GROWTH AND YIELD RESPONSE OF FOUR NEWLY- BRED COWPEA VARIETIES (*VIGNA UNGUICULATA* (L.) WALP) TO *ALECTRA VOGELII* (BENTH) INOCULATION AND NPK FERTILIZER APPLICATION

BY

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(P13SCBS8032)

DEPARTMENT OF BIOLOGY,
FACULTY OF LIFE SCIENCES,
AHMADU BELLO UNIVERSITY,
ZARIA, NIGERIA

JULY, 2018

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A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN BIOLOGY

DEPARTMENT OF BIOLOGY,
FACULTY OF LIFE SCIENCES,
AHMADU BELLO UNIVERSITY,
ZARIA, NIGERIA

JULY, 2018

DEDICATION

This research work is dedicated to the loving memory of my dear mother Late Lady Ngozi Nonye Okeh.

DECLARATION

I declare that the work in this dissertation entitled **"Growth and Yield Response of Four Newly-Bred Cowpea Varieties to *Alectra vogelii* (Benth) Inoculation and NPK Fertilizer Application"** has been carried out by me in the Department of Biology under the supervision of Prof. S. O. Alonge and Prof. D. N. Iortsuun. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this Dissertation was previously presented for another degree or diploma at this and any other institution.

Okeh, Miriam Onyinyechi _____ _____

Signature Date

CERTIFICATION

This dissertation entitled "GROWTH AND YIELD RESPONSE OF FOUR NEWLY-BRED COWPEA VARIETIES TO *ALECTRA VOGELII* (BENTH) INOCULATION AND NPK FERTILIZER APPLICATION" by Miriam Onyinyechi OKEH meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

Cowpea (vigna unguiculata) is an important source of protein and income for farmers in Africa but its production has been constrained by *Alectra vogelii* Benth, a parasitic weed which attaches itself to the root of cowpea plants and diverts the assimilate from cowpea roots to itself. Therefore, two pot trials were conducted in the Horticultural Garden of the Department of Agronomy and under a Screen house in the Department of Soil Science, Institute for Agricultural Research, Ahmadu Bello University, Zaria to evaluate the Growth and Yield Response of Four Newly-bred Cowpea (*Vigna unguiculata* (L.) Walp) Varieties to *Alectra vogelii* Inoculation and NPK Fertilizer (15:15:15) Application. The trial consist of four cowpea varieties (IT08K-125-107, IT06K-128, IT07K-303-1, IT07K-299-6) obtained from International Institute of Tropical Agriculture, Kano Substation and four levels of NPK fertilizer (0, 100, 200 and 400 kgNPK/ha). The treatments were applied with *Alectra vogelii* (0 kgNPK/ha + Alectra) and without *Alectra vogelii i*noculation (0 kgNPK/ha + zero *Alectra*). The experiments were designed in a completely randomized design in three replications and with six (6) pots to represent each replicate. Growth and yield parameters such as plant height, shoot fresh weight, root fresh weight, number of root nodules, leaf area index, pod weight, pod length, 100 seed weight, number of pods per plant and grain yield were evaluated. Generally, NPK fertilizer application significantly improved vegetative growth and yield of the cowpea varieties with 400 kgNPK/ha giving the best growth and yield. Fertilizer application at 400 kgNPK/ha significantly enhanced plant height (23.72 cm), shoot fresh weight (71.48 g) and leaf area index (1.22) when compared with the control (18.65 cm, 14. 92g and 0.17 respectively) at 9 WAS in Trial 1. *Alectra* inoculation significantly reduced root fresh weight (0.90 g) and root nodules (40.77) of cowpea plants inoculated with *Alectra* when compared with the *Alectra* uninoculated cowpea plants (1.00 g and 46.58 respectively) at 7 WAS in Trial II. Highest grain yield per plot was observed under cowpea variety IT07K-303-1

in Trial I (75.95 g) and Trial II (70.15 g) while the lowest grain yield was observed under cowpea variety IT08K-125-107 in Trial I (58.11 g) and Trial II (49.39 g). The best grain yield (68.49 g) was due to the application of 400 kgNPK/ha fertilizer when compared with the untreated control (59.98 g) in Trial I. Number of pods/plant, pod length, and seed weight per pod of cowpea plants were significantly reduced due to *Alectra* inoculation when compared with the uninoculated cowpea plants in Trial I. Cowpea variety IT07K-303-1 was observed to have supported the highest number of *Alectra vogelii* shoots per plot (2.00) and cowpea variety IT06K-128 supported the lowest number of *Alectra vogelii* shoots per plot (0.29) in Trial II. In conclusion, the study showed that, application of NPK fertilizer enhanced vegetative growth and yield parameters of the cowpea varieties. *Alectra vogelii* inoculation generally reduced most of the vegetative growth parameters and consequently yield parameters. Cowpea variety IT07K-303-1 was tolerant to *Alectra vogelii*. Therefore, cowpea variety IT07K-303-1 and 400 kgNPK/ha fertilizer rate can be recommended for effective control of *Alectra vogelii* and improved cowpea yield.

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ABBREVIATIONS

WAS: Weeks after Sowing

NS: Not Significant

SE: Standard Error

FAO: Food and Agriculture Organization

IITA: International Institute of Tropical Agriculture

IAR: Institute for Agricultural Research

IBPGR: International Board for Plant Genetic Resources

ANOVA: Analysis of Variance

NDMRT: New Duncan's Multiple Range Test

N.B: Note Bene (Take special note of)

PASCON: Pan-African *Striga* Control Network

NPK: Nitrogen, Phosphorus, Potassium

ICRISAT: International Crops Research Institute for the Semi-Arid Tropics

IDRC: International Development Research Center

Na: Sodium

Mg: Magnesium

Ca: Calcium

GLM: General Linear Model

CHAPTER ONE

1.0 INTRODUCTION

1.1 Botanical Classification of Cowpea

Cowpea (*Vigna unguiculata* (L.) Walp) belongs to the class Dicotyledonae, order Fabales, family Fabaceae, subfamily Faboideae, tribe Phaseoleae, subtribe Phaseolinae, and genus *Vigna* (Padulosi and Ng, 1997). All cultivated cowpeas are grouped under *Vigna unguiculata*, which is subdivided into four cultivar groups (cv. gr.): *unguiculata* (the common cowpea), *biflora* (the catjang), *sesquipedalis* (the yard-long bean) and *textilis* (used for fibers) (2001; Singh *et al.*, 1997).

1.2. Origin, Domestication and Geographic Distribution of Cowpea

The specific origin of cowpea (*Vigna unguiculata*) has remained a controversial focus for study to many botanists especially the specific primary centre of cultivation in Africa, since it is the only place around the world where the diversity of wild forms of cowpeas are found (Steele, 1979). Cowpea is considered to have been domesticated in Africa from its wild ancestral form, *V. unguiculata* subsp dekindtiana (Harms) Verdc (Ng and Marechal, 1985). However, the precise location of origin where cowpea was first domesticated is still under speculation.

According to Ba *et al*. (2004), cowpea was probably domesticated in West Africa. Some evidence shows that, the North-eastern part of Africa is the primary point of cowpea domestication based on molecular studies (Coulibaly *et al*., 2002). South Africa is also reported as the centre of origin but it is not yet clear where the crop was first planted in the region (Timko and Singh, 2008).

Cowpea was probably introduced from Africa to the Indian subcontinent approximately 2000 to 3500 years ago (Tosti and Negri, 2002). From West Indies, cowpea was taken to USA in about 1700 BC (Purseglove, 1984). The slave trade from West Africa resulted in

the crop reaching the southern United States of America in early 18th century, However, many US cultivars appear more closely related to germplasm from Asia or southern Europe than West Africa (Fang *et al*., 2007). Presently, cowpea is grown throughout the tropical and subtropical regions of the world.

1.3 Botanical Description of Cowpea

Vigna unguiculata is a herbaceous, prostrate, climbing or sub erect annual plant, growing 15-80 cm high. Leaves are alternate trifoliate with petiole 5-25 cm long. The lateral leaflet is opposite and asymmetrical, while the central leaflet is symmetrical and ovate. The inflorescence are racemose, flowers are white, cream, yellow or purple. Growth habit is either determinate or indeterminate. Seeds are variable in size and shape (kidney, ovoid, crowder, globose or rhomboid) (IBPGR, 1983). Seeds are of various colours: white, brown, black, cream or grey, dotted (black, brown), purple or red. Pod's length ranges from 8-22 cm with 10-20 seeds per pod (Timko and Singh, 2008).

1.4 Climatic and Soil Requirements for Cowpea Growth

Cowpea is a warm season crop and thrives in hot, moist conditions. Cowpeas have similar growth requirements to soybeans and should not be planted until after the last frost and only when the soil temperature has reached 18.3 °C (65 °F) to prevent seeds rotting in the ground (Quinn, 2014). The plant is sensitive to frost. Cowpeas can be planted in a wide range of soils, from acidic (pH 4) to neutral, as long as they are well-drained but the plants are not well adapted to alkaline soil. For best results, cowpea should be planted in a well drained sandy loam soil with a pH between 5.5 and 6.5 in an area that receives full sunlight. Cowpeas are drought resistant and very heat tolerant, which means they can be grown successfully in many areas (Quinn, 2014).

1.5. Importance of Cowpea

Cowpea occupies a very unique position in the world agriculture by value of its high protein and starch contents and capacity to fix atmospheric nitrogen (Tarawali *et al*., 2002). In many of the developing countries, cowpea is the major source of dietary protein. IITA (2009) noted that there is a big market for cowpea grains and fodders in West Africa; and that in Nigeria, farmers who cut and store cowpea fodder for sale at the peak of the dry season have been found to increase their annual income by 25 % (Dugje *et al.*, 2009). Cowpea farmers, who adopted improved cowpea varieties and management practices, reported an average of 55 per cent rise in their incomes (IITA, 2011).

Cowpea is among the major legume food in sub-Saharan Africa, especially in Southern Africa where the grain and leaves are major sources of food and family income, particularly for the low income households. The seed is reported to contain 24 % crude protein, 53 % carbohydrates and 2 % fat (FAO, 2012), and also serves as a cheap source of vitamins and minerals. The crop enhances the quality of the cereal based diets when its high lysine content is combined with the high content of methionine and cystine of cereals (Lambot, 2002). In terms of utilization, cowpeas can be used to prepare various dishes, which are traditionally acceptable and valued. The young tender leaves can be cooked and eaten as vegetable and the green pods can be cooked and eaten just like green beans (Tarawali *et al.*, 2002). In addition, the seeds can be cooked when fresh (semi-ripe) or eaten as pulses when fully matured and dried. In most parts of Nigeria, this protein-rich crop is processed into bean cakes, moi-moi and beans soup (IITA, 2011).

A variety of birds, including wild turkey, eat the seeds and the plant can be used by quail as cover. Some varieties of cowpea are used specifically for wildlife purposes (Hall *et al*., 2003).

Cowpea can be used as forage, hay and silage. When used as forage, it should only be lightly grazed after flowering (FAO, 2012). If there are several buds left after defoliation, the plant will regenerate. When used as silage, it can be mixed with *Sorghum*, maize, or molasses to provide sugar for fermentation (FAO, 2012). In some African countries, several varieties of Cowpea have been grown together for both food and feeds (Cook *et al*., 2005).

Cowpea has been used as both a cover crop and green manure (Clark, 2007). In addition, the crop improves the cropping systems and soil fertility by reducing soil erosion, suppressing the weeds and fixing atmospheric nitrogen which contributes to increased yields of non-nitrogen fixing crops grown with or after it (Tarawali *et al*., 2002).

Allelopathic compounds in the plant may help to suppress weeds (Clark, 2007). Cowpea has also been used successfully as groundcover in orchards and intercropped with cash crops such as cotton.

1.6 Cowpea Production

Cowpea is grown on approximately 12.5 million hectare of land in the world from which 3 million tonnes of grains are produced (FAOSTAT, 2012). Africa is the leading producer, with West and Central Africa accounting for about 64 % of world production (Singh *et al*., 2002). Nigeria is the world's leading cowpea producing country, and accounts for more than 50 % of the total world cowpea grain production, followed by Brazil (Singh *et al*., 2002; FAOSTAT, 2008). Other countries from West Africa which are important producers of cowpea are Niger, Burkina Faso, Senegal, Ghana, Cameroon and Mali (Fery, 2002; FAOSTAT, 2008). Considerable production also takes place in Asia and Oceania, the Middle East, Southern Europe, Southern USA, Central and South America (Singh *et al*., 2002). The other important producers in Eastern and Southern

Africa are Ethiopia, Kenya, Tanzania, Malawi, Botswana, Zimbabwe and Mozambique (Ehlers and Hall, 1997; NGICA, 2006).

In Nigeria, the greatest production of cowpea comes from the northern region. The north produces about 1.7 million metric tonnes from 4 million hectares. This represents over 60 % of the total production (FAO, 2010). In 2010, Nigeria produced 2.2 million metric tonnes of cowpea, making her the largest producer and consumer of the crop with the estimated yield put at 687 kg/ha (FMARD, 2011).

1.6.1 Cowpea production constraints

Although cowpea is widely cultivated, the average yield on farmers' fields are low, estimated at 300 kg/ha (Takim and Uddin, 2010). The low yields have been attributed to a number of biotic stresses such as insect pests, nematodes, diseases and parasitic weeds and abiotic stresses such as drought, high temperatures, low soil fertility, low pH and aluminum toxicity (Ehlers and Hall, 1997; Hall, 2004). Other factors include economic constraints, wrong intercropping practices, inappropriate sowing date, use of poor varieties, low plant density, use of late maturing varieties as well as inaccessibility to extension services by the farmers (Coulibaly *et al*., 2002 and Stahley *et al*., 2012).

Parasitic weeds cause considerable damage and reduce the yield of cowpea in the savanna belt of Nigeria. The most important parasitic weeds that affect cowpea in these regions are *Striga gesnerioides* and *Alectra vogelii*. The damage on the crop is done before the parasitic weed seedlings emerge above the ground (Singh and Emechebe, 1991). *Striga gesnerioides* is mostly confined to the Sudan and Sahel savanna while *Alectra* occurs mostly in the northern Guinea savanna; they are regarded as hemi-parasite. *Alectra vogelii* has been shown to cause extensive damage in groundnuts (*Arachis hypogaea*), cowpea (*Vigna unguiculata*) and soybean (*Glycine max*) among other legumes, with yield losses on cowpea reaching up to 70 % and even 100 % under

severe infestation (Kwaga *et al*., 2010a; Xie and Yoneyama, 2010)). *Alectra vogelii* was reported to be one of the noxious weeds that contribute to yield losses in cowpea that need to be managed in order to ensure high yield in production areas where this parasitic weed was found to be a problem (Mbwaga *et al*., 2010).

1.7 Statement of Research Problem

Cowpea production has been constrained by *Alectra vogelii* (Benth) which attaches itself to the roots of cowpea plants and diverts the assimilate from roots to itself, and hence causes the reduction of the total biomass and yield (Singh and Emechebe, 1997). The problem of *Alectra vogelii* appears to be widely spread in the sub-Saharan Africa (Kabambe *et al*., 2005 and Karanja *et al*., 2013) and high cowpea yield losses have been reported in areas infested by the parasitic weed (Emechebe *et al*., 1991; Lagoke *et al*., 1994).

The effect of *Alectra* is equally devastating in heavily infested cowpea fields in Botswana (Parker and Riches, 1993), Kenya (Bagnall-Oakely *et al*., 1991) Southern and Eastern Africa (Kabambe *et al*., 2005; Mbwaga *et al*., 2010 and Karanja *et al*., 2013). Yield losses associated with *Alectra vogelii* have been reported to range from 83 - 100 % (Singh *et al.*, 1993). Several cultivated lands have been abandoned due to high infestations by this noxious parasitic weed (Lagoke *et al*., 1988). Dugje *et al.*, (2006) carried out a survey of the level of *Alectra vogelii* infestation on farmers' field in North Eastern Nigeria and reported that, more than 81 % of the fields grown to cowpea in this region were infested with *Alectra vogelii,* resulting in serious yield losses.

Kudi and Abdulsalam (2008) reported that, *Alectra vogelii* spreads rapidly in areas of low fertility and decreasing plant diversity; an experience of poor farmers in dry land zones.

Different control measures have been widely proposed for the control of *A. vogelii* and these include hand weeding, chemical control, crop rotation and use of trap crop but with little success (Boukar *et al.,* 2004). The ability of the parasite to produce high quantity of seeds, which can be dormant in the soil for more than ten years, and their intimate physiological interaction with their host plants, are the main difficulties that limit the development of successful control measures that can be adopted and used by subsistence farmers (Rugare *et al*., 2013).

It has been suggested that, organic manure should be used in place of chemical fertilizer to avoid long-term negative effects of chemical fertilizer on the soil (Parr *et al*., 1990). However, organic manure is usually required in large quantity to sustain crop production and may not be available to small scale farmers (Nyathi and Campbell, 1995), hence the need for inorganic fertilizer.

1.8 Justification

Cowpea's high protein content, its adaptation to different types of soil and intercropping systems, its resistance to drought, and its ability to improve soil fertility and prevent erosion makes it an important economic crop in many developing regions. The sale of cowpea haulms as livestock feed during the dry season also provides a vital income for farmers. It is widely grown in the semi-arid zones of West Africa, where *Alectra vogelli* (Benth.) is an important weed which affects the growth and development of the crop and leads to yield reduction. Controlling *Alectra vogelii* has become an enormous task. There is a need for continuous effort in solving *Alectra* problem in order to achieve sustainable food production. Nitrogen fertilization is known to ameliorate the effects of *Alectra* on cowpea.

The growth, development and yield of *Alectra vogelii* infested cowpea has been reduced compared to the uninfected crop, hence the need for effective control measures to combat the devastating effect of *Alectra* on cowpea.

For effective management in the fields, the survey carried out by Karanja (2009) indicated that the combined use of host plant resistance/tolerance and crop rotation with non-host nitrogen fixing legumes or increase in soil fertility and proper soil management may not only stop further spread of the weed, but also reduce soil *Alectra* seed bank Several authors have reported high yielding *Striga/ Alectra* resistant cowpea genotypes which are becoming popular with farmers in West African Savanna (Singh *et al*., 2002; Kamara *et al*., 2008). Therefore, evaluating the growth and yield responses of newly-bred cowpea varieties under *A. vogelii* infestation and NPK fertilizer will provide useful information on the reaction of the crop to the parasitic weed and amelioration of the negative effect on the crop by fertilization.

1.9 Aim

The aim of this study is to evaluate the growth and yield response of some newly-bred cowpea varieties to *Alectra vogelii* infestation and NPK fertilizer application

1.10 Objectives

1. To determine the effects of NPK fertilizer on the vegetative growth parameters of some newly- bred cowpea varieties.
2. To determine the effects of NPK fertilizer on the yield parameters of some newly- bred cowpea varieties.
3. To determine the effects of NPK fertilizer on *Alectra* infestation of some newly-bred cowpea varieties.

1.11 Hypotheses

1. The NPK fertilizer has no significant effect on the vegetative growth parameters of some newly-bred cowpea varieties.
2. The NPK fertilizer has no significant effect on the yield parameters of some newly-bred cowpea varieties.
3. The NPK fertilizer has no significant effect on *Alectra vogelii* infestation of some newly-bred cowpea varieties.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1 Origin and Spread of *Alectra vogelii*

Alectra vogelii Benth is a parasitic weed which attacks most of the legume crops in Sub-Saharan Africa. Cowpea (*Vigna unguiculata*) is a major host for this weed but other legumes like groundnuts (*Arachis hypogaea* L.), soybean (*Glycine max*. (L.) Merrill), common bean (*Phaseolus vulgaris*) and other tropical legumes have been found to be infested by *A. vogelii* (Kureh *et al*., 2005). *Alectra* is an annual weed which has spread in most cowpea growing areas in Eastern Africa and yield losses of 50 to 100 % have been observed in heavily infested fields (Kureh *et al*., 1999; Karanja *et al*., 2013).

