiments survived up to maturity). Grain compactness was determined for those treatments that had 10 grains and above only. Ten grains per pot was considered as maximum number since most treatments had very few grains. Harvest index and shelling percentage were determined using the following relationships:-

$$\text{Harvest index} = \frac{\text{Weight of grain (g)}}{\text{Weight of grain + shoots (g)}} \text{ x } 100$$

$$\text{Shelling \%} = \frac{\text{Total weight of grains per pot (g)}}{\text{Weight of } u\text{nshelled pods per pot (g)}} \text{ x } 100$$

(x) Host damage severity (using a scale of 1–9):- The *Alectra* "syndrome" ratings in cowpea was done at 10 WAS using *Striga* rating scale adopted from Berner *et al.*, (1993) as narrated below (with some modifications):-

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. Slight 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 scorched; 50% reduction in height; most stems collapsing; no useful pod formed; plant dead or nearly dead.

(xi) Number of nodules:- The cowpea genotypes used were grown in a separate experiment and soil washed of the roots at five weeks to determine number of nodules per plant.

3.7.5.3 Weather data

Temperature inside the screen house was recorded twice per week in the morning and afternoon and average data of each growth period computed as shown in Table 4.

Table 4: Temperature inside the screen house

Time	9.00 a.m.	9.00 a. m.	15.00 p.m.	15.00 p.m.
Temperature	Min. (^{o}C)	Max. (^{o}C)	Min. (^{o}C)	Max. (^{o}C)
January-March, 2007	17.1	30.23	23.22	36.82
May-August, 2007	14.8	23.6	18.5	30.6

3.7.6 Data analysis

Data obtained were subjected to analysis of variance (ANOVA) using MSTAT-C computer statistical package (Michigan State University, 1991), and significant means separated using Tukey's honest significant difference ($P \leq 0.05$). Linear regression analyses were conducted to determine the relationship between *Alectra* and cowpea growth parameters and yield components. The statistical model used was:

$Yij = \mu + Ai + ai + Bj + (AB)ij + eij$

Where,

Yij = response, μ = general effect, Ai = main factor effect, Bj = sub factor effect, ai = main factor error, (AB)ij = main factor and sub factor interaction, eij = sub factor effect error.

3.8 Examination of response/reaction of cowpea cultivars to *A. vogelii* infection at early stages of cowpea growth

3.8.1 Objective

To investigate the parasitism of selected cowpea cultivars by *Alectra vogelii* and levels of resistance.

3.8.2 Materials and methods

3.8.2.1 Inoculation and growing of cowpea cultivars

All cowpea cultivars that were evaluated in the pot experiments were also grown in small pots (measuring 10.5 cm top diameter and 8 cm deep) to study parasitism of selected cowpea cultivars by *Alectra vogelii* and levels of resistance at early cowpea growth stages. Growth media, rate of inoculum's per pot and pre-conditioning procedures were similar to the ones used in section 3.7. The experiment was divided into two portions. In the first portion plants were grown for two weeks, after which roots were washed to remove soil and observed under a dissecting microscope (20x) to assess attached *Alectra* seeds. A total of four plants were evaluated per each cultivar. In the second portion, plants were grown under similar conditions as above but these plants were grown for five weeks for the purpose of observing tubercles development (successful attachments).

3.8.2.2 Experimental design and treatments

Pots were arranged in a complete random design (CRD) and four plants per cultivar were evaluated where each plant represented one replication.

3.8.2.3 Data recorded

(i) Number of *Alectra* seedlings attached:- cowpea roots of each treatment were observed under the microscope at 2 WAS and attached *Alectra* seedlings per root system counted.

(ii) Number of *Alectra* seedlings with tubercles and tubercle's diameter:- At 5 WAS, the soil was washed off the plant roots and *Alectra* seedlings that formed tubercles per root system of each particular plant counted and recorded. The diameter of up to six tubercles per plant was measured and average diameter of tubercles per plant determined.

(iii) Length of *Alectra* shoots:- Up to six *Alectra* shoots per plant root system (ranging from shortest to longest) were measured on tubercles that formed shoots and average length determined.

(iv) Number of rhizobium nodules on each plant were counted and recorded.

3.8.3 Data analysis and treatment means comparison

Data obtained of number of attached *Alectra* and those that formed tubercles were logarithmic transformed, while number of nodules was transformed by square root before being subjected to analysis of variance. All *Alectra* data had multiplicative effects and some crop data followed a poisson distribution wherein the variance was equal to the mean. Such data, according to Gomez and Gomez (1984), has violated some assumptions

of the analysis of variance and should be transformed. Statistical analysis and mean separation procedures was similar to section 3.7.6. The statistical model used was:

$Yij = \mu + Aj + Bij$, where,

Yij = response, μ = overall response, Aj = treatment effect and Bij = random error.

CHAPTER FOUR

4.0 RESULTS

4.1 General observations

Temperatures in the screen house were much higher during growth period of the first set of screen house experiments than in the repeated experiments as shown in Table 4. Powdery mildew and angular leaf spots diseases, aphids, red spider mites and leaf minor insects were noticed in the screen house at both growth periods and fungicides and insecticides were applied as indicated in section 3.7.4.

In the screen house experiments death of some *Alectra* shoots was observed in some pots from nine weeks after sowing but was not consistent among affected treatments in all replications. This inconsistent confounded the *Alectra* growth variable results which consequently caused high coefficient of variation. Comparison of number of emerged *Alectra* shoots per pot among cultivars was thus best observed at 9 WAS which was a period before death of *Alectra* shoots started to occur. Cowpea cultivars were categorized into resistant and susceptible based on distinction between resistant and tolerant as defined by Somani (1989) section 2.6).

4.2 Viability and germination tests of *Alectra* seeds

Results of the viability and germination tests of *A. vogelii* seeds used in the laboratory and pot experiments are presented in Tables 5 and 6 respectively. Percentage viability of samples tested was (76.77%) and percentage germination was (81%).Viable seeds had reddish to red endosperm, while non-viable seeds had white endosperm and some had black inclusions.

Table 5: Percentage viability of *Alectra* seed

Disk number	Total number of *Alectra* seed per disk	Red and pink stained seed per disk	Lightly stained seed per disk	Percentage viability
1.	65	47	18	72.1
2.	37	28	9	75.7
3.	48	38	10	79.2
4.	44	33	11	75.0
5.	74	58	16	78.4
6.	65	53	12	81.5
7.	39	27	12	69.2
8.	53	44	9	83.0
Average	53.1	41.0	12.1	76.8

Table 6: Percentage germination of *Alectra* seed

Disk number	Number of *Alectra* seed per disk	Number of germinated *Alectra* seed per disk	Percentage germination
1.	37	31	83.8
2	21	17	81.0
3	26	21	80.8
4	25	20	80.0
5	18	15	83.3
6	20	16	80.0
7	21	16	76.2
8	28	22	78.6
9	24	20	83.3
10	35	29	82.9
Average	**25.5**	**20.7**	**81.0**

4.3 Laboratory experiment

4.3.1 Evaluation of production of *A. vogelii* germination stimulant by cowpea

Results are presented in Fig. 3. All cowpea cultivars and positive control treatment (GR24) stimulated *A. vogelii* seeds to germinate at a percentage which was significantly ($P<0.05$) higher than that of negative control treatment (distilled water). Cowpea genotypes IT 98k-692 and IT 03k-378-4 exhibited significantly lowest percentage germination of *Alectra* seeds amongst the cowpea genotypes tested. Positive control treatment (GR 24), exhibited significantly ($P<0.05$) highest percentage germination of *Alectra* seeds compared to other

treatments but it did not significantly differ with IT 97K-499-35, IT 97K-829-118, IT 99K-573-1-1 and Tumaini.

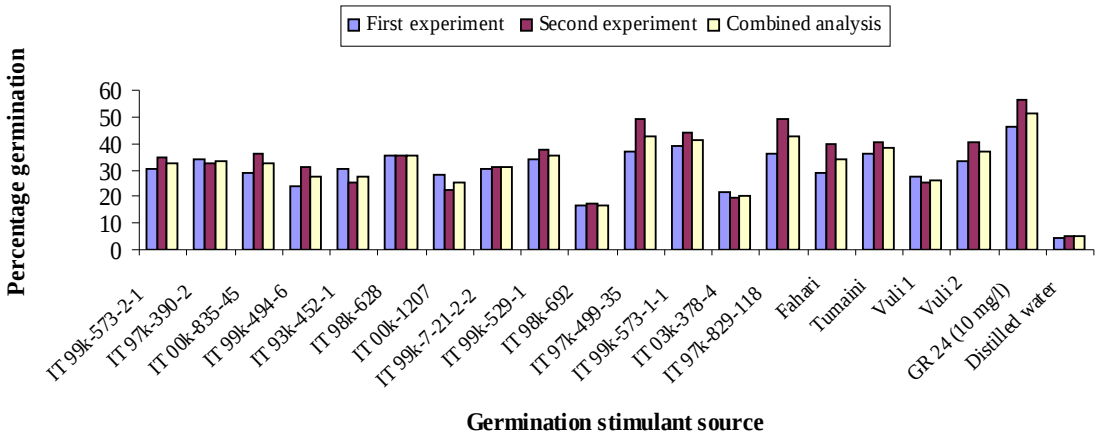

Figure 3: Germination of *Alectra vogelii* seeds in response to exposure to stimulant from excised root pieces of cowpea cultivars.

4.3.1.1 Effect of distance on *Alectra* seed germination

Germination of *A.vogelii* seeds as affected by distance of seeds from stimulant source results are presented in Table 7. Generally germination of *A. vogelii* seeds decreased significantly ($P<0.05$) with increased distance from the source of stimulant.

Table 7: Mean germination percentages of *A. vogelii* seeds exposed to root exudates of different cowpea cultivars at different distances

Disk distance	Percentage germination[#]
5 mm	39.3a
10 mm	37.7a
15 mm	32.5b
20 mm	27.8c
25 mm	20.0d
se	0.6
Cv (%)	14.9
Mean	31.4

[#]Data subjected to Arcsine transformation before ANOVA.
Means in the same column followed by the same letter(s) do not differ significantly at $P \leq 0.05$ using Tukey's Honestly Significant Difference Test (THSDT).

4.4 Screen house experiments

4.4.1 Effect of *Alectra vogelii* on growth and yield variables of *Alectra/Striga* resistant and local cowpea cultivars

4.4.1.1 Experiment 1: High stimulant production cultivars

4.4.1.1.1 *Alectra* shoots seedling emergence on high stimulant production cultivars

The number of emerged *Alectra* shoots and date to first emergence of *Alectra* per pot at six sampling dates is shown for each cultivar in Fig. 4 and Table 8 respectively. *Alectra* emerged significantly ($P<0.05$) late and increased at a slow rate in genotypes IT 97K-829-118 and IT 98K-628. Genotypes IT 97K-499-35 and IT 99K-573-1-1 supported moderate emergence of *Alectra* shoots and they increased at a moderate rate, while *Alectra* emerged early and profusely in cultivars IT 99K-529-1, Vuli II, Vuli I and Tumaini. Number of emerged *Alectra* decreased at 9 WAS in cultivars IT 99K-573-1-1 and Vuli I due to death of *Alectra* shoots.

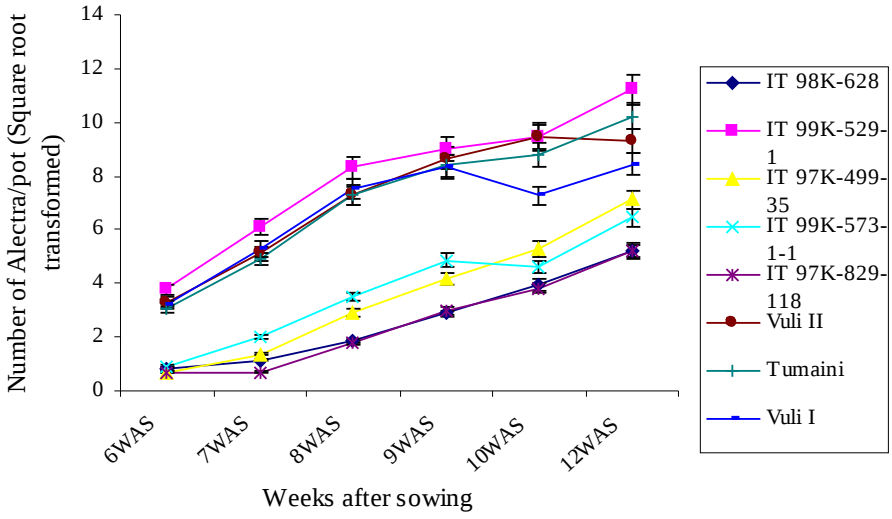

Figure 4: Mean number of emerged *Alectra* per pot at different weeks on high stimulant production cultivars.

4.4.1.1.2 *Alectra* growth variables on high stimulant production cultivars

Results of *Alectra* growth variables are presented in Table 8. Cultivars Vuli II, Tumaini, Vuli I and IT 99K-529-1 were not significantly different (P<0.05) from each other in vigour score and recorded significantly highest value compared to four other cultivars. Lowest value was recorded on genotypes IT 98K-628 and IT 97K-829-118. *Alectra* shoots in genotypes IT 99K-573-1-1 and IT 97K-829-118 did not flower up to the time of harvesting but flowered significantly (P<0.05) early in Tumaini, Vuli I, Vuli II and IT 99K-529-1 compared to IT 98K-628 and IT 97K-499-35. Cultivars Vuli II, Tumaini and IT 99K-529-1 supported significantly (P<0.05) high number of *Alectra* shoots with flowers compared to other cultivars. Cultivars, IT 99K-529-1, Vuli II and Tumaini supported significantly (P<0.05) high dry *Alectra* shoot weight compared to other cultivars. Number of unemerged *Alectra* plants at harvest did not differ significantly (P<0.05) among cowpea cultivars. Genotype IT 98K-628 exhibited lowest number of unemerged *Alectra* shoots per pot.

Table 8: Growth variables for *Alectra*

Cowpea cultivar	Number of days to first emergence of *Alectra*	*Alectra vigour score* *	Number of days to first *Alectra* flowering[+]	Number of flowered *Alectra* shoots per pot* [z]	Dry weight of *Alectra* shoots (g) *	Number of unemerged *Alectra**
IT 98K-628	55.9b	1.2c	84.6a	0.6b	1.9b	12.5
IT 99K-529-1	37.6de	3.0a	79.0b	34.9a	5.9a	19.4
IT 97K-499-35	49.3bc	1.6bc	84.3a	3.0ab	3.0ab	23.6
IT 99K-573-1-1	46.4cd	1.4c	85.5a	0.0b	1.9b	20.1
IT 97K-829-118	56.4b	1.2c	85.5a	0.0b	1.4bc	20.2
Vuli II	36.8e	2.6ab	77.8b	33.0a	5.4a	15.3
Tumaini	37.8de	3.5a	76.8b	28.7a	5.5a	18.3
Vuli I	36.1e	2.5ab	78.0b	16.7ab	3.5ab	14.3
Mean	**65.0**	**2.1**	**83.5**	**14.6**	**3.6**	**18.0**
se	**1.7**	**0.06**	**1.0**	**0.8**	**0.1**	**0.5**
Cv (%)	**7.5**	**14.7**	**3.4**	**79.5**	**30.2**	**51.2**

* Analysis were performed after square root transformation of data $[(x+0.5)^{0.5}]$.

[+] The maximum value of 85.5 days marks the end of the experiment and indicates that no flowering of *Alectra* plants occurred.

[z] Data based on one experiment.

Mean values in the same column followed by the same letter do not differ significantly at (P≤0.05) using (THSDT).

4.4.1.1.3 Cowpea plant height of high stimulant production cultivars

Plant height of cowpea cultivars at five sampling dates is presented in Table 9. A significant difference (P<0.05) among treatments in plant height was observed at 7 WAS, 8 WAS and 9 WAS but not at 5WAS and 6WAS. Uninoculated treatments of Tumaini and Vuli II were taller than inoculated treatments of these cultivars while plant height of Vuli I was not influenced by *Alectra* infestation. Inoculated treatments of five other cultivars were taller than their uninoculated treatments.

Table 9: Effect of *Alectra* on plant height

Treatment combinations	**Plant height (cm)**				
	5WAS	**6WAS**	**7WAS**	**8WAS**	**9WAS**
Alectra levels effects					
Inoculated	47.7a	56.2a	60.9a	64.6a	66.5a
Uninoculated	45.1b	51.3b	55.5b	58.6b	59.4b
Se±	0.6	1.0	1.1	1.4	1.5
Interaction between *Alectra* levels effects and cowpea cultivars					
IT 98K-628 + *Alectra*	38.1	43.8	44.5ef	44.8ef	44.8fg
IT 98K-628 – *Alectra*	34.7	37.3	37.7f	37.7f	37.7g
IT 99K-529-1 + *Alectra*	61.8	73.4	79.1ab	81.7ab	82.0ab
IT 99K-529-1 – *Alectra*	57.8	65.1	67.9bc	72.1abc	73.2a-d
IT 97K-499-35 + *Alectra*	44.5	50.0	53.6c-f	58.5cde	59.7c-g
IT 97K-499-35 – *Alectra*	40.5	45.1	46.6ef	46.8ef	46.8efg
IT 99K-573-1-1 + *Alectra*	53.8	73.0	85.1a	89.9a	90.2a
IT 99K-573-1-1 – *Alectra*	44.4	56.9	66.2bc	71.6abc	71.9a-d
IT 97K-829-118 + *Alectra*	41.7	47.1	52.6c-f	64.1b-e	77.1abc
IT 97K-829-118 – *Alectra*	39.6	43.2	45.4ef	50.9def	53.9d-g
Vuli II + *Alectra*	44.9	47.4	48.1def	49.0def	49.0efg
Vuli II – *Alectra*	44.9	49.7	54.2c-f	58.4cde	59.2c-g
Tumaini + *Alectra*	45.6	54.7	59.8cde	61.3b-e	61.3b-f
Tumaini – *Alectra*	47.9	53.7	59.9cde	63.3b-e	64.2b-f
Vuli I + *Alectra*	51.3	60.5	64.5bcd	67.4bcd	68.1b-e
Vuli I – *Alectra*	51.0	59.0	66.4bc	68.0bcd	68.0b-e
Mean	**46.4**	**53.7**	**58.2**	**61.6**	**62.9**
se	**1.8**	**2.8**	**3.2**	**3.9**	**4.2**
Cv (%)	**10.3**	**14.9**	**15.7**	**18.2**	**19.0**

Mean values in the same column followed by the same letter (s) do not differ significantly at (P≤ 0.05) using (THSDT).

4.4.1.1.4 Cowpea grain yield and yield components of high stimulant production cultivars

Results of cowpea grain yield and yield components are presented in Table 10. No pods were recorded in inoculated cultivar Tumaini. Inoculated treatments of Vuli I, Vuli II and IT 99K-529-1 had significantly ($P<0.05$) low number of pods per pot compared to other treatments. Significant difference ($P<0.05$) in number of pods per pot between inoculated and uninoculated treatments, was observed in Vuli I, Vuli II and IT 99K-529-1 but not in the other four cultivars..

