STUDIES ON THE REACTION OF SOYBEAN CULTIVARS TO *Alectra vogelii* (Benth), MECHANISM OF RESISTANCE AND CONTROL USING ANTI-TRANSPIRANTS

BY

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DECLARATION

I hereby declare that this has been written by me and that it is a record of my own research work. It has not been precented in any previous publication for higher degree.

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CERTIFICATION

This dissertation entitled "STUDIES ON THE REACTION OF SOYBEAN CULTIVARS TO *Alectra vogelii* (Benth), MECHANISM OF RESISTANCE AND CONTROL USING ANTI-TRANPIRANTS" By Kureh, Ibrahim meets the regulations governing the degree of Doctor of Philosophy of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to my wife, Rakiya and daughter, Gberya for their love, patience and encouragement during the course of my study.

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ABSTRACT

Screen-house, field and laboratory trials were conducted between 1995 and 1998 at Samaru in the northern Guinea savanna ecological zone of Nigeria to study the reaction of soybean cultivars to *Alectra vogelii,* mechanism of resistance and control using anti-transpirants.

Results of the response of soybean cultivars to *Alectra vogelii* showed that TGX 1649-11F. TGX 1681-3F, TGX 1674-3F. TGX 1636-7F. TGX 1670-1F. TGX 1670-3F and TGX 1660-191- exhibited resistance to *Alectra* by support for low and delayed *Alectra* shoot emergence both in the screen-house and field trials. Also, exhibited low crop syndrome reaction score, reduction in nodulation, shoot dry matter production, plant height, and days to first crop flowering and produced high seed yield. TGX 1740-7F and TGX 1740-2F exhibited low to moderate resistance by support for low to moderate and delayed *Alectra* shoot emergence. These cultivars exhibited low crop reaction score, low reduction in crop parameters and produced seed yield comparable to the highest and significantly higher than the least in all the field trials. Inspite of support for high *Alectra* shoot emergence, exhibition of moderate to high crop syndrome reaction score and high reduction in crop parameters. TGX 1660-15F. TGX 1485-1D. SAMSOY 2. TGX 1440-IE and TGX 536-02D produced high seed yield, thus exhibiting obvious tolerance. However, soybean cultivars. TGX 1019-2EB. M-351, TGX 87D-516. TGX 849-313D and TGM 344 exhibited susceptibility to *Alectra* parasitism through support for high *Alectra* shoots in all the trials. Also, these cultivars exhbited high crop syndrome reaction score, high reduction in crop parameters and produced low seed yields

in all the field trials

Alecrra shoot emergence was negatively correlated with the number of branches. 100-seed weight, seed yield and percentage reduction in crop parameters. Seed yield was positively correlated with the number of pods and branches and 100-seed weight. 100-seed weight and number of pods per plant and their combined contributions were the major yield determinants in soybean.

In the mechanism of resistance study. TGX 1649-1 IF, TGX 1681-3F. TGX 1740-7F, TGX 1660-IF. TGX 1740-2F. TGX 1670-3F and TGX 1660-19F exhibited multiple mechanism of resistance through the stimulation of low *Alecrra* seed germination and were insensitive to *Alectra* produced 'toxins'. SAMSOY 2 stimulated high *Alecrra* seed germination but was insensitive to *Alecrra* produced 'toxins'.

Results of the control of *Alecrra* using anti-transpirants in the screen-house trial showed that abscisic acid at all concentration did not affect *Alecrra* plants. However. shea butter and paraffin oils resulted to over 90 and 100% death *of Alecrra* shoots at 5 and 10 days after application, respectively. Gum arabic, vaseline, kaoline and talc-magnesite also caused between 68 and 90% control of *Alecrra* within 10 days after-application. The loeal anti-transpirants used in this investigation are promising and cheap but require further work under field condition for confirmation.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Soybean Production and Utilization.

Soybean (*Glycine max (L.) Merrill*) is an important leguminous crop of the Family Fabaceae. Total world production of the crop in 1995 was estimated at 127.0 million metric tons from 62.5 million hectares (FAO, 1995). In Africa, estimated production was 554,000 metric tons from 489 hectares in 1995 (FAO, 1995). Soybean cultivation in Africa is mainly centred around Nigeria, South Africa, Cote Divoire and Zimbabwe. Available information on soybean production indicates that there is excellent potential for the crop in Nigeria (Joke, 1986; Olufajo, 1994). The domestic and commercial production have not been fully exploited since the crop is produced only in Benue, Kaduna, Niger, Plateau, Nassarawa and Taraba states by peasant farmers. Olufajo (1994) reported that eighteen states of the federation of Nigeria including the federal capital territory have the potential for soybean production. The highest tonnage production of the crop since introduction into the country was 196, 000 metric tons in 1995. (FAO, 1995).

Much emphasis have been accorded to soybean both as cash and food crop (Olufajo, 1994, Olowoniyan, 1994). It is currently recognised as an important source of protein and energy. Approximately 3O to 50% of the total dry matter of whole soybean is protein with a high digestive nutrient percentage (91.9%). It contains more lycine than all other sources of plant protein (Faryna, 1985). It is therefore of value both

for meeting human dietry needs and for compounding livestock feed. Because of the high protein content, soybean is used to fortify traditional foods (which are mostly cereals and tubers), such as cereal, pounded yam, spaghetti, patties, 'moimoi', 'tuwo','pate' and 'danwake' (Olowoniyan *et. al.*, 1993). Local snacks like biscuits, 'puff-puff' and 'chin-chin', are common (NAERLS, 1989). Soybean is used in baking because of its moisture retaining property and enhancement of taste through improved tenderness. Immature soybean can be cooked green and made into patties to give acceptable flavour.

Soybean flour is used to replace melon in vegetable soup without any loss in flavour inspite of high protein content. Fermented soybean can be made into 'dadawa' which is a traditional flavouring material in various dishes including soups and stew (NAERLS,1989).

Soybean unlike other legumes can be processed into many food products such as milk and cheese. The milk is refreshing and nutritious (Olowoniyan, 1994). Apart from its high protein content the seed is also rich in oil which forms 14 to 20% of the dry weight. The oil contains, short-chain fatty acid and is used in cooking and salad making. Some of the oil can be used for making paints, vanishes, adhesives, insecticides and soap (NAERLS, 1987).

The crop is also used as forage either alone or mixed with grasses to make excellent feed for livestock. The meal (residue after oil extraction) has become the leading protein supplement in recent years for all kinds of livestock feed (NAERLS,1989). The ability of soybean to fix atmospheric nitrogen via rhizobia of the root nodules has made it an important crop as replenisher of soil nitrogen especially in

the traditional farming systems. Nitrogen derived from fixation by soybean at flowering was up to 55% (Carsky *et al.*, 1995). This reduces total dependance on inorganic fertilizer, thus reducing crop production cost.

The recent discovery of *striga* suppression by soybean suggests its potential for used as trap-crop for *striga* management in traditional farming systems (Ariga and Berner,1995; Lagoke *et al.*, 1997).

1.2. Parasitic Weed Problem.

In addition to erratic rainfall, drought, diseases and pests; root parasitic flowering plants of the family Scrophulariaceace have devastating effects on crops in sub-saharan Africa. More than half of the total efforts of farming, especially in the tropical region are being devoted to the battle against weeds especially parasitic weeds (Singh and Emechebe, *et al.*, 1991; Kim, 1991). The problem of parasitism of *Striga* and related species like *Alectra* differ from that caused by other weed species because of the close biological association with their hosts (Lagoke *et al.*, 1991). Yield losses caused by parasitic weeds exceed the losses from any category of agricultural pest (Lagoke *et al.*, 1991).

Striga and related parasitic weeds including *Alectra* are presently the most important biological constraints to food production in Africa (Emechebe *et al.*, 1983). Although *Alectra* is not widely distributed as *Striga*, it is a potential danger in all areas where leguminous crops are cultivated through out the African continent south of the sahara (Emechebe *et al.*, 1991). BARO (1991) and Bagnall-Oakeley *et al.* (1991) reported that *Alectra* parasitism caused serious crop yield losses in legumes like dolichos,

broad and velvet beans, groundnut, bambara groundnut and grams. Parasitic weeds infest about 40% of the arable land in the savanna region and another 40% arable land may become infested in the next years (Lagoke *et al.*, 1991). Fields once infested with parasitic weeds are difficult to disinfect due to the considerable amount of seeds produced by the parasites and adaptation/dormancy mechanism of the seeds which remain viable in the soil for several years (Khadir, 1983; Emechebe *et al.*, 1983). Several cultivated lands have been abandoned consequent to the high soil infestation of these parasites (Emechebe *et al.* 1983; Lagoke *et al.* 1988). Further more, Emechebe *et al.* (1991) and Emechebe (1994) reported that many farmers' fields in the sudan and sahel ecologies in Nigeria, have been plighted by *Striga* and *Alectra* and that damage is aggravated by the marginal nutrient status of the soil and unreliable rainfall.

The growth of infested host is retarded and crop yields are lowered or reduced to zero under condition of severe infestation (Kroschel *et al.*, 1996). A conservative estimate of crop losses due to *Striga* infestation in Africa is 40%, representing an annual loss of cereals worth US $7 billion (Mboob, 1986). The losses, however, vary with countries, depending on the ecological zones which they contain. Higher losses occur in countries situated entirely in the savanna and/or sahel zones. With erratic rainfall, less animal waste, encroaching desert, intensive land use and the introduction of machinery and irrigation, the spread of parasitic weeds has increased with a consequent decrease in food production in many countries. In Nigeria, losses of 10 to 90 percent with an average of 35 percent in sorghum and maize yields have been attributed to *Striga hermonthica* (Parkinson, 1985). This was estimated to be worth US $250 million

annually (Lagoke, 1989). Although, attack by *Alectra* is less dramatic than that of *Striga*, total yield loss is not uncommon in fields heavily infested by one of these parasites when susceptible crop varieties are planted.

1.3. Objectives of the Study.

Root parasitic flowering plants depends on the host for water, nutrients and metabolites (Okonkwo, 1987; Chidley and Drennan, 1987, Obilana and Ramiah, 1992). The production of large number of seeds and the existence of physiological strains, sub-species ecotypes and morphotypes of the parasitic weeds with a wide range of adaptation to environment and host have made their control very difficult (Khadir,1983). Considerable work has been done on various control methods for parasitic weed species although *Alectra* has recieved little attention. However, differential response of soybean varieties to *Alectra* seed inoculum and preconditioning have been reported (Kureh *et al.*, 1994). In recent times, soybean production in Nigeria is gaining increasing popularity due to its high nutritive value and economic importance (Olufajo, 1994). *Alectra* was previously not a problem of groundnut and cowpea, but currently devastates the two crops as the production of these crops were intensified. Similar situation may also be experienced with soybean if an appropriate intervention is not developed. *Alectra* is largely a problem of subsistence farmer in Africa and has been neglected. The local names of *Striga* and related parasitic weed *Alectra* in Nigeria are 'Wuta-wuta' (Fire-fire), 'Makasa' (Killer) and 'Amu' (Burning) in Kano, Zaria, and Jaba-Dhuyah localities, respectively. It will therefore, be partinent to study the mechanism and reaction of

soybean cultivars to *Alectra* and develop a control approach based on the stomata behaviour. The objective of this study are:-

1. To evaluate soybean cultivars for their reaction to *Alectra vogelii*
2. To study the mechanism of resistance of soybean cultivars to *Alectra vogelii*
3. To study the efficacy of selected anti-transpirants for the control of *Alectra vogelii*

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Biology of *Alectra vogelii* Benth.

The genus *Alectra* belongs to the family Scrophulariaceae. Botanically, the genus is characterized by opposite leaves, irregular large yellow flowers, dust-like seeds and parasitic habit (Riches *et al.*, 1992). *Alectra* has herbaceous shoot and seeds are produced in capsules. Each capsule may have 400 to 500 seeds; over 90,000 seeds may be produced by a single plant depending on branching and growth (Parker, 1991; Singh and Emechebe, 1997). The miniscule seeds measure 0.15 to 0.25mm in length and 0.12 to 0.20mm in width (Visser, 1978). *Alectra* seeds which are well protected by thick seed coat may remain viable in the soil for 15 to 20 years depending on climatic conditions (Parker, 1991). *Alectra* seeds cannot germinate at the end of the crop season in which they are produced, but require a period of after-ripening of seed and germination improves with long term dry storage (Visser, 1978; Logan and Stewart, 1992). Germination only occurs after pre-conditioning in moist conditions for one to five weeks and in response to a chemical stimulus from a host root (Kust, 1963; Kuijt, 1969; Musselman, 1980).

After germination the radicles elongate, showing a chemotropic response to a concentration gradient of root exudates. Once in contact with the host roots, the redicular apex develop numerous hairs which are attached to host root. The *Alectra*

radicle penetrates and stimulates cell division in the host root. The new host cells, together with growing parasite tissue, form a large haustorium, uniting the parasite tissue in the host stele which permits transfer of water and nutrients from host to parasite. Both *Striga* and *Alectra* shoots emerge from the ground about six weeks after infection and grow into plants which may be 15 to 25cm tall. The plants of both parasites usually branch below the ground and emerge as a bunch above the ground (Lane *et al.* 1991: Singh and Emechebe, 1997). Hemi-parasite phase after emergence follows the halo-parasitic development of the parasite (Botha, 1948; Kuijt, 1969). Majority of the parasitc weed seeds within 2mm of the host root receive sufficient stimulant to germinate, thus some seedlings are wasted by being to far away from host root. Most of the parasitic weed seeds which imbibe water enter a period of wet dormancy if they are not stimulated to germinate (Reid and Parker, 1979).

Biological factors which contribute to the dispersal of parasitic weeds include very high seed productivity, the minute size of the seed and an electrostatic charge that causes them to adhere to other seeds, clothes, soils and equipment. In addition, parasitic weed seeds survive for a long time (Bebawi *et al.*, 1984).

2.2. Ecology and Distribution of Root Parasitic Flowering Plants.

The main regions of distribution of root parasitic flowering plants are located in the arid and semi arid tropics, which receive 500 to 1000mm rainfall per annum. These regions have a predominant vegetation of natural savanna, semi-evergreen and deciduous rain forest (Sauerborn, 1992).

Alectra exhibits great phenotypic plasticity and wide environmental tolerance.

preferring permanently disturbed habitat. *Alectra* is a native to grasslands of the old world tropics, reaching great diversity in sub-saharan Africa (Musselman, 1987). *Alectra* spp. are widely distributed in Africa with the main species *Alectra vogelii*. However, other species viz, *A. picta, A. sessiliflora and A. orobanchoides* are reported in Latin America and Asia (Anon., 1996). *Alectra* is known to parasitize cultivated legumes from Swaziland to the transvaal in South Africa, the range of this purely African vegetation, extends through Central Africa to Burkina Faso and Mali in the West and Kenya and Ethiopia in the East of the continent (Riches, 1987). In Nigeria, Emechebe *et al* (1991) reported that *Alectra* appears to be very destructive in the northern Guinea and Sudan savanna agro-ecologies. Singh and Emechebe (1997) reported that presently *Alectra* is fast spreading beyond the Guinea - Sudan belt.

It has been shown that the primary agents of *Striga* dispersal are human beings and that this dispersal frequently occurs as a result of contamination of planting materials with *Striga* seeds. Berner *et al* (1993) reported that *Striga* and related parasitic weed *Alectra* can be disseminated through the seeds of host crops that are contaminated by the parasites on fields that are hitherto not infested. *Alectra* seeds are soil borne.

Emechebe *et al* (1983) and Lagoke (1989) reported that *Alectra* seeds are spread by contaminated agricultural equipment and machinery. The seeds of parasitic weeds could also be spread when the plant is fed to animals by farmers for food or as medicine in mixture with other pasture or through grazing with other herbs. Undigested in their alimentary canals, spread them through their feaces during the nomadic or seasonal movement across the savanna zones. *Alectra* seeds are also dispersed by hooves of

animals, clothes and shoes of farm workers, tyres of vehicles and tractors, run-off, irrigation water and wind (Lagoke, 1989; Barner *et al*, 1993; Anon. 1996).

2.3 Symptoms of Root Parasitc Flowering Plants Infection on Hosts.

The physiological disorder caused by parasitic weeds on their host is a drastic and extensive loss of carbohydrate, mainly sucrose with mannitol as the end product (Ba, 1983; Fer *et al*, 1993). Bulk losses of water and nutrients from host-plants have also been reported (Okonkwo, 1987; Chidley and Drennan, 1987). Such bulk losses correlate with the robust haustoria of the parasite (Ba, 1983). In addition to *Striga* produced 'toxins' the removal of these compounds, in large quantities, results in extensive damage which include wilting, reduction in plant size, less yield and lower quality of the host plants produce despite the relative small size of the parasite (Butler and Ejeta, 1997).

Symptoms of infection by *Striga* and *Alectra* can be noticed on cowpea plants much before emergence of the parasitic plants above ground, because parasitism begins about 2 to 3 weeks before emergence (Singh and Emechebe, 1997). The common symptoms of *Striga gesnerioides* infection of cowpea are interveinal chlorosis, general stunting and smaller leaves. On a heavily infested plant an important symptom is foliar desication which may be proceeded by interveinal, rusty brown to purplish spots; a few days later the areas around the spots suddently dessicate to produce straw -coloured necrotic spots with water soaked margins. A leaflet may be completely dessicated before

blight spreads to rachis, necrosis of which results in the dessication of other leaflets. Dissication later spreads from the petioles to other points of attachment to the stem which then dries up downward and rarely upward. However, pre-mature abscission of the leaf or leaflets prevent internode dessication. In addition, a less severely infected plant may be stunted while mild chlorosis is symptomic of even lighter infection (Emechebe *et al.*, 1991). Plants infected by *Alectra* have symptoms similar to,but less dramatic than plants infected by *Striga*. Infected plants usually show stunting and wilting with reduced number of flowers and pods, but plants may be completely wilted if there is acute moisture deficit (Mugabe,1983). Total destruction of cowpea has been reported in Sokoto, Kano, Borno, and Bauchi states due to the *Striga/Alectra* complex (Emechebe *et al.*, 1991). In fields that are heavily infested with both *Striga gesnerioides* and *Alectra*, the host crop is mostly damaged by *Striga* if the host cultivar is equally susceptible to both parasites. However, if the host cultivar is resistant or moderately resistant to *Striga* and susceptible to *Alectra*, *Alectra* infection is very severe (Singh and Emechebe, 1991; 1997).

2.4. Mechanisms of Resistance of Host Crops to Root Parasitic Flowering Plant.

The defence of the host plant against their potential parasites may be through avoidance or resistance.

Avoidance reduces the chance of contact between the prospective host tissue and the parasite (Parlveliet, 1977). Early planting or tolerance to conditions which advertly affect parasite development, such as extremes of temperature or humidity, are examples of avoidance mechanisms. Early studies indicated that if susceptible photosensitive cowpea lines are planted at a date that will enable flowering to occur before the period

of *Striga* emergence, they may escape damage (IITA/SAFGRAD, 1982). Ramiah and Parker (1982) similarly suggested that early planting of sorghum in South Africa may reduce *Striga* shoot emergence. Root growth habit of host plants has also been implicated as an avoidance mechanism. Tolerant host cultivars have little branching of roots in the top soil (Dixon and Parker, 1984; Cherif-Ari *et al.*, 1990).

Resistant host cultivars, do not stimulate parasite seed germination, they are not parasitized, they do not support the parasite's development to maturity, or they support significantly fewer parasitic plants than susceptible cultivars (Wegmann, 1996; Hess and Haussman, 1997). Thus, resistance levels may vary from low to total immunity (Robinson, 1969). Several authors have reported that resistance to parasitic weeds may occur at pre-and/or post attachment stage and is as a result of one or more of the following mechanisms:

Pre-attachment mechanisms.

a. Low or no germination stimulant production (Parker, *et al.*, 1977; Ramiah and Parker, 1982; Hess *et al.*, 1992). *Striga* and *Alectra* seeds need some chemical stimulants produced by susceptible host crops to induce germination. Absence of such compounds in the host root exudates confers resistance to the host by not stimulating germination of the parasitic weed seeds (Parker *et al.*, 1977). The recognition of parasitic weed seeds' requirement for host-derived germination signal suggests low stimulant production as a possible mechanism of resistance (Ramiah and Parker, 1982; Hess *et al.*, 1992).

b. Low haustoria inducing factors (Reda *et al.*, 1993, Wegmann, 1996; Hess and Haussman, 1997). Crop genotypes which produce normal levels of germination stimulant but produce low haustoria initiator factor, -the second host-derived signal required for *striga* development, would not only be resistant to *striga* but also facilitate depletion of *striga* seed population in the soil by promoting sucidal germination (Cai, *et al.*, 1993; Reda *et al.*, 1993). Anti-haustoria factors as the name implies, operate after the *Striga/Alectra* seeds have successfully germinated and before they are established on the host root (Ramiah, 1987; Lane *et al.*, 1991).

c. Inhibition of germ tube exoenzymes by host root exudates (Wegmann, 1996; Hess and Haussman, 1997). The inhibition of action of germ tube exoenzymes by host root exudates have been reported as a mechanism of resistance of host plants to parasitc weeds (Wegmann, 1996; Hess and Haussman, 1997).

Post-attachment mechanisms.

a. Mechanical barriers like lignification and inability to penetrate cortex by enzymatic action (Saunder, 1933; Maiti *et al.*, 1984; Wegmann, 1996.; Hess and Haussman, 1997). Saunders (1933) described host-plant resistance based on mechanical barriers, which impede invasion of cortical cells by haustoria, thickened inner walls of the endodermal cells, and

hardened vascular cylinders of host root. Lignified pericycle cells and endodermal cells thickened with silica deposits physically obstruct attachement of haustoria to roots of sorghum genotypes known to have good field resistance (Maiti *et al.*, 1984; Wegmann, 1996). The inability of haustoria to penetrate the cortex of host root due to enzymatic action from the host root is another mechanism of host-plant resistance based on mechanical barrier (Emechebe, 1994; Hess and Haussman, 1997).

b. Antibiosis through phytoalexin formation and hypersensitivity (Ramiah, 1987; Doggett, 1988; Wegmann, 1996; Hess and Haussman, 1997). Antibiosis (Doggett, 1988) in which germination and attachment is normal, but subsequent development of the parasite is discouraged through the production of compounds that are toxic to the parasite and/or hypersensitivity (Aggarwal *et al.*, 1984; Singh and Emechebe, 1990; Lane *et al.*, 1991). In Burkina Faso, field reports of the death of small *Striga* shoots on resistant cowpea variety SUVITA-2 within 3-4 days after emergence could be attributed to antibiosis (Aggarwal *et al.*, 1984). Lane and Bailey (1991) observed that on cowpea variety B301, radicles of *Striga gesnerioides* penetrated the host roots and form small tubercles, which failed to develop beyond 1-2mm in diameter subsequently with severe restriction in stem development. The mechanism of resistance exhibited by cowpea varieties 58-57 and B359 to *Alectra* was also based

on limited development of parasite tubercle, similar to antibiosis expressed by B301 (Lane *et al.*, 1991). Antibiotic responses to *Striga* and *Alectra* infections are also exhibited by the cowpea varieties, IT82D-849 and IT81D-994, respectively (Singh and Emechebe, 1990; Emechebe *et al.*, 1991) which restricted the growth and development of the attached parasites.

c. Another suggested mechanism of resistance is the maintenance of high photosynthetic efficiency as a result of host insensitivity to *Striga* derived 'toxins' (Efron *et al.*, 1988; Butler and Ejeta, 1997; Hess and Haussman, 1997).

2.5 Control of Root Parasitic Flowering Plants.

It is now well recognised that no single method of control can effectively solve the parasitic weed problem. However, the three major principles of parasitic weed control include reduction of seed number in the soil, prevention of new seed production and prevention of movement of seeds from infested to non infested areas (Obilana and Ramiah, 1992).

Cultural practices recommended to limit the number of parasitic weed seeds in the soil include catch and trap cropping (Lagoke *et al.*, 1991), crop rotation and deep ploughing (Konate, 1986; Carson, 1986), soil solarization (Obilana and Ramiah, 1992; Sauerborn, 1992) and the use of chemicals such as germination stimulants; ethylene gas,

strigol and strigol analogs (Hauck *et al.*, 1992; Muller *et al.*, 1992) and methyl bromide fumigation (Sauerborn, 1992). With the prevailing erratic rainfall, it is very unlikely that farmers would be prepared to sacrifice part of the season to grow catch crops without any return. The limited resources available to the small-scale farmer make the preposition unacceptable since it involves labour and other inputs without an immediate benefit. Deep cultivation, a tedious and expensive operation, may not be very practicable, considering the problems faced by most farmers in acquiring land preparation equipment. The efficacy of the use of germination stimulants and fumigants to control *Alectra* and certain species of *Striga* have received little attention and some of these chemicals have some major drawbacks. They are expensive and some times need to be applied with special equipments that put them out of the reach of the small scale farmer. The timing of application to ensure adequate pre-conditioning of parasitic weed seeds is another limitation (Lagoke *et al.*, 1991).

Prevention of production of new seeds by parasitic weeds can be achieved through hand pulling, uprooting and constant hoe weeding (Olunuga and Akobundu, 1980; Ramiah, 1985; Babawi, 1987; Lagoke, *et al.*, 1991), sowing of early maturing crop varieties, high density sowing, irrigation and floading (Obilana and Ramiah, 1992; Sauerborn, 1992), the use of fertilizers and manures (Adu *et al.*, 1989, Emechebe *et al.*, 1991, Magani,1994), the use of herbicides (Eplee and Norris, 1987; Lagoke *et al.*, 1990; 1991; 1993; Sauerborn, 1992; Magani, 1994) and the use of resistant varieties (Emechebe, 1989; Atokpe, 1989; Lagoke *et al.*, 1990; 1991; 1993; Kureh and Katung, 1993; Kureh *et al.*, 1994; Magani,1994). Cultural practices like hand pulling, uprooting

and hoe weeding are tedious, expensive and only feasible in situation of light infection. The use of nitrogen fertilizer, density planting and manures prevent complete crop failure, however, the results have been inconsistent and inconclusive (Adu *et al.*, 1989; Emechebe *et al.*, 1991). The use of herbicides and anti-transpirants proved useful in the control of certain species of Striga but literature on their efficacy against Alectra is scanty. Post emergence herbicide application does not prevent the damage caused by the parasite prior to emergence. The use of early maturing varieties with respect to sowing date have threefold advantage - escape damage, prevent parasitic weeds seed build up and acts as a catch crop. Host-plant resistance involving the development and use of resistant crop is apparently the most desirable, feasible and easily acceptable method of control of parasitic weeds. Unless the use of resistant crop variety is combined with other weed control practices that pre-clude the presence of flowering parasitic weed plants, re-infestation of the fields is likely to occur (Aggarwal, 1986).

Prevention of spread of parasitic weed seeds from infested to non infested fields is the key to protection. Some of the mechanisms of the spread of root parasitic flowering plants are natural seed dispersal, relocation by people, animals and equipment through tillage operation and the use of contaminted crop seeds (Emechebe *et al.*, 1983; Lagoke, 1989; Berner *et al.*, 1993). Some procedures and precautions that can be used to prevent the spread of parasitic weed seeds from infested to non infested sites include the prevention of plants from producing viable seeds (Eplee, 1996), planting uncontaminated crop seeds (Berner *et al.*, 1993), phytosanitary practices such as feeding only parasitic weeds free fodder to livestock or grazing in fields free of parasitic weeds

and practices such as anti-soil erosion (Lagoke, 1989; Obilana and Ramih, 1992). It is apparent that despite the seriousness of the problem of parasitic weeds, no single method can adequately control them. A number of methods in an integrated approach (package) will be required for their effective control.

2.6 Effect of Anti-transpirants on Root Parasitic Flowering Plants.

Striga and related parasitic weed *Alectra* were reported to have remarkably high rates of transpiration which exceed those of other annuals of similar environments (Smith, 1978; Shah *et al.*, 1987; Press *et al.*, 1987; Riches, 1990). The stomata remain open when plants are placed in darkness (Shah *et al.*, 1987) and at night (Riches. 1990) and are relatively insensitive to water stress (Press *et al.*, 1987). The high rates of transpiration and the unusual feature of stomata behaviour exhibited by parasitic weeds can best be interpreted as means of maximising the flux of resources from the host to the parasite, thus ensuring supplies of water and inorganic and organic solutes (Shah *et al.*, 1987). The nutritional dependence of parasitic weeds on high transpiration rates suggests the possibility that anti-transpirants might be used to limit the growth of the parasites and thus provide a novel control method. Obilana and Ramiah (1992) observed that any action that interfers with parasitic weeds transpiration functions restricts cooling, raises internal temperature and ultimately causes death of the plants.

Shah *et al.* (1987) reported that *Striga* stomata are insensitive to abscisic acid, an antitranspirant. However, the application of commercially available anti-transpirant, 'wilt pruff', S600^{R} which contains a biodegradable coating material, di-1-menthene, that

impede water vapour loss from the leaf surface produced dramatic and unexpected results both in the laboratory and the field (Press *et al.*, 1989). Within only 4 to 5 hours of its application the leaves of *Striga* began to blacken and shrivel (Nour *et al.*, 1988). This rapid and dramatic response suggested an effect over and above that of simply reducing the flux of solute to the parasite, thus it was established that the anti-transpirant induces heat stress in *Striga* (Press *et al.*, 1989). Leaf temperature of *Striga* are substantially below those of the surrounding air and at an air temperature of 40°C, leaf temperature is 33°C (Stewart *et al.*, 1991). The differential between leaf and air temperature is as a result of the high rates of transpiration which cause evaporative cooling of the leaf, thus application of an anti-transpirant reduces stomata conductance and transpiration, with a resulting rise in leaf temperature (Stewart *et al.*, 1991). Physiological studies have established that *Striga* is sensitive to heat stress, the optimum temperature for photosynthesis is 37°C and the upper limit is 42°C (Nour *et al.*, 1988; Press *et al.*, 1989). Riches (1990) obtained encouraging results when guar gum solution was applied to *Striga* as an anti-transpirant. Furthermore, he reported that application of guar gum may provide a cheap *Striga* control strategy.

CHAPTER THREE

3.0. MATERIALS AND METHODS.

3.1 Experimental Site.

The investigations were carried out between 1995 and 1998 at Samaru (11°11', 7°38'E.,686m above seas level) in the northern Guinea savanna zone of Nigeria, with an annual mean rainfall of 1050mm distributed within 5 months and good sunshine during growth and drying periods. The soil of the experimental sites was loam.

3.2 Origin and Description of Materials.

The characteristics of the 24 soybean cultivars used in all the trials were as follows (IAR. 1989; Olufajo, 1992; 1994; 1996; Chiezey, 1997; Lagoke *et al.*, 1997):

TGX 1660-15F: Developed at IITA, Ibadan, Nigeria, early maturing, resistant to cercospora leaf spot and bacterial pustule moderate in height, stimulate low *Striga* seed germination, resistant to shattering and high yielding.

TGX 1485-ID: Developed at IITA, Ibadan, Nigeria, early maturing, moderately resistant to cercospora leaf spot and bacterial pustule, short in height moderate in stimulating *Striga* seed germination, susceptible to shattering and high yielding.

TGX 1649-11F: Developed at IITA, Ibadan, Nigeria, early maturing, resistant to

cercospora leaf spot and bacterial pustule, short, stout plant, low in stimulating *Striga* seed germination, moderately resistant to shattering and moderate yielding.

TGX 1681-3F: Developed at IITA, Ibadan, Nigeria, early maturing, moderately resistant to cercospora leaf spot and bacterial pustule, tall plant, stimulate high *Striga* seed germination, resistant to shattering and high yielding.

TGX 1019-2EB: Developed at IITA, Ibadan, Nigeria, early maturing, resistant to cercospora leaf spot but moderately resistant to bacterial pustule moderate in height, stimulate high *Striga* seed germination, resistant to shattering and moderate yielding.

TGX 1519-ID: Developed at IITA, Ibadan, Nigeria, early maturing, moderately resistant to cercospora leaf spot and bacterial pustule, tall in height, stimulate low *Striga* seed germination, moderately resistant to shattering and high yielding.

TGX 1740-7F: Developed at IITA, Ibadan, Nigeria, early maturing, resistant to cercospora leaf spot and bacterial pustule, moderate in height, moderate in stimulating *Striga* seed germination, resistant to shattering and high yielding.

TGX 923-2E: Developed at IITA, Ibadan, Nigeria, medium maturing, resistant to cercospora leaf spot and bacterial pustule, moderate in height, moderate in stimulating *Striga* seed germination susceptible to

shattering and moderate yielding.

SAMSOY 2: Developed at IAR, Samaru, Nigeria, a cross between Malayan and CNS, adapted to SGS, short, stout plant; determinate growth habit, large yellow seed; bears pods in cluster well above ground; moderately susceptible to cercospora leaf spot and bacterial pustule diseases, resistant to shattering, high yielding and stimulate high *Striga* seed germination.

M-351: Introduced from Malaysia, medium maturing, moderately resistant to cercospora leaf spot and bacterial pustule, tall prostrate plants, stimulate low *Striga* seed germination, susceptible to shattering and moderate yielding.

TGX 1448-2E: Developed at IITA, Ibadan, Nigeria, medium maturing, moderately resistant to cercospora leaf spot and bacterial pustule, moderate in height, low in stimulating *Striga* seed germination, resistant to shattering and high yielding.

TGX 1440-IE: Developed at IITA,Ibadan, Nigeria, medium maturing, moderately susceptible to cercospora leaf spot and bacterial pustule, moderate in height, stimulate moderate *Striga* seed germination, resistant to shattering and high yielding.

TGX 1479-IE: Developed at IITA, Ibadan, Nigeria, medium maturing, resistant to cercospora leaf spot and bacterial pustule disease, moderate in height, stimulate high *Striga* seed germination, resistant to

shattering and high yielding.