Little is known of the origin of *Alectra vogelii*. It is presumably to have moved with the cowpea crop during human migrations from West and Central Africa (CABI, 2012). Although, *A. vogelii* is already widespread in semi-arid areas of Africa, further spread might have occurred through contaminated seed shipments to markets or in grain samples distributed throughout sub-Saharan Africa for trials by research organizations. The accidental introduction of the related *Striga asiatica*, a noxious parasitic weed of maize and other cereals, into the USA in the 1950s (Parker and Riches, 1993) demonstrates that, long-distance spread of the tiny seeds of these root parasites is possible.

In East and Southern Africa, cowpeas are heavily infested by *Alectra vogelii* which reduces yield and sometimes total yield losses may be observed under the heavy infestation by this parasitic weed (Atokple *et al*., 1995, Singh and Emechebe, 1997, Singh *et al*., 1997).

Alectra vogelii has spread in various parts of South and East Africa. Most parts of Malawi including Lilongwe, Kasungu plains, Dowa and Blantyre Shile Highlands are known to be infested with *A. vogelii* (Mainjeni, 1999, Kabambe *et al*., 2005,). Yield losses ranging from 20 to 100 % has been observed in *Alectra vogelii* infested areas (Bagnall-Oakley *et al*., 1991; Karanja *et al*., 2010). *Alectra vogelii* infestations have been observed in other legume crops grown in Eastern and Southern Africa in various regions. Groundnuts (*Arachis hypogaea* (L.)), bambara nut (*Vigna subteraneane*), soybeans (*Glycine max* (L.)) and common beans (*Phaseolus vulgaris* (L.)), have also been observed to be infected by *Alectra vogelii* (Riches, 1989, Riches *et al*., 1992, Lagoke *et al*., 1993).

Alectra as a weed shows great phenotypic plasticity, wide environmental tolerance but prefers permanently disturbed habitats (Emechebe and Singh, 1990). *Alectra* is known to parasitize cultivated legumes in many parts of Africa. From Switzerland to the Transvaal in Southern Africa, the range of this purely African species extends through Central Africa to Burkina Faso and Mali in the West and Kenya in the East of the continent (Riches, 1987). The seeds of most parasitic weed plants can be disseminated by a combination of wind and water. Seeds of *Alectra* are also soil borne. Emechebe *et al*. (1983) and Lagoke (1989) reported that, the seeds are spread by contaminated agricultural equipments from one field to another and also by movement of the seeds of cowpea or groundnut contaminated by the parasite from one place to another. There are speculations that these parasitic weeds fed to animals on medicinal grounds are eaten inadvertently by the animals in combination with other herbs, passed out undigested in their excreta and therefore spread through their nomadic or seasonal movement across the savanna zones (Berner *et al.,* 1995).

Alectra vogelii is widely spread in Botswana, Malawi, Tanzania and Zimbabwe, with few occurrences in countries such as Sudan, Burkina Faso, Ethiopia, Namibia and DRC Congo. *Alectra vogelii* distribution is restricted in countries like Nigeria, Mali, South Africa, Kenya and Angola. *Alectra vogelii* has been reported to be indigenous to Botswana, Burkina Faso, Cameroon, Ethiopia, Ghana and Congo but not invasive in the aforementioned countries (Table 1).

2.2 Botany of *Alectra vogelii*

Alectra vogelii Benth belongs to a family Scrophulariaceae (Timko and Singh, 2008), it is an annual herb, 20–50 cm high; stems erect, simple or with several branches arising from the base. The base of the stem and roots are orange-yellow. *Alectra* has yellow flowers, leaves are opposite, ovate 7–25 mm long and 3–8 mm wide (Ghazanfar *et al.*, 2008). Other features of *Alectra* are the herbaceous shoot habit, dust-like seeds which are produced in large numbers. Seeds are produced in capsule, each of which may have 400-500 seeds and over 90,000 seeds may be produced by a single plant depending upon the branching and growth of the plants. The seeds are very small, measuring 0.15-0.25 mm in length (Singh and Emechebe, 1997). Longevity of the seeds in the soil varies between 6 months and 20 years according to climatic conditions (Bebawi and Farah, 1981).

2.3 The life cycle of *Alectra*

Parasitic plants have evolved specific traits which allow parasitism or reflect the consequences of adaptation to a parasitic life style. Critical stages in the life of an obligate root parasite are as follows (Atera and Itoh, 2011; Cardoso *et al.*, 2011):

Table 1: Geographical distribution of *A. vogelii* in Africa

Country	Distribution	Origin	Invasive	References
Angola	Restricted Distribution			Hutchinson and Dalziel,1963
Botswana	Widespread	Native	Not invasive	Philcox, 1990
Burkina Faso	Present, few occurrences	Native	Not invasive	Ramiah *et al*., 1988
Cameroon	Restricted distribution	Native	Not invasive	Parker and Riches, 1993
DRC Congo	Present, few occurrences	Native	Not invasive	Anota, 1991
Ethiopia	Present, few occurrences	Native	Not invasive	Stroud and Parker, 1989
Ghana	Restricted distribution	Native	Not invasive	Hutchinson and Dalziel, 1963
Guinea	Restricted distribution	Native	Not invasive	Hutchinson and Dalziel, 1963
Kenya	Restricted distribution	Native	Not invasive	Bagnall-Oakeley et al., 1991
Malawi	Widespread			Philcox, 1990
Mali	Restricted distribution			Hoffman and Diara, 1991
Mozambique	Restricted distribution			Philcox, 1990
Namibia	Present, few occurrences			Visser, 1978
Nigeria	Restricted distribution		1963	Hutchinson and Dalziel,
Sierra Leone	Present, few occurrences			Visser, 1978
South Africa	Restricted distribution			Parker and Riches,1993
Sudan	Present, few occurrences			Melchior, 1941
Swaziland	Restricted distribution			Visser, 1978
Tanzania	Widespread			Philcox, 1990
Uganda	Present, few occurrences			Riches, 1989
Zambia	Restricted distribution			Philcox, 1990
Zimbabwe	Widespread			Philcox, 1990

Source: CABI, 2012

i. the identification of a suitable host, thus associating germination and seedling growth with the presence and direction of a potential host;

ii. gain of access to the host's nutrients and water supply; this process involves the production of a functional haustorium;

iii. Completion of the life cycle on the host; this includes the establishment of parasitism and its maintenance until seeds are set.

2.4 Host Range of *Alectra vogelii*

Cowpea is the major crop host of *A. vogelii* (Parker and Riches, 1993). Alternative host include bambara nuts, groundnuts, common bean, soyabean, mung-bean, and tepary beans and it has also been reported to infest chickpea and runner bean (Parker and Riches, 1993). There is a clear geographic variation in the host range in different regions of Africa infested by *A. vogelii*. Although, different populations of *Alectra vogelii* that infest legume plant most are mostly host specific, infesting groundnuts, cowpea, bambara nuts or mung-bean (Riches *et al*., 1992). Apart from legume crops, *Alectra* has also been reported as a parasite on non-legume weeds including *Acanthospermum hispidum, Vernonia poskeana* (Compositae), *Euphorbia spp*. (Euphorbiaceae) and *Hibiscus* (Malvaceae) species, in addition to common legume weeds including *Indigofera* and *Tephrosia* species.

2.5 Nature of Parasitism of *Alectra Vogelii* to Cowpea

2.5.1 Attachment of *Alectra vogelii* to cowpea

The biology of the cowpea parasite, *Alectra vogelii* shares many biological characteristics with another cowpea parasite; *Striga gesnerioides* (Igbinnosa and Okonkwo, 1991; Samb and Chamel, 1992). *Alectra vogelii* seeds germinate when exposed to root exudates from cowpea, other host and a few non-host plants. Radicle

elongates, showing a chemotropic response to a concentration gradient of roots exudates. Radicular apex develops numerous hairs, which attach to host roots, once it comes into contact with the host roots. *Alectra* radicle penetrates and stimulate cell division in the host root (Frost *et al*., 1997). The new host cells, together with growing parasite tissue, form a large haustorium, uniting the parasite with tissue in the host's stele which eventually permits transfer of water and nutrients from host to parasite. *Alectra* tends to form a large haustorium than *Striga*. However, both *Striga* and *Alectra* shoots emerge from the haustorium about 2 weeks after attachment and grow into plants which may be 15-25 cm tall (Agrios, 2005). The haustorium is the nodal point in the identification of the parasitic habit in Angiosperms. It is a vital conducting organ for parasitism and forms an anatomical bridge through which physiological continuity is maintained between the parasite and host.

2.5.2. Symptoms of Infestation by *Alectra vogelii* to Cowpea

The parasitism of *Alectra* begins about 2-3 weeks before its emergence above the soil, but symptoms of infection by *Alectra* can be noticed on cowpea plants much earlier before emergence of the parasite. Symptoms associated with *Alectra* infected plant include general stunting and wilting with reduced numbers of flowers and pods, and plant may be completely wilted, if there is acute moisture deficit (Emechebe *et al*., 1991). However, time and level of infestation in cowpea by *Alectra* determine the extent of yield reduction (Singh and Emechebe, 1991; Parker and Riches, 1993; Lagoke *et al*., 1993). Cowpea plants that are infested by *A.vogelii* often appear wilted prior to *Alectra* emergence. Serious crop yield losses caused by *A. vogelii*, have also been reported in cowpea and groundnut (Atokple *et al*., 1995).

2.6 Effects of *Alectra vogelii* Infestation on Growth and Yield Components of Cowpea

Cowpea is among the legume crops which suffers a serious damage from infestation by *A. vogelii* in various part of the Sub- Saharan African (Mbwaga *et al*., 2010; Kabambe *et al*., 2008). The negative effect of *Alectra* in reducing the vegetative and grain yield of cowpea is due to competition for growth factors. It can reduce the yield of host crop by >50 % and may even cause complete crop failure (100 % yield loss) under severe infestation. Hence, the weed does not only deprive the host plant of nutrients, but it also wastes the energy utilized for their uptake (Singh *et al*., 2002).

Other workers have found out that, *Alectra vogelii* infestation causes a reduction in number of pods per plant, weight of pod, number of seeds per pod, weight of seeds and chlorophyll contents of the leaves among susceptible genotypes (Kutama *et al*., 2013). Effect of *A. vogelii* infestation on cowpea was also observed in roots biomass, the thickness of the stem, root nodulation as well as reduction on plant biomass (Geleta, 2010; Omoigui *et al*., 2012; Kutama *et al*., 2013; Karanja *et al*, 2013).

Alectra vogelii causes premature defoliation in groundnut as it depletes the crop of nutrient thereby causing dramatic reduction in crop yield (Kwaga, 2004). Noubissie *et al.* (2010) reported that, cowpea varieties that supported a higher number of *Striga* had lower number of pods, grain and fodder yield than the *Striga*- resistant genotypes. Cowpea plants that are infested by *A.vogelii* often appear wilted prior to *Alectra* emergence. Infection also results in delayed onset of flowering, reduced number of flowers and pods, and hence a reduced yield of cowpea seed even when soil moisture is not limiting (Magani and Lagoke, 2009). Studies also show that, *Alectra* infection reduced shoot dry matter by over 50 % (Alonge *et al*., 2002). Alonge *et al.* (2001a) also reported that, *Alectra* infestation reduced leaf area and inhibited nodules formation of

most cowpea varieties at certain growth stages, and this was much more severe in the heavily infested and late sown crop. The carbon transfer from the shoots to the roots due to changes in sink demands largely accounted for the reduction in shoot biomass and was reported to be responsible for the reduction in pod formation (Rambakudzibga, 2000).

2.7 Control of *Alectra Vogelii*

With reference to non-parasitic weeds, the control of parasitic weeds has proved to be exceptionally difficult. The parasitic weeds are propagated by seeds. The ability of the parasite to produce a tremendously high number of seeds, which can remain viable in the soil for more than ten years, and their intimate physiological interaction with their host plants, are the main difficulties that limit the development of successful control measures that can be accepted and used by subsistence farmers (Rugare *et al*., 2013). In small scale farmers' fields, common traditional methods of weed control like hand weeding by hoe and crop rotation have been used since long time and they are still under practice to date since they are simple and affordable to anyone but not effective as much as parasitic weed control strategies are concerned (Boukar *et al*., 2004). Screen house evaluation of *Azadirachta indica* and *Parkia biglobosa* to control *S. hermonthica* seeds germination were effective to reduce *Striga* emergence (Marley *et al.*, 2004).

Several control methods have been evaluated on parasitic weeds (Parker and Riches, 1993; Kroschel, 2001 and Omanya, 2001) and details are explained in sub-sections 2.7.1 to 2.7.5 below.

2.7.1. Cultural control

Part of the cultural control options being used for parasitic weeds are; catch and trap-cropping available for reducing the size of the *Alectra vogelii* seed bank in the soil.

Catch crop

Catch crop is a susceptible species which is sown in and harvested after parasite attachment but before emergence and seed production. Catch crops are those susceptible to the parasite and thus become infested. Before the parasite has the chance to flower and to set seeds, the farmer should uproot the catch crop to destroy the parasite (Oswald *et al.,* 1999). The most promising catch crop for *Striga hermonthica* control is the use of Sudan grass (*Sorghum sudanense* L.) (Last, 1961; Oswald *et al.,* 1999). However, catch cropping has rarely been used by small scale farmers to control *Striga* because the technique is not well known or understood and holds serious disadvantages, if not adapted to a specific cropping system (Oswald *et al.,* 1999).

Trap crop

Trap crop is a crop which stimulates *Striga* seed germination, but cannot be infested by the parasite. Trap cropping is a control measure adopted against parasitic weeds such as *Alectra* and related parasitic weeds. Soyabean has been shown to reduce the seed bank of *Striga hermonthica* a semi-parasitic weed in cereals such as *Sorghum* and millet, by causing suicidal germination. After induction of germination of *Striga* seeds, it prevents the attachment of the parasite to its roots which lead to death of the parasite (Kureh *et al*., 2005). De Groote *et al.* (2010) also found that, the use of leguminous trap crops that include varieties of groundnut (*Arachis hypogaea*), soybean (*Glycine max*), cowpea (*Vigna unguiculata)* and sesame (*Sesamum indicum*) stimulate the suicidal germination of *Striga*. Trap-crops produce the *Alectra* germination stimulant in their root exudates but are not susceptible to attack by the parasite seedlings. Some grain or fodder cultivars of pearl millet and bambara nut, are not attacked by the local biotype of the parasite, but are potent stimulators of *A. vogelii* germination (Parker and Riches, 1993). These can be used in a rotation to cause suicidal germination of the parasite and hence reduce the

number of seed in the soil. Yunusa *et al*. (2013) reported that, pre-treating *Alectra* infested soil by growing *Amaranthus* lines before planting susceptible cowpea SAMPEA 7 reduced the emergence of *Alectra* in the soil infested with the parasitic weed seeds. Lagoke *et al*. (1997), Oswald (1997) and Ariga *et al*. (1997), reported that, intercropping of maize with non-host crop improved soil productivity and reduction of *S. hermonthica* seed bank in the soil as a result of suicidal germination of *Striga* seeds by non-host.

The most promising trap crops reported for *Striga* species are recently listed by Kroschel (2001). Trap cropping for *Striga* control include rotation with groundnut, bambara groundnut, pigeon pea and soyabean. It is obvious that, farmers from countries or regions with possibilities for marketing *Striga* trap crops like cotton and soybean have an overall advantage in adopting such farming systems (Kroschel and Sauerborn, 1996). *Alectra vogelii* may also be controlled through the use of trap crops such as dolichos bean (*Lablab purpureus* [L.] *Sweet*), cotton (*Gossypium*), Okra (*Hibiscus esculentus* L.) and faba bean.

2.7.2. Chemical control

Alectra vogelii is predominantly a pest of crops grown by peasant farmers who rarely have the finance to access herbicides. Little attention has therefore been given to the development of chemical control. The chemicals being tried in the control of witchweed can be divided into two general categories, i.e. pre–emergence and post-emergence (Ayensu *et al*., 1984). Pre–emergence herbicides that are capable of controlling these parasitic plants include the dinitroanilines (DAN's) and Diphenylethers (Eplee *et al*., 1991). These herbicides act as barriers to prevent *Striga* emergence. Post– emergence herbicides most commonly used to stop the reproduction of *Striga* are the salt formulations of 2, 4–D as reported by Lagoke *et al*. (1993). These chemicals are applied

to *Striga* foliage at about the time of flowering at the rate of 0.5 – 1.0 kga.i/ha (Choudhary and Lagoke, 1980). Garcia-Torres *et al*. (1992) also reported an effective control of *Alectra vogelii* with imazaquin at 0.80 kg a.i/ha.

The potential for controlling the weed by treating cowpea seeds with the herbicide imazaquin before planting has been demonstrated (Berner *et al*., 1994). Results of experiments to develop a cowpea seed treatment in the laboratory and screen house to control both *Striga gesnerioides* and *Alectra vogelii*, that consisted of a five minutes seeds soaking in solutions of imazaquin in concentrations ranging from 1.8 to 7.2 mg a.i/ml reduced parasite attachment by 90 % in comparison to untreated controls (Berner *et al.*, 1994). Results of experiments also proved that, herbicide seed treatment using imazathpyr appears to be a promising approach for the control of *Striga* in maize or *Sorghum* (Kabambe *et al.*, 2008). Satish *et al.* (2012) has also reported that, coating of *Sorghum* seeds with herbicide reduced *Striga* infestation, *Striga* flowering and *Striga* seed set, and it is considered as the most effective as it does not affect *Sorghum* biomass.

Magani and Lagoke (2009) reported an acceptable cowpea yield and lower number of plants infested by the parasitic weed using a combination of pre-emergence (metazachlor + antidote) herbicide. Satish *et al*. (2012) reported that, a combination of urea and dicamba effectively controlled *Striga* between 62-92 % in *Sorghum*, while chlorsulfuron in combination with dicamba controlled *Striga* as much as 77-100 % in *Sorghum*. They also concluded that farmers can reduce cowpea infection by *A. vogelii* when pre-emergence herbicide mixtures containing pre-emergence (metazachlor + antidote) are applied, followed by post-emergence application of imazaquin at 0.18 kg active ingredient/ha (Magani and Lagoke, 2009).

Many herbicides are useful in preventing the build- up of *Striga* seeds in the soil but may not prevent damage prior to their emergence (Xier and Yoneyama, 2010).

2.7.3 Use of resistant varieties

Improved cowpea cultivars which combine resistance to *A. vogelii, Striga gesnerioides,* and several insect pests and fungal diseases have been developed in West Africa (Singh *et al.*, 2006). These include the cultivars like IT90K-76-6 and IT90K-82-2 which have been released for commercial production in Nigeria (Singh *et al.*, 2006). These are not, however, resistant to biotypes of *A. vogelii* from southern Africa (Riches, 2001). The Botswana cowpea landrace accession B359 has been shown to be resistant to samples of the parasite from Botswana, Malawi and Kenya, so could be used as a parent for breeding improved cultivars for East and Southern Africa (Riches *et al*., 1992; Riches, 2001). Potentially, useful levels of resistance to *Alectra* have also been demonstrated in germplasm of bambara nut (Riches *et al*., 1992) and cultivars of soyabean (Kureh and Alabi, 2003), but multi-location testing is needed to confirm the value of these lines in the field. Several authors have reported improved, high yielding *Striga*/*Alectra*- resistant cowpea genotypes, which are becoming popular among farmers in West African Savanna (Singh *et al*., 2002; Kamara *et al.*, 2008).

2.7.4 Biological control

The objective of weed biological control is not the eradication of weeds but the reduction and establishment of a weed population to a level below the economic threshold (Atera *et al.*, 2011). Means of biological control of weeds comprise of herbivorous insects, microorganisms (especially fungi) and smother plants (Ejeta, 2007). The method involves importation, colonization and establishment of exotic natural enemies which include predators and parasitoids. Efforts to manage weeds using biological control have been gaining momentum throughout the world, especially in the recent past. Biological control is considered as a potential cost-effective, safe and environmentally beneficial

alternative mean of reducing weed populations in crops, forests or rangelands (De Groote *et al*., 2010).

2.7.5. Integrated control

Integrated control method was found to be built around the use of resistant crop cultivars (if possible), or choice of the tolerant cultivar that is currently available. Timely destruction of legume crop residues is important to prevent parasite seed production after harvest. Hand-pulling by uprooting the *A. vogelii* shoots carried out on lightly infested areas, particularly in fields which have not previously had a history of infestation has also been included as part of integrated control method (CABI, 2012). Moderately tolerant varieties which help to reduce *Alectra* seed bank in soil when they are used in combination with other control measures was also found as good part of integrated control method of *A. vogelii* (Adetimirin *et al.*, 2000; Kim, 2000). Adu *et al*. (1989) reported that, lower levels of N in combination with some host resistance would be appropriate to reduce *Striga* infection.

Combined use of row planting, fertilizers and hand pulling (during flowering) registered 48 % higher grain yield and over 50 % reduction in *Striga* shoot count (Hearne, 2009). For effective management in the fields, the survey carried out by Karanja, (2009) indicated that, a combined use of host plant resistance/tolerance and crop rotation with non-host nitrogen fixing legumes, increase of soil fertility and proper seed management may not only stop further spread of the weed, but also reduced soil seed bank for *Alectra.*

2.8 The Role of Nitrogen Fertilizer on the Growth and Yield Components of Cowpea

Hasan *et al*. (2010) conducted a study to investigate the effect of nitrogen on the biomass yield of cowpea forage and found that, application of Nitrogen at the rate of 25 kgN/ ha gave a biomass yield of 5.47 tonnes/ ha and increasing the application to 30 kgN /ha did

not differ significantly with a yield of 5.49 tonnes/ ha. Graham and Scott (1984) reported that, nodulation in cowpea was inhibited by nitrogen fertilizer application at rates greater than 30 Kg/ha. Also, Abayomi *et al*. (2008) reported that, nodulation in cowpea significantly reduced as fertilizer rate increased from 0 to 300 kg NPK/ha and this was in line with an earlier finding that, nodulation in cowpea was inhibited by nitrogen fertilizer application at rates greater than 30 kg/ha (Rhodes, 1981). Also, application of inoculant and nitrogen reduced the nodule number significantly (Emmanuel, 2014). Dart *et al*. (1977) reported that, application of a small quantity of nitrogen (20 kg N/ha) enhanced early vegetative growth and this may be due to the stimulating effect of nitrogen on root activity and rooting pattern (Buries, 1959). This was confirmed by the report from Abayomi *et al*. (2008) that, application of NPK fertilizer enhanced growth parameters of cowpea. A study carried out by Whitney (1984) showed that, even though the application of nitrogen fertilizer at flowering promoted vegetative dry weight of cowpea, it decreased nodule dry weight.

2.9 The Role of Phosphorus Fertilizer on the Growth and Yield Components of Cowpea

Ayodele and Oso (2014) working in Ekiti, sub-humid Nigeria, found that, application of P at 20 kg/ ha in the presence of basal 20 kg N and 30 kg/ ha is optimum P rate for cowpea production with a grain yield of 1.26 tonnes/ ha compared to 0.78 tonnes/ ha for the control. Similarly, Magani and Kuchinda (2009) reported that, grain yields realized with 35.5 kg P/ha did not differ significantly from that of 75 kg P/ ha giving a yield of 1.85 tonnes/ ha and 1.91 tonnes/ ha, respectively. Ndor *et al*. (2012) also suggested that, 40 kg P/ ha fertilizer could be the best P fertilizer level for cowpea in the Southern Guinea Savanna zone of Nigeria. Osunde *et al*. (2007) evaluated the response of 15 cowpea lines to low (0 kg P/ ha), intermediate (20 kg P/ ha) and high (40 kg P/ ha)

phosphorus level in the Southern Guinea Savanna zone of Nigeria. With a basal application of 20 kgNha^{-1} and 30 kgN /ha, the grain yields of the cowpea lines increased as applied P rates were increased. Yields ranged from 1.7 tonnes ha^{-1} to 3.0 tonnes ha^{-1}. The addition of 20 kg P ha^{-1} significantly increased the yield of 5 lines while 3 other lines had yield increases due to application of 40 kgP ha^{-1}. Seven lines however did not show yield increase due to P application which was attributed to genotypic variations. Azarpour *et al*. (2011) reported that, 45 kg P ha^{-1} gave the highest grain yield of 1.57 tonnes ha^{-1} against the yield of 0.88 tonnes ha^{-1} from the control plot in Iran. According to Abayomi *et al*. (2008), application of phosphorus fertilizer decreased nodulation in cowpea which was contrary to a report by Ayodele and Oso (2014) that, nodule count and weight increased with applied P and were highest at 60 and 40 kg P^{-1}, respectively, which is one of the advantages of P application on cowpea (Okeleye and Okelana, 1997). Ayodele and Oso (2014) observed that, application of 20 kg P /ha produced the highest leaf area index, number of flowers and pods/plant and this resulted in the highest yield grain at the same rate.

2.10 The Role of Potassium Fertilizer on the Growth and Yield Components of Cowpea

Potassium plays an important role in the growth and development of legumes. It increases frost and disease tolerance, palatability and storage quality, as well as yield. Potassium regulates several plant processes including water and nutrient transport across cell walls and regulation of water and carbon dioxide exchange through stomata (Manitoba soil fertility guide, 2004).

Potassium is the most abundant cation in plants and contributes to 10 % of the dry plant mass (Leigh and Jones, 1984). Potassium is applied in the form of potassium sulphate or potassium chloride (water soluble). Potassium is an important macro nutrient for

metabolic growth and stress adaptation (Tiwani *et al*, 2001). It is important in stabilizing protein synthesis, activation of enzymes as well as maintenance of cytoplasm pH (Marschner, 1995). The overall functioning of plant parts depends on the mobility of potassium as it is responsible for sustaining the mobility of other factors like H^+, sugars and NO_3^- throughout the whole plant (Marschner, 1995). Potassium is reported not only to increase yield but also to increase the uptake of major nutrients like nitrogen, phosphorus, magnesium, calcium and sulphur required for plant growth. There was up to 56 % increase in yield of soybean when 20 kgK/ha was applied ((Marschner, 1995). Grewal *et al.* (1994) reported seed yield of soybean on loamy sandy soils following the application of 25 kgK/ha of potassium fertilizer. Plant height of soyabean was significantly increased by the effect of potassium. Mokoena (2013) reported a reduction in leaf area index of soybean due to application of 20 kgK/ha. Application of potassium enhanced the pod length and pod weight of soybean (Mokoena, 2013). Dixit *et al.* (2011) reported a significant increase in 100 seed weight of cowpea plant by an application of 40 kgK/ha in comparison to farmers' practice where there was no application of potassium. The highest grain yield was obtained with the highest application of potassium as reported by Mokoena (2013).

2.11 The Role of Organic Manure on the Growth and Yield Components of Cowpea

Adeniyan and Ojeniyi (2005) reported that, integrated application of poultry manure and NPK fertilizer increased maize yield. Akanbi *et al.* (2005) reported that, the combined application of 4 t/ha of maize straw compost and N mineral fertilizer at 30 kg/ha on soybean improved its yield significantly. Omotosho (2014) reported that, the number of nodules per plant of cowpea was significantly reduced as poultry manure rate increased. Omotosho (2014) reported that, combined applications of pig manure and inorganic fertilizer NPK enhanced cowpea growth and development when compared to untreated

plots. Also, Omotosho (2014) reported that number of leaves and number of branches per plant were also significantly increased with the increased rate of fertilizer application and that the highest number of leaves and number of branches were observed with the application of 8 t/ha Pig manure + 60 kg NPK. Similarly, Adeoye *et al*. (2011) reported that, a combination of poultry manure and cattle manure improved leaf area and height of cowpea plants. This improvement is associated with increased nitrogen, phosphorus and potassium levels in the soil as affirmed by Reyhan and Amiraslani (2006). Adeoye *et al.* (2011) observed that, poultry manure improved cowpea yield when compared with cattle manure and this was in line with the findings of Reyhan and Amiraslani (2006) that, high cowpea yield may be inhibited by the application of cattle manure due to its salinity effect, if too high may affect the yield considerably. Karanja *et al*. (2011) concluded that, farmyard manure application is advantageous in reducing the effect of *Alectra* parasitism on cowpea. They reported that, application of farmyard manure at 5 and 10 tonnes/ha reduced *A. vogelli* density by >50 % at 6, 8, 10 and 12 WAP with increase in mean number of pods per plant and yield.

2.12 Role of N. P. K Fertilizer on *Alectra* Infestation on Cowpea

Different control strategies as mentioned in Section 2.3 have been developed and used by farmers in the areas where *Alectra* appears to be a problem in order to alleviate the damage caused by this parasitic weed. Emechebe *et al.* (1991) reported that, the application of high nitrogen dose (120 kgN/ha) drastically reduced the incidence of infestation by *Striga gesnerioides* in cowpea without significantly affecting grain yield. Magani *et al.* (2008) reported that, early germination of *Alectra* was achieved with application of N at rate of 30 KgN/ha. Nitrogen has been reported to delay *Striga* emergence, cause the stunting of emerged shoots and reduce its flowering and dry matter production (Gworgwor and Weber, 1991).

In India, N applied to heavily infested *Striga* fields grown with pearl – millet reduced the incidence of *Striga* and doubled crop yields (Marthur and Marthur, 1967). Also, in Sudan, application of 90 KgN/ha on soil that was lightly infested with *S. hermonthica* tripled grain yields of millet from 1278 to 3957 Kg/ha while the relative effect was greater in highly infested soil with severe attack (Last, 1961). Also, nitrogen application at the rate of 50 kgN/ha did not only reduce parasitism in groundnut but also enhanced yield as reported by Kwaga *et al*. (2010a).

Earlier works have shown that, high N reduces stimulant production from *Sorghum* and can delay *Striga* emergence and reduce its infestation (Parker, 1984; Sharif and Parker, 1986; Raju et al., 1990). This might be through physiological changes in the growth rate of the cell in the active stimulant producing area of *Sorghum* roots. The mechanism by which high N reduced *Striga* infestation could be attributed to the production of low germination stimulant by *Sorghum* under high Nitrogen (Parker, 1984; Adeosun, 1990; Ngawa, 1992). Psech *et al.* (1991) remarked that, urea exerted inhibitory effects on the germination and development of *Striga* radicle. Similarly, Egley (1971) observed that mineral nutrients exhibited toxicity to parasite once the minerals exceeded certain threshold level.

Zerihun (2015) reported that, the number of *Striga* decreased as N level increased from zero to 92 kg N ha-1. Kwaga *et al*. (2010a) reported that, *Alectra* incidence was suppressed by application of fertilizer at 50 kgN/ ha and thus increased pod yield above that of unfertilized treatment. This was attributed to the low nitrogen status of the experimental site (Enwezor *et al*., 1989). Similarly, Magani *et al.* (2008) reported that the number of infested plants were consistently reduced by 60 kgN/ha, although, this rate depressed cowpea grain yield compared with 0 and 30 kg N/ha. In a similar study in sand culture, Emechebe *et al*. (1991) showed that, 140 ppm N applied as sodium nitrate

($NaNO_3$) solution completely reduced the incidence of *S. gesnerioides* with a concomitant decrease in nodule numbers.

Phosphorus fertilization is beneficial in improving groundnut yield even under *Alectra* infestation. Application of 20 Kg P/ha of phosphorus significantly increased groundnut pod weight and seed yield compared with zero phosphorus application (Magani *et al*., 2008). It was also observed that, the highest levels of N and P increased days to *Alectra* emergence (Magani *et al*., 2008). Similarly, Magani (1994) and Olufajo (1996) reported an increase in cowpea grain yield with the application of phosphorus under *Alectra* infestation. However, Phosphorus fertilization enhanced root density thereby resulting in greater production of stimulant that could have induced emergence of more *Alectra* shoots (Ngawa, 1992). The use of either 30 Kg N/ha, 20 Kg P/ha or 40 Kg P/ha alone in cowpea variety VITA – 3 reduced days to *Alectra* emergence compared with the highest in cowpea variety TN 93 – 80 as reported by Magani *et al* (2008). However, the number of plants infected with *Alectra* were also observed to be highest in SAMPEA – 7 treated with 40 Kg P/ha.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1. Experimental Sites

Two pot trials were conducted, one in the Department of Agronomy from April to August 2016, and the other in the Screen house of the Department of Soil Science, from October 2016 to January, 2017, both in Institute for Agricultural Research (I.A.R).

3.2. Experimental Materials and Sources

Cowpea Seeds

A total of four (4) newly-bred cowpea Lines (IT08K-125-107, IT06K-128, IT07K-303-1, and IT07K-299-6) were sourced from the International Institute of Tropical Agriculture (IITA), Kano sub-station. These varieties were bred for; Drought tolerance, Pest and disease resistance (Aphid tolerance) and High yield.

***Alectra vogelii* Seeds**

Matured *Alectra vogelii* plants were collected from an *Alectra* infested field in Darawa, Dutsin-Ma, Katsina State. The *Alectra* plants were bagged in paper bags and sun dried. The well dried *Alectra floral* heads were tapped gently with a wooden stick to release the seeds. The seeds were then sieved using a 150 micron sieve and were stored at room temperature till use.

Soil

The top soil used in the experiment was collected from I.A.R farm, Shika, and fine sand was collected from a stream in Area BZ, Ahmadu Bello University Staff Quarter, Zaria. The top soil and sharp sand soils were mixed at a ratio of 1:1.

NPK Fertilizer (15:15:15)

NPK fertilizer (15:15:15) was purchased from Samaru market.

3.3 Soil Analysis

Prior to pot preparation, a sample of the top soil and sand mixture was taken and analyzed for its physical and chemical parameters including particle size distribution, pH, exchangeable cations, total nitrogen, available P and organic matter at the Department of Soil Science, Institute for Agricultural Research, Samaru.

3.4 Preparation of *Alectra* Innoculum

Alectra seeds innoculum was prepared by mixing 10 g of *Alectra* seeds with 250 g of sieved sand .The mixture was shaken thoroughly in air-filled polythene bag for 5 minutes to ensure a uniform distribution of *Alectra* seeds as described by Alonge (2000).

Pot soil was inoculated with *Alectra* by making a hole/depression in the centre of the soil each pot, and a soft drink bottle cap full of the *Alectra* innoculum (about 4.8 g) was introduced into the hole (Alonge 2000).

3.5 Treatment and Experimental Design

The study involved two trials, each with the following treatments:

1. Four (4) levels of NPK fertilizer (0, 100, 200 and 400 kgNPK/ha),
2. Four cowpea varieties (IT08K-125-107, IT06K-128, IT07K-303-1, and IT07K-299-6)
3. Two *Alectra* inoculation levels (inoculated and uninoculated)

For each treatment, there was a total of 576 polythene bags (20 cm x 18.9 cm), each filled with 3 kg of the soil mixture each. The pots were arranged in a completely randomized design with three replication and 6 pots to represent each treatment replicate. Fertilizer was applied to the plants at two weeks after sowing (2 WAS).

3.5.1 Sowing of cowpea seeds

Four seeds each of the cowpea varieties dressed with Apron star were sown per pot. Thinning was done at 2 weeks after sowing (WAS), reducing the seedlings to two per pot thereby reducing intra-specific competition.

3.5.2 Cultural practices Adopted

Cultural practices employed included, weed control by weekly hand-pulling control, watering was done at intervals of two days using a 200 ml water beaker. Insect pests were controlled using Lambda-cyhalothrin (Karate 2.5 EC) sprayed at 5 ml/litre of water using a CP30 knapsack sprayer. Spraying commenced at 3 WAP and continued at intervals of 2 weeks till pod maturity.

3.6 Harvesting of cowpea pods

Harvesting of the pods commenced when the pods had matured. The pods were then dried under the sun and threshed.

3.7 Sampling of cowpea plants

Sampling of the cowpea plants was conducted at 6, 9 and 12 WAS in trial I and at 5, 7 and 9 WAS in trial II, one pot from each treatment in each replicate was sampled. The soil was gently separated from the plant root and washed thoroughly in clean water; the sampled plants were spread on clean table for water to drain off. A razor blade was used in separating the roots from the shoots.

3.8 Data Collection

Data such as plant height, root fresh weight, shoot fresh weight, number of emerged *Alectra* shoots, number of attached *Alectra* roots, number of pods per plant, dry pod weight, 100 seeds weight and leaf area index were collected.

Plant Height: Plant height was measured by placing a metre rule from the stem base at soil level to the apex of the tallest shoot at 6, 9 and 12 WAS, and 5, 7 and 9 WAS in trial I and II respectively.

Root Fresh Weight: The plants were removed from the soil and excess soil was washed off. Surface moisture was drained off by placing the plant on a clean table. The root of the plant was detached from the shoot using a razor blade and weighed immediately on a weighing balance at 6, 9 and 12 WAS, and 5, 7 and 9 WAS in trial I and II respectively.

Shoot Fresh Weight: the detached plant shoot was weighed on a weighing balance.

Leaf Area Index per pot: The area of the cowpea leaf was determined using a leaf area meter (Licor, LI-3100C Area meter) and the leaf area index was calculated using the following formula

$$\text{Leaf area index} = \frac{\text{Leaf Area } (\text{cm}^2)}{\text{Ground Area } (\text{cm}^2)}$$

Root Nodules Count: The washed sampled plants were used to determine the root nodules. The root nodules which are very visible to the naked eyes were detached and counted while those that are not very visible with the naked eyes were counted with the aid of a hand lens.

Number of Emerged *Alectra* Shoots per plot: This was determined by taking a head count of the *Alectra* shoots per pot at 9 WAS.

Pod Weight: Pod weight was obtained by placing the harvested pods on a weighing balance and the average weight per pot was recorded

Number of Seeds per Pod: The number of seeds per pod was obtained by randomly selecting dried pods from each treatment replicate. The randomly selected pods were split open and the seeds were collected and counted.

100 - Seed Weight: The harvested pods were threshed and winnowed, before one hundred (100) seeds were selected from each treatment replicate and placed on a weighing balance and the weight recorded as 100 seed weight

3.9 Data Analysis

The data collected on the above parameters were subjected to analysis of variance (ANOVA) using the SAS System (GLM procedure). Significant means treatment differences were separated using the New Duncan Multiple Range test (NDMRT) at 5 % probability level.

CHAPTER FOUR

4.0 RESULTS

4.1 Physical and Chemical Properties of the Soil

The physical and chemical properties of the soil mixture used in the experiment showed that the soil was sandy loam. The soil used in the experiment is sandy loam. The chemical properties of and contains Calcium (7.20 mol/kg) and Nitrogen (0.18 mol/kg) Phosphorus, Organic carbon, Mg, K, and had a pH of 5.90 (Table 1).

4.2 The Effect of NPK Fertilizer and *Alectra* on Vegetative Growth Parameters

4.2.1 Plant height of cowpea varieties in Trial I

The plant height of cowpea variety IT07K-303-1 was significantly taller than that of IT07K-299-6 at 6 WAS and also IT08K-125-107 and IT06K-128 at 9 WAS (Table 3). At 12 WAS, IT06K-128 resulted in taller plants than all the other varieties, followed by I07K-303-1 which was in turn taller than the others. On the other hand, Cowpea variety IT07K-299-6 produced significantly shorter plants than all the other varieties. Application of NPK fertilizer did not influence plant height att all the applied rates at 6 WAS. The control treatment produced significantly shorter plants than all the higher rates at 9 and 12 WAS (Table 3). Plant height increased with NPK rate from100 – 400 kgNPK/ha and 0 – 200 kgNPK/ha beyond which plant height was depressed at 12 WAS (Table 3).

The *Alectra* inoculated plants produced significantly shorter plants than the uninoculated plants at 9 and 12 WAS. At 6 WAS, the *Alectra* inoculated and uninoculated plants resulted in similar plants (Table 3).

Table 2: Physical and chemical Properties of the Soil Sample used in the Experiment

Parameter	Value
Soil Characteristics	
Clay (%)	20
Silt (%)	4
Sand (%)	76
Textural Class	Sandy Loamy
pH in water	5.90
pH in 0.01N $CaCl_2$	6.45
Organic Carbon (g/kg^{-1})	1.36
Phosphorus (mg/kg^{-1})	12.49
Nitrogen (g/kg^{-1})	0.07
Exchangeable Cations (Mol/Kg^{-1})	
Ca	7.20
Mg	4.37
K	0.60
Na	0.18

Table 3: The Effect of NPK fertilizer and *Alectra* on Plant height of Cowpea Varieties in Trial I in 2016

	Plant height (cm) at:		
Treatment	6 WAS	9WAS	12WAS
Variety (V)			
IT08K-125-107	12.39[ab]	19.25[c]	27.33[c]
IT06K-128	14.09[a]	20.61[b]	35.36[a]
IT07K-303-1	13.71[a]	23.87[a]	31.90[b]
IT07K-299-6	11.13[b]	19.86b[c]	24.28[d]
SE±	0.71	0.45	0.53
Fertilizer (KgNPK/ha) (F)			
0	12.46[a]	18.65[c]	23.44[d]
100	13.50[a]	18.90[c]	29.02[c]
200	13.36[a]	22.33[b]	34.65[a]
400	12.00[a]	23.72[a]	31.76[b]
SE±	0.71	0.45	0.53
***Alectra* inoculation (A)**			
Inoculated	12.93[a]	19.69[b]	25.35[b]
Uninoculated	12.73[a]	22.11[a]	34.09[a]
SE±	0.51	0.32	0.37

N.B Values followed with the same letter(s) in each column under each treatment group are not significantly different (P = 0.05) using DMRT.

Keys:
WAS: weeks after sowing

4.2.2 Plant Height of Cowpea Varieties in Trial II

Plant heights of Cowpea varieties IT06K-128 and IT07K-303-1 were each significantly higher than that of IT08K-125-107 and IT07K-299-6 (Table 4). Cowpea variety IT07K-299-6 produced significantly shorter plants than all the other varieties. Application of NPK fertilizer at 100, 200 and 400 kgNPK/ha resulted in significantly taller plants than the control on each sampling date. The tallest plants on each sampling date was due to 60 kgN/ha treatment (Table 4).

At 5 WAS application of 100- 400 kgNPK/ha fertilizer produced similar and taller plants than the untreated control which gave the shortest (Table 4). At 7 WAS, 60 kgN/ha NPK resulted in the tallest plants than the 200 kgNPK/ha and below which However, at 9 WAS, the highest plant height due to application of 60 kg/N fertilizer treatment was significantly higher than the other treatments. The control produced the shortest plants (Table 4).

Throughout the sampling period (5 – 9 WAS) *Alectra* inoculated plants produced shorter plants than the uninoculated plants. This difference was not significant (Table 4).

4.2.3 Shoot Fresh Weight of Cowpea Varieties in trial I

Crop variety, NPK fertilizer and *Alectra* inoculation significantly influenced shoot fresh weight of cowpea at all the sampling periods from 6 -12 WAS (Table 5). At 6 WAS, IT07K-303-1 and IT07K-299-6 resulted in higher fresh shoot weight than IT08K-125-107. Shoot weight by IT06K-128 was similar to the lowest and the highest at this period. At 9 WAS, varieties IT08K-125-107 and IT07K-303-1 gave higher fresh shoot weight than the other two varieties. Variety IT06K-128 in turn gave higher fresh shoot weight than the least by IT07K-299-6. At 12 WAS, IT06K-128 resulted in higher shoot fresh

Table 4: The Effect of NPK Fertilizer and *Alectra* on Plant Height of Cowpea Varieties in Trial II in 2016

	Plant height (cm) at:		
Treatment	5 WAS	7 WAS	9 WAS
Variety (V)			
IT08K-125-107	9.52[b]	11.80[b]	14.67[b]
IT06K-128	11.55[a]	12.52[ab]	15.44[ab]
IT07K-303-1	11.55[a]	13.19[a]	15.84[a]
IT07K-299-6	7.65[c]	9.44[c]	11.55[c]
SE±	0.28	0.38	0.33
Fertilizer (KgNPK/ha) (F)			
0	9.18[b]	10.16[c]	11.20[c]
100	10.20[a]	11.57[b]	14.54[b]
200	10.25[a]	12.34[ab]	15.23[b]
400	10.65[a]	12.89[a]	16.52[a]
SE±	0.28	0.38	0.33
***Alectra* inoculation (A)**			
Inoculated	9.81[a]	11.45[a]	14.32[a]
Uninoculated	10.33[a]	12.03[a]	14.43[a]
SE±	0.20	0.27	0.23

N.B: Values followed with the same letter(s) in each column under each treatment group are not significantly different (P = 0.05), using DMRT.

Keys:
WAS: weeks after sowing

Table 5: The Effect of NPK Fertilizer and *Alectra* on Shoot Fresh Weight of Cowpea Varieties in Trial I in 2016

	Shoot Fresh Weight (g) at:		
Treatment	6 WAS	9 WAS	12 WAS
Variety (V)			
IT08K-125-107	18.98^{b}	65.74^{a}	70.34^{c}
IT06K-128	26.27^{ab}	50.93^{b}	92.86^{a}
IT07K-303-1	30.55^{a}	70.38^{a}	85.56^{b}
IT07K-299-6	33.59^{a}	35.85^{c}	49.37^{d}
SE±	2.70	1.92	1.14
Fertilizer (KgNPK/ha) (F)			
0	23.69^{bc}	43.32^{c}	60.57^{c}
100	32.15^{a}	48.47^{c}	61.37^{c}
200	22.56^{c}	59.63^{b}	91.75^{a}
400	30.99^{ab}	71.48^{a}	84.44^{b}
SE±	2.70	1.92	1.14
***Alectra* inoculation (A)**			
Inoculated	22.42^{b}	45.82^{b}	64.57^{b}
Uninoculated	32.27^{a}	65.63^{a}	84.50^{a}
SE±	1.91	1.36	0.81

N.B Values followed with the same letter(s) in each column under each treatment group are not significantly different (P = 0.05) using DMRT.

Keys:
WAS: weeks after sowing

weight than all the other two. The least weight was by IT07K-299-6 and this was lower than all the others (Table 5).

At 6 WAS, application of 100 kgNPK/ha fertilizer resulted in higher fresh shoot weight than the lower rates, except 400 kgNPK/ha, which was in turn higher than the 200 kgNPK/ha treatment. At 9 WAS, shoot fresh weight increased with NPK rate from 100 – 400 kgNPK/ha. The fresh weight by the untreated control was similar to that of 100 kgNPK/ha at this period. At 12 WAS, 200 kgNPK/ha fertilizer rate resulted in higher shoot fresh weight than the higher and lower rates. In turn, 400 kgNPK/ha fertilizer gave higher shoot fresh weight than 0 and 100 kgNPK/ha, which were similar (Table 5).

The inoculated plants resulted in lower shoot fresh weight than the uninoculated throughout the sampling period from 6 – 12 WAS (Table 5).

4.2.4 Shoot Fresh Weight of the Cowpea Varieties in Trial II

Cowpea variety, NPK fertilizer rate and *Alectra* inoculation significantly influenced cowpea shoot fresh weight at 5 -7 WAS except *Alectra* inoculation at 7 WAS. At 5 WAS, IT06K-128 and IT07K-303-1 resulted in higher shoot fresh weight than the other two varieties. Variety IT08K-125-107 in turn produced higher shoot fresh weight than the lowest by IT07K-299-6 (Table 6). At 7 WAS, IT07K-303-1 gave higher shoot fresh weight than all the other varieties, followed by IT06K-128, which was in turn higher than the other two. The least shoot fresh weight was by IT07K-299-6. At 9 WAS, IT07K-303-1 again gave the highest shoot fresh weight followed by IT06K-128, which was higher than the other two varieties, whose weights were similar and least in the trial. At 5 WAS, application of 400 kgNPK/ha fertilizer rate gave the highest shoot fresh weight in cowpea. Shoot weights by 100 and 200 kgNPK/ha rates were similar and

Table 6: The Effect of NPK Fertilizer and *Alectra* on Shoot Fresh Weight of the Cowpea Varieties in Trial II in 2016

	Shoot Fresh Weight (g) at:		
Treatment	5 WAS	7 WAS	9 WAS
Variety (V)			
IT08K-125-107	11.34[b]	18.61[c]	26.29[c]
IT06K-128	13.69[a]	23.14[b]	32.93[b]
IT07K-303-1	14.22[a]	28.44[a]	40.85[a]
IT07K-299-6	10.16[c]	14.19[d]	26.48[c]
SE±	0.31	0.93	1.14
Fertilizer (F) (KgNPK/ha)			
0	10.90[c]	14.92[d]	24.59[d]
100	12.03[b]	19.09[c]	29.63[c]
200	12.85[ab]	23.28[b]	34.37[b]
400	13.62[a]	27.09[a]	37.94[a]
SE±	0.31	0.93	1.14
***Alectra* inoculation (A)**			
Inoculated	11.76[b]	20.28[a]	30.35[b]
Uninoculated	12.94[a]	21.91[a]	32.92[a]
SE±	0.22	0.66	0.80

N.B: Values followed with the same letter(s) in each column under each treatment group are not significantly different (P = 0.05), using DMRT

Keys:
WAS: weeks after sowing

higher than the least by the untreated control. At 7 and 9 WAS, cowpea shoot fresh weight increased with NPK rates from 0 - 400 kgNPK/ha (Table 6).

At 5 and 9 WAS, the uninoculated cowpea plant gave higher shoot fresh weight than the inoculated, but at 7 WAS, inoculation did not influence the shoot fresh weight of cowpea plants (Table 6).

4.2.5 Root Fresh Weight of Cowpea Varieties in Trial I

Root fresh weight produced by the cowpea varieties showed no significant difference among them at 6 and 9 WAS. At 12 WAS, IT07K-299-6 produced significantly lower root fresh weight than the other varieties (Table 7). On the other hand, the root fresh weight in varieties IT06K-128 and IT07K-303-1 was significantly higher than that of other varieties at 12 WAS. All the treatments produced root fresh weights that were not significantly different at 6 WAS.

Application of 400 kgNPK/ha fertilizer treatment resulted in the highest root fresh weight which was significantly higher than the other treatments at 9 and 12 WAS. Next to this was that due to 200 kgNPK/ha fertilizer treatment at 9 and 12 WAS (Table 7).

Alectra inoculated plants produced higher root fresh weight than the uninoculated plants on all the sampling dates. However, this difference was only significant at 12 WAS (Table 7).

4.2.6 Root Fresh Weight of Cowpea Varieties in Trial II

All the cowpea varieties produced similar root fresh weight at 5 and 7 WAS. However, at 9 WAS, all the cowpea varieties except IT07K-299-6 produced significantly lower root fresh weight that was comparable with the lowest from variety IT08K-125-107. More so, Cowpea variety IT07K-299-6 produced the highest root fresh weight on each sampling date (Table 8).

Table 7: The Effect of NPK Fertilizer and *Alectra* on Root Fresh Weight of Cowpea Varieties in Trial I

	Root Fresh Weight (g) at:		
Treatment	6 WAS	9 WAS	12 WAS
Variety (V)			
IT08K-125-107	3.98[a]	6.92[a]	7.97[b]
IT06K-128	4.55[a]	7.00[a]	9.18[a]
IT07K-303-1	5.22[a]	6.94[a]	9.08[a]
IT07K-299-6	4.48[a]	7.18[a]	6.78[c]
SE±	0.47	0.21	0.24
Fertilizer (KgNPK/ha) (F)			
0	4.68[a]	6.17[c]	7.67[b]
100	4.43[a]	6.18[c]	7.55[b]
200	4.54[a]	7.26[b]	8.00[b]
400	4.58[a]	8.43[a]	9.80[a]
SE±	0.47	0.21	0.24
***Alectra* inoculation (A)**			
Inoculated	4.85[a]	7.14[a]	8.96[a]
Uninoculated	4.27[a]	6.88[a]	7.55[b]
SE±	0.33	0.15	0.17

N.B Values followed with the same letter(s) in each column under each treatment group are not significantly different (P = 0.05) using DMRT.

Key:
WAS: weeks after sowing

Table 8: The Effect of NPK Fertilizer and *Alectra* on Root Fresh Weight of Cowpea Varieties in Trial II in 2016

Treatment	Root Fresh Weight (g) at: 5 WAS	7 WAS	9 WAS
Variety (V)			
IT08K-125-107	0.73[a]	0.94[a]	1.30[b]
IT06K-128	0.74[a]	0.93[a]	1.32[b]
IT07K-303-1	0.72[a]	0.93[a]	1.23[b]
IT07K-299-6	0.76[a]	1.01[a]	1.46[a]
SE±	0.04	0.04	0.05
Fertilizer (kgNPK/ha) (F)			
0	0.72[a]	0.85[b]	1.33[ab]
15	0.75[a]	1.02[a]	1.26[b]
30	0.75[a]	0.98[a]	1.30[ab]
60	0.73[a]	0.95[ab]	1.42[a]
SE±	0.04	0.04	0.05
***Alectra* Infestation (A)**			
Inoculated	0.75[a]	0.90[b]	1.29[a]
Uninoculated	0.73[a]	1.00[a]	1.37[a]
SE±	0.03	0.03	0.04

N.B: Values followed with the same letter(s) in each column under each treatment group are not significantly different (P = 0.05), using DMRT.

Keys:
WAS: Weeks after Sowing

Application of NPK fertilizer had no significant effect on root fresh weight of cowpea varieties at 5 WAS. Generally, root fresh weights under all the fertilizer treatments were similar throughout the sampling dates (Table 8).

At 5 WAS, fertilizer application at 100 and 200 kgN/ha resulted in the highest root fresh weight which was not significantly higher than the lowest due to the untreated control.

At 7 WAS, fertilizer application at 100 kgNPK/ha resulted in the highest root fresh weight which was only significantly higher than the lowest due to the control treatment. At 9 WAS, fertilizer application at 400 kgNPK/ha resulted in the highest root fresh weight which was only significantly higher than the lowest due to 100 kgNPK/ha NPK fertilizer treatment (Table 8).

The uninoculated plants produced root fresh weight that was similar to the *Alectra* inoculated plants at 5 and 9 WAS but produced significantly higher root fresh weight than the inoculated plants at 7 WAS (Table 8).

4.2.7 Number of Root Nodules of Cowpea Varieties in Trial I

Generally, cowpea variety IT06K-128 produced the highest number of root nodules at 6 and 9 WAS. This was significantly higher than that of cowpea varieties IT08K-125-107 and IT07K-299-6 at 9 WAS. At 12 WAS variety IT07K-303-1 produced significantly higher root nodules than the other varieties. Generally, application of 30 kgN/ha fertilizer resulted in the highest number of root nodules at 6 and 9 WAS while the control produced the lowest number of root nodule at 9 and 12 WAS (Table 9).

At 6 WAS, application of 200 kgNPK/ha resulted in the highest number of root nodules which was significantly higher than that of the control and 400 kgNPK/ha fertilizer treatments. Application of 200 and 400 kgNPK/ha fertilizer treatments resulted in the

Table 9: The Effect of NPK Fertilizer and *Alectra* on Number of Root Nodules of Cowpea Varieties in Trial I in 2016

	Number of root nodules at:		
Treatment	6 WAS	9 WAS	12 WAS
Variety (V)			
IT08K-125-107	16.92[a]	30.46[b]	23.75[c]
IT06K-128	21.88[a]	37.21[a]	29.71[b]
IT07K-303-1	20.50[a]	36.88[a]	32.83[a]
IT07K-299-6	19.08[a]	32.88[b]	23.17[c]
SE±	2.25	0.91	0.84
Fertilizer (KgNPK/ha) (F)			
0	17.21[bc]	28.13[b]	20.75[d]
100	23.21[ab]	34.88[a]	24.83[c]
200	24.25[a]	37.38[a]	28.92[b]
400	13.71[c]	37.04[a]	34.96[a]
SE±	2.25	0.91	0.84
***Alectra* inoculation (A)**			
Inoculated	17.67[a]	33.96[a]	22.42[b]
Uninoculated	21.52[a]	34.75[a]	32.42[a]
SE±	1.59	0.64	0.60

N.B Values followed with the same letter(s) in each column under each treatment group are not significantly different (P = 0.05) using DMRT.

Key:
WAS: weeks after sowing

highest number of root nodules which was significantly higher than the lowest due to the control at 9 and 12 WAS respectively (Table 9).

The *Alectra* inoculated plants produced fewer number of root nodules than the uninoculated plants. However, this difference was only significant at 12 WAS (Table 9).

4.2.8 Number of Root Nodules of the Cowpea Varieties in Trial II

The number of root nodules produced by Cowpea variety IT08K-125-107 was significantly higher than that of IT06K-128 and IT07K-299-6 on each sampling date (Table 10).

The highest number of root nodules produced by IT07K-303-1 was only significantly higher than that of varieties IT06K-128 and IT07K-299-6 at 5 WAS (Table 10).

At 7 and 9 WAS, IT08K-125-107 produced the highest number of root nodules which was significantly higher than that of other varieties, while variety IT07K-299-6 produced the lowest (Table 10).

Number of root nodules produced due to 200 kgNPK/ha NPK fertilizer application was similar with that of 400 kgNPK/ha on each sampling date but was significantly higher than that of 100 kgNPK/ha and untreated control at 5 and 9 WAS (Table 10).

At 5 WAS, application of 400 kgNPK/ha NPK fertilizer treatment resulted in the highest number of root nodules which was only significantly higher than that of the control and 100 kgNPK/ha NPK treatments (Table 10).

Table 10: The Effect of NPK Fertilizer and *Alectra* on the Number of Root Nodules of the Cowpea Varieties in Trial II in 2016

	Number of Root Nodules at:		
Treatment	5 WAS	7 WAS	9 WAS
Variety (V)			
IT08K-125-107	51.30[a]	52.92[a]	50.25[a]
IT06K-128	45.38[b]	40.63[bc]	37.04[b]
IT07K-303-1	52.08[a]	44.13[b]	36.96[b]
IT07K-299-6	47.13[b]	37.04[c]	33.08[b]
SE±	1.36	1.46	1.59
Fertilizer (kgNPK/ha) (F)			
0	45.21[b]	44.33[a]	35.33[c]
100	46.42[b]	43.00[a]	36.67[bc]
200	50.83[a]	42.56[a]	44.50[a]
400	53.42[a]	44.92[a]	40.83[ab]
SE±	1.36	1.46	1.59
***Alectra* infestation**			
Inoculated	44.86[b]	40.77[b]	38.15[a]
Uninoculated	53.08[a]	46.58[a]	40.52[a]
SE±	0.96	1.03	1.13

N.B: Values followed with the same letter(s) in each column under each treatment group are not significantly different (P = 0.05), using DMRT.

Key:
WAS: weeks after sowing

At 9 WAS, 200 kgNPK/ha NPK fertilizer application resulted in the highest number of root nodules which was only significantly higher than that of the control and 100 kgNPK/ha NPK treatments (Table 10).

The *Alectra* inoculated plants produced lower number of root nodules than the uninoculated plants on each sampling dates. However, this difference was only significant at 5 and 7 WAS

4.2.9 Leaf Area Index of Cowpea Varieties in Trial I

There was no significant difference in the leaf area index of the cowpea varieties at 6 and 9 WAS. Generally IT07K-303-1 produced the highest leaf area index on each sampling date. This difference was only significant at 12 WAS. Application of 400 kgN/ha fertilizer application resulted in the highest leaf area index at 6 and 9 WAS (Table 11).

At 6 WAS, the application of 400 kgNPK/ha resulted in the highest leaf area index which was significantly higher than the other treatments. Application of 400 kgNPK/ha resulted in the highest leaf area index which was not significantly higher than the lowest due to the control at 9 WAS. At 12 WAS, application of 200 kgNPK/ha fertilizer treatment resulted in the highest leaf area index which was significantly higher than that of the control and 100 kgNPK/ha fertilizer treatment (Table 11).

The leaf area index due to *Alectra* inoculation was similar with that of the uninoculated plants on each sampling date (Table 11).

Table 11: The Effect of NPK Fertilizer and *Alectra* on Leaf Area Index of Cowpea Varieties in Trial I in 2016

	Leaf area index at:		
Treatment	6 WAS	9 WAS	12 WAS
Variety (V)			
IT08K-125-107	0.20[a]	0.22[a]	0.25[c]
IT06K-128	0.20[a]	0.22[a]	0.26[b]
IT07K-303-1	0.21[a]	0.24[a]	0.29[a]
IT07K-299-6	0.20[a]	0.12[a]	0.22[d]
SE±	0.01	0.47	0.00
Fertilizer (KgNPK/ha) (F)			
0	0.14[c]	0.17[a]	0.24[b]
100	0.19[b]	0.19[a]	0.23[c]
200	0.20[b]	0.21[a]	0.28[a]
400	0.27[a]	1.22[a]	0.27[a]
SE±	0.01	0.47	0.00
***Alectra* inoculation (A)**			
Inoculated	0.19[a]	0.24[a]	0.25[a]
Uninoculated	0.21[a]	0.66[a]	0.25[a]
SE±	0.01	0.34	0.00

N.B Values followed with the same letter(s) in each column under each treatment group are not significantly different (P = 0.05) using DMRT.

Key:
WAS: weeks after sowing

4.2.10 Leaf Area Index of Cowpea Varieties in Trial II

The entire cowpea varieties exhibited similar leaf area index at 5 and 7 WAS (Table 12). Leaf area index at 5 WAS under all the NPK fertilizer treatments were similar. However, fertilizer application at 200 and 400 kgNPK/ha produced higher leaf area index which was significantly higher than that of the control and 100 kgNPK/ha NPK fertilizer treatments at 7 and 9 WAS (Table 12).

The *Alectra* uninoculated plants exhibited larger leaf area index than the *Alectra* inoculated plants on each sampling date; however, this difference was not significant (Table 12).

4.3 The Effect of NPK Fertilizer, Cowpea Varieties and *Alectra* on Yield Parameters in Trial I

4.3.1 Number of pods per plant

Cowpea variety IT08K-125-107 resulted in the lowest number of pods per plant which was only significantly lower than the highest due to IT07K-303-1 (Table 13).

Application of 400 kgNPK/ha NPK fertilizer treatment produced the highest number of pods per plant which was significantly higher than that of the other treatments (Table 13).

The *Alectra* inoculated plants significantly produced fewer number of pods than the uninoculated plants (Table 13).

4.3.2 Pod weight

Cowpea variety IT07K-303-1 produced the highest pod weight which was significantly higher than that of other varieties. This was followed by that of IT06K-128. The lowest pod weight was due to IT07K-299-6.

Table 12: The Effect of NPK Fertilizer and *Alectra* on Leaf Area Index of Cowpea Varieties in Trial II in 2016

	Leaf Area Index at:		
Treatment	5 WAS	7 WAS	9 WAS
Variety (V)			
IT08K-125-107	0.13[a]	0.17[a]	0.18[c]
IT06K-128	0.18[a]	0.18[a]	0.20[b]
IT07K-303-1	0.16[a]	0.18[a]	0.22[a]
IT07K-299-6	0.13[a]	0.18[a]	0.17[d]
SE±	0.02	0.00	0.00
Fertilizer (kgNPK/ha) (F)			
0	0.14[a]	0.14[c]	0.15[c]
100	0.14[a]	0.17[b]	0.17[b]
200	0.14[a]	0.20[a]	0.23[a]
400	0.19[a]	0.20[a]	0.23[a]
SE±	0.02	0.00	0.00
***Alectra* infestation (A)**			
Inoculated	0.13[a]	0.18[a]	0.19[a]
Uninoculated	0.17[a]	0.18[a]	0.20[a]
SE±	0.01	0.00	0.00

N.B: Values followed with the same letter(s) in each column under each treatment group are not significantly different (P = 0.05), using DMRT.

Key:
WAS: weeks after sowing

Application of 400 kgNPK/ha NPK fertilizer resulted in the highest pod weight which was significantly higher than the other treatments (Table 13).

The *Alectra* inoculated plants significantly produced lower pod weight than the uninoculated plants.

4.3.3 Pod length

Cowpea variety IT06K-128 produced the longest pods which was significantly longer than that due to IT07K-303-1 and IT08K-125-107. Cowpea variety IT07K-303-1 was significantly shorter than that of others (Table 13).

The longest pod length was produced as a result of the application of 400 kgNPK/ha which was significantly longer than that of other treatments. The shortest pods were due to the control treatment (Table 13).

Alectra uninoculated plants significantly produced longer pods than the *Alectra* inoculated plants (Table 13).

4.3.4 Number of seeds per pod

Cowpea variety IT07K-299-6 produced the highest number of seeds per pod which was significantly higher than that of IT06K-128 and IT07K-303-1 cowpea varieties (Table 13).

The untreated control treatment yielded the least number of seeds per pod but application of 400 kgNPK/ha fertilizer resulted in the highest number of seeds per pod which was significantly higher than that of the other treatments (Table 13).

4.3.5 100 seed weight

Cowpea variety IT07K-303-1 produced the highest seed weight which was significantly higher than that of the other varieties. This was followed by that of variety IT06K-128.

Table 13: The Effect of NPK Fertilizer, Cowpea Varieties and *Alectra* on Yield and Yield Components in Trial I in 2016

Treatment	NPP	PW (g)	PL (cm)	NSPP	100 SW (g)	SWPP (g)	Grain yield /plot(g)
Variety (V)							
IT08K-125-107	14.58[b]	3.30[d]	16.98[b]	15.67[a]	18.51[c]	2.90[c]	58.11[c]
IT06K-128	17.78[a]	4.06[b]	17.70[a]	13.50[b]	19.66[b]	2.80[c]	59.31[bc]
IT07K-303-1	19.56[a]	4.76[a]	16.49[c]	13.88[b]	25.55[a]	3.94[a]	75.95[a]
IT07K-299-6	18.11[a]	3.64[c]	17.40[ab]	15.63[a]	18.49[c]	3.26[b]	63.57[b]
SE±	0.62	0.07	0.23	0.48	0.31	0.09	1.61
Fertilizer (kgNPK/ha (F)							
0	12.90[d]	3.44[c]	15.52[d]	13.00[c]	19.47[c]	2.73[c]	59.98[c]
100	16.53[c]	3.84[b]	16.74[c]	13.54[c]	20.30[bc]	3.14[b]	62.84[bc]
200	18.82[b]	4.02[b]	17.42[b]	15.17[b]	21.06[ab]	3.44[a]	65.64[ab]
400	21.77[a]	4.45[a]	18.90[a]	16.96[a]	21.37[a]	3.58[a]	68.49[a]
SE±	0.62	0.07	0.23	0.48	0.31	0.09	1.61
***Alectra* inoculation (A)**							
Inoculated	16.19[b]	3.86[b]	16.64[b]	13.88[b]	20.52[a]	3.12[b]	62.62[b]
uninoculated	18.82[a]	4.02[a]	17.65[a]	15.46[a]	20.59[a]	3.33[a]	67.65[a]
SE±	0.44	0.05	0.16	0.34	0.22	0.06	1.14

N.B: Values followed with the same letter(s) in each column under each treatment group are not significantly different (P = 0.05), using DMRT.

Keys:
PW = Pod weight
PL= Pod length
NSPP = Number of seeds per pod
SW = Seed Weight
SWPP= Seed weight per pod
NPP = Number of pods per plant

The lowest 100 seed weight due to IT08K-125-107 was similar to that of IT07K-299-6 (Table 13).

Application of 400 kgNPK/ha NPK fertilizer resulted in the highest 100 seeds weight which was significantly higher than that due to the control and 100 kgNPK/ha fertilizer treatments. The lowest 100 seed weight due to the control was significantly lower than that of other treatments (Table 13).

Alectra inoculated plants had lower 100 seeds weight than the uninoculated. This difference was not significant.

4.3.6 Seed weight per pod

The highest seed weight per pod produced by IT07K-303-1 was significantly higher than that of the other varieties. This was followed by that due to IT07K-299-6 and 1T08K-125-107. The least seed weight per pod by IT06K-128 was lower than that of other varieties (Table 13).

The application of NPK fertilizer at 400 kgNPK/ha resulted in the highest seed weight which was significantly higher than that of 100 kgNPK/ha and control treatments (Table 13).

The uninoculated plants had higher seed weight/pod than the *Alectra* infested plants. This difference was significant (Table 13).

4.3.7 Grain yield per plot (g)

Cowpea variety IT07K-303-1 produced the highest grain yield which was significantly higher than that of the other varieties. This was followed by that due to IT07K-299-6. The Lowest Grain yield was due to IT08K-125-107 (Table 13).

Application of NPK fertilizer treatment at 400 kgNPK/ha resulted in the highest grain yield which was significantly higher than that due to the control and 100 kgNPK/ha (Table 13).

Alectra inoculated plants resulted in significantly lower yield than the uninoculated (Table 13).

4.4 The Effect of NPK Fertilizer, Cowpea Varieties and *Alectra* on Yield Parameters in Trial II

4.4.1 Number of pods per plant

Cowpea variety IT07K-303-1 produced the lowest number of pods per plant which was only significantly lower than that of IT06K-128 and IT07K-299-6. Cowpea variety IT06K-128 produced significantly higher number of pods per plant than other varieties (Table 14).

Application of 400 kgNPK/ha NPK fertilizer treatment produced the highest number of pods per plant which was significantly higher than that of the other treatments (Table 14).

The *Alectra* uninoculated plants produced higher number of pods than the inoculated plants. This difference was significant (Table 14).

4.4.2 Pod weight

Cowpea variety IT07K-303-1 produced the highest pod weight which was significantly higher than that of other varieties. This was followed by that of IT07K-299-6. The lowest pod weight from IT06K-128 was comparable with that of IT08K-125-107 (Table 14).

Application of 100 kgNPK/ha NPK fertilizer resulted in the highest pod weight which was only significantly higher than the lowest due to the control treatment (Table 14).

The *Alectra* inoculated plants produced comparable pod weight with the uninoculated plants.

4.4.3 Pod length

Cowpea variety IT06K-128 produced the longest pods which was significantly longer than that of the other varieties. This was followed by that due to IT08K-125-107 and IT07K-299-6, while that of IT07K-303-1 was significantly shorter than that of others (Table 14).

The longest pods were produced as a result of the application of 400 kgNPK/ha and was significantly longer than that of other treatments. The shortest pods were due to the control treatment (Table 14).

The *Alectra* uninoculated plants produced longer pods than the *Alectra* inoculated plants. This difference was significant (Table 14).

4.4.4 Number of seeds per pod

Cowpea variety IT07K-299-6 produced the highest number of seeds per pod which was only significantly higher than that of IT06K-128 and IT07K-303-1 cowpea varieties (Table 15).

The control treatment yielded the least number of seeds per pod but application of NPK fertilizer at 400 kgNPK/ha rate resulted in the highest number of seeds per pod which was significantly higher than that of the other treatments (Table 14).

The *Alectra* inoculated plants produced similar seeds per pod with the uninoculated plants (Table 14).

4.4.5 100 seed weight

Cowpea variety IT07K-303-1 produced the highest seed weight which was significantly higher than that of the other varieties. This was followed by that of variety IT06K-128.

The lowest 100 seed weight due to IT08K-125-107 was similar to that of IT07K-299-6 (Table 14).

Application of 400 kgNPK/ha NPK fertilizer resulted in the highest 100 seeds weight which was significantly higher than that of the other treatments. This was followed by that due to 100 and 200 kgNPK/ha NPK fertilizer treatments. The lowest 100 seed weight due to the control was significantly lower than that of other treatments (Table 14).

Alectra inoculated plants had higher 100 seeds weight than the uninoculated. This difference was significant.

4.4.6 Seed weight per pod

The highest seed weight per pod produced by IT07K-303-1 was significantly higher than that of the other varieties. This was followed by that due to IT07K-299-6 and 1T08K-125-107. The least seed weight per pod by IT06K-128 was lower than that of other varieties (Table 14).

The application of NPK fertilizer at 400 kgNPK/ha resulted in the highest seed weight which was only significantly higher than that of 100 kgNPK/ha and control treatments (Table 14).

The non-infested plants had higher seed weight/pod than the *Alectra* infested plants. This difference was significant (Table 14).

4.4.7 Grain yield per plot (g)

Cowpea variety IT07K-303-1 produced the highest grain yield which was significantly higher than that of the other varieties. This was followed by that due to IT06K-128. The Lowest Grain yield due to IT08K-125-107 was significantly lower than that of other varieties (Table 14).

Application of NPK fertilizer treatment at 400 kgNPK/ha resulted in the highest grain yield which was significantly higher than that of the other treatments. This was followed

Table 14: The Effect of NPK Fertilizer, Cowpea Varieties and *Alectra* on Yield and Yield Components in Trial II in 2016

Treatment	NPP	PW (g)	PL (cm)	NSPP	100 SW (g)	SWPP (g)	Grain yield /plot(g)
Variety (V)							
IT08K-125-107	11.95^{bc}	2.87^{c}	16.54^{b}	13.88^{a}	16.88^{c}	2.44^{b}	49.39^{d}
IT06K-128	14.84^{a}	2.86^{c}	17.29^{a}	12.08^{b}	17.70^{b}	2.08^{c}	52.78^{b}
IT07K-303-1	10.71^{c}	3.67^{a}	15.83^{c}	12.54^{b}	23.53^{a}	3.21^{a}	70.15^{a}
IT07K-299-6	13.24^{b}	3.43^{b}	16.81^{b}	14.33^{a}	17.15^{c}	2.49^{b}	50.78^{c}
SE±	0.50	0.060	0.14	0.30	0.19	0.06	0.44
Fertilizer (kgNPK/ha) (F)							
0	9.16^{c}	2.92^{b}	15.17^{d}	11.83c	17.58^{c}	2.13^{c}	52.38^{d}
100	12.49^{b}	3.39^{a}	16.12^{c}	12.79b	18.67^{b}	2.51^{b}	55.11^{c}
200	12.49^{b}	3.24^{a}	16.87^{b}	13.00b	19.21^{b}	2.75^{a}	57.10^{b}
400	16.59^{a}	3.28^{a}	18.32^{a}	15.21a	19.78^{a}	2.84^{a}	58.50^{a}
SE±	0.50	0.06	0.14	0.30	0.19	0.06	0.44
***Alectra* inoculation (A)**							
Inoculated	11.21^{b}	3.19^{a}	16.14^{b}	12.98^{a}	19.09^{a}	2.49^{b}	55.71^{a}
Uninoculated	14.15^{a}	3.24^{a}	17.10^{a}	13.44^{a}	18.54^{b}	2.62^{a}	55.84^{a}
SE±	0.35	0.05	0.10	0.21	0.13	0.04	0.31

N.B: Values followed with the same letter(s) in each column under each treatment group are not significantly different (P = 0.05), using DMRT.

Keys:
PW = Pod weight
PL= Pod length
NSPP = Number of seeds per pod
SW = Seed Weight
SWPP= Seed weight per pod
NPP = Number of pods per plant

by that due to 100 and 200 KgNPK/ha treatments. The lowest grain yield due to the control was significantly lower than that of other treatments (Table 14).

Alectra inoculated plants had lower yield than the uninoculated. However, this difference was not significant (Table 14).

4.5 Effects of cowpea variety, NPK Fertilizer, and *Alectra* inoculation on the Number of *Alectra vogelii* Shoots per plot and number of Infested Cowpea stands per plot in Trial I

Generally, the data showed that, NPK fertilizer application reduced the number of *Alectra* shoots and number of plants infested (Table 15).

Cowpea variety IT07K-303-1 supported the highest number of *Alectra* shoots which was significantly higher than that of the other treatments. Cowpea variety IT07K-299-6 supported the lowest number of *Alectra* shoots.

The control resulted in the highest number of *Alectra* shoots and plants infested which was significantly higher than the other treatments except 100 kgNPK/ha (Table 15).

4.6 Effects of cowpea variety, NPK Fertilizer, and *Alectra* inoculation on the Number of *Alectra vogelii* Shoots per plot and number of Infested Cowpea stands per plot in Trial II

Generally, the data showed that, NPK fertilizer application reduced the number of *Alectra* shoots and number of plants infested (Table 16).

Cowpea variety IT07K-303-1 supported the highest number of *Alectra* shoots which was significantly higher than that of the other treatments. Cowpea variety IT06K-128 supported the lowest number of *Alectra* shoots (Table 16).

The control resulted in the highest number of *Alectra* shoots and plants infested which was significantly higher than the other treatments except 100 kgNPK/ha in number of plants infested (Table 16).

Table 15: The Effect of NPK Fertilizer and *Alectra* on the Number of *Alectra vogelii* Shoots per plot and Cowpea Plants Infested per plot in Trial I in 2016

Treatment	No. of *Alectra* Shoots	No. of Plants Infested
Variety (V)		
IT08K-125-107	0.67[b]	0.21[b]
IT06K-128	0.21[b]	0.13[b]
IT07K-303-1	2.00[a]	0.65[a]
IT07K-299-6	0.38[b]	0.25[b]
SE±	0.24	0.09
Fertilizer (kgNPK/ha) (F)		
0	1.63[a]	0.50[a]
100	0.75[b]	0.33[ab]
200	0.54[b]	0.21[b]
400	0.33[b]	0.17[b]
SE±	0.24	0.09
***Alectra* Inoculation**		
Inoculated	1.63[a]	0.60[a]
Uninoculated	0.00[b]	0.00[b]
SE±	0.17	0.06

N.B: Values followed with the same letter(s) in each column under each treatment group are not significantly different (P = 0.05), using DMRT.

Table 16: The Effects of NPK Fertilizer, and *Alectra* on the Number of *Alectra vogelii* Shoots per plot and number of infested Cowpea stands per plot in Trial II in 2016

Treatment	No. of *Alectra* Shoots	No. of Plants Infested
Variety (V)		
IT08K-125-107	0.65[b]	0.25[b]
IT06K-128	0.29[b]	0.17[b]
IT07K-303-1	1.28[a]	0.46[a]
IT07K-299-6	0.25[b]	0.21[b]
SE±	0.22	0.07
Fertilizer (kgNPK/ha) (F)		
0	1.13[a]	0.42[a]
100	0.58[ab]	0.38[a]
200	0.38[b]	0.17[b]
400	0.37[b]	0.13[b]
SE±	0.22	0.07
***Alectra* Inoculation**		
Inoculated	1.23[a]	0.55[a]
Uninoculated	0.00[b]	0.00[b]
SE±	0.15	0.05

N.B: Values followed with the same letter(s) in each column under each treatment group are not significantly different (P = 0.05), using DMRT.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Vegetative Growth parameters of Cowpea Varieties

In the two trials, the application of NPK fertilizer enhanced the growth parameters of all the cowpea varieties. The improvement in the growth parameters is associated with the increase in plant nutrients as affirmed by Reyhan and Amiraslani (2006). This was also in line with the report by Abayomi *et al.* (2008) that application of NPK fertilizer enhanced the growth parameters of cowpea varieties. The effect of high dose of Nitrogen on plant could be due to the utilization of more nitrogen as nitrogen is an essential nutrient for growth. Also, the availability of sufficient growth nutrients from inorganic fertilizers lead to improved cell activities, enhanced cell multiplication and enlargement and luxuriant growth as reported by (Fashina *et al.*, 2002). Nitrogen fertilizer reduced the severity of *Striga* attack while simultaneously increasing the host performance (Lagoke and Isah, 2010). The increase in plant height in *Alectra* inoculated cowpea varieties with increased nitrogen rates is not unexpected and might be more possible due to the direct effect of nitrogen on vegetative growth and its indirect effect by reducing *Alectra* infestation which was reported to have negative effect on plant height (Olupot *et al*., 2003). *Alectra* inoculation caused a slight increase in plant height at 6 WAS but decreased in the subsequent sampling ages in the first trial. However, *Alectra* inoculation significantly reduced plant height in the second trial on all the sampling dates. The slight increase in plant height at 6 WAS could be attributed to low sink demand or low *Alectra* infestation. This is in line with Bashir (2008), who reported an increase in plant height in *Alectra* inoculated cowpea varieties as compared with the uninoculated cowpea varieties. 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. At later growth stage, decrease in plant height due to *Alectra* infestation was as a result of more assimilates being directed to *Alectra* rather than the host. In the two trials, cowpea variety IT07K-299-6 produced the lowest plant height on at least two sampling ages. On the other hand, IT07K-303-1 produced the highest plant height on all the sampling ages in trial II but at 9 WAS in trial I. These differences could be the character resulting from the crop genetic makeup and their differences in response to the effect of NPK fertilizer.

The application of NPK fertilizer enhanced fresh shoot weight production in all the varieties and this agrees with the findings of Abayomi *et al* (2008) that, application of inorganic fertilizer leads to more leaves and branches of cowpea. Also, Omotosho (2014) reported that, the number of leaves and number of branches per plant were also significantly increased with the increased rate of fertilizer application. *Alectra* inoculation significantly reduced shoot fresh weight when compared with the uninoculated varieties on almost all the sampling ages in the two trials. This was due to the activities of *Alectra vogelii* on the cowpea varieties as reported by Alonge *et al*. (2002) that, *Alectra* infestation reduced shoot dry matter by 50 %. This also agrees with the report that *Alectra* infestation reduced shoot-root ratio of most cowpea varieties (Alonge *et al*., 2002). Kutama *et al*. (2013) reported a significantly lower plant biomass in the infested cowpea varieties. This is apparently due to intensive *Alectra vogelii* infection thereby reducing the yield of the plants (Singh, 2002). Also, attachment of *A. vogelii* plants to the roots of the host results in an increase in sink demand in the roots. This carbon transfer from the shoots to the roots due to changes in sink demands largely accounts for the reduction in shoot biomass (Rambakudzibga, 2000).

There was barely any significant difference between the root fresh weight of the *Alectra* inoculated control and those treated with NPK fertilizer on at least two of the sampling ages. *Alectra* infestation increased the root fresh weight of the control treatment in the first trial. This was a as a result of infection i.e. the attachment of *Alectra* on the root of the cowpea varieties, which could have added to the initial weight of the root. Application of NPK fertilizer significantly increased root fresh weight of the cowpea varieties. This could be attributed to the presence of adequate nitrogen which reduced the production of germination stimulant by the cowpea varieties, hence suppressing the attachment of *Alectra* root on the cowpea varieties. This was in line with the findings of Ngawa (1992) that, reduction in *Striga* infestation could be attributed to the production of low germination stimulant by *Sorghum* under high Nitrogen. Also, the germination and severity of *A. vogelii* attachment is determined by the amount of germination stimulants produced by different hosts or non-hosts as well as the spatial relationship between the host roots and *Striga* seeds (Mwakabobo and Zwannenburg, 2011).

The number of root nodules of the cowpea varieties uninoculated with *Alectra* increased with the increase in NPK fertilizer level in almost all the sampling dates in the two trials. Increased nodule number could be due to the presence of adequate phosphorus. This could be attributed to phosphorus stimulating root growth and initiating nodule formation (Asuming-Brempong *et al.,* 2013). Also, the results of the increased nodule numbers agrees with the report of Armstrong (1999) and Yakubu *et al.* (2010) which stated that, increasing P levels increased the number and size of nodules. *Alectra vogelii* significantly decreased the number of root nodules of the inoculated cowpea varieties which were not treated with NPK fertilizer when compared with the treated cowpea varieties. This reduction could be due to depletion of phosphorus and other essential nutrients in the soil by *Alectra* which goes in line with the report that, phosphorus

stimulate root and plant growth, initiate root nodule formation as well as influence the general efficacy of the rhizome-legume symbiosis (Asuming-Brempong *et al.,* 2013).

In the two trials, all the cowpea varieties showed similar leaf area index on at least two of the sampling ages. However, at 12 and 9 WAS, IT07K-299-6 produced the lowest leaf area index. This was due to IT07K-299-6 producing smaller leaves than other varieties, which could be a character in its genetic makeup. Application of NPK fertilizer at 30 and 60 kgN/ha significantly increased leaf area index in the two trials, with 60 kgN/ha fertilizer application resulting in the highest leaf area index. Adeoye *et al*. (2011) reported that, a combination of poultry manure and cattle manure improved leaf area. This improvement is associated with increased nitrogen, phosphorus and potassium levels in the soil as affirmed by Reyhan and Amiraslani (2006). In the two trials, *Alectra i*nfestation reduced leaf area index of the cowpea plants. However, this reduction was not significant. This reduction could be due to the depletion of essential nutrients such as nitrogen and phosphorus which could have enhanced cowpea vegetative growth by *Alectra vogelii.* This could also be attributed to induced water stress due to the parasite's characteristically high transpiration rate which limits vegetative growth and reduce leaf area (Alonge *et al.,* 2001a).

5.2 Yield and Yield Components of Cowpea Varieties

Fertilizer application significantly improved number of pods per plant, pod weight, pod length, 100 seed weight, seed weight per pod and grain yield of the four cowpea varieties in the two trials. This is due to the activities of the NPK fertilizer on root/vegetative growth and root nodulation. These growth parameters were significantly improved by the application of NPK fertilizer and hence significant increase in grain yield and yield parameters. This is in line with the report of Abayomi *et al. (*2008) that, yield parameters and consequently grain yield were significantly increased by fertilizer application at 30-

15-15-kgN-P-K/ha. *Alectra vogelii* inoculation significantly reduced all the yield parameters except 100 seed weight of inoculated cowpea varieties in the first trial. This is in accordance with the report that, *A. vogelii* infestation causes a reduction in number of pods per plant, weight of pod, number of seeds per pod, weight of seeds and chlorophyll contents of the leaves among susceptible genotypes (Kutama *et al*., 2013). However, with the application of NPK fertilizer, the activities of *Alectra* were suppressed and that resulted in a significant increase in pod weight, pod length and seed weight per pod. This increase was due to the presence of adequate nitrogen in the soil resulting from the NPK fertilizer application. This observation is in line with the findings of Kwaga *et al*. (2010a) that, *Alectra* incidence was suppressed with fertilizer application at 50 kgN/ ha and thus increased pod yield above that of unfertilized plant. Emechebe *et al.* (1991) also reported that, the application of high nitrogen dose (120 kgN/ha) drastically reduced the incidence of infestation by *Striga gesnerioides* in cowpea without significantly affecting grain yield but enhanced yield components.

In the two trials, there was reduction in grain yield due to *Alectra* infestation on the inoculated cowpea varieties. This could also be attributed to reduction in the number of root nodules, shoot and root growth observed in this study. This finding is in line with the reports of Karanja *et al*. (2012) that, the devastation of cowpea grain yield at 0 ton/ha of farmyard manure by *Alectra* could be attributed to the reduced root nodulation, root and shoot growth and nutrients uptake exhibited by susceptible varieties (K80 and M66) at stages of vegetative growth as compared to 5 and 10 tonnes/ha where there was more supply of nutrients. Generally, cowpea variety IT07K-303-1, despite the high number of *Alectra* shoots present, produced the highest grain yields. This variety is either moderately resistance or tolerant to *A. vogelii.* This might be due to the death of the *Alectra* shoots shortly after emergence which is one of the resistance mechanism

advocated by Kwaga *et al*. (2010b). Kureh and Alabi (2003) considered tolerance as a horizontal resistance which is polygenic in contrast to vertical resistance which breaks down faster with time. Since the tolerant genotype can produce high yield in spite of high parasitism, it implies that it is very efficient in the production of assimilates to support the parasites and still have enough to give high yields (Musell, 1980).

5.3 *Alectra vogelii* Parameters

This study has shown varieties IT06K-128 and IT07K-299-6 as exhibiting the highest resistance to *Alectra* having shown the lowest *Alectra* incidence in trial I and II respectively. This could be attributed to the possibility of its producing the least germination stimulant (Kwaga *et al.,* 2010a). However, IT07K-303-1 was found to support the highest number of *Alectra* shoots throughout the growth period. Application of 60 kgN/ha NPK fertilizer reduced the number of *Alectra* shoots in all the cowpea varieties and in some cases did not support *Alectra* emergence. This could be due to the presence of high level of Nitrogen in the soil. The efficacy of nitrogen in reducing *Alectra* shoots in Soybean was reported by Tarfa *et al*. (1996). Similar effect of the nutrient was observed on cowpea by Magani (1994). Similarly, Kwaga *et al*. (2010a), reported significant reduction in shoot population of *Alectra vogelii* when 25 kgN was applied to groundnut. The suppressing effect of nitrogen on parasitic weeds has to do with the lethal effect of the nutrient on the weeds.

CHAPTER SIX

6.0 Conclusions and Recommendations

6.1 Conclusions

1. Application of NPK fertilizer at 15 – 60 kgN/ha generally enhanced the vegetative growth parameters, grain yield and yield parameters of the four cowpea varieties on *Alectra* uninoculated soil. The highest vegetative growth, grain yield and yield were achieved with the application of 60 kgN/ha NPK fertilizer.
2. Application of NPK fertilizer reduced the number of *Alectra* shoots per cowpea stand and the number of cowpea plants infested by *Alectra*, and enhanced most of the vegetative growth and yield parameters of the cowpea varieties under *Alectra* infestation.
3. Cowpea variety IT07K-303-1 had the highest incidence of *Alectra vogelii* but was also observed to have produced the highest grain yield. This indicates that the variety has high tolerance to the parasite.

6.2 Recommendations

With the result above, it can be recommended that, NPK fertilizer should be considered as an efficient control measure for *Alectra* infestation on susceptible cowpea varieties due to its ability to supply adequate nutrient to the soil to enhance its fertility, which in turn combats the adverse effects of *Alectra vogelii* infestation thereby enhancing good growth and yield of cowpea plants.

For better yield and growth of cowpea, tolerant varieties such as IT07K-303-1 should be cultivated most especially for commercial purpose.

REFERENCES

Abayomi, Y. A., Ajibade, T. V., Samuel, O. F. and Sa'adudeen, B. F. (2008). Growth and Yield Responses of Cowpea (*Vigna unguiculata* (L.) Walp) Genotypes to Nitrogen Fertilizer (N.P.K.) Application in the Southern Guinea Savanna Zone of Nigeria. *Asian Journal of Plant Sciences*. 7(2): 170-176.

Adeniyan, O. N. and Ojeniyi, S. O. (2005). Effect of Poultry Manure, NPK 15:15:15 and Combination of their Reduced Levels on Maize Growth and Soil Chemical Properties. *Nigerian Journal of Soil Science* 15:34-41.

Adeosun, J. O. (1990). Evaluation of Sowing Date, Nitrogen Level, Variety and Herbicide for the Control of *Striga hermonthica* (Del.) Benth in *Sorghum* (*Sorghum bicolor* (L.) Moench). An Unpublished M.Sc. Thesis, Ahmadu Bello University, Zaria, Nigeria, 102pp.

Adeoye, P. A., Adebayo, S. E. and Musa, J. J. (2011). Growth and Yield Response of Cowpea (*Vigna unguiculata* (L.) Walp) to Poultry and Cattle Manure as Amendment on Sandy Loam Soil Plot. *Agricultural Journal*, 6(5): 218 – 221.

Adetimirin, V. O., Kim, S. K. and Aken'ova, M. E. (2000). Expression of Mature Plant Resistance to *Striga hermonthica* in Maize. *Euphytica*. 34:1-10.

Adu, J. K., Leleji, O. and Emechebe, A. M. (1989). Nitrogen Fertilizer Effects on *Striga* Attack of Cowpea in Northern Nigeria. Paper presented at the Maize and Cowpea Joint Workshop of SAFGRAD at Lome, Togo, March 20 – 24, 1989

Agrios, G. N. (2005). Plant pathology. Academic Press. United States of America.

Alonge, S. O. (2000). Effect of *Alectra vogelii* (Benth.) and *Striga gesnerioides* Vatkes on the Growth, Yield and Grain Chemical Composition of Cowpea (*Vigna unguiculata* (L) Walp) Varieties. Unpublished Ph.D. Thesis Submitted to the Department of Biological Sciences, A.B.U. Zaria, 321pp.

Alonge, S. O., Lagoke, S. T. O. and Ajakaiye C. O. (2001a). Cowpea Reactions to *Alectra vogelii* I: Effect on Growth. *Crop Protection*, 20: 283-290.

Alonge, S. O., Lagoke, S. T. O. and Ajakaiye, C. O. (2001b). Cowpea Reactions to *Alectra vogelii* II: Effect on Yield and Nutrient Composition. *Crop Protection*, 20: 291-296.

Alonge, S. O., Tehatchoua, D. T. and Musa, S. D. (2002), Effect of *Alectra vogelii* on the Nutrient Composition of Cowpea Varieties. *Nigerian* Journal *of Weed Science*, 15:31 – 37.

Anota, T. (1991). Improving *Striga* Management in Africa. *Proceedings of the Second General Workshop of the Pan-African Striga Control Network*, Accra, Ghana: Food and Agriculture Organisation of the United Nations. pp.135-137.

Ariga, E. S., Ransom, J. K., Odihiambo, G .D., Abayo, G. and Ndungu, D. K. (1997). Potentials of using Cotton and other Trap Crops for *Striga hermonthica* Management in Cereals in Kenya. In: Adipala, E; Tusiimes, G. and Okori, P. (Eds): *Proceedings of the 16 biennial Weed Science Society Conference for Eastern Africa*, Kampala, pp.247-254.

Armstrong, D. L. (1999)**.** Phosphorus for Agriculture. *Better Crops with Plant Food* 83(1): 1- 39.

Asuming-Brempong, S., Wiafe, Y. and Aggrey-Martin, K. (2013). Nodulation of Cowpea (*Vigna unguiculata* (L.) Walp) at Different Levels of Phosphorus in a Typic kandiustalf. *Agricultural Science Research Journal* 3(12): 387- 394.

Atera, E. and Itoh, A. (2011). Evaluation of Ecologies and Severity of *Striga* Weed on Rice in Sub-Saharan Africa. *Agricultural and Biological Journal of North America*, 2: 752–760.

Atokple, I. D. K., Singh, B. B. and Emechebe, A. M. (1995). Genetics of Resistance to *Striga* and *Alectra* in Cowpea. *Journal of Heredity*, 86: 45-49.

Ayensu, E. S., Dogget, H., Keynes, R. D., Marton-Lefevre, J., Musselman, L. J., Parker, C. and Pickering, A. (1984). *Striga Biology and Control:* International Council of Scientific Unions Press, Paris. 216pp.

Ayodele, O. J. and Oso, A. A. (2014). Cowpea Responses to Phosphorus Fertilizer Application at Ado-Ekiti, South-West Nigeria. *Journal of Applied Science and Agriculture*, 9(2): 485-489.

Azarpour, E., Danesh, R. K., Mohammadi, S., Bozorgi, H. R. and Moraditochaee, M. (2011). Effects of Nitrogen Fertilizer under Foliar Spraying of Humic Acid on Yield and Yield Component of Cowpea. *World Applied Sciences Journal* 13(6): 1445 – 1449.

Ba, F. S., Pasquet, R. E. and Gepts, P. (2004). Genetic Diversity in Cowpea (*Vigna unguiculata* (L.) Walp) as Revealed by RAPD Markers. *Genetic Resource Crop Evolution*. 51:539-550.

Bagnall-Oakeley, H., Gibberd, V. and Nyongesa, T. E. (1991).The incidence and Control of *Alectra vogelii* in Embu District, Kenya. *Proceedings of the 5th International Symposium of Parasitic Weeds*, Nairobi, Kenya, 24-30 June 1991. Nairobi, Kenya; CIMMYT (International Maize and Wheat Improvement Center), pp.340-345.

Bashir, R. M. (2008). Assessment of Cowpea [*Vigna unguiculata* (L) Walp] Cultivars against *Alectra vogelii* (Benth*)* (Witchweed) Collected from Dodoma, Tanzania. M.Sc. Thesis Submitted to the Sokoine University of Agriculture Morogoro, Tanzania. pp.36-38

Bebawi, F. F. and Farah, A. F. (1981). Effect of Parasitic and Non-Parasitic Weed on *Sorghum. Experimental Agriculture* 17:337- 341.

Berner, D. K., Awad, A. E. and Aigbokhan, E. I. (1994). Potential of Imazaquin Seed Treatment for Control of *Striga gesnerioides* and *Alectra vogelii* in Cowpea (*Vigna unguiculata* (L.) Walp). *Journal of Plant Disease.*78 (1):18-23.

Berner, D. K., Kling, J. C. and Singh, B. B. (1995). *Striga* Research and Control: Perspective from Africa. *Journal of Plant Disease* 79: 652-670.

Borg, S. J. and Van Ast, A. (1991). Parasitic Plants as Stimulants of Host Growth. In: *Proceedings of the 5th International Symposium of Parasitic Weeds.* (Edited by Ransom, J. K., Musselman, L. J., Worsham, A. D. and Parker, C.), 24-30 June, 1991, Nairobi, Kenya. pp. 442-446.

Boukar, O., Kong, L., Singh, B. B., Murdock, L. and Ohm, H. W. (2004). AFLP and AFLPm Derived SCAR Markers Associated with *Striga gesnerioides* Resistance in Cowpea. (*Vigna unguiculata* (L.) Walp.). *Crop Science* 44: 1259-1264.

Broome, W. (2010). *Fertilizers and Soil Fertility*. The Agriculture Institute, College of Agriculture and Life Sciences, North Carolina State University. pp.33-39.

Buries, R. H. (1959). Nitrogen Nutrition. *Annual Review of Plant Physiology*, 20: 301 – 308.

CAB International (2012). Invasive Species Compendium http://www.cabi.org/isc/?compid=5&dsid=4234&loadmodule=datasheet&page=481&site=144 retrieved 7th January, 2012.

Cardoso, C., Ruyter-Spira, C. and Bouwmeester, H. J. (2011). Strigolactones and Root Infestation by Plant-Parasitic *Striga*, *Orobanche* and *Phelipanche* spp. *Plant Science,* 180: 414- 420.

Choudhary, A. H. and Lagoke, S. T. O, (1980). Zonal Herbicides Trial. Department of Agronomy, *Fifth Annual Report*, Ahmadu Bello University, Zaria, Nigeria, pp.22-23 May, 1983, IAR, Samaru, Nigeria.

Clark, A. (2007). Cowpeas (*Vigna unguiculata*). In: Managing Cover Crops Profitably. 3rd Edition. Sustainable Agricultural Research and Education, College Park, MD. pp125–129. http://www.sare.org/Learning-Center/Books/Managing-Cover-

Crops-Profitably-3rd-Edition/Text-Version/Legume-Cover-Crops/Cowpeas (accessed 6 Jun. 2012).

Cook, B. G., Pengelly, B. C., Brown, S. D., Donnelly, J. L., Eagles, D. A., Franco, M. A., Hanson, J., Mullen, B. F., Partridge, I. J., Peters, M. and Schultze-Kraft, R. (2005). Tropical Forages: an interactive selection tool. *Vigna unguiculata* (L.) Walp CSIRO, DPI&F(Qld), CIAT, and ILRI, Brisbane, Australia. http://www.tropicalforages.info/key/Forages/Media/Html/*Vigna_unguiculata*.htm (accessed 6 Jun. 2012).

Coulibaly, S., Pasquet, R. S., Papa, R. and Gepts, P. (2002). AFLP Analysis of the Phenotic Organization and Genetic Diversity of *Vigna unguiculata* (L.) Walp. Reveals Extensive Gene Flow between Wild and Domesticated Types. *Theoretical Applied Genetics*. 104: 358-366.

Dart, P. J., Day, R., Islam, A. and Dobereiner, J. (1977). Some Effects of Temperature and Composition of the Rooting Medium in Symbiotic Nitrogen Fixation in Plants Synthesis. In: Tropical Grain Legume, Nutman R. S. (Ed), Cambridge University Press, pp361 – 383.

De-groote, H., Rutto, E., Odhiambo, G., Kanampiu, F., Khan, Z., Coe, R. and Vanlauwe, B. (2010). Participatory Evaluation of Integrated Pest and Soil Fertility Management Options using Ordered Categorical Data Analysis. *Agricultural System*. 98:83-94.

Dixit, A. K., Tomar, D. S., Saxena, A. and Kaushik, S. K. (2001). Assessment of Potassium Nutrition in Soybean for Higher Sustainability Yield in Medium Black Soils of Central Indian. *International Potash Institute*. 26: 1 - 11

Dugje, I. Y., Omoigui, L. O., Ekeleme, F, Kamara, A. Y. and Ajeigbe, H. (2009). Farmers Guide to Cowpea Production in West Africa. International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria.

Dugje, I. Y., Kamara, A. Y. and Omoigui, L. O. (2006). Infestation of Crop Fields by *Striga* Species in the Savannas of North East Nigeria. *Agricultrure, Ecosystem and Environment* 116: 251-254.

Egley, G. H. (1971). Mineral Nutrient and the Parasitic Host Relationship of Witchweed. *Weed Science*. In: Mussellman, L.Y. (Ed). *Cultural Practices in Weed Management in Agriculture* 1: 160- 171.

Ehlers, J. D. and Hall, A. E. (1997). Cowpea (*Vigna unguiculata* (L.) Walp.). *Field Crops Research*. 53: 187- 204.

Ejeta, G. and Butler, L. G. (1993). Host Plant Interactions throughout the *Striga* Life Cycle, and their Contributions to *Striga* Resistance. *African Crop Science Journal* 1(2):75-80.

Ejeta, G. (2007). Breeding for *Striga* Resistance in *Sorghum*: Exploitation of Intricate Host Parasite Biology. *Crop Science*, 47:216-227.

Emechebe, A. M. (1980). A Checklist of Diseases of Crop in Savanna and Semi-Arid Areas of Nigeria, Samaru, Zaria, I. A. R. Samaru Miscellaneous Paper. 100.

Emechebe, A. M., Leleji, O. and Salako, E. A. (1983). Control of Root Parasitic Weeds in Cowpea and Groundnut. Paper presented at IAR Symposium on *Striga* and its control, 23 May, 1983, IAR Samaru, Zaria, Nigeria.

Emechebe, A. M. and Singh, B. B. (1990): Further Studies on Parasitic Weeds of Cowpea. In*:* Legumes and Oil Seeds Research Programmes Report of 1990. Cropping Scheme Meeting of Institute for Agricultural Research, Zaria, Nigeria. Pp. 103 – 105.

Emechebe, A. M., Singh, B. B., Leleji, O. I., Atokple, I. D. K. and Adu, J. K. (1991). Cowpea *Striga* Problems and Research in Nigeria. In: Kim, S. K. (Ed.) Combating *Striga* in Africa. *Proceedings of an International Workshop*, 1988 August, 22-24; Ibadan, Nigeria. Pp. 18-28.

Emmanuel, O. C. (2014). Growth and Yield Response of Cowpea (*Vigna unguiculata* (L.) Walp) to NPK Fertilizer and Rhizobia Inoculation in the Guinea and Sudan Savanna Zones of Ghana. Unpublished Ph.D Thesis Submitted to the Department of Crop and Soil Sciences, Faculty of Agriculture, College of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. pp.83- 85.

Enweozor, W. O., Udoh, E. Y., Usoruh, N., Ayotade, K. A., Adepotu, J. A. and Udegbe, O. I. (1989). Fertilizer Use and Management Practices for Crops in Nigeria Fertilizer Procurement and Distribution Division, Federal Ministry of Agriculture, Water Resources and Rural Development. Pp. 18.

Eplee, R. E., Westbrooks, R. G. and Norris, R. S. (1991). Chemical Control of *Striga*, In: Kim S. K, (Ed.), Combating *Striga* in Africa. *Proceedings of International Workshop Organized by IITA, ICRISAT and IDRC*: 22 – 24th August, 1988, Ibadan, Nigeria. Pp. 61 – 65.

Fang, J. G., Chao, C. T., Robert, P. A. and Ehlers, J. D. (2007). Genetic Diversity of Cowpea (*Vigna unguiculata* (L.) Walp) in Four West African and USA Breeding Programs As Determined by AFLP Analysis. *Genetic Resources and Crop Evolution* 54: 1197-1209

FAO. (2010). Crop Statistics for Africa and S. Asia (http: //faostat.fao. org, accessed on 10 April, 2015).

FAOSTAT, (2008). World Cowpea Production. available on http://faostat.fao.org. Accessed on 10/10/2010.

FAOstatistics. (2010).www.fao.org

Fashina, A. S.. Olatunji, K. A. and Alasiri, K. O. (2002). Effects of Different Plant Population and Poultry Manure on Yield of Ugu (*Telfairia occidentalis*) in Lagos State, Nigeria. In: *Proceedings of the Annual Conference of Horticultural Society of Nigeria* (HORTON), pp.123-127.

Federal Ministry of Agriculture and Rural Development (FMARD), (2011). Agricultural Production Survey Data (1999-2010). FCT, Abuja, Nigeria.

Fen, D. B., Steven, G. H., Venne, J. and Watson, A. K. (2007). The *Striga* Scourge in Africa- a Growing Pandemic. In: Ejeta, G. and Gressel, J. (Eds.). Integrating New Technologies for *Striga* Control towards Ending the Witch-hunt. Word Scientific Publishing Co., Singapore. pp. 3-16.

Fery, R. L. and Dukes, P. D. (2002). Southern Blight (*Sclerotium rolfsii* Sacc.) of Cowpea: Yield- Loss Estimates and Sources of Resistance. *Crop Protection*, 21(5): 403- 408.

Food and Agriculture Organization (FAO). (2012). Grassland Species Index. *Vigna unguiculata* http://www.fao.org/ag/AGP/AGPC/doc/Gbase/data/pf000090.htm(accessed 6 Jun. 2012)

Food and Agriculture Organization Corporate Statistical Database, (2012). http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor

Frost, D. L., Gumey, A. L., Press, M. C. and Scholes, J. D. (1997). *Striga hermonthica* Reduces Photosynthesis in *Sorghum*: The Importance of Stomatal Limitations and a Potential Role for ABA?, *Plant Cell and Environment* 20: 483-492

Garcia–Torres, L., Lopez–Granades, F. and Garcia–Riuz, R. (1992). Susceptibility of Sunflower *Heliathus annuus* (L.) Cultivars to Broom Rape *Orobanche cernua* Loef. Proceedings, 1992 Congress of the Spanish Weed Science Society. Pp.373 – 378.

Geleta, L. F. (2010). Cowpea Landraces of Botswana: A Potential Resistance Source for *Alectra vogelii*. *Aspect of Applied Biology*. 96pp.

Ghazanfar, S. A., Hepper, F. N. and Philcox, D. (2008). Flora of Tropical East Africa. In: Beentje, H. J. and Ghazanfar, S. A. (Eds.). Scrophulariaceae. Royal Botanic Gardens, Kew. pp. 1-8.

Graham, A. and Scott, R. (1984). Response of Cowpea (*Vigna unguiculata* (L.) Walp) to Nitrogen and *Alectra* Inoculation in Trinidad. *Tropical Agriculture*, 6: 56-58.

Grewal, H. S., Kolar, J. S., Dalip S. and Singh, D. (1994). Effect of Potassium on the Growth and Yield of Soybean (*Glycine max* L.) Merr.) *Journal of Potassium Research.* 10: 173 – 177.

Gworgwor, N. A. and Weber, H. C. (1991): Effect of N Application on *Sorghum* Growth, *Striga* Infestation and the Osmotic Pressure of the Parasite in Relation to the Host. *Journal of Plant Physiology* 139: 194-198.

Hall, A. E. (2004) Breeding for Adaptation to Drought and Heat in Cowpea. *European Journal of Agronomy*., 21: 447-454.

Hall, A. E., Cisse, N., Thiaw, S.,. Elawad, H. O. A., Ehlers, J. D., Ismail, A., Ferry, R., Roberts, P., Kitch, L. W., Murdock, L. L., Phillips, B. R. D. and K. H. McWatters. (2003). Development of Cowpea Cultivars and Germplasm by the Bean/ Cowpea CRSP. *Field Crops Research* 82: 103-134.

Hasan, M. R., Akbar M. A., Khandaker, Z. H. and Rahman, M. M. (2010)**.** Effect of Nitrogen Fertilizer on Yield Contributing Character, Biomass Yield and Nutritive Value of Cowpea Forage. *Bangladesh Journal of Animal Science*. 39(1&2):83 – 88.

Hearne, S. J. (2009). Control; the *Striga* conundrum. *Pest Management Science,* 65:603-614.

Hoffman, G. and Diara, S. (1991). Improving *Striga* Management in Africa. *Proceedings of the Second General Workshop of the Pan-African Striga Control Network*, Accra, Ghana: Food and Agriculture Organisation of the United Nations. pp. 43-50.

Hutchinson, J. and Dalziel, J. M. (1963). Flora of West Tropical Africa. 2nd Edition. London, UK: Crown Agents.

International Board for Plant Genetic Resources (IBPGR). (1983). Descriptors for Cowpea. Crop Genetic Resource Centre, Plant Production and Protection Division, Food and Agriculture Organization of the United Nations, Rome, Italy. 12pp.

Igbinnosa, I. and Okonkwo, S. N. C. (1991) Studies on Seed Germination of Cowpea Witchweed (*Striga gesnerioides*) and its Effect on Cowpea (*Vigna unguiculata*).

In: Ransom, J. K., Musselman, L. J., Warsham, A. D. and Parker, C. *Proceedings, 5th International Symposium of Parasitic Weeds*, 24-30th June, 1991, Nairobi, Kenya, (Eds.) The International Wheat and Maize Improvement Center (CIMMITY), Mexico, D. F. Mexico.

International Institute of Tropical Agriculture (IITA), (2011). Agency Report, Cowpea Driving Silent Economic Revolution in Nigeria. IITA, Ibadan, Nigeria.

International Institute of Tropical Agriculture, (2009). Maize. www.iitaresearch.org. Accessed 08/08/2010.

Kabambe, V. H., Katunga, L., Kapewa, T, and Ngwira, A. R. (2008). Screening Legume for Integrated Management of Witchweeds (*Alectra vogelii* and *Striga asiatica*) in Malawi. *African Journal of Agricultural Research* 3(10):708-715.

Kabambe, V. H, Nambuzi, S, Kauwa, A. E, Ngwira, A. R. (2005) Role of Cowpea and Silverleaf Intercropping on Witchweed (*Striga asiatica* (L.) Kuntze) in maize in Malawi. In: Safalaoh, A. C. L, Gowela J. P. and Mtethiwa, A. H. (Eds). *Proceedings of the Second Bunda College Research Dissemination Conference*, Lilongwe, Malawi. Pp. 22-27.

Kamara, A. Y., Chikoye, D., Ekeleme, F., Omoigui, L.O. and Dugje, Y. (2008). Field Performance of Improved Cowpea Varieties under Conditions of Natural Infestation by Parasitic Weed *Striga gesnerioides. International Journal of Pest Management* 54 (3): 189-195.

Karanja, J. (2009). *Alectra vogelii*: A Threat to Cowpea Production in the Arid and Semi-Arids Regions of Kenya. *Annual Report*, Kenya Agricultural Research Institute, Katumani Research Centre. Pp. 117- 120.

Karanja, J. K., Nguluu., S. N. and Gatheru, M. (2010). Farm Yard Manure Reduces the Virulence of *Alectra vogelii* (Benth) on Cowpea (*Vigna unguiculata)*. Paper presented at Bondo University College Conference, February, 2010.

Karanja, J., Nguluu, S. N., Wambua, J. and Gatheru, M. (2013). Response of Cowpea Genotype to *Alectra vogelii* Parasitism in Kenya. *African Journal of Biotechnology*. 12 (47): 6591-6598.

Karanja, J., Nguluu, S. N, and Mwangi, G. (2011). The Reaction of Cowpea (*Vigna unguiculata*) to *Alectra vogelii* (Benth.) Parasitism as Influenced by Nitrogen and Phosphorus Fertilization. KASAL end of Programme Conference and Exhibition, August, 2011. http://www.kari.org/kasal.

Karanja, J, Nguluu, S, and Gatheru, M. (2012). Farm Yard Manure Reduces the Virulence of *Alectra vogelii* (Benth) on Cowpea (*Vigna unguiculata*). .*African Journal of Plant Science*, 6(3):130-136.

Kim, S. K. (2000). Horizontal Resistance, Misunderstanding, Approach and Importance. In: Kim, S. K., Robinson, K., Atkinson, V. O., Adetimirin, C., and Salle, G. (Eds.) Combating *Striga* Parasitic Weeds Through Horizontal Resistance. *Proceedings of the International Workshop on Horizontal Resistance for Controlling Parasitic Weeds*, held at Hotel President World Centre, Brussel, Belgium, pp.35-53**.**

Kroschel, J. (2001). A Technical Manual for Parasitic Weed Research and Extension. Kluwer. *Academic Publishers*. Dordrecht, the Netherlands. 256pp.

Kroschel, J. and Sauerborn, J. (1996). Farming Systems and the Problems of Applying *Striga* Control Methods - A Comparison of Case Studies from Northern Ghana, Tanzania and Malawi. In: Moreno, M. T., Cubero, J. I., Berner, B., Joel, D. M., Musselman, L. J. and Parker, C., (Eds.). *Advances in Parasitic Plant Research*. *Proceedings of the 6th Parasitic Weed Symposium*. Cordoba, Spain. pp.843- 853.

Kureh, I, Katung, P. D, and Orakwue, F. C (1999) Reaction of Soybean Varieties to Pre-Conditioning and Concentration of Seed Inoculum of *Alectra vogelii* (Benth)., *Journal of Pure and Applied Science*, 2 (1): 116-124.

Kureh, I., Alabi, S. O. and Kamara, A. Y., (2005). Response of Soyabean Genotype to *Alectra vogelii* Infestation under Natural Field Conditions. *Tropicultura*, 23(3): 183-189.

Kureh, I. and Alabi, S.O. (2003). The Parasitic Angiosperm *Alectra vogelii* (Benth.) can Influence the Growth and Nodulation of Host Soybean (*Glycine max* (L.) Merrill). *Crop Protection*. 22(2):361-367.

Kureh, I., Segun, A., Lagoke S. T. O. and Mohammed, S. (2005). Host Plant Resistant and Anti-Transpirant for the Control of *Alectra vogelii* in Soyabean. *Journal of Food Agriculture and Environment*. 3(2):176-180.

Kutama, A. S., Hayatu, M. and Umar, S. (2013). Effect of *Alectra vogelii* (Benth) Infestation on the Growth of some Genotypes of Cowpea (*Vigna unguiculata* [L.] Walp). *Standard Research Journal of Agricultural Science.* 2 (3): 033- 039.

Kudi, T. M. and Abdulsalam, Z. (2008). Costs and Returns Analysis of *Striga* Tolerant Maize Variety in Southern Guinea Savanna of Nigeria. *Journal of Applied Sciences Research*, 4(6): 649-651.

Kwaga, Y. M., Olufajo, O. O., Tanimu, B., Shebayan J. A. Y. and Lagoke. S. T. O. (2010a). The Reaction of Groundnut (*Arachis hypogaea* L.) to *Alectra* Parasitism as Influenced by Nitrogen and Phosphorus Fertilization at Samaru, Nigeria. *American-Eurasian Journal of Agriculture and Environmental Science.* 7(6):628-633.

Kwaga, Y. M., Olu, O., Balarabe, T., Shebayan J. and Lagoke, S. T. O. (2010b). Genotype Effect on the Reaction of Groundnuts to *Alectra vogelii* (Benth.) Infestation in a Sub-humid Environment. *Journal of American Science*, 6(10): 644-651.

Kwaga, Y. M. (2004). Effect of Genotype, N, P and Herbicide Seed Treatment on the Reaction of Groundnut (*Arachis hypogea*) to *Alectra vogelii* (Benth). Ph.D Thesis, Department Of Agronomy, Ahmadu Bello University, Zaria. pp.79 -206.

Lagoke, S. T. O., Shebayan, J. Y., Magani, I. E, Olorunju, P., Olufajo, O. O., Elemo, K. A., Uvah, I., Adeoti, A. A. Chindo, P. S., Kureh, I., Jatau, S., Emechebe, A. M., Ndahi, W. B., Kim, S. K., Weber, G., Singh, B. B., Odion, C., and. Avan, A., (1997). *Striga* Problem and Development of Appropriate Control Technologies in Various Crops in Nigeria. In: Lagoke, S. T. O; L. E. Vander Straten and S. S. M. Boob (Eds.). Integrated Management of *Striga* for the African Farmers, *Proceedings of Third General Workshop of the Pan-African Striga Control Network (PASCON)*. 18-23 October, 1993, Harare, Zimbabwe, Accra, Ghana: FAO. pp.89-100.

Lagoke, S. T. O., Parkison, V. and Agunbiade, R. M. (1988). Parasitic Weeds and Control in Africa. In: Kim, S. K (Eds). *Combating Striga in Africa*. *Proceedings of International Workshop* organized by IITA, ICRISAT and IDRC, IITA, Ibadan, Nigeria, pp. 3 – 17.

Lagoke, S. T. O. and Isah, K. M. (2010). Reactions of Maize Varieties to *Striga hermonthica* as Influenced by Food Legume Intercrop, Spacing and Split Application of Compound Fertilizer. *Nigerian Journal of Weed Science*, 23:45-58.

Lagoke, S. T. O., Shebayan, J. Y, Magani, I. E., Olorunju, P., Olufajo, O. O., Elemo, K. A., Uvah, I., Adeoti, A. A., Chindo, P. S., Kureh, I., Emechebe, A. M., Ndahi, W. B., Kim, S. K., Webber, G., Singh, B. B., Salawu, A., Avav, T. and Sule, T. T. (1993). *Striga* Problem and Control in Nigeria. *A Report of Activities of Striga and Related Parasitic Weeds in Nigeria.* Presented at the Third General Workshop of PASCON at Harare, Zimbabwe, October 18-23, 1993. pp. 70-79.

Lagoke, S. T. O., Shebayan, J. Y., Weber, G., Olufajo, O., Elemo, K.., Adu, J. K.., Emechebe, A. M., Singh, B. B., Zaria, A., Awad, A., Ngawa, L., Olaniyan, G. O., Olafare, S. O., Adeoti, A. A. and Odion, C.(1994). Survey of *Striga* Problem and Evaluation of *Striga* Control Methods and Packages in Crops in the Nigerian Savannah. In: Lagoke, S. T. O., Hoevers, R., M'Boob, S. S. and Traboulsi, R. (Eds.), *Improving Striga Management in Africa. Proceedings, Second General Workshop of the Pan-African Striga Control Network* (PASCON), 23-29 June, 1991, Nairobi, Kenya, FAO, Accra, Ghana, pp. 91-120.

Lagoke, S. T. O. (1989). *Striga* in Nigeria. In: Robson, T. O, Broad H. R. (Eds.), *Striga Improved Management in Africa*. FAO. Plant Production and Protection Paper No. 96, FAO, Rome, Italy, pp.68–73.

Lambot, C. (2002) Industrial Potential of Cowpea. In: Fatokun, C. A., Tarawali, S. A., Singh, B. B., Kormawa, P. M. and Tamo, M. (Eds). *Challenges and Opportunities for Enhancing Sustainable Cowpea Production*. *Proceedings of the World Cowpea Conference III, International Institute of Tropical Agriculture* (IITA), Ibadan, Nigeria, pp. 4 - 8.

Last, F. T. (1961). Direct and Residual Effects of *Striga* Control Treatments on *Sorghum* Yields. *Tropical Agriculture* (Trinidad) 38:49-55.

Leigh, R. A. and Jones, R. G. N. (1984). A Hypothesis Relating Critical Potassium Concentration for Growth to the Distribution and Functions of this Ion in the Plant Cell. *New Phytologists*, 97(1): 1 - 13

Magani, E. I. (1994). Effects of fertilizers and herbicides on the reaction of cowpea varieties (*Vigna unguiculata* (L.) Walp) to *Alectra vogelii* (Benth).Ph.D. Thesis, Ahmadu Bello University, Zaria, Nigeria, 185pp.

Magani, I. E. and Lagoke, S. T. O. (2009). Mechanism of Reaction of Cowpea Varieties to *Alectra vogelii* (Benth) and its Control. *Journal of Applied Biosciences*. 14:775 - 781 :www.biosciences.elewa.org.

Magani, I. E., Lagoke S. T. O. and Emechebe, A. M. (2008). Developing an Appropriate Technique for Evaluating Cowpea Varieties' Reaction to Parasitic Plant *Alectra vogelii* (Benth.). *Journal of Applied Bioscience*. 10(2): 547-553.

Magani, I. E., Lagoke, S.T.O., Emechebe, A. M. (2009). Effect of Nitrogen and Phosphorus Application on The Reaction of Cowpea to the Parasitic Plant *Alectra vogelii*. *Journal of Applied Biosciences*. 10(2):500 – 506.

Magani, I. E. and Kuchinda, C. (2009). Effect of Phosphorus Fertilizer on Growth, Yield and Crude Protein Content of Cowpea (*Vigna unguiculata* [L.] Walp) in Nigeria. *Journal of Applied Bioscience* 23: 1387 - 1393.

Mainjeni, C. E. (1999). The Host Range of *Alectra vogelii* Benth.from Malawi and Resistance in Common Bean and Cowpea. M.Sc. Thesis, University of Bath, UK. 83pp.

Manitoba Soil Fertility Guide Lines (2004). Potassium (K). Manitoba Agricultural Food and Rural Initiatives

Mansfield, R. A. (1982). *Striga* Research at the Institute for Agricultural Research, Agronomy Department, 1979 – 1982. Mimeographed Publication, 38pp.

Marley, P. S., Shebayan, J. A. Y. and Idem, N. U. A. (2004). Possibilities for Control of *Striga hermonthica* in *Sorghum* (*Sorghum bicolor*) using Neem (*Azadirachta indica*) and Parkia (*Parkia biglobosa)* Based Products. *International Journal of Pest Management*. 50: 291-296.

Marschner, H. (1995). *Mineral Nutrition of Higher Plants.* Academic Press London. 889pp.

Mokoena, T. Z. (2013). The Effect of Direct Phosphorus and Potassium Fertilization on Soybean (*Glycine max* (L.) Yield and Quality. An M.Sc. Thesis Submitted to the Department of Agronomy, University of Pretoria. Pp 52 – 57.

Mathur, R. L. and Mathur, B. N. (1967). Effects of Fertilizers on the Incidence of *Striga lutea* and Yield of Bajra (*Pennisetum typhoides*). *Industrial Phytopathology* 20: 270 – 272.

Mbwaga, A. M., Kabambe, V., and Riches, C. (2007). Development and Promotion of *Alectra* Resistant Cowpea Cultivars for Smallholder Farmers in Malawi and Tanzania. *Annual Report. McKnight Foundation Collaborative Crops Research Project No: 06-741.* 2- 38.

Melchior, H. (1941). Die Gattung *Alectra* Thunb. Notizblatt der botanischen garten und museum Berlin-Dahlem, 15:423-447.

Musell, H. (1980). Tolerance to Disease. In: Horsfall, J. and Cowling, E. B. (Ed.). How Plant Defend themselves. *An Advanced Treatise Academic Press*, New York. 5:39-46.

Mwakabobo, A. S. and Zwanenburg, B. (2011). Strigolactone Analogs Derived from Ketones using a Working Model for Germination Stimulants as a Blueprint. *Plant Cell Physiology*. 52(4):699-715.

Ndor, E., Dauda, N. S., Abimuku, E. O., Azagaku, D. E. and Anzaku, H. (2012). Effect of Phosphorus Fertilizer and Spacing on Growth, Nodulation Count and Yield of Cowpea (*Vigna unguiculata* [L.] Walp) in Southern Guinea Savanna Agroecological Zone, Nigeria. *Asian Journal of Agricultural Sciences* 4(4): 254-257.

Ng, N. Q, and Marechal, R. (1985). Cowpea Taxonomy, Origin and Germplasm. In: Singh, S. R. and Rachie, K.O. (Eds.), *Cowpea Research, Production and Utilization*. John Wiley and Sons, Chichester, UK, pp.11-12.

Ngawa, L, (1992). Effects of Sowing Dates, Nitrogen Levels, and Herbicides on the Reaction of Varieties of *Sorghum* (*Sorghum bicolor* (L.)). An M.Sc. Thesis, Ahmadu Bello University, Zaria, Nigeria, 101pp.

NGICA, (2006). Network for the Genetic Improvement of Cowpea for Africa [Online]. Available on http://www.entm.purdue.edu/ngica/cowpea.html. Accessed on 20/7/2006.

Noubissie, T. J. B., Bell, J. M., Guissai, B. S., Gonne, S. and Youmbi, E. (2010). Varietal Response of Cowpea (*Vigna unguiculata* (L.) Walp.) to *Striga gesnerioides* (Wild.) Vatke Race SG5 Infestation. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*. 38 (2): 33-41.

Nyathi, P. and Campbell, B. M. (1995). The Effect of Tree Leaf Litter, Manure, Inorganic Fertilizer and their Combination on above Ground Production and Grain Yield of Maize. *African Journal of Crop Science*, 3: 451 – 456.

Okeleye, K. A. and Okelana M. A. O. (1997). Effect of Phosphorus Fertilizer on Nodulation, Growth and Yield of Cowpea (*Vigna unguicualata* (L.) Walp) Varieties. *Indian Journal of Agricultural Science*, 67: 56 – 58.

Olufajo, O. O. (1996). Effects of Some Cultural Practices on *Alectra vogelii* (Benth) Infestation and Yields of Cowpea in the Northern Guinea Savanna of Nigeria. *Striga* Newsletter of Pan-Africa *Striga* Control Network, 6: 18-19.

Olupot, J. R., Osiru, D. S. O., Oryokot, J. and Gebrekidan, B. (2003). The Effectiveness of *Celosia argentia* (*Striga* Chaser) to Control *Striga* in *Sorghum* in Uganda. *Crop Protection*, 22: 463-468

Omanya, G. O. (2001). Variation for Indirect and Direct Measures of Resistance to *Striga hermonthica (*Del.) Benth.) in Two Recombinant Inbred Populations of *Sorghum* (*Sorghum bicolor* (L.) Moench). Verlag Grauer, Beuren, Stuttgart, Germany. 141pp.

Omoigui, L. O., Yeye, M., Boukar, O., Bhavani, S. G. and Timko, M. P. (2012). Molecular Characterization of Cowpea Breeding Lines for *Striga* Resistance using SCAR Markers. *Journal of Agricultural Science and Technology* 2:362-367.

Omotoso, S. O. (2014). Influence of NPK 15-15-15 Fertilizer and Pig Manure on Nutrient Dynamics and Production of Cowpea (*Vigna unguiculata* L. Walp). *American Journal of Agriculture and Forestry* 2(6): 267-273.

Osunde, A. O., Bala, A. and Uzoma, A. (2007). Differential Response of Cowpea ((*Vigna unguiculata* (L.) Walp) Lines to Phosphorus Fertilizer in a Low Phosphorus Soil in the Southern Guinea Savanna of Nigeria. *Nigerian Journal of Soil Science* 17: 52-64.

Oswald, A., Ramsom, J. K., Kroschel, J. and Sauerborn J. (1999): Developing a Catch-Cropping Technique for Small-Scale Subsistence Farmers. In: Kroschell, J.

Mercer – Quarshe, H. and Sauerborn, J., (Eds.). *Advances in Parasitic Weed Control of On-Farm Level*. Joint Action to Control *Striga* in Africa. Margraf verlag, Weikersheim, Germany 1: 181 – 187.

Padulosi, S. and Ng, N. Q. (1997). Origin, Taxonomy, and Morphology of *Vigna unguiculata* (L.) Walp. In: Singh, B. B., Mohan Raj D. R., and Dashiell, K. E. and Jackai, L. E. N. (Eds.) *Advances in Cowpea Research.* Co-publication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). Sayce, Devon, UK, pp.1–11.

Parker, C, (1984). The Influence of *Striga* Species on *Sorghum* under Varying Nitrogen Fertilization. In: Parker, C.; Musselman, L. J., Polhill, R. M. and Wilson, A. K. (Eds.). *Proceeding, 3rd International Symposium of Parasitic Weeds.* Aleppo: ICARDA pp.90 – 98.

Parker, C. and Riches, C. R. (1993). *Striga* and *Alectra* on Cowpea and other Broad-leaved Crops. In: Parker, C. and Riches, C. R. (Eds.): *Parasitic Weeds of the World*. CAB International Wallingford, UK, pp.75-109.

Parr, J. F., Stewart, B. A., Homid, S. B. and Singh, R. P. (1990). Improving the Sustainability of Dry Land Farming System. A Global Perspective. In: Singh R. P., Parr, J. F. and Stewart, B. A. (Eds). *Advances in Soil Science*, New York, pp.1 -8.

Philcox, D. (1990). *Alectra* Thunb. In: Launert, E, (Ed.). *Flora Zambesiaca Scrophulariaceae.* London, UK: Flora Zambesiaca Managing Committee. (8)2:12-18.

Psech, C., Piererse A. H., and Stoop W. A. (1991). Inhibition of Germination in *Striga* by Means of Urea. In: *Proceedings of Second International Workshop. International Crops Research Institute For Semi-Arid and the Tropics*. Held at Ouagadougou, Burkina Faso.

Purseglove, J. W (1984) *Tropical crops: Dicotyledons* (volumes 1&2 combined), First Edition, Longman Group Limited, England, 719pp.

Quinn, J. (2014). *Cowpea. A Versatile Legume for Hot, Dry Conditions*. Jefferson Institute. Available at: http://www.hort.purdue.edu/newcrop/articles/ji-cowpea.html. [Accessed 14 November 2014]. Free to access.

Raju, P. S., Osman M. A., Soman P. and Peacock J. M. (1990). Effect of N.P.K. on *Striga asiatica* Seed Germination and Infestation of *Sorghum*. *Weed Research* 30: 139 – 144.

Ramaiah, K. V., Safa, S. B. and Musselman, L. J. (1988). *Alectra* and *Striga aspera* in Burkina Faso. *Haustorium*, 19pp.

Rambakudzibga, A. M. (2000). Aspects of the Host-Parasite Association between the Grain Legume *Vigna unguiculata* L. (Walp) and the Parasitic Angiosperm *Alectra vogelii* Benth. (Ph.D. Thesis). Der Justus-Liebig-Universitat Gieben, Gieben, Germany.

Reyhan, M. K. and Amiraslani, F. (2006). Study of the Relationship between Vegetation and Physicochemical Properties of Soil, Case Study: Taba Region, Iran. *Pakistani Journal of Nutrition*, 5:169 -171.

Rhodes, E. R. (1981). The Economic Importance of Fertilizing Cowpea (*Vigna unguiculata* (L.) Walp) with Basic Slag on an Oxisol in Njala and the Effect of the Fertilizer on Leaf Lamina N, P, Zn contents and Nodulation. *Tropical Grain Legume Bulletin*, 22: 6 – 10.

Riches, C. R. (1987). The Identification of Resistance of *Alectra vogelii* Benth. (Scrophulariaceae) in Cowpea. In: Weber H.C. and Forstreuter W. (Eds.). *Parasitic Flowering Plants. Proceedings of the Fourth International Symposium on Parasitic Seeds Plants*. Philips University of Marburg, Germany. pp.701-708.

Riches, C. R. (1989). The Biology and Control of *Alectra vogelii* Benth. (Scrophuliariacea) in Botswana. Ph.D Thesis, Reading, UK: University of Reading.

Riches, C. R., (1990). *The Biology and Control of Alectra vogelii Benth (Scrophulariaceae) in Botswana*. Ph.D Thesis, University of Reading, UK 208pp.

Riches, C. R. (2001). *Alectra vogelii* Benth. - A Constraint to Cowpea Production in Southern Africa. In: Mgonja, M. A., Chivinge, O. A., Monyo, E. S., (Eds.). *Striga* Research in Southern Africa and Strategies for Regionalized Control Options. Bulawayo, Zimbabwe: *International Crops Research Institute for the Semi-arid Tropics*. pp.87-91.

Riches, C. R., Hamilton, K. A. and Parker, C. (1992). Parasitism of Grain Legumes by *Alectra* Species (Scrophulariaceae). Natural Resources Institute, Chatham Maritime, Kent ME4 4TB, UK. *Annuals of Applied Biology*, 2:361-370.

Rugare, J. T., Mbwasa, S. and Tsekenedza, S. (2013) Response of Cowpea (*Vigna unguiculata* L.) Genotypes to Witch Weed (*Alectra vogelii* Benth) Infection. *Asian Journal of Agricultural and Rural Development*, 3(9):667-673.

Samb, P. I, and Chamel, A. (1992). Foliar Absorption and Translocation of 14C-Dicamba into Host (Pearl Millet and Cowpea) and Parasitic Plant of the Genus *Striga gesnerioides. Weed Research* 32:129-136.

Satish, K., Gutema, Z., Grenier, C., Rich, P. J. and Ejeta, G. (2012). Molecular Tagging and Validation of Microsatellite Markers Linked to the Low Germination Stimulant Gene (Igs) for *Striga* Resistance in *Sorghum* (*Sorghum bicolor* (L.) Moench). *Theoretical Applied Genetics*, 124:989-1003.

Sharif, A. M. and Parker, C. (1986). Effect of Nitrogen Sources and Organic Matter on *Sorghum bicolor* (L.) Moench and *Striga hermonthica* (Benth). *Ethiopian Journal of Agricultural Science*. 8(1): 19 – 35.

Singh, B. B. (2002)**.** Breeding Cowpea Varieties for Resistance to *Striga gesnerioides* and *Alectra vogelii*. In: Fatokun, C. A., Tarawali, S. A., Singh, B. B., Kormawa, P. M. and Tamo, M. (Eds.). *Challenges and Opportunities for Enhancing Sustainable Cowpea Production.* IITA, Ibadan, Nigeria. pp.154-166.

Singh, B. B., Chamblis, O. L. and Sharma, B. (1997). Recent Advances in Cowpea Breeding. In: Singh, B. B., Mohan Raj, D. R., Dashiell, K. E. and Jackai, L.E.N. (Eds.). *Advances in Cowpea Research*. Co-publication of International Institute of Tropical Agriculture (IITA) and Japan International Research Centre for Agricultural Sciences (JIRCAS), IITA, Ibadan, pp. 30–49.

Singh, B. B., Ehlers, J. D., Sharma, B, and Freire-Filho, F. R. (2002). Recent Progress in Cowpea Breeding. In: Fatokun, C. A., Tarawali, S. A., Singh, B. B., Kormawa, P. M. and Tamo, M. (Eds.). *Challenges and Opportunities for Enhancing Sustainable Cowpea. Production*, IITA, Ibadan, Nigeria. pp. 22-40.

Singh, B. B. and Emechebe, A. M (1997). Advances in Research on Cowpea, *Striga* and *Alectra*. In: Singh, B.B., Mohan, R., Dashiell, K.E and Jackai, L.E.N (Eds.). *Advances in Cowpea Research*. IITA, Ibadan, Nigeria. pp.215-224.

Singh, B. B., Emechebe, A. M, and Atopke, I. D. K. (1993). Inheritance of *Alectra* Resistance in Cowpea Genotype B301. *Crop Science* 33:70-72.

Singh, I., Badaga, S. N. and Tikka, S. B. S. (2006). Combining Ability for Yield over Environments in Cowpea (*Vigna unguiculata* L. Walp). *Indian Journal of Crop Science*. 88: 67- 77.

Stahley, K., Slakie, E., Derksen-Schrock, K., Gugerty, M. K. and Anderson, C. I. (2012). LSMS Integrated Surveys on Agriculture, United Republic of Tanzania: Legumes. EPAR Brief. Washington: *Evans School Policy Analysis and Research* – University of Washington.

Steele, W. M (1979) Cowpeas. In: N. W. Simmonds, (Ed.). *Evolution of Crop Plants.* Longman, London, UK.

Steele, W. M. (1972). Cowpeas in Nigeria, Ph.D. Thesis, University of Reading, UK.

Stroud, A. and Parker, C. (1989). *A Weed Identification Guide for Ethiopia*. Rome, Italy: Food and Agriculture Organization.

Takim, F. O, and Uddin, R. O. (2010). Effect of Weed Removal on Insect Populations and Yield of Cowpea [*Vigna unguiculata* (L.) Walp]. *Australia Journal of Agricultural Engineering*. 1:194-199.

Tarawali, S. A., Singh, B. B., Gupta, S. C., Tabo, R., Harris, F., Nokoe, S., Ferna´ndez-Rivera, S., Bationo, A., Manyong, V. M., Makinde, K. and Odion, E. C. (2002). Cowpea as a Key Factor for a New Approach to Integrated Crop–Livestock Systems Research in the Dry Savannas of West Africa. In: Fatokun, C. A., Tarawali S., Singh, B. B., Kormawa, P M. and Tamo, M. (Eds.). *Challenges and Opportunities for Enhancing Sustainable Cowpea Production.* International Institute of Tropical Agriculture, Ibadan, Nigeria, pp. 233–251.

Tarfa, B. D., Kureh, I. and Lagoke, S. T. O. (1996). Effects of Nitrogen and Phosphorus Levels on the Reaction of Soybean Cultivars to *Alectra vogelli* (Benth) *Striga* Newsletter of Pan-Africa *Striga* Control Network, September, (7): 16.

Timko, M. P, Singh, B. B. (2008). Cowpea, a Multifunctional Legume In: Moore, P. H, and Ming, R. (Eds), *Genomics of Tropical Crop Plants*, Springer Science + Business Media, LLC, New York, NY, pp. 227-258.

Tiwani, P. S., Joshi, O. P. and Billore, S. D. (2001). Reliable Yield Potential of Soybean Varieties at Farm Level in India. In: Sourvenir. Harnessing Soy Potential for Health and Wealth. *India Soy Forum*, Pp. 108-112

Tosti, N. and Negri, V. (2002). Efficiency of Three PCR-Based Markers in Assessing Genetic Variation among Cowpea (*Vigna unguiculata* subsp. *unguiculata*) Landraces. *Genome* 45: 268–275.

Van Ast, A., Bastiaans, L., Katile, S. (2005) Cultural Control Measures to Diminish *Sorghum* Yield Loss and Parasite Success under *Striga hermonthica* Infestation. *Crop Protection Journal*. 24:1023-1034.

Visser, J. H. (1978). The Biology of *Alectra vogelii* Benth., an Angiospermous Root Parasite. Beitrage zur Chemischen Kommunikation in Bio- und Okosystemen, pp. 279-294.

Westwood, J. H. A. and Fey C. L. (1999). Influence of Nitrogen and Early Development of Broomrape (*Orobanche* Spp.). *Weed*, 47:2-7.

Whitney, A. B. (1984). Contribution of Forage Legumes to the Nitrogen Economy of Mixed Swards. A Review of Relevant Hawaiian Research.. In: Ayanaba, A. and Dart, P. J. (Eds). *Biological Nitrogen Fixation in Farming Systems of the Tropics*. John Willey and Sons, New York. pp. 89 -96.

Xie, X. and Yoneyama, K. (2010). The Strigolactone Story. *Annual Review of Phytopathology*. 48:93-117.

Yakubu, H., Kwari, J. D. and Sandabe M .K. (2010)**.** Effect of Phosphorus Fertilizer on Nitrogen Fixation by Some Grain Legume Varieties in Sudano – Sahelian Zone of North Eastern Nigeria. *Nigerian Journal of Basic and Applied Science* 18(1): 19-26.

Yunusa, A. (2013). Use Of *Amaranthus* Lines as Trap Crop for the Control of *Alectra vogelii* (Benth) in Cowpea [*Vigna unguiculata* (L.) Walp]. Production. Unpublished M.Sc. Thesis submitted to the Department of Biological Sciences, A.B.U. Zaria, 134pp.

Zerihun, S. (2015). Effect of Nitrogen Fertilizer on *Striga* Infestation, Yield and Yield Related Traits in *Sorghum* (*Sorghum bicolor* (L.) Moench) Varieties at Kile, Eastern Ethiopia. M.Sc. Thesis Submitted to the Postgraduate Program Directorate (School of Plant Sciences), Haramaya University, pp. 65- 66.