EFFECTS OF FERTILIZERS AND HERBICIDES ON THE REACTION OF COWPEA VARIETIES (Vigna unguiculata (L.) Walp.) TO Alectra vogelii (Benth.)

BY

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A thesis subnitted to the Postgraduate School, Ahnadu Bello University, Zaria in partial fulfilment of the requirement for the Degree of Doctor of Philosophy in Agronomy.

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DECLARATION

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



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CERTIFICATION

This thesis entitled "EFFECTS OF FERTILIZERS AND HERBCIDES ON THE REACTION OF COWPEA VARIETIES (*Vigna unguiculata* (L.) Walp.) TO *Alectra vogelii* (Benth.)" by Enoch Istifanus Magani 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, Margaret and Son, Bapije for their love, Patience and encouragement during the course of my study.

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ABSTRACT

Field and green house trials were conducted to study the effects of fertilizers and herbicides on the reaction of cowpea varieties to Alectra voqelii (Benth.) at Samaru in the northern Guinea savanna ecological zone of Nigeria in 1991 and 1992 wet seasons and the reaction of cowpea varieties to Alectra seed concentration in the green house in 1992 and 1993 dry seasons.

Cowpea variety B 301 and the derivatives of its crosses with IT84 S-2246-4 (IT 90 K-59 and IT 90 K-76) did not support Alectra emergence. The varieties also produced cowpea grain yields that were comparable to the maximum in the 1991 trial and significantly higher than the least in the two years. The nodulation of these varieties were however reduced in the pot by 21.57%, 43.9 and 76.9%. for B 301, IT 90K-59 and IT90K-76, respectively. However, IT 89 KD-245 and IT 89KD-245-1, both of which are derivatives of B 301 and local variety Kananado supported low emergence of Alectra. Inspite of high reduction of nodulation in the pot by Alectra and support for low Alectra infection in all the trials, IT86D-534 did not suffer any reduction in cowpea grain yield in two field trials. Inspite of high infestation by Alectra and very low pod number Kano 1696 still produced acceptable grain yield. Cowpea varieties IT82D-849 and SUVITA-2 known to be resistant to Striqa qesnerioides, exhibited susceptibility to Alectra. Both TVx 3236 and SAMPEA 7, supported high Alectra infection with consequent high susceptibi1ty to the parasite in the field. In the green house

TVX 3236 initiated early emergence of Alectra and had more number of emerged Alectra compared with all the other varieties. Under artificial inoculation, all the varieties tested, including B 301, produced lower grain yield than VITA-3, the only variety in which Alectra infection did not cause cowpea grain yield reduction in 1992.

In the evaluation of nitrogen and phosphorus combinations on the reaction of cowpea varieties to Alectra voqelii, cowpea varieties TN93-S0 and IT89KD-245-1 significantly delayed Alectra emergence compared with VITA-3 and SAMPEA-7 in 1991 and 1992, respectively. Inspite of higher number of plants infected and Alectra shoot count, VITA-3 still produced cowpea grain yield comparable to the maximum tined by IT 89 KD-245-1 in 1992. Phosphorus application at 20 kg P/ha significantly increased cowpea grain yield without any significant effect on Alectra incidence. Nitrogen application at 60 kg M/ha consistently reduced the number of plants infected and Alectra shoot count, but resulted in cowpea grain yield depression compared with 0 and 30 kg N/ha. It was apparent from the 2-order interaction, that varieties which exhibited moderate (TN 93-80 in 1991) to high (IT89KD-245-1 in 1992) resistance responded to high doses of N (60 kg/ha) and P(40 Kg P/ha) by delaying the emergence of Alectra.

In the two years, pre-emergence herbicide applications the mixtures containing Pree (metazachlor + antidote) followed by imazaquin at 0.18 kg a.i./ha resulted in significantly lower number of plants infected. Similarly, in 1991, Pendimetha1 in plus imazaquin at 0.87 + 0.15 and 1.09 + 0.19 kg a.i/ha and

pendimethalin plus imazethapyr at 1.58 + 0.12 kg a.i/ha, all followed by imazaquin at 0.18 kg a.i/ha, resulted in lower number of cowpea plants infected by Alectra compared with the weedy check. In 1992, post-emergence application of Pree plus imazethapyr at 1.0 + 0.075 kg a.i/ha resulted in lower number of infected plants compared with the maximum obtained with pendimenthalin plus imazaquin at 1.09 + 0.19 and pendimethalin plus imazethapyr at 1.58 + 0.12, both followed by SHW which also resulted in significantly higher cowpea grain yield than the weedy check.

In the green house, the reaction of cowpea varieties to pre-conditioning and concentration of seed inoculant of Alectra voqelii indicated that Alectra emergence increased wih Alectra seed concentrations in the first trial, while lOc.c/pot Alectra seed gave the highest number of emerged Alectra with compared to other Alectra seed concentrations in the second trial. Pre-conditioning period had no significant effect on number of days to Alectra emergence but Alectra emergence increased with pre-conditioning period of 7 and 14 days.

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1.0 INTRODUCTION

1.1 Production and Uses of Cowpea

Cowpea (Vigna unquiculata (L.) Walp.) is the most important grain legume in the semi-arid regions of West Africa. World cowpea production in 1981 was estimated at 2.27 million tonnes from 7.7 million hectares (Rachie, 1985). According to Rachie (1985) current world realistic production levels may exceed 2.5 million tonnes of dry seeds on about 9 million hectares. Most of the world cowpea crop is grown in West Africa and Nigeria is by far the most important producer. World cowpea production figures indicate that West Africa accounts for over 75% of the hectarage and grain production with most of this (60% of the world production) in Nigeria (Singh and Singh, 1982). In Nigeria, about 1 million metric tonnes of cowpea was produced from about 4 million hectares of land (Hartmans, 1983; Raheja, 1986). Although Nigeria is the leading producer of cowpea in the world, grain yield per hectare is generaly lower than those of many other countries; about 189 Kg/ha was reported for Nigeria in 1975 (Anon 1975). Recently, Hartmans (1983) reported an average grain yield of 250 Kg/ha for Nigeria compared with 3,103 Kg/ha and 651 Kg/ha reported for Egypt and Malawi, respectively (Anon, 1975). The low yield in Nigeria has been attributed to the fact that the crop is rarely planted sole, the unreliable distribution of rainfall in northern Guinea and the Sudan ecological zones which are the major areas of production.

Cowpea seed is an important pulse in the tropics and sub-tropics, particularly in Africa. The dry pulse contains

essential elements as well as 23.4% protein, 1.3% fat, 56.8% carbohydrate, 3.9% fibre and 3.6% ash (Langworthy and Hunt, 1959). In tropical Africa, the dry seed of cowpea is primarily cooked as a pulse in a large variety of dishes. The tender green leaves and pods are cooked as vegetables or as relish in many areas of West Africa. The ability of cowpea to fix atmospheric nitrogen (60-70 Kg N/ha to the proceeding crop) via the rhizobia of the root nodules has made it an important crop as replinisher of soil nitrogen especially in the traditional farming systems (Steele, 1976; Rachie 1985).

1.2 Parasitic Weed Problem in Cowpea

In addition to insect pests and diseases, two distinct root parasitic weeds namely Striga gesnerioides (Willd.) Vatke and Alectra vogelii (Benth). of the family Scrophulariaceae have devastating effects on cowpea. While Striga is more wide-spread in the Sahel, Sudan, northern and southern Guinea savanna of the sub-Saharan Africa, Alectra appears to be more destructive in the northern Guinea and Sudan savannas (Aggarwal, 1985; Emechebe et al, 1991). Although attack by Alectra is less dramatic than that by Striga, total yield loss is not uncommon in fields heavily infested by these parasites when susceptible varieties of cowpea are planted (Emechebe, 1981; Emechebe et al, 1983). Alectra has been reported to cause yield losses of up to 100% in a susceptible variety of cowpea, groundnut and soyabean (Emechebe et al, 1983; Lagoke, 1989). Atople et al. (1991) reported yield loss of up to 100% in a susceptable, and up to 90% in moderately resistant cowpea varieties when Striga gesnerioides population

was over 10/plant. Fields infested with the parasites are difficult to clean due to the considerable amount of seeds produced and the dormancy mechanisms of these parasites, making it possible for them to stay in the soil for several years (Uttaman, 1950; Emechebe et al., 1983). Several cultivable lands have been abandoned consequent to the high soil infestations of these noxious weeds.