Table 10: Grain yield and yield components

Treatment combination	Number of pods/pot	Pod length (cm)	Number of seeds per pod	Weight of grains/ pot (g)	10 grain weight (g) *	Shelling per centage*	Harvest Index*
***Alectra* levels effects**							
Inoculated	3.5b	7.4b	3.6b	2.9b	0.7b	93.1a	35.2b
Uninoculated	7.6a	14.1a	9.2a	9.5a	1.5a	88.7b	51.2a
Se±	0.2	0.2	0.2	0.2	0.02	0.3	0.5
Interaction between cowpea cultivars and *Alectra* levels effects							
IT 98K-628 + *Alectra*	8.1ab	10.7d	5.2e	6.9def	1.6abc	89.0e	47.8bcd
IT 98K-628 – *Alectra*	9.4a	10.8d	4.9ef	7.9cde	1.8abc	88.6e	45.6cde
IT 99K-529-1 + *Alectra*	0.9d	5.7e	2.2fg	0.4h	0.0g	94.3bcd	28.8g
IT 99K-529-1 – *Alectra*	6.1bc	15.0ab	9.0bc	10.6ab	2.1a-d	89.0e	52.7abc
IT 97K-499-35 + *Alectra*	4.3c	12.2bcd	6.1cde	4.0g	1.5abc	89.1e	38.0f
IT 97K-499-35 – *Alectra*	6.4bc	14.0abc	8.4cd	9.3abc	1.8abc	89.7de	47.0cd
IT 99K-573-1-1 + *Alectra*	6.8bc	13.9abc	5.7de	6.3efg	1.7a-d	88.5e	44.5def
IT 99K-573-1-1 - *Alectra*	8.0ab	15.3a	7.2cde	11.1a	2.0ab	89.9de	52.0abc
IT 97K-829-118 + *Alectra*	6.3bc	9.8d	6.4cde	5.2fg	1.2bcd	91.0cde	39.0ef
IT 97K-829-118 - *Alectra*	8.5ab	11.6cd	7.1cde	8.4b-e	1.5a-d	88.9e	46.0cde
Vuli II + *Alectra*	0.4d	2.1fg	1.2g	0.2h	0.1fg	98.2ab	27.8g
Vuli II – *Alectra*	7.4ab	15.3a	12.8a	9.5abc	1.0de	88.9e	55.3a
Tumaini + *Alectra*	0.0d	0.0g	0.0g	0.0h	0.0g	100a	25.5g
Tumaini – *Alectra*	7.5ab	15.2a	12.4a	10.4ab	1.2cd	87.4e	56.7a
Vuli I + *Alectra*	1.3d	4.8ef	2.3fg	0.6h	0.5ef	94.9bc	30.3g
Vuli I – *Alectra*	7.5ab	15.4a	11.8ab	9.1a-d	1.0de	87.2e	54.6ab
Mean	**5.5**	**14.8**	**6.4**	**6.2**	**1.3**	**90.9**	**43.2**
se	**0.5**	**0.5**	**0.6**	**0.5**	**0.1**	**0.9**	**1.4**
Cv (%)	**25.0**	**10.8**	**24.9**	**20.6**	**11.6**	**2.9**	**9.1**

Mean values in the same column followed by the same letter (s) do not differ significantly at ($P\leq 0.05$) using (THSDT).

*Analysis were performed after square root transformation of data $[(x+0.5)^{0.5}]$.

Inoculated treatments of IT 99K-529-1, Vuli II and Vuli I recorded lowest pod length. Significant pod length reduction due to *Alectra* infestation was only observed in cultivars, Vuli I, Vuli II and IT 99K-529-1 but not in the other four cultivars.

Inoculated treatments of Vuli I, Vuli II and IT 99K-529-1 had significantly ($P<0.05$) lowest number of seeds per pod compared to other treatments. No significant differences were recorded on number of seeds per pod due to *Alectra* infestation in IT 98K-628, IT 97K-499-35, IT 99K-573-1-1 and IT 97K-829-118. Inoculated treatmenst of Vuli I, Vuli II and IT 99K-529-1 recorded significantly ($P<0.05$) lowest grain weight compared to other treatments. No grains were observed in inoculated treatment of Tumaini. Highest 10 grain weight was recorded in uninoculated treatment of genotype IT 99K-529-1 and it did not significantly differ ($P<0.05$) with 10 other treatments. Uninoculated treatments of IT 99K-529-1, Vuli II, Tumaini and Vuli I had significantly ($P<0.05$) high shelling percentages compared to other treatments. Inoculated treatments of IT 99K-529-1, Vuli II, Tumaini and Vuli I had significantly ($P<0.05$) lowest harvest index compared to other treatments.

4.4.1.1.5 Other cowpea growth variables of high stimulant production cultivars

Results of other cowpea growth variables are presented in Table 11. Numbers of leaves per plant were reduced due to *Alectra* infestation in Vuli I and Vuli II while in other six cultivars it was increased. Inoculated treatments of Vuli II and Tumaini flowered significantly ($P<0.05$) late compared to other treatments except inoculated treatment of Vuli I. Cultivars, Vuli II, Vuli I and Tumaini recorded significantly ($P<0.05$) high damage score compared to other cultivars while IT 99K-529-1 had significantly moderate damage score. A significantly ($P<0.05$) late maturity was observed in the inoculated treatments of Tumaini, Vuli II and IT 99K-529-1 compared to other treatments. Other treatments

matured relatively early and they did not significantly differ among themselves. Inoculated treatments of all cultivars did not significantly differ (P<0.05) with their uninoculated treatments in weight of shoots per pot except IT 99K-529-1.

Table 11: Other growth variables

Treatment combination	Number of leaves per plant[ᶻ]	Days to cowpea flowering	Cowpea damage syndrome (10 WAS)	Days to physiological maturity[±]	Weight of shoots/pot (g) *	Weight of roots/pot (g) *	Shoot to Root ratio*
***Alectra* levels effects**							
Inoculated	9.0a	50.6a	4.3a	76.0a	7.7b	7.8a	0.4b
Uninoculated	8.5b	44.5b	1.0b	72.1b	9.4a	3.1b	2.2a
Se±	0.2	0.9	0.02	0.5	0.2	0.1	0.03
Interaction between cowpea cultivars and *Alectra* levels effects							
IT 98K-628 + *Alectra*	10.1abc	38.8c	2.35cd	70.4c	8.1cde	7.9	0.6
IT 98K-628 – *Alectra*	8.1cd	39.5c	1.0e	69.3c	11.5abc	3.9	2.3
IT 99K-529-1 + *Alectra*	8.1cd	42.5c	5.4b	76.3bc	4.9ef	9.9	0.1
IT 99K-529-1 – *Alectra*	7.6d	41.8c	1.0e	71.1c	8.7bcd	2.9	2.3
IT 97K-499-35 + *Alectra*	9.1a-d	47.5bc	2.6c	74.4c	11.7abc	12.9	0.4
IT 97K-499-35 – *Alectra*	8.5bcd	45.9bc	1.0e	74.5c	12.0ab	4.6	1.2
IT 99K-573-1-1 + *Alectra*	10.8ab	43.0bc	1.9d	71.8c	10.0bcd	8.5	0.8
IT 99K-573-1-1 - *Alectra*	9.0a-d	43.8bc	1.0e	71.8c	9.6bcd	2.9	2.5
IT 97K-829-118 + *Alectra*	11.4a	44.5bc	1.9d	73.6c	14.4a	10.8	0.8
IT 97K-829-118 - *Alectra*	10.3abc	44.1bc	1.0e	72.8c	12.0ab	4.3	2.2
Vuli II + *Alectra*	7.3d	64.5a	7.0a	81.8ab	3.9f	7.1	0.2
Vuli II – *Alectra*	8.3cd	50.6bc	1.0e	75.6bc	7.4def	2.1	2.2
Tumaini + *Alectra*	8.5bcd	67.9a	6.9a	85.5a	4.4f	9.2	0.02
Tumaini – *Alectra*	8.4bcd	46.1bc	1.0e	71.4c	7.3def	2.7	1.6
Vuli I + *Alectra*	6.8d	56.5ab	6.6a	74.4c	4.3f	5.9	0.3
Vuli I – *Alectra*	8.0cd	44.4bc	1.0e	70.8c	6.6def	2.0	2.5
Mean	**8.8**	**47.6**	**2.7**	**74.1**	**8.6**	**5.6**	**1.2**
se	**0.5**	**2.7**	**0.1**	**1.4**	**0.7**	**0.2**	**0.1**
Cv (%)	**10.4**	**15.9**	**12.0**	**5.2**	**23.2**	**20.2**	**17.3**

Mean values in the same column followed by the same letter (s) do not differ significantly at (P≤ 0.05) using (THSDT).

*Analysis were performed after square root transformation of data $[(x+0.5)^{0.5}]$.

[ᶻ]Analysis is based on one experiment data.

[±]Maximum days of 85.5 days mark the end of the experiment and indicate that no pods were formed since maturity was based on pods condition.

Weight of shoots in genotypes IT 99K-573-1-1 and IT 97K-829-118 were increased due to *Alectra* infestation though not significantly different (P<0.05) from their uninoculated treatments. Weight of cowpea roots per pot was high in inoculated treatments compared to

uninoculated treatments of each cultivar though not significantly different (P<0.05). Shoot to root ratio was not significantly different among treatments but was low in inoculated treatments of IT 99K-529-1, Vuli II and Tumaini compared to other treatments.

4.4.1.1.6 Correlation matrix of high stimulant production cultivars

The correlation matrix for *Alectra* growth and cowpea yield characteristics are presented in Table 12. Days to *Alectra* emergence showed high positive significant correlation with all yield components, while number of *Alectra* at harvest and weight of *Alectra* shoots showed negative significant correlation with all yield components. Number of *Alectra* at harvest gave highest positive correlation with weight of *Alectra* shoots (r = 0.94, P = 0.000).

Table 12: Correlation matrix between *Alectra* growth and yield characteristics of high stimulant production cowpea cultivars

	1[t]	2	3	4	5	6	7	8	9
1[t]	-								
2	-0.70***								
3	-0.724***	0.94***							
4	-0.35***	0.451***	0.483***						
5	-0.24**	0.427***	0.391***	0.455***					
6	0.741***	-0.648***	-0.676***	-0.52***	-0.301**				
7	0.729***	-0.733***	-0.736***	-0.566***	-0.488***	0.716***			
8	0.742***	-0.651***	-0.667***	-0.373***	-0.326***	0.564***	0.866***		
9	0.872***	-0.694***	-0.729***	-0.431***	-0.277**	0.846***	0.829***	0.775***	
10	0.605***	-0.656***	-0.68***	-0.548***	-0.417***	0.684***	0.711***	0.489***	0.714***

Significant regression correlation between cowpea and *Alectra* variables (P<0.05)*; (P<0.01)**; (P<0.001)***

[t] Variables

1 = Days to *Alectra* emergence
2 = Number of *Alectra* at harvest
3 = Weight of *Alectra* shoots
4 = Days to cowpea flowering
5 = Days to physiological maturity
6 = Number of pods/pot
7 = Pod length
8 = Number of seeds per pod
9 = weight of grains/pot
10 = 10 grains weight

4.4.1.2 Experiment 2: Medium stimulant production cultivars

4.4.1.2.1 *Alectra* shoots seedling emergence on medium stimulant production cultivars

The number of emerged *Alectra* shoots and date to first emergence of *Alectra* per pot at six sampling dates is shown for each cultivar in Fig. 5 and Table 13 respectively. *Alectra* emerged significantly ($P<0.05$) late and increased at a very slow rate in genotype IT 99K-7-21-2-2 compared to other cultivars. Genotype IT 99K-573-2-1 supported moderate emergence but increased rapidly from 8 WAS. *Alectra* emerged early and profusely in six other cultivars (IT 97K-390-2, IT 00K-835-45, IT 93K-452-1, Fahari Tumaini and Vuli I).

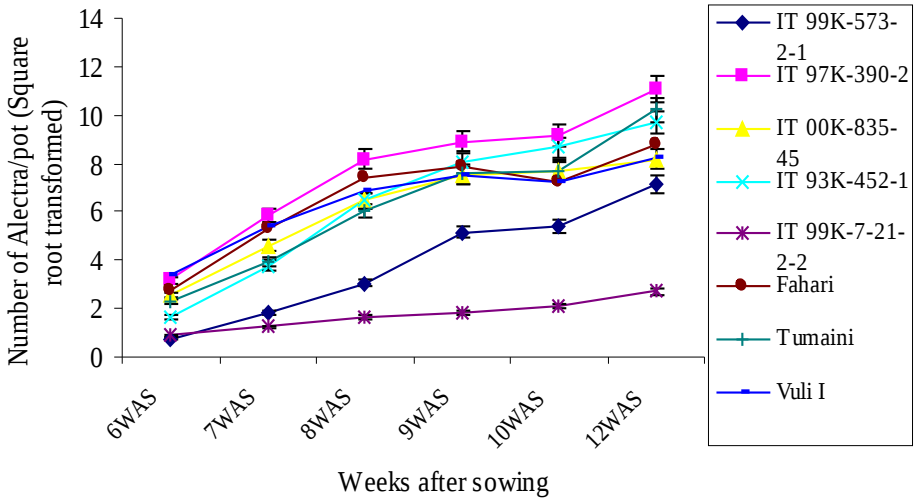

Figure 5: Mean number of emerged *Alectra* per pot at different weeks on medium stimulant production cultivars.

4.4.1.2.2 *Alectra* growth variables on medium stimulant production cultivars

Results on growth variables for *Alectra* are presented in Table 13. Genotype IT 99K-7-21-2-2 had significantly ($P<0.05$) lowest *Alectra* vigour score compared to other cultivars except IT 99K-573-2-1. *Alectra* shoots in IT 99K-7-21-2-2 flowered late but it only differed significantly ($P<0.05$) with Vuli I, Tumaini and IT 97K-390-2. Genotype IT 99K-

7-21-2-2 had lowest number of flowered *Alectra* shoots but it did not significantly differ (P<0.05) with IT 99K-573-2-1, IT 00K-835-45 and IT 93K-452-1. Likewise, IT 99K-7-21-2-2 had significantly lowest dry weight of *Alectra* shoots compared to other cultivars.There was no significant difference (P<0.05) in number of unemerged *Alectra* shoots among cultivars. Lowest number of unemerged *Alectra* shoots was recorded in genotype IT 99K-7-21-2-2.

Table 13: Growth variables for *Alectra*

Cowpea cultivar	Number of days to first emergence of *Alectra*	*Alectra vigour score* *	Number of days to first *Alectra* flowering[+]	Number of flowered *Alectra* shoots per pot*[≠].	Dry weight of *Alectra* shoots (g) *	Number of unemerged *Alectra**.
IT 99K-573-2-1	44.1c	1.8bc	83.1abc	8.3bcd	2.5a	13.2
IT 97K-390-2	39.1cd	2.4ab	78.1cd	42.3ab	4.3a	15.8
IT 00K-835-45	39.3cd	2.2ab	79.9bcd	19.8abc	3.1a	19.0
IT 93K-452-1	41.4cd	2.8ab	79.8bcd	19.3abc	3.4a	28.2
IT 99K-7-21-2-2	50.9b	0.8c	84.3ab	0.6cd	0.3b	4.4
Fahari	39.1cd	2.6ab	80.6a-d	21.9ab	4.2a	13.2
Tumaini	38.0d	2.7ab	78.4cd	31.3ab	4.5a	26.0
Vuli I	37.6d	3.2a	75.9d	47.4a	3.9a	16.3
Mean	**63.3**	**2.3**	**82.8**	**2.7**	**1.3**	**2.4**
se	**1.0**	**0.1**	**1.1**	**0.7**	**0.1**	**0.5**
Cv (%)	**4.4**	**19.3**	**3.7**	**51.0**	**28.5**	**64.9**

* Analysis were performed after square root transformation of data $[(x+0.5)^{0.5}]$.

[≠]Data based on one experiment.

Mean values in the same column followed by the same letter do not differ Significantly at (P≤0.05) using (THSDT).

4.4.1.2.3 Cowpea plant height of medium stimulant production cultivars

Results on effect of *A. vogelii* on plant height of eight cowpea cultivars at five sampling dates are presented in Table 14. Across all five sampling dates, inoculated treatments of IT 00K-835-45, Fahari, Tumaini and Vuli I were shorter than uninoculated treatments of these cultivars. Plant height of IT 99K-7-21-2-2 was not affected by *Alectra* infestation Inoculated treatments of three other cultivars were taller than their respective uninoculated treatments.

Table 14: Effect of *Alectra* on plant height

Treatment combinations	Plant height (cm)				
	5WAS	**6WAS**	**7WAS**	**8WAS**	**9WAS**
***Alectra* levels effects**					
Inoculated	50.1a	56.7	59.6	61.2	61.9
Uninoculated	47.6b	54.1	59.3	61.8	62.2
Se±	0.6	0.8	0.9	1.1	1.04
Interaction between *Alectra* levels effects and cowpea cultivars effects					
IT 99k-573-2-1 + *Alectra*	49.7b	60.0bcd	65.0bcd	67.8bcd	68.0b-e
IT 99k-573-2-1 – *Alectra*	41.5bc	44.9efg	49.5ef	49.7ef	49.7fg
IT 97k-390-2+ *Alectra*	47.4bc	56.6cd	60.5b-e	62.5b-e	63.2c-f
IT 97k-390-2- *Alectra*	49.7b	55.1de	59.2b-e	61.7b-e	62.2c-f
IT 00k-835-45+ *Alectra*	66.6a	70.3ab	72.0ab	74.9ab	78.8ab
IT 00k-835-45- *Alectra*	64.1a	74.4a	80.2a	86.1a	87.2a
IT93k-452-1+ *Alectra*	59.1a	66.7abc	70.19ab	72.2ab	73.4abc
IT93k-452-1- *Alectra*	44.5bc	52.2d-g	53.9c-f	54.3def	54.4efg
IT 99k-7-21-2-2+ *Alectra*	39.3c	42.2fg	42.9f	43.3f	43.4g
IT 99k-7-21-2-2- *Alectra*	39.6c	41.3g	43.5f	44.0f	44.1g
Fahari+ *Alectra*	46.6bc	49.6d-g	51.3def	51.8ef	51.8fg
Fahari- *Alectra*	47.1bc	53.1def	63.3b-e	67.3bcd	67.9b-e
Tumaini+ *Alectra*	45.6bc	51.6d-g	54.0c-f	54.8c-f	54.8d-g
Tumaini- *Alectra*	45.6bc	52.8def	58.5b-e	61.5b-e	61.9c-f
Vuli 1+ *Alectra*	46.9bc	57.0cd	60.8b-e	62.0b-e	62.0c-f
Vuli 1- *Alectra*	49.0b	59.1cd	66.3abc	69.9bc	69.9bcd
Mean	**48.9**	**55.4**	**59.5**	**61.5**	**62.1**
se	**1.6**	**2.13**	**2.7**	**3.0**	**2.9**
Cv (%)	**9.5**	**10.9**	**12.9**	**13.7**	**13.4**

Mean values in the same column followed by the same letter (s) do not differ significantly at (P≤ 0.05) using (THSDT).