TGX 1670-IF: Developed at IITA, Ibadan, Nigeria, medium maturing, resistant to cercospora leaf spot and bacterial pustule, short in height, stimulate low *Striga* seed germination, resistant to shattering and high yielding.

TGX 1740-2F: Developed at IITA, Ibadan, Nigeria, early maturing, resistant to cercospora leaf spot and bacterial pustule, moderate in height moderate in stimulating *Striga* seed germination, resistant to shattering and high yielding.

TGX 87D-516: Developed at IITA, Ibadan, Nigeria medium maturing, moderately resistant to cercospora leaf spot and bacterial pustule, tall in height, stimulate high *Striga* seed germination resistant to shattering and moderate yielding.

TGX 1670-3F: Developed at IITA, Ibadan, Nigeria, medium maturing, resistant to cercospora leaf spot and bacterial pustule, tall in height, stimulate low *Striga* seed germination, resistant to shattering and high yielding.

TGX 1660-19F: Developed IITA, Ibadan, Nigeria, medium maturing, resistant to cercospora leaf spot and bacterial pustule, tall in height, stimulate low *Striga* seed germination, resistant to shattering and moderate yielding.

TGX 536-02D: Developed at IITA, Ibadan, Nigeria, early maturing, moderately tall in height, stimulate low *Striga* seed germination, susceptible to shattering, high yielding.

TGX849-313D: Developed at IITA, Ibadan, Nigeria, early maturing, moderately resistant to cercospora leaf spot and bacterial pustule, tall plant, stimulate low *Striga* seed germination, resistant to shattering and high yielding.

TGM 344: Introduced from Malaysia, moderately resistant to cercospora leaf spot and bacterial pustule, tall in height, stimulate moderate *Striga* seed germination susceptible to shattering and moderate yielding.

TGX 1636-7F: Developed at IITA, Ibadan, Nigeria, early maturing, resistant to cercospora leaf spot and bacterial pustule, short in height, stimulate moderate *Striga* seed germination, resistant to shattering and moderate yielding.

TGX 1449-2D: Developed at IITA, Ibadan, Nigeria, medium maturing, moderately resistant to cercospora leaf spot and bacterial pustule, tall in height, stimulate low *Striga* seed germination, susceptible to shattering and moderate yielding.

MALAYAN: Introduced from Malaysia, medium maturing, moderately resistant to cercospora leaf spot and bacterial pustule, tall in height, stimulate moderate *Striga* seed germination, moderate in shattering

and moderate yielding.

3.3 Experimental Design.

Trials were conducted in the screen-house, field and laboratory.

Screen House Trials.

Three screen house trials were carried out at Samaru between 1995 and 1997.

In experiment I, eleven (11) each of early (90-105 days to maturity) and medium (110-130 days to maturity) maturing soybean cultivars were evaluated for their reactions to *Alectra vogelii* in the pots and arranged in a completely randomized design with three repetitions. Half of the 132 plastic pots (each 18cm in diameter and 2.16 liters in volume) used were inoculated with about 2,000 *Alectra* seeds per pot, while the remaining half were used as control. The experiment was conducted in March to May 1995 and repeated in August to October 1995.

Inoculum Preparation and Inoculation.

In a polythene bag, 25cc of unsterilized sieved sand ($<180\mu$m particle size) and 15cc (about 2,000) *Alectra* seeds were mixed resulting in 40cc *Alectra* seeds/sieve sand mixture. The polythene bag was close tightly after trapping some air in the bag and the mixture was shaken manually for 5 minutes. This was followed by adding 40, 20,to make it 100cc then 100, 200, 400, and 200cc of sieved sand to finally give 1,000cc *Alectra* seeds/sieve sand mixture; the shaking process was repeated to ensure

homogeneity. 100cc of the inoculant stock that will give 2,000 *Alectra* seeds was stocked one-third, shaken thoroughly and used to inoculate each plastic pot (2.16 litres) that has been filled with unsterilized soil-sand mixture (1:1, v/v) up to two third.

After inoculation, the *Alectra* seeds were pre-conditioned for seven days by watering the soil in the pots to field capacity daily. After the pre-conditioning of *Alectra* seeds, eight soybean seeds were planted per pot. The experimental pots were subsequently watered to field capacity throughout the period of the trial. At two weeks after sowing, soybean plants were thinned to four per pot. At 10WAs in the first screen-house experiment, roots of soybean plants were freed from soil by immersing each pot in a 20 litre bucket of water for five minutes. The pot was then inverted to release the ball of soil and the roots were then carefully freed of adhering soil in such a way that there was no loss of both emerged and unemerged *Alectra* plants and nodules.

Evaluation of Abscisic acid (ABA) on *Alectra*.

In experiment II, the effect of abscisic acid at four concentrations (0, 100, 200, and 400ppm) on *Alectra* in five susceptible soybean cultivars was evaluated in pots arranged in a complete randomized design with three repetitions in June to September, 1997. All the 154 plastic pots used were inoculated with about 2,000 *Alectra* seeds per pot.

ABA application was carried out at 60 days after sowing of the inoculated soybean cultivars using a white flag sprayer. The control was sprayed with distilled water while ABA was sprayed with 100, 200 and 400ppm, respectively. In practice

15mls of distilled water or abscisic acid was used to spray *Alectra* plants in each pot.

Evaluation of Local Materials as Anti-transpirants.

In experiment III, six local materials used as anti-transpirants were evaluated for their efficacy in controlling *Alectra vogelii* in a susceptible soybean cultivar. The treatments were compared with the control (distilled water) in a completely randomised design and repeated four times. A total of 28 plastic pots were used and all were inoculated with 2,000 *Alectra* seeds per pot. The experiment was conducted in August to November 1997.

The local materials used as anti-transpirants were applied to *Alectra* shoots at 60 days after sowing of the inoculated soybean. The liquid based materials (distilled water, gum arabic, sheabutter oil and paraffin) were applied using a white flag sprayer while the paste based materials (vaseline, kaoline and Talc-magnesite) were applied using brushes. The control was sprayed with distilled water. 15mls of distilled water or anti-transpirant were used to spray *Alectra* plants on each pot while the paste based materials were prepared by dissolving each in 15mls of water.

Field Trials.

These were conducted during the wet seasons at two naturally infested sites in 1995, 1996 and one site in 1997, respectively, to study the response of soybean cultivars to *Alectra* under natural field infestation. Treatments consisted of 11 each of early and

medium maturing soybean cultivars arranged in randomized block design replicated three times. Each plot consisted of 4 ridges, 75cm apart and 5m long, thus the gross plot size was 5x3m.

Cultural Practices.

At all the experimental sites in the three years, the land was ploughed and disc harrowed in order to get a fine tilt and ridge at 75cm width before planting. At one site (bush field), planting was done on 13 July and 28 June in 1995 and 1996, respectively. However, at the other site (B_3) planting was done on 18 July, 20 June and 27 June 1995, 1996 and 1997, respectively.

Seeds of soybean cultivars were sown by drilling on 75cm ridges at a spacing of 3.3cm to achieve a plant population of 200,000 plants per hectare. The gross and net plot sizes were $15m^2$ and $7.5m^2$, respectively. Fertilizer was applied to all plots at the rate of 20kg N/ha and 26kg P/ha using urea (46% N) and single super phosphate (18% P_2O_5), respectively. Weeds were controlled with pre-emergence application of formulated mixture of metobromuron + metolachlor (Galex), at the rate of 2.5kg a.i./ha followed by one hoe weeding at six weeks after sowing. Harvesting was done when the crop reached harvesting maturity (R8, Fehr and Cavines, 1977), signified by the yellowing, drying and eventual dropping of the leaves. The pods also turned yellow. Harvested soybean from the net plot was allowed to thoroughly air dried for two weeks before threshing.

Threshing was carried out manually and the clean seeds from each plot were

weighed for determination of seed yield.

Determination of Soil Nutrient Status.

Prior to planting, soil samples were taken to the depth of 30cm before fertilizer application and analyzed for physical and chemical properties. The texture was analyzed by the hydrometer method (Bouyoucos, 1951) and the textural class was determined by the soil texture triangle.

Total nitrogen was determined by the macro-kjeldahl procedure (Bremmer, 1965). Available phosphorus was determined by the method described by Troug (1930). The extractable phosphate was determined by the molybdate blue colour method modified by Murphy and Riley (1962). Exchangeable cations were determined by the acetic acid method (Reith, 1967). Magnesium, calcium and potassium were determined by the atomic absorption spectrophotometry using Perkin Elmer model 403.

Laboratory Trials for Stimulation of Germination of *Alectra* Seeds.

Two laboratory trials were conducted at Samaru in 1997 and 1998. In experiment I, 22 soybean cultivars were evaluated for stimulation of germination of seeds of *Alectra vogelii* using cowpea variety TVX 3236 as control. The treatments were arranged in a completely randomized design repeated three times. The trial was conducted in April to September 1997 using the center-ring (cut-root) technique developed at IITA, Ibadan (Dejongh *et al.*, 1993; Berner *et al.*, 1993) and the materials were evaluated at 2, 3, and 4 weeks after sowing (WAS).

In experiment II six soybean cultivars, one cowpea variety (TVX 3236)and three abscisic acid concentration (100, 200 and 400ppm) were evaluated for stimulation of germination of seeds of *Alectra vogelii* using cowpea variety SAMPEA 7 as control. The treatments were arranged in a completely randomized design repeated three times. The trail was conducted in March to April 1998 and the materials were evaluated at 3 and 4 WAS, respectively.

Soybean seeds were surface sterilized using 5% sodium hydrochlorite (NaOCl) and rinsed three times with distilled water. The seeds were then placed in petric dishes lined with moistened filter paper, wrapped in aluminium foil and incubated at 28°C for 48 hours to germinate. The pre-germinated seeds (seedlings) were planted in pots containing 1:1 ratio of sieved sand/soil mixture. The soybean cultivars were grown for 14, 21 and 28 days.

Alectra vogelii seeds were surface sterilized using 5% sodium hypochlorite and rinsed three times with distilled water. The seeds were dried and spread on whatman glass micro fibre disc (8mm in diameter) and pre-conditioned in an incubator at 28°C for 14, 21, or 28 days. At the end of the 14, 21 and 28 days, roots of soybean cultivars were obtained and washed free of soil before 1g of cut root pieces were put in a ring, made of cellotape, placed at the centre of petric-dish lined with filter paper. 1ml of distilled water was added to each of the rings containing cut-root pieces. The treatments that contain ABA did not have cut-root pieces, thus, 1ml of ABA solution was applied to the rings.

Twenty (5x4) glass micro-fibre disc containing pre-conditioned *Alectra* seeds were

placed in a diverging manner from the ring in the petric dishes. The petric-dishes were covered with cellotape, wrapped in aluminium foil and incubated for 7 days. Thereafter, data were recorded on germinated and ungerminated *Alectra* seeds with the aid of microscope.

3.4 Observations Recorded.

Screen House Trials:Reaction of Soybean Cultivars to *Alectra*.

Observations on *Alectra* parameters included number of emerged *Alectra* shoots at 6, 7, 8, 9 and 10WAS, number of unemerged *Alectra* at 10WAS and number of days to first *Alectra* emergence. Crop plant parameters observed included host plant damage severity (crops syndrome reaction score) at 10WAS using a scale of 1-9 (Kim, 1991), where 1 - normal plant growth, no chlorosis, no blotching, no leaf scorching and 9 = total leaf scorching and/or obviously stunted or dead plants; number of days to first flowering recorded from the time of sowing to when flower first appear in each pot (V1-V9-R1, Fehr and Cavines, 1977); number of nodules per plant, plant height and shoot dry weight at harvest (10WAS). Plant height was measured from soil level to the growing point of the plant while shoot dry weight was determined by weighing oven dry samples (at 70°C for 48 hours and then heated to 105°C for 1 hour to remove bound water). Reduction in the number of nodules, plant height and shoot dry weight were calculated as percentages of the control.

Evaluation of Abscisic acid for the Control of *Alectra*.

Data collected include number of emerged *Alectra* shoots before the application of ABA and at 2 weeks after application, number of days to first *Alectra* emergence and number of days to first flowering (V1-V9-R1, Fehr and Cavines, 1977). The opening of the stomata of the leaf of *Alectra* plants was also observed using a microscope. two weeks after the application of ABA.

Evaluation of Local Materials Used as Anti-transpirants for the Control of *Alectra*.

Observations recorded include number of emerged *Alectra* shoots before the application of anti-transpirant, number of live *Alectra* shoots at 5 and 10 days after application, number of dead *Alectra* shoots at 5 and 10 days after application of the local materials and percentage of dead *Alectra* shoots at 5 and 10 days after application of local materials using the following formula;

$$\% \text{ dead } \textit{Alectra} \text{ shoots} = \frac{\text{Number of dead Alectra shoots}}{\text{Number of Alectra shoots before the application of anti-transpirants}} \times \frac{100}{1}$$

Reaction of Soybean Cultivars to *Alectra* in the Fields.

Observations on *Alectra* parameters that were recorded included number of days to first *Alectra* emergence, number of emerged *Alectra* shoots at 9 and 10WAS.

The crop parameters observed included plant height (cm) at 4 and 8WAS and at harvest, number of days to first flowering (V1-V9-R1, Fehr and Cavines, 1977); number of days to physiological maturity (V1-R1, Fehr and Cavines, 1977); number of branches

per plant; number of pods per plant; 100-seed weight (g) and seed yield (kg/ha).

Laboratory Trials to Screen Soybean Cultivars for *Alectra* Seed Germination.

Data were recorded on germinated *Alectra* seeds, thereafter, percentage germination of *Alectra* relative to the control were calculated using the formula:

$$\% \text{ germination of } \textit{Alectra} \text{ seeds} = \frac{\% \text{ germination of } \textit{Alectra} \text{ seeds induced by soybean cultivars}}{\% \text{ germination of } \textit{Alectra} \text{ seeds induced by the control}} \times \frac{100}{1}$$

3.5. Statistical Analysis.

The data collected were subjected to analysis of variance as described by Cox and Cochran (1967) after transformation using missing plot technique for days to *Alectra* emergence and addition of one to all replicates for *Alectra* shoot count. Combined analysis of the field trials was also carried out and significant differences among treatment means were compared using Duncan's New Multiple Range Test (Duncan. 1955). Coefficient of correlation (r) between *Alectra* infection and other soybean parameters were also determined.

Path-coefficent analysis was carried out to determine the direct, indirect and total contributions as well as percentage contributions of some crop parameters to seed yield as described by Dewey and Lu (1959).

3.6 Meteorological Data.

Data on rainfall, temperature, relative humidity sunshine hours (day duration) during the period of the trials were obtained from the I.A.R. meteorological station, Samaru (see appendix 2-4).

CHAPTER FOUR

4.0 RESULTS.

4.1 Reaction of Soybean Cultivars to *Alectra vogelii* Infestation.

The reaction of soybean cultivars to *Alectra* infestation are contained in tables 1 to 19 and figutres 1 to 9. Significance of *Alectra* and crop parameters of soybean are indicated in the means squares from analysis of variance in appendix 6 - 14.

4.1.1. *Alectra* Infestation.

Emerged *Alectra* shoots increased from 6 WAS to 10 WAS (harvest) in the two screen house trials in all the soybean cultivars evaluated except in TGX 1674-3F where there was no *Alectra* emergence in the first trial (Tables 1 and 2). Soybean cultivars M-351 and TGX 849-313D supported emerged and unemerged *Alectra* plant count which was either the highest or comparable to the highest until 10 WAS in the two screen-house trials. TGX 87D-516 also supported unemerged *Alectra* plants in both trials and *Alectra* shoot emergence until 10 WAS and 9 WAS comparable to the highest in the first and second trials, respectively. Soybean cultivars TGX 1485-1D, TGX1479-1E and TGX536-02D supported *Alectra* shoot count comparable to the highest in the first trial only while the later two cultivars also similarly supported the number of emerged

Table 1. Reaction of soybean cultivars to *Alectra* in the screen house as shown by number of emerged and unemerged *Alectra* per pot, first trial, Samaru, 1995.

Cultivars	Number of emerged *Alectra* shoots per pot. 6WAS[1]	7WAS	8WAS	9WAS	10WAS	No. of unemerged *Alectra* per pot at harvest.
TGX 1660-15F	0.7	0.7bc[2]	1.3c-e	1.7d-g	3.0e-h	3.0d-g
" 1485-1D	0.0	3.3a-c	6.7a-d	13.0a-d	19.7a-d	4.3d-g
" 1649-11F	0.0	1.0bc	1.7c-e	2.3d-g	3.7gh	2.0e-g
" 1681-3F	0.0	0.0c	0.7de	1.0e-g	1.0gh	0.3g
" 1674-3F	0.0	0.0c	0.0e	0.0g	0.0h	2.0e-g
" 1019-2EB	0.0	1.3bc	3.0b-e	10.0a-f	18.0a-d	9.0a-e
" 1519-1D	0.0	0.0c	0.3de	1.7d-g	5.7d-h	4.7c-g
" 1636-7F	0.0	0.0c	0.3de	0.3fg	0.7gh	1.0fg
" 923-2E	0.0	4.0a-c	9.7a-c	15.3a-c	23.3ab	12.7ab
SAMSOY 2	0.0	1.7bc	4.3a-e	14.3a-c	24.3ab	12.7ab
M-351	1.7	6.3ab	10.3a-c	22.0a	35.0a	14.0ab
TGX 1448-2E	1.3	2.7a-c	5.7a-e	9.7a-e	12.0b-f	12.0a-c
" 1440-1E	0.0	2.3a-c	3.0b-e	4.7c-g	9.0b-g	9.0a-e
" 1479-1E	0.0	2.7a-c	6.7a-d	13.0a-d	17.3a-d	10.0a-d
" 1670-1F	0.0	0.0c	0.3de	0.3fg	0.7gh	0.7fg
" 1449-2D	0.0	1.3bc	2.3b-e	4.0c-g	7.0c-h	13.3ab
" 87D-516	0.0	5.3a-c	12.0a	17.3a-c	24.0ab	16.3a
" 1670-3F	0.0	0.0c	0.7de	0.7fg	1.3gh	1.0fg
" 1660-19F	0.0	0.7bc	1.7c-e	2.0d-g	2.0gh	1.3fg
" 536-02D	0.0	3.3a-c	7.0a-d	12.0a-d	18.7a-d	9.0a-e
" 849-313D	0.0	11.3a	16.0a	22.3a	24.3a-c	12.0a-c
MALAYAN	1.0	1.0bc	2.7b-e	5.7b-g	13.0b-e	8.0b-f
SE±	0.51	2.07	2.99	4.35	4.75	2.16

1 WAS = weeks after sowing

2 Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

Table 2. Reaction of soybean cultivars to *Alectra* in the screen house as shown by number of emerged and unemerged *Alectra* perpot, second trial, Samaru, 1995.

Cultivars	Number of emerged *Alectra* shoots per pot. 6WAS[1]	7WAS	8WAS	9WAS	10WAS	No. of unemerged *Alectra* per pot at harvest.
TGX 1660-15F	0.3	1.0bc[2]	2.0d-g	2.3g-i	4.0ef	1.7fg
" 1485-1D	0.0	1.7a-c	5.0b-f	16.7c-e	27.3b-d	11.7a
" 1649-11F	0.0	0.3c	2.0d-g	2.3g-i	2.7f	2.3e-g
" 1681-3F	0.0	0.0d	0.7fg	0.7hi	1.0f	2.0fg
" 1674-3F	0.0	0.0d	0.7fg	0.7hi	0.7f	2.0fg
" 1019-2EB	0.0	0.7c	7.3b-e	19.3c-e	38.7bc	6.0c-e
" 1519-1D	0.0	0.0d	1.0fg	2.0hi	3.0ef	4.0d-f
" 1740-7F	0.0	0.0d	1.3d-g	1.7hi	3.0ef	2.0fg
" 923-2E	0.7	2.0ab	6.3b-d	19.3b-d	32.0bc	10.3ab
SAMSOY 2	0.7	2.0ab	15.7a	32.3ab	54.0ab	9.0a-c
M-351	1.0	3.7a	11.7a-c	32.0a-c	47.0ab	11.0ab
TGX 1448-2E	0.7	1.3a-d	2.0d-g	4.0f-i	9.0d-f	10.0ab
" 1440-1E	0.3	1.3a-d	2.3d-g	3.3f-i	5.7ef	7.7b-d
" 1479-1E	0.3	1.0bc	3.0c-g	6.3e-h	17.3c-e	7.7b-d
" 1670-1F	0.0	0.0d	0.0g	0.0i	0.3f	0.0g
" 1740-2F	0.0	0.3cd	1.0e-g	2.7f-i	4.3ef	3.7e-g
" 87D-516	1.0	2.0ab	11.7ab	31.3a-c	44.0b	10.3ab
" 1670-3F	0.0	0.0d	0.7fg	1.3hi	1.3f	0.7fg
" 1660-19F	0.0	0.0d	0.7fg	1.0hi	2.0f	1.0fg
" 536-02D	0.7	1.3a-d	3.7c-g	11.0d-f	48.7ab	9.0a-c
" 849-313D	0.3	1.7a-c	13.0ab	41.3a	78.7a	10.0ab
TGM 344	0.0	1.3a-d	2.7c-g	10.0d-h	16.3c-e	2.0fg
SE±	0.32	0.55	2.34	4.29	8.05	1.09

1 WAS = weeks after sowing

2 Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

Alectra plants. SAMSOY 2 supported unemerged *Alectra* plants and emerged *Alectra* shoot count comparable to the highest until harvest from 8 WAS and 7 WAS in the first and second trials, respectively.

In contrast, soybean cultivars TGX 1681-3F, TGX 1670-IF, TGX 1670-3F and TGX 1660-19F consistently supported *Alectra* shoot infestation until harvest comparable to the least in the two trials. The two cultivars, TGX 1740-2F and TGX 1740-7F which were only evaluated in the second trial as well as TGX 1674-3F, similarly supported very low *Alectra* infestation in the second trial while TGX 1636-7F and TGX 1519-1D only exhibited similar reaction in the first trial.

In the two screen-house trials at harvest, soybean cultivars differed in the total number of *Alectra* shoots (Figures 1 and 2). The highest total number of *Alectra* shoots was supported by soybean cultivars, M-351 and TGX 849-313D in the first and second trials, respectively, while the least was supported by TGX 1681-3F and TGX 1670-1F in the first trial and TGX 1670-1F in the second trial. In the two trials, soybean cultivars, TGX 1660-15F, TGX 1649-11F, TGX 1681-3F, TGX 1674-3F, TGX 1670-1F, TGX 1670-3F and TGX 1660-19F as well as TGX 1636-7F in the first trial and TGX1740-7F and TGX 1740-2F in the second trial supported lower total number of *Alectra* shoots (0.3 to 8 *Alectra* shoots per pot), while TGX 1485-1D, TGX 1019-2EB, TGX 1519-1D, TGX 923-2E, SAMSOY 2, M-351, TGX 1448-2E, TGX 1440-1E, TGX 87D-516, TGX 536-02D and TGX 849-313D in the two trials as well as TGX 1479-1E and MALAYAN in the first trial and TGM 344 in the second trial supported higher total number of *Alectra* shoots (10 to 89 *Alectra* shoots per pot) than

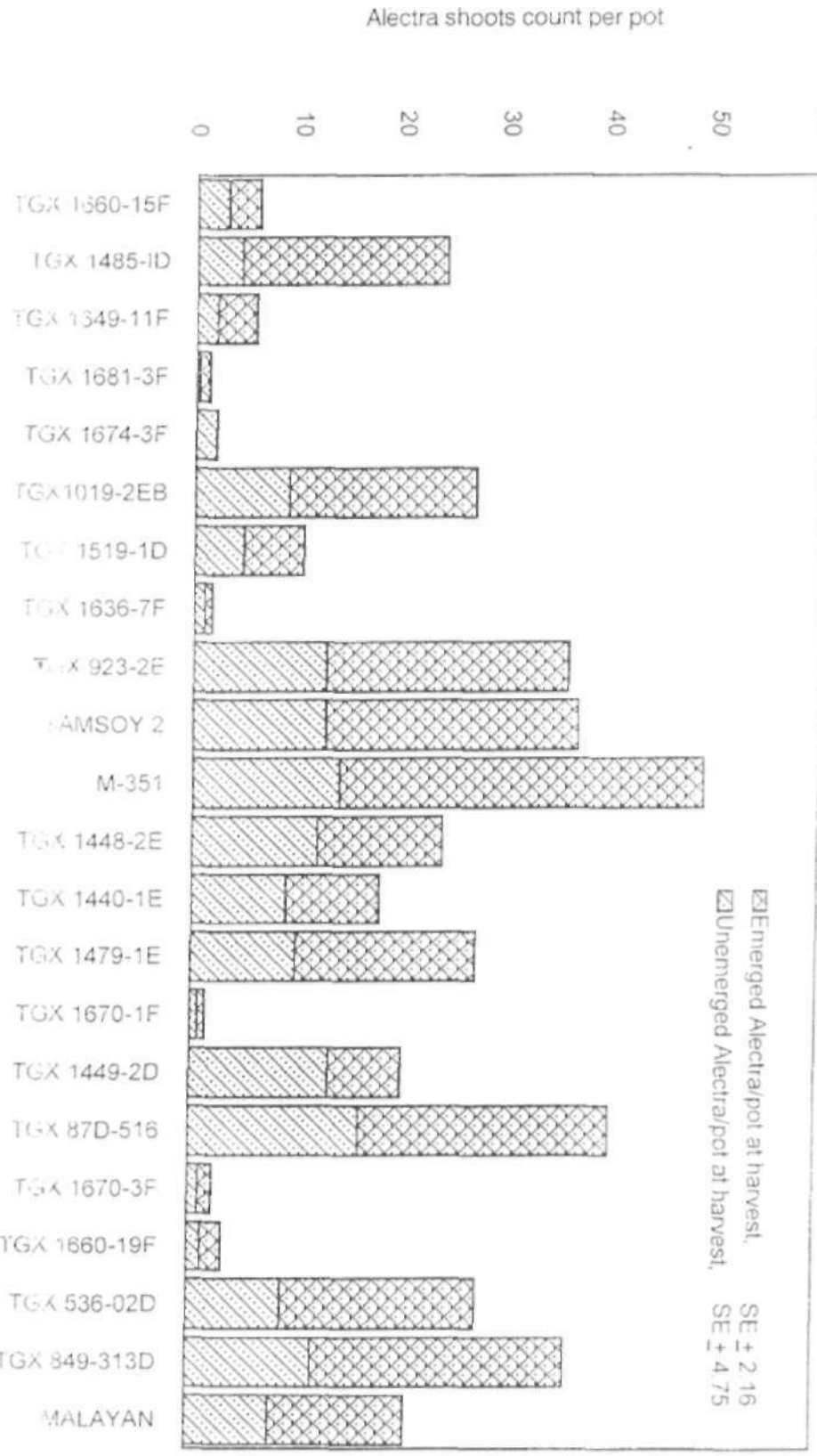


Figure 1. Reaction of soybean cultivars to *Alectra* in the screen house as shown by number of emerged and unemerged *Alectra* shoots perpot at harvest, first trial, Samaru, 1995

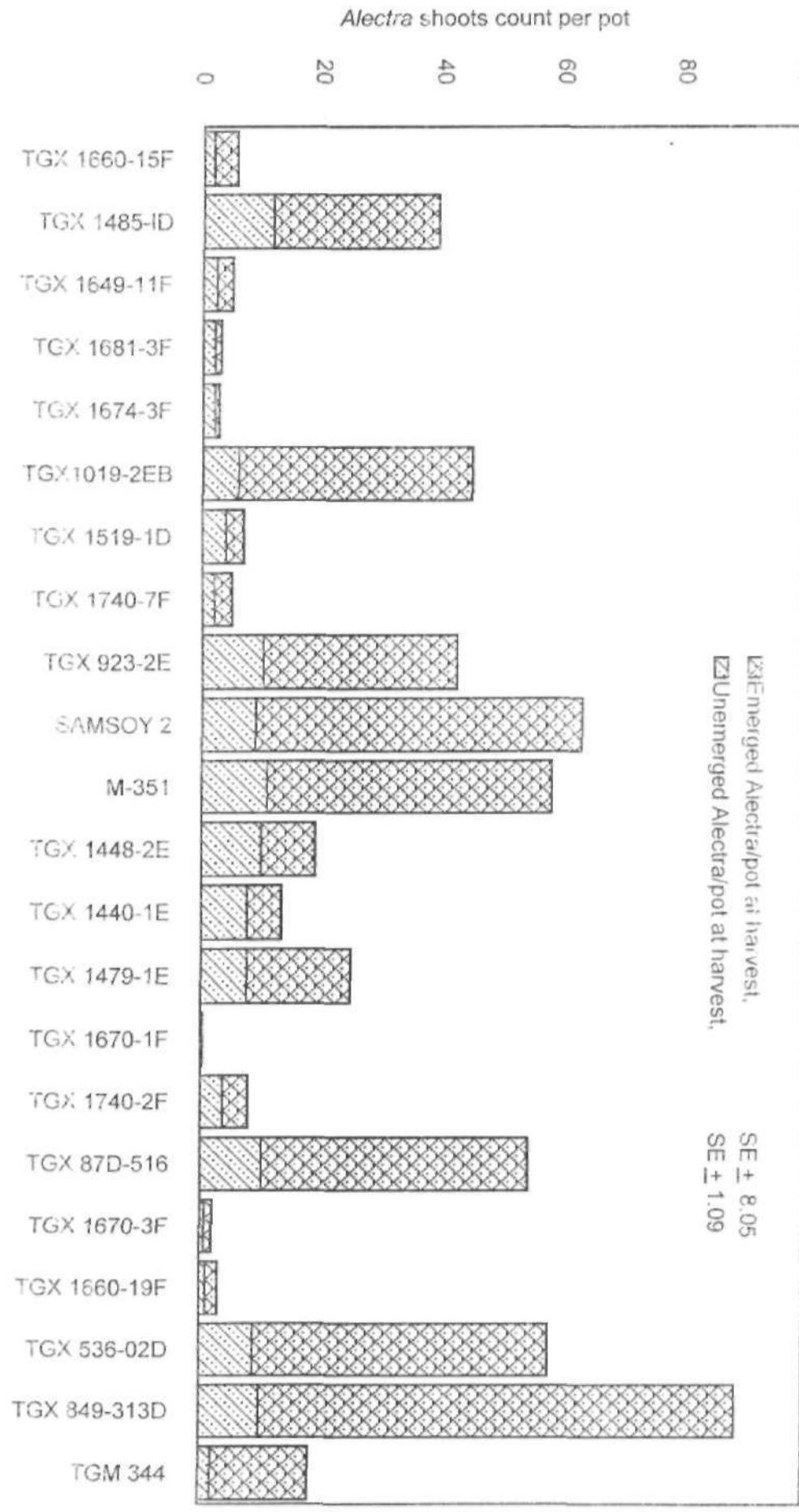


Figure 2. Reaction of soybean cultivars to *Alectra* in the screen house as shown by number of emerged and unemerged *Alectra* shoots per pot at harvest, second trial, Samaru, 1995.

the former.

The highest *Alectra* shoot at 9 and 10 WAS in the field was supported by TGX 87D-516 at both sites in 1995 and 1996 and TGX 1019-2EB at site 1 in 1997 (Tables 3 and 4). M-351 at 9 WAS and with TGX 1019-2EB at 10 WAS at site 2 in 1995 as well as TGX 1019-2EB at 9 WAS both sites and with TGX 1485-1D at site 2 in 1996 supported *Alectra* shoot count comparable to the highest. In addition to those mentioned at both sites and years, TGX 1019-2EB supported higher *Alectra* shoot count at site 1 in 1995 than the least. In 1997, TGX 1019-2EB also supported the highest *Alectra* shoot emergence, while TGX 87D-516 at 9 WAS and TGM 344 in addition at 9 WAS was comparable. Among the cultivars that supported lower *Alectra* shoot emergence than the highest in 1997, TGX 1485-1D, SAMSOY 2 and TGX 849-313D at 9 WAS as well as TGX 536-02D and TGM 344 in addition at 10 WAS also supported significantly higher *Alectra* shoot emergence than the least obtained with TGX 1649-11F. Soybean cultivars, TGX 1649-11F, TGX 1681-3F, TGX 1674-3F, TGX 1740-7F, TGX 1670-1F, TGX 1740-2F, TGX 1670-3F and TGX 1660-19F supported number of Alectra shoot count at both sites in all years comparable to the least, wherever they did not support the least themselves.

4.1.2. **Crop Reaction Score**.

Crop syndrome reaction score was highest in soybean cultivars TGX 536-02D in the first trial and TGX 536-02D and TGX849-313D in the second screen house trial (Table 5). TGX 923-2E, M-351 and TGX 849-313D exhibited crop reaction score

Table 3. Emerged *Alectra* shoots on soybean cultivars under natural field infestation of *Alectra* at 9WAS, Samaru, 1995, 1996 and 1997 wet seasons.