1.3 Control of Parasitic weeds in Cowpea

Considerable work has been done on various control methods for parasitic seed plant species, although S. gesnerioides and A. vegelii have received relatively little attention. Cultural practices recommended to limit Striga infestation include such methods as catch and trap cropping, crop rotations and tillage operations (Timson, 1929; Andrew, 1947; Dogget, 1954). Though the use of high nitrogen fertilizer has proved effective in preventing complete crop loss by Striga in cereals (Last, 1960; Ogborn, 1970; Bebawi, 1981; Ogunlela, 1983; Ramaiah, 1984), the results have been inconsistent and inconclusive with cowpea Striga (Emechebe, et al., 1991; Adu et al., 1989). Preliminary studies in sand culture, however, showed that 140 ppm N, applied as Sodium nitrate solution, drastically reduced the incidence of S. gesnerioides infection in potted cowpea (Emechebe et al., 1988). There was however a coresponding decrease in number of nodules. The constant weeding advocated by Olunuga and Akonbundu (1980) has been found ineffective because of intensive labour requirements, re-emergence of Striga and Alectra (Emechebe et al., 1983) and the severe crop damage done by the subterranean

Striga prior to it emergence (Press and Stewart, 1987). Emphasis on control of Striga and Alectra in cowpea has been placed mainly on host-plant resistance (Aggarwal, 1985; 1986; Emechebe et al., 1988; Atokple, 1989). However, complete reliance on host-plant resistance is not advisable; rather a strategy that combines striga-resistant cultivars with appropriate complementary agronomic practices has been advocated (Ramaiah, 1984; Lagoke et al, 1988; 1990; Lagoke, 1989). Alectra is largely a problem of subsistence farmers in Africa and has therefore been neglected.

The study was conducted with following objectives:

(1) To evaluate the reaction of cowpea varieties to Alectra vogelii

(2) To evaluate the effect of nitrogen and phosphorus combination on the reaction of cowpea varieties to Alectra vogelli

(3) To evaluate herbicides for the control of Alectra vogelii, in cowpea

(4) To develop an appropriate technique for evaluating cowpea varieties for their reaction to Alectra in the green house.

2.0 LITERATURE REVIEW

2.1 Biology of parasitic weeds of cowpea

Alectra vogelii and Striga gesnerioides are parasitic weeds belonging to the family Scrophulariaceae (Kuijt, 1969). Alectra has large yellow flowers, which clearly distinguish it from Striga gesnerioides which usually has purple flowers. Other features of Alectra like Striga is the herbaceous shoot habit and tiny dust-like seed, which are produced in large numbers. Seed size is of the order of 0.25-0.35mm long x 0.12 - 0.20mm broad. Alectra is alleaged to produce from 40,000 to 450,000 seeds per plant with an average seed range per capsule of 431 to 1,761 (Kust 1963). Longevity of seeds in the soil vary between 6 months and 20 years according to climatic conditions (Saunders, 1933; Bebawi, et al., 1984a). Alectra seed germination occurs in response to the root exudates of potential host and hemi-parasitic after emergence follows the holoparasitic development of the plant host (Botha, 1946; Kuijt, 1969). Root exudates from the various members of the leguminosae obtained by Botha (1948), induced sensitizd Alectra seed to germinate. Alectra seeds are well protected by thick seed coats and usually remain dormant until they are induced to germinate by exudates from the root of the hosts (Okonkwo and Nwoke, 1975; Visser, 1975). The majority of the seeds within 2mm of the host root receive sufficient stimulant to germinate, so few seedlings are wasted through being too far away from a host root. Much of the seed which has imbibed water enters a period of "wet dormancy" if it is not stimulated to germinate (Reid and Parker, 1979). Salako (1984)

stated that long rotations seem to allow time for the seeds of Alectra to break dormancy.

The attachment and penetration of Alectra seedlings to the host occurs when the radicle of the seedlings grow towards the host root, apparently controlled by a rather weak chemotrophic influence. The radicle of the parasite first penetrates the host cortex. Alectra then induces lateral root formation by the host, while general dilation of the host root progress into the stele and then xylem, thereby completing the connection between the host and parasite. A complex tuberous structure is then formed by the haustorium of the parasite and the host root.

2.2 Ecology and Distribution of Alectra vogelii

Alectra, as a weed, shows great phenotypic plasticity, wide environmental tolerance, but prefers permanently disturbed habitats. Alectra is known to parasitize cultivated legumes in many parts of Africa. From Swaziland to the Transvaal in Southern Africa the range of this purely African species, extends through central Africa to Burkina Faso and Mali in the west and Kenya and Ethiopia in the east of the continent (Riches, 1987).

The seeds of most parasitic weed plants can be disseminated by a combination of wind and water. Seeds of Alectra are soil borne. Emechebe et al. (1983) and Lagoke. (1989) noted that the seeds are spread by contaminated agricultural equipment from one field to another and also by movement of seeds of cowpea or groundnut contaminated by this parasite from one place to another. There are speculations that these parasitic weeds fed to animals by famers on medicinal grounds or eaten in advertently

by the animal in combination with other herbs pass undigested in their excreta and therefore spread through their nomadic or seasonal movements across the savanna zones.

2.3 Effect of Parasitic Weeds on Cowpea

A considerable damage is inflicted on food and fodder plants by wide spread occurence of these parasitic flowering plants. Striga is presently the most important biological constraint to food production in Africa (Sauerborn, 1991; Emechebe et al, 1991). Visser (1978) stated that, although Alectra is not yet considered very important agriculturally, it is a potential danger in all areas where leguminous crops are being cultivated throughout the African continent south of the Sahara. Alectra has been reported to cause yield loss of up to 100% in a susceptible variety of cowpea, groundnut and soyabean (Emechebe et al., 1983; Lagoke, 1989). Atokple et al (1991) reported yield loss as of up to 100% in a susceptible, and 90% in moderately susceptible cowpea varieties infected by Striga gesnerioides when the level of attack was up to 10 Alectra plants per cowpea plant. Earlier Aggarwal and Oedraogo (1989) reported that yield loss of cowpea due to S. gesnerioides varied from 56% on a susceptible variety with 83% plants infected, through 30% loss on less susceptible varieties with 40-50% of the plants infected.

2.4 Symptom of Parasitic Weeds Infections in Host Crops

The physiological disorder caused by S. gesnerioides in cowpea is a drastic and extensive loss of carbohydrates, which have been shown to be mainly sucrose (Ba, 1983). Such bulk loss

of carbohydrates from the host cowpea plant correlated with the robust haustoria of the parasite which consists of phloem, in addition to other transport cells (Ba, 1983). The removal of these organic compounds, mainly carbohydrates, in large quantities results in extensive damage to the cowpea plant, despite the relatively small size of the parasite.

The following account of the above ground symptoms of attack of cowpea by S. gesnerioides is based solely on the report of Emechebe et al (1983; 1988). The commonest symptom observed on cowpea infected by S. gesnerioides in the field as well as in the screen house is interveinal chlorosis. The striga plants may or may not emerge above the soil level before the appearance of chlorosis or, any other external symptom. On a heavily infected plant an important symptom is foliar desiccation which may be preceded by interveinal, rusty brown to purplish spots; a few days later, the areas around spots suddenly dessiccate to produce straw-coloured necrotic spot with watersoaked margins. Coalescence of several spots result in blighting of the lamina. A leaflet may be completely desiccated before blight spreads to the rachis, necrosis of which results in the desiccation of other leaflets. Desiccation later spreads from the petioles to their points of attachment to the stem which then dries up downwards and rarely upwards. However, premature abscission of the leaf or leaflet prevents internode desiccation. In addition, a less severely infected plant may be stunted while mild chlorosis is symptomatic of even lighter infection. The effect of Alectra on cowpea is invariably the same as described above, although less dramatic (Emechebe et al., 1983).