4.4.1.2.4 Cowpea grain yield and yield components of medium stimulant production cultivars

Results of cowpea grain yield and yield components are presented in Table 15. No pods were recorded in inoculated treatment of variety Fahari. Lowest number of pods per pot was recorded in inoculated treatment of cultivar IT 97K-390-2, IT 00K-835-45, Tumaini and Vuli I and they were significantly different (P<0.05) with other treatments. Significant number of pods reduction due to *Alectra* infestation was observed in all cultivars except in genotypes IT 99K-573-2-1 and IT 99K-7-21-2-2. No pods were recorded in inoculated treatment of Fahari. Significantly (P<0.05) reduction in pod length due to *Alectra*

infestation in each individual cultivar was observed in all cultivars except in IT 93K-452-1 and IT 99K-7-21-2-2. Likewise, no seeds were recorded in inoculated treatment of Fahari. Inoculated treatments of IT 97K-390-2, IT 00K-835-45, IT 93K-452-1 Tumaini and Vuli I, had significantly (P<0.05) very low number of seeds per pod compared to other treatments.

Table 15: Grain yield and yield components

Treatment combination	Number of pods/pot	Pod length (cm)	Number of seeds per pod	Weight of grains/pot (g)	10 grain weight (g) *	Shelling percentage*	Harvest Index*
***Alectra* levels effects**							
Inoculated	2.3b	6.1b	0.5b	1.9b	0.5b	94.6a	32.9b
Uninoculated	8.0a	13.9a	3.0a	9.4a	1.5a	88.9b	53.1a
Se±	0.1	0.2	0.04	0.1	0.01	0.3	0.5
Interaction between cowpea cultivars and *Alectra* levels effects							
IT 99k-573-2-1 + *Alectra*	5.6de	13.4abc	1.3f	5.1d	1.5b-e	88.0fg	43.3de
IT 99k-573-2-1 - *Alectra*	6.4cde	15.1ab	2.2de	9.9ab	1.2abc	89.2d-g	50.5abc
IT 97k-390-2+ *Alectra*	0.5g	3.9gh	0.2g	0.4e	0.1g	97.6a	28.8f
IT 97k-390-2- *Alectra*	4.9ef	16.2a	3.0bc	9.0abc	1.4c-f	88.6d-g	54.6ab
IT 00k-835-45+ *Alectra*	0.1g	1.1hi	0.02g	0.0e	0.0g	98.9a	23.8f
IT 00k-835-45- *Alectra*	14.0a	9.0de	4.2a	9.9ab	1.0ef	91.4c-f	54.6ab
IT93k-452-1+ *Alectra*	3.3f	8.0ef	0.4g	1.5e	0.8f	92.4cd	36.7e
IT93k-452-1- *Alectra*	10.3b	10.9cde	2.3cd	9.6abc	1.7a-d	92.1cde	55.7a
IT 99k-7-21-2-2+ *Alectra*	6.9cd	12.3bcd	1.5ef	7.6c	2.1ab	88.4efg	48.3bcd
IT 99k-7-21-2-2- *Alectra*	6.4cde	12.8abc	1.4f	7.9bc	2.4a	88.8d-g	47.5cd
Fahari+ *Alectra*	0.0g	0.0i	0.0g	0.0e	0.0g	99.9a	24.5f
Fahari- *Alectra*	7.3cd	15.8a	3.5ab	10.1a	1.2def	86.4g	54.0abc
Tumaini+ *Alectra*	0.6g	4.4gh	0.1g	0.3e	0.1g	97.5ab	28.6f
Tumaini- *Alectra*	6.8cde	15.5ab	3.5ab	9.3abc	1.1def	87.6fg	53.8abc
Vuli 1+ *Alectra*	1.3g	5.3fg	0.3g	0.5e	0.3g	93.6bc	29.4f
Vuli 1- *Alectra*	7.9c	15.5ab	3.6ab	9.2abc	1.1def	86.7g	53.7abc
Mean	**5.1**	**10.0**	**1.7**	**5.6**	**1.2**	**91.7**	**43.0**
se	**0.4**	**0.7**	**0.1**	**0.4**	**0.04**	**0.8**	**1.3**
Cv (%)	**20.7**	**19.1**	**23.0**	**20.2**	**11.3**	**2.4**	**8.8**

Mean values in the same column followed by the same letter (s) do not differ significantly at (P≤ 0.05) using (THSDT).
*Analysis were performed after square root transformation of data $[(x+0.5)^{0.5}]$.

Significant reduction in number of seeds per pod due to *Alectra* infestation was observed in all cultivars except in IT 99K-7-21-2-2. No grains were recorded in inoculated treatment of Fahari. Significant (P<0.05) low grain weight per pot was recorded in inoculated treatments of Vuli I, Tumaini, IT 93K-452-1, IT 97K-390-2, IT 00K-835-45 compared to other treatments. Significantly (P<0.05) low 10 grains weight was recorded in inoculated

treatments of IT 97K-390-2, Vuli I and Tumaini. All cultivars had significant 10 grain weight reduction due to *Alectra* infestation except IT 99K-573-2-1 and IT 99K-7-21-2-2. Shelling percentage was increased in inoculated treatments of all cultivars except in IT 99K-573-2-1 and IT 99K-7-21-2-2. Harvest index was significantly ($P<0.05$) reduced in all cultivars due to *Alectra* infestation except in genotype 99K-7-21-2-2.

4.4.1.2.5 Other cowpea growth variables of medium stimulant production cultivars

Results of other cowpea growth variables are presented in Table 16. Inoculated and uninoculated treatment of genotype IT 00K-835-45 had significantly ($P<0.05$) more number of leaves per plant compared to other treatments. Increase in number of leaves due to *Alectra* infestation, was observed in IT 99K-573-2-1, IT 00K-835-45 and IT 99K-7-21-2-2. Significantly ($P<0.05$) late flowering of cowpea cultivars was observed in inoculated treatments of IT 97K-390-2, IT 00K-835-45, Fahari, Tumaini and Vuli I compared to other treatments. Damage syndrome score in Vuli I, Tumaini and Fahari was significantly ($P<0.05$) high compared to other cultivars. Damage syndrome score of genotype IT 99K-7-21-2-2 was significantly ($P<0.05$) low compared to other treatments. Uninoculated treatments of all cultivars matured relatively early and no significant difference ($P<0.05$) was observed among themselves. Inoculated treatments of IT 99K-573-2-1, IT 93K-452-1 and IT 99K-7-21-2-2 did not significantly differ ($P<0.05$) with all uninoculated treatments in days to maturity. Significant ($P<0.05$) reduction in weight of shoots per pot was only observed in varieties Fahari and Tumaini. Weight of cowpea roots per pot was high in inoculated treatments compared to uninoculated treatments of each cultivar though not significantly different ($P<0.05$). Shoot to root ratio was not significantly different ($P<0.05$) among treatments but was low in inoculated treatments of IT 99K-7-21-2-2 compared to other treatments.

Table 16: Other growth variables

Treatment combinations	Number of leaves/plant[≠]	Days to cowpea flowering	Cowpea damage syndrome (10 WAS)	Days to physiological maturity[±]	Weight of shoots/pot	Weight of roots/pot*	Shoot to Root ratio*
***Alectra* levels effects**							
Inoculated	8.3	58.8a	4.7a	77.6a	5.7b	7.8a	0.5
Uninoculated	8.5	42.9b	1.0b	71.2b	7.7a	2.8b	1.2
Se±	0.2	1.0	0.1	0.4	0.2	0.1	0.03
Interaction between cowpea cultivars and *Alectra* levels effects							
IT 99k-573-2-1 + *Alectra*	9.3bc	42.5d	2.6c	70.8ef	8.9ab	9.1	0.7
IT 99k-573-2-1 - *Alectra*	7.3c	43.6d	1.0d	70.8ef	9.4ab	3.5	2.0
IT 97k-390-2+ *Alectra*	7.1c	66.0ab	4.9b	79.0bcd	4.4ef	9.0	0.1
IT 97k-390-2- *Alectra*	9.3bc	43.0d	1.0d	69.4f	7.1b-e	2.5	1.9
IT 00k-835-45+ *Alectra*	14.0a	80.5a	5.3b	83.3ab	4.9def	10.3	0.2
IT 00k-835-45- *Alectra*	12.8ab	39.9d	1.0d	69.5f	6.6b-f	2.4	2.0
IT93k-452-1+ *Alectra*	7.9c	39.8d	3.5c	72.8ef	5.3c-f	7.9	0.4
IT93k-452-1- *Alectra*	7.9c	35.6d	1.0d	74.8c-f	5.9c-f	2.7	2.1
IT 99k-7-21-2-2+ *Alectra*	7.3c	43.4d	1.5d	73.4def	9.1ab	4.9	1.3
IT 99k-7-21-2-2- *Alectra*	6.5c	45.3cd	1.0d	72.6ef	10.0a	3.3	2.2
Fahari+ *Alectra*	6.8c	72.9ab	6.5a	85.5a	4.5ef	5.5	0.6
Fahari- *Alectra*	8.6c	47.5cd	1.0d	71.3ef	7.6a-d	3.1	1.7
Tumaini+ *Alectra*	7.0c	66.6ab	6.8a	80.1abc	4.2f	9.4	0.2
Tumaini- *Alectra*	7.9c	48.5cd	1.0d	72.3ef	8.1abc	3.1	1.7
Vuli 1+ *Alectra*	7.0c	59.9bc	6.6a	76.4cde	4.7ef	7.3	0.4
Vuli 1- *Alectra*	7.8c	39.9d	1.0d	69.0f	7.0b-e	2.1	2.3
Mean	**8.4**	**50.8**	**2.9**	**74.4**	**6.7**	**5.0**	**1.1**
se	**0.6**	**2.8**	**0.2**	**1.2**	**0.5**	**0.3**	**0.1**
Cv (%)	**15.5**	**15.7**	**17.4**	**4.5**	**22.7**	**33.1**	**22.5**

Mean values in the same column followed by the same letter (s) do not differ significantly at (P≤ 0.05) using (THSDT).

*Analysis were performed after square root transformation of data $[(x+0.5)^{0.5}]$.

[≠]Analysis is based on one experiment data.

[±]Maximum days of 85.5 days mark the end of the experiment and indicate that no pods were formed since maturity was based on pods condition.

4.4.1.2.6 Correlation matrix of medium stimulant production cultivars

The correlation matrix for *Alectra* growth and cowpea yield characteristics are presented in Table 17. Days to *Alectra* emergence showed high positive significant correlation with all yield components, while number of *Alectra* at harvest and weight of *Alectra* shoots showed negative significant correlation with all yield components. Number of *Alectra* at harvest gave highest positive correlation with weight of *Alectra* shoots (r = 0.931, P = 0.000). With regard to yield components, weight of *Alectra* shoots gave highest negative correlation with weight of grains per pot (r = -0.724, P = 0.000).

Table 17: Correlation matrix between *Alectra* growth and cowpea yield characteristics of medium stimulant production cowpea cultivars

	1[t]	2	3	4	5	6	7	8	9
1[t]	-								
2	-0.697***								
3	-0.744***	0.931***							
4	-0.539***	0.57***	0.551***						
5	-0.436***	0.597***	0.584***	0.679***					
6	0.746***	-0.578***	-0.627***	-0.641***	-0.429***				
7	0.728***	-0.66***	-0.693***	-0.727***	-0.668***	0.593***			
8	0.844***	-0.599***	-0.642***	-0.532***	-0.395***	0.841***	0.707***		
9	0.894***	-0.672***	-0.724***	-0.607***	-0.45***	0.857***	0.795***	0.905***	
10	0.638***	-0.578***	-0.639***	-0.666***	-0.561***	0.636***	0.764***	0.498***	0.752***

Significant regression correlation between cowpea and *Alectra* variables (P<0.05)*; (P<0.01)**; (P<0.001)***

[t] Variables

1 = Days to *Alectra* emergence
2 = Number of *Alectra* at harvest
3 = Weight of *Alectra* shoots
4 = Days to cowpea flowering
5 = Days to physiological maturity
6 = Number of pods/pot
7 = Pod length
8 = Number of seeds per pod
9 = weight of grains/pot
10 = 10 grains weight

4.4.1.3 Experiment 3: Low stimulant production cultivars

4.4.1.3.1 *Alectra* shoots seedling emergence on Low stimulant production cultivars

The number of emerged *Alectra* shoots and date to first emergence of *Alectra* per pot at six sampling dates is shown for each cultivar in Fig. 6 and Table 18 respectively. *Alectra* emerged early and profusely in Tumaini and Vuli I and IT 03K-378-4, while only a few plants emerged significantly (P<0.05) late in IT 99K-494-6. Genotypes IT 00K-1207 and IT 98K-692 exhibited moderate emergence of *Alectra* which also increased at a moderate rate.

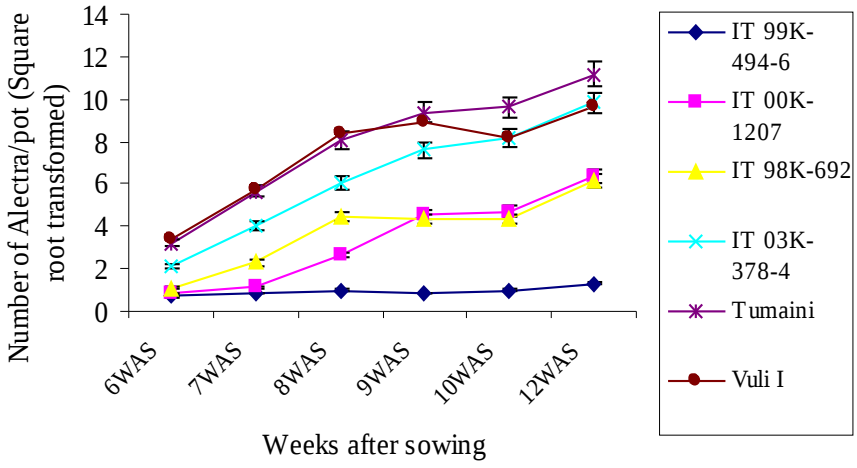

Figure 6: Mean number of emerged *Alectra* per pot at different weeks on low stimulant production cultivars.

4.4.1.3.2 *Alectra* growth variables on Low stimulant production cultivars

Results on growth variables for *Alectra* are presented in Table 18. *Alectra* shoots supported by genotype IT 99K-494-6 had significantly ($P<0.05$) low vigour score compared to other cultivars. Highest vigour score was observed on cultivar IT 03K-378-4 and Tumaini. *Alectra* shoots did not flower in genotype IT 99K-494-6 but flowered significantly ($P<0.05$) late in IT 00K-1207 and IT 98K-692 compared to three other cultivars. Significantly ($P<0.05$) high number of flowered *Alectra* shoots per pot was observed on cultivars IT 03K-378-4, Tumaini and Vuli I compared to genotype IT 00K-1207 and IT 98K-692. Genotype IT 99K-494-6 supported significantly ($P<0.05$) lowest dry *Alectra* shoot weight (0.09 g) while Tumaini supported significantly highest dry *Alectra* shoot weight (5.9 g) compared to other cultivars. Genotype IT 99K-494-6 had significantly ($P<0.05$) lowest number of unemerged *Alectra* shoots compared to other cultivars except Vuli I.

Table 18: Growth variables for *Alectra*

Cowpea cultivar	Number of days to first emergence of *Alectra*	*Alectra vigour score* *	Number of days to first *Alectra* flowering[+]	Number of flowered *Alectra* shoots per pot*[≠]	Dry weight of *Alectra* shoots (g) *	Number of unemerged *Alectra**
IT 99K-494-6	74.5a	0.2d	85.5a	0.0b	0.1d	3.1bc
IT 00K-1207	51.8b	2.1bc	82.0a	2.3b	2.7b	19.0a
IT 98K-692	48.3bc	1.8c	83.1a	6.5b	2.0bc	17.7a
IT 03K-378-4	39.0c	3.1a	77.4b	29.5a	3.6ab	28.7a
Tumaini	38.1c	3.0a	77.5b	47.5a	5.9a	19.9a
Vuli I	37.8c	2.7ab	77.6b	36.0a	4.3ab	13.4ab
Mean	**66.9**	**1.1**	**83.0**	**2.3**	**1.3**	**2.4**
se	**2.5**	**0.5**	**0.8**	**0.4**	**0.1**	**0.4**
Cv (%)	**10.6**	**112.4**	**2.7**	**34.4**	**32.3**	**48.3**

* Analysis were performed after square root transformation of data $[(x+0.5)^{0.5}]$.

[+] The maximum value of 85.5 days marks the end of the experiment and indicates that no flowering of *Alectra* plants occurred.

[≠]Data based on one experiment.

Mean values in the same column followed by the same letter do not differ significantly at ($P \leq 0.05$) using (THSDT).

4.4.1.3.3 Cowpea plant height of Low stimulant production cultivars

Results of effect of *A. vogelii* on plant height of six cowpea cultivars at five sampling dates are presented in Table 19. A significant difference ($P<0.05$) in plant height among treatments was observed at 8WAS and 9WAS but not at 5 WAS, 6 WAS and 7 WAS. Across all five sampling dates, inoculated treatments of IT 99K-494-6, IT 00K-1207 and IT 98K-692 were taller than uninoculated treatments of these cultivars, while inoculated treatments of IT 03K-378-4, Tumaini and Vuli I were shorter than their uninoculated treatments.

Table 19: Effect of *Alectra* on plant height

Treatment combinations	Plant height (cm)				
	5WAS	**6WAS**	**7WAS**	**8WAS**	**9WAS**
***Alectra* levels effects**					
Inoculated	45.2	51.0	54.4	56.4	56.8
Uninoculated	45.6	51.3	54.6	57.5	59.1
Se±	0.4	0.7	0.8	1.0	1.1
Interaction between cowpea cultivars and *Alectra* levels effects					
IT 99k-494-6 + *Alectra*	40.0	43.2	48.5	51.8b	52.3c
IT 99k-494-6 – *Alectra*	40.3	45.7	47.2	49.3b	49.3c
IT 00k-1207 + *Alectra*	47.0	50.6	53.5	56.6ab	57.9bc
IT 00k-1207 – *Alectra*	47.6	50.8	52.4	52.8b	53.1bc
IT 98k-692 + *Alectra*	48.1	54.8	58.4	60.3ab	60.3bc
IT 98k-692 – *Alectra*	44.4	49.4	51.7	51.8b	51.9c
IT 03k-378-4 + *Alectra*	43.7	49.8	51.2	51.5b	51.5c
IT 03k-378-4	45.5	50.5	52.5	57.3ab	57.4bc
Tumaini + *Alectra*	44.7	52.8	55.7	57.8ab	58.0bc
Tumaini – *Alectra*	46.7	54.1	60.1	65.9a	66.7ab
Vuli 1 + *Alectra*	47.9	55.2	59.4	60.6ab	60.8bc
Vuli 1 – *Alectra*	48.9	57.2	63.6	67.9a	76.3a
Mean	**45.4**	**51.2**	**54.5**	**57.0**	**58.0**
se	**1.0**	**1.6**	**2.0**	**2.4**	**2.8**
Cv (%)	**6.3**	**9.0**	**10.3**	**11.8**	**13.6**

Mean values in the same column followed by the same letter (s) do not differ significantly at (P≤ 0.05) using (THSDT).

4.4.1.3.4 Cowpea grain yield and yield components of Low stimulant production cultivars

Results of cowpea grain yield and yield components are presented in Table 20. Significant (P<0.05) low number of pods per pot was observed in inoculated treatments of all cultivars compared to uninoculated treatments except genotype IT 99K-494-6. Inoculated treatments of Tumaini and IT 03K-378-4 had significantly (P<0.05) low pod length compared to other treatments. Significant (P<0.05) low number of seeds per pod was recorded in inoculated treatments of Vuli I, Tumaini and IT 03K-378-4. Uninoculated treatments of all cultivars did not significantly differ (P<0.05) among themselves in weight of grains per pot however, reduction in grain weight due to *Alectra* infestation was observed in all cultivars except in IT 99K-494-6 and IT 98K-692. 10 grains weight of

inoculated treatment of IT 99K-494-6 and IT 98K-692 was significantly (P<0.05) similar to those of all uninoculated treatments. Shelling percentage was not significantly different among treatments but generally inoculated treatments of all cultivars had higher shelling percentage than uninoculated treatments. Harvest index was significantly (P<0.05) reduced in Vuli I, Tumaini and IT 03K-378-4 due to *Alectra* infestation but not in the other three genotypes.