	Number of emerged *Alectra* shoots per 4.5m² at 9WAS[1].				
	1995	1995	1996	1996	1997
Cultivars	Site 1	Site 2	Site 1	Site 2	Site 1
TGX 1660-15F	6.0bc[2]	2.7bc	2.0b	2.7d	2.0ef
" 1485-1D	18.0bc	11.3bc	17.7b	27.0bc	8.7c-e
" 1649-11F	1.0c	1.0c	0.7b	0.3d	0.3f
" 1681-3F	1.0c	0.7c	0.3b	0.7d	0.3f
" 1674-3F	0.0c	0.3c	0.0b	0.0d	0.3f
" 1019-2EB	43.0bc	21.3b	140.0a	66.7ab	45.0a
" 1519-1D	2.0c	1.7c	6.7b	0.7d	1.3ef
" 1740-7F	1.0c	0.7c	0.3b	1.0d	0.3f
" 923-2E	8.0bc	7.9bc	3.7b	1.0d	3.3ef
SAMSOY 2	49.0bc	11.3bc	16.3b	12.3cd	8.0c-e
M-351	11.0bc	89.3ab	12.7b	11.7cd	15.3bc
TGX 1448-2E	2.0c	1.3c	1.7b	5.3cd	1.3ef
" 1440-1E	3.0c	2.7bc	3.0b	1.0d	2.3ef
" 1479-1E	5.0bc	2.3bc	2.3b	1.0d	1.7ef
" 1670-1F	0.0c	0.7c	0.3b	0.0d	0.7ef
" 1740-2F	0.0c	0.0c	0.7b	0.3d	0.7ef
" 87D-516	393.0a	160.0a	197.7a	91.3a	27.7ab
" 1670-3F	0.0c	0.7c	0.3b	0.3d	0.3f
" 1660-19F	1.0c	0.3c	0.0b	0.3d	0.3f
" 536-02D	11.0bc	2.7bc	8.3b	3.3d	5.0d-f
" 849-313D	90.0b	17.0bc	19.0b	6.3cd	15.0b-d
TGM 344	5.0bc	3.3bc	11.0b	7.3cd	19.7a-c
SE±	58.13	29.65	27.12	11.94	6.85
MEAN	30.0	15.4	20.2	10.9	7.3
Interaction					
C x Y	NS	NS	NS	NS	NS

1 WAS = Weeks after sowing.
2 Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

Table 4. Emerged *Alectra* shoots on soybean cultivars under natural field infestation of *Alectra* at 10WAS, Samaru, 1995, 1996 and 1997 wet seasons.

	Number of emerged *Alectra* shoots per 4.5m² at 10WAS[1].				
	1995	1995	1996	1996	1997
Cultivars.	Site 1	Site 2	Site 1	Site 2	Site 1
TGX 1660-15F	10.0b-d[2]	5.0bc	5.0b	7.0c	4.3ef
" 1485-1D	32.0b-d	19.3bc	32.0b	46.7ab	14.7b-e
" 1649-11F	1.0d	1.7c	1.0b	0.3c	0.3f
" 1681-3F	1.0d	1.3c	1.0b	1.3c	1.0f
" 1674-3F	1.0d	0.7c	0.0b	0.0c	0.7f
" 1019-2EB	66.0bc	38.3a-c	168.7a	93.0a	72.0a
" 1519-1D	3.0d	3.0c	8.0b	1.7c	2.0ef
" 1740-7F	2.0d	1.3c	0.3b	1.3c	0.7f
" 923-2E	11.0b-d	12.0bc	5.3b	2.3c	6.3d-f
SAMSOY 2	58.0b-d	16.7bc	21.0b	18.3bc	13.7c-e
M-351	15.0b-d	140.3ab	24.0b	17.3bc	20.3b-d
TGX 1448-2E	3.0d	2.7c	3.3b	9.0c	2.7ef
" 1440-1E	4.0cd	4.0c	5.3b	2.0c	5.0ef
" 1479-1E	7.0b-d	3.7c	4.0b	1.3c	3.0ef
" 1670-1F	0.0d	1.0c	0.7b	0.0c	1.0f
" 1740-2F	0.0d	0.0c	1.0b	0.3c	1.3ef
" 87D-516	482.0a	225.7a	297.7a	130.7a	40.0ab
" 1670-3F	1.0d	1.0c	0.7b	0.7c	0.7f
" 1660-19F	1.0d	0.3c	0.0b	0.3c	0.7f
" 536-02D	16.0b-d	5.7bc	12.7b	5.3c	10.0c-e
" 849-313D	124.0b	36.0bc	25.3b	11.7bc	22.3b-d
TGM 344	7.0b-d	6.7bc	16.3b	13.3bc	28.0bc
SE±	68.52	45.06	43.85	18.17	9.70
MEAN	38.0	23.9	28.8	16.5	11.4
Interaction					
C x Y	NS	NS	NS	NS	NS

1 WAS = Weeks after sowing.
2 Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

comparable to the highest in the first trial. The cutivars which had lower score than the highest but significantly higher than the least incude TGX 1485-1D, TGX 1019-2EB, TGX 1448-2E and TGX 1479-1E in the trial. Although none of the cultivars was comparabe to the highest in crop reaction score, in the second trial, TGX 1019-2EB had higher crop reaction score of up to 5.7 and TGX 923-2E and M-351 were comparable. In contrast, TGX 1674-3F and TGX 1670-3F in the two trials as well as TGX 1636-7F in the first trial and TGX 1740-7F in the second trial, exihited the least crop syndrome reaction score. TGX 1660-15F, TGX 1649-11F, TGX 1681-3F, TGX 1519-1D and TGX 1660-19F exhibited crop reaction score comparable to the least in the two trials. SAMSOY 2, TGX 1440-1E, TGX 1449-2D, TGX 87D-516 and MALAYAN only exhibited crop reaction score comparable to the least in the first trial while TGX 1740-2F was only comparable in the second trial that it was evaluated.

4.1.3. **Number of Days to *Alectra* Shoot Emergence**.

The earliest time of emergence of *Alectra* on soybean was 43 (TGX 1660-15F) and 40 (TGX 87D-516) days in the first and second screen-house trials, respectively (Table 5). In the screen house trials, days to first *Alectra* emergence was highest on TGX 1670-1F. In the first trial, the number of days to *Alectra* emergence on cultivars TGX 1485-1D, TGX 1681-3F, TGX 1519-1D, TGX 1636-7F and TGX 1660-19F were comparable to the highest and significantly higher than the least with TGX 1660-15F. However, in the second trial, none of the cultivars was comparable

table 5

Table 5. Reaction of soybean cultivars to *Alectra* in the screen house as shown by crop reaction score and number of days to first *Alectra* emergence, first and second trials, Samaru, 1995.

Cultivars	Crop reaction score[1] at 10WAS.		No. of days to 1st *Alectra* emergence.	
	1st trial.	2nd trial.	1st trial.	2nd trial.
TGX 1660-15F	2.0f-h[2]	1.7fg	43d	45g-h
" 1485-1D	4.7b-e	3.7c	54a-c	49d-g
" 1649-11F	3.0e-h	2.0e-g	47cd	48e-h
" 1681-3F	2.3f-h	1.7fg	54a-c	54b-d
" 1674-3F	1.0h	1.0g	51b-d	52c-f
" 1019-2EB	3.7d-g	5.7b	52a-d	51c-f
" 1519-1D	2.0f-h	2.0e-g	60ab	58b
" 1636-7F	1.0h	ne	60ab	ne
" 923-2E	6.0a-c	5.0b	45cd	43h-j
SAMSOY 2	3.0e-h	3.3cd	48cd	45g-i
M-351	5.7a-d	5.0b	45cd	40j
TGX 1448-2E	4.0c-f	3.0c-e	45cd	44g-j
" 1440-1E	3.0e-h	3.0c-e	45cd	45g-i
" 1479-1E	4.0c-f	2.3d-f	50b-d	48e-h
" 1670-1F	1.7gh	1.0g	62a	65a
" 1449-2D	2.0fh	ne	47cd	ne
" 87D-516	2.0fh	2.6c-f	49cd	40j
" 1670-3F	1.0h	1.0g	53a-d	55bc
" 1660-19F	1.7gh	1.0g	54a-c	54b-d
" 536-02D	7.0a	7.0a	50b-d	42ij
" 849-313D	6.3ab	7.0a	48cd	45g-i
MALAYAN	2.0fh	ne	44cd	ne
TGX 1740-7F	ne	1.0g	ne	56bc
" 1740-2F	ne	2.0e-g	ne	53b-e
TGM 344	ne	2.3d-f	ne	47f-i
SE±	0.61	0.31	3.29	1.46

1 = Crop reaction score is based on a scale of 1-9 where 1 = no crop reduction or injury and 9 = complete crop destruction

2 Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

ne = Not evaluated in the trial

to TGX 1670-1F in the number of days to *Alectra* emergence, but TGX 1519-1D also delayed emergence to 58 days after sowing (DAS). TGX 1681-3F, TGX 1670-3F, TGX 1660-19F, TGX 1740-7F and TGX 1740-2F were, however, comparable to TGX 1519-1D in days to *Alectra* emergence. In the two trials, TGX 923-2E, TGX 1448-2E and TGX 1660-15F supported the first emergence of the parasitic weed comparable to the earliest observed with M-351.

The earliest emergence of *Alectra* on TGX 87D-516 was 40 days at site 2 in 1995 and 1996, 42 days at site 1 in 1995 and 41 days at site 2 in 1996 and 1997 in the field trials (Table 6). *Alectra* did not emerge on TGX 1740-2F at both sites and TGX 1740-7F at site 1 in 1995, TGX 1674-3F at both sites, TGX 1660-15F at site 1 and TGX 1670-1F at site 2 in 1996. The highest number of days to *Alectra* emergence in the field was observed on TGX 1660-19F at both sites in 1995, TGX 1670-1F at site 1 and TGX 1649-11F at site 2 in 1996 and TGX 1660-19F and TGX 1674-3F in 1997 (Tabe 6). In all the field trials TGX 1649-11F, TGX 1674-3F, TGX 1479-1E, TGX 1670-1F and TGX 1660-19F consistently delayed *Alectra* emergence comparable to the highest number of days and significantly higher than the least at sites where tested. Number of days to first emergence of *Alectra* on TGX 1485-1D and TGX 1740-7F was comparable to the highest and significanty higher than the least at site 2 in 1995 and 1996 as well as at site 1 in 1995 by cultivar TGX 1740-7F. Similarly, days to emergence of *Alectra* on TGX 1674-3F were comparable to the highest and significantly higher than the least at both sites in 1995. Cultivar TGX 1740-2F and TGX 1670-3F only caused comparable delay in *Alectra* emergence to the highest at the second site in 1996.

Table 6. Number of days to first *Alectra* shoots emergence of soybean cultivars under natural field infestation of *Alectrs*. Samaru, 1995, 1996 and 1997 wet seasons.

	Number of days to first *Alectra* emergence				
	1995	1995	1996	1996	1997
Cultivars.	Site 1	Site 2	Site 1	Site 2	Site 1
TGX 1660-15F	55b-d[1]	50c-f	56b-d	54a-e	57b-d
" 1485-1D	55b-d	52a-d	56b-d	54a-e	56c-e
" 1649-11F	57a-c	58ab	60ab	60a	61a
" 1681-3F	55b-d	51b-e	54d-f	53b-f	55c-f
" 1674-3F	61ab	58ab	ne	ne	54d-g
" 1019-2EB	48d-f	46d-g	50f-h	48e-h	49hi
" 1519-1D	52c-e	50c-f	52d-h	52c-g	53e-g
" 1740-7F	56a-c	52a-d	55c-e	55a-d	55c-f
" 923-2E	48d-f	48c-f	49gh	47f-i	48i
SAMSOY 2	46ef	44fg	43l	43hi	41j
M-351	52c-e	48c-f	50f-h	47f-i	52f-h
TGX 1448-2E	53b-d	50c-f	51e-h	49d-g	52f-h
" 1440-1E	55a-e	51b-e	52d-h	50c-g	54d-g
" 1479-1E	56a-c	55a-c	59a-c	56a-c	60ab
" 1670-1F	ne	55a-c	61a	ne	60ab
" 1740-2F	ne	ne	56b-d	59ab	58bc
" 87D-516	42f	40g	41i	40i	42j
" 1670-3F	54b-e	51b-e	53d-g	56a-c	56c-e
" 1660-19F	64a	59a	ne	59ab	63a
" 536-02D	53b-e	51b-e	51e-h	48f-i	51g-i
" 849-313D	52c-d	51b-e	51e-h	49d-h	51g-i
TGM 344	47d-f	44e-g	48h	46g-i	49hi
SE±	2.57	1.95	1.28	1.62	0.80
MEAN	53	50	52	51	54
Interaction					
C x Y	NS	NS	NS	NS	NS

1 = Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).
ne = No *Alectra* emergence.

4.1.4. **Number of Days to Crop Flowering.**

Cultivars differed significantly in the number of days to first flowering, with and without *Alectra* infection in both trials conducted in the screen-house (Table 7). Soybean cultivars, MALAYAN, TGX 1636-7F and TGX 1449-2D were only evaluated in the first trial and TGX 1740-7F, TGX 1740-2F and TGM 344 were included in the second trial only. *Alectra* infection differentially reduced the number of days to first flowering in most cultivars that supported emergence by between 1 and 11 days. Days to first flowering was significantly more with cultivar TGX 923-2E in the first trial and without inoculation only in the second trial. In the second trial, more number of days were obtained with TGM 344, TGX 1670-1F and TGX 1660-19F. Soybean cultivars TGX 1660-19F and MALAYAN in the first trial and TGX 1670-3F in the second trial, both with inoculation as well as TGX 1479-1E and TGX 1670-1F were comparable to the highest in the number of days to first flowering. Some cultivars that were not comparable to the highest but also delayed flowering included TGX 1670-3F and TGX 1660-19F with and without inoculation, respectively in the first trial as well as TGX 923-2E with inoculation and TGX 1448-2E, TGX 1440-1E, M-351, TGX 1479-1E and TGX 1670-3F without inoculation both in the second trial. The least number of days to flowering was observed with TGX 1019-2EB, TGX 1636-7F and TGX 536-02D with inoculation and TGX 1636-7F without inoculation in the first trial as well as TGX 1485-1D with and without inoculation and TGX 1649-11F, TGX 1681-3F, TGX 1674-3F and TGX 1740-7F without inoculation in the second trial. Without inoculation, TGX 1019-2EB and TGX 1740-2F were comparable to the least in

Table 7. Reaction of soybean cultivars to *Alectra* in the screen house as shown by number of days to first crop flowering, first and second trials, Samaru, 1995.

	Number of days to first crop flowering.			
	1st trial.		2nd trial.	
Cultivars.	inoculated.	uninoculated.	inoculated.	uninoculated.
TGX 1660-15F	45d-f[1]	48bc	40f-h	42f-h
" 1485-1D	37hi	41d-f	34i	40h
" 1649-11F	42e-g	45cd	38gh	40h
" 1681-3F	41fg	41d-f	39f-h	40h
" 1674-3F	39g-i	41d-f	39f-h	40h
" 1019-2EB	35i	40f	37hi	42f-h
" 1519-1D	41fg	44c-e	43d-g	46d-f
" 1636-7F	35i	35g	ne	ne
" 923-2E	54a	62a	46b-d	53a
SAMSOY 2	39g-i	45cd	39f-h	46d-f
M-351	40f-h	45cd	42e-h	48b-d
TGX 1448-2E	41fg	46c	44c-e	48b-d
" 1440-1E	42fg	45cd	45c-e	48b-d
" 1479-1E	39g-i	44c-e	41e-h	46d-f
" 1670-1F	46c-e	47c	50a	52ab
" 1449-2D	44de	48bc	ne	ne
" 87D-516	39g-i	45cd	37hi	43e-g
" 1670-3F	47b-d	48bc	48a-c	48b-d
" 1660-19F	51ab	53b	50a	51a-c
" 536-02D	36i	47c	39f-h	45d-g
" 849-313D	39g-i	45cd	39f-h	47cd
MALAYAN	50a-c	54b	ne	ne
TGX 1740-7F	ne	ne	39f-h	40h
" 1740-2F	ne	ne	39f-h	41gh
TGM 344	ne	ne	51a	54a
SE±	1.28	1.24	1.14	1.20

1 = Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).
ne = Not evaluated in the trial

the second trial only while with innoculation TGX 1485-1D, TGX 1674-3F, SAMSOY 2, TGX 1479-1E, TGX 87D-516 and TGX 849.313D in the first trial and TGX 1019-2EB and TGX 87D-516 in the second trial were comparable to the least in the number of days to flowering. *Alectra* infection did not reduce the number of days to first flowering in cultivars TGX 1681-3F and TGX 1636-7F in the first trial and TGX 1670-3F in the second trial, and only reduced by one day in the alternate trial.

The highest reduction in time to flowering by *Alectra* of 11 days occured with TGX 536-02D in the first trial (figure 3). The cultivars which had high reduction in the days to flowering due to *Alectra* infection in the two trial (that is greater than 5 days) included M-351, TGX 1448-2E, TGX 1019-2EB, SAMSOY 2, TGX 87D-516, TGX 849-313D, TGX 923-2E and TGX 1485-1D. Cultivars in which *Alectra* infection caused less than 2 days reduction to first flowering were TGX 1674-3F, TGX 1670-1F and TGX 1660-19F in the two trials as well as TGX 1740-7F and TGX 1740-2F in the second trial only.

The highest number of days to crop flowering was observed with TGM 344 in the field trials in all years (Table 8). The number of days to first flowering of TGX 923-2E was comparabe to the highest and significantly higher than the least at site 1 in 1996 and 1997 and site 2 in 1995. Although none of the cultivars was comparable to TGM 344 in number of days to crop flowering, TGX 923-2E delayed crop flowering to 53 DAS and 48 DAS at site 1 in 1995 and site 2 in 1996, respectively. The earliest crop flowering was observed with TGX 1649-11F at site 1 in 1995, 1996 and 1997 and site 2 in 1996, TGX 1740-7F at site 1 in 1997 as well as site 2 in 1995 and TGX 87D-516

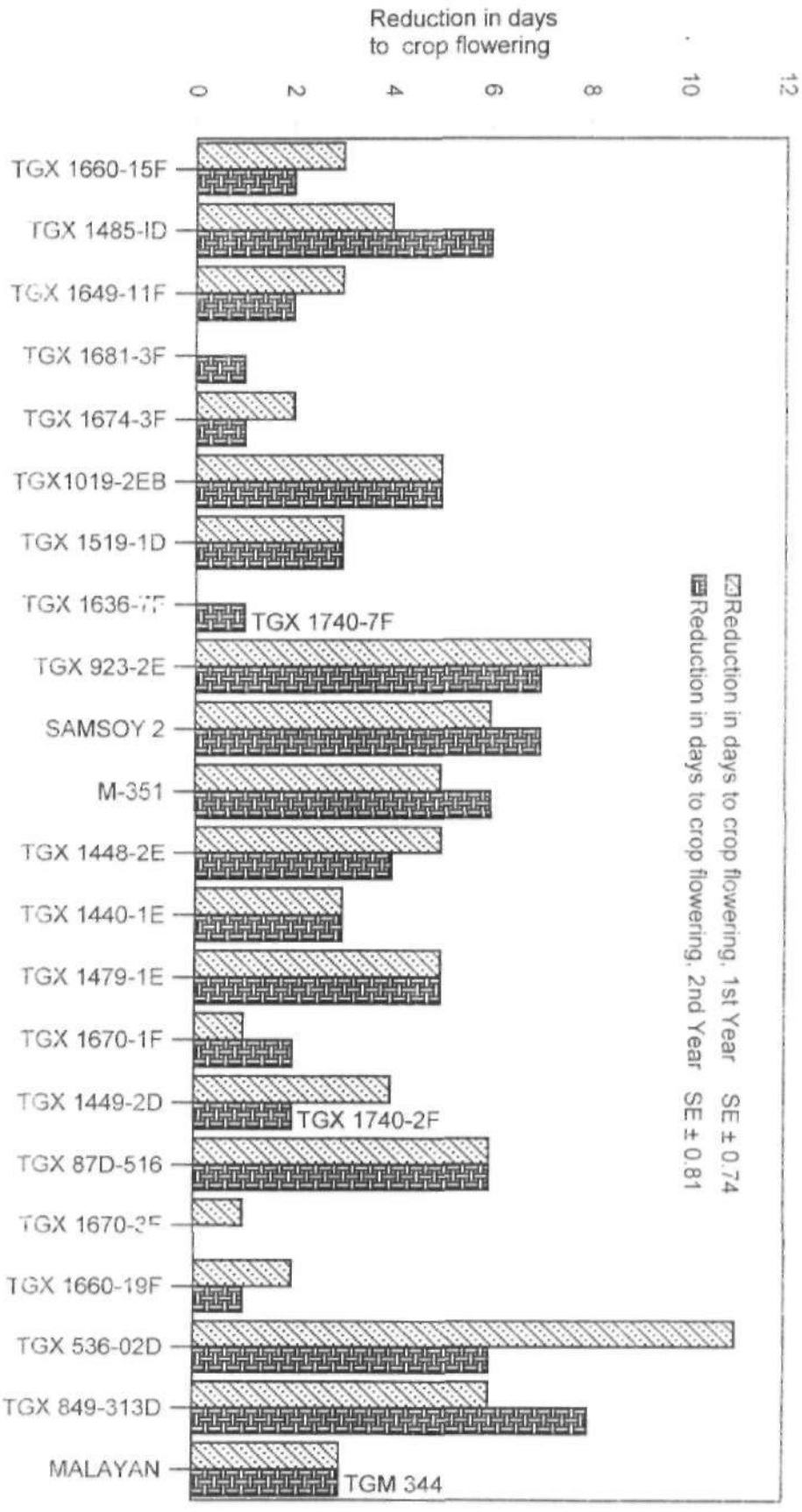


Figure 3. Reaction of soybean cultivars to *Alectra* in the screen house as shown by reduction in days to crop flowering, first and second trials, Samaru, 1995.

Table 8. Number of days to first crop flowering of soybean cultivars under natural field infestation of *Alectra*, Samaru, 1995, 1996 and 19970 wet seasons.

	Number of days to first crop flowering				
	1995	1995	1996	1996	1997
Cultivars.	Site 1	Site 2	Site 1	Site 2	Site 1
TGX 1660-15F	44e[1]	42d-g	42d-f	44b-d	41d-g
" 1485-1D	39fg	40fg	40fg	42b-d	39fg
" 1649-11F	37g	39g	37g	39d	38g
" 1681-3F	40f	41e-g	40fg	40cd	39fg
" 1674-3F	40f	39g	40fg	40cd	40e-g
" 1019-2EB	40f	40fg	40fg	39d	40e-g
" 1519-1D	47cd	45c-e	45b-d	44b-d	44b-f
" 1740-7F	39fg	40fg	40fg	42b-d	40e-g
" 923-2E	53b	51ab	52a	48b	49ab
SAMSOY 2	48cd	47bc	46bc	43b-d	46b-d
M-351	48cd	47bc	47bc	44b-d	46b-d
TGX 1448-2E	46de	44c-f	44c-e	43b-d	45b-e
" 1440-1E	47cd	44c-f	47bc	44b-d	47bc
" 1479-1E	46de	44c-f	44c-e	41b-d	44b-f
" 1670-1F	48cd	47bc	48b	44b-d	46b-d
" 1740-2F	39fg	38g	40fg	40cd	38g
" 87D-516	41f	39g	41ef	39d	40e-g
" 1670-3F	46de	45c-e	45b-d	48b	44b-f
" 1660-19F	49c	47bc	48b	43b-d	46b-d
" 536-02D	44e	42d-g	44c-e	40cd	42c-g
" 849-313D	48cd	46cd	47bc	43b-d	46b-d
TGM 344	56a	54a	54a	56a	53a
SE±	0.61	1.22	0.81	2.00	1.46
MEAN	45	44	44	43	43
Interaction					
C x Y	NS	NS	NS	NS	NS

1 Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

and TGX 1019-2E ony at site 2 in 1996. TGX 1681-3F, TGX 1674-3F and TGX 1019-2EB were only comparable to the earliest in the number of days to crop flowering at both sites in 1996, site 1 in 1997 and site 2 in 1995. However, TGX 1660-15F, TGX 87D-516, and TGX 536-020 were comparable to the earliest in number of days to crop flowering only at site 1 in 1997 and site 2 in 1995 and 1996. while TGX 1519-1D, TGX 1448-2E, SAMSOY 2, M-351, TGX 1440-1E, TGX 1479-1E, TGX 1670-1F, TGX 1660-19F and TGX 849-313D were only comparable at site 2 in 1996.

4.1.5. **Nodulation**.

Cultivars, TGX 1519-1D and TGX 1019-2EB produced the highest and the lowest number of nodules, respectively with and without inoculation in the two screen house trials (Table 9). TGX 1670-3F also produced number of nodules that was highest under *Alectra* inoculation and that comparable to the highest without inoculation in the second screen house trial. TGX 1485-1D, TGX 1681-3F, TGX 1674-3F and SAMSOY 2 were also comparable to the highest and significantly higher than the least in number of nodules without *Alectra* inoculation in the second trial. In all the situations, TGX 536-02D also produced nodule count comparable to the least. Without inoculation, TGX 1485-1D, TGX 1660-15F, TGX 1674-3F, TGX 1636-7F, M-351, TGX 1448-2E, TGX 1660-19F, TGX 536-02D and TGX 849-313D in the first trial and TGX 1660-15F, TGX 536-02D and TGX 849-313D in the second trial supported low number of nodules comparable to the least. However, with inoculation, TGX 1485-1D, TGX 923-2E,

Table 9. Reaction of soybean cultivars to *Alectra* in the screen house as shown by number of nodules per plant, first and second trials, Samaru, 1995.

	Number of nodules per plant.			
	1st trial.		2nd trial	
Cultivars.	inoculated.	uninoculated.	inoculated	uninoculated
TGX 1660-15F	20.0de[1]	24.0c-e	15.4ef	17.9de
" 1485-1D	11.7f-h	22.0c-e	11.0g	23.5cd
" 1649-11F	24.3cd	28.7bc	15.6e	19.3d
" 1681-3F	24.7cd	26.7b-d	26.1b	29.3a-d
" 1674-3F	17.0ef	18.3e	25.0b	27.5a-d
" 1019-2EB	8.6h	18.3e	6.2i	7.2e
" 1519-1D	51.8a	68.8a	32.3a	39.3a
" 1636-7F	17.3ef	18.7e	ne	ne
" 923-2E	11.9f-h	28.0b-d	6.9hi	17.1de
SAMSOY 2	12.3f-h	30.0bc	13.2fg	33.0a-d
M-351	10.0gh	25.0c-e	7.7hi	20.0d
TGX 1448-2E	12.7f-h	25.3c-e	16.2de	21.5d
" 1440-1E	19.3d-e	27.6b-d	17.3de	22.5cd
" 1479-1E	14.7e-g	30.3bc	12.3g	20.3d
" 1670-1F	32.3b	34.2b	22.6c	22.9cd
" 1449-2D	14.5e-g	26.7b-d	ne	ne
" 87D-516	12.1f-h	33.7b	8.6h	20.2d
" 1670-3F	27.7bc	27.0b-d	33.9a	36.8ab
" 1660-19F	20.9de	23.2c-e	18.3de	20.3d
" 536-02D	8.8h	20.0de	7.4hi	18.8de
" 849-313D	11.3f-h	26.3b-e	6.9hi	18.6de
MALAYAN	13.8e-h	27.0b-d	ne	ne
TGX 1740-7F	ne	ne	16.6de	19.6d
" 1740-2F	ne	ne	23.1c	25.6b-d
TGM 344	ne	ne	20.5cd	27.3a-d
SE±	1.8	2.62	0.64	3.88

1 Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).
ne = Not evaluated in the trial.

SAMSOY 2, M-351, TGX 1448-2E, TGX 87D-516, TGX 526-02D, TGX 849-313D and MALAYAN in the first trial and TGX 923-2E, M-351, TGX 536-02D and TGX 849-313D in the second trial; also resulted in nodule count comparable to the least with TGX 1019-2EB.

The highest percentage reduction in nodulation by *Alectra* occurred with M-351 and TGX 849-313D (64%) in the first trial and TGX 849-313D (58%) in the second trial (Figures 4 and 5). The cultivars which had high percentage reduction in nodulation due to *Alectra* infection in the two trials (greater than 40%) included TGX 1485-1D, TGX 1019-2EB, TGX 923-2E, SAMSOY 2, M-315, TGX 1479-1E, TGX 87D-516. TGX 536-02D and TGX 849-313D as well as TGX 1448-2E, TGX 1449-1E and MALAYAN in the first trial. Cultivars in which *Alectra* infection caused less than 10% reduction in nodulation were TGX 1681-3F, TGX 1674-3F, TGX 1670-1F, TGX 1670-3F and TGX 1660-19F in the two trials as well as TGX 1636-7F in the first trial. The other cultivars evaluated had moderate reduction in percent nodulation as a result of *Alectra* infection.

1.4.6. **Short Dry Weight per Plant.**

TGX 1670-3F produced the highest shoot dry weight with and without *Alectra* inoculation in the two screen house trials (Table 10). In all the situations, soybean cultivars TGX 1674-3F and TGX 1479-1E produced shoot dry weight comparabe to the highest and significantly higher than the least. In the first trial TGX 1440-1E and TGX 536-02D with and without inoculation as well as TGX 1449-2D without inoculation

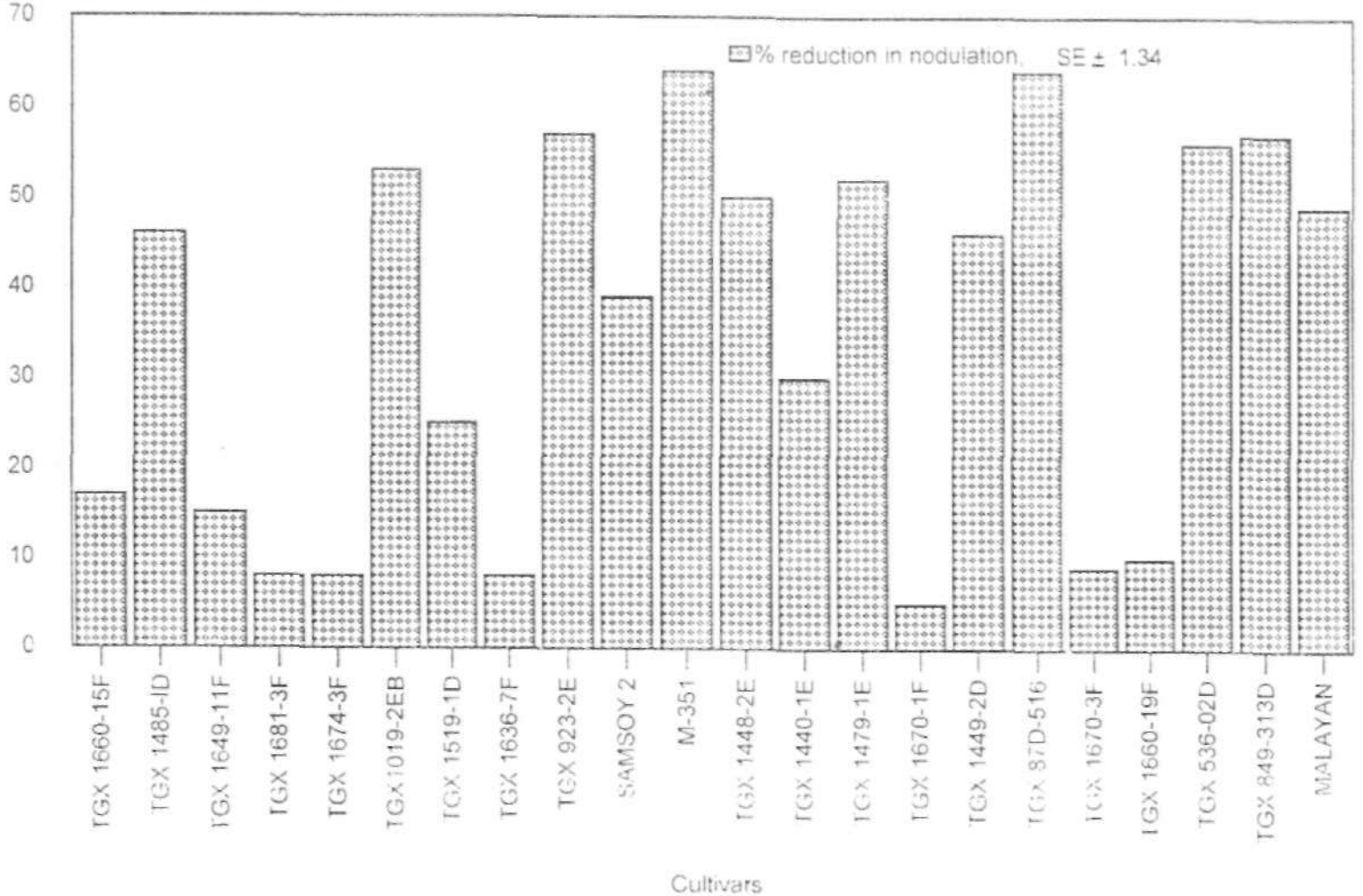


Figure 4: Reaction of soybean cultivars to *Alectra* in the screen house as shown by percentage reduction in nodulation, first trial, Samaru, 1995.