2.5 Sources of resistance to Striga and Alectra in Cowpea

Although no absolute resistance to Striga has been found in cereals, several sources of true resistance to S. gesnerioides and A. vogelii have been identified in cowpea. Field screening of 54 varieties at Kamboinse, Burkina Faso in 1981 indicated two Striga resistant varieties: SUVITA-2 from Burkina Faso and 58-57 from Senegal (IITA/SAFGRAD, 1981, IITA, 1982). These two varieties supported little or no Striga emergence compared to a large number of emerged Striga on susceptible check varieties. From 1983 to 1986, systematic field testing programmes were conducted in Niger, NIgeria, Burkina Faso and Mali (IITA/SAFGRAD, 1983) involving these resistant varieties and derivatives of crosses from SUVITA-2 to ascertain the stability of Striga resistance across the West African Savanna. The result showed that SUVITA-2 and 58-57 maintained their high level of resistance only in Burkina Faso and Mali, but low to very low level of resistance or complete susceptibility in other countries, giving credence to the presence of different strains of S. gesnerioides (Aggarwal, 1986; IAR, 1986; 1987). Screenhouse studies conducted at Weed Research Organization (WRO) in U.K using seeds of these cowpea varieties and Striga from countries in West Africa, confirmed the previous field observations that there is at least two strains of S. gesnerioides in West Africa (IITA, 1984; 1985; 1986; and Aggarwal, 1985). The search for additional sources of resistance identified two new sources of resistance as B301 and IT82D-849 in 1987. They showed stable resistance to Striga across Burkina Faso, Mali, Republic of Niger, and Nigeria

(Aggarwal, 1988; Emechebe, et al., 1991). B301, a germplasm line from Botswana was initially identified to be resistant to Alectra vogelii in Botswana (C. Riches, 1984, personal communication). IT82D-849 is an imporved breeding line developed at IITA. Parker and Polniaszek (1990) and Bailey and Terry (1990) independently reported the combined resistance to Striga and Alectra in B301 and confirmed stable resistance of B301 and IT82D-849 across the strains of Striga within the West African sub-region. However, IT82D-849 is highly susceptible to Alectra. SUVITA-2 which is resistant to Striga in Nigeria but highly susceptible to Alectra. Systematic genetic studies have revealed a single dominant gene for Striga and independent duplicate dominant genes for Alectra resistance in B301 (Singh and Emechebe, 1990a, 1990b; Singh et al. 1993; Atokple et al. 1993). Also, studies have shown that resistance in IT82D-849 to Striga is controlled by a single dominant gene but it is different from that of B301 Atokple et al., 1993. Screening the parents of IT82D-849 and allelic test have revealed that its source of Striga resistance is from Emma 60, a variety from Uganda. In addition to these sources of resistance to Striga and Alectra, a number of moderately resistant lines have been identified. These improved breeding lines including IT81D-994, IT86D-472, IT84D-666, IT86D-534 and IT86D-371 were developed at IITA and showed delayed emergence of smaller number of Striga and Alectra which rarely grow to maturity (Singh and Emechebe, 1990b).

2.6 Host Responses to Parasites

The defence of host plants against their potential parasites

may be due to either evoidance or resistance mechanisms. Avoidance reduces the chance of contact between the prospective host tissue and the parasite, whereas resistance operates when host tissue and the parasite come into contact (Parlevliet, 1977).

Early maturity or tolerance of conditions which adversely affect parasite development, such as extremes of temperature or humidity, are example of avoidance mechanisms. Earlier studies had indicated that if susceptible photosensitive cowpea lines are planted at a date that will enable flowering to occur at about the period of Striga emergence, they may escape some damage (IITA/SAFGRAD, 1982). Ramaiah and Parker (1982) similarly suggest that early planting of sorghum in Southern Africa may reduce Striga attack as the crop can become established before the soil temperature will favour the conditioning of Striga seeds.

A host that is able to restrict the development of a parasite after contact is resistant (Robinson, 1969). Resistance levels may vary from low to total immunity. The mechanism of resistance to S. gesnerioides and Alectra vogelii in cowpea to S. hermothica in sorghum and to Orobanche spp are not clearly understood. According to several workers (Saunders, 1933; Parker, et al 1977; Ramaiah, 1987) resistance to Striga and Orobanche species may be caused by one or more of the following factors:

(a) low or no stimulant production (germination factors)

(b) mechanical barriers (anti-haustorical factors), and

(c) antibiosis.

Striga and Alectra seed need some chemical substances produced by susceptible host crops to be able to germinate. The absence of such compounds in the host root exudates confers resistance on the host by not stimulating germination of parasite seeds.

Anti-haustorial factors, as the term implies, operate after the Striga seed is successfully germinated and before it is fully established on the host root (Ramaiah, 1987; Lane et al., 1991). In the resistant cowpea variety, 58-57, Lane et al (1991) observed that there was a hypersensitive reaction producing necrosis of root tissue around invading Striga radicle and consequently death of parasite within 2-3 days.

According to Ramaiah (1984), antibiosis, the phenomenon of the host arresting normal growth and development of the attached Striga, may be due to incompatibility between the host and the parasite leading to the premature death of latter. He observed that this could be manifested immediately after successful invasion of the host tissue and establishment with the host vascular system. In Burkina Faso, field reports of the death of small Striga shoots on resitant cowpea variety SUVITA-2 within 3-4 days after emergence (Aggarwal et al., 1986) could be taken as antibiotic response. Lane and Bailey (1991) observed that on cowpea variety B301, the radicle of S. gesnerioides penetrated the host roots and formed small tubercles, which even after 12 weeks failed to develop beyond 1-2mm in diameter and stem development was also severely resistricted. The mechanism of resistance shown by cowpea variety, B359 to Alectra was also

bassed on limited development of parasite tubercle, similar to the antibiosis expressed by B301. Other classical antibiotic responses to Striga and Alectra infections are exhibited by the cowpea varieties, IT82D-849 and IT81D-994 respectively (Emechebe et al, 1991; Singh and Emechebe, 1990b) which restrict the growth and development of the attached parasites respectively.

2.7 Effect of Nitrogen on Alectra vogelii and Cowpea Grain yield

The influence of N-fertilization and manuring as farm practices in the management of parasitic weeds are generally not consistent and repeatable. Studies in sand culture (Emechebe et al., 1988; 1991) showed that 140ppm N supplied as sodium nitrate ($NaNO_3$) solution completely inhibited Striga attachment to cowpea roots while at the same time reducing nodule numbers. Results of subsequent field trials conducted in two consecutive years in the Sudan savanna of Nigeria were inconsistent and therefore inconclusive (Emechebe et al., 1991; Adu et al., 1989). The use of nitrogen in controlling S. gesnerioides in cowpea seems to be limited due to its detrimental effect on nodulation with high doses and consequent yield reduction. However, Adu et al. (1989) reported that lower doses of nitrogen in combination with some level of host resistance would be appropriate for conteracting Striga infection.

However, with sorghum, different sources and rates of N fertilizers have been used to suppress S. hermonthica and consequently increase sorghum grain yield. Urea at three rates of 43, 80 and 172 Kg N/ha increased sorghum yields by 14, 25 and

45%, respectively and decreased Striga shoot yield by 14, 21 and 35% compared with the untreated control (Bebawi and Abdulaziz, 1983) Ogborn (1979) reported that though high level of nitrogen increased sorghum grain yield, it also resulted in increased number of emerged Striga plants. In a pot culture under various nutrient levels, shoot yields of sorghum were reduced by Striga to about 75% at low nutrient level. Striga set seed at all nutrient levels, but the sorghum host produced seed at the highest nutrient level only (Egley, 1971).

It may be concluded from the above references that at least under certain conditions, low N resulted in increasing Striga, while high N could sustantially suppress it. But the mechanism by which nitrogen brings about its effect has not clearly been clarified. With regard to the effect of high N, according to Ogborn (1984), it could act in at least two ways. In the first place, it is possible to increase nitrogen in the host root to a level at which parasitism by Striga is inhibited. Secondly, reducing light intensity on soil surface (shading of the soil) as a result of a denser crop canopy, could result in less favourable temperature for Striga germination (Parker, 1984). On the basis of pot experiments, Parker (1984) proposed that N tends to change the balance of host root and shoot growth in favour of shoots, leaving the parasite relatively starved on the roots.

2.8 Chemical Control of Parasitic Weeds of Cowpea

The use of chemical to control witchweed can be divided into two general categories, namely pre-emergence and post-emergence (Ayensu et al., 1984; Dogget, 1988). Pre-emergence herbicides

capable of controling these parasites include the dinitroanilines (DNA's) and Diphenyl ethers (Eplee et al, 1991). Among the DNA's trifluralin, benefin, fluchloralin and pendimethalin have been found effective. Another new promising member of the group is formesafen (Eplee et al., 1991). All these herbicides act as barriers to prevent Striga emergence.