Table 20: Grain yield and yield components

Treatment combination	Number of pods/pot	Pod length (cm)	Number of seeds per pod	Weight of grains/pot (g)	10 grain weight (g) *	Shelling percentage*	Harvest Index*
***Alectra* levels effects**							
Inoculated	3.8b	6.4b	4.0b	3.2b	0.6b	94.9	36.8b
Uninoculated	8.3a	12.8a	8.9a	9.4a	1.4a	88.3	50.5a
Se±	0.2	0.2	0.2	0.3	0.01	2.4	1.3
Interaction between cowpea cultivars and *Alectra* levels effects							
IT 99k-494-6 + *Alectra*	10.1a	11.3cd	6.8bc	9.1ab	1.4b	89.5	50.9ab
IT 99k-494-6 – *Alectra*	10.3a	11.8cd	6.9bc	9.7ab	1.4b	89.3	53.0a
IT 00k-1207 + *Alectra*	5.1c	7.4ef	6.9bc	3.0cd	0.9c	88.0	36.0bcd
IT 00k-1207 – *Alectra*	9.9a	9.9de	8.2b	9.9ab	1.3b	89.4	49.7ab
IT 98k-692 + *Alectra*	4.9c	10.9cd	5.3cd	6.1bc	1.4b	104.9	49.8ab
IT 98k-692 – *Alectra*	8.1a	13.0bc	7.5bc	7.7ab	1.4b	85.7	50.2ab
IT 03k-378-4 + *Alectra*	0.5d	1.6g	0.6e	0.2d	0.0e	96.2	21.0d
IT 03k-378-4	5.6bc	11.2cd	7.0bc	9.3ab	2.4a	91.5	44.4abc
Tumaini + *Alectra*	0.3d	2.3g	1.5e	0.1d	0.0e	97.1	31.0cd
Tumaini – *Alectra*	8.1a	15.2ab	12.3a	10.5a	1.1bc	88.8	51.8ab
Vuli 1 + *Alectra*	1.6d	5.0f	2.7de	0.8d	0.3d	93.7	32.1cd
Vuli 1 – *Alectra*	8.0ab	15.9a	11.6a	9.4ab	1.1bc	85.1	54.1a
Mean	**6.0**	**9.6**	**6.4**	**6.3**	**1.2**	91.6	43.64
se	**0.5**	**0.5**	**0.5**	**0.8**	**0.03**	5.8	3.2
Cv (%)	**22.9**	**16.1**	**23.1**	**35.6**	**6.5**	17.9	20.9

Mean values in the same column followed by the same letter (s) do not differ significantly at (P≤ 0.05) using (THSDT).
*Analysis were performed after square root transformation of data $[(x+0.5)^{0.5}]$.

4.4.1.3.5 Other cowpea growth variables of Low stimulant production cultivars

Results of other cowpea growth variables are presented in Table 21. Decrease in number of leaves due to *Alectra* infestation was observed only in Tumaini and Vuli I.Inoculated treatments of other cultivars had more leaves per plant but they did not significantly differ (P<0.05) with their respective uninoculated treatments. Genotype IT 99K-494-6 recorded

significantly (P<0.05) lowest damage score compared to other cultivars. Inoculated treatments of IT 03K-378-4 and Tumaini flowered and matured significantly (P<0.05) late compared to other treatments. Significant (P<0.05) reduction in weight of shoots per pot was only observed in genotype IT 03K-378-4. Uninoculated treatments of each cultivar had more root weight compared to their inoculated treatments though not significantly different (P<0.05). Shoot to root ratio was significantly (P<0.05) low in *Alectra* uninoculated treatments of all cultivars compared to their respective inoculated treatments except genotype IT 99K-494-6.

Table 21: Other growth variables

Treatment combination	Number of leaves per plant≠	Days to cowpea flowering	Cowpea damage syndrome (10 WAS)	Days to physiological maturity	Weight of shoots/pot (g)*	Weight of roots/pot (g) *	Shoot to root ratio*
***Alectra* levels effects**							
Inoculated	8.9a	55.8a	4.1a	76.9a	6.9b	8.0a	0.4b
Uninoculated	8.4b	47.1b	1.0b	73.5b	8.9a	2.3b	2.2a
Se±	0.2	1.1	0.1	0.4	0.2	0.1	0.03
Interaction between cowpea cultivars and *Alectra* levels effects							
IT 99k-494-6 + *Alectra*	11.0a	45.9b	1.6d	74.6cd	8.6bc	4.7	1.4b
IT 99k-494-6 – *Alectra*	9.3a-d	46.8b	1.0e	75.3cd	7.5b-e	2.4	2.3ab
IT 00k-1207 + *Alectra*	8.4b-e	47.5b	2.8c	75.4cd	10.0b	10.1	0.5c
IT 00k-1207 – *Alectra*	7.6cde	48.5b	1.0e	74.8cd	10.3b	3.2	2.6a
IT 98k-692 + *Alectra*	9.9ab	41.6b	2.6c	72.3def	5.0ef	6.7	0.3c
IT 98k-692 – *Alectra*	8.1b-e	43.0b	1.0e	69.8ef	7.5bcd	2.5	2.2ab
IT 03k-378-4 + *Alectra*	9.4a-d	76.0a	4.8b	83.4a	8.8bc	10.6	0.4c
IT 03k-378-4	8.6b-e	52.5b	1.0e	78.5bc	14.8a	5.3	2.2ab
Tumaini + *Alectra*	8.0b-e	69.3a	7.0a	81.1ab	4.4f	9.0	0.1c
Tumaini – *Alectra*	9.6abc	47.6b	1.0e	73.9de	6.6c-f	2.4	1.9ab
Vuli 1 + *Alectra*	7.0e	54.3b	6.5a	74.5cd	4.6ef	8.0	0.2c
Vuli 1 – *Alectra*	7.3de	44.4b	1.0e	69.1f	7.0c-f	2.4	2.0ab
Mean	**8.7**	**51.4**	**2.6**	**75.2**	**7.9**	**5.2**	**1.2**
se	**0.4**	**2.8**	**0.1**	**0.9**	**0.6**	**0.1**	**0.1**
Cv (%)	**9.5**	**15.3**	**13.6**	**3.3**	**20.8**	**16.6**	**15.5**

Mean values in the same column followed by the same letter (s) do not differ significantly at (P≤ 0.05) using (THSDT).

*Analysis were performed after square root transformation of data $[(x+0.5)^{0.5}]$.

≠ Analysis is based on data for one experiment

4.4.1.3.6 Correlation matrix of low stimulant production cultivars

The correlation matrix for *Alectra* growth and cowpea yield characteristics are presented in Table 22. Days to *Alectra* emergence showed positive significant correlation with all yield components, while number of *Alectra* at harvest and weight of *Alectra* shoots showed negative significant correlation with all yield components. Number of *Alectra* at harvest gave highest positive correlation with weight of *Alectra* shoots (r = 0.899, P = 0.000).

Table 22: Correlation matrix between *Alectra* growth and cowpea yield characteristics of low stimulant production cultivars

	1[t]	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1[t]	-								
2	-0.702***								
3	-0.726***	0.899***							
4	-0.447***	0.678***	0.614***						
5	-0.136ns	0.518***	0.525***	0.618***					
6	0.763***	-0.728***	-0.747***	-0.603***	-0.371***				
7	0.749***	-0.783***	-0.777***	-0.721***	-0.478***	0.686***			
8	0.699***	-0.683***	-0.657***	-0.576***	-0.326***	0.549***	0.878***		
9	0.785***	-0.643***	-0.684***	-0.503***	-0.197***	0.757***	0.76***	0.698***	
10	0.686***	-0.708***	-0.699***	-0.605***	-0.366***	0.681***	0.71***	0.533***	0.742***

Significant regression correlation between cowpea and *Alectra* variables (P<0.05)*; (P<0.01)**; (P<0.001)***

[t] Variables

1 = Days to *Alectra* emergence
2 = Number of *Alectra* at harvest
3 = Weight of *Alectra* shoots
4 = Days to cowpea flowering
5 = Days to physiological maturity
6 = Number of pods/pot
7 = Pod length
8 = Number of seeds per pod
9 = weight of grains/pot
10 = 10 grains weight

Plate 1: Effect of *Alectra* on cowpea growth and development on *Alectra/Striga* resistant genotypes.

For each of these pairs, pots on the left side are inoculated with *Alectra* and on the right side are uninoculated. A: and B: Resistant genotype, C: and D: are susceptible cultivars.
(Note the difference in cowpea plant height and number of pods between inoculated and uninoculated pots in each pair).

4.4.2 Experiment 4: Effect of *Alectra vogelii* on growth and yield variables of "no spray" cowpea genotypes

4.4.2.1 *Alectra* shoots seedling emergence on 'no spray' cowpea cultivars

The number of emerged *Alectra* shoots and date to first emergence of *Alectra* per pot at six sampling dates is shown for each cultivar in Fig. 7 and Table 23 respectively. *Alectra* shoots emerged significantly ($P<0.05$) late in genotype IT 98K-205-8 and the number increased at a very low rate at all six sampling dates. With the exception of IT 98K-506-1 and IT 98K-555-1 which supported early emergence of *Alectra* shoots, other cultivars had moderate emergence of *Alectra* shoots. *Alectra* shoots increased at a moderate rate in genotypes, IT 97K-568-18, IT 99K-530-1 and IT 98K-131-2 but at a high rate in nine other cultivars. At 10 WAS number of emerged *Alectra* shoots decreased in some cultivars due to death of *Alectra* shoots.

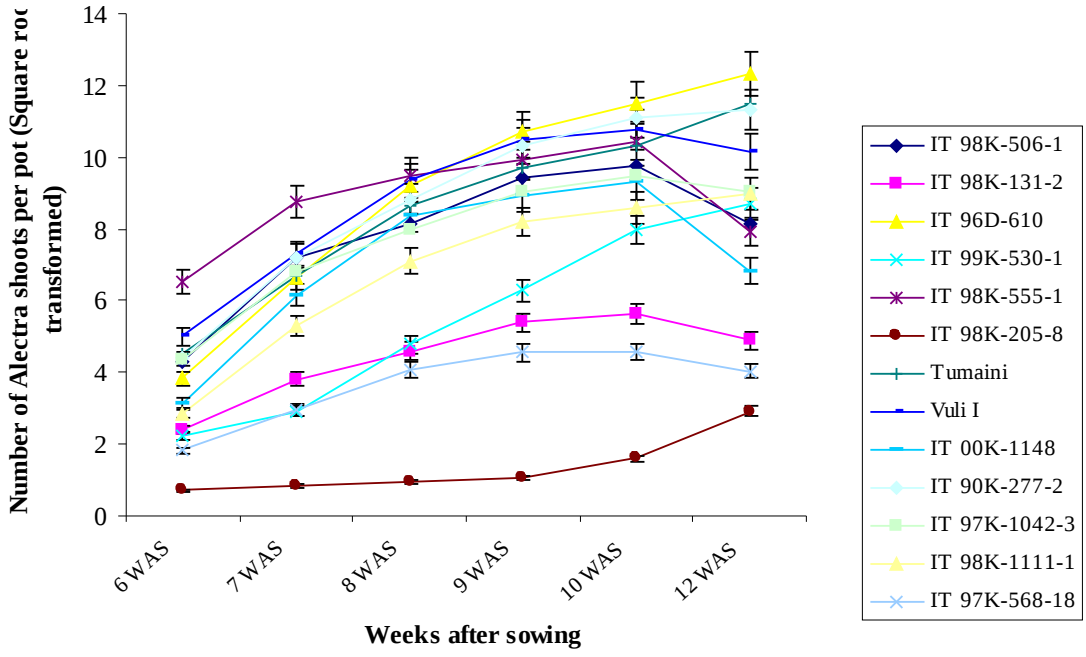

Figure 7: Mean number of emerged *Alectra* per pot at different weeks on "no spray" cowpea cultivars.

4.4.2.2 *Alectra* growth variables on 'no spray' cowpea cultivars

Alectra growth variables of 'no spray' cowpea cultivars are presented in Table 23. *Alectra* vigour score was not significantly different (P<0.05) among cowpea cultivars, however genotype IT 98K-205-8 scored lowest value. Similarly, there was no significant difference (P<0.05) in weight of dry *Alectra* shoots among cultivars. Genotype IT 98K-205-8 had less dry *Alectra* shoots weight (0.24 g) while variety Tumaini recorded highest weight (5.55 g). Cowpea cultivars did not differ significantly (P<0.05) in days to flowering of *Alectra* shoots. A single flower occurred in cultivar IT 98K-205-8 on harvesting day (87 DAS). There was no significant difference (P<0.05) in number of Flowered *Alectra* shoots. Lowest number of *Alectra* shoots with flowers was recorded in genotypes IT 98K-205-8 and IT 99K-530-1. Number of unemerged *Alectra* shoots was not significantly different (P<0.05) among cultivars. Genotype IT 98K-205-8 recorded lowest number of unemerged *Alectra* shoots per pot.

Table 23: *Alectra* growth variables on 'no spray' cowpea cultivars

Cowpea cultivar	Number of days to first emergence of *Alectra*	*Alectra vigour score* *	Number of days to first *Alectra* flowering+	Number of flowered *Alectra* shoots *	Dry weight of *Alectra* shoots *	Number of unemerged *Alectra**
IT 98K-506-1	33.0 d	2.2	80.0	7.1	2.9	27.4
IT 98K-131-2	37.8 cd	2.2	75.3	7.9	1.3	4.0
IT 96D-610	36.5 cd	3.0	74.75	38.3	4.7	19.1
IT 99K-530-1	42.0 c	2.7	81.0	2.8	2.5	17.9
IT 98K-555-1	32.3 d	1.9	79.5	17.7	3.1	8.5
IT 98K-205-8	58.8 b	1.0	87.0	0.1	0.2	3.3
Tumaini	36.0 cd	2.7	74.8	31.4	5.6	20.7
Vuli I	33.8 cd	2.0	76.5	23.5	4.7	14.8
IT 00K-1148	34.0 cd	2.2	77.3	7.5	1.7	5.9
IT 90K-277-2	37.8 cd	3.2	76.5	28.1	4.0	13.9
IT 97K-1042-3	34.8 cd	2.7	74.3	16.6	3.3	10.9
IT 98K-1111-1	39.3 cd	1.3	82.0	8.3	2.1	5.0
IT 97K-568-18	39.3 cd	2.2	77.3	5.8	1.0	1.4
Mean	**62.5**	**1.2**	**82.6**	**2.2**	**1.2**	**2.0**
se	**1.5**	**0.1**	**1.9**	**0.8**	**0.2**	**0.6**
Cv (%)	**4.6**	**18.0**	**4.5**	**74.7**	**38.3**	**60.9**

* Analysis were performed after square root transformation of data $[(x+0.5)^{0.5}]$.

+ The maximum value of 87 days marks the end of the experiment and indicates that no flowering of *Alectra* plants occurred.

Mean values in the same column followed by the same letter do not differ significantly at P≤ 0.05 using (THSDT).

4.4.2.3 Cowpea plant height on 'no spray' cowpea cultivars

Results of cowpea plant height are presented in Table 24. Results of effects of *Alectra* on plant height at five sampling dates on 'no spray' cowpea cultivars are presented in Table 24. Inoculated treatments of genotypes IT 98K-506-1, IT 99K-530-1 IT 98K-1111-1 and IT 97K-568-18 were stimulated to grow taller compared to their uninoculated treatments while inoculated treatments of other cultivars were shorter than their inoculated treatments.

Table 24: Effect of *Alectra* on plant height

Teatment combinations	**Plant height (cm)**				
	5 WAS	**6 WAS**	**7 WAS**	**8 WAS**	**9 WAS**
IT 98K-506-1 +*Alectra*	37.9	45.0 c-g	58.5 a-d	64.0 a-d	65.5 a-e
IT 98K-506-1 -*Alectra*	37.3	44.2 c-g	50.6 c-g	55.1 b-f	55.1 b-g
IT 98K-131-2 + *Alectra*	46.9	48.9 c-g	49.4 c-g	49.9 c-f	49.9 c-g
IT 98K-131-2 - *Alectra*	46.0	50.1 b-g	51.6 b-g	53.7 b-f	53.7 b-g
IT 96D-610 + *Alectra*	46.5	47.6 c-g	47.7 c-g	47.7 c-f	47.7 d-g
IT 96D-610 - *Alectra*	46.8	46.9 c-g	47.0 c-g	47.1 c-f	47.1 d-g
IT 99K-530-1 + *Alectra*	43.3	56.5 abc	62.4 abc	72.3 ab	73.8 ab
IT 99K-530-1 - *Alectra*	43.7	46.6 c-g	48.4 c-g	49.0 c-f	49.0 d-g
IT 98K-555-1 + *Alectra*	45.1	45.7 c-g	46.0 c-g	46.0 c-f	46.0 d-g
IT 98K-555-1 - *Alectra*	46.1	45.9 c-g	46.8 c-g	46.8 c-f	46.8 d-g
IT 98K-205-8 + *Alectra*	37.9	38.8 efg	39.3 fg	39.3 ef	39.3 fg
IT 98K-205-8 - *Alectra*	39.3	39.3 efg	40.0 efg	41.6 ef	41.6 fg
Tumaini + *Alectra*	44.5	46.1 c-g	47.8 c-g	49.6 c-f	49.6 d-g
Tumaini – *Alectra*	49.3	50.9 a-f	54.6 b-f	66.6 abc	66.6 a-d
Vuli I + *Alectra*	49.4	53.5 a-d	57.9 a-e	59.7 a-e	61.0 a-f
Vuli I – *Alectra*	52.4	64.1 ab	74.8 a	79.6 a	81.0 a
IT 00K-1148 + *Alectra*	35.9	35.9 g	35.6 g	35.6 f	35.6 g
IT 00K-1148 - *Alectra*	37.0	37.2 fg	37.2 fg	37.2 f	37.2 g
IT 90K-277-2 + *Alectra*	44.7	44.7 c-g	44.7 c-g	44.7 def	44.7 efg
IT 90K-277-2 - *Alectra*	46.4	46.6 c-g	46.8 c-g	46.8 c-f	46.8 d-g
IT97K-1042-3 + *Alectra*	40.1	40.4 d-g	40.5 d-g	40.5 ef	40.5 fg
IT 97K-1042-3 - *Alectra*	41.1	41.4 d-g	41.4 d-g	41.4 ef	41.4 fg
IT98K-1111-1 + *Alectra*	53.5	64.8 a	69.0 ab	71.4 ab	71.4 abc
IT 98K-1111-1 - *Alectra*	48.4	52.8 a-e	53.4 b-g	53.6 b-f	53.6 b-g
IT97K-568-18 + *Alectra*	43.3	44.6 c-g	44.6 c-g	45.3 c-f	45.4 d-g
IT 97K-568-18 - *Alectra*	42.1	42.9 c-g	42.9 d-g	42.9 def	42.9 fg
Mean	**6.3**	**10.6**	**12.8**	**14.6**	**14.8**
se	**1.4**	**2.5**	**3.15**	**3.7**	**3.8**
Cv (%)	**44.0**	**46.9**	**49.2**	**51.1**	**51.3**

Mean values in the same column followed by the same letter do not differ significantly at P≤ 0.05 using (THSDT).

4.4.2.4 Cowpea grain yield and yield components of 'no spray' cowpea cultivars

Results of cowpea grain yield and yield components are presented in Table 25. No pods were formed in the inoculated treatments of cultivars IT 96D-610, IT 98K-555-1, Tumaini and IT 90K-277-2. Significant reduction in number of pods due to *Alectra* infestation was observed in all cultivars except in genotypes IT 99K-530-1, IT 98K-205-8 and IT 97K-568-18. Pods of inoculated treatments of cultivars IT 98K-506-1, Vuli I and IT 98K-1111-1 were significantly ($P<0.05$) shorter compared to other treatments. Inoculated treatments of IT 98K-506, Vuli I, IT 97K-1042-3 and IT 98K-1111-1 had very low number of seeds per pod and were significantly ($P<0.05$) different from all uninoculated treatments. No grains were obtained in inoculated treatments of cultivars IT 96D-610, IT 98K-555-1, Tumaini and IT 90K-277-2. Significant grain weight reduction due to *Alectra* infestation was not observed in genotype IT 98K-205-8. Inoculated treatments of Vuli I had significantly ($P<0.05$) low 10 grains weight but it did not significantly differ with IT 00K-1148 and IT 97K-1042-3. Shelling percentage was significantly increased in inoculated treatments of IT 96D-610, IT 98K-555-1, Tumaini and IT 90K-277-2. Harvest index was significantly ($P<0.05$) reduced due to *Alectra* infestation in all cultivars except in IT 99K-530-1, IT 98K-205-8, IT 97K-1042-3 and IT 97K-568-18.

Table 25: Cowpea grain yield and yield components

Treatment combinations	**Number of pods per pot**	**Pod length (cm)**	**Number of seeds per pod**	**Weight of grains per pot (g)**	**10 grains weight***	**Shelling percentage***	**Harvest Index***
Inoculated	2.0b	6.3b	3.1b	1.6b	0.5b	93.3a	39.6b
Uninoculated	7.7a	13.2a	7.4a	7.9a	1.5a	87.5b	57.6a
Se±	0.2	0.3	0.2	0.1	0.01	0.4	0.7
IT 98K-506-1 +*Alectra*	0.8a	4.7cd	1.5efg	0.3g	0.0e	94.3a-d	28.5h
IT 98K-506-1 -*Alectra*	6.8b-e	13.5ab	7.6bc	8.2ab	1.7a	89.1b-e	51.3a-f
IT 98K-131-2 + *Alectra*	3.5d-g	12.7ab	6.9bcd	3.5def	1.6a	89.1b-e	46.4c-f
IT 98K-131-2 – *Alectra*	7.8abc	13.4ab	6.9bcd	8.4ab	1.7a	89.9b-e	61.7ab
IT 96D-610 + *Alectra*	0.0g	0.0d	0.0g	0.0g	0.0e	100a	25.0h
IT 96D-610 – *Alectra*	7.8abc	11.9ab	6.2cd	7.8ab	1.7a	90.0b-e	58.7a-e
IT 99K-530-1 + *Alectra*	3.8d-g	9.7bc	5.0c-f	2.5efg	1.4ab	89.0b-e	38.3fgh
IT 99K-530-1 – *Alectra*	7.3a-d	12.7ab	6.0cde	6.8bc	1.6a	86.3d-g	44.5efg
IT 98K-555-1 + *Alectra*	0.0g	0.0d	0.0g	0.0g	0.0e	100a	28.2h
IT 98K-555-1 – *Alectra*	7.0a-e	13.1ab	6.3bcd	7.6b	1.8a	85.6d-g	53.4a-e
IT 98K-205-8 + *Alectra*	6.3b-e	12.4ab	7.7bc	6.9bc	1.5a	87.8c-f	48.4b-f
IT 98K-205-8 – *Alectra*	6.8b-e	12.1ab	7.0bcd	7.6b	1.6a	89.1b-e	48.7b-f
Tumaini + *Alectra*	0.0g	0.0d	0.0b	0.0g	0.0e	100a	30.7gh
Tumaini – *Alectra*	6.8b-e	16.6a	12.9a	9.1ab	1.1abc	85.1efg	64.8a
Vuli I + *Alectra*	0.5g	3.7d	3.0d-g	0.6g	0.2de	97.4ab	45.2d-g
Vuli I – *Alectra*	7.8abc	14.6ab	10.8ab	8.6ab	1.1abc	86.2d-g	61.2abc
IT 00K-1148 + *Alectra*	2.0fg	9.9bc	4.3c-g	1.3fg	0.6cd	89.5b-e	55.4a-e
IT 00K-1148 – *Alectra*	7.0a-e	12.34ab	6.2cd	6.9bc	1.8a	87.9c-f	65.6a
IT 90K-277-2 + *Alectra*	0.0g	0.0d	0.0g	0.0g	0.0e	100a	29.3h
IT 90K-277-2 – *Alectra*	9.5ab	11.4ab	6.7bcd	10.1a	1.8a	91.9a-e	59.1a-e
IT 97K-1042-3 + *Alectra*	3.3efg	11.6ab	3.6c-g	1.1fg	0.6bcd	79.3fg	51.6a-f
IT 97K-1042-3 – *Alectra*	10.8a	13.6ab	4.5c-f	5.0cd	1.1abc	78.1g	59.0a-e
IT 98K-1111-1 + *Alectra*	1.0fg	3.8d	1.1fg	0.2g	0.0e	96.0abc	37.6fgh
IT 98K-1111-1 – *Alectra*	6.8b-e	13.0ab	7.8bc	8.3ab	1.6a	90.4b-e	61.4ab
IT 97K-568-18 + *Alectra*	4.8c-f	12.9ab	7.3bcd	4.8cde	1.4a	90.5b-e	49.8b-f
IT 97K-568-18 – *Alectra*	7.8abc	14.1ab	7.8bc	8.5ab	1.4ab	88.0c-f	59.6a-d
Mean	**4.8**	**9.8**	**5.3**	**4.8**	**1.2**	**90.4**	**48.6**
se	**0.7**	**0.9**	**0.8**	**0.4**	**0.1**	**1.5**	**2.6**
Cv (%)	**27.8**	**19.8**	**30.1**	**18.5**	**8.9**	**3.4**	**10.8**

* Analysis were performed after square root transformation of data $[(x+0.5)^{0.5}]$.
Mean values in the same column followed by the same letter do not differ significantly at ($P \leq 0.05$) using (THSDT).

4.4.2.5 Other cowpea growth variables of 'no spray' cowpea cultivars

Results of other cowpea growth variables are presented in Table 26. Number of Leaves in IT 97K-568-18 was not influenced by *Alectra* infestation. Increase in number of leaves due to *Alectra* infestation was only observed in IT 98K-506-1, IT 96D-610, IT 99K-530-1, IT 98K-205-8 and IT 98K-1111-1. Inoculated treatments of cultivars IT 98K-555-1, Tumaini and IT 90K-277-2 did not flower up to harvesting time. Inoculated treatments of cultivar Vuli I flowered significantly ($P<0.05$) late compared to other treatments.Genotype IT 98K-

205-8 had significantly (P<0.05) lowest damage syndrome score while genotypes IT 97K-568-18, IT 98K-131-2 and IT 99K-530-1 had significantly (P<0.05) moderate damage syndrome score compared to other cultivars.

Table 26: Other growth variables of 'no spray' cowpea cultivars

Teatment combinations	Number of leaves per plant	Days to cowpea flowering+	Cowpea damage syndrome (10 WAS)	Days to physiological maturity+	Weight of shoots/pot (g) *	Weight of roots/pot (g) *	Shoot to Root ratio*
IT 98K-506-1 +*Alectra*	9.4abc	68.5abc	5.8a	86.8a	4.4b-f	9.2ab	0.1
IT 98K-506-1 -*Alectra*	8.3a-e	45.8de	1.0e	78.0abc	7.6abc	4.5a-e	1.3
IT 98K-131-2 + *Alectra*	7.0c-f	49.5de	4.0bc	82.3abc	0.5a-e	5.6a-d	0.4
IT 98K-131-2 - *Alectra*	8.4a-e	48.8de	1.0e	79.5abc	2.9c-g	1.2de	1.5
IT 96D-610 + *Alectra*	7.5c-f	59.3bcd	6.3a	87.0a	4.0b-f	11.5a	-0.1
IT 96D-610 - *Alectra*	7.4c-f	43.5de	1.0e	76.5abc	3.6b-g	1.9de	1.2
IT 99K-530-1 + *Alectra*	8.5a-e	43.3de	4.0bc	79.3abc	7.1a-d	8.8abc	0.3
IT 99K-530-1 - *Alectra*	7.6c-f	42.8de	1.0e	77.3abc	11.0a	5.0a-d	1.6
IT 98K-555-1 + *Alectra*	7.3c-f	87.0a	6.5a	87.0a	2.8c-g	5.4a-d	0.1
IT 98K-555-1 - *Alectra*	9.3abc	43.3de	1.0e	76.5abc	5.7a-e	2.9cde	1.4
IT 98K-205-8 + *Alectra*	7.3c-f	41.8de	1.8de	74.3c	7.9abc	5.1a-d	1.0
IT 98K-205-8 - *Alectra*	6.3def	42.5de	1.0e	74.3c	8.6ab	3.2b-e	2.0
Tumaini + *Alectra*	6.3def	87.0a	6.5a	87.0a	2.1efg	8.8abc	-0.2
Tumaini – *Alectra*	8.0b-f	48.3de	1.0e	75.0bc	2.3dfg	2.0de	0.7
Vuli I + *Alectra*	5.8ef	72.0ab	6.5a	85.3ab	0.8fg	4.7a-e	-0.2
Vuli I – *Alectra*	7.3c-f	46.0de	1.0e	74.5bc	3.2c-g	1.7de	1.2
IT 00K-1148 + *Alectra*	5.38f	41.5de	5.5a	76.3abc	0.6g	2.3de	0.0
IT 00K-1148 - *Alectra*	6.0ef	40.3e	1.0e	73.3c	1.5efg	0.7e	1.3
IT 90K-277-2 + *Alectra*	7.0c-f	87.0a	6.5a	85.3ab	2.5d-g	8.0abc	-4.7
IT 90K-277-2 - *Alectra*	8.9a-d	46.5de	1.0e	78.5abc	4.8b-e	3.7b-e	0.8
IT97K-1042-3 + *Alectra*	10.8ab	50.0cde	5.3ab	80.5abc	0.9fg	5.2a-d	-0.3
IT 97K-1042-3 - *Alectra*	10.9a	43.8de	1.0e	75.3bc	2.2efg	2.0de	0.6
IT98K-1111-1 + *Alectra*	7.0c-f	40.5e	6.0a	77.5abc	1.6efg	2.8cde	0.2
IT 98K-1111-1 - *Alectra*	6.6c-f	39.5e	1.0e	74.0c	3.0c-g	2.0de	0.9
IT97K-568-18 + *Alectra*	7.3c-f	47.8de	3.0cd	79.8abc	5.0a-e	4.6a-e	0.6
IT 97K-568-18 - *Alectra*	7.3c-f	46.3de	1.0e	72.3c	3.7b-g	2.1de	1.1
Mean	**7.6**	52.7	**3.1**	79.0	**3.7**	**4.0**	**0.6**
se	**0.5**	2.7	**0.2**	2.0	**0.2**	**0.2**	**0.1**
Cv (%)	**12.8**	10.2	**15.5**	4.9	**18.7**	**20.6**	**22.2**

* Analysis were performed after square root transformation of data $[(x+0.5)^{0.5}]$.
Mean values in the same column followed by the same letter do not differ significantly at (P≤0.05) using (THSDT).
+ The maximum value of 87 days marks the end of the experiment and indicates that no flowering of cowpea plants occurred.

A significant difference (P<0.05) between inoculated and uninoculated treatments in days to physiological maturity was only observed in cultivar Tumaini. Among treatments, inoculated treatments of all cultivars did not significantly differ (P<0.05) with their uninoculated treatments in weight of shoots per pot. Weight of roots per pot was high in inoculated treatments compared to uninoculated treatments of each cultivar. Shoot to root ratio was not significantly different (P<0.05) among treatments but was low in inoculated treatments of all cultivars except IT 98K-205-8.

4.4.2.6 Correlation matrix of 'no spray' cowpea cultivars

The correlation matrix for *Alectra* growth and cowpea yield characteristics are presented in Table 27. Days to *Alectra* emergence showed high positive significant correlation with all yield components, while number of *Alectra* at harvest and weight of *Alectra* shoots showed negative significant correlation with all yield components.Among yield components, days to *Alectra* emergence gave highest positive correlation with weight of grains per pot (r = 0.898, P = 0.000).

Table 27: Correlation matrix between *Alectra* growth and cowpea yield characteristics in 'no spray' experiment

	1[t]	2	3	4	5	6	7	8	9
1[t]	-								
2	-0.673***								
3	-0.691***	0.952***							
4	-0.528***	0.611***	0.689***						
5	-0.587***	0.584***	0.623***	0.656***					
6	0.845***	-0.728***	-0.714***	-0.642***	-0.598***				
7	0.683***	-0.792***	-0.771***	-0.78***	-0.641***	0.754***			
8	0.653***	-0.712***	-0.687***	-0.637***	-0.588***	0.636***	0.907***		
9	0.898***	-0.743***	-0.729***	-0.597***	-0.611***	0.879***	0.787***	0.811***	
10	0.729***	-0.745***	-0.712***	-0.698***	-0.609***	0.809***	0.846***	0.764***	0.845***

Significant regression correlation between cowpea and *Alectra* variables (P<0.05)*; (P<0.01)**; (P<0.001)***

[t] Variables

1 = Days to *Alectra* emergence
2 = Number of *Alectra* at harvest
3 = Weight of *Alectra* shoots
4 = Days to cowpea flowering
5 = Days to physiological maturity
6 = Number of pods/pot
7 = Pod length
8 = Number of seeds per pod
9 = weight of grains/pot
10 = 10 grains weight

Plate 2: Effect of *Alectra* on cowpea growth and development on 'no spray' genotypes.

For each of these pairs, pots on the left side are uninoculated with *Alectra* and on the right side are inoculated. A: and B: Resistant genotypes, C: is susceptible genotype. (Note the difference in cowpea plant height and number of pods between inoculated and uninoculated pots in each pair).

4.5 Effect of cowpea cultivars on attachment of *A. vogelii* seeds, tubercles and *Alectra* shoots development

4.5.1 *Alectra* attachment and tubercles formation

4.5.1.1 *Alectra* attachment and tubercles formation on *Alectra/Striga* resistant and local cowpea cultivars

Results of *Alectra* attachment and tubercle formation are presented in Figs.8 and Plate 3. All 18 cowpea cultivars stimulated germination of *Alectra* seeds and supported attachment of *Alectra* radicles to their roots at 2 WAS (Fig. 8). Genotype IT 99K-494-6 supported significantly ($P<0.05$) lowest number of attached *Alectra* seedling compared to other cultivars. Genotypes IT 97K-829-118, IT 00K-1207, IT 98K-692, supported significantly ($P<0.05$) low number of attached *Alectra* compared to moderate numbers supported by Vuli I, IT 99K-7-21-2-2 and IT 98K-628. Eleven other cultivars supported significantly ($P<0.05$) high number of attached *Alectra* seedlings per plant. Attached *Alectra* seedlings could not be removed by gentle brushing with a fine paintbrush.

At 5 WAS, *Alectra* radicles penetrated cowpea roots and formed tubercles (swellings) on cowpea roots at point of infection and *Alectra* shoots aroused in some cultivars (Plate 3). Genotype IT 99K-494-6 supported significantly ($P<0.05$) lowest number of *Alectra* with tubercles compared to other cultivars. Genotypes, IT 98K-628, IT 00K-1207, IT 99K-7-21-2-2, IT 97K-499-35 and IT 97K-829-118 permitted significantly ($P<0.05$) low number of *Alectra* with tubercles compared to moderate number of *Alectra* with tubercles supported by IT 98K-692, IT 99K-573-1-1 and IT 99K-573-2-1 Nine other cultivars supported high number of *Alectra* with tubercles.

At 5WAS number of *Alectra* with tubercles was much less compared to the number of *Alectra* that were attached to the plant root system at 2 WAS in genotypes, IT 99K-494-6, IT 98K-628, IT 00K-1207, IT 99K-7-21-2-2, IT 97K-499-35 and IT 97K-829-118 (Fig. 8). Almost all attachments exhibited by IT 99K-573-1-1, IT 99K-573-2-1 and IT 98K-692 resulted in tubercles formation. Nine other cultivars exhibited an increase in number of *Alectra* with tubercles at 5 WAS compared to those that were attached at 2 WAS.

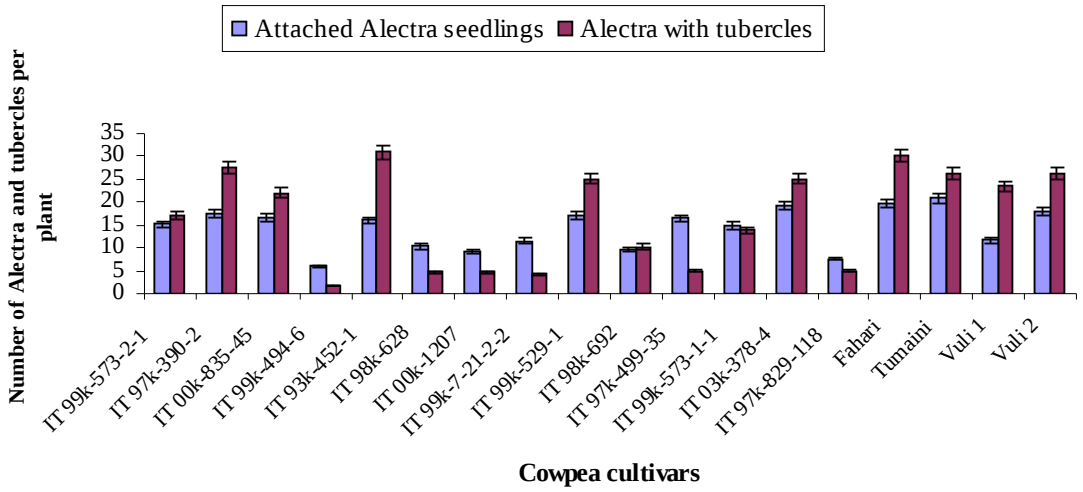

Figure 8: Mean number of attached *Alectra* at 2WAS and *Alectra* with tubercles formation at 5 WAS per plant root system on *Alectra/Striga* resistant and local varieties

Plate 3: Expression of resistance to *Alectra* in cowpea on *Alectra/Striga* resistant genotypes.

A: Resistant genotype-very small tubercles without *Alectra* shoots. **B-H**: Resistant genotypes-small tubercles with short *Alectra* shoots. I: Susceptible variety-large tubercles with long *Alectra* shoots.

4.5.1.2 *Alectra* attachment and tubercles formation on 'no spray' cowpea genotypes

Results of *Alectra* attachment and tubercle formation are presented in Figs. 9 and Plate 4. At 2 WAS all cowpea cultivars evaluated, supported *Alectra* attachment to their root systems but at a varying magnitude. Genotype IT 98K-205-8 supported lowest number of attached *Alectra* but it was significantly ($P<0.05$) comparable to IT 97K-568-18 and IT 98 K-131-2. Other eight genotypes; IT 98K-506-1, IT 96D-610, IT 99K-530-1, IT 98K-555-1, IT 00K-1148, IT 90K-277-2, IT 97K-1042-3, IT 98K-1111-1 and check variety Tumaini supported significantly ($P<0.05$) high number of attached *Alectra* per plant root system.

Likewise, at 5 WAS, genotype IT 98K-205-8 supported significantly ($P<0.05$) lowest number of *Alectra* with tubercles per plant than any other cultivar. Genotypes IT 97K-568-18 and IT 98K-131-2 supported significantly ($P<0.05$) low number of *Alectra* with tubercles compared to moderate number of tubercles supported by IT 99K-530-1 and hing number of *Alectra* with tubercles supported seven other cultivars and the control, Tumaini (Plate 4).

Reduction in number of attached *Alectra* in comparison to those that formed tubercles was observed only in IT 98K-205-8. Almost all attachments resulted in tubercles formation for genotypes IT 98K-131-2, IT 99K-530-1 and IT 97K-568-18 (Fig.9). In other cultivars, number of *Alectra* with tubercles was high compared to the attached ones.

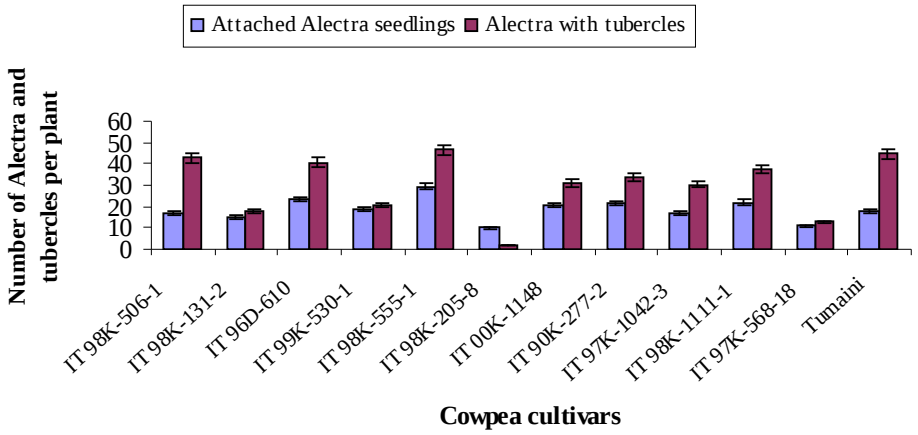

Figure 9: Mean number of attached *Alectra* at 2 WAS and *Alectra* with tubercles formation at 5 WAS per plant root systems on "no spray" cowpea cultivars

Plate 4: Expression of resistance to *Alectra* in "no spray" cowpea genotypes.

A: Highly resistant genotype:-small tubercles without *Alectra* shoots. **B:** and **C**: Resistant genotypes:-medium size tubercles with short shoots. **D: E**: and **F:** Susceptible genotypes:-large tubercles with long shoots.

4.5.2 Length of *Alectra* shoots and diameter of tubercles

4.5.2.1 *Alectra* shoot length and diameter of tubercle of *Alectra/Striga* resistant cowpea genotypes at five weeks after sowing

Results of *Alectra* shoot length and diameter of tubercles are presented in Fig. 10. Cowpea cultivars Fahari, Tumaini, Vuli I, Vuli II, IT 03K-378-4, IT 99K-529-1, IT 93K-452-1, IT 00K-835-45 and IT 97K-390-2 had significantly ($P<0.05$) longest *Alectra* shoots and largest tubercles compared to other cultivars. IT 99K-494-6 had significantly ($P<0.05$) smallest tubercles without *Alectra* shoots.

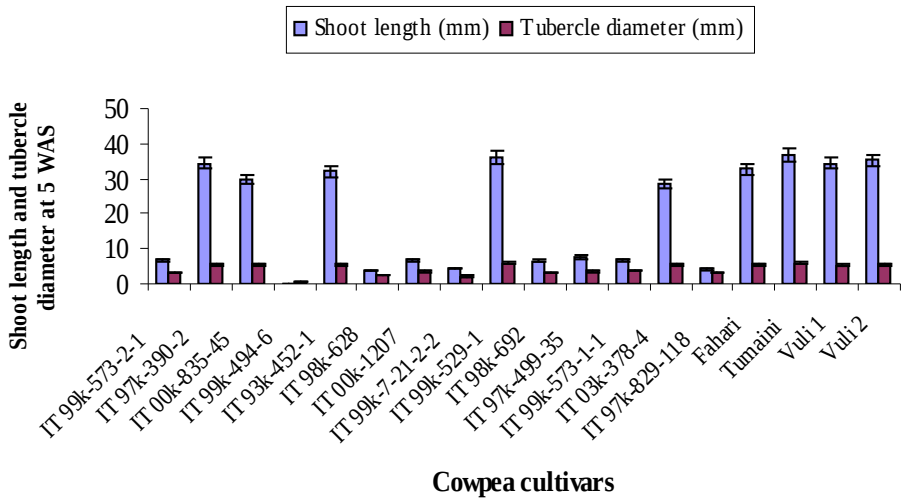

Figure 10: *Alectra* shoot length and diameter of tubercle on *Alectra/Striga* resistant genotypes and local varieties at 5 WAS.

4.5.2.2 *Alectra* shoot length and diameter of tubercle of 'no spray' cowpea genotypes at five weeks after sowing

Results of *Alectra* shoot length and diameter of tubercles are presented in Fig. 11. Genotypes IT 98K-205-8, IT 97K-568-18, IT 98K-131-2 and IT 99K-530-1 had significantly ($P<0.05$) shortest *Alectra* shoots and smallest diameter of tubercles compared

to other genotypes and the control variety, Tumaini. Although IT 99K-530-1 had some long shoots, the proportion of short shoots was about 70% to that of long shoots. IT 98K-205-8 had significantly ($P<0.05$) smallest tubercles without *Alectra* shoots.

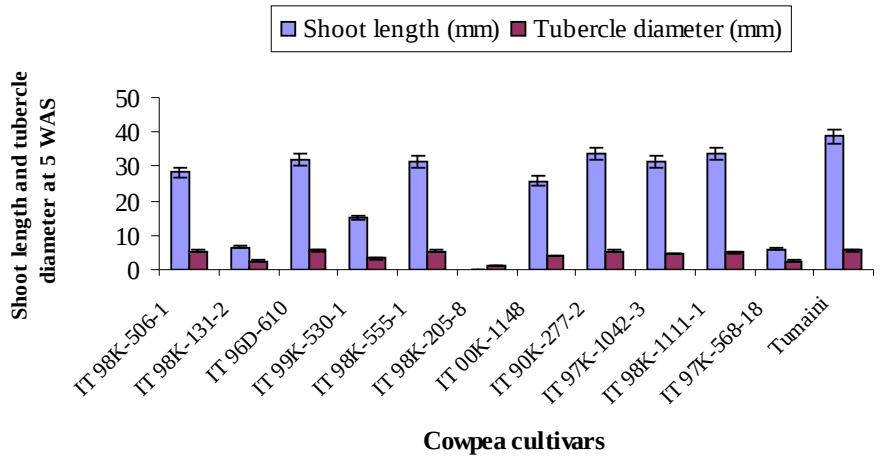

Figure 11: *Alectra* shoot length and diameter of tubercle on 'no spray' genotypes at 5 WAS.

4.6.1 Nodulation on *Alectra/Striga* resistant and local cowpea cultivars as affected by *Alectra vogelii*

Results of nodule counts are presented in Fig. 12. Generally, uninoculated treatments had significantly ($P<0.05$) more nodules per plant compared to inoculated treatments. Inoculated treatments of IT 99K-494-6, IT 00K-1207, IT 99K-7-21-2-2, IT 98K-692, IT 97K-499-35 , IT 98K-628 and IT 97K-829-118 produced more nodules compared to uninoculated treatments of the same genotypes. Number of nodules in inoculated treatments of other 11 cultivars, was low compared to number of nodules of uninoculated treatments of these cultivars.

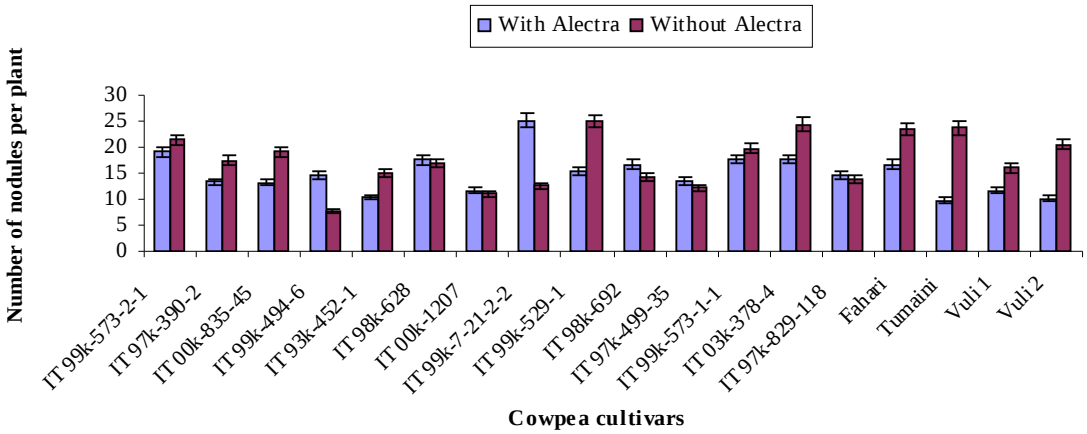

Figure 12: Mean number of nodules per root systems on *Alectra/Striga* resistant genotypes and local varieties

4.6.2 Nodulation on 'no spray' cowpea genotypes as affected by *Alectra vogelii*

Results of nodule counts are presented in Fig. 13. With the exception of genotype IT 98K-205-8, number of nodules in uninoculated treatments was higher compared to those of inoculated treatment. Nodule counts in inoculated treatments of genotype IT 97K-568-18 were comparable to those of its uninoculated treatment.

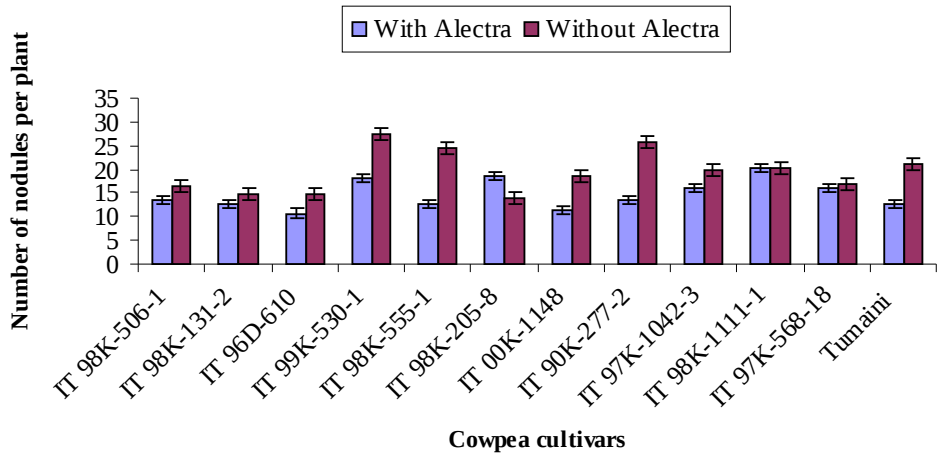

Figure 13: Mean number of nodules per plant root systems on 'No spray' cowpea genotypes

CHAPTER FIVE

5.0 DISCUSSION

5.1 Viability and germination capacity of *Alectra* seeds

Ungerminated *Alectra* seeds exhibited white or black endosperm in viability test which according to Kroschel, (2001) is an indication of fungal and bacterial growth. *Alectra* seeds used in this study were collected from mature capsules but plant shoots were still green. According to Berner *et al*. (1997) parasitic seeds store better and are less susceptible to fungal spoilage once the trash is removed. Hence, slightly low percentages viability (76.8%) and percentages germination (81%) (down from 100%) of *Alectra* seed used in the experiments could be to a large extent be attributed to fungal and bacterial infection. Signs of fungal infestation were observed on *Alectra* seed capsules before threshing.

The low percentages viability recorded compared to percentages germination of *Alectra* seeds was probably due to difficult of staining small seeds with TTC. *Alectra* seeds are relatively small thus it is difficult to distinguish stained and unstained seeds precisely during viability test. Reliable test as suggested by Kroschel (2001) requires the comparison of germination and viability tests. This is due to the fact that even higher concentrations of TTC do not necessarily produce a more pronounced staining in small seeds.

5.2 Production of *A. vogelii* germination stimulants

Percentages germination of *Alectra* seeds as stimulated by cowpea root exudates which ranged from 16.9-42.7% indicates that none of the cowpea cultivar evaluated exhibited a high degree of low stimulant production (Fig. 3).Treatments that exhibited relatively low

percentage germination, had long *Alectra* seedling radicles which, according to Okonkwo and Raghavan (1982) and Parker and Riches (1993), stands a good chance of making contact with cowpea roots. Production of high *Alectra* germination stimulant from cowpea roots has been reported by (Müller *et al.,* 1992) who observed high stimulation of *A. vogelii* seeds (up to 50%) by alectrol compound extracted from cowpea roots, even at a dilution of 10^{-12} M. The high stimulation of *A. vogelii* seeds among cowpea cultivars in this study, even on genotypes into which *Alectra* resistant genes have been incorporated suggests that resistant mechanism of cowpea cultivars to *A.vogelii* is not determined by low stimulant production.

These results agree with earlier reports by Parker and Riches (1993) who noted that resistance to *Alectra* and *Striga gesnerioides* in cowpea is not associated with a reduced ability of the host to stimulate the germination of seeds of either parasite species. In sorghum, on the other hand resistance mechanism against *Striga* has been noted to be due to, among other things, low stimulant production (Ramaiah *et al.,* 1990).All cowpea cultivars and controls (distilled water and GR24) induced a germination of *Alectra* seeds to a level that was slightly different in the two experiments (Fig. 3). Emechebe and Ahonsi (2003) reported similar trend on percentages germination in *Striga hermonthica* which was ascribed to variation in stimulant extraction time among repeated treatments. Emechebe and Ahonsi (2003) observed significantly higher germination percentage of *S. hermonthica* seeds when stimulant extraction was done immediately after cutting plant parts than three hours later. Mangnus *et al.* (1992) also noted variation on percentage germination of *S. hermonthica* even when stimulated by GR24 solutions in repeated experiments. They associated the variations with season-effects in which germination percentages were lower during winter although seeds were stored under same conditions.

Hence, Mangnus *et al.* (1992) suggested GR24 to be included in every test, to enable comparison of activities in different test series with respect to the activity of GR24. In this particular study, it was difficult to inoculate each treatment in the two sets of experiments within exactly the same time duration. Thus difference in time of stimulant extraction could be a possible reason for such variations.

The 4.95 % germination of *Alectra* seeds in the negative control treatment (distilled water) was due to remains of residual sodium hypochlorite used during sterilization. According to Okonkwo and Nwoke (1975) hypochlorite is highly active on *A. vogelii* and is thought to be due to disruption of seed coat permeability or the removal of germination inhibitors. However, radicle length of *Alectra* seed in the distilled water treatment were very short compared to those stimulated by GR 24 and cowpea root exudates. The implication of such short radicles is that they have less chance of making successful attachement and penetration of cowpea root.

The low percentage germination of *Alectra* seed placed 5 mm from stimulant compared to 10 mm and 15 mm in some cowpea cultivars (Appendix 1) can be associated with presence of inhibitors. Similar results have been reported in other studies. Emechebe and Ahonsi (2003) found that one gram of excised cowpea roots in a cut root assay experiment, gave higher germination than two grams suggesting a relative increase in inhibitory materials with increase in plant material. Müller *et al.* (1992), observed repeated inhibitory effect on highly concentrated solution of strigol, alectrol or GR-7. In line with this, Alabi (2000) reported that germination percentage of *S. hermonthica* was negatively correlated with cowpea root weight. It is likely that in this particular experiment, 5 mm being close to source of stimulant was more affected by inhibitory compounds than other distances.

5.3 Effect of *Alectra* on cowpea growth and development

Inoculated *Alectra*-resistant cultivars exhibited an increase in plant height compared to uninoculated *Alectra*-resistant cultivars. This trend was mostly noticed from 7 WAS e.g. IT 98K-628, IT 97K-499-35, IT 99K-573-1-1 and IT 97K-829-118 (Table 9), IT 99K-494-6 (Table 19) and IT 97K-568-18 (Table 24). On the other hand, inoculated treatments of susceptible cultivars such as Vuli II, Tumaini and Vuli I (Table 9) were stimulated to increase in plant height at 5 and 6 WAS but severely affected at later growth stages compared to their uninoculated treatments.

Alonge *et al*. (2001a) noted that *Alectra* infestation on cowpea shoot growth, was more apparent between 7 and 9 WAS and stimulation on most of susceptible cowpea varieties was at early growth period. According to Borg and Van Ast (1991), 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. This implies that under high sink-activity due to parasite infestation, rate of photosynthesis will surpass sink-activity. Stimulation of susceptible cultivars to increase in plant height at early stages and resistant cultivars at later growth stages as has also been demonstrated in this study, suggests that the system works in favour of the host plant when the infestation of *Alectra* is low or when the sink demand is low i.e. there is a temporary overcapacity of the photosynthetic system. Borg and Van Ast (1991) also noted parasitism of *Vicia faba* L. by broomrape (*Orobanche crenata* Forssk.) tolerant cultivar Giza 402, to be in the intermediate stages of host growth, when most *Orobanche* plants were in their early stages of development, and that of

susceptible cv. Giza 2 at early stages when most orobanche plants were still small and not yet emerged.

On the other hand, Rambakudzibga *et al.* (2002) reported that total dry matter production (cowpea plant plus *Alectra* shoots) remained unchanged as a result of *Alectra* infestation which means that severe decrease in plant height on susceptible cultivars at later growth stages is a result of more assimilates being directed to the *Alectra* rather than the host. The observed trend on stimulation of host growth in respect to resistant and susceptible cultivars was not consistent e.g. susceptibe genotype IT 99K-529-1 (Table 9) increased in plant height and inoculated treatments of resistant genotypes, IT 97K-7-21-2-2 (Table 14) and IT 98K-205-8 (Table 24), had a slight decrease in plant height compared to their uninoculated treatments. Similar inconsistences have been reported on stimulation of different cultivars of *Vicia faba* infected by broomrape (Borg and Van Ast, 1991) in which the authors suggested the change in balance between the green plant parts (the sources) and the sinks during plant life to be different between cultivars.

Likewise, highly susceptible cultivars had few numbers of leaves per plant compared to resistant cultivars, though not consistent and reduction in weight of shoots per pot due to *Alectra* infestation was high for susceptible cultivars compared to resistant cultivars in all experiments. Previous reports (Graves *et al.,* 1992) have indicated that *Alectra* has very low rate of photosynthesis coupled with very high rate of respiration. According to Gouwns *et al*. (1980), photosynthetic activity of *A. vogelii* is only half that of host leaf on a per gram dry mass basis. *A. vogelii* thus reduced host growth by being additional sink for water, nutrients and photosynthates. Similar observations on increase in plant growth on *Alectra* resistant cultivars were made on soybean resistant to *Alectra vogelii* (Kureh and

Alabi, 2003) and on cowpea (Guney *et al.*, 1995; Alonge *et al.*, 2001a). The authors attributed this to increased production of growth-promoting substances after *Alectra* infection, for maintenance of high rate of photosynthesis to ensure partitioning of the assimilates to the host and extra sink produced by *Alectra.*

Narrow variation among cultivars in number of nodules per plant was probably due to genetic differences among cultivars or due to age of the cowpea plants at the time of assessment which was only 5 WAS. According to Motior *et al*. (1998) maximum number of nodules in legumes occurs at the beginning of the pod formation stage. However, the general trend was interesting; cowpea cultivars that were resistant to *Alectra vogelii* infestation were stimulated to produce or to maintain high rhizobium nodulation rates when infested compared to susceptible cultivars. Hence, inoculated treatments of genotypes IT 99K-494-6, IT 99K-7-21-2-2 and IT 98K-692 (Fig. 12) and IT 98K-205-8 and IT 97K-568-18 (Fig. 13) had more nodules than uninoculated treatments of the same genotypes. High nodulation stimulation has also been reported in *Alectra* tolerant soybean cultivars (Kureh and Alabi, 2003), and on resistant cowpea cultivars (Singh *et al.*, 1993; Atokple *et al.*, 1995; Alonge *et al*., 2001a) in which the authors commented that resistant cultivars maintained high rhizobium nodulation as a result of increased rate of photosynthesis and genetic factors. On the other hand, uninoculated susceptible cowpea cultivars e.g. Fahari and Tumaini (Fig. 12) and IT 98K-555-1 and IT 90K-277-2 (Fig. 13) had high number of nodules per plant root system compared to uninoculated treatments of resistant cultivars such as IT 99K-494-6. This can be associated with genetic differences.

Inoculated cowpea cultivars that were highly susceptible to *A. vogelii* such as Tumaini, Vuli II, Fahari, IT 00K-835-45 (Table 15) and IT 03K-378-4 (Table 20), flowered late

compared to resistant cultivars such as IT 99K-494-6 (Table 20). Parker and Riches (1993); Singh and Emechebe (1997); Alonge *et al*. (2001a) also observed delay in flowering in cowpea cultivars due to *Alectra* infestation and they noted that flower initiation coincides with critical period of *Alectra* infestation. Most assimilates were therefore allocated to the addition sink rather than to the formation of flowers. In this experiment, negative correlation between days to *Alectra* emergence and days to cowpea flowering (e.g. r = -0.35, P = 0.000, Table 12; r = -0.539, P = 0.000, Table17) indicates that cowpea cultivars that supported late emergence of *Alectra* shoots (*Alectra* resistant cultivars) flowered early. Days to cowpea flowering was positively correlated with number of *Alectra* at harvest e.g. (r = 0.678, P = 0.000, Table 22 and r = 0.611, P= 0.000, Table 27). These results indicate that days to flowering of cowpea increased as the number of *Alectra* shoots increased.

Inoculated treatments of susceptible cowpea cultivars matured late compared to resistant cultivars e.g. Vuli II, Tumaini, IT 00K-835-45 and Fahari (Table 15) and IT 03K-378-4 (Table 20). In contrast, Rambakudzibga *et al.* (2002) reported no effect on duration to anthesis and physiological maturity in infected determinate cowpea cultivar used in their study. These discrepancies could be due to cultivar differences. Most cowpea cultivars used in this study were indeterminate. Furthermore, harvesting date in this study was considered as days to maturity on cultivars that never set flowers since physiological maturity assessment was based on condition of the pods. The high number of days to maturity on *Alectra* susceptible cultivars was thus partly contributed by severely affected treatments of these cultivars which never formed flowers and pods. Negative correlation of days to physiological maturity with days to *Alectra* emergence e.g. (r = -0.24, P = 0.01, Table 12; r = -0.436, P = 0.000, Table 17) implies that cultivars that supported late

emergence of *Alectra* shoots (resistant cultivars) matured early compared to susceptible cultivars.

The low shoot to root ratio of inoculated treatments of susceptible cultivars compared to those of inoculated treatments of resistant cultivars means that in susceptible cultivars more photosynthates were allocated to the roots rather than shoots probably to increase rate of nutrient uptake. The reduction in number of leaves and plant growth in susceptible cultivars could have contributed to the reduced shoot growth. Low shoot: root ratio in susceptible cowpea cultivars has also been reported by Alonge *et al*. (2001a). It has been shown that apart from nutrient competition between parasite and host plant and reduced rate of photosynthesis in the leaves of *Striga* infested plants (Press, 1995) there is also reduction in the level of growth hormones in the host crop (Drennan and El-Hiweris, 1979).

5.3.1 Effect of *Alectra* on cowpea grain yield and yield components

Cowpea cultivars that were highly susceptible to *Alectra vogelii* such as IT 99K-529-1, Vuli II, Tumaini and Vuli I (Table 10), IT 97K-390-2, IT 00K-835-45 and Fahari (Table 15), IT 03K-378-4 (Table 20), had very few pods and severely affected cultivars did not set pods at all. Reduction in number of pods due to *Alectra* infestation in susceptible cowpea cultivars has been reported (Mugabe, 1983; Alonge *et al*., 2001b). Alonge *et al*. (2001a) established that the period of flower initiation and first phase of pod development in cowpea which is between 7 and 9 WAS coincides with the period when *Alectra* infestation on cowpea becomes more critical. In this particular study the number of *Alectra* shoots in susceptible cultivars increased very profusely from 7 WAS e.g. (Figs. 4, 5, 6 and 7), which agrees with observations by Alonge *et al*. (2001a) above. The negative correlation between number of pods per pot and number of *Alectra* at harvest e.g.

(r = -0.728, P = 0.000, Table 22) indicates that in susceptible cultivars more photosynthates were allocated to *Alectra* growth rather than formation of pods.

High reduction in number of seeds per pod (> 75%) and pod length (> 62%) observed in highly susceptible cultivars such as Tumaini (Table 10), IT 97K-390-2, Fahari and Tumaini (Table 15) and Tumaini (Table 20) indicates that *Alectra* had severe effect on these variables in susceptible cowpea cultivars. The positive correlation between number of seeds per pod and pod length e.g. (r = 0.866, P = 0.000, Table 12) indicates that more space is provided for longer pods. Likewise, positive correlation between pod length and days to *Alectra* emergence e.g. (r = 0.729, P = 0.000, Table 12) indicates that pod development decreased at the expense of early emergence and development of *Alectra* shoots. The time of emergence of parasitic weeds has been found to be as important as number of infections. Kropff *et al*. (1992) established that relative emergence time is critical factor next to weed density. They noted that even a delay of one week has tremendous effects as competition is often asymmetric, meaning that small difference in starting position are enlarged towards the end. Similarly, Van Ast *et al.* (2005) noted that days to *Striga hermonthica* emergence in sorghum were as important as the number of infections. In their experiment to investigate cultural control measures to diminish sorghum yield loss and parasite success under *S. hermonthica* infestation they observed no significant yield increase despite the strong reduction in *Striga* infestation level by 85% in some treatments. Van Ast *et al.* (2005) attributed this to no difference in days to *Striga* emergence and establishment among treatments in their trial.

The slight decrease in grain yield (3.8-38.1 %) and seed size (0-12.5%) observed in resistant genotypes in this study disagree with Alonge *et al.* (2001b) observations who noted an increase in yield and yield components of most of the resistant cowpea varieties

on *Alectra* inoculated plots in a field experiment. Alonge *et al.* (2001b) attributed this to the earlier moderate or high frequency of root and/or shoot growth stimulation, none to moderate infestation of *Alectra* and probable less export of assimilate to the parasite that ensured adequate biomass accumulation and grain development. Differences in location of the experiment (screen house in this study) and field experiments (in Alonge *et al.* (2001b) might be part of the reason for such discrepancies.

Alectra infestation resulted in the worst yield loss in susceptible cultivars such as IT 99K-529-1, Vuli II, Tumaini and Vuli I (Table 10); IT 97K-390-2, Fahari, Tumaini and Vuli I (Table 15) (ranging from 78-100%). Previous reports, (Mbwaga *et al.*, 2000; Alonge *et al*., 2001b) noted 50% yield loss due to *Alectra* infestations in susceptible cultivars where in Kenya, Bagnall-Oakeley, (1991) reported total yield loss. Reduced weight of seeds and other yield components due to *Alectra* infestation have also been reported (Mugabe, 1983).

Grain yield was negatively correlated with number of *Alectra* per pot e.g. ($r = -0.694$, $P = 0.000$, Table 12; $r = -0.672$, $P = 0.000$, Table 17) and *Alectra* biomass e.g. ($r = -0.729$, $P = 0.000$, Table 12; $r = -0.724$, $P = 0.000$, Table 17). These results indicate that with high number of *Alectra*, more photosythate is allocated to the *Alectra* rather than cowpea crop development and *Alectra* biomass increased at the cost of crop performance. However, Gurney *et al.* (1999) and Van Ast *et al.* (2005) reported non-linear relationship between *Striga hermonthica* biomass and grain production in sorghum and hence proposed that above a specific infection level host grain production is independent of parasite number particularly if the actual infection level is way above the ‘‘saturation level’’, any measure that reduces *Striga* infection will not automatically result in an increased sorghum yield.

Cowpea genotypes that were resistant to *A. vogelii* in this study were associated with low grain yield compared to highly susceptible cultivars e.g. 16% increase in grain yield of susceptible variety Tumaini over resistant genotype IT 98K-205-8 (Table 25). Such observation has also been noted in sorghum varieties that are resistant to *Striga* (Ramaiah and Parker, 1982). In line with this, Oliver *et al.* (1991) also reported similar observation in sorghum varieties that are resistant to *Striga hermonthica* and they also noted that such observation has been reported in many plant species that are resistant to pathogens and insects.

Observed high harvest indecies of inoculated treatments of resistant cultivars compared to those of inoculated treatments of susceptible cultivars in all trials (Tables 10, 15, 20 and 25) implies that in resistant cultivars more resources were available for grain development. Increased rate of photosynthesis coupled with reduced sink-activities in resistant cultivars as suggested earlier, could be a major attribute of increased grain yield and consequently high harvest index. Observed high shelling percentages in susceptible cultivars infested with *Alectra* compared to resistant genotypes (Tables 10, 15, 20 and 25) implies that with few seeds per pod, more resources were allocated to the seeds rather than seed shells.

5.3.2 Effect of cowpea cultivars on *Alectra* emergence and development

High numbers of emerged *Alectra* shoots in the repeated screen house experiments compared to first experiments (data not shown) is probably attributed by differences in screen house temperatures between the two experiments. According to Dawoud and Sauerborn (1994), optimum day/night temperature for germination and attachment of *A. vogelii* is 25/15 and 30/20 ^{o}C and deviation in temperature from the optimum significantly reduced germination and attachment of the parasite. In this study, the mean screen house

temperatures for the first experiment was high (30.2-36.8ºC) compared to temperatures in the repeated experiments (23.6-30.6 ºC) (Table 4). Hence *Alectra* seeds in the repeated experiment had more conducive environment for germination and attachments.

Alectra seeds used in the repeated screen house experiments were only two weeks old. High number of germinated *Alectra* seeds in the repeated screen house experiments (data not shown), confirm earlier findings (Parker and Riches, 1993) that *Alectra* seeds have no after-ripening requirements. The death of *Alectra* shoots was observed in some cultivars particularly after 9 WAS. Alonge *et al.* (2001a) had similar observations on heavily infested cowpea varieties and they attributed this to be due to intense intraspecific competition for the host nutrient and water. However, in the current study death of *Alectra* shoots was also observed on genotypes that had low infestation of *Alectra* e.g. IT 99K-573-1-1 (Fig. 4), IT 98K-131-2 and IT 97K-568-18 (Fig.7). Uneven watering could be part of the reason.

Although growth media used in the repeated experiment was acidic (pH 6.2) while the one used in the first experiment was slightly alkaline (pH 7.1), *Alectra* growth and cowpea cultivars response were similar in both experiments. The only difference was high numbers of *Alectra* shoots that emerged in the repeated experiments.

5.4 Effect of cowpea cultivars on *Alectra* attachment, tubercles and shoot development

Reduction in number of *Alectra* with tubercles at 5 WAS by 2.7-69.3% compared to number of *Alectra* that were attached at 2 WAS in IT 99K-494-6, IT 98K-628, IT 00K-1207, IT 99K-7-21-2-2, IT 97K-499-35, IT 97K-829-118 and IT 98K-205-8 (Figs. 8

and 9) is an indication of hypersensitive reaction. These results imply that these genotypes stimulated germination of *Alectra* seeds and permitted attachment with cowpea roots but *Alectra* seedlings that formed haustorial was reduced due to death of some *Alectra* seedlings after attachment. Likewise, maintainance of same number of *Alectra* with tubercles at 5 WAS compared to number of *Alectra* that were attached at 2 WAS in IT 99K-573-1-1, IT 99K-573-2-1, IT 98K-692, IT 98K-131-2 and IT 97K-568-18 (Figs. 8 and 9) means that some *Alectra* seedlings died due to hypersensitive reaction but to a lesser extent than in the seven genotypes above. Lane *et al*. (1991b) using tray system to study parasitism of cowpea by *Striga gesnerioides* also observed death of the *Striga* seedlings within 2-3 days on resistant cowpea variety 58-57 after penetration of cowpea roots. Parker and Riches (1993) attributed death of *Alectra* seedlings to production of inhibitory substances which prevent the post-germination elongation of *A. vogelii* radicles and consequently penetration of cowpea roots.

Number of tubercles supported by these 12 genotypes which exhibited resistance to *Alectra* was 35.4-95.7% less compared to 35.5 tubercles per plant in susceptible check variety Tumaini. Exhibition of also short *Alectra* shoots at 5 WAS ranging from 0-7.6 mm compared to 37.8 mm in Tumaini and small tubercle diameter (0.8-3.9mm) compared to 5.8 mm in Tumaini implies that resistance of these 12 genotypes to *A. vogelii* is also governed by limited development of tubercles and *Alectra* shoots. Similar trend was observed on cowpea line B 359 by Lane *et al*. (1991a) and on variety IT 82D-849 by Atokple *et al*. (1995) in which *Striga* radicles penetrated host roots and formed small tubercles which failed to develop beyond 1-2 mm in diameter with stems/shoots less than 6 mm in length at 3 weeks after inoculation. Lane *et al*. (1991a) suggested that resistance of B 359 was based on limited development of parasite tubercles.

Genotype IT 99K-530-1 exhibited susceptibility to *Alectra* by having some *Alectra* shoots that were long (35 mm)resulting in high average *Alectra* shoot length (15.1 mm) compared to 0-7.6 mm in resistant genotypes above and high number of tubercles/plant (19.8) compared to 35.5 in Tumaini (Plate 4). Exhibition of large tubercles (4-6 mm in diameter) and *Alectra* shoots of 25.8-38.7 mm in length which were comparable to those of the check variety Tumaini (37.8 mm), high number of tubercles per plant ranging from 20.78-45.6 in 12 other genotypes and all four local varieties compared to 35.5 tubercles/ plant in Tumaini, implies that these cultivars were susceptible to *Alectra vogelii*. These findings are in line with those of Lane *et al.* (1991a) who indicated that *A. vogelii* on susceptible cultivar (Black eye) formed shoots of 40-50 mm long within three weeks. Reduction in *Alectra* shoots growth and tubercle's diameter in all genotypes that showed hypersensitive reaction is an indication of production of growth inhibitors. Most of the genotypes that showed hypersensitive reaction in this study, stimulated germination of *Alectra* seeds ranging from 16.9-42.3% in the cut root assay experiment (Section 4.3.1) which was high in relation to that of negative control (4.9%). These results imply that resistance of cowpea to *Alectra vogelii* is not due to low germination stimulant production. Lane *et al.* (1991a) using tray system noted similar observation on *Alectra* susceptible cv. Blackeye and resistant variety B 359 in which germination percentage of *Alectra* seed exceeded 70% in both varieties.

Although resistant genotypes had low number of attached *Alectra*/plant at 2 WAS (4.89- 14.9) compared to susceptible cultivars (10.6-28.4) there was no clear demarcation between the two classes. These results indicate that resistance of cowpea to *Alectra* was expressed after attachment of *Alectra* seedlings to cowpea roots. These findings agree

with earlier observation by Lane *et al*. (1991a, b); Lane *et al* 1993 and Atokple *et al.* (1995) that resistance mechanism in cowpea is an active defense mechanism after parasite infection and in expressed after penetration of cowpea roots by the parasite. However, low number of attached *Alectra* per plant expressed by some genotypes e.g. IT 99K–494-6 and IT 98K-205-8 suggests that resistance if these genotypes was also expressed before attachments, by probably production of inhibitors. It is also possible that *Alectra* seedlings were detached at the very early stages but were unnoticed since observations were made using a dissecting microscope rather than electronic microscope. Lane *et al*. (1993) also suggested that host and non-host plants are able to stimulate suicidal germination of the parasite by releasing compounds for the inducation of *Striga* germination followed by disruption of a specific early development stages. Alternatively, Goldwasser *et al*. (2002) suggest that induction of lignification of phytoalexin biosynthetic pathways may accompany other, as yet unidentified responses that play a more direct role in effective defence responses. For example, the hypersensitive response as has been proposed as a mechanism of cowpea resistance to *S. gesnerioides* and *Alectra vogelii* based on localized host root necrosis at the site of parasite penetration.

5.5 Response of cowpea cultivars following exposure to *Alectra vogelii*

Cowpea cultivars were categorized into resistant and susceptible to *Alectra* based on screen house experiment observations due to inconsistent of laboratory and screen house experiment results. For, example some cultivars such as IT 97K-829-118 induced high percentage germination of *Alectra* seed in the laboratory (42.3%) but exhibited resistance to *Alectra* in both pot experiments.

Genotypes IT 99K-494-6, IT 98K-628, IT 99K-7-21-2-2, IT 97K-829-118, IT 97K-499-35, IT 99K-573-2-1, IT 99K-573-1-1, IT 00K-1207, IT 98K-692, IT 98K-205-8, IT 97K-568-18, IT 98K-131-2 and IT 99K-530-1 showed resistance to *A. vogelii*. The hypersensitive reaction to *Alectra* expressed by these genotypes (section 5.4) together with less number of emerged *Alectra* shoots/pot at 9 WAS by 58.4-99.7 % compared to 80.9 shoots/pot supported by the susceptible check variety Tumaini, late emergence of *Alectra* shoots ranging from 37.8 – 74.5 DAP compared to 36 DAP in Tumaini and high grain yield (2.5-9.1 g/pot) compared to 0.13g/pot in Tumaini confirm the resistance of these genotypes to *A. vogelii*. Effect of late emergence of parasitc weed on grain yield have also been observed in sorghum by Mutengwa *et al*. (1999) in which sorghum cultivars that supported late emergence of *Striga asiatica* did not loose their yields. Genotype it 97k – 499 -35 has been recommended for release in the Northern Guinea Savanna of Nigeria for its high yield, resistance to *Striga, Alectra*, major diseases and insects (Singh *et al.*, 2006). However low grain yield (3.0g/pot) exhibited by this genotype in the *Alectra* infested pots compared to other resistant genotypes e.g. 9.1g/pot in IT 99K- 494-6 in this experiment, could to a large extent be attributed by variation of *Alectra* strains between Nigeria and Tanzania (Parker and Riches, 1993). Genotype IT 99K-530-1 was categoriesd as susceptible in section 5.4. However, it is considered as resistant considering the amount of grain yield it produced (2.5g/pot) and number of emerged *Alectra* per pot (38.9 compared to 80.9 in Tumaini. Further, the proportion long *Alectra* shoots was only 30% of the short ones and *Alectra* emerged at 42 DAS compared to 36 DAS in Tumaini which implies that 99K-530-1 produced some *Alectra* growth inhibitors.

All four locally grown varieties namely Tumaini, Fahari, Vuli I and Vuli II and 12 genotypes from IITA; IT 97K-390-2, IT 00K-835-45, IT 93K-452-1, IT 99K-529-1, IT

03K-378-4, IT 98K-506-1, IT 96D-610, IT 98K-555-1, IT 00K-1148, IT 90K-277-2, IT 97K-1042-3 and IT 98K-1111-1 showed susceptibility to *Alectra* at early growth stagesas discussed in section 5.4. These observations were further supported by the magnitude of low grain yield 0-1.5g/pot), early *Alectra* emergence (32.3-41.4 DAP which was comparable to 36 DAP in Tumaini), high number of emerged *Alectra* shoots per pot (55.5-114.4) compared to 80.9 *Alectra*/pot in Tumaini in screen house experiments. Other authors, (Gil *et al.,* 1987; Cubero, 1991; Rubiales *et al*., 2006) have also indicated that the number of emerged parasites in pot and field experiments as the most widely used index for resistance to *Orobache, Alectra* and *Striga.* They noted this index to be simple to measure and more accurate than other index, but it can be misleading, particularly when considering vigour and weight of parasitic shoots. For example, they observed that when the number of attached *Orobache* were few they had less competition for resources and thus resulting in similar weights of broomrape collected on susceptible and resistant plants. This observation agrees with weight of *Alectra* shoots observed in moderately resistant genotypes IT 00K-1207 (2.7g) and IT 97K-499-35 (3.0g) which were significantly ($P< 0.05$) similar to 3.5g recorded in susceptible variety Vuli I. Weight and numbers of *Alectra* shoots at harvest can also be misleading due to death of *Alectra* shoots as has been observed in some cultivars at various growth stages.

All cowpea cultivars that showed resistant to moderately resistant to *A. vogelii* were white, cream or orange in seed coat colour (Table 1). None of the cultivar that possessed brown or red seed coat colour was resistant to *A. vogelii.* In contrary Mgonja (2005) observed variation in seed coat in inhibition of radicle growth of the *S. asiatica* seeds by bambara groundnut of different seed coat colour in the order of black seeded bambara groundnut > red seeded > cream seeded. The author attributed this to variation in flavonoids levels in

seed coats. Dark grain legumes have been found to contain higher percentages of flavonoids than those pocessing light seed coat colours (Ndakidemi and Dakora, 2003). Susceptibility of cowpea pocessing dark seed coat colour to *Alectra* in this study implies that flavonoids levels in cowpea had no influence on radicle growth. This may require further investigation.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

(i) Results from the laboratory study showed that screening cowpea for low germination stimulant production is unreliable for assessing resistance of cowpea cultivars to *A. vogelii*. Stimulation of germination percentages of *Alectra* seeds by cowpea root exudates ranging from 16.9-42.7% revealed that resistance of cowpea to *A. vogelii* is not due to low stimulant production.

(ii) Evaluation of cowpea cultivars at 2 and 5 WAS in the study to investigate the parasitism of selected cowpea cultivars by *Alectra vogelii* and levels of resistance in the cowpea genotypes revealed that susceptibility or resistance of cowpea to *A. vogelii* can be expressed within 5 weeks after inoculation. In addition, resistance of cowpea to *Alectra* is a hypersensitive type of reaction and is expressed after germination and attachment and/or penetration of *Alectra* seedlings into cowpea roots.

(iii) Generally cowpea cultivars that supported early emergence and high numbers of *Alectra* shoots in the pot experiments were equally highly susceptible to *A. vogelii* and severely affected in growth, grain yield and yield components. However variation in *Alectra* emergence and grain yields in the screen house experiment among cultivars that showed resistance at 5 WAS revealed that data on early infection studies need to be supplemented with screen house and field observations.

(iv) Based on the data of screen house pot experiments at early growth stages and in evaluating growth and yield variables, it can be concluded that genotype IT 99K-494-6, IT 98K-628, IT 97K-829-118, IT 99K-7-21-2-2, IT 98K-205-8, IT 97K-499-35, IT 99K-573-2-1, IT 99K-573-1-1, IT 00K-1207, IT 98K-692, IT 97K-568-18, IT 98K-131-2 and IT 99K-530-1 are resistant to *A. vogelii* strains from Dodoma, Tanzania. All four locally grown varieties; Tumaini, Fahari, Vuli I and Vuli II and 12 genotypes from IITA; IT 97K-390-2, IT 00K-835-45, IT 93K-452-1, IT 99K-529-1, IT 03K-378-4, IT 98K-506-1, IT 96D-610, IT 98K-555-1, IT 00K-1148, IT 90K-277-2, IT 97K-1042-3 and IT 98K-1111-1 are susceptible.

(v) Among the cowpea cultivars evaluated, no cultivar exhibited tolerance to *Alectra vogelii.*

6.2 Recommendations

(i) Since there is no tolerance, cultivars supporting high numbers of *Alectra* with tubercles and long shoots at 5 WAS can be discarded early before subjecting materials for further screen house and field screenings.

(ii) Cowpea cultivars that exhibited resistance to *Alectra vogelii* should eventually undergo field testing for confirmation of degree of resistance and assessment for yield, resistance to other pests and farmer’s preference.

(iii) Growing resistant cowpea genotypes in the infested areas is recommended. This will reduce *Alectra* seed levels in the soil by limiting formation of new *Alectra* seeds.

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APPENDICES

Appendix 1: Mean germination percentages of *A. vogelii* seeds exposed to root exudates of different cowpea cultivars at different distances (Arcsine transformed)

Cowpea Cultivar	Distance from the source (mm)				
	5	10	15	20	25
IT 99k-573-2-1	40.7a-j	39.6a-j	36.7a-n	31.3c-p	25.6i-t
IT 97k-390-2	39.9a-j	40.6a-j	40.5a-j	32.9b-o	32.9b-o
IT 00k-835-45	41.3a-i	44.4a-f	38.0a-l	28.0f-s	21.8k-t
IT 99k-494-6	36.2a-n	40.3a-j	32.9b-o	28.1f-s	20.7n-t
IT 93k-452-1	31.2c-p	31.1c-p	31.2c-p	33.3b-o	32.5b-o
IT 98k-628	41.3a-i	40.5a-j	33.9a-o	39.7a-j	27.2g-t
IT 00k-1207	39.8a-j	35.5a-n	28.2e-s	26.6g-t	21.0m-t
IT 99k-7-21-2-2	44.9a-e	40.5a-j	33.8a-o	28.3e-s	21.5l-t
IT 99k-529-1	44.4a-f	39.6a-j	39.9a-j	33.2b-o	26.1h-t
IT 98k-692	27.9f-s	25.3i-t	24.4j-t	26.0h-t	17.8o-t
IT 97k-499-35	45.3a-d	48.5ab	38.5a-k	40.7a-j	31.1c-p
IT 99k-573-1-1	42.9a-g	41.8a-i	41.2a-i	40.5a-j	34.2a-o
IT 03k-378-4	30.3c-q	29.0d-r	28.9d-r	25.1i-t	21.6l-t
IT 97k-829-118	45.6a-d	42.6a-h	43.2a-g	40.2a-j	31.4c-p
Fahari	40.6a-j	38.8a-j	36.7a-n	30.7c-q	31.8c-o
Tumaini	45.4a-d	47.0abc	39.8a-j	31.5c-p	27.9f-s
Vuli I	36.1a-n	37.7a-m	32.3b-o	27.2g-t	21.1m-t
Vuli II	39.4a-j	33.7a-o	34.9a-n	36.6a-n	31.5c-p
GR 24 (10 mg/l)	50.4a	50.2a	44.9a-e	45.4a-d	38.5a-k
Distilled water	12.8rst	10.6t	14.9p-t	11.7st	14.3q-t

Mean values in the same column followed by the same letter do not differ Significantly at (P≤0.05) using (THSDT).

Appendix 2: Summary of analysis of variance (ANOVA) for evaluation of cowpea cultivars in production of *Alectra* germination stimulant.

Source of variation	Degree of freedom	Sum of Squares	Mean Square	F-value
Periods (P)	1	862.2	862.2	10.3***
R(P)	6	1131.4	188.6	2.3**
Factor A (Stimulant source)	19	37720.5	1985.3	23.7***
PA	19	2172.7	114.4	1.4ns
Error	114	9538.6	83.7	
Factor B (Disk distance)	4	15882.2	3970.6	74.8***
PB	4	2301.8	575.4	10.8***
AB	76	7150.1	94.1	1.8***
PAB	76	8897.2	117.1	2.2***
Error	**480**	**2546.9**	**53.1**	
Total	**799**	**111121.6**		
CV (%)	**21.45**			

ns = not statistically significant, *, ** and *** = significant at 5%, 1% and 0.1% level respectively. CV = coefficient of variation**.**

Appendix 3: Summary of analysis of variance (ANOVA) for variables analysed in high stimulant production cowpea cultivars screen house experiment

Variables analysed	MS for factor A x B	MS for Error	F -value	Probability value
Days to cowpea flowering	298.4	56.9	5.24***	0.0002
Cowpea plant height at 9 WAS	494.7	142.6	3.47**	0.0044
Days to *Alectra* appearance	296.9	23.7	12.5***	0.0000
Days to *Alectra* flowering	59.7	8.1	7.36***	0.0000
Cowpea damage syndrome rating	22.1	0.1	217.48***	0.0000
Days to physiological maturity	91.0	14.6	6.24***	0.0000
Number of pods/pot	28.3	1.9	14.73***	0.0000
Pod length (cm)	146.7	2.5	58.13***	0.0000
Number of seeds/pod	106.4	2.6	41.69***	0.0000
Weight of grains/pot (g)	49.1	1.6	29.68***	0.0000
10 grain weght (g)	0.4	0.02	17.78***	0.0000
Harvest index (%)	589.1	15.6	37.81***	0.0000
Shelling %	104.5	7.0	14.9***	0.0000
Weight of cowpea shoots/pot (g)	0.5	0.1	5.11**	0.0002
Weight of cowpea roots/pot (g)	0.2	0.3	0.84ns	-
Shoot:Root ratio	0.1	0.1	1.19ns	0.325
Number of leaves/plant	2.8	0.8	3.35*	0.0123
Number of flowered *Alectra* shoots/pot	11.1	2.4	4.58**	0.0023
Number of *Alectra*/pot at 6 WAS	7.6	0.3	27.95***	0.0000
Number of *Alectra*/pot at 7 WAS	19.7	0.5	42.99***	0.0000
Number of *Alectra*/pot at 8 WAS	31.2	0.7	43.1***	0.0000
Number of *Alectra*/pot at 9 WAS	28.9	1.3	22.0***	0.0000
Number of *Alectra*/pot at 10 WAS	24.0	2.4	9.94***	0.0000
Number of *Alectra*/pot at harvest	20.5	3.9	5.32***	0.0002
Alectra vigour score	0.3	0.03	10.3***	0.0000
Weight of *Alectra* shoots/pot (g)	0.8	0.2	5.09***	0.0002
Number of unemerged *Alectra*/pot	0.8	1.6	0.46ns	-

MS = mean square, A = cowpea cultivars, B = *Alectra* levels
ns = not significant, *,** and *** = significant at 5%, 1% and 0.1% level respectively.

Appendix 4: Summary of analysis of variance (ANOVA) for variables analysed in medium stimulant production cowpea cultivars screen house experiment

Variables analysed	MS for factor A x B	MS for Error	F -value	Probability value
Days to cowpea flowering	881.3	63.8	13.81***	0.0000
Cowpea plant height at 9 WAS	652.3	69.5	9.39***	0.0000
Days to *Alectra* appearance	78.6	7.9	9.99***	0.0000
Days to *Alectra* flowering	29.4	9.2	3.2**	0.0072
Cowpea damage syndrome rating	15.7	0.3	63.44***	0.0000
Days to physiological maturity	155.8	11.4	13.64***	0.0000
Number of pods/pot	78.1	1.1	69.41***	0.0000
Pod length (cm)	119.4	3.6	33.0***	0.0000
Number of seeds/pod	8. 5	0.2	54.49***	0.0000
Weight of grains/pot (g)	43.9	1.3	33.95***	0.0000
10 grain weght (g)	0.2	0.0	8.15***	0.0000
Harvest index (%)	503.9	14.2	35.49***	0.0000
Shelling %	119.9	4.6	25.92***	0.0000
Weight of cowpea shoots/pot (g)	0.2	0.1	2.55*	0.0258
Weight of cowpea roots/pot (g)	0.65	0.6	1.07ns	0.3996
Shoot:Root ratio	0.11	0.1	1.37ns	0.2385
Number of leaves/plant	4.3	1.7	2.57*	0.0397
Number of flowered *Alectra* shoots/pot	7.3	1.8	3.99**	0.0050
Number of *Alectra*/pot at 6 WAS	4.0	0.6	6.74***	0.0000
Number of *Alectra*/pot at 7 WAS	11.4	0.6	19.21***	0.0000
Number of *Alectra*/pot at 8 WAS	17.9	1.4	13.27***	0.0000
Number of *Alectra*/pot at 9 WAS	20.5	2.4	8.56***	0.0000
Number of *Alectra*/pot at 10 WAS	20.1	3.3	6.18***	0.0000
Number of *Alectra*/pot at harvest	26.6	4.4	6.01***	0.0000
Alectra vigour score	0.24	0.1	4.62***	0.0005
Weight of *Alectra* shoots/pot (g)	0.8	0.1	5.54***	0.0001
Number of unemerged *Alectra*/pot	3.8	2.4	1.57ns	0.1663

MS = mean square, A = cowpea cultivars, B = *Alectra* levels
ns = not significant, *,** and *** = significant at 5%, 1% and 0.1% level respectively.

Appendix 5: Summary of analysis of variance (ANOVA) for variables analysed in low stimulant production cowpea cultivars screen house experiment.

Variables analysed	MS for factor A x B	MS for Error	F -value	Probability value
Days to cowpea flowering	539.8	62.0	8.71***	0.0000
Cowpea plant height at 9 WAS	338.4	62.5	5.42***	0.0008
Days to *Alectra* appearance	799.7	50.1	15.96***	0.0000
Days to *Alectra* flowering	48.9	4.8	10.1***	0.0000
Cowpea damage syndrome rating	19.7	0.1	157.73***	0.0000
Days to physiological maturity	36.5	6.2	5.93***	0.0004
Number of pods/pot	28.8	1.9	15.03***	0.0000
Pod length (cm)	113.5	2.4	47.3***	0.0000
Number of seeds/pod	76.5	2.2	34.62***	0.0000
Weight of grains/pot (g)	67.5	5.1	13.37***	0.0000
10 grain weght (g)	0.6	0.01	93.19***	0.0000
Harvest index (%)	418.1	82.8	5.05**	0.0013
Shelling %	218.8	270.0	0.81ns	-
Weight of cowpea shoots/pot (g)	0.5	0.1	7.58***	0.0001
Weight of cowpea roots/pot (g)	0.4	0.2	2.37ns	0.0590
Shoot:Root ratio	0.1	0.04	3.14*	0.0188
Number of leaves/plant	3.3	0.7	4.91*	0.0052
Number of flowered *Alectra* shoots/pot	13.2	0.6	20.9***	0.0000
Number of *Alectra*/pot at 6 WAS	5.7	0.2	25.07***	0.0000
Number of *Alectra*/pot at 7 WAS	18.9	0.6	33.32***	0.0000
Number of *Alectra*/pot at 8 WAS	35.1	0.7	48.3***	0.0000
Number of *Alectra*/pot at 9 WAS	43.2	0.8	57.35***	0.0000
Number of *Alectra*/pot at 10 WAS	41.5	0.9	48.04***	0.0000
Number of *Alectra*/pot at harvest	52.12	1.3	39.37***	0.0000
Alectra vigour score	0.6	0.02	31.05***	0.0000
Weight of *Alectra* shoots/pot (g)	1.4	0.2	8.44***	0.0000
Number of unemerged *Alectra*/pot	5.6	1.3	4.27**	0.0038

MS = mean square, A = cowpea cultivars, B = *Alectra* levels
ns = not significant, *,** and *** = significant at 5%, 1% and 0.1% level respectively.

Appendix 6: Summary of analysis of variance (ANOVA) for variables analysed in 'no spray' cowpea cultivars screen house experiment.

Variables analysed	MS for factor A x B	MS for Error	F -value	Probability value
Days to cowpea flowering	589.8	42.8	13.75***	0.0000
Cowpea plant height at 9 WAS	292.7	57.7	5.07***	0.0001
Days to *Alectra* appearance	93.1	8.4	11.05***	0.0000
Days to *Alectra* flowering	26.7	14.1	1.9ns	0.0653
Cowpea damage syndrome rating	4.8	0.2	20.6***	0.0000
Days to physiological maturity	31.0	14.7	2.1*	0.0403
Number of pods/pot	11.5	1.8	6.41***	0.0000
Pod length (cm)	64.1	3.7	17.11***	0.0000
Number of seeds/pod	32.0	2.5	12.79***	0.0000
Weight of grains/pot (g)	14.1	0.8	18.15***	0.0000
10 grain weght (g)	0.2	0.01	18.82***	0.0000
Harvest index (%)	242.6	27.45	8.84***	0.0000
Shelling %	60.3	9.3	6.48***	0.0000
Weight of cowpea shoots/pot (g)	0.3	0.2	2.24*	0.0285
Weight of cowpea roots/pot (g)	0.4	0.2	2.08*	0.0427
Shoot:Root ratio	0.04	0.1	0.8ns	-
Number of leaves/plant	2.6	1.0	2.76**	0.0082
Number of flowered *Alectra* shoots/pot	5.1	2.6	1.96ns	0.0559
Number of *Alectra*/pot at 6 WAS	4.8	0.7	6.79***	0.0000
Number of *Alectra*/pot at 7 WAS	10.4	1.0	10.39***	0.0000
Number of *Alectra*/pot at 8 WAS	13.8	1.6	8.91***	0.0000
Number of *Alectra*/pot at 9 WAS	16.6	1.8	9.1***	0.0000
Number of *Alectra*/pot at 10 WAS	17.1	1.9	8.86***	0.0000
Number of *Alectra*/pot at harvest	16.9	7.3	2.3*	0.0246
Alectra vigour score	0.1	0.1	1.75ns	0.0928
Weight of *Alectra* shoots/pot (g)	0.4	0.2	1.86ns	0.0713
Number of unemerged *Alectra*/pot	2.8	1.5	1.9ns	0.0654

MS = mean square, A = cowpea cultivars, B = *Alectra* levels
ns = not significant, *,** and *** = significant at 5%, 1% and 0.1% level respectively.