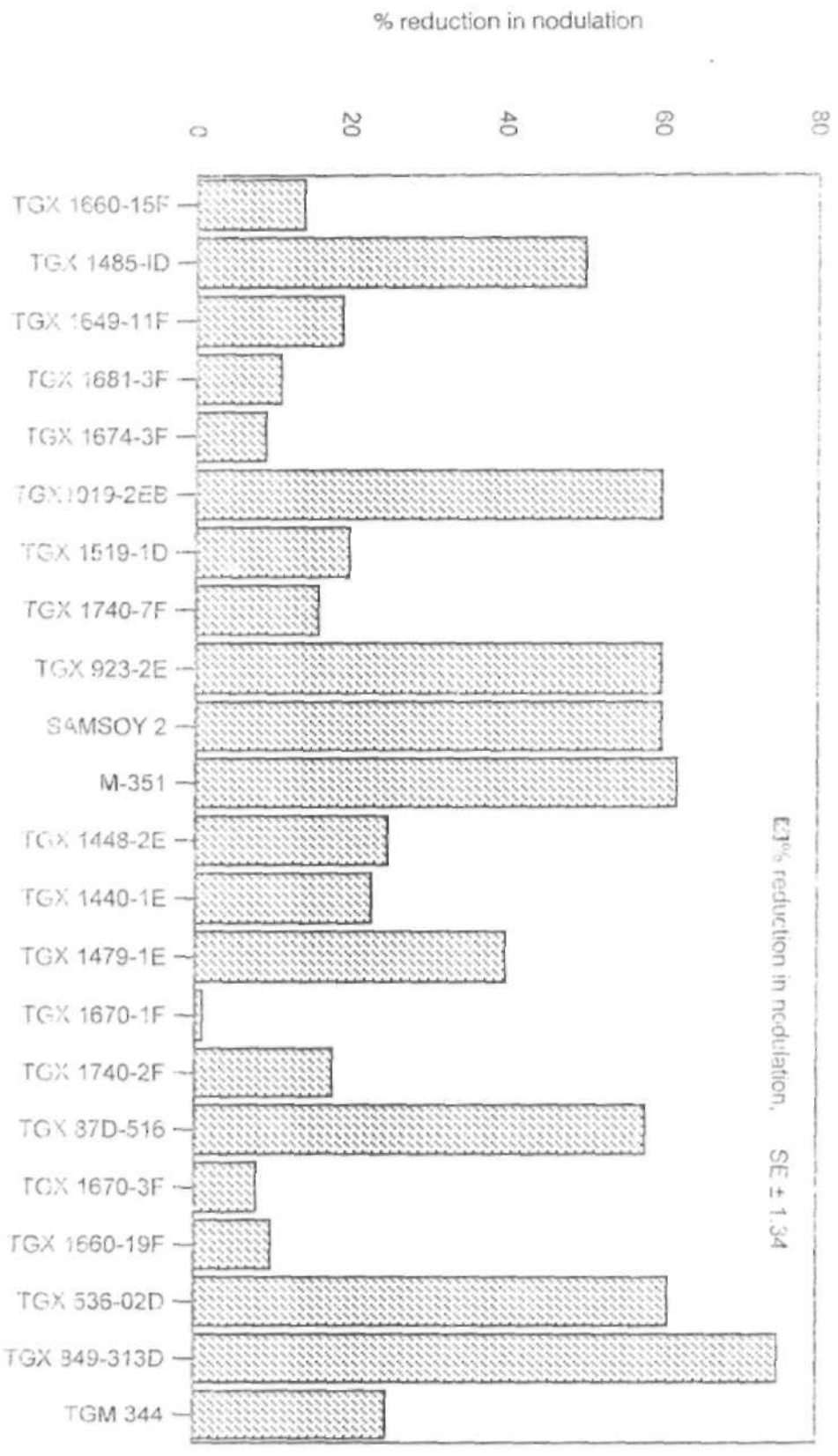


Figure 5. Reaction of soybean cultivars to *Alectra* in the screen house as shown by percentage reduction in nodulation, second trial, Samaru, 1995.

Table 10. Reaction of soybean cultivars to *Alectra* in the screen house as shown by shoot dry weight (g) per plant, first and second trials. Samaru, 1995.

	Shoot dry weight/plant			
	1st trial		2nd trial	
Cultivars.	inoculated.	uninoculated.	inoculated	uninoculated
TGX 1660-15F	6.1c-f[1]	6.8cd	4.7e-i	5.1h
" 485-1D	5.8ef	7.1b-d	4.9d-i	6.5c-e
" 1649-11F	6.5b-f	7.3bc	6.7ab	7.7ab
" 1681-3F	6.1c-f	6.3cd	6.1a-d	6.4c-f
" 1674-3F	7.7ab	7.9a-d	7.0ab	8.2a
" 1019-2EB	4.7g	5.9ef	3.7i	5.2gh
" 1519-1D	5.7ef	6.5cd	5.4c-h	5.0d-h
" 1636-7F	6.3b-f	6.6cd	ne	ne
" 923-2E	3.7h	5.2f	3.9i	5.1h
SAMSOY 2	4.4gh	6.2de	4.2hi	6.1d-h
M-351	4.5gh	6.7cd	4.5f-i	6.5c-e
TGX 1448-2E	6.0d-f	7.2bc	5.3c-g	6.2d-g
" 1440-1E	6.0a-d	8.0ab	5.8b-f	6.4c-e
" 1479-1E	6.8a-d	8.3ab	7.3a-c	8.2a
" 1670-1F	6.2b-f	6.3cd	5.3c-h	5.4f-g
" 1449-2D	6.6b-e	7.8ab	ne	ne
" 87D-516	3.8h	5.4ef	4.0i	5.9c-h
" 1670-3F	8.7a	8.8a	8.0a	8.2a
" 1660-19F	6.2b-f	6.5cd	4.8d-i	5.1h
" 536-02D	7.1ab	8.4a	4.2g-i	5.3gh
" 849-313D	4.4gh	6.6c	4.3g-i	6.1d-h
MALAYAN	5.6f	6.4cd	ne	ne
TGX 1740-7F	ne	ne	5.5b-g	5.8e-h
" 1740-2F	ne	ne	5.9b-e	6.4cd
TGM 344	ne	ne	4.9d-i	5.8e-h
SE±	0.26	0.27	0.38	0.29

1 Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

ne = Not evaluated in the trial.

also produced shoot dry weight comparable to the highest. Similarly, in the second trial TGX 1649-11F with and without inoculation and TGX 1681-3F with inoculation also produced shoot dry weight comparable to the highest. Soybean cultivars, TGX 923-2E produced the least shoot dry weight with and without inoculation in the two trials. TGX 87D-516 was comparable in shoot dry matter production in the two trials both with and without inoculation. In the first trial, SAMSOY 2, M-351 and TGX 849-313D with inoculation and TGX 1019-2EB without inoculation also resulted in shoot dry weight comparable to the least. Similarly, in the second trial, TGX 1660-15F, TGX 1019-2EB, SAMSOY 2, TGX 1660-19F, TGX 536-02D, TGX 849-313D and TGM 344 with and without inoculation, TGX 1485-1D and M-351 with inoculation and TGX 1740-7F without inoculation all produced shoot dry weight comparable to the least.

The highest percentage reduction in shoot dry weight by *Alectra* occurred with M-351 (33%) and SAMSOY 2 (33%) in the first and second trials, respectively (Figures 6 and 7). The cultivars which had high percentage reduction in shoot weight (>15%) due to *Alectra* infection in the two trials included TGX 1485-1D, TGX 1019-2EB, TGX 923-2E, SAMSOY 2, M-351, TGX 1479-1E, TGX 87D-516, TGX 536-02D and TGX 849-313D as well as TGX 1448-2E and TGX 1449-2D in the first trial and TGM 344 in the second trial. Cultivars in which *Alectra* infection caused less than 5% reduction in shoot dry weight were TGX 1681-3F, TGX 1674-3F, TGX 1670-1F, TGX 1670-3F and TGX 1660-19F in the two trials as well as TGX 1636-7F in the first trial. The other soybean cultivars evaluated had moderate percentage reduction in shoot dry weight due to *Alectra* infection.

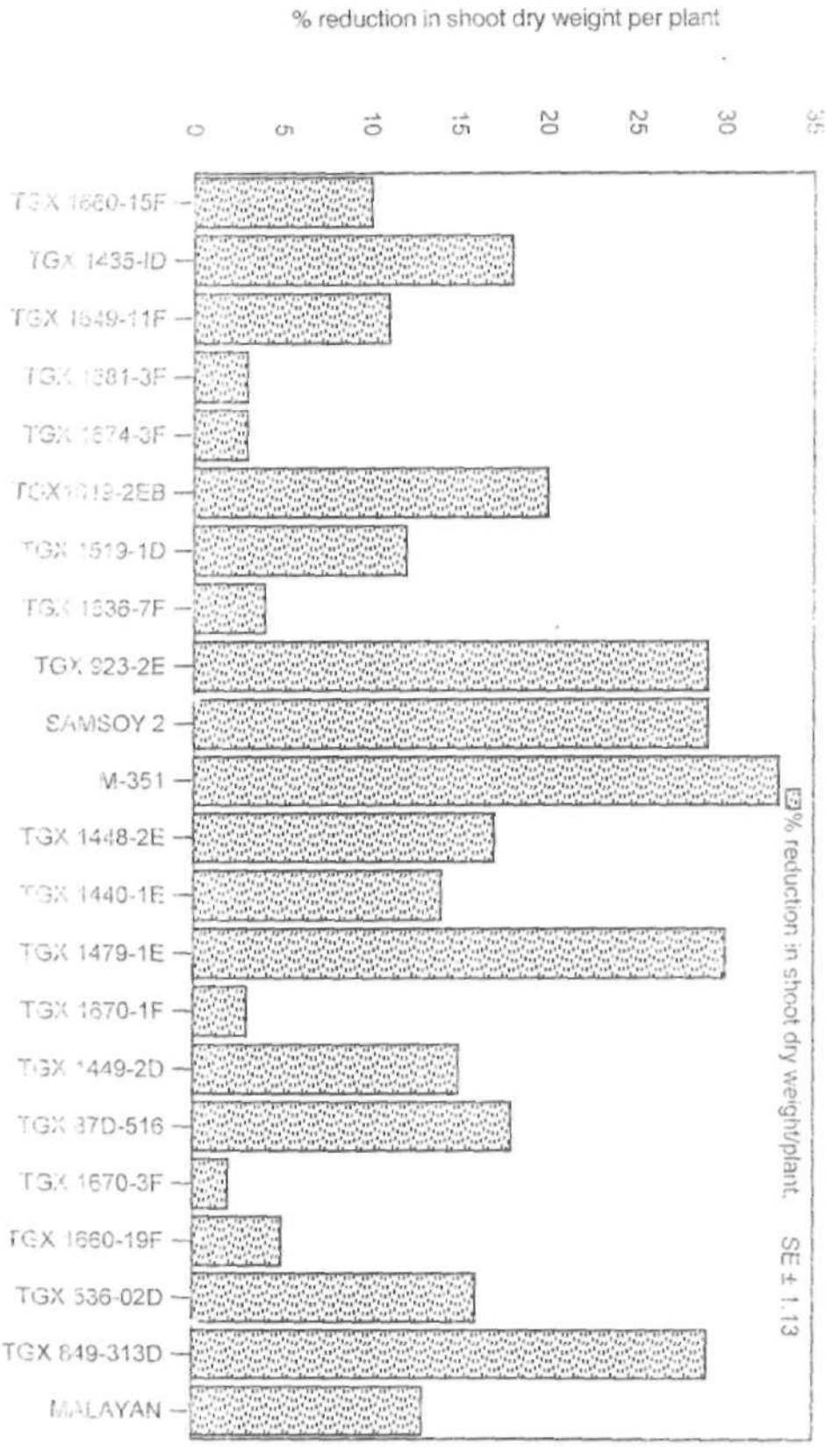


Figure 6. Reaction of soybean cultivars to *Alectra* in the screen house as shown by percentage reduction in shoot dry weight per plant, first trial, Samaru, 1995.

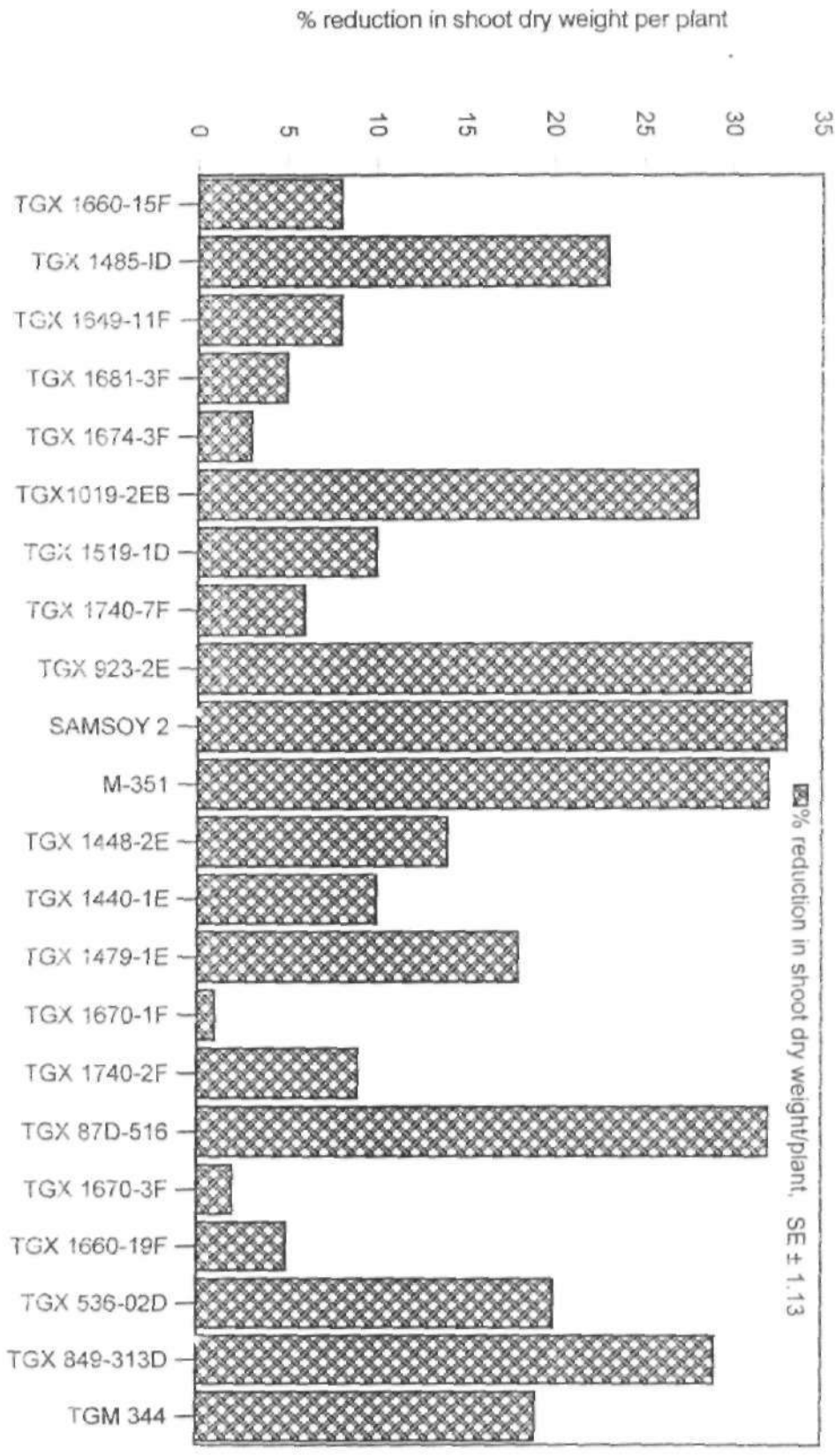


Figure 7. Reaction of soybean cultivars to *Alectra* in the screen house as shown by percentage reduction in shoot dry weight per plant, second trial, Samaru, 1995

4.1.7. **Plant Height**.

The plants of MALAYAN and TGM 344 were the tallest in the first and second trial, respectively (Table 11). Cultivars TGX 1479-1E with and without inoculation, TGX 1670-3F and TGX 1660-19F with inoculation and TGX 1019-2EB, M-351 and TGX 1449-2D without inoculation produced plants comparable to the tallest and were significantly taller than the least in the first trial. Although, none of the cultivars was comparable to TGM 344 in plant height in the second trial, with and without inoculation TGX 923-26, TGX 1479-1E, TGX 1660-19F and TGX 1740-2F produced plant height of 32 to 39cm while without inoculation TGX 1019-2EB, M-351, TGX 1448-2E, TGX 1440-1E and TGX 87D-516 produced plant height greater than 32cm. The shortest plants were produced by TGX 1485-1D in the two trials, while TGX 1660-15F also produced the shortest plants without *Alectra* inoculation. Plants of TGX 1660-15F, TGX 1649-11F and TGX 1681-3F were comparable to the shortest with and without *Alectra* in the first trial. The plants of SAMSOY 2 and TGX 536-02D under *Alectra* infection and those of TGX 1674-3F and TGX 1636-7F without *Alectra* were also comparable to the shortest in the first trial. However, TGX 1660-15F with and without inoculation was comparable to the shortest plants, while TGX 1649-11F and TGX 1740-7F were only comparable without inoculation in the second trial.

The highest percentage reduction in plant height by *Alectra* was observed with TGX 87D-516 (32%) and TGX 849-313D (30%) in the first and second trials, respectively, while the least reduction was observed with TGX 1681-3F, TGX 1636-7F and TGX 1670-1F in the first trial and TGX 1674-3F and TGX 1670-1F in the second

Table 11. Reaction of soybean cultivars to *Alectra* in the screen house as shown by plant height per plant, first and second trials, Samaru, 1995.

	Plant height per plant (cm).			
	1st trial.		2nd trial.	
Cultivars.	inoculated.	uninoculated.	inoculated	uninoculated
TGX 1660-15F	20.7gh[1]	21.7f	19.9hi	20.7h
" 1485-1D	18.0h	21.7f	16.6i	20.7h
" 1649-11F	21.5gh	22.8ef	20.8h	22.0h
" 1681-3F	21.8f-h	22.8ef	22.8g	23.5gh
" 1674-3F	27.8bc	29.2c-f	26.2e-g	26.7fg
" 1019-2EB	28.5b-e	38.7ab	26.8ef	32.8de
" 1519-1D	30.5bc	32.7b-d	29.5de	31.5de
" 1636-7F	24.5d-g	25.7d-f	ne	ne
" 923-2E	28.2b-e	37.5a-c	32.5b-d	38.7b
SAMSOY 2	23.5e-h	31.8b-d	23.2f-h	30.2ef
M-351	27.5c-f	38.7ab	25.6fg	34.2c-e
TGX 1448-2E	28.4b-e	34.2bc	30.5cd	33.3de
" 1440-1E	30.0b-d	34.0b-d	31.0cd	33.7de
" 1479-1E	33.5ab	44.0a	32.7b-d	38.8b
" 1670-1F	32.2bc	33.2b-d	30.8cd	31.7de
" 1449-2D	32.5bc	43.2a	ne	ne
" 87D-516	24.0e-g	35.3bc	25.7fg	33.3bc
" 1670-3F	33.2a-c	34.5bc	30.1cd	31.0de
" 1660-19F	33.5ab	35.2bc	33.5bc	34.5cd
" 536-02D	23.2e-h	30.2c-e	20.5h	26.8fg
" 849-313D	24.7d-g	32.7b-d	22.0gh	31.3de
MALAYAN	38.5a	45.2a	ne	ne
TGX 1740-7F	ne	ne	23.3f-h	24.0gh
" 1740-2F	ne	ne	36.0b	38.3bc
TGM 344	ne	ne	39.7a	43.0a
SE±	1.63	2.41	1.01	1.16

1 Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

ne = Not evaluated in the trial.

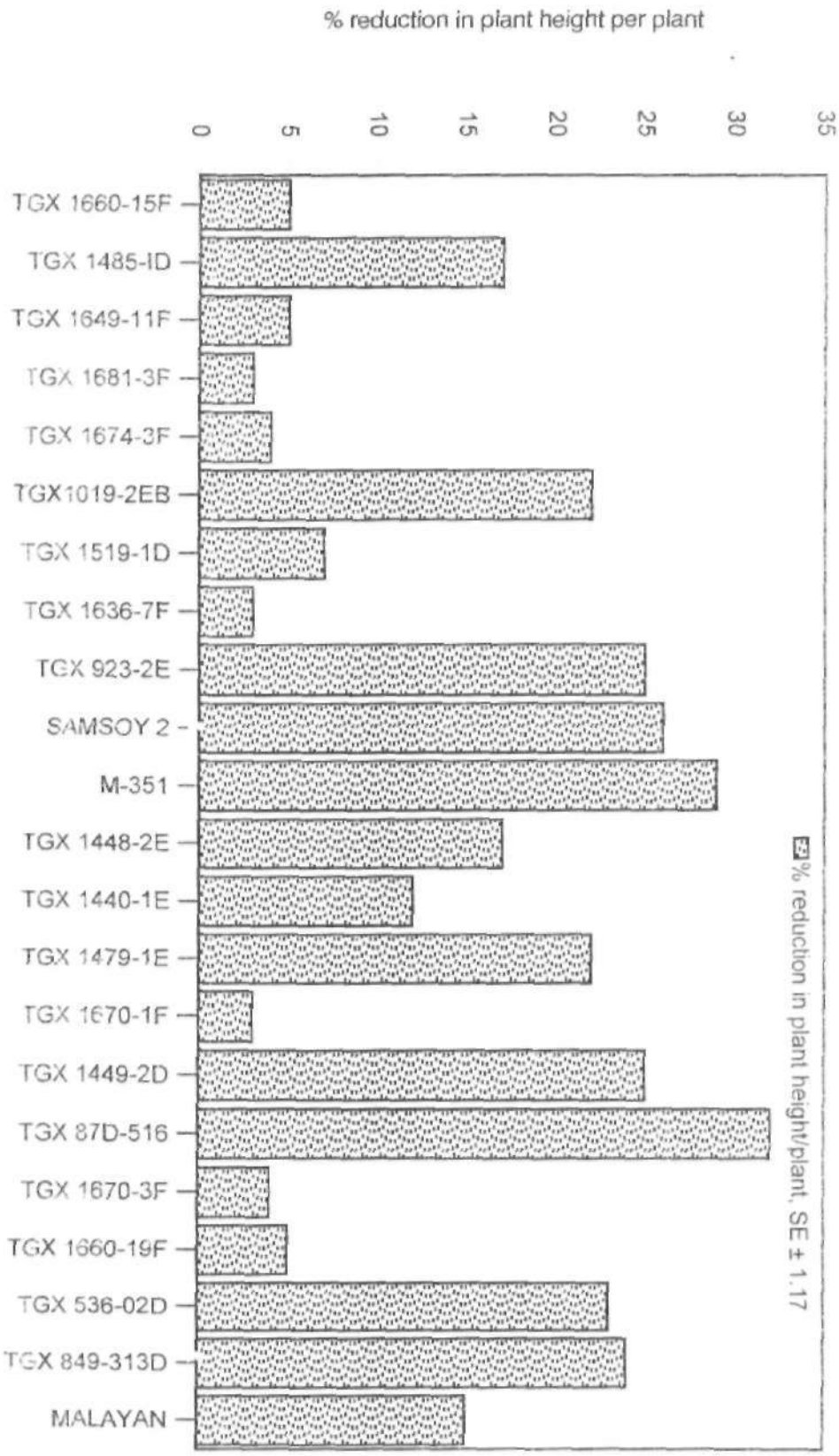
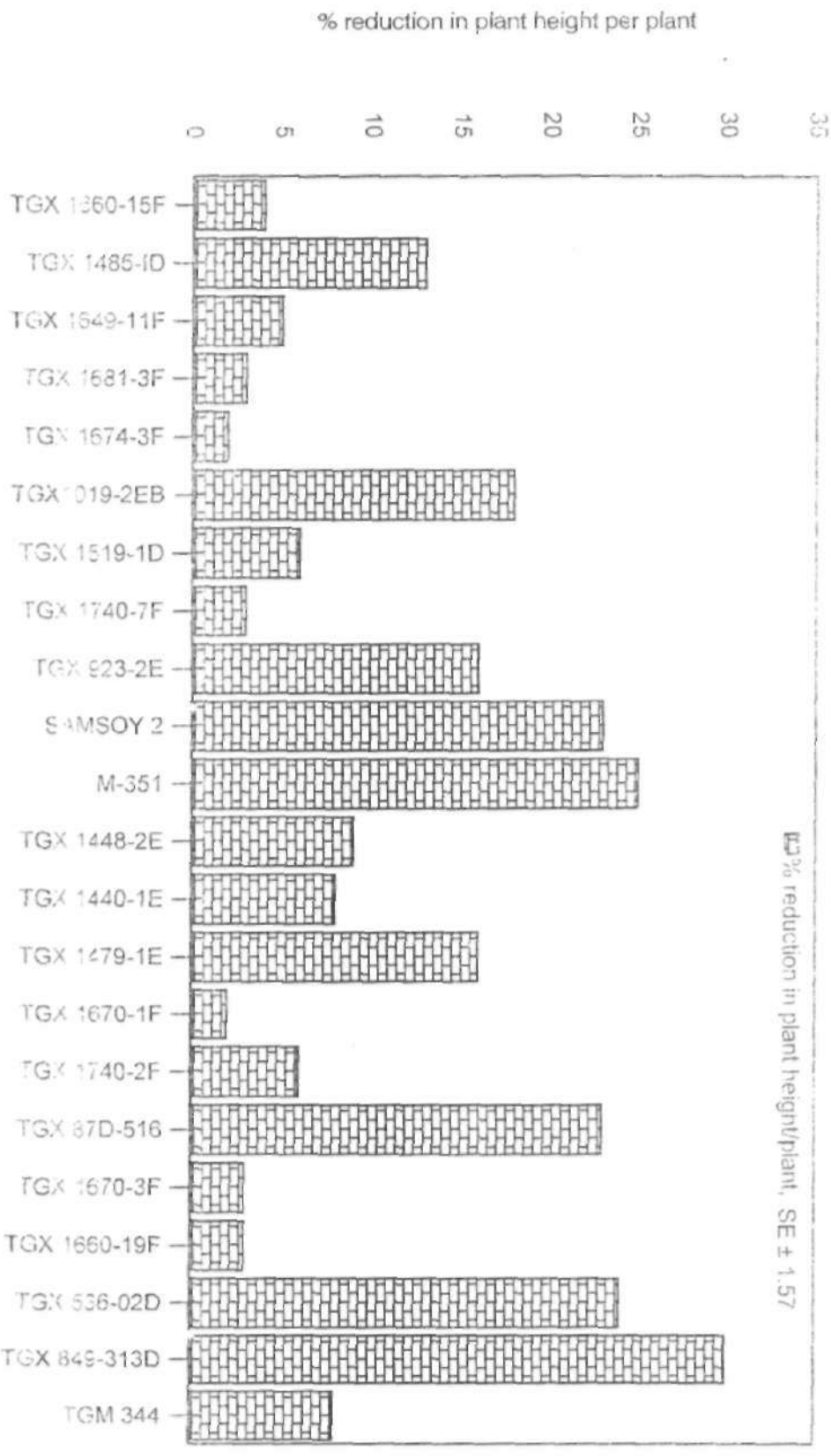


Figure 8. Reaction of soybean cultivars to *Alectra* in the screen house as shown by percentage reduction in plant height per plant, first trial, Samaru, 1995.



Cultivars

Figure 9. Reaction of soybean cultivars to *Aiectra* in the screen house as shown by percentage reduction in plant height per plant, second trial, Samaru, 1995

trial (Figures 8 and 9). *Alectra* infection also caused high reduction in height (>15%) of soybean cultivars TGX 1019-2EB, TGX 923-2E, SAMSOY 2, M-351, TGX 1479-1E, TGX 87D-516, TGX 536-02D and TGX 849-313D in the two trials as well as TGX 1485-1D, TGX 1448-2E and MALAYAN in the first trial. The parasitic weed however caused less than 5% reduction in the heights of cultivars TGX 1660-15F, TGX 1649-11F, TGX 1681-3F, TGX 1674-3F, TGX 1670-1F, TGX 1670-3F and TGX 1660-19F in the screen house trials as well as TGX 1636-7F in the first trial and TGX 1740-2F in the second trial. The other soybean cultivars evaluated had moderate percentage reduction in plant height due to *Alectra* infection.

In the field, naturally infested with *Alectra*, the plant heights varied with varieties and weeks after sowing across the sites and years (Tables 12, 13 and 14). At 4 WAS (Table 12) most of the soybean cultivars except TGX 1440-1E and TGX 1670-1F did not differ from the tallest plants in the field trials. Plants of soybean cultivars TGX 1440-1E at site one in all years and site 2 in 1996 and TGX 1674-3F at site 2 in 1995 produced the shortest plants. TGX 1670-1F at both sites in all years, TGX 1649-11F at site 2 in 1995, TGX 1674-3F at site 1 in 1995 and 1997 and site 2 in 1996, TGX 1019-2EB at both sites in 1995 and site 2 in 1996, TGX 923-2E at site 1 in 1997 and site 2 in 1995, SAMSOY 2 at site 1 in 1997, TGX 1479-1E at site 2 in 1996 and 1997 and TGX 1740-2F at both sites in 1995 were all comparable to the shortest and significantly shorter than the tallest plants.

Table 12. Plant height of soybean cultivars under natural field infestation of *Alectra* at 4WAS, Samaru, 1995, 1996 and 1997 wet seasons.

	Plant height (cm) at 4WAS[1]				
	1995	1995	1996	1996	1997
Cultivars.	*Site 1*	*Site 2*	*Site 1*	*Site 2*	*Site 1*
TGX 1660-15F	17.8a-c[2]	16.7a-e	17.7a-c	17.3a-d	18.8a-c
" 1485-1D	15.9a-d	16.3a-e	17.3a-c	16.2a-d	16.7a-e
" 1649-11F	15.6a-d	14.7b-e	17.3a-c	16.0a-d	16.7a-e
" 1681-3F	16.7a-d	16.7a-e	16.7a-c	16.9a-d	18.0a-d
" 1674-3F	12.8d	12.7e	15.7a-c	14.3bd	14.2de
" 1019-2EB	13.9cd	13.3e	18.8a-c	13.6cd	18.1a-c
" 1519-1D	19.1ab	18.7a-c	18.9a-c	18.0ab	19.5ab
" 1740-7F	16.0a-d	16.3a-e	15.4a-c	15.0a-d	16.7a-e
" 923-2E	15.5a-d	14.7b-e	16.0a-c	15.6a-d	16.0b-e
SAMSOY 2	16.1a-d	16.5a-e	19.0a-c	15.3a-d	16.0b-e
M-351	21.3a	20.4a	19.8a	18.7a	20.0a
TGX 1448-2E	17.2a-d	16.3a-e	15.9a-c	15.3a-d	16.2a-e
" 1440-1E	12.4d	13.3e	14.6c	13.3d	14.1e
" 1479-1E	15.7a-d	15.3a-e	15.0bc	15.0a-d	15.5c-e
" 1670-1F	12.9d	13.3e	14.7bc	14.3b-d	15.3c-e
" 1740-2F	14.5cd	13.7de	16.5a-c	15.3a-d	17.0a-e
" 87D-516	18.9ab	17.7a-d	18.8a-c	17.6a-c	17.2a-e
" 1670-3F	17.3a-d	16.7a-e	17.3a-c	17.0a-d	16.9a-e
" 1660-19F	15.5a-d	14.7b-e	16.9a-c	15.6a-d	16.1b-e
" 536-02D	15.7a-d	16.4a-e	16.9a-c	15.3a-d	16.2a-e
" 849-313D	21.1a	20.3a	19.0ab	18.7a	19.8ab
TGM 344	19.2ab	18.7a-c	19.1ab	18.7a	20.0a
SE±	1.66	1.18	1.25	1.17	1.08
MEAN	16.5	15.9	17.1	16.1	17.0
Interaction					
C x Y	NS	NS	NS	NS	NS

1 WAS = Weeks after sowing.

2 Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

At 8 WAS (Table 13), plants of TGX 1681-3F, M-351, TGX 87D-516, TGX 536-02D, TGX 849-313D and TGM 344 were either the tallest or comparable to the tallest at both sites in all the field trials. However, TGX 1479-1E at both sites in 1995, TGX 923-2E at site 1 in 1995 and both sites in 1996, and TGX 1660-15F, TGX 1519-1D, TGX 1740-7F, TGX 1670-3F and TGX 160-19F at site 1 in 1997 were comparable to the tallest plants. Cultivar SAMSOY 2 produced the shortest plants, while TGX 1649-11F and TGX 1674-3F at both sites in 1995, TGX 1519-1D at both sites in 1996, TGX 1019-2E at both sites in 1995 and at site 2 in 1996 and TGX 1740-7F at site 1 were comparable to the shortest and significantly shorter than the tallest plants.

Plants of soybean cultivars TGX 1674-3F, M-351, TGX 87D-516, TGX 536-02D and TGM 344 were either the tallest or comparable to the tallest at both sites in all field trials at harvest (Table 14). TGX 923-2E, and TGX 1670-3F at both sites in 1995, TGX 1740-2F and TGX 1660-19F at site 1 in 1995, TGX 1019-2E at both sites in 1996 and at site 1 in 1997 and TGX 849-313D at site 1 in 1996 and 1997 were all comparable to the tallest at harvest. SAMSOY 2 at both sites in all years as well as TGX 1485 at site 1 in 1995 and 1997 and at site 2 in 1995 produced the shortest plants. Plants of soybean cultivars TGX 1485-1D, TGX 1649-11F, TGX 1681-3F, SAMSOY 2, TGX 1448-2E and TGX 1670-1F were either the shortest or comparable to the shortest at both sites in all years of the field trials. TGX 1519-1D and TGX 849-313D at site 1 in 1995, TGX 1660-15F at site 1 in 1996, TGX 1440-1E at both sites in 1996 and site 1 in 1995 and TGX 1479-1E at both sites in 1995 and site 2 in 1996 and 1997 were comparable to the shortest and significantly shroter than the tallest plants.

Table 13. Plant height of soybean cultivars under natural field infestation of *Alectra* at 8WAS, Samaru, 1995, 1996 and 1997 wet seasons.

	Plant height (cm) at 8WAS[1].				
	1995	1995	1996	1996	1997
Cultivars.	Site 1	Site 2	Site 1	Site 2	Site 1
TGX 1660-15F	46.7a-e[2]	46.3de	49.5b-g	47.0c-f	49.3c-e
" 1485-1D	35.0ef	32.3h	37.3hi	33.6i	38.0gh
" 1649-11F	41.9c-f	38.3f-h	48.9b-g	42.2f-g	45.5ef
" 1681-3F	50.5a-d	49.7a-d	54.1a-c	50.0a-d	52.9a-d
" 1674-3F	41.1d-f	39.0f-h	46.8b-h	42.9e-h	47.3c-f
" 1019-2EB	41.5d-f	38.3f-h	47.3b-g	37.0g-i	47.4c-e
" 1519-1D	46.0a-e	44.7d-g	40.0g-i	38.3f-i	46.7d-f
" 1740-7F	47.4a-e	46.7c-f	41.5f-i	44.7e-g	47.3c-f
" 923-2E	48.7a-e	47.3b-e	51.3a-f	50.0a-d	50.2cd
SAMSOY 2	31.2f	31.3h	35.2i	33.3i	35.7h
M-351	59.7a	56.0a	59.5a	54.0a	58.4a
TGX 1448-2E	42.1c-f	38.3f-h	43.3d-i	37.0g-i	40.7f-h
" 1440-1E	42.1c-f	37.0f-h	40.1g-i	38.7f-i	40.9f-h
" 1479-1E	50.7a-d	49.7a-d	46.8b-h	47.3c-e	50.1cd
" 1670-1F	39.5d-f	38.0gh	42.4e-i	38.0f-i	40.3f-h
" 1740-2F	44.1b-f	38.7f-h	42.4e-i	37.0g-i	40.0f-h
" 87D-516	55.5a-c	53.3a-c	52.1a-e	51.3a-c	53.5a-c
" 1670-3F	46.3a-e	46.7c-f	45.9c-h	44.0e-h	45.3ef
" 1660-19F	49.3a-d	48.0b-e	45.9c-h	45.3d-g	46.9de
" 536-02D	53.1a-d	50.0a-d	52.9a-d	50.7a-c	52.1a-d
" 849-313D	57.4ab	54.0ab	56.2ab	53.3ab	56.9ab
TGM 344	51.6a-d	50.0a-d	51.1a-f	50.3a-c	52.0a-d
SE±	3.96	1.92	2.82	1.40	1.84
MEAN	46.4	44.9	46.8	45.1	47.7
Interaction					
C x Y	NS	NS	NS	NS	NS

1 WAS = Weeks after sowing

2 Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

Table 14. Plant height of soybean cultivars under natural field infestation of *Alectra* at harvest, Samaru, 1995, 1996 and 1997 wet seasons.

	Plant height (cm) at harvest.				
	1995	1995	1996	1996	1997
Cultivars	Site 1	Site 2	Site 1	Site 2	Site 1
TGX 1660-15F	62.9b-e[1]	53.3ef	51.4g-i	50.7hi	60.9fg
" 1485-1D	43.3f	42.0i	41.8i	43.0j	44.0i
" 1649-11F	53.1d-f	47.3g-i	55.1f-i	46.3ij	49.4hi
" 1681-3F	53.2d-f	49.0g-i	56.2e-i	46.9ij	49.5hi
" 1674-3F	67.3a-d	76.7ab	72.8a-d	72.9ab	73.8a-d
" 1019-2EB	61.1c-e	56.0d-f	70.9a-e	72.9ab	73.4a-d
" 1519-1D	56.1c-f	53.0e-g	68.4b-f	64.7e-g	67.4d-f
" 1740-7F	61.3b-e	63.0cd	66.2c-g	63.3fg	66.7d-f
" 923-2E	67.5a-d	71.0ab	68.5b-e	64.3e-g	67.5d-f
SAMSOY 2	43.3f	42.0i	41.6i	42.0j	44.0i
M-351	75.0ab	70.3ab	81.1ab	73.9ab	80.5a
TGX 1448-2E	49.6ef	45.3hi	49.8hi	46.7ij	50.0hi
" 1440-1E	54.7c-f	52.0e-g	55.7f-i	47.3ij	56.0gh
" 1479-1E	54.8c-f	48.3g-i	56.9e-i	53.6h	49.2hi
" 1670-1F	48.8ef	46.7g-i	56.2e-i	47.3ij	49.5hi
" 1740-2F	64.8a-e	61.3c	63.6d-h	62.0g	64.4ef
" 87D-516	75.7ab	71.3ab	82.3a	73.6ab	76.9a-c
" 1670-3F	67.0a-d	70.3ab	67.6b-f	66.0d-g	66.8d-f
" 1660-19F	64.9a-e	62.3c	65.1d-g	63.3fg	65.3ef
" 536-02D	70.7a-c	70.0ab	83.6a	73.2ab	80.2a
" 849-313D	60.5b-f	57.3de	79.4a-c	70.9b-d	73.4a-d
TGM 344	80.6a	77.3a	85.0a	78.7a	81.7a
SE±	4.95	2.03	4.17	1.65	2.23
MEAN	60.7	57.5	64.4	59.7	63.9
Interaction					
C x Y	NS	NS	NS	NS	NS

1 Means followed by the same letter(s) within a column and among yearly means are not significantly different at 5% level of probability (DMRT).

4.1.8. **Number of Days to Physiological Maturity.**

The highest number of days to physiological maturity was observed with TGM 344 in all the field trials at site 1 and at site 2 in 1995 as well as TGX 1448-2E at site 2 in 1995 and 1996 (Table 15). TGX 1670-3F, TGX 1660-19F and TGX 1448-2E in 1995 and 1996 as well as TGX 1440-1E and TGX 1479-1E in 1995 were comparable to the highest in number of days to physiological maturity at site 1. At site 2 in 1995 and 1996 and site 1 in 1997 none of the cultivars was comparable to the highest as indicated earlier. TGX 1674-3F had the least number of days to physiological maturity in all the field trials. TGX 1485-1D at site 2 in 1995, at both sites in 1996 and site 1 in 1997 and TGX 1740-7F at both sites in 1996 also had the least number of days to physiological maturity. At site 1 in 1995 TGX 1740-2F, TGX 87D-516 also exhibited number of days to physioogical maturity comparabe to the least. The other cultivars evaluated exhibited intermediate maturity of between 100 to 119 days.

4.1.9. **Number of Primary Branches per Plant.**

The highest number of primary branches per pant were produced by TGX 1440-1E in all the years at site 1, TGX 1740-7F and SAMSOY 2 in 1996 and 1997, TGX 923-2E, TGX 1448-2E, TGX 1740-2F and TGX 849-313D in 1996 as well as at site 2 by TGX 849-313D in 1995 and 1996 (Table 16). At site 1, TGX 1660-15, TGX 1485-1D, TGX 1681-3F, TGX 1674-3F, M-351, TGX 1670-1F, TGX 1670-3F, TGX 1660-19F and TGX 536-02D in all years, TGX 1519-1D and TGM 344 in 1995 and 1996, TGX 923-2E, TGX 1740-2F, TGX 87D-516 and TG 849-313D in 1995 and

Table 15. Number of days to physiological maturity of soybean cultivars under natural field infestation of *Alectra*. Samaru, 1995, 1996 and 1997 wet seasons.

	Number of days to physiological maturity.				
	1995	1995	1996	1996	1997
Cultivars.	*Site 1*	*Site 2*	*Site 1*	*Site 2*	*Site 1*
TGX 1660-15F	102ef[1]	100c	101fg	100c	104cd
" 1485-1D	93fg	91e	90i	92d	93f
" 1649-11F	104de	101c	100g	101c	104cd
" 1681-3F	106de	103c	104e	103c	108cd
" 1674-3F	92g	91e	90i	92d	92f
" 1019-2EB	104de	101c	103ef	102c	104cd
" 1519-1D	104de	101c	104e	103c	104cd
" 1740-7F	96e-g	92de	92i	90d	96ef
" 923-2E	117bc	115b	119c	120b	120b
SAMSOY 2	104de	102c	104e	101c	105cd
M-351	113cd	115b	116d	118b	117b
TGX 1448-2E	126ab	127a	128ab	130a	127a
" 1440-1E	126ab	126a	126b	126a	127a
" 1479-1E	126ab	126a	126b	128a	128a
" 1670-1F	102ef	101c	100g	100c	100d
" 1740-2F	96e-g	100c	96h	100c	96ef
" 87D-516	101e-g	98cd	100g	100c	102c-e
" 1670-3F	126ab	126a	128ab	128a	128a
" 1660-19F	126ab	127a	128ab	128a	127a
" 536-02D	105de	101c	104e	102c	104cd
" 849-313D	113cd	116b	115d	119b	114b
TGM 344	127a	127a	129a	129a	130a
SE±	2.64	1.67	0.70	1.51	1.83
MEAN	109	108	109	110	111
Interaction					
C x Y	NS	NS	NS	NS	NS

1 Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

Table 16. Number of branches per plant under natural field infestation of *Alectra*, Samaru, 1995, 1996 and 1997 wet seasons.

	Number of branches per plant.				
	1995	1995	1996	1996	1997
Cultivars.	Site 1	Site 2	Site 1	Site 2	Site 1
TGX 1660-15F	5.3ab[1]	4.3d	6.0ab	5.0b-e	6.7a-c
" 1485-1D	5.7ab	5.0cd	6.3ab	5.0b-e	6.3a-c
" 1649-11F	5.0b	4.7d	6.0ab	4.3cd	7.0a-c
" 1681-3F	6.0ab	6.0cd	6.0ab	5.0b-e	7.3a-c
" 1674-3F	5.3ab	5.0cd	6.0ab	4.7c-e	6.3a-c
" 1019-2EB	5.3ab	4.7d	3.7b	4.7c-e	4.7c
" 1519-1D	5.7ab	5.0cd	5.0ab	4.7c-e	5.0bc
" 1740-7F	7.7ab	6.7a-d	8.3a	6.3a-d	9.0a
" 923-2E	8.7ab	7.3a-c	7.7a	6.0a-e	8.3ab
SAMSOY 2	7.0ab	6.0cd	7.7a	5.3a-e	9.0a
M-351	6.7ab	6.0cd	6.3ab	5.7a-e	5.7a-c
TGX 1448-2E	7.7ab	7.4a-c	8.7a	6.7a-c	8.0a-c
" 1440-1E	10.0a	8.7ab	8.7a	7.0ab	8.7a
" 1479-1E	5.0b	4.3d	5.3ab	4.0e	4.7c
" 1670-1F	8.0ab	7.3a-c	7.3ab	6.3a-d	8.0a-c
" 1740-2F	8.3ab	7.3a-c	7.7a	6.7a-c	7.0a-c
" 87D-516	8.3ab	5.3cd	3.7b	4.7c-e	6.0a-c
" 1670-3F	5.3ab	6.3b-d	7.3ab	5.0b-e	7.7a-c
" 1660-19F	7.3ab	5.3cd	6.0ab	5.0b-e	6.3a-c
" 536-02D	5.7ab	6.0cd	6.0ab	5.0b-e	6.0a-c
" 849-313D	6.3ab	9.0a	8.0a	7.3a	7.3a-c
TGM 344	9.3ab	6.0cd	5.7ab	5.3a-e	4.7c
SE±	1.39	0.72	1.14	0.59	0.98
MEAN	6.7	6.1a	6.5	5.4b	6.8
Interaction					
C x Y	NS	NS	NS	NS	NS

1 Means followed by the same letter(s) within a column and between yearly means are not significantly different at 5% level of probability (DMRT).

1997, TGX 1649-11F in 1996 and 1997 and TGX 1019-2E, TGX 1740-7F, SAMSOY 2 and TGX 1448-2E in 1995 as well as TGX 1740-7F, TGX 923-2E, TGX 1448-2E, TGX 1440-1E, TGX 1670-1F and TGX 1740-2F in 1995 and 1996 and SAMSOY 2, M-351 and TGM 344 in 1996 produced number of branches comparable to the appropriate maximum. At both sites, TGX 1649-11F and TGX 1479-1E in 1995 and TGX 1019-2EB and TGX 87D-516 in 1996 produced the least number of branches. however, at site 1 in 1997, TGX 1019-2EB, TGX 1519-1D, TGX 1479-1E and TGM 344 produced the least number of branches. The other soybean cultivars evaluated were intermediate in the number of branches produced.

4.1.10. **Number of Pods per Plant**.

Number of pods only differed significantly among the cultivars in 1995 and 1996 (Table 17). In the two years, TGX 1440-1E at both sites and TGX 1448-2E at site 2 produced the highest number of pods per plant. At site 1, cultivars, TGX 1660-15F, TGX 1448-2E and TGX 1660-19 in 1995 and 1996, TGX 1019-2EB, TGX 1740-2F and TGX 923-2E in 1995 and TGX 536-02D and TGX 849-313D in 1996, produced number of pods comparable to the highest and significantly higher than the least. The cultivars that produced number of pods in excess of the mean were TGX 1660-15F, TGX 1485-1D, TGX 1649-11F, TGX 1019-2EB, TGX 1740-7F, TGX 923-2E, TGX 1448-2E, TGX 1440-1E, TGX 1740-2F, TGX 1670-3F and TGX 1660-19F in 1995 and 1996 as well as TGX 1670-1F, TGX 536-02D, TGX 849-313D and TGM 344 in 1996. SAMSOY 2 at both sites in 1995 and at site 2 in 1996, TGX 1681-3F and TGX 1674-3F at both sites in 1996, TGX 87D-516 at site 1 in 1995 and TGX 1519-1D and M-351 at

Table 17. Number of pods per plant of soybean cultivars under natural field infestation of *Alectra*, Samaru, 1995, 1996 and 1997 wet seasons.

	Number of pods per plant.				
	1995	1995	1996	1996	1997
Cultivars.	Site 1	Site 2	Site 1	Site 2	Site 1
TGX 1660-15F	54.0a-c[1]	51.3bc	75.7ab	54.7b	63.0
" 1485-1D	48.0bc	47.0b-f	53.7b-d	50.0bc	53.0
" 1649-11F	48.3bc	48.0b-e	50.3cd	50.0bc	44.7
" 1681-3F	43.0bc	40.3gh	34.3e	41.3e	44.0
" 1674-3F	44.0bc	41.7f-h	34.3e	41.0e	45.0
" 1019-2EB	52.7a-c	47.3b-f	50.7c-e	50.0bc	48.0
" 1519-1D	42.0bc	40.3gh	42.7de	40.0e	44.7
" 1740-7F	52.7a-c	51.0bc	49.3c-e	50.0bc	45.3
" 923-2E	53.0a-c	51.7b	55.0b-e	49.7bc	46.0
SAMSOY 2	33.0c	39.3h	51.7b-e	40.0c	56.0
M-351	46.0bc	44.7d-h	47.0c-e	42.7e	56.3
TGX 1448-2E	66.7ab	58.7a	67.0a-d	55.7a	61.3
" 1440-1E	77.3a	60.7a	83.0a	60.7a	61.0
" 1479-1E	40.3bc	40.0gh	47.7c-e	44.0de	49.3
" 1670-1F	45.3bc	41.7f-h	56.7b-e	50.3bc	47.0
" 1740-2F	50.3bc	48.7b-d	48.0c-e	50.0bc	54.0
" 87D-516	35.3c	40.0gh	47.7c-e	44.3de	45.7
" 1670-3F	46.0bc	50.0b-d	52.3b-e	51.0bc	47.3
" 1660-19F	66.7ab	49.3b-d	69.3a-c	52.3bc	63.0
" 536-02D	49.0bc	46.3b-f	60.7a-d	50.3bc	52.3
" 849-313D	49.3bc	45,.3c-g	61.3a-d	48.7cd	54.3
TGM 344	45.7bc	42.3e-g	52.3b-e	49.0cd	50.0
SE±	7.68	1.65	7.04	1.49	5.54
MEAN	49.5	46.6	54.1	48.1	51.9
Interaction					
C x Y	NS	NS	NS	NS	NS

1 Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

site 2 in 1996 produced the least number of pods. The other soybean cultivars evaluated were intermediate in the number of pods produced.

4.1.11. **100 - Seed Weight**.

At site 1, the highest 100-seed weight was produced in 1996 (Table 18). Soybean cultivars, TGX 87D-516 at both sites in 1995, TGX 1485-1D at site 1 in 1996 and 1997 as well as SAMSOY 2 at site 2 in 1996 produced the highest 100-seed weight. TGX 1674-3F at both sites in all years, SAMSOY 2 at both sites in all years except at site 2 in 1996. TGX 1448-2E, TGX 1479-1E, TGX 1670-1F and TGX 1670-3F at both sites in 1996 and at site 1 in 1997, TGX 1440-1E and TGX 87D-516 at both sites in 1996, TGX 1740-2F at both sites in 1995 and at site 1 in 1997 as well as TGX 1485-1D and TGX 1740-7F at site 2 in 1996 produced 100-seed weight comparable to the highest and significantly higher than the least. In contrast, the least 100-seed weight was produced by TGX 1740-7F and TGX 923-2E at both sites in 1995 and by TGX 923-2E at site 1 in 1997, TGX 1681-3F at site 1 in 1996 and site 2 in 1995, TGX 1660-15F, M-351 and TGX 1660-19F at site 2 in 1995 as well as TGX 1660-19F and TGM 344 at site 2 in 1996. Soybean cutivars, TGX 536-02D and TGX 849-313D at both sites in all

Table 18. Seed size of soybean cultivars under natural field infestation of *Alectra*, Samaru, 1995, 1996 and 1997 wet seasons.

	100-seed weight (g).				
	1995	1995	1996	1996	1997
Cultivars.	Site 1	Site 2	Site 1	Site 2	Site 1
TGX 1660-15F	9.5d-f[1]	8.0d	11.7de	9.2d	11.1b-g
" 1485-1D	11.5b-d	10.3b-d	14.3a	11.5a-c	14.1a
" 1649-11F	10.2de	10.0b-d	11.8c-e	10.4b-d	10.9b-g
" 1681-3F	10.3c-e	9.0cd	11.0e	10.0cd	10.6e-g
" 1674-3F	12.3a-c	11.0a-c	12.5a-e	11.5a-c	12.2a-e
" 1019-2EB	9..9de	8.0d	11.7de	10.3cd	10.8c-g
" 1519-1D	10.5c-e	10.0b-d	11.3de	10.0cd	10.2fg
" 1740-7F	7.9f	8.0d	12.0b-e	11.0a-c	10.9b-g
" 923-2E	8.0f	8.3d	11.5de	10.3cd	9.8g
SAMSOY 2	12.5a-c	10.8a-c	13.7a-c	12.3a	12.8ab
M-351	8.5ef	8.0d	11.7de	10.0cd	11.40b-g
TGX 1448-2E	10.9bc	10.3b-d	13.8ab	11.3a-c	12.3a-e
" 1440-1E	10.5c-e	9.3cd	13.2a-d	11.0a-c	11.9b-f
" 1479-1E	10.3c-e	9.0cd	12.7a-e	11.0a-c	12.5a-d
" 1670-1F	11.3b-d	10.3b-d	12.8a-e	12.0ab	12.7a-c
" 1740-2F	12.9ab	11.7ab	12.3b-e	10.0cd	12.3a-e
" 87D-516	13.9a	13.0a	12.5a-e	11.0a-c	11.8b-f
" 1670-3F	9.8d-f	10.0b-d	12.5a-e	12.0ab	12.2a-e
" 1660-19F	8.7ef	8.0d	12.3b-e	10.6b-d	11.9b-f
" 536-02D	9.0ef	10.0b-d	11.8c-e	10.0cd	11.1b-g
" 849-313D	9.0ef	9.0cd	11.5de	10.0cd	11.5b-g
TGM 344	8.5ef	9.0cd	10.7e	9.0d	10.4e-g
SE±	0.57	0.66	0.54	0.47	0.54
MEAN	10.2c	9.6b	12.2a	10.7a	11.6b
Interaction					
C x Y	NS	NS	NS	NS	NS

1 Means followed by the same letter(s) within a column are not significantly different at 5% level probability (DMRT).

years, TGX 1649-11F and TGX 1681-3F at site 1 in 1996 and 1997 and at site 2 in both years, TGX 1660-15F at site 1 and in all years, M-351 and TGX 1660-19F at site 1 in all the years and at site 2 in 1996, TGX 1019-2EB and TGX 1519-1D at site 1 in 1997 and site 2 in both years, TGX 923-2E and TGX 1740-2F at both sites in 1996. TGX 1479-1E and TGX 1670-1F at site 2 in 1995, TGX 1670-3F at site 1 in 1995 as well as TGX 1440-1E at site 2 in 1996 produced 100-seed weight comparable to the least and significantly lower than the highest.

4.1.12. **Seed Yield.**

At site 1, the highest seed yield was produced in 1997 (Table 19). Soybean cultivars, TGX 1660-15F at both sites in 1995, SAMSOY 2 at both sites in 1996 and at site 1 in 1995, TGX 1670-3F at site 1 in 1997 and site 2 in 1995 as well as TGX 1649-11F, TGX 1681-3F, TGX 1674-3F, TGX 1670-1F and TGX 1740-2F at site 2 in 1995, produced the highest seed yield. TGX 1649-11F at both sites in 1995 and 1996, TGX 1674-3F and TGX 1670-1F at site 1 in all years and at site 2 in 1996, TGX 1681-3F, TGX 1740-7F, TGX 1740-2F and TGX 1670-3F at site 1 in 1995 and 1996 and at site 2 in 1996, TGX 1660-15F, TGX 1660-19F and TGX 536-02D at both sites in 1996, SAMSOY 2 at site 1 in 1995 and 1997, TGX 1449-1E at site 1 in 1996 and 1997, TGX 1485-1D and TGX 1448-2E at site 1 in 1996 as well as TGX 1479 at site 2 in 1996, produced seed yield comparabe to the highest. In contrast, the least seed yield was produced by M-351 at site 1 in 1995 and 1996, TGM 344 at site 1 in 1997 and at

Table 19. Seed yield of soybean cultivars under natural field infestation of *Alectra*, Samaru, 1995, 1996 and 1997 wet seasons.

Cultivars.	Seed yield (kg/ha). 1995 Site 1	1995 Site 2	1996 Site 1	1996 Site 2	1997 Site 1
TGX 1660-15F	1889a[1]	1979a	1347a-e	1333a-f	1844b-e
" 1485-1D	1467b-e	1111f-i	1253a-e	1027f-h	1533d-f
" 1649-11F	1778a-c	2296a	1233a-e	1620ab	1822b-e
" 1681-3F	1785a-c	1949a	1533a-e	1527a-d	1789b-f
" 1674-3F	1800ab	1956a	1547a-e	1540a-d	1955a-d
" 1019-2EB	911f-h	963g-i	1033de	813h	1333fg
" 1519-1D	1378c-e	1185e-h	1133b-e	1240c-f	1533d-f
" 1740-7F	1833ab	1444b-f	1633a-c	1413a-e	1600d-f
" 923-2E	1467b-e	1333d-f	1453a-e	1213d-g	1800b-e
SAMSOY 2	1666a-d	1964a	1787a	1673a	1978a-d
M-351	615h	963g-i	987e	1093e-h	1444e-g
TGX 1448-2E	1200ef	1407b-f	1240a-e	1307b-f	1444e-g
" 1440-1E	1289d-f	1296d-g	1320a-e	1267c-f	2089a-c
" 1479-1E	1222ef	1256d-h	1200b-e	1347a-f	1442e-g
" 1670-1F	1800ab	1944a	1547a-e	1493a-d	2199ab
" 1740-2F	1778a-c	1949a	1667ab	1467a-d	1600d-f
" 87D-516	956f-h	852i	1040de	1013f-h	1466e-g
" 1670-3F	1667a-d	1956a	1560a-d	1567a-c	2311a
" 1660-19F	1111e-g	1259d-g	1587a-d	1613ab	1633c-f
" 536-02D	1378c-e	1444c-f	1280a-e	1453a-d	1778b-f
" 849-313D	933f-h	926hi	1093c-e	880gh	1022g
TGM 344	778gh	815i	1027de	1080e-h	1022g
SE±	119.09	104.80	163.43	98.86	131.75
MEAN	1395b	1352	1341b	1317	1665a
Interaction					
C x Y	NS	NS	NS	NS	NS

1 Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

site 2 in 1995, TGX 849-313D at site 1 in 1997 as well as at site 2 by TGX 87D-516 in 1995 and TGX 1019-2EB in 1996. Soybean cultivars, TGX 1485-1D at site 2 in both years, TGX 1019-2EB at site 1 in all years and at site 2 in 1995, TGX 1519-1D at site 1 in 1996, M-351 at site 1 in 1997 and at site 2 in both years TGX 1448-2E at site 1 in 1997, TGX 1479-1E at site 1 in 1996 and 1997 and at site 2 in 1995, TGX 87D-516 at site 1 in all years and at site 2 in 1996, TGX 849-313D at both sites in 1995 and 1996 as well as TGM 344 at site 1 in 1995 and 1996 as well as at site 2 in 1996 produced seed yield comparable to the least.

4.1.13. **Correlation.**

In the first and second screen-house trials, association between crop and *Alectra* parameter and among various parameters are presented in correlation matrices in Tables 20 and 21, respectively. In the two screen house trials, emerged, unemerged and total *Alectra* shoots as well as crop syndrome reaction score in the second trial (Table 21) were negatively correlated to soybean shoot dry weight (r=-0.60, -0.46, -0.61, and -0.59, respectively). Number of days to first *Alectra* emergence and number of nodules per plant were positively correlated with shoot dry weight (r=0.40, 0.64, respectively). Percentage reduction in crop parameters were positively correlated with crop reaction score and *Alectra* emergence in the two trials. *Alectra* parameters except number of days to *Alectra* emergence were positively correlated with each other.

In the field, *Alectra* emergence at 9 and 10 WAS were negatively correlated with 100-seed weight and seed yield of soybean at both sites in all years (Tables 22 to 26).

Table 20. Correlation coefficient between *Alectra* and crop parameters, first screen house trial, Samaru, 1995

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.00											
2	0.58**	1.00										
3	0.96**	0.79**	1.00									
4	0.68**	0.31*	0.62**	1.00								
5	-0.46**	-0.37**	-0.48**	-0.38**	1.00							
6	-0.29*	-0.19	-0.28*	-0.23	0.01	1.00						
7	-0.41**	-0.45**	-0.47**	-0.42**	0.38**	0.16	1.00					
8	0.65**	0.72**	0.75**	0.58**	-0.27*	-0.26*	-0.65**	1.00				
9	-0.48**	-0.41**	-0.51**	-0.22	0.12	-0.07	0.29*	-0.51**	1.00			
10	0.64**	0.62**	0.70**	0.57**	-0.28*	-0.24	-0.53**	0.79**	-0.55**	1.00		
11	-0.09	0.02	-0.06	-0.21	0.06	0.47**	0.21	-0.04	0.19	-0.12	1.00	
12	0.67**	0.75**	0.77**	0.51**	-0.28*	-0.26*	-0.65**	0.92**	-0.55**	0.81*	-0.08	1.00

* significant at 5% level of probability (r= 0.26). ** significant at 1% level of probability (r=0.34).

1 = No. of emerged *Alectra* at 10WAS.
2 = " unemerged " ".
3 = Total No of *Alectra* at 10WAS.
4 = Crop syndrome reaction score
5 = No of days to 1st *Alectra* emergence.
6. = No of days to 1st crop flowering.
7. = No. of nodules/plant.
8. = % reduction in number of nodules/plant.
9. = Shoot dry weight/plant.
10. = % reduction in shoot dry weight/plant.
11. = Plant height/plant.
12. = % reduction in plant height/plant.

Table 21. Correlation coefficient between *Alectra* and crop parameters, second screen house trial, Samaru, 1995.

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.00											
2	0.59**	1.00										
3	0.99**	0.68**	1.00									
4	0.71**	0.70**	0.74**	1.00								
5	-0.49**	-0.55**	-0.52**	-0.56**	1.00							
6	-0.31*	-0.27*	-0.32*	-0.31**	0.15	1.00						
7	-0.69**	-0.67**	-0.72**	-0.75**	0.62**	0.44**	1.00					
8	0.83**	0.78**	0.87**	0.83**	-0.59**	-0.37**	-0.85**	1.00				
9	-0.60**	-0.46**	-0.61**	-0.59**	0.40**	0.18	0.64**	-0.63**	1.00			
10	0.79**	0.74**	0.83**	0.84**	-0.62**	-0.29*	-0.79**	0.94**	-0.66**	1.00		
11	-0.27*	-0.20	-0.28*	-0.15	0.18	0.67**	0.32*	-0.29*	0.12	-0.16	1.00	
12	0.85**	0.68**	0.87**	0.77**	-0.57**	-0.37**	-0.77**	0.93**	-0.56**	0.86**	-0.24	1.00

* significant at 5% level of probability (r= 0.26). ** significant at 1% level of probability (r=0.34).

1 = No. of emerged *Alectra* at 10WAS.
2 = " unemerged " ".
3 = Total No of *Alectra* at 10WAS.
4 = Crop syndrome reaction score
5 = No of days to 1st *Alectra* emergence.
6. = No of days to 1st crop flowering.
7. = No. of nodules/plant.
8. = % reduction in number of nodules/plant.
9. = Shoot dry weight/plant.
10. = % reduction in shoot dry weight/plant.
11. = Plant height/plant.
12. = % reduction in plant height/plant.

Table 22. Correlation coefficients between *Alectra* and crop parameters field trial at site 1, Samaru, 1995 wet season.

	1	2	3	4	5	6	7	8	9	10
1	1.00									
2	-0.31*	1.00								
3	-0.31*	0.99**	1.00							
4	-0.10	0.42**	0.42**	1.00						
5	0.31*	-0.13	-0.13	-0.28	1.00					
6	0.21	-0.17	-0.18	-0.02	0.65**	1.00				
7	0.11	-0.11	-0.09	-0.15	0.28	0.09	1.00			
8	0.11	-0.20	-0.18	-0.08	0.04	0.04	0.47**	1.00		
9	0.15	-0.40**	-0.41**	-0.16	0.41**	0.29**	0.27	-0.14	1.00	
10	0.21	-0.34*	-0.36*	-0.42**	0.39**	0.33**	0.31*	0.41**	0.48**	1.00

* significant at 5% level of probability (r=0.29).
** significant at 1% level of probability (r=0.38)

1. Plant height/plant at harvest.
2. Number of emerged *Alectra* 9WAS.
3. " " " " " 10WAS.
4. " " days to 1st *Alectra* emergence.
5. " " " " Crop flowering.
6. Number of days to physiological maturity
7. " " branches/plant
8. No. of pods/plant.
9. 100-seed weight (g).
10. Seed yield (kg/ha).

Table 23. Correlation coefficients between *Alectra* and crop parameters field trial at site 1, Samaru, 1996 wet season

	1	2	3	4	5	6	7	8	9	10
1	1.00									
2	-0.32*	1.00								
3	-0.30*	0.99**	1.00							
4	-0.30*	0.34**	0.32*	1.00						
5	0.28	-0.19	-0.17	-0.24	1.00					
6	0.26	-0.19	-0.19	-0.13	0.70**	1.00				
7	0.13	-0.17	-0.13	-0.13	0.15	0.17	1.00			
8	0.08	-0.16	-0.13	-0.01	0.22	0.19	0.41**	1.00		
9	0.46**	-0.29*	-0.40**	-0.10	0.29*	0.17	0.03	-0.12	1.00	
10	0.43**	-0.35*	-0.34*	-0.32*	0.30*	0.20	0.37**	0.38**	0.45**	1.00

* significant at 5% level of probability (r=0.29).
** significant at 1% level of probability (r=0.38).

1. Plant height/plant at harvest.
2. Number of emerged *Alectra* 9WAS.
3. " " " " " 10WAS.
4. " " days to 1st *Alectra* emergence.
5. " " " " Crop flowering.
6. Number of days to physiological maturity
7. " " branches/plant
8. No. of pods/plant.
9. 100-seed weight (g).
10. Seed yield (kg/ha).

Table 24. Correlation coefficients between *Alectra* and crop parameters field trial at site 1. Samaru, 1997 wet season.

	1	2	3	4	5	6	7	8	9	10
1	1.00									
2	-0.30*	1.00								
3	-0.28*	0.99**	1.00							
4	-0.24	0.40**	0.41**	1.00						
5	0.25	-0.11	-0.12	-0.10	1.00					
6	0.22	-0.13	-0.05	-0.04	0.64**	1.00				
7	0.36	-0.20	-0.21	-0.11	0.13	0.07	1.00			
8	0.08	-0.10	-0.07	-0.10	0.12	0.10	0.46**	1.00		
9	0.15	-0.35**	-0.29*	-0.14	0.29*	0.16	0.06	-0.14	1.00	
10	0.42**	-0.35**	-0.34*	-0.36**	0.31*	0.28*	0.36**	0.44**	0.49**	1.00

* significant at 5% level of probability (r=0.29).
** significant at 1% level of probability (r=0.38).

1. Plant height/plant at harvest.
2. Number of emerged *Alectra* 9WAS.
3. " " " " " 10WAS.
4. " " days to 1st *Alectra* emergence.
5. " " " " Crop flowering.
6. Number of days to physiological maturity
7. " " branches/plant
8. No. of pods/plant.
9. 100-seed weight (g).
10. Seed yield (kg/ha).

Table 25. Correlation coefficients between *Alectra* and crop parameters field trial at site 2, Samaru, 1995 wet season

	1	2	3	4	5	6	7	8	9	10
1	1.00									
2	-0.29*	1.00								
3	-0.30*	0.99*	1.00							
4	-0.22	0.28*	0.28*	1.00						
5	0.32*	-0.16	-0.15	-0.24	1.00					
6	0.20	-0.06	-0.05	-0.01	0.69**	1.00				
7	0.09	-0.07	-0.06	-0.15	0.32*	0.27	1.00			
8	0.10	-0.20	-0.19	-0.17	0.07	0.22	0.30*	1.00		
9	0.07	-0.28*	-0.28*	-0.14	0.28*	0.20	0.11	-0.11	1.00	
10	0.35*	-0.28*	-0.28*	-0.39**	0.28*	0.26	0.29**	0.34**	0.37**	1.00

* significant at 5% level of probability (r=0.29).
** significant at 1% level of probability (r=0.38).

1. Plant height/plant at harvest.
2. Number of emerged *Alectra* 9WAS.
3. " " " " " 10WAS.
4. " " days to 1st *Alectra* emergence.
5. " " " " Crop flowering.
6. Number of days to physiological maturity
7. " " branches/plant
8. No. of pods/plant.
9. 100-seed weight (g).
10. Seed yield (kg/ha).

Table 26. Correlation coefficients between *Alectra* and crop parameters field trial at site 2, Samaru, 1996 wet season

	1	2	3	4	5	6	7	8	9	10
1	1.00									
2	-0.41**	1.00								
3	-0.30*	0.99**	1.00							
4	-0.33*	0.32*	0.31*	1.00						
5	0.25	-0.22	-0.21	0.01	1.00					
6	0.17	-0.13	-0.22	0.06	0.40**	1.00				
7	0.06	-0.17	-0.18	0.05	0.08	0.09	1.00			
8	0.11	-0.04	-0.03	0.06	0.19	0.15	0.39**	1.00		
9	0.48**	-0.34*	-0.33*	0.23	0.30*	0.30*	0.01	-0.10	1.00	
10	0.38**	-0.36*	-0.36*	0.51**	0.39*	0.30*	0.31*	0.35*	0.42**	1.00

* significant at 5% level of probability (r=0.29).
** significant at 1% level of probability (r=0.38).

1. Plant height/plant at harvest.
2. Number of emerged *Alectra* 9WAS.
3. " " " " " 10WAS.
4. " " days to 1st *Alectra* emergence.
5. " " " " Crop flowering.
6. Number of days to physiological maturity
7. " " *branches/plant*
8. No. of pods/plant.
9. 100-seed weight (g).
10. Seed yield (kg/ha).

Number of days to first *Alectra* emergence was positively correlated to *Alectra* emergence in all field trials. Number of days to crop flowering was positively correlated with number of days to physiological maturity, number of branches per plant was positively correlated with number of pods and seed yield of soybean. Also number of pods per plant and 100-seed weight were positively correlated with seed yield of soybean in all field trials.

The path diagram showing interrelations of seed yield (kg/ha) and some crop parameters at site 1 during 1995-1997 is presented in Figure 10. The direct, indirect and total contributions of some crop parameters on soybean seed yield is presented in Table 27. Out of the total contribution of 0.351 by plant height to seed yield, 0.225 was directly contributed, while the indirect contributions via number of branches and number of pods and 100-seed weight were 0.008, 0.040 and 0.078, respectively. Of the total contribution of 0.350 by number of branches to seed yield, the direct contribution was 0.025 while the indirect contributions via number of pods, plant height and 100-seed weight were 0.199, 0.067 and 0.059, respectively. Number of pods per plant contributed a total of 0.815 to seed yield with 0.442 as direct and 0.342, 0.20 and 0.011 as indirect contributions via 100-seed weight, plant height and number of branches, respectively. Out of a total of 0.836 by 100-seed weight, the direct contribution was 0.489, while the indirect contributions via number of pods and branches and plant height were 0.309, 0.003 and 0.036, respectively.

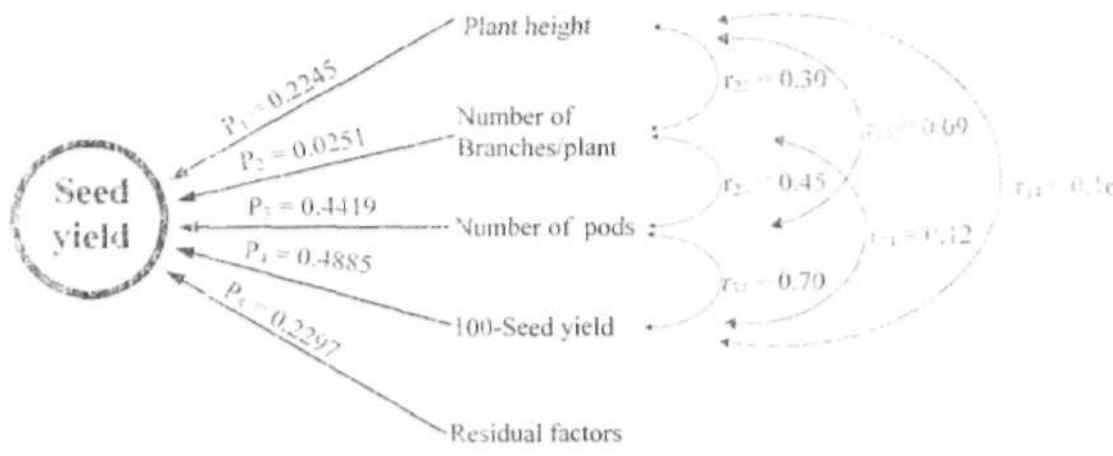


Fig. 10. Path diagram showing interrelations of seed yield (kg/ha) and some soybean parameters under natural field *Alectra* infestation during the 1995-1997 wet seasons (combined analysis) at Samaru.

Table 27. The direct, indirect and total contributions of some crop parameters to seed yield of soybean during the 1995 - 1997 wet seasons (Combined analysis) under *Alectra* infestation at Samaru.

Crop parameters	Contribution
Plant height per plant and seed yield.	
Direct contibution of plant height	0.225
Indirect contribution via number of branches per plant	0.008
Indirect contribution via a number of pod per plant	0.040
Indirect contribution via 100-seed weight	0.078
Total contribution (Direct and Indirect)	**0.351**
Number of branches per plant and seed yield.	
Direct contibution of number of branches per plant	0.025
Indirect contribution via plant height	0.067
Indirect contribution via number of pod per plant	0.199
Indirect contribution via 100-seed weight	0.059
Total contribution (Direct and Indirect)	**0.350**
Number of pods per plant and seed yield.	
Direct contibution of number of pods per plant	0.442
Indirect contribution via plant height	0.020
Indirect contribution via number of branches per plant	0.011
Indirect contribution via 100-seed weight	0.342
Total contribution (Direct and Indirect)	**0.815**
100-seed weight and seed yield.	
Direct contibution of 100-seed weight	0.489
Indirect contribution via plant height	0.036
Indirect contribution via number of branches per plant	0.003
Indirect contribution via number of pods	0.309
Total contribution (Direct and Indirect)	**0.839**

The percentage contribution by individual factors as well as combinations of the factors to seed yield (Table 28), revealed that 100-seed weight and number of pods contributed 23.86 and 19.53%, respectively to seed yield, while contributions by other factors were small (0.06-5.04%). The highest contribution was made by number of pods table 27 in combination with 100-seed weight (30.22%), while contribution by the other combinations was low (0.29-3.51%). The remaning unaccounted residual effects was 14.36%.

4.2. Mechanism of Resistance.

4.2.1. Stimulation of Germination of *Alectra* Seeds.

The percentage of germination of *Alectra* seeds induced by soybean cultivars, cowpea varieties and levels of abscisic acid indicated remarkable significance (Appendix 15 and 16).

In the first trial (Table 29), in all the crop growth stages, significant differences among soybean cultivars were recorded in the stimulation of *Alectra* seed germination (Table 29). Similarly, the germination of *Alectra* seeds was observed to improve with the stage of crop growth used for *Alectra* seed germination. Soybean cultivars, TGX 1019-2EB, SAMSOY 2 and TGX 87D-516 stimulated high germination of *Alectra* seeds at all the stages of crop growth comparable to the highest with the cowpea control, TVX 3236. The cowpea variety, TVX 3236, that was used as the control stimulated lower *Alectra* seed germination than TGX 1674-3F, TGX 1019-2EB, SAMSOY 2, M-351 and TGX 87D-516 when 28 day-old plants were used although the differences were not

Table 28. The percentage contribution of some crop parameters to soybean seed yield during 1995-1997 wet seasons (Combined analysis) under *Alectra* infestation at Samaru.

Crop Parameters	Contributions (%)
Individual Factors	
Plant height	5.03
Number of branches	0.06
Number of pods	19.53
100-seed weight	23.86
Combined Factors.	
Plant height and number of branches	0.34
Plant height and number of pods	1.79
Plant height and 100-seed weight	3.51
Number of branches and number of pods	1.00
Number of branches and 100-seed weight	0.29
Number of pods and 100-seed weight	30.22
Residual effect	14.36
Total	100.00

Table 29. Germination percentage of *Alectra Vogelii* seeds induced by soybean cultivars at 14, 21 and 28 days after sowimg. Samaru, 1997.

	Days after sowing.		
Cultivars.	14	21	28
TGX 1660-15F	13.2bc[1]	51.0ab	81.0cd
" 1485-1D	19.0bc	25.0ab	51.0d
" 1649-11F	0.0c	2.7b	10.0d
" 1681-3F	14.0bc	51.3ab	86.0cd
" 1674-3F	19.3bc	68.7ab	113.0b-d
" 1019-2EB	38.0ab	60.0ab	233.0a-d
" 1519-1D	4.0c	10.0b	16.0d
" 1740-7F	6.0c	7.0b	5.0d
" 923-2E	12.7bc	49.3ab	73.0cd
SAMSOY 2	44.7ab	38.3ab	267.0a-c
M-351	16.7bc	24.3ab	140.0b-d
TGX 1448-2E	13.0bc	22.0ab	41.0d
" 1440-1E	6.7c	18.0b	60.0cd
" 1479-1E	10.0bc	20.0ab	69.0cd
" 1670-1F	0.0c	0.0b	24.0d
" 1740-2F	5.7bc	40.0ab	73.0cd
" 87D-516	35.0ab	65.0ab	300.0ab
" 1670-3F	0.0c	4.3b	14.0d
" 1660-19F	0.0c	0.0b	37.0d
" 536-02D	16.7bc	28.7ab	20.0d
" 849-313D	20.0bc	15.3b	367.0a
TGM 344	22.0bc	61.0ab	93.0b-d
Control TVX 3236	100.0a	100.0a	100.0b-d
SE±	11.64	25.37	71.64

1 Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT).

significant. At all stages of crop growth, soybean cultivars, TGX 1649-11F, TGX 1519-1D, TGX 1740-7F, TGX 1448-2E, TGX 1440-1E, TGX 1670-1F, TGX 1670-3F and TGX 1660-19F, stimulated significantly lower *Alectra* seed germination than the highest with the TVX 3236 control at 14 and 21 DAS and TGX 849-313D at 28 DAS. The indicated soybean cultivars which stimulated low *Alectra* seed germination were the only cultivars with TGX 849-313D which stimulated low germination when 21 day-old plants were used. Using 14 day-old plants, most soybean cultivars stimulated lower *Alectra* seed germination than the TVX 3236 control. Soybean cultivars, TGX 1649-11F, TGX 1670-1F, TGX 1670-3F and TGX 1660-19F did not stimulate *Alectra* seed germination, while most cultivars except TGX 1019-2EB, SAMSOY 2 and TGX 87D-516 were comparable. Cultivar, TGX 849-313D stimulated the highest *Alectra* seed germination, while SAMSOY 2, TGX 87D-516 and TGX 1019-2EB were comparable when the roots of 28 day-old plants were used for *Alectra* seed germination stimulation. All the other cultivars including TGX 1019-2EB were comparable to the least obtained with TGX 1740-7F in *Alectra* seed germination stimulation.

In the second trial, when roots of 21 day-old plants were used soybean cultivars, TGX 1485-1D stimulated the highest *Alectra* seed germination (Table 30). The soybean cultivars, TGX 1440-1E, TGX 1019-2EB and SAMSOY 2 as well as abscisic acid (ABA) at 100 and 200 ppms stimulated high *Alectra* seed germination, although the differences were not significant. SAMSOY 2 stimulated the highest germination of *Alectra* seeds when 28 day-old plants were used. Only cowpea variety SAMPEA-7 stimulated comparable *Alectra* seed germination to SAMSOY 2. The other soybean cultivars and

Table 30. Germination percentage of *Alectra vogelii* seeds induced by soybean cultivars, cowpea varieties and concentrations of ABA at 21 and 28 days after sowing, Samaru, 1998.

Cultivars	Days after sowing	
	21	28
TGX 1681-3F	0c[1]	32b
" 1740-2F	9bc	44b
" 1440-1E	157a-c	75b
" 1485-1D	446a	66b
" 1019-2EB	309ab	56b
SAMSOY 2	82a-c	255a
100 ppm ABA	290ab	63b
200 " "	192a-c	50b
400 " "	83a-c	29b
TVX 3236	10bc	59b
SAMPEA 7	67a-c	100ab
SE±	151.34	53.04

1. Means followed by the same letter(s) within a column are not significantly different at 5% level of probability (DMRT)

the cowpea variety TVX 3236 as well as ABA at all concentrations stimulated lower *Alectra* seed germination than SAMSOY 2 with the 28 day-old plants.

4.3.0. **Control of *Alectra* using Anti-transpirants**.

4.3.1. **Effects of Soybean Cultivars and Concentration of Abscisic acid on *Alectra vogelii***.

Significance of *Alectra* and crop parameters of soybean as affected by anti-transpirants are indicated in the mean squares from analysis of variance in Appendix 17 and 18.

Results on crop cultivars and *Alectra vogelii* as affected by concentrations of abscisic acid are presented in Table 31.

4.3.1.1. **Number of Live *Alectra* Shoots.**

Soybean cultivar, TGX 1019-2EB supported significantly more live *Alectra* shoots than other cultivars evaluated while TGX 1440-2E and TGX 1519-1D supported the least number. TGM 344 and M-351 did not differ significantly in the number of live Alectra shoots but were statistically different from TGX 1519-1D and TGX 1440-1E. No change in the number of live *Alectra* shoots were observed on all the cultivars at two weeks after the application of abscisic acid. Using light microscope it was observed that the stomata of the leaf of *Alectra* plants remained open for the two weeks period after the application of ABA.

4.3.1.2. **Number of Days to First *Alectra* Emergence**.

The highest number of days to *Alectra* emergence was observed on TGX 1440-1E. TGX 1519-1D was comparable to TGX 1519-1D in the number of days

to *Alectra* emergence, while TGX 1019-2EB was comparable to M-351. TGM 344 supported the earliest emergence of the parasitic weed on soybean.

4.3.1.3. **Number of Days to Crop Flowering**.

Number of days to crop flowering was highest on the medium maturing soybean cultivar TGM 344. Although, none of the cultivars were comparable to TGX 344 in number of days to crop flowering, M-351 took 50 days to reach crop flowering and was significantly higher than the least. Also, TGX 1019-2EB was significantly higher than

Table 31. Effect of variety and abscisic acid concentrations on the number of live *Alectra* at 9 and 11 WAS, number of days to first *Alectra* emergence and first crop flowering in the screen house, Samaru, 1997.

Cultivars.	No. of live *Alectra* before ABA app. 9WAS[1]	No. of live *Alectra* after ABA app. 11WAS	No of days to 1st *Alectra* emergence.	No. of days to 1st crop flowering.
TGX 1019-2EB	8.4a	8.4a	44c	42c
TGX 1440-2E	0.3c	0.3c	50a	41d
TGM 344	2.3b	2.3b	38d	54a
TGX 1519-1D	0.3c	0.3c	48ab	41d
M-351	3.1b	3.1b	46bc	50b
SE±	0.61	0.61	0.77	0.23
ABA Conc. (ppm)				
0	1.6b	1.6b	45	46
100	3.1ab	3.1ab	45	46
200	4.4a	4.4a	45	45
400	2.3b	2.3b	47	45
SE±	0.55	0.55	0.69	0.21
Interaction				
V x C	NS	NS	NS	NS

1 WAS = weeks after sowing.
2 Means followed by the same letter(s) within a column are not statistically different at 5% level of probability (DMRT).

the least in the number of days to crop flowering. TGX 1440-1E and TGX 1519-1D supported earliest flower emergence in the crop.

4.4.2. Effect of Local Sources of Anti-transpirants on *Alectra vogelii* in Soybean.

The number of *Alectra* shoots did not differ significantly before the application of the anti-transpirants (Table 32). Both paraffin and shea butter resulted in significantly higher death of *Alectra* shoot plants at 5 and 10 days after application compared with the control (Table 32 and Plates I-XIV). Both vaseline and Talc-magnesite also caused significantly lower *Alectra* death than the highest with paraffin at 5 days after application. although percentage dead *Alectra* plant was only lower with Talc-magnesite. All the anti-transpirants caused similar percentage dead *Alectra* plant compared with the control at 10 days after application. The control did not result in the death of *Alectra* shoots throughout the period of the investigation.

Table 32. Effect of local sources of anti-transpirants on the number of live, dead and percentage of dead *Alectra* shoot at five and ten days after application in the screen house. Samaru. 1997.

Local anti-transpirants.	Number of *Alectra* plants at application.	No. of dead *Alectra* plants		Percentage of dead *Alectra* plant	
		5DAA[1]	10DAA	5DAA	10DAA
Control-distil water	13.0	0.0c[2]	0.0b	0.0c	0.0
Gum arabic	12.3	7.3abc	11.0ab	68.3ab	84.3a
Kaoline	12.5	7.8abc	10.3ab	66.5ab	91.3a
Vaseline	10.8	3.8bc	5.5ab	59.3ab	68.8a
Shea butter	11.3	10.5ab	11.3ab	90.3a	100.0a
Talc-magnesite	15.5	5.3bc	10.0ab	34.0bc	70.5a
Paraffine	13.8	13.5a	13.8a	98.0a	100.0a
SE±	4.49	2.39	3.35	14.05	11.32

1 DAA = Days after application of anti-transpirants

2 Means followed by the same letter(s) within a column are not statistically different at 5% level of probability (DMRT).



Plate 1: 5DAA

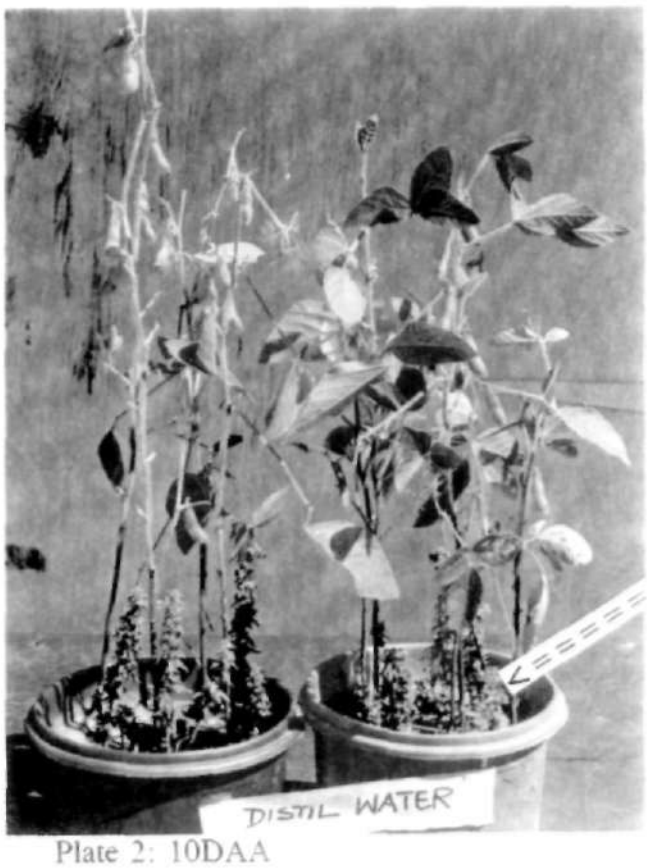


Plate 2: 10DAA

Effect of distilled water on *Alectra* plants
= = = = = > *Alectra* **Plant**



Plate 3: 5DAA



Plate 4: 10DAA

Effect of gum arabic on *Alectra* plants
= = = = = > *Alectra* **Plant**

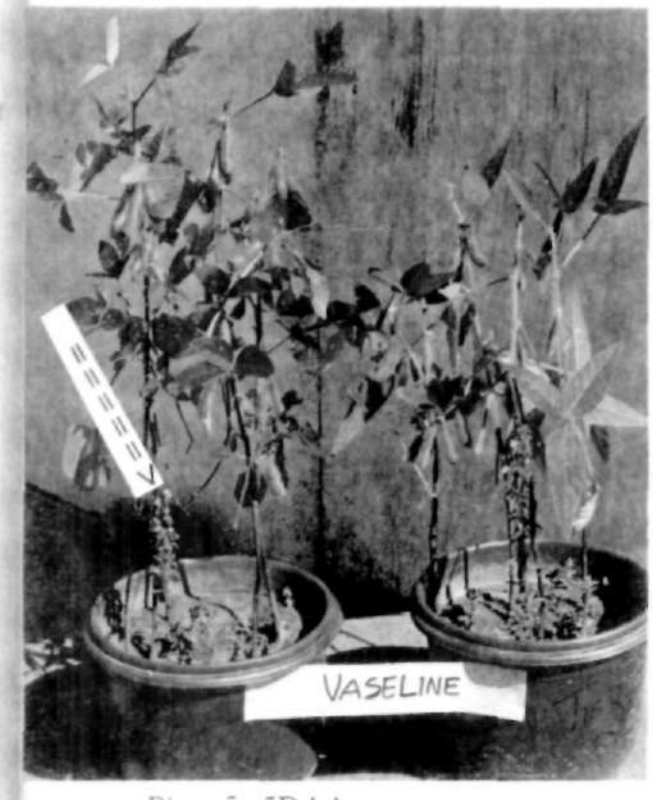


Plate 5: 5DAA



Plate 6: 10DAA

Effect of vaseline on *Alectra* plants
= = = = = > *Alectra* Plant

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Plate 7: 5DAA

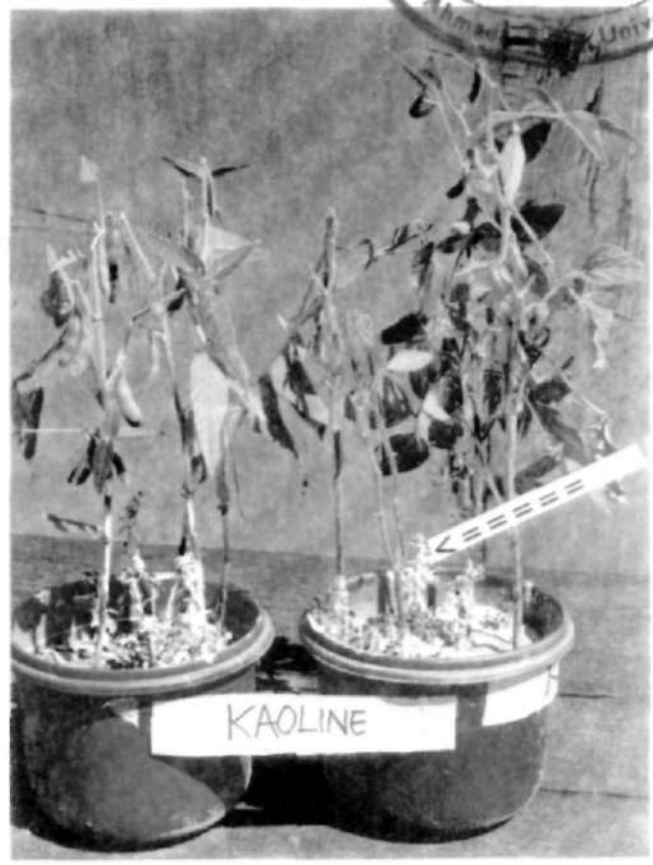


Plate 8: 10DAA

Effect of kaoline on *Alectra* plants
= = = = = > *Alectra* Plant



Plate 9: 5DAA



Plate 10: 10DAA

Effect of shea butter oil on *Alectra* plants
= = = = = > ***Alectra* Plant**



Plate 11: 5DAA

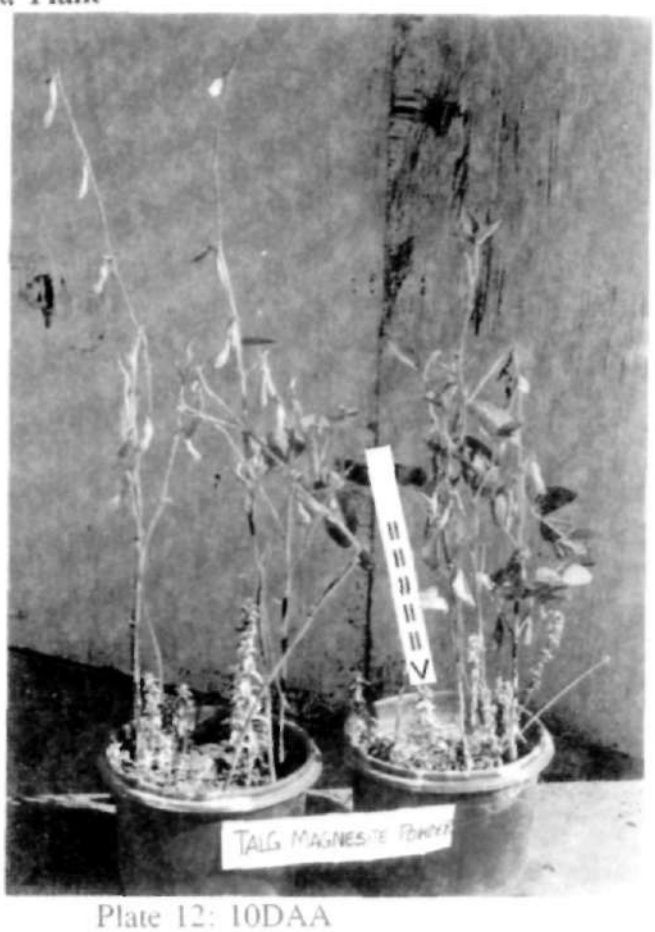


Plate 12: 10DAA

Effect of talc-magnesite on *Alectra* plants
= = = = = > ***Alectra* Plant**



Plate 13: 5DAA

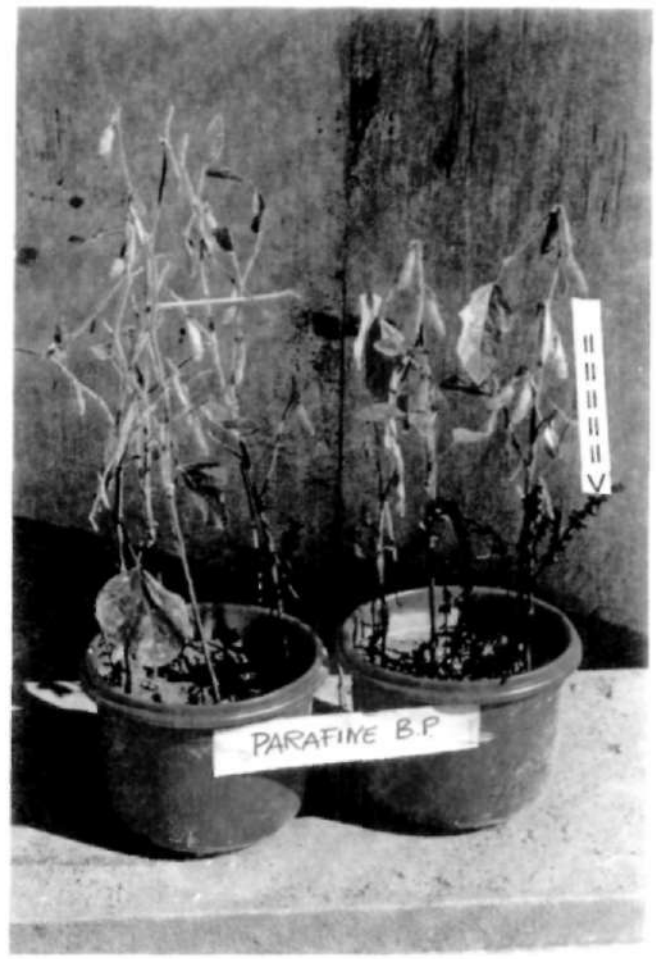


Plate 14: 10DAA

Effect of paraffin oil on *Alectra* plants

= = = = = > ***Alectra*** **Plant**

CHAPTER FIVE

5.0 DISCUSSION.

The seed yields of 1.4, 1.3 and 1.7t/ha obtained under natural *Alectra* field infestaation in 1995, 1996 and 1997 (Table 19), respectively in this study were lower than 2.9, 2.1 and 2.7t/ha obtained from soybean at sites free of *Alectra* infestation in the corresponding years by Olufajo (1995, 1996) and Chiezey (1997). *Alectra* infestation at sites of the trials was probably responsible for the low yields of soybean obtained. Reduction of host productivity by a similar hemiparasitic weed, *Striga* was earlier attributed to the export of carbon from the host to the parasite as well as parasite - induced reduction in host photosynthesis (Stewart *et al.* 1991). Similarly, Butler and Ejeta (1997) suggested that the diminished productivity of *Striga* - infested crops was due to toxic effects of *Striga* on the host in addition to diversion of water, nutrients and photosynthates of the host. Reduction in seed yield due to *Alectra* infestation have been reported in soybean (Kureh *et al.*, 1994a; 1994b) and cowpea (Lane, *et al.*, 1991, Sauerborn, 1992, Magani, 1994, Lagoke *et al.*, 1996).

5.1.1 Reaction of Soybean Cultivars to *Alectra*.

In all the trials, soybean cultivars TGX 1649-11F, TGX 1681-3F, TGX 1674-3F, TGX 1670-1F, TGX 1670-3F and TGX 1660-19F supported low *Alectra* shoot emergence both in the screen house (Tables 1 and 2) and the field (Tables 3 and 4). These cultivars also produced high soybean seed yields that were significantly higher than the least in all the trials under natural *Alectra* field infestation (Table 19). These results

confirmed earlier reports by Lane and Bailey (1991), Magani (1994) who found that the *Alectra* resistant cowpea variety B301 and its derivatives produced seed yield that were comparable to the highest under *Alectra* infection. Reduction in nodulation (Figures 4 and 5), shoot dry matter production (Figures 6 and 7), plant height (Figures 8 and 9) and days to first crop flowering (Figure 3) in the screen house trials were observed to be low as *Alectra* emergence was delayed. This was probably responsible for the high seed yield recorded in these *Alectra* resistant cultivars. Earlier reports had indicated that any factor that prevents high reduction in nodulation and growth in soybean (Chiezey, 1990; Kureh *et al*., 1994b; 1994c; Olufajo, 1996) and cowpea (Whitney, 1975; Emechebe and Singh, 1989; Magani, 1994) would definitely increase seed yield of the crops. In the present study, it was apparent that the *Alectra* resistant soybean cultivars were not completely immuned from the effect of the parasite as low reduction in shoot dry weight, plant height, nodulation as well as days to first crop flowering were observed. Similarly, Magani (1994) reported low reduction in crop growth, nodulation and days to first crop flowering in *Alectra* resistant cowpea varieties. TGX1636-7F, which was evaluated only in the first screen house trial, was also observed to support low Alectra shoots and exhibited low crop syndrome reaction score. Kureh *et al* (1994b) earlier reported that under natural field infestation, TGx1636-7F exhibited resistance through support for low *Alectra* shoot emergence and the production of seed yield comparable to the highest.

TGX1740-7F and TGX1740-2F which were evaluated only in the second screen house and all the field trials supported low to moderate *Alectra* shoot count and exhbited low crop syndrome reaction score (Table 5). These soybean cultivars also delayed

Alectra shoot emergence (Table 5) and produced seed yield comparable to the highest and significantly higher than the least in all the field trials. This suggested low to moderate resistance to *Alectra* due to delayed *Alectra* emergence as earlier reported on soybean (Kureh *et al*., 1994b; 1994c) and cowpea (Magani, 1994).

A combination of high seed yield potential and low support for *Alectra* emergence by the *Alectra* resistant soybean cultivars make them suitable candidates for use to improve the genetic base of existing cultivars and the varieties being developed for *Alectra* resistance/tolerance. Several authors (Emechebe and Singh, 1989; Lagoke *et al*., 1993, Kureh and Katung, 1993; Magani, 1994; Singh and Emechebe, 1997) have indicated that the use of host plant resistance for parasitic weed management is a more plausable approach for parasitic weed control.

The soybean cultivars, SAMSOY 2, TGX1485-1D, TGX1660-15F, TGX1440-1E, and TGX536-02D recommended for production, exhibited appreciable level of tolerance to *Alectra* parasitism in this study. Inspite of support for high *Alectra* emergence in all the trials (Tables 1-4) and moderate to high reduction in nodulation, shoot dry matter production, plant height and days to first crop flowering in the screen house trials with *Alectra* infection, these cultivars produced seed yield comparable to the highest in the field trials (Table 19).

SAMSOY 2 was observed to produe low pod number but high 100-seed weight. The tolerance of this cultivar might be due to high yield potential which SAMSOY 2 achieved through reduction in pod number but compensated for in seed size which consequently increased seed yield of the crop. Being a medium maturing cultivar,

SAMSOY 2, still produced adequate leaves for the production of assimilates for seed filling at the later stage of the life-cycle inspite of the adverse effect of *Alectra* infection. The production of heavy seeds by SAMSOY 2 and the apparent delay in *Alectra* emergence, were responsible for the tolerance of TGX1485-1D to *Alectra* parasitism. Similar observations had been reported by Magani (1994) and Lagoke *et al* (1996) on cowpea variety 'KANO 1696'. They attributed the high seed yield to the production of heavy seeds inspite of support for high *Alectra* shoot emergency.

A high yield potential exhibited through the production of high number of branches and pods and the delay in *Alectra* emergence were observed as being responsible for the tolerance of TGX1660-15F, TGX1440-1E and TGX536-02D to *Alectra* parasitism. Possibly a delay in the production of adequate germination stimulant might be suggested as being responsible for the delay in *Alectra* emergence as earlier reported on cowpea *Alectra* (Magani, 1994). A high yield potential inspite of high *Alectra* shoot emergence exhibited by tolerant cultivars would be a major agronomic and economic consideration in cultivars' adoption. Several authors (Singh and Emechebe, 1991; 1997; Kim, 1991; Adetirimin *et al.*, 1997) have indicated that the use of tolerance varieites in combination with other control measures help in the depletion of *Alectra/Striga* soil seed bank. Furthermore, they also reported that tolerance is a more durable resistance because it is controlled by multiple genes.

Soybean cultivars, TGX1019-2EB, M-351, TGX87D-516, TGX849-313D and TGM344 exhibited susceptibility to *Alectra* parasitism through support for high *Alectra* shoot emergence in all the trials, high reduction in nodulation, shoot dry matter

production and days to first crop flowering with *Alectra* infection in the screen house trials and poroduction of low seed yields under *Alectra* infestation in the field (Table 19). In the screen house trials *Alectra* infection caused 53 to 75% and 17 to 33% reduction in nodulation and shoot dry weight (Figures 4 and 5, 6 and 7), respectively in these susceptible soybean cultivars. Stewart *et al* (1991) found that *Striga hermonthica* reduced the shoot and grain weights of sorghum by 66 and 96%, respectively while 65% reduction in shoot dry weight and complete loss of grain was observed in maize.

The reduction in shoot dry weight and plant height with *Alectra* infection in the screen house trials (Figures 6 and 7, 8 and 9, respectively) may therefore be attributed to the transport of metabolites from the host to the parasite and reduction in the photosynthesis of the host as earlier observed by Stewart *et al* (1991). The authors had earlier observed that the rates of carbon dioxide fixation and respiration were generally low and high, respectively in the parasitic weed *Striga* and that there was little or no net gain in carbon assimilation. Experimental evidence also indicate that 34 to 42% of the carbon in mature *Striga* plants is host derived and this accounted for 80% reduction in host growth (Stewart *et al.*, 1991).

The high reduction in nodulation with *Alectra* infection in the susceptible soybean cultivars (Figures 4 and 5) suggests that *Alectra* and nodules compete for nodule sites for attachment. Kureh *et al* (1994a; 1994b) and Magani (1994) have similarly reported reduction in the nodulation of *Alectra* infected soybean and cowpea, respectively. These findings supported the hypothesis that suggests that *Alectra* and nodules compete for nodule sites for attachment (Emechebe, 1981). *Alectra* inoculation induced early

flowering in susceptible soybean cultivars. Reduction in number of days to first flowering of soybean and cowpea by *Alectra* infection have also been reported by a number of workers (Kureh *et al.*, 1994a, Magani, 1994; Wegmann, 1996). Wegmann (1996) reported that root parasitic flowering plants affect hormonal balance with a resultant increase in the synthesis of gibberellic acid (GA) that induce early flowering. Furthermore, he observed that the parasite produced water stress situation in the host root which induced the production of phytochrome abscisic acid that changes the physiology of the whole plant, consequently there is reduced photosynthesis and enhanced maturation.

5.1.2. **Correlation and Path Co-efficient Analysis**.

The negative correlation of emerged *Alectra* shoots with number of branches per plant, 100-seed weight and seed yield of soybean in all the field trials, the correlation of *Alectra* parameters with the crop parameters in the screen house trials are indications of the vunerability of the parameters to *Alectra* parasitism. Negative correlation of emerged *Alectra* shoots with the yield and yield components as well as crop parameters of cowpea have also been reported earlier by Atokple *et al.* (1991) and Magani (1994). Several workers reported that reduced productivity of host by *Striga* was as a reuslt of diversion of water, nutrients and photosynthates and the toxic effect of the parasite on the host (Stewart *et al.*, 1991; Sauerborn, 1992; Obilana and Ramiah, 1992; Butler and Ejeta, 1997). The possitive correlation of *Alectra* shoot count with percentage reduction in nodulation, shoot dry matter production, plant height and days to first crop flowering

suggest that percentage reduction in crop parameters could be useful indices for evaluating soybean cultivars for their reaction to *Alectra*. Similar observations have been reported earlier on maize (Adetimirin *et al.*, 1997) and rice (Lagoke *et al.*, 1996) under *Striga hermonthica* infestation. Possitive correlation of seed yield with number of pods and branches and 100-seed weight in all the field trials is an obvious indication that these yield components are important determinants of seed yield in soybean. This result confirmed earlier reports (Olufajo, 1989; Chiezey, 1990; Kureh, 1993; Shebayan, 1998) which indicated that the number of pods and 100-seed weight were important yield determinants of soybean seed yield.

From the result of the path-coefficient analysis, it was obvious that 100-seed weight and number of pods were the most important contributing factors to soybean seed yield under *Alectra* infestation. The 100-seed weight and number of pods individually contributed 23.86% and 19.53%, respectively while combined contribution of these two factors was high (30.22%). The 100-seed weight also had high direct (0.489) and total (0.839) contributions to seed yield; its combined contribution via number of pods was also high, 0.309. Similarly, number of pods per plant had high direct (0.442) and total (0.815) contributions to seed yield while combined contribution via 100-seed weight was also high, 0.342. Shebayan (1998) had also observed that number of pods and 100-seed weight of soybean gave high direct contributions to soybean seed yield at site free of *Alectra*. Thus, a breeding programme focussed on increasing the production of pods and seed size of soybean would facilitate improved productivity of the crop.

5.2. Mechanism of Resistance.

In the laboratory, soybean cultivars TGX1649-11F, TGX1740-7F, TGX1670-1F, TGX1670-3F and TGX1660-19F stimulated low *Alectra* seed germination when TVX3236 a poor control was used (Table 29). However, TGX1681-3F and TGX1740-2F that stimulated high *Alectra* seed germination when TVX3236 was used as the control were observed to stimulate low *Alectra* seed germination when SAMPEA 7, a better control was used (Table 30). All these soybean cultivars supported low *Alectra* shoots and were observed to dealy *Alectra* emergence both in the screen house and field trials. Because of the disparity in the performance of the two controls, stimulation of germination of *Alectra* by soybean needs further investigation. However, low stimulant production could be implicted in this study. Thus it could be inferred that these soybean cultivars exhibited resistance through low or delayed stimulation of germination of *Alectra* seeds at the early stage of crop growth. Earlier reports have attributed stimulation of germination of *Striga* seeds by the sorghum host to the quantity and quality of the chemostimulant (Parker, 1977; Ramiah and Parker, 1982; Hess *et al.*, 1992; Hauck *et al.*, 1992; Butler and Ejeta, 1997). In addition, these soybean cultivars were observed to have low crop syndrome reaction score and low reduction in crop parameters in the screen house trials. While syndrome reaction score is a product of reaction and defensive mechanism, the *Alectra* resistant cultivars exhibited another resistance mechanism that may be attributed to the insensitivity of host plant to *Alectra* produced 'toxins'. These soybean cultivars seem to have multiple mechanism of resistance (low stimulant production and insensitivity to *Alectra* produced 'toxins'). This finding

confirmed similar observations that highly resistant sorghum genotypes produced low germination stimulant and were insensitive to *Striga* produced 'toxins' due to the maintenance of high photosynthetic efficiency (Butler and Ejeta, 1997; Hess and Haussman, 1997).

TGX1674-3F which stimulated high *Alectra* seed germination when TVX3236 was used as the control was observed to support low *Alectra* shoots both in the screen house and field trials. The mechanism of resistance of TGX1674-3F might be due to the production of anti-haustorial inducing factors as earlier reported by Reda *et al* (1993), Wegmann (1996) and Hess *et al* (1997); inhibition of germ tube exoenzymes by host root exudates (Wegmann, 1996; Hess and Haussman, 1997); Mechanical barriers (Sauder, 1993; Maiti *et al*., 1984); insensivitiy to *Alectra* produced 'toxins' (Butler and Ejeta, 1997; Hess and Haussman, 1997) and/or anti-biosis in which germination and attachment is normal, but subsequent development of the parasite is discouraged. Several authors have reported limited development of tubercle and stem of *Alectra* in resistant cowpea varieties (Singh and Emechebe, 1990; 1997; Emechebe *et al*., 1991; Lane *et al*., 1991).

SAMSOY 2 that stimulated high *Alectra* seed germination in the laboratory and supported high *Alectra* shoots both in the screen house and field trials, was observed to exhibit low crop syndrome reaction and produced high seed yield. Since syndrome reaction is a product of reaction and defensive mechanism, the mechanism of tolerance of SAMSOY 2 would therefore, be due to the insensitivity of host plant to *Alectra* poduced 'toxins' which it probably achieved through the maintenance of high photosynthetic efficiency as earlier reported on sorghum under *Striga* infection (Butler and Ejeta, 1997; Hess and Haussman, 1997).

5.3. Control of *Alectra* Using Local Materials as Anti-transpirants.

Abscisic acid at all concentrations did not affect *Alectra* shoots (Table 31). The stomata of *Alectra* remained open throughout the period of the experiment. This observation confirmed the findings of Shah *et al* (1987). They reported that *Striga* stomata are insensitive to abscisic acid, thus stomata conductance and transpiration were maintained high to cause substantial evaporative cooling of the leaf and allow the influx of water, metabolites and solutes to the parasite. However, the use of local materials as anti-transpirants indicated dramatic changes. Application of shea-butter and paraffin oils resulted in over 90% and 100% death of *Alectra* shoots at 5 and 10 DAA, respectively. Gum arabic, vaseline, kaoline and talc-magnesite also caused 68 to 91% control of *Alectra* at 10 DAA. The leaves of *Alectra* began to blacken and shrivel after application of the local materials suggesting an effect over and above that of simply reducing the flux of solutes to the parasite by stomata closure. The local materials applied as anti-transpirants probably induced heat stress in *Alectra*. Nour *et al* (1988) and Press *et al* (1989) reported effective control of *Striga* with the application of an anti-transpirant wilt pruff S600(R). Similarly, Riches (1990) obtained encouraging results when guar gum solution was applied to *Striga* as anti-transpirants. The local materials used in this investigation are cheap and may provide a cheap *Alectra* control method if validated under field condition. The selection of these materials would be greatly facilitated by studies of the mechanism of stomata control in *Alectra* as earlier suggested for Striga (Stewart *et al.*, 1991).

SUMMARY AND CONCLUSION

Screen-house, field and laboratory trials were conducted between 1995 and 1998 at Samaru (11°11`N, 7°38`E: 686m above sea level) in the northern Guinea Savanna zone of Nigeria, to study the reaction of soybean cultivars to *Alectra vogelii*, mechanism of resistance and control using anti-transpirants.

In the investigation to study the response of soybean cultivars, 22 soybean cultivars were evaluated in two screen-house trials and arranged in completely randomized design with three repetitions. Half of the plastic pots used were inoculated with about 2,000 *Alectra* seed per pot. The same 22 soybean cultivars evaluated in the screen house were also evaluated during the wet seasons at two naturally infested sites in 1995 and 1996 and one site in 1997. Treatments were arranged in randomized complete block design replicated three times. In the mechanism of resistance study, the same 22 soybean cultivars were evaluated in the laboratory for stimulation of germination of *Alectra* seeds using cowpea variety TVX3236 as control in the first trial. However, in the second trial, six soybean cultivars, three levels of abscisic acid, TVX3236 were evaluated for stimulation of germination of *Alectra* seeds using cowpea variety SAMPEA 7 as control. Both trials were laid out in completely randomized design repeated three times. In the investigation of control using anti-transpirants, the effect of abscisic acid at four concentrations (0, 100, 200 and 400 ppm) on *Alectra* in five soybean cultivars were evaluated in the screen-house. In the second screen house trial, six local materials used as anti-transpirants were evaluated for their control of *Alectra vogelii* in a susceptible soybean cultivar. Both trials were arranged in completely randomized design

repeated three times. All the pots used were inoculated with about 2,000 *Alectra* seeds/pot.

Results of the response of soybean cultivars to *Alectra* indicated that TGX1649-11F, TGX1681-3F, TGX1674-3F, TGX1636-7F, TGX1670-1F, TGX1670-3F and TGX1660-19F supported low and delayed *Alectra* shoot emergence both in the screen house and field trials. The reduction in nodulation, shoot dry matter production, plant height and days to first crop flowering in the screen house were also low. These soybean cultivars exhibited low crop syndrome reaction and produced high soybean seed yield that were significantly higher than the least in all the field trials under natural *Alectra* field infestation. TGX1740-7F and TGX1740-2F supported low to moderate and delayed *Alectra* shoot emergence, exhibited low crop syndrome reaction score and produced seed yield comparable to the highest and significantly higher than the least in all the field trials. Thus exhibiting low to moderate resistance to *Alectra*. Inspite of support for high *Alectra* shoots in all trials, exhibition of moderate to high crop reaction score and high reduction in nodulation, shoot dry matter production, plant height and days to first crop flowering, TGX1660-15F, TGX1485-1D, SAMSOY 2, TGX1440-1E and TGX536-02D recommended for production, produced seed yield comparable to the highest. These soybean cultivars exhibited obvious tolerance to *Alectra* parasitism. However, soybean cultivars TGX1019-2EB, M-351, TGX87D-516D, TGX849-313D and TGM344 exibited susceptibility to *Alectra* parasitism through the support for high *Alectra* shoot emergence in all the trials, high crop syndrome reaction and high reduction in crop parameters with *Alectra* infection in the screen house trials and production of low seed yield under *Alectra*

infestation in the field.

The possitive correlation of seed yield with number of pods and branches and 100-seed weight shows that these parameters are important attributes to seed yield in soybean. The negative association between *Alectra* shoots and number of branches, 100-seed yield and seed yield indicates the detrimental effect of the parasite on the crop. The possitive correlation of Alectra shoot count with percentage reduction in crop parameters suggests that percentage reduction in crop parameters could be useful indices for evaluating soybean cultivars for their reaction to *Alectra*. Path-coefficient analysis revealed that 100-seed and number of pods are the most important contributing factors to soybean seed yield. A breeding programme focussed on increasing the production of pods and seed size of soybean would facilitate in improving productivity of the crop.

The results of the mechanism of resistance showed that TGX1649-11F, TGX1740-7F, TGX1681-3F, TGX1670-1F, TGX1670-3F, TGX1740-2F and TGX1660-19F stimulated low *Alecta* seed germiantion, exhibited low crop syndrome reaction and low reduction in crop parameters in the screen house and produced high seed yields in all the field trials. It could be inferred that these cultivars exhibited multiple mechanisms of resistance through low or delay stimmulation of germination of *Alectra* seeds and insentivity of host plant to *Alectra* produced 'toxins'. TGX 1674-3F stimulated high *Alectra* seed germination but supported low *Alectra* shoot emergence and produced high seed yield in all field trials. The mechanism of resistance of this cultivar could not be ascertained from this investigation, however it could be due to one or a combination of the following resistant mechanisms, anti-haustoria inducing factor, inhibition of germ

tube by host exudates, mechnical barrier and/or antibiosis.

SAMSOY 2 stimulated high *Alectra* seed germination in the laboratory and supported high *Alectra* shoots in all trials but exhibited low crop syndrome reaction and produced high seed yields in all the field trials. Thus, the mechanism of tolerance of SAMSOY 2 is due to insensitivity of the cultivar to *Alectra* produced 'toxins'.

In the control of *Alectra* using anti-transpirants, abscisic acid at all concentrations did not affect *Alectra* plants, however, application of shea butter and paraffin oils resulted to over 90 and 100% death of *Alectra* shoots at 5 and 10 DAA, respectively. Gum arabic, vaseline, kaoline and talc-magnesite all caused 68-91% control of *Alectra* at 10 DAA.

In conclusion, this investigation showed that soybean cultivars, TGX 1649-11F, TGX 1681-3F, TGX 1674-3F, TGX 1635-7F, TGX 1670-1F, TGX 1670-3F and TGX 1660-19F supported low *Alectra* shoot emergence and produced high seed yield thus exhibiting resistance. TGX1740-7F and TGX1740-2F supported low to moderate *Alectra* shoots and produced high seed yield indicating low to moderate resistance to *Alectra* parasitism. Inspite of support for high *Alectra* emergence TGX 1660-15F, TGX 1485-1D, SAMSOY 2, TGX 1440-1E and TGX 536-02D produced high seed yield thus exhibiting obvious tolerance to *Alectra* parasitism. However, TGX 1019-2EB, M-351, TGX 87D-516, TGX 849-313D and TGM 344 exhibited susceptibility to *Alectra* parasitism through support for high *Alectra* shoot emergence and production of low seed yield.

TGX 1649-11D, TGX 1681-3F, TGX 1740-7F, TGX 1670-1F, TGX 1740-2F, TGX 1670-3F and TGX 1660-17F exhibited low stimulant production and insensitivity to *Alectra* produced 'toxins' as mechanisms of resistance while SAMSOY 2 exhibited insensitivity to *Alectra* produced 'toxins' as the mechanisms of tolerance.

Abscisic acid did not affect *Alectra* plants, however shea-butter and paraffin oils caused 100% control of *Alectra* within 10 days of application while gum arabic, vaseline, kaoline and talç-magnesite resulted to 68 and 91% death of *Alectra* shoots within the same period. The local materials used in this investigation are promising anti-transpirants and cheap. These need validation under field condition to provide an effective *Alectra* control method in soybean and perhaps other related legumes.

REFERENCES

Adu, J.K., Leleji, O and Emechebe, A.M. (1989). Nitrogen fertilizer effects on *Striga* attack of cowpea in Northern Nigeria. Paper presented at maize and cowpea *Joint Workshop of SAGRAD at Lome*, Togo, March 20 -24 1989.

Aggarwal, V.D. (1985). Cowpea *Striga* Research. In: Singh. S.R. and Rachie, K.O. (eds). *Cowpea Research, Production and Utilization* Production. John Wiley and Sons, pp. 335-340.

Aggarwal, V.D. (1986). An approach to cowpea *Striga* control through plant breeding, pp. 162-169, *In Proceedings of the FAO/OAU All-African Government Consultation on Striga Control*, 20-24 Oct., 1986, Maroua, Cameroun.

Aggarwal, V.D., Muleba, N., Drabo, J., Souma, J. and Mewe, M. (1984). Inheritance of *Striga gesnerioides* resistance in cowpea. *Third International Symposium on Parasitic Weeds held at ICARDA,* Aleppo, Syria, 7-11 May, 1984.

Anonymous (1996). Biology and Control of Parasitic Weeds. 4th edition of the training manual of the Supra-regional project, *"Ecology and Management of Parasitic Weeds"*. GIZ University of Hohenheim, Stuttgart, Germany.

Ariga, E.S., Berner, D.K. (1995). Isolation of *Striga hermonthica* seed germination stimulants from non-host crops and field testing for control efficacy. Paper presented at the *Third Regional Striga Working Group Meeting*, 12-14th June, 1995, Mombasa (Kenya) - Tanga (Tanzania).

Atokple, I.D.K. (1989). Inheritance of resistance to *Striga gesnerioides* in cowpea. *M.Sc. Thesis, Ahmadu Bello University*, Zaria, Nigeria. 112pp.

Ba, A.T. (1983). Evidence of enzyme activities in the haustorium of *Striga gesnerioides* (Scrophulariaceae). In: Ramiah, K.V. and Vasdeva Rao, M.J. (eds). *Proceeding of the Second International Workshop on Striga*, ICRISAT, Patancheru, India. pp. 78-100.

Bagnall-Oakeley, H., Gibberd, V. and Nyongesa, T.E. (1991). The incidence and control of *Alectra vogelii* in Embu district, Kenya. In: Ransom, J.K., Musselman. L.J., Yorsham, A.D. and C. Parker (eds). *Proceedings of the 5th Interrnational Symposium of Parasitic Weeds*. Nairobi: CIMMYT pp. 340-345.

B.A.R.O. (1988). Cowpea witch weed, *Alectra vogelii* a parasite of legumes (Molelwane, Matebele). *Crop Husbandry Agrifacts* pp 12-15.

Bebawi, F.F., R.E. Eplee, C.E. Harris and R.S. Norris (1984). Longevity of witchweed (*Striga asiatica*) seed. *Weed Science* 32: 494-297

Bebawi, F.F. (1987). Cultural practices in witchweed Management.' In: Musselman, L.J. (ed). *Parasitic Weeds in Agriculture Vol. 1*. Boca Raton, FL. USA. CRS Press Inc. Pp 159-172.

Berner, D.K., Cardwell, K.F., Kim, S.K., Wing, J.G., Smith, J. and Weber, G.K. (1993). Some new developments in IITA's Integrated Approach to *Striga* Research and Control. Pp. 27-31. In: Lagoke, S.T.O., Van der Straten, L.E. and M'Boob, S.S. (eds), 1997. Integrated Management of *Striga* for the African Farmer. *Proceedings, Third General Workshop of PASCON*, 18-23 October 1993. Harare, Zimbabwe. 157 pp. Accra (Ghana): FAO.

Botha, P.J. (1948). The parasitism of *Alectra vogelii* (Benth.) with special reference to the germination of its seeds. *Journal of South African Botany 16*: 49-72.

Bouyoucas, G.H. (1951). A Recalibration of the Hydrometer method for Making Mechanical Analysis of Soils. *Agronomy Journal*, 43: 434-438.

Bremmer, J.W. (1965). Total Nitrogen. In: Methods of Soil Analysis Part 2. Black, C.A. (ed). Chemical and Microbiological Properties. *American Society of Agronomy*, Madison, Wiscousin pp. 1149-1178.

Butler, L.G. and Ejeta, G. (1993). Several approaches to the *Striga* problem being developed at Purdue University. 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 PASCON*, 23-29 June, 1991, Nairobi, Kenya. Accra (Ghana): FAO, pp. 179-182.

Butler, L.G. and Ejeta, G. (1997). Control of *Striga*: New Approaches at Purdue University. In: Lagoke, S.T.O., Van der Straten, L.E. and M'Boob, S.S. (eds), 1997. Integrated Management of *Striga* for the African Farmer, *Proceedings, Third General Workshop of PASCON*, 18-23. October, 1993. Harare, Zimbabwe. Accra (Ghana): FAO. pp. 42-47.

Cai, T., Babiker, A.G.T., Ejeta, G. and Butler, L.G. (1993). Morphological response of witchweed (*Striga asiatica*) to in vitro culture. *Journal of Experimental Botany*, in press.

Carsky, J.R., Singh, L. and Ndikawa, R. (1995). Suppression of *Striga hermonthica* on sorghum using cowpea intercrop. *Experimental Agriculture* 30: 349-358.

Carson, A.G. (1986). Research and development strategies for the control of *Striga* hermonthica in the Gambia. PP. 100-117, in: Proceedings of the FAO/OAU. *All African Government Consultation on Striga Control*, 20-24 October, 1986. Maroua, Cameroun.

Cherif-Ari, O., Housley, T.L. and Ejeta, G. (1990). Sorghum root length density and potential for avoiding parasitism. *Plant and Soil*, 121:67.

Chidley, V.L., Drennan, D.S.H. (1987). In vitro culture of *Striga asiatica* (L.) Kuntze (Scrophulariaceae). In: Webar H.C. and Forstreuter, W. (eds). *Proceedings of the Fouth International Symposium on Parasitic Flowering Plants*. Marbary, Philips University, pp. 829-831.

Chiezey, U.F. (1990). Effects of plant density and phosphorus fertilizer on the yield and yield components of soybean (*Glycine max* (L) Merrill) in Nigeria. Ph.D. Thesis, Ahmadu Bello University, Zaria, Nigeria. 132pp.

Chiezey, U.F. (1997). The performance of early and medium maturing soybean varieties. Notes on the multi-locational soybean varietal trials. Paper presented at the 1997 *Cropping Scheme Meeting*, National Cereal Research Institute, Badeggi, Nigeria.

Cobley, L.S. (1976). An Introduction to botany of tropical crops. 2nd edition, Cobley, L.S. and Steele, W.M. (eds). Longman, London, 311pp.

Cox, G.M. and Cochram, H.G. (1967). Experimental design, 2nd edition; John Willey and Sons.

Dart, P.J. and Mercer, F.V. (1965). The effect of growth chamber level of ammonium nitrates and light intensity on the growth and nodulation of cowpea (*Vigna sinensis*). *Australian Journal of Agricultural Research 16:* 321-345.

Dejongh, K., Van Damme, P. and Berner, D.K. (1993). Suicidal germination of *Striga* seeds using several trap crop varieties. *Med. Fac. Landbouww. Univer. Gent* 58/3a: pp. 983-993.

Dewey, D.R. and K.K. Lu (1959). A correlation and path coefficient analysis of crested grass seed production. *Agronomy Journal* 51: 515-518.

Dixon, N.H. and Parker, C. (1984). Aspects of resistance of sorghum varieties to *Striga* species. In: Parker *et al.*, (eds). *Proceedings, Third International Symposium on Parasitic Weeds*. Aleppo, Syria pp. 123-132.

Doggett, H. (1988). Sorghum. Second edition pp. 368-404. John Wiley and Sons, New York, N.Y.

Duncan, D.B. (1955). Multiple range and multiple F-test. *Biometrics* 11, pp. 1-42.

Efron, Y., Kim, S.K., Parkinson, V. and Boxque-Perez, N.A. (1988). IITA strategies to develop *Striga* resistant maize germplasm. *FAO Plant Production and Protection Paper*. 96:141-153.

Emechebe, A.M. (1994). Integrated pest management for the control of root parasitic flowering plants, Crop Protection Department Seminar, Ahmadu Bello University, Zaria, Nigeria.

Emechebe, A.M. (1981). Cowpea pathology: Notes on cowpea and grain legume improvement programme. Paper presented for a *Cropping Scheme Meeting* Institute for Agricultural Research, Samaru, Zaria, Nigeria.

Emechebe, A.M. Leleji, O.T. 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, Samaru, Nigeria.

Emechebe, A.M. and Singh, B.B. (1989). Further studies on parasitic weeds of cowpea. pp. 103-105. In: Legumes and oilseeds research programme report to 1990 *Cropping Scheme Meeting* IAR, Samaru, Zaria.

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, International Workshop Organized by IITA, ICRISAT and IDRC*. 22-24 August, 1988. IITA, Ibadan, Nigeria pp. 18-28.

Eplee, R.S. (1979). The *Striga* eradication programme in United States. In: Musselman, L.J. (ed). Parasitic plants in Agriculture: *Proceeding of the Second International Symposium on Parasitic Weeds*. 16-19 March, 1979. North Carolina State University, MC. pp. 269-272.

Eplee, R.S. (1996). Dispersal of seeds of *Striga* species. In: Moreno, M.T., Cubero, J.I., Berner, D., Ramsom, D., Musselman, L.J. and Parker, C. (eds.). Advances in Parasitic Plant Research. *Sixth International Parasitic Plants Symposium*. 16-18 April, 1996, Cordoba, Spain. pp. 384-388.

Eplee, R.S. and Norris, P.E. (1987). Chemical control of *Striga*. In: Musselman, L.J. (ed). Parasitic Plants in Agriculture, Vol. 1. Boca Raton, FL, USA: CRC Press Inc. pp. 173-182.

F.A.O. (1995). Food and Agricultural Organization quarterly bulletin of statistics. Volume 8. Published by the Food and Agricultural Organization, Rome 12.

Faryna, P.J. (1985). Soybean in the Nigerian Diet. *Extension* Bulletin number 21. Home economics series number 1 *NAERLS*, Ahmadu Bello University, Zaria, Nigeria.

Fehr, W.R. and Caviness, C.E. (1977). Stages of Soybean development. Special report 80: IOWA State agriculture and home economics experimetnal station.

Fer, A.F., Simier, L., Arnaud, L., Ray, L. and Renaudin, S. (1993). Carbon acquisition and metabolism in a root hemi-parasitic angiosperm, *Thesis humile* (Santalaceae) grown on wheat (*Triticum vulgare*). *Australian Journal of Plant Physiology*, 20: 15-24.

Hauck, C. Muller, S. and Schidknecht, H. (1992). A germination stimulant for parasitic flowering plants from *Sorghum bicolor* a genuine host plant. *Journal of Plant Physiology*. 139:474-478.

Hess, D.E. and Haussman, B.I.G. (1997). Status quo of *Striga* control: Prevention, mechanical and biological control methods and host polant resistance. *Paper presented at the Region Workshop*, Joint Action to Control Striga in Africa: Experiences from Ghana. 6-9 October, 1997, Sogakope, Ghana.

Hess, D.E., Ejeta, G. and Butler, L.G. (1992). Selecting sorghum genotypes expressing a quantitative biosynthetic trait that confers resistance to *Striga*. *Phytochemistry* 31: 493-497.

I.A.R. (1992). Code and descriptor list of crop varieties released by Institute for Agricultural Research, Samaru, Nigeria.

I.I.T.A./SAFGRAD (1982). Cowpea Programme. IITA/SAFGRAD *1992 Annual Report*. pp. 127-133.

Joke, D. (1986). Soybean (*Glycine max* (L.) Merrill). Its adaptation in Nigeria. In Proceedings of the 5th National Meeting of the Nigerian Soybean Scientist., Ibadan, Nigeria, pp. 29 - 35.

Khadir, M.C. (1983). *Striga* research in Sudan. *Proceedings of the Second Regional Workshop on Sorghum and Millet Improvement in East Africa*, 21-26 June, 1983. SAFGRAD/ICRISAT Regional Programme, Nairobi, Kenya, pp. 169-177.

Kim, S.K. (1991). Breeding maize for *Striga* tolerance and the development of a field infestation technique. In: Kim, S.K. (ed). Combating *Striga* in Africa. *Proceedings, International Workshop Organized by IITA, ICRISAT and IDRC*, 22-24 August, 1988. IITA, Ibadan, Nigeria, pp. 96-110.

Konate, A. (1986). *Striga* in Mali, pp. 58-61. *In: Proceedings of the FAO/OAU All-African Government Consultation on Striga Control.* 20-24 October, 1986. Maroua, Cameroun.

Kroschel, J., Mossner, B. and Sauerborn, J. (1996). Estimating Maize Yield Losses caused by *Striga asiatica* in Malawi In: Moreno, M.T., Cubero, J.I., Berner, D.K., Joel, D., Musselman, L.J. and Parker, C. (eds). Advances in Parasitic Plant Research. *Sixth International Parasitic Weed Symposium.* 16-18 April, 1996, Cordoba, Spain, pp. 336-345

Kuijt, J. (1969). The biology of parasitic flowering plants, University of California, Berkeley Press. 246 pp.

Kureh, I. (1993). Effect of certain production factors on growth, development and seed yield of soybean (*Glycine max* (L.) Merrill) varieties. M.Sc Thesis, Ahmadu Bello University, Zaria, Nigeria. 99pp.

Kureh, I. and Katung, P.D. (1993). Control of root parasitic weeds: The only option for the small scale farmer. *Paper presented at the 29th Annual Conference of the Agricultural Society of Nigeria.* 30 October to 3 November, 1993, Umudike, Nigeria.

Kureh, I., Lagoke, S.T.O., Magani, E.I., Olufajo, O.O. and Emechebe, A.M. (1994a). Reaction of soybean varieties to pre-conditioning and concentration of seed inoculum of *Alectra vogelii* (Benth). *Paper presented at the World Soybean Research Conference* V. 20-27 February, 1994, Chiang Mai, Thailand.

Kureh, I., Lagoke, S.T.O., Olufajo, O.O., Gupta, U.S., Dashiell K. and Magani, E.I. (1994b). Influence of variety and sowing date on *Alectra* infection and seed yield of early maturing soybean. *15th Annual Conference of Nigerian Soybean Association.* 9-12 May, 1994, Kaduna, Nigeria.

Kureh, I., Lagoke, S.T.O., Olufajo, O.O., Gupta, U.S., Dashiell, K. and Magani, E.I. (1994c). Influence of variety and sowing date on *Alectra* infection and seed yield of medium maturing soybean. *15th Annual Conference of Nigerian Soybean Association.* 9-12 May, 1994, Kaduna, Nigeria.

Kust, C.A. (1963). Dormancy and viability of witchweed seeds as affected by temperature and relative humidity during storage. *Weeds* 11: 247.

Lagoke, S.T.O. (1989). *Striga* in Nigeria. Cereals Research Programme: *Cropping Scheme Report*, 1989. Institute for Agricultural Research, Zaria, Nigeria.

Lagoke, S.T.O., Parkinson, V. and Agunbiade, R.M. (1988). Parasitic weeds and control methods in Africa pp. 3-14. In: Kim, S.K. (ed). Combating *Striga* in Africa. *Proceedings International Workshop organized by IITA, ICRISAT and IDRC*, 22-24 August, 1998. IITA, Ibadan, Nigeria.

Lagoke, S.T.O., Shebayan, J.Y., Adeosun, J.O., Asiribo, O.E., Iwuafor, E.N.O., Olukosi, J.O., Yayock, J.Y. and Olugbemi, L.B. (1990). Survey of *Striga* problem and evaluation of *Striga* control methods in Nigeria, 1989 wet season. *Interim Report of FAO Sponsored Programme*.

Lagoke, S.T.O., Shebayan, J.Y., Weber, G., Olufajo, O.O.; Elemo, K., Adu, J.K., Emechebe, A.M., Zaria, A., Award, A., Ngawa, L., Olaniyan, G.O., Olafare, S.O. and Adeoti, A.A. (1991). Survey of *Striga* problem and evaluation of *Striga* control methods and packages in crops in the Nigerian Savanna, pp 91-120. 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 PASCON*, 23-29 June, 1991, Nairobi, Kenya. Accra (Ghana) FAO.

Lagoke, S.T.O., M'Boob, S.S., Hoevers, R. and Emechebe, A.M. (1993). Combating *Striga* problem in Africa: Pan-African *Striga* Control Network approach, pp. 14-29. In: Kuria, J.N. (ed). Proceedings of the 13th Biennial Weed Science Conference. *Weed Science Society of East Africa*, Nairobi, Kenya.

Lagoke. S.T.O., C.C. Alahira, R. Alabi and B.B. Singh (1996). Seed treatment for the control of *Striga gesnerioides* (Wild) vatke and *Alectra vogelii* Benth in cowpea (*Vigna unguiculata* (L.) Walp). Paper presented at the *4th general workshop of PASCON*. Held on 28 October to 2 November, 1996, Bamako Mali.

Lagoke, S.T.O., Shebayan, J.Y., Magani, E.I., Olorunju, P., Olufajo, O.O., Elemo, KA., Uvah, I., Adeoti, A.A., Chindo, P.S., Kureh, I., Emechebe, A.M., Ndahi, W.B., Kim, S.K., Weber, G., Singh, B.B., Salawu, A., Avav, T. and Sule, T.T. (1997a). *Striga* problem and development of appropriate control technologies in various crops in Nigeria. pp 89-100. In: Lagoke, S.T.O., Van der Straten, L. E. and M'Boob, S.S. (eds), 1997. Integrated Management of *Striga* for the African Farmer. *Proceedings, 3rd General Workshop of PASCON*. 18-23 October, 1993, Harare, Zimbabwe. 157pp. Accra (Ghana): FAO.

Lagoke, S.T.O., Kureh, I., Alabi, S.O. and Aliyu, L. (1997b). The use of trap-crop for the control of *Striga hermonthica* in maize. *Interim report of West-East Central African Maize Research Network* (WECAMAN) Sponsored Project.

Lane, J.A. and Bailey, J.A. (1991). Resistance of cowpea (*Vigna unguiculata* to *Striga gesnerioides*. In: Wegmann, K. and Musselman, L.J. (eds). Progress in *Orobanche* Research. *Proceedings, International Workshop on Orabanche Research*, Obermarchtal 1989: Eberhard-Karls Universitat, Tubingen.

Lane, J.A., Bailey, J.A. and Terry, P.J. (1991). An in-vitro growth system for studying the parasitism of cowpea (*Viga unguiculata*) by *Striga gesnerioides Weed Research*, 1991 volume 31: 211-217.

Logan, D.C. and Stewart, G.R. (1992). Germination of the seeds of parasitic angiosperms. *Seed Science Research* 2: 179-190.

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. pp. 185.

Maiti, R.K., Ramiah, K.V, Bisen, S.S. and Chidley, V.L. (1984). A comparative study of the haustorical development of *Striga asiatica* on sorghum cultivars. *Annual Botany* 54: 447.

M'Boob, S.S. (1986). A region programme for West and Central. *All-African Government Consultation on Striga Control*, 20-24 October, 1986, Maroua, Cameroun.

Mugabe, N.R. (1983). Effect of *Alectra vogelii* (Benth) on cowpea (*Vigna unguiculata* (L.) Walp.) 1. Some aspects of reproduction of cowpea. *Zimbabew Journal of Agricultural Research* 21: 135-147.

Muller, S.G, Hauck, G. and Schildknecht, H. (1992). Germination Stimulants produced by *Vigna unguiculata* Walp C.V. Saunders upright. *Journal of Plant Growth Regulation* 11: 77-84.

Murphy, J. and Riley, J.R. (1962). A modified single solution method for the determination of P in natural waters. *Annals of Chemistry Acta* 27: 31-36.

Musselman, L.J. (1980). The Biology of *Striga, orobanche* and other root parasitic weeds. *Annual Review of Phytopathology*. 18: 463-489.

Musselman, L.J. (1987). Taxonomy of witchweeds pp. 3-12. In: Musselman, L.J. (ed.) Parasitic weeds in agriculture. Volume 1 CRC Press, Boca Raton, FL, USA.

NAERLS (1987). Soybean utilization in Nigeria. *Proceedings of the National Agricultural Extension Research Liaison Services Workshop*, 1987.

NAERLS (1989). Soybean in the Nigerian diet. *NAERLS extention Bulletin* No. 21.

Nour, J.J., Press, M.C., Bebawi, F.F. and Stewart, G.R. (1988). Anti-transpirant-induced heat stress in *Striga* a novel method of control. *Plant Physiology* 86:5-60.

Obilana, A.T. and Ramiah, K.V. (1992). *Striga* (witchweeds) in Sorghum and millet: Knowledge and future research needs. Pp 187-201. In: de Milliano, W.AJ., Frederiksen, R.A. and Bengstown, G.D. (eds). Sorghum and Millet diseases. *International Research Institute for the Semi-Arid Tropics*. (CP741). Patancheru, AP. 502 323, India.

Okonkwo, S.N.C. (1987). Development studies in witchweeds. Pages 63-75. *In: Musselman, L.J. (ed). Parasitic weeds in Agriculture vol. I Striga*, Boca Raton, FL, USA. CRC Press Inc.

Olowaniyan, F.O. (1994). Household processing and utilization of soybeans in Nigeria. Paper presented at the *Society for International Development (SID) and West African Farming Systems Research Network (WAFSRN) Joint Workshops*, 2-4, 7-9, 10-12, 14-16. November, 1994, Zaria, Nigeria.

Olufajo, O.O. (1989). Effect of cultivation method on soybean pp. 72-75, 1989. *Annual Report, Agronomy Department*, Ahmadu Bello University, Zaria, Nigeria.

Olufajo, O.O. (1992). The performance of early and medium maturing soybean varieties. Notes on the multilocational varietal trial. Paper presented at the 1992 cropping scheme Meeting, IAR, Samaru, Nigeria.

Olufajo, O.O. (1993). The performance of early and medium maturing soybean varieites. Notes on the Multilocational varietal trial. Paper presented at the 1993 Cropping Scheme Meeting, IAR., Samaru, Nigeria.

Olufajo, O.O. (1994). Soybean production and Marketing. Paper presented at the society for International Development (SID) and West African Farming Systems Research Network (WAFSRN) Joint Workshops, 2-4, 7-10, 10-12, 14-16 November, 1994, Zaria. Nigeria.

Olufajo, O.O. (1995). The performance of early and medium maturing soybean varieties. Notes on the multilocational varietal trial. Paper presented at the 1995 *Cropping Scheme Meeting*, IAR, Samaru, Nigeria.

Olufajo, O.O. (1996). The performance of early and medium maturing soybean varieites. Notes on the multilocational varietal trial. Paper presented at the 1996 *Cropping Scheme Meeting*, NCRI, Badeggi, Nigeria.

Olunuga, B.A. and Akobundu, I.O. (1980). Weed problems and control practices in field and vegetable crops in Nigeria. *In: Akobundu, I.O. (ed). Weeds and their control in humid and semi-humid tropics*, Ibadan Nigeria, IITA Proc. Ser. 3: 138-146.

Parker, C. (1984). The physiology of *Striga* spp. Present State of knowledge and priorities for future research. Pp 179-193, *In: Striga biology and control, Ayensu, E.S; Doggett, H., Keynes, R.D. Marton-Lefevre, J., Musselman, L.J. Parker, C. and Pickering, A. (eds)*. ICSU Press, France.

Parker, C. (1991). Protection of crops against parasitic weeds *Crop Protection* 10:6-13.

Parker, C., Hitchcock, A.M. Ramiah, K.V. (1977). The germination of *Striga* species by crop root exudates techniques for selecying resistance crop cultivars. *Proceedings, 6th Asian - Pacific weed science society conference*, Indiana, Indonesia 1: 67.

Parkinson, V. (1985). *Striga* serious threat to maize production in Africa and research being conducted at IITA. pp. 47-57 *In: Proceedings of the FAO/OAU workshop on striga*, 23-27 September 1985, Yaounde, Cameroon. FAO, Rome.

Parlevliet, J.E. (1977). Plant phytosystems: An attempt to eluciadate horizontal resistance. *Euphytica* 26: 559 - 560.

Press, M.C., Shah, N. Tuohy, J. and Stewart, G.R. (1987). Carbon isotpe ratios demonstrated carbon flux from C4 host to C3 parasite. *Plant physiology* 83:1143 - 1145.

Press, M.C, Nour. J.J., Bebawi, F.F. and Stewart, G.R. (1989). Anti-transpirant - induced heat stress in the parasitic plant *Striga hermonthica* a novel method of control. *Journal of Experimental Botany* 40: 585-591.

Press, M.C., Graves, J.D. and Stewart, G.R. (1990). Physiology of the interaction of antiosperm parasites and their higher plant hosts. *Plant Cell and Environment* 13:91-104.

Ramaiah, K.V. (1984). Physiology. p 58. *In: Parker, C, Musselman, L.J. Poihill, R.M. and Wilson, A.K. (eds.). Proceedings, 3rd symposium on parasitic weeds*, ICARDA, Aleppo, Syria.

Ramiah, K.V. (1985). Hand pulling of *Striga hermonthica* in pearl millet. *Tropical Pest Management* 31:326-327.

Ramiah, K.V. (1987). Breeding cereal grains for resistance to witchweed, pp 227-242. *In: Musselman, L.J. (ed). parasitic weeds in agriculture*. Volume 1. CRC Press, Boca Raton, FL, USA.

Ramiah, K.V. and Parker, C. (1982). *Striga* and other weeds in sorhum, pp 291-302. *In: sorghum in the eighties Volume 1. Proceedings, International symposium on sorghum*, 2-7 November 1981. Patancheru, India. ICRISAT, Patancheru, A.P. 502-324, India, 473pp.

Reda, F., Butler, L.G., Ejata, G and Ramson, J.K. (1993). Screening of maize genotypes for low *Striga* stimulant production using agar gel technique. *Proceedings, First crop science conference for Eastern and Southern Africa*, 14-18 June 1993, Kampala, Uganda, in Press.

Reid, D.C. and Parker, C. (1979). Germination requirements of *Striga* species, pp. 202-210. *In: Musselman, L.J., Washman, A.D. and Eplee, R.E. (eds). Proceedings, second international symposium on parasitic weeds*: North Carolina State University.

Reith, J.W. (1967). Effects of soil magnesium and manganese dressings on crop yield and composition. *Technical Bulletin Minstry of Agriculture and Fisheries* 14: 92-109.

Riches, C.R. (1987). The identification of resistance to *Alectra vogelii* Benth. (Scrophulariaceae) in cowpea, pp. 701-708. *In: Weber, Chr. H and Forstreuter, W (eds)*. Parasitic flowering plant. *Proceedings, fourth international symposium on parasitic seed plants*, Marburg.

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

Riches, C.R., Hamilton, K.A. and Packer, C. (1992). Parasitism of grain legumes by *Alectra* species (Scrophulariaceae). *Annals of Applied Biology*, 121:361-370.

Robinson, R.A. (1969). Disease resistance terminology. *Review of Applied Mycology*, 48: 539-605.

Sauerborn, J. (1992). Parasitic flowering plants: ecology and management of parasitic weeds, gtz-UH, Germany.

Sanders, A.R. (1933). Studies on phaneorganic parasitism with particular reference to *Striga lutea* (Lour). *South Africa Department of Agricultural Science Bulletin* 128: 56pp.

Shah, N., Smirnoff, N. and Stewart, G.R. (1987). Photosythesis and stomatal characteristics of *Striga hermonthica* in relation to its parasitic habit. *Physiologia plantarum* 69: 699-703.

Shebayan, J.Y. (1998). Effect of row spacing on the response of soybean (*Glycine max* (L.) Merril) to weed competition in the northern Guinea savanna of Nigeria. *Agronomy Seminar*, Ahmadu Bello University, Zaria, Nigeria.

Singh, B.B. and Emechebe, A.M. (1991). Breeding for resistance to *Striga* and *Alectra* in cowpea, pp. 303-305. *In: Ransom, J.K., Musselman, L.J., Worsham, D.A. and Parker, C. (eds.). Proceedings, 5th International symposium on parasitic weeds*, 24 - 30th June, 1991, Nairobi, Kenya. CIMMYT, D.F. Mexico.

Singh, B.B. and Emechebe, A.M. (1997). Advances in research on cowpea *Striga* and *Alectra*, pp. 215 - 224. *In: Singh, B.B., Mohan Raj, D.R., Dashiell, K.E. and Jackai, L.E.N. (eds.). 1997.* Advances in cowpea research. Copublication of IITA and JIRCAS. IITA, Ibadan, Nigeria.

Smith, W.K. (1978). Temperature of desert plants: another perspective on the adaptability of leaf size. *Science* 201: 614-616.

Stewart, G.R., Press, M.C. and Graves, J.D. (1990). The physiology and biochemistry of parasitic angiosperms. Annual *Review of Plant Physiology and Plant Moleculat Biology* USA 41:127-151.

Stewart, G.R., Press, M.C., Graves, J.D., J.J. Nour and A. Wylde (1991). A physiology characterisation of the host-parasite association between *Sorghum bicolor* and *Striga hermonthica* and its implications for *Striga* control. In: Kim, S.K. (ed). Combating *Striga* in Africa. *Proceedings. International Workshop Organised* by IITA, ICRISAT and IDRC, IITA, Ibadan, Nigeria. pp. 48-54.

Troug, E. (1930). The determination of readily available phosphorus of soils. *Journal of American Society of Agronomy* 22: 870.

Visser, J.H. (1978). The biology of *Alectra vogelii* (Benth). An angiospermous root parasites. *Bio und okosystem. witzenhausen* 279-294.

Wegmann, H.C.K. (1996). Physiology and Biochemistry of host/parasite relations. Paper presented at the training course: Biology and control of parasitic weeds. The Supra-region project, ecology and management of parasitic weeds, gtz/UH

10-21 June 1996, Kisimu, Kenya.

Witney, A.S. (1975). Contribution of forage legumes to the nitrogen economy of mixed swards: A review of relevant Hawalian research pp. 89-96. *In: Ayanaba, A. and Dart, P.J. (eds). Biological nitrogen fixation in farming systems of the tropics*, John Wiley and Sons, New York.

Appendix 1. Physico-chemical analysis of the soil taken to the depth of 30cm from the experimental sites at Samaru in 1995, 1996 and 1997.

Soil composition.	Site 1, B3			Site 2, Bush field.	
	1995	1996	1997	1995	1996
Particle size					
Clay	14	12	12	14	14
silt	28	34	36	48	50
Sand	58	54	52	38	36
Soil textural class	sandy loam	loam	loam	loam	silt loam
Soil pH in water	6.30	6.00	6,10	5.90	5.70
pH in 0.01M $CaCl_2$	6.10	5.80	6.00	5.70	5.60
Organic Carbon (%)	0.58	0.53	0.55	0.39	0.44
Total Nitrogen (%)	0.07	0.10	0.08	0.07	0.08
Available P (ppm)	8.06	11.68	11.00	4.48	8.06
Exchangeable bases (meg/100g soil)					
Calcium (Ca)	3.40	2.80	3.00	0.60	0.80
Magnesium (Mg)	2.33	0.17	0.20	0.17	0.34
Potassium (K)	0.80	0.17	0.50	0.20	0.27
Sodium (Na)	0.37	0.27	0.30	0.08	0.09
Cation exchange capacity (CEC)	8.70	6.30	6.00	3.20	3.80

Appendix 2. Total rainfall, maximuma and minimum temperature, relative humidity and sunshine hours at ten days interval during the period of the experiments at Samaru in 1995.

Months	Days	Total rainfall (mm)	Temperature		Relative humidity (%)	Sunshin hours
			Maximum °C	Minimum °C		
March	1-10	0.0	36.2	17.1	23.1	NA
	11-20	0.0	36.1	17.1	30.8	NA
	21-31	0.0	35.1	20.6	24.0	NA
April	1-10	0.0	37.4	19.2	28.3	NA
	11-20	14.0	36.9	20.5	28.4	NA
	21-31	76.5	31.3	16.9	60.7	NA
May	1-10	30.8	32.5	16.8	75.0	NA
	11-20	0.0	27.9	14.4	64.7	NA
	21-31	14.5	35.7	16.5	65.1	NA
June	1-10	39.4	NA	NA	NA	NA
	11-20	66.4	32.4	14.0	69.7	NA
	21-31	19.6	27.2	17.1	71.5	NA
July	1-10	36.8	28.9	21.7	76.6	NA
	11-20	52.3	30.2	22.7	96.0	NA
	21-31	67.8	30.3	20.8	82.1	NA
August	1-10	88.4	28.7	19.9	84.5	NA
	11-20	73.6	29.1	19.5	82.8	NA
	21-31	70.1	28.4	20.8	78.5	NA
September	1-10	39.3	29.5	21.9	81.9	NA
	11-20	80.5	29.4	18.9	81.6	NA
	21-31	39.3	28.1	18.6	73.2	NA
October	1-10	32.5	31.1	20.1	77.8	NA
	11-20	0.0	32.6	18.7	71.2	NA
	21-31	0.0	32.2	18.2	73.2	NA
November	1-10	0.0	27.6	17.2	64.1	NA
	11-20	0.0	29.4	14.9	39.5	NA
	21-31	0.0	25.7	13.0	24.9	NA
December	1-10	0.0	34.5	13.3	18.8	NA
	11-20	0.0	34.3	16.3	21.4	NA
	21-31	0.0	30.1	12.8	22.4	NA

NA = Not available

Appendix 3. Total rainfall, maximum and minimum temperature, relative humidity and sunshine hours at ten days interval during the period of the experiments at Samaru in 1996.

Months	Days	Total rainfall (mm)	Temperature		Relative humidity (%)	Sunshine (hours)
			Maximum °C	Minimum °C		
June	1-10	91.3	29.8	18.4	75.7	NA
	11-20	38.8	30.9	20.2	77.2	NA
	21-31	13.2	27.1	18.0	72.4	NA
July	1-10	NA	28.4	19.3	78.4	NA
	11-20	NA	27.6	18.2	82.3	NA
	21-31	NA	27.2	19.5	77.7	NA
August	1-10	NA	28.4	10.0	72.1	NA
	11-20	NA	26.9	20.0	75.4	NA
	21-31	NA	15.3	10.7	81.9	NA
September	1-10	NA	20.8	14.7	74.2	NA
	11-20	NA	30.2	19.3	81.6	NA
	21-31	NA	27.6	17.9	73.0	NA
October	1-10	28.7	28.4	20.0	78.0	NA
	11-20	31.2	31.6	19.9	76.9	NA
	21-31	0.0	30.9	15.8	40.9	NA
November	1-10	0.0	28.7	13.7	27.6	NA
	11-20	0.0	31.2	13.7	26.1	NA
	21-31	0.0	28.6	11.1	21.9	NA
December	1-10	0.0	32.1	13.2	18.9	NA
	11-20	0.0	33.4	11.7	16.6	NA
	21-31	0.0	32.3	11.2	13.3	NA

NA = Not available

Appendix 4. Total rainfall, maximum and minimum temperature, relative humidity and sunshine hours at ten days interval during the period of the experiments at Samaru in 1997.

Months	Days	Total rainfall (mm)	Temperature		Relative humidity (%)	Sunshine (hrs)
			Maximum °C	Minimum °C		
March	1-10	0.0	36.2	17.1	12.7	NA
	11-20	0.0	36.1	17.1	12.9	NA
	21-31	0.0	35.1	20.6	43.9	NA
April	1-10	0.0	37.4	19.2	61.7	NA
	11-20	14.0	36.9	20.5	53.9	NA
	21-31	76.5	31.3	16.9	61.7	NA
May	1-10	30.8	32.5	16.8	77.6	NA
	11-20	0.0	27.9	14.4	69.5	85.2
	21-31	14.5	35.7	16.5	77.3	79.1
June	1-10	39.4	NA	NA	73.9	75.8
	11-20	66.4	32.4	14.0	82.0	50.5
	21-31	19.6	27.2	17.1	75.4	47.3
July	1-10	36.8	28.9	21.7	82.1	51.7
	11-20	52.3	30.2	22.7	86.4	57.9
	21-31	67.8	30.3	20.8	85.0	77.6
August	1-10	88.4	28.7	19.9	81.8	54.0
	11-20	73.6	29.1	19.5	86.9	42.9
	21-31	70.1	28.4	20.8	80.8	82.7
September	1-10	39.3	29.5	21.9	81.9	60.0
	11-20	80.5	29.4	18.9	80.3	64.4
	21-31	39.3	28.1	18.6	72.9	68.4
October	1-10	32.5	31.1	20.1	84.4	82.2
	11-20	0.0	32.6	18.7	78.0	79.9
	21-31	0.0	32.2	18.2	76.8	78.2
November	1-10	0.0	27.6	17.2	66.0	88.4
	11-20	0.0	29.4	14.9	34.7	87.5
	21-31	0.0	25.7	13.0	26.6	88.5
December	1-10	0.0	34.5	13.3	20.3	92.5
	11-20	0.0	34.3	16.3	18.7	68.7
	21-31	0.0	30.1	12.8	16.8	90.0

NA = Not available

Appendix 5. Crop syndrome reaction score (1-9) used for measurement of tolerant of maize to *Striga* based on *Striga* damage symptoms on the host plant (1 = tolerant; 9= highly susceptible).

1.	No chlorosis, no blotching, and no leaf scorching (firing) and normal plant growth.
2.	Mild leaf blotching and scorching and about 10% of leaves with purplish brown necrotic spots, almost normal plant growth. No stunting and no ear size reduction.
3.	Mild definite leaf blotching and scorching on about 20% of leaves with some purplish-brown necrotic spots. Mild stunting and ear size reduction.
4.	Some definite leaf scorching on about 30% of leaves with some purblish-brown necrotic spots; some stunting and ear and tassel size reduction.
5.	Definite leaf scorching on about 40% of leaves with gray brown necrotic spots. Some stunting and ear and tassel reduction.
6.	Definite leaf scorching on about 50% of leaves with mostly gray necrotic spots. Definite stunting and stem diameter, ear size and tassel size reduction.
7.	Definite leaf scorching on about 60% of leaves with severe gray necrotic spots and leaf wilting and rolling. Definite stunting and stem diameter, ear size, and tassel size reduction, often cause severe stalk lodging and husk opening at late growing stage.
8.	Definite leaf scorching on about 70% of leaves with definite gray necrotic spots. Conspicuous stunting, leaf wilting, rolling and stem diameter, ear size and tassel size reduction.
9.	Complete leaf scorching of all leave causing premature dead of host plant and no ear formation.

Appendix 6: Mean squares from analysis of variance for *Alectra* and crop parameters as affected by reaction of soybean cultivars to *Alectra* at Samaru, first screen house trial, 1995.

		Alectra shoot count					crop reaction score.	Days to *Alectra* emergence.	Days to flowering.	Number of nodules.	Shoot dry weight.	Plant height.
Source of variation	DF	6WAS[1]	7WAS	8WAS	9WAS	10WAS						
Repetitions	2	0.01	0.05	0.80	1.09	1.68	3.02	107.00	6.05	1.57	0.40	3.47
Cultivars	21	0.09	1.34*	2.23**	4.63**	7.21**	9.67**	484.30**	80.69**	290.94**	3.74**	79.78**
Error	42	0.10	0.65	0.75	1.05	1.06	1.13	229.80	4.93	9.81	0.22	8.04
Total	63	0.10	0.81	1.25	2.25	3.11	3.98	314.60	30.19	103.52	1.39	31.95

1 WAS = Weeks after sowing .

Appendix 7. Mean squares from analysis of variance for *Alectra* and crop parameters as affected by reaction of soybean cultivars to *Alectra* at Samaru. Second screen house trial. 1995.

Source of variation	DF	*Alectra* shoot count					crop reaction score.	Days to *Alectra* emergence	Days to flowering.	Number of nodules.	Shoot dry weight.	Plant height.
		6WAS[1]	7WAS	8WAS	9WAS	10WAS						
Repetitions	2	0.05	0.09	0.27	0.58	0.99	0.26	18.29	2.00	1.03	0.26	0.38
Cultivars	21	0.08	0.42**	2.55**	9.55**	18.12**	10.73**	118.03**	66.11**	222.63**	3.03**	102.31**
Error	42	0.07	0.11	0.46	0.65	1.26	0.25	12.44	3.94	1.26	0.45	3.07
Total	63	0.07	0.21	1.15	3.61	6.88	3.74	50.67	24.66	75.05	1.31	36.15

1 WAS = Weeks after sowing.

Appendix 8. Mean squares from analysis of variance for *Alectra* and crop parameters of soybean cultivars under natural field infestation of *Alectra* at Site 1, Samaru, 1995.

Sources of variation	DF	Plant height			*Alectra* shoot count		Days to Alectra emergence.	Days to crop flowering.	Days to physiological maturity.	No. of branches.	No. of pods.	100-seed weight.	Seed yield.
		4WAS[1]	8WAS	Harvest	9WAS	10WAS							
Replications	2	2.99	17.03	26.42	4.07	4.39	4.74	0.20	1.96	6.52	104.40	0.09	45366
Cultivars	21	20.86*	146.51**	309.76**	42.41**	54.54**	14.39**	75.81**	440.11**	16.65**	309.10*	7.32**	450992**
Error	42	8.33	47.10	73.63	8.65	10.47	5.82	1.15	20.90	5.79	177.4	1.00	42525
Total	63	12.51	80.24	152.34	19.90	25.16	8.68	26.04	160.64	6.04	221.30	3.11	178681

1 WAS = Weeks after sowing.

Appendix 9. Mean squares from analysis of variance for *Alectra* and crop parameters of soybean cultivars under natural field infestation of *Alectra* at Site 1, Samaru, 1996.

Sources of variation	DF	Plant height			Alectra shoot count		Days to *Alectra* emergence.	Days to crop flowering.	Days to physiological maturity.	No. of branches.	No. of pods.	100-seed weight.	Seed yield.
		4WAS[1]	8WAS	Harvest	9WAS	10WAS							
Replications	2	0.41	8.04	1.57	2.71	2.54	4.81	1.69	1.74	0.74	45.6	0.79	9694
Cultivars	21	7.13*	116.06**	519.90**	30.13**	41.11**	15.78**	54.75**	541.80**	6.06*	420.7**	2.55**	171470*
Error	42	3.70	23.94	52.30	4.16	6.40	5.61	2.00	1.47	3.90	148.9	0.89	80095
Total	63	4.51	54.65	208.17	12.82	17.97	9.00	19.58	181.58	4.62	239.5	1.45	110553

1 WAS = Weeks after sowing.

Appendix 10: Mean squares from analysis of variance for *Alectra* and crop parameters of soybean cultivars under natural field infestation of *Alectra* at Site 1, Samaru, 1997.

Sources of variation	DF	Plant height.			*Alectra* shoot count.		Days to Alectra emergence.	Days to crop flowering.	Days to physiological maturity.	No. of branches.	No. of pods.	100-seed weight.	Seed yield.
		4WAS[1]	8WAS	Harvest	9WAS	10WAS							
Replications	2	1.79	16.76	7.86	1.64	1.28	2.68	3.47	3.14	3.20	100.65	0.63	43080
Cultivars	21	9.00*	99.37**	398.36**	7.45**	11.42**	18.67**	46.33**	493.23**	5.70*	127.16	3.03**	333533**
Error	42	3.54	10.24	15.04	0.98	1.36	5.88	6.47	10.14	2.91	92.18	0.87	52049
Total	63	5.36	39.95	142.81	3.13	4.71	6.81	19.76	171.17	3.84	103.84	1.59	145877

1 WAS = Weeks after sowing

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Appendix 11. Mean squares from combined analysis of variance of *Alectra* and crop parameters of soybean cultivars under natural field infestation of *Alectra* at site 1, Samaru 1995 to 1997.

Sources of variation	DF	Plant height.			*Alectra* shoot count.		Days to Alectra emergence.	Days to crop flowering.	Days to physiological maturity.	No. of branches.	No. of pods.	100-seed weight.	Seed yield.
		4WAS[1]	8WAS	Harvest	9WAS	10WAS							
Replications	2	5.78	39.37	3.98	5.34	7.23	3.90	4.26	8.13	2.29	65.40	0.17	30942
Years	2	8.59	27.25	21.90	17.15	16.44	14.24	31.97	31.97	1.43	154.80	4.60*	698988*
Cultivars	21	29.77**	335.85**	1157.2**	66.06**	90.25**	21.72*	172.62**	146.18**	15.49*	364.40**	8.73**	745980**
Years x cultivars	42	3.61	13.04	35.41	6.97	8.14	8.56	2.14	3.97	1.39	96.30	1.09	105008
Error	130	17.04	105.83	54.96	15.24	20.54	13.58	11.72	27.09	8.77	270.30	1.25	212920
Total	197	7.79	58.28	167.77	11.95	15.95	8.16	21.79	171.13	4.83	188.2	2.05	145037

1 WAS = weeks after sowing.

Appendix 12. Mean squares from analysis of variance for *Alectra* and crop parameters of soybean cultivars under natural infestation of *Alectra* at Site 2, Samaru, 1995.

Sources of variation	DF	Plant height.			*Alectra* shoot count.		Days to *Alectra* emergence.	Days to crop flowering.	Days to physiological maturity.	No. of branches	No. of pods.	100-seed weight.	Seed yield.
		4WAS[1]	8WAS	Harvest	9WAS	10WAS							
Replications	2	2.22	3.64	6.48	9.30	13.36	3.49	1.38	2.35	2.29	5.29	0.35	33687
Cultivars	21	17.68**	129.09**	298.85**	15.82*	24.12**	11.16*	50.63**	518.21**	5.24**	103.95**	5.16**	371672**
Error	42	4.20	11.10	12.47	7.10	10.60	5.82	4.52	8.144	1.57	8.19	1.35	32963
Total	63	8.70	50.43	107.93	10.01	15.11	7.60	19.89	178.16	2.79	40.11	2.62	145866

1 WAS = Weeks after sowing.

Appendix 13. Mean squares from analysis of variance for *Alectra* and crop parameters of soybean cultivars under natural infestation of *Alectra* at Site 2, Samaru, 1996.

Sources of variation	DF	Plant height.			*Alectra* shoot count.		Days to *Alectra* emergence.	Days to crop flowering.	Days to physiological maturity.	No. of branches.	No. of pods.	100-seed weight	Seed yield.
		4WAS	8WAS	Harvest	9WAS	10WAS							
Replications	2	2.30	2.71	0.91	3.60	3.28	4.19	8.23	2.61	0.79	3.82	0.21	10975
Cultivars	21	7.69*	102.48**	373.61**	14.36**	21.21**	15.26*	41.50**	584.24**	2.55*	78.18**	2.34**	184575**
Error	42	4.12	5.91	8.20	2.10	3.23	6.85	12.12	6.88	1.07	6.68	0.67	29304
Total	63	5.31	38.10	130.01	6.18	9.22	9.65	21.91	199.33	1.57	30.51	1.22	81061

1 WAS = Weeks after sowing.

Appendix 14. Mean squares from combined analysis of variance for *Alectra* and crop parameters of soybean cultivars under natural field infestation of *Alectra* at site 2, Samaru 1995 and 1996.

Sources of variation	DF	Plant height.			*Alectra* shoot count.		Days to *Alectra* emergence	Days to crop flowering.	Days to physiological maturity.	No. of branches	No. of pods.	100-seed weight	Seed yield
		4WAS[1]	8WAS	Harvest	9WAS	10WAS							
Replications	2	1.13	1.27	20.42	6.71	10.24	6.12	2.40	5.43	0.77	7.69	0.94	
Years	1	0.56	1.80	4.01	0.28	1.30	10.87	2.92	4.14	8.69	4.82	4.11*	16166
Cultivars	21	23.29**	226.88**	638.82**	27.92**	41.89**	21.50**	84.29**	198.97**	7.31**	158.27**	5.05**	32331
Years x cultivars	21	2.09	4.70	33.64	2.26	3.44	4.92	7.85	3.47	0.48	23.85	1.44	53500
Error	86	5.29	9.77	30.76	11.31	17.16	12.45	10.72	12.94	2.09	15.12	1.96	47299
Total	131	7.00	44.27	118.97	8.10	12.17	8.63	20.90	188.75	2.18	35.31	1.92	11346

1 WAS = Weeks after sowing.

Appendix 15. Mean Squares from analysis of variance for percentage germination of *Alectra* seeds induced by soybean cultivars, laboratory trial. Samaru, 1997.

Sources of variation	Df	Percentage germination of *Alectra* seeds.		
		2WAS[1]	3WAS	4WAS
Repetitions	2	3.41	6.48	8.16
Cultivars	22	13.14*	24.91*	66.95*
Error	44	5.78	11.01	33.25
Total	68	8.23	13.50	37.82

1 WAS = Weeks after sowing

Appendix 16. Mean Squares from analysis of variance for percentage germination of *Alectra* seeds induced by soybean cultivars, cowpea varieties and concentrations of abscisic acid, laboratory trial, Samaru, 1998.

Sources of variation	DF	Percentage germination of *Alectra* seeds.	
		3WAS[1]	4WAS
Repetitions	2	64.22	65.1
Cultivars	10	558.24**	620.38**
Error	20	63.02	115.76
Total	30	63.40	117.30

1 WAS = Weeks after sowing.

Appendix 17. Mean Squares from analysis of variance for *Alectra* shoot count and crop parameters as affected by soybean cultivars and concentrations of absisic acid, screen house trial, Samaru, 1997.

		Alectra shoot count.		Days to *Alectra* emergence.	Days to crop flowering.
Sources of variation.	DF	9WAS[1]	11WAS		
Cultivars	4	3.02**	3.49**	1.31**	430.44**
Concetrations	3	0.35	0.44**	0.08	0.59
Cultivars x concentrations	12	0.21	0.26	0.04	1.28
Error	40	0.09	0.11	0.04	0.68
Total	59	0.33	0.39	0.18	29.94

1 WAS = Weeks after sowing

Appendix 18. Mean squares from analysis of variance for number of live, dead and percentage of dead *Alectra* plants as affected by anti-transpirants, screen house trial, Samaru, 1997.

Sources of variation	DF	*Alectra* Shoot.				
		Total before application.	No. of dead 5DAA[1].	No. of dead 10DAA.	% of dead 5DAA.	% of dead 10DAA.
Repetitions	3	1.40	1.16	1.22	3.55	0.38
Anti-transpirants	6	0.34	3.79**	4.12**	39.59**	43.47**
Error	18	1.67	0.77	0.97	4.93	2.33
Total	24	1.35	1.52	1.76	13.59	12.61

1 DAA = Days after application

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College of Advance Studies, Zaria	1981	1983	IJMB
Ahmadu Bello University, Zaria	1983	1987	B.Sc Agric. (2^1)
Ahmadu Bello University, Zaria	1990	1993	M.Sc Crop Physiology

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College of Education Kafanchan	1988	1989	Lecturer
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