Post-emergence herbicides most commonly used to stop the reproduction of Striga are the salt formulations of 2,4-D (Choudhari et al., 1980; Yaduraju and Hosmani, 1979; Lagoke et al., 1993a, 1993b). They are applied to Striga foliage about the time of flowering at the rate of 0.5-1.0 Kg a.i/ha.

Pre-and post-emergence herbicides are effective in preventing Striga seed production. However, these treatments do not prevent the irreversible damage inflicted between the time of parasite attachment and emergence. A noble approach now under investigation is the use of systemic herbicides to control Striga at incipient attachment (Eplee et al., 1991). Schmitt et al. (1979) demonstrated the effectiveness of the systemic non-selective herbicide glyphosate in killing broomrape (Orobanche spp.) on broad beans (Vicia faba) and other crops at or soon after parasite attachment.

Metolachlor and pendimethalin are the two pre-emergence herbicides that were recently found in field trials to provide sufficient suppression of Striga attachment (Eplee et al., 1991). Pendimethalin, applied pre-emergence to the surface at 1.7 Kg a.i/ha, gave a 100% reduction to early Striga emergence (Eplee et al., 1991).

2.8.1 Imidazolinone herbicides

This class of herbicides is characterised by high phytotoxicity that makes it possible to apply members of this group at very low doses (0.15-0.75 kg/ha) for weed control. The mode of action of these herbicides is the inhibition of amino acid synthesis. This is followed by necrosis of the apical meristem. Some susceptible weeds, especially grasses, may show a purpling of the leaves that starts at the midrib and spreads to the lamina before death occurs.

2.8.1.1 Imazaquin

Imazaquin (2-(4-isopropyl-4-methyl-5-oxo-2-imidazoline-2-yl) quinoline-3-carboxylic acid), with the common name "Scepter". is a selective broad spectrum herbicide for weed control and post-emergence (Parker and Wilson, 1986). It is formulated both as an emulsifiable concentrate and water dispersable granules 70% w/w a.i. symptoms of phytotoxicity include stunting and chlorosis which develop into necrosis of tissues in susceptible plants. The new and young leaves are sometimes distorted while patchy chlorosis develops later on older sprayed leaves. In general, necrosis and death are usually preceeded by a pronounced chlorosis (Richardson et al., 1984).

Imazaquin is absorbed by the roots and foliage and translocated to other parts in both the xylem and phloem (Shaner et al., 1983). The uptake of imazaquin has however been suggested to be mainly through the root (Orwick et al., 1983).

Richardson et al. (1984) tried imazaquin on many weed species and crops and observed that the activity was generally greater in

the soil applied treatments, especially pre-emergence. The effects of the foliar spray were apparent on all species even at the lower doses the perennials like Polygonium amphibium and Elynus repens were sensitive while dwarf beans showed some degree of tolerance. In the post-emergence selectivity study six annual weeds were controlled at the lowest dose of 0.05 Kg a.i./ha of imazaquin, including two grasses (Poa trivalis and Festuca rubra). At higher doses a further 13 weed species were controlled including several grasses and broad leaved plants. The other perennials, although not adequately controlled were severely suppressed at higher doses.

In trials carried out both in the greenhouse and the field, imazaquin applied both pre-emergence and post-emergence at rates ranging from 0.025 to 0.4 Kg/ha has been reported to effectively and selectively control a wide range of weeds such as Amaranthus, Cyperus spp. and Euphorbia spp. in cowpea (Oneil et al., 1985) At 0.025 Kg/ha, legume crops including cowpea tolerated imazaquin but were however damaged a litle at 0.1 kg/ha in the greenhouse. At higher rates, a wide range of weeds including Rottboellia cochinchinesis was controlled by imazaquin (Parker and Wilson, 1986). Applied pre-emergence in mixture with other herbicides, imazaquin gave season long weed control in soyabean Wilson and Hines, 1986; IITA, 1984). Gofung (1987) found that imazaquin and its mixture with metolachlor at 0.25 + 1.25 kg a.i./ha in soyabean and groundnut and at 0.15 + 1.25 and 0.33 + 1.25 kg a.i/ha in cowpea gave effective weed control and high yield.

In Nigeria, Magani et al, (1992) reported that Pree plus

mazaquin at 1.0 + 0.13 Kg a.i./ha and pendimethalin plus imazaquin at 1.09 + 0.19 kg a.i/ha, all followed by one supplementary hoe-weeding at 6 WAS when compared with two hoe-weedings resulted in lower Alectra shoot count and number of infested plants with consequent increase in cowpea grain yield.

2.8.1.2 Imazethapyr

Imazethapr (±)-(4, 5-dihydro-4-methyl-4-(1-methyl ethyl)-5-oxo-1 H-imidazol-2-yl) -5 ethyl-3-pyridune carboxylic acid (±)-5-ethly-2-(4-isoprophyl-4-methyl-5-oxo-2 imidazolin-2-1l), has the common name of pursuit, with the ammonium salt formulated as an aqueous solutions of different acid equivalent concentrations depending upon geographic region.

Imazethapyr herbicide kills weeds by reducing the level of the three-branched-chain aliphatic amino acid, isoleucine, leucine and valine, through the inhibition of acetohydroxy acid synthase (AHAS), an enzyme common to the biosynthetic path way of these amino acids. This inhibition causes a disruption in protein synthesis which in turn lead to an interference in DNA synthesis and cell growth.

Imazethapyr is readily absorbed through the roots and foliage translocated in the xylem and phloem throughout the plants. After pre-emergence or pre-plant incorporated application, susceptible weeds may germinate and emerge, however, normal growth stops at the cotyledon stage in broadleaved weeds and before the 2-leaf stage in grasses.

The selectivity of imazethapyr in soyabeans is the result of rapid metabolism of the herbicide by the soyabean plants.

Susceptible weeds either cannot metabolise the herbicide or metabolise it too slowly for detoxification.

2.8.2 Chloro-acetamides

The chloro-acetamides constitute a major sub-division of the amide class of herbicide which have a mono chlorinated methyl in the R-1 position (Clenn et al, 1975).

Chloroacetamides are principally used for the control of seedling grass and certain broadleaved weeds in vegetable and field crops. They are more effective in controlling grasses than broad-leaved weeds. Chloroacetamides are normaly applied pre-emergence to the weeds and crops although some of them like propanil primarily have post-emergency activity (Anderson, 1977).

Chloroacetamides are readily absorbed by susceptible plants, primarily by seeds and first node of germinating seedlings and appear to be translocated primarily in the apoplast but limited symplastic movement occur (Klingman et al., 1975). They inhibit mitochondrial phosphorylation and mitotic division. The inhibition increases with increasing concentration and varies with different species.

2.8.2.1 Metolachlor

Metolachlor (2-chloro-N-(2-ethyl-6-methyl-pheny)-N-(2-methoxyl-1-methyl ethyl) acetamide, is principally applied pre-emergence for selective control of annual grass, yellow nutsedge and certain broadleaved species in maize, groundnut, soyabean, yam, potato, cotton and cowpea (Anon, 1983). Metolachlor has been reported to give effective weed control in cowpea when applied singly. Mixtures of metolachlor with various herbicides

such as imazaquin, metobromuron, diuron and prometryne have been reported to give selective weed control in cowpea by many workers (Akobundu, 1978; Hussain, et al, 1979; Lagoke et al., 1982). Metolachlor has recently been found in field trials to provide sufficient suppression of Striga attachment (Eplee et al 1991); applied preplant incorporated (PPI) at 2.2 Kg a.i./ha it caused an 80% reduction in Striga emergence.

2.8.2.2 Metazachlor (Pree)

Metazachlor N-(2,6-Dimethylphenyl)-N-(1-Pyrazolyl methyl)-chloroacetamide is principally applied pre-emergence for selective control of annual grass and yellow nutsedge in cotton, rape, potatoes, groundnuts, soyabeans, tobacco and cowpea (Thomas, 1990). On light soils, heavy rainfall after application may cause some crop injury. It is reported to give maximum weed control when not applied on a rough or cloddy seedbed. It is very compatable with many other herbicides.

Studies on control of broadleaved weed winter rape in the UK, showed that metazachlor at 0.5-1.25 Kg, cyanazine at 0.59 kg successfully controlled Stellaria media. Single application of metazachlor or cyanazine or applications of both at 0.5-0.75 Kg and 0.38 Kg, respectively, consistently controlled Veronica spp. (Bowerman, 1990). Walker et al (1990) reported that the best weed control in 10 out of 13 trials was obtained with metazachlor alone or in mixtures, but in the absence of high levels of volunteer cereals there was no relationship between weed density and yield response. Laureti (1989) reported that metazachlor at

2 kg/ha product pre-emergence or 2.5 Kg post-emergence; at the 2-leaf stage of the crop performed well when applied singly or in mixtures to oilseed rape. Presowing and pre-emergence treatments were the most satisfactory.

2.8.3 Dinitroaniline herbicides

Many members of this group are soil-active herbicides with little or no foliar activity. They tend to volatilize when applied on the soil surface, thus making soil incorporation necessary. Pendimethalin and oryzalin are two members of this group that are less volatile and can be applied pre-emergence without soil incorporation. Pendimethalin is the only member of this group herbicidally active when used as a pre-plant incorporated, pre-emergence or post-emergence herbicide.

Dinitroaniline herbicides kill seedling weeds by inhibiting the development of lateral roots in susceptible plants. Other characteristics of dinitroanilines are stunting of the above-ground parts of susceptible plants, development of dark green colour swelling and brittlenes of the stem or the hypocotyl of seedlings (Parka and Soper, 1977). As a group the dinitroanilines are very effective in the control of corn grass (Rottboellia cochinchinesis).

2.8.3.1 Pendimethalin

Pendimethalin (N-(1-ethylpropyl)-3, 4-dimethyl-2-6-dinitrobenxenamine), like other dinitroaniline herbicides, generally inhibits weed seed germination and associated physiological growth process by disorganizing mitotic divisions

in root cells (Oliver and Frans, 1968). Pendimethalin has been widely used mainly as a pre-emergence herbicide for the control of annual grasses and broad-leaved weeds in some crops, such as beans, onions, tomatoes (Ashton, 1978; Idris, 1983). Pendimethalin has a narrow weed control spectrum which can be considerably broadened by tank mixing with metobromuron in cowpea.

Pendimethalin, applied pre-emergence to the surface at 1.7 kg a.i/ha, gave a 100% reduction in early Striga emergence (Eplee et al., 1991). The mode of action of these herbicides in preventing early season Striga attachment is not yet known. Magani et al. (1992) reported that pendimethalin plus imazaquin at 1.09 + 0.19 Kg a.i/ha followed by one supplementary hoe-weeding at 6 WAS resulted in lower Alectra shoot count and number of infected plants with consequent increase in cowpea grain yield.

3.0 MATERIALS AND METHODS

3.1 Experimental materials

The materials used in these studies included 18 cowpea lines.

B 301

B 301 is a local land race from Botswana where it is mainly grown for its leaves as vegetables. It is late maturing but photoperiod-insensitive. The growth habit is semi-erect with twining tendency. The leaves are subglobous; pods are straight and pendant in attachment to the peducles which are mostly held below canopy. The seeds are rather small, creamy in colour with

smooth testa. This line has cross resistance to all strains of cowpea striga and Alectra in the southern, central and West Africa sub-regions. The mechanism of resistance to both parasites is antibiotic characterized by no haustoria formations and death of parasites. This line is also fairly resistant to most diseases prevalent in the savanna zones.

IT82D-849

This is an improved breeding line from IITA, Ibadan, Nigeria, which is early maturing and photoperiod - insensitive. It has an erect plant architecture with the straight pods pendant and mostly above the canopy. This line also exhibits an antibiotic mode of resistance to Striga, restricting growth to minute haustoria formations. There are occasional emergence but very weak plants which die before maturing. However, the high susceptibility of IT82D - 849 to Alectra and bacterial blight nullifies the benefits of Striga resistance in terms of yield loss offset.

SUVITA - 2

SUVITA - 2, otherwords known as Gorom Local originates from Burkina Faso. It is medium maturing and photoperiod - insensitive and mainly cherished for its drought tolerance. It has semi-erect growth habit with most of its hemispherical pods above the canopy. The medium-size seeds are brown in colour with rough seed coat. This line shows high level of resistance to Striga only in Burkina Faso but low to very low resistance or complete susceptibility in other countries like, Mali, Niger, and Nigeria. The resistance is characterized by very few or no emergence of

attached Striga which is caused by antihaustorial factors. SUVITA - 2 is however, highly susceptible to Alectra and cowpea yellow mosaic virus disease.

IT81D - 994

This is an improved breeding line from IITA, which is late maturing and photoperiod-sensitive. Its prostrate growth habit pushes most of the hemispherical pods above the canopy. The rough-textured, medium sized seeds are white in colour with black eyes. This line is moderately resistant to Striga and highly resistant to Alectra. The resistance is characterized by less and delayed emergence which are weak, and slow growing Alectra plants. IT81D-994 has the added advantage of being resistant to bruchids.

IT84S - 2246 - 4

This photoperiod - insensitive improved variety from IITA is susceptible to both Striga and Alectra. It is otherwise resistant to several diseases and thrips. It also combine high yield potential with early maturing. IT84S - 2246 - 4 has an erect growth habit with its straight pods acute to the peduncle and held above the canopy. The medium-sized seeds are brown in colour with rough testa.

TVX3236

This photoperiod-insensitive variety is susceptible to Striga and Alectra. It is medium maturing and resistant to thrips. The medium size seeds are white cream eye.

IT90K-59

It is photoperiod-insensitive, early maturing and resistant to aphids, bruchids and thrips. It has an erect growth habit with its straight pods held above the canopy. The small-sized seeds are brown in colour with rough testa.

IT90K-76

It is photoperiod-insensitive, early maturing and resistant to aphids, bruchids and thrips. It has an erect growth habit with it pods held above the canopy. The medium-sized seeds are brown in colour with rough testa.

IT86D-534

It is early maturing with multiple disease resistance. IT86D-534 is moderately resistant to Striga and Alectra. It is resistant to bruchids. The medium-sized seeds are brown in colour with smooth testa.

IT81D-985

This is an improved breeding line from IITA, which is late maturing and photoperiod-sensitive. Its prostrate growth habit pushes most of the hemispherical pods above the canopy. The medium sized seeds are rough and white in colour. IT81D-985 is moderately resistant to Striga and Alectra. The resistance is characterized by less and delayed emergence which are weak, slow growing Alectra plants. It is resistant to bruchids.

IT89KD-245-1

It is photoperiod-sensitive. Its prostrate growth habit

pushes most of the hemispherical pods above the canopy. The rough-textured, large sized seeds are white in colour. It is dual purpose and resistant to aphids and bruchids.

VITA-3

VITA-3 is photoperiod-insensitive and medium maturing. It has semi-erect growth with most of the straight pods above the canopy. The seeds are large and red in colour with smooth testa.

IT89KD-245

It is photoperiod-sensitive. Its prostrate growth habit pushes most of pods above the canopy. The rough-textured, large sized seeds are white in colour. It is dual purpose and resistant to aphids and bruchids.

IT86D-843

This photoperiod-insensitive improved variety from IITA is medium maturing and has multiple disease resistance. The medium-sized seeds are rough textured and white in colour.

TN121-80

TN121-80 originates from INRAN Niger Republic. It is late maturing and moderately resistant to Striga.

SAMPEA 7

This is an improved variety from IAR. It is highly susceptible to both Striga and Alectra. SAMPEA 7 is photoperiod-insensitve, early maturing, erect growth with pods held above the canopy. The medium sized seeds are rough-textured and brown in colour.

TN 93-80

This also originates from INRAN Niger Republic. It is late maturing and moderately resistant to Striga. The medium size seeds are white with rough testa.

Kano 1696

It is photoperiod-sensitive variety that is late maturing. It is dual purpose with prostrate growth habit. The pods are carried above the canopy. The large sized seeds are rough-textured and white in colour with black eye spot.

Table 1a: Pedigree/origin of cowpea varieties evaluated

Varieties	Pedigree/origin
IT84S-2246-4	IITA
Kano 1696	Nigeria (local)
IT89KD-245-1	B301 x Local Kananado
TVX 3236	IITA
IT90K-59	B301 x IT84S-2246-4
IT90K-76	B301 x IT84S-2246-4
IT86D-534	IITA
IT89KD-245	B301 x Local Kananado
IT82D-849	IITA
B301	Botswana
IT81D-985	IITA
IT81D-994	IITA
IT86D-843	IITA
TN 93-80	Niger
TN 121-80	Niger
VITA-3	IITA
SUVITA-2	IITA/SAFGRAD
SAMPEA-7	IAR

3.2 Description of Experimental sites

Field experiments were conducted in 1991 and 1992 wet seasons at Samaru (11^{o} 11'N 07^{o} 38'E) in the northern Guinea savanna ecological zone of Nigeria. The sites used for the 1991

trials and herbicide evaluation trial in 1992 was naturally and heavily infested with Alectra vogelii. In 1992, the field was divided into two blocks; one block was artificially inoculated with Alectra seeds at the approximate rate of 2,000 seeds per hill two weeks before crop planting while the second block was not inoculated but planted with the same varieties evaluated in the first block. The soil of the experimental sites was sandy loam. Details of the physico-chemical characteristics of the soils and rainfall distribution records during the periods of experimentation are presented in Tables 1 and 2, respectively.

3.3 Green-house Experiments

3.3.1 Description and location

All the experiments were conducted in the green-house of the Institute for Agricultural Research Samaru located in the northern Guinea savanna ecological zone of Nigeria. The screening of cowpea varieties for Alectra resistance experiment was conducted between February and May, 1992 with a total of 108 pots, half of which was inoculated with Alectra seeds. While the first and second experiments on developing an appropriate technique for evaluating cowpea varieties for their reaction to Alectra were conducted from February to May and July to September, respectively in 1993. Details of the meteorological records during the period of the experiment are shown in Table 3.

3.4 General Fields Cultural Practices

At all trial sites in the two years, the land was ploughed and discharrowed at about two weeks intervals in order to get a

fine tilth before sowing. Planting was done on 29 and 30 July in 1991 and 1992, respectively. In the two years trials, three seds per hole of cowpea were planted on 75cm wide ridges at an intra-row spacing of 30cm. These were thinned to two plants per stand at two weeks later at random. Application of single superphosphate at the rate of 24 Kg P/ha was done at cowpea emergence in the evaluation of varieties and herbicides for Alectra control experiments. In 1992, the Alectra seed/sand inoculum was prepared by mixing 10g of Alectra seeds with 250g of sieved sand (180 um size). The mixture was shaken thoroughly in an air-filled polythene bag for 5 minutes to ensure a uniform distribution of Alectra seeds in the sand/seed stock.

Fungal diseases were controlled by the application of mixture of benomyl (Benlate) and Mancozeb (Dithane M45), at the product rate of 0.6 Kg plus 2.5 Kg/ha, thrice weekly commencing from 4 weeks after planting (WAP). Cypermethrin (Cymbush 10 EC) and dimethoate (perferkthion 40 EC) were each applied forthnightly at the rate of 0.75 litre/ha each as tank-mixture beginning from 6 WAS until harvest to control various categories of insect pests.

Table 1b: Physico-chemical analysis of soil taken from experimental sites

Soil Composition	1991 Soil depth (cm) 0-15	1991 Soil depth (cm) 15-30	1992 Soil depth (cm) 0-15	1992 Soil depth (cm) 15-30
Particle size (%)				
Sand	56	46	53	49
Silt	32	30	40	38
Clay	12	24	7	13
Soil textural class	sandy	loam	sandy	loam
Soil pH in water	5.7	5.8	4.7	4.8
pH in 0.01M $CaCl_2$	4.7	4.7	4.1	4.1
Organic carbon (g/kg)	4.5	3.9	3.7	3.0
Total nitrogen (g/kg)	0.4	0.3	0.5	0.4
Available P (mg/kg)	8.39	5.06	8.91	7.17
Exchangeable Bases (Cmol/Kg)				
Sodium (Na)	0.10	0.13	0.03	0.04
Potassium, (K)	0.09	0.09	0.21	0.21
Calcium (Ca)	0.75	1.31	1.21	2.29
Magnesium (Mg)	0.34	0.75	0.38	0.58
Cation Exchange Capacity (Cmol/kg)	5.2	8.8	4.52	4.80

Table 2: Total rainfall; maximum and minimum temperature, relative humidity and sunshine hours at ten day intervals during the period of the experiments 1991-1992

Month	Days	Total rainfall (mm)		Maximum Temperature ^{o}C		Minimum Temperature ^{o}C		Relative Humidity (%)		Sun Shine (hrs)	
		1991	1992	1991	1992	1991	1992	1991	1992	1991	1992
	1-10	71.0	74.3	28.0	28.0	20.0	19.5	79.7	81.5	5.9	6.0
July	11-20	22.7	130.9	28.3	28.3	19.9	19.9	78.5	84.9	5.9	6.0
	21-31	95.9	38.4	28.0	20.1	20.0	20.0	82.6	81.3	5.3	6.5
	1-10	56.9	150.7	27.7	27.7	20.1	19.8	85.0	81.8	4.4	5.3
Aug.	11-20	103.2	152.1	27.9	27.9	19.2	19.3	83.1	79.9	5.1	1.6
	21-31	168.9	32.6	28.2	28.2	19.7	19.5	85.2	72.2	5.5	2.7
	1-10	20.0	56.2	30.6	30.6	20.0	20.4	75.9	80.7	8.4	5.4
Sept	11-20	25.1	80.4	31.4	31.4	19.6	19.8	71.5	86.1	7.6	4.3
	21-31	6.1	72.9	31.9	31.9	20.4	19.9	54.4	83.8	8.3	5.3
	1-10	28.7	4.7	31.5	31.5	20.3	18.8	73.1	67.1	7.3	8.4
Oct.	11-20	-	-	31.7	31.7	17.7	19.4	67.9	70.7	8.9	9.5
	21-31	-	-	32.7	32.7	17.0	15.2	57.8	46.9	9.1	10.4
	1-10	-	-	31.6	31.6	13.3	16.7	22.1	45.1	9.5	7.8
Nov.	11-20	-	-	31.0	31.0	12.7	13.9	21.2	25.8	7.9	9.3
	21-31	-	-	33.0	33.0	12.4	14.6	17.4	26.3	9.4	2.8
	1-10	-	-	32.0	32.0	12.8	12.8	16.6	30.4	8.9	7.9
Dec.	11-20	-	-	27.6	27.6	13.0	12.8	21.8	20.0	6.2	8.8
	21-30	-	-	26.5	26.5	12.2	11.4	23.3	24.9	7.9	7.1

Source: Meteorological Unit, Institute for Agricultural Research, Samaru, Zaria Nigeria

Table 3: Total monthly rainfall, mean temperature, radiation, humidity, sunshine and evaporation during the period of green-house study, February to September, 1992 and 1993 at Institute for Agricltural Research (IAR) Samaru

	Rainfall (mm)		Relative humidity (%)		Sunshine (hrs)		Evaporation (mm)		Temperature (^{o}C)	
Month	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
Feb.	0.0	0.0	10.9	21.4	7.9	8.0	271.0	231.1	22.5	23.2
March	0.0	0.0	20.0	30.6	5.9	7.2	314.0	320.3	27.2	26.3
April	32.3	8.3	56.3	38.3	7.4	8.1	246.7	248.5	28.9	29.9
May	73.1	113.6	58.1	54.9	7.4	8.2	237.0	275.2	29.5	29.9
June	112.4	155.8	64.6	62.3	6.2	7.6	184.4	205.9	24.6	26.3
July	243.6	269.0	75.4	67.6	6.2	6.6	108.2	178.3	24.1	24.9
Aug.	287.3	300.8	78.9	72.0	4.9	5.0	119.5	300.8	24.7	24.8
Sept.	229.7	181.8	71.9	67.5	4.6	7.0	149.6	181.2	24.8	26.4

Source: Meteorological Unit, Institute for Agricultural Research, Samaru-Zaria

3.5 General Green-house Practices

3.5.1 Alectra Seed Inoculant Preparation

In all the green-house trials, different concentrations (5-20cc) of Alectra seeds were measured and sieved dry sand (180 um size) were mixed in an air filled polythene bag and shaken thoroughly for five minutes to ensure a uniform distribution of Alectra seeds. Then 20cc sand was added to the 20cc of Alectra seed/sand mixture and again thoroughly shaken for five minutes. The Alectra seed/sand mixture was then mixed with equal volume of the sieved sand before the shaking process was repeated. Subsequently 20cc, 100cc and 200cc of the sieved sand were serially added to the Alectra seed/sand mixture and the shaking process repeated after every addition to bring the final volume of Alectra seeds/sand mixture to 400cc. The mixture of the 400cc was shaken for 3 minutes; poured out on a sheet of polythene. The mixture was quarted and coned 5 times with a hand towel. It was then poured back again into the polythene bag and shaken for 2 minutes. The mixing process was continued with addition of 400cc of the sieved sand to the 400cc Alectra seed/sand mixture. The 800cc Alectra seed/sand mixture obtained was then made up to a final volume of 1000cc by addition of 200cc of sand. The 1000cc contained about 160,000 seeds (as determined by Emechebe).

To prepare inoculated soil for each pot 100cc of the stock was used containing about 2,000 Alectra seeds/pot by addition of 700cc of soil/sand mixture (1:1 v/v). This gave 800cc of inoculated soil. To the bottom of the plastic pots (14cm x 14cm) was added about 100cc of sand. The 800cc of inoculated soil was then added.

3.6 Treatments, Experimental Design and Plot Sizes

3.6.1 Screening of cowpea varieties for *Alectra* resistance/tolerance

3.6.1.1 Field experiment

In this study, 18 cowpea varieties each were planted out in a randomised complete block design replicated three times in a field naturally infested by *Alectra* in 1991. The same 18 varieties were used in 1992 but in that year the experimental field was divided into two blocks; one block was artificially inoculated while the other was *Alectra* free.In the two field trials, the gross and net plot sizes were $9m^2$ and $4.5m^2$, respectivley.

3.6.1.2 Green-house

The same 18 varieties evaluated in the field were evaluated in greenhouse with and without *Alectra* infestation in a complete randomized design with three replicates with a total of 108 pots, half of which was inoculated with approximately 2,000 *Alectra* seeds/pot. Four seeds of cowpea were planted per pot, and thinned to two plants/pot two weeks after cowpea emergence. The pots were watered to field capacity once a day. The experiment was terminated 80 days after sowing (DAS). The roots were freed of soil by immersing each pot in a large bucket of water for 5 minutes, the pot was then inverted to release the ball of soil and roots were then carefully freed of adhering soil in such a way that there was no loss of attached *Alectra* plants, both the emerged and the subterranean.

3.6.2 Effect of nitrogen and phosphorus combinations for the control of Alectra

In the fertilizer trial, three cowpea varieties (B301, TN93-80, VITA-3) and four varieties (IT89KD-245-1, TN93-80, VITA-3, SAMPEA-7) were used in 1991 and 1992, respectively as main plot treatment while three levels each of nitrogen (0, 30 and 60 Kg N/ha) and phosphorus (0, 20 and 40 Kg P/ha) fertilizers, in factorial combinations, all applied at planting, were the sub-plot treatments. The trial was laid out in a split-plot design and replicated three times in each block. Variety B301 was replaced in the investigation in 1992, since B301 did not support Alectra emergence at all in 1991. The gross and net plot sizes in the two years were $12m^2$ and $6m^2$, respectively.

3.6.3 Effect of herbicides combinations for the control of Alectra

In the berbicides evaluation trial, 25 herbicides treatments were compared with hoe-weeding at 3 and 6 weeks after sowing (WAS) and a weedy check in a randomized complete block design with 3 replications using cowpea variety SAMPEA-7. The pre-emergence herbicide treatments were applied one day after sowing in the two years, while post-emergence treatments were applied at 3 WAS. The herbicides were applied with a Knapsack (CP_3) sprayer in a spray volume of 250 l/ha using a deflector nozzle at a pressure of 2.1 Kg/cm^2. The gross and net plot sizes inthe two years were $12m^2$ and $6m^2$, respectively.

3.6.4 Developing an appropriate technique for evaluating cowpea varieties for their reaction to Alectra in the green house

In the technique developing trials, different concentrations (5-20cc) of Alectra seeds were measured into polythene bags. The procedure as described under general green house practices was carried out on each of the Alectra seed concentrations. Based on enuration by Emechebe (Personal communication) the original 5cc, 10cc and 20cc Alectra inoculant contained 1000, 2000 and 4000 seeds, respectively.

From the 1000cc Alectra inoculant stock, 100cc was taken and used to inoculate a plastic pot (14cm x 14cm) containing $^{2}/_{3}$ of soil/sand mixture (1:1, $^{v}/_{v}$). Thus, ten plastic pots were inoculated for every 1000cc Alectra inoculant stock. Each pot contained 1000, 2000 and 4000 seeds for the 5, 10 and 20cc, respectively, Alectra inoculant concentrations. After inoculation, pre-conditioning of Alectra seeds started immediately by irrigating the pots. This was followed by daily application of water to the soil to field capacity level.

After the pre-conditioning of Alectra seeds in soils in the pot for the required period, six seeds of cowpea were sown per pot and irrigated daily. At two weeks after sowing, the plants were thinned to four and two plants per pot in the first and second trials, respectively. The trials were terminated 65 days after sowing. The roots were freed of 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 un-emerged Alectra plants attached.

3.7 Observation

3.7.1 Field experiments

The following observation were taken.

3.7.1.1 Alectra parameters

Data collected on Alectra from the net plots included the number of days to first Alectra emergence, number of plants infected with Alectra at 8, 9, 10 WAS and at harvest and Alectra shoot count at 8, 9, 10 WAS and at harvest.

3.7.1.2 Crop establishment and growth

Observations on crop growth parameters were (i) crop stand count: crop stand count at 10 DAS and at harvest from the net plot areas in order to assess the effective establishment of the crops,

(ii) Damage symptom score on crop plants: Damage symptoms on crop plants on a scale of 1-5 at 9 WAS where 1 = normal crop plant growth, no chlorosis, no blotching no leaf scorching and 5 = total leaf scorching or/and obviously stunted or dead plants,

(iii) Crop vigour score. Crop vigour score at 9 WAS in order to assess the vigour of crop growth using the scale 0 to 10, where 10 was assigned to plots with fully healthy crop and 0 was to those with complete death of crop. In the visual observation, plant height, greeness of foliage and the spread of the plant canopy were taken into consideration.

3.7.1.3 Yield and yield components

Data collected on yield and yield components from the net plots included number of pods, weight of pods, weight of 1000

grains and cowpea grain yield. The dry pods of each plot were picked, weighed, and counted before threshing. The seeds obtained after threshing were also weighed.

3.7.2 Green-house trials

Observations recorded included number of days to Alectra emergence, number of emerged and un-emerged Alectra at the end of the experiments, number of nodules/plant, crop reaction syndrome, days to crop flowering and dry shoot weight at harvest.

3.8 Statistical Analysis of Data

All data obtained during the experiments were subjected to appropriate transformation before analysis of varience using 'F' test as described by Snedecor Cochran (1967). Treatment means were then compared using Duncan Multiple Range Tests. Where no difference were observed between the analysis of original and transformal values, the means based on the former values were used for comparison. Coefficient of correlation (r) between cowpea grain yield and other parameters were also determined.

4.0 RESULTS

4.1 Screening of cowpea varieties for Alectra resistance/tolerance

Reactions of cowpea varieties to Alectra parameters viz number of plants infected, Alectra shoot count, days to Alectra emergence; crop growth, and yield and yield components such as number and weight of pods, weight of 1000 grains and cowpea grain yield are presented in Tables 4 to 13.

4.1.1 Number of plants infected and Alectra shoot count

In the two field trials, cowpea varieties differed significantly with respect to the number of plants infected and Alectra shoot count at 9 WAS (Tables 4 & 5). Generally, number of plants infected with Alectra was highest in varieties SAMPEA-7 and TVX 3236 in 1991 and 1992, respectively. No Alectra shoot was observed in varieties B301, IT90K-59 and IT90K-76 throughout the crop life-cycle in the two years. The number of plants infected by Alectra in varieties IT89KD-245-1, IT89KD-245, IT81D-994, IT86D-534 and IT81D-985 did not differ significantly from those of B301 in the two years. In addition to SAMPEA-7 and TVX 3236 VITA-3, Kano 1696, IT82D-849 and IT84S-2246-4 also supported significantly higher incidence of Alectra. In 1992, Kano 1696 and TN 93-80 supported significantly higher incidence of plants infectd compared to B301. Similarly, all cowpea varities except TVX3236, SUVITA-2 and SAMPEA-7 gave Alectra shoot count comparable to that of B301.

4.1.2 Crop damage symptom Score

In the two trials, crop damage syndrome score differed

significantly among cowpea varieties at 9 WAS (Tables 4 and 5). The highest damage syndrome score was observed in IT82D-849 and SUVITA-2 in 1991 and 1992, respectively. In 1991, the damage syndrome score obtained with varieties IT89KD-245, IT89KD-245-1, IT86D-534 and IT81D-994 did not differ significantly from those in B301. In 1992, except TVX3236, IT82D-849, TN93-80 and VITA-3, all other varieties had damage scores comparable to that of B301.

4.1.3 Crop vigour score

Cowpea varieties differed in crop vigour score at 9 WAS in the two trials (Tables 4 and 6). In 1991, IT82D-849 had the least growth vigour compared with other varieties. Varieties IT84S-2246-4, Kano 1696, VITA-3 and SAMPEA-7 also had lower score than B301. In 1992, under artificial Alectra infestation, plants that were not infected had significantly higher crop growth vigour compared with those infected (Table 6). Among the varieties SUVITA-2, IT84S-2246-4, Kano 1696, IT89KD-245, TVX 3236, IT82D-849, TN 93-80, IT81D-985, TN 121-80 and SAMPEA-7 had significantly lower crop growth vigour compared with B301, the resistant variety.

Interaction between cowpea varieties x infection on crop vigour score was significant (Table 6). In Alectra infected plots, only B 301 that gave comparable crop vigour score to the highest obtained with B 301 plants that were not infected with Alectra; while without infestation, Kano 1696, IT90K-59, IT90K-76, IT86D-534, VITA 3 and IT89KD-245 gave comparable growth score. Alectra infection significantly depressed crop growth vigour in Kano 1696, TVX 3236, IT90K-59 and SUVITA-2 compared

Table 4: Reaction of cowpea varieties to Alectra at Tasha Zomo, 1991 wet season

Varieties	Number of days to first Alectra	Number of host plant infected with Alectra/ 4.5 m^2 9 WAS	Alectra count/ 4.5n2 9 WAS[1]	Crop vigour[2] score at 9 WAS	Crop damag score on crop plants 9 WAS
IT84S-2246-4	49	10.3 abc	36.7 ab	7.3 bcd	4.3 ab
Kano 1696	51	11.0 ab	37.7 ab	6.7 cd	4.3 ab
IT89KD-245-1	64	2.3 efg	4.7 d	8.7 abc	2.0 d-g
TVX 3236	49	7.7 a-d	26.3 bc	9.0 ab	2.7 b-f
IT90K-59	-	0.0 g	0.0 d	9.7 a	1.0 g
IT90K-76	-	0.0 g	0.0 d	9.7 a	1.7 efg
IT86D-534	71	0.3 g	0.7 d	8.7 abc	2.7 b-g
IT89KD-245	56	2.3 efg	6.3 d	9.0 ab	2.3 c-g
IT82D-849	50	9.3 a-d	51.0 a	3.3 e	5.0 a
B 301	-	0.0g	0.0 d	9.7 a	1.0 g
IT81D-985	56	2.3 efg	4.7 d	8.3 a-d	2.0 efg
IT81D-994	58	1.3 fg	1.7 d	9.3 a-d	1.3 fg
IT86D-843	59	5.0 def	10.7 cd	9.0 ab	3.0 b-f
TN 93-80	55	6.3 cde	14.3 cd	7.7 a-d	4.0 abc
TN 121-80	49	7.3 bcd	13.7 cd	8.0 a-d	3.0 b-f
VITA 3	54	9.3 a-d	37.0 ab	6.3 d	3.3 a-e
SUVITA 2	52	5.7 def	11.7 cd	7.3 bcd	3.7 a-d
SAMPEA-7	47	12.0 a	41.3 ab	6.3 d	4.0 abc
S.E ±	10.66	1.40	16.49	1.95	1.55

1 = Weeks after sowing

2 = Crop vigour score scale (0-10); where 0 = completely killed plants and 10 = most vigorous plants

3 = Crop damage score using scale (1-5), where 1 = normal crop plant growth, no chlorosis, no blotching, no leaf scorching and 5 = total leaf scorching or/and obviously stunted or dead plants

4 = Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

Table 5: Performance of cowpea varieties under artificial Alectra infestation at Samaru, 1992 wet season

Varieties	Number of plants infected with Alectra/4.5m^2 9 WAS	Alectra count 9 WAS1	Number of days to first emergence Alectra	Crop damage^2 score on plants 9 WAS
IT84S-2246-4	2.0 def	7.3 b	40 bc	1.3 cd
Kano 1696	3.7 b-e	12.3 b	39 bc	1.7 bcd
IT89KD-245-1	1.7 ef	6.3 b	42 bc	1.3 cd
TVX 3236	8.7 a	49.3 a	37 c	2.3 abc
IT90K-59	0.0 f	0.0 b	-	1.0 d
IT90K-76	0.0 f	0.0 b	-	1.0 d
IT86D-534	1.3 ef	2.0 b	50 a	1.0 d
IT89KD-245	1.7 ef	1.7 b	50 a	1.0 d
IT82D-849	2.7 b-f	6.0 b	43 abc	2.7 ab
B 301	0.0 f	0.0 b	-	1.0 d
IT81D-985	2.3 c-f	6.0 b	46 ab	1.3 cd
IT81D-994	1.3 ef	3.3 b	44 abc	1.0 d
IT86D-843	2.7 b-f	4.0 b	51 a	1.3 cd
TN 93-80	5.7 abc	13.0 b	38 bc	2.3 abc
TN 121-80	2.0 def	4.3 b	41 bc	1.7 bcd
VITA 3	3.0 b-f	6.7 b	39 bc	2.3 abc
SUVITA 2	6.0 ab	35.7 a	36 c	3.0 ad
SAMPEA 7	5.3 bcd	34.0 a	38 bc	2.0 a-d
S.E +	1.06	6.67	2.57	0.39

1 Weeks after sowing

2 Crop damage symptom score scale (1-5), where 1 = normal crop plant growth, no chlorosis, no blotching, no leaf scorching and 5 = total leaf scorching or/and obviously stunted or dead plants.

3 Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

Table 6: Performance of cowpea varieties under artificial Alectra infestation at Samaru, 1992 wet season

Varieties	Crop vigour at 9 WAS[1] Infection: Infected	Un-infected	Mean
IT84S-2246-4	6.1 g-j	6.5 d-j	6.3 b
Kano 1696	5.8 ig	7.6 abc	6.7 b
IT89KD-245-1	6.7 c-i	5.9 hij	6.3 b
TVX 3236	5.5 jk	7.0 b-g	6.3 b
IT90K-59	7.0 b-g	8.0 a	7.5 a
IT90K-76	6.9 b-h	7.7 ab	7.3 ab
IT86D-534	7.0 b-g	7.4 a-e	7.2 ab
IT89KD-245	6.8 b-i	7.5 a-d	7.1 ab
IT82D-849	5.9 hij	6.2 f-j	6.1 b
B 301	7.2 a-f	8.0 a	7.6 a
IT81D-985	6.6 c-i	6.8 b-i	6.7 b
IT81D-994	6.7 c-i	7.5 a-d	7.1 ab
IT86D-843	6.8 b-i	7.8 ab	7.3 ab
TN 93-80	6.2 f-j	6.2 f-j	6.2 b
TN 121-80	6.2 b-h	6.4 e-j	6.3 b
VITA 3	6.9 b-h	7.7 ab	7.3 ab
SUVITA 2	5.9 hij	4.7 k	5.3 c
SAMPEA 7	5.9 hij	6.5 d-j	6.2 b
(Int.) S.E ±	0.31	(V) S.E ±	0.22
Mean	6.5b	6.9a	
(I) S.E ±	0.07		

1 Weeks after sowing

2 Means followed by the same letter (s) within a treatment group in the marginal means and within the first order of interactions are not different statistically by DMRT at 5% level

3 Crop vigour score scale (0-10); where 0 = completely killed plants and 10 = most vigorous plants

(Int.) = Interaction, (V) = variety, (I) = Infection

with corresponding Alectra-free plants.

4.1.4 Stand count at harvest

Crop stand count at harvest was significantly affected by Alectra infestation in the two trials (Tables 7 and 8). In 1991, varieties IT82D-849, TVX3236 and SUVITA-2 had significantly lower crop stand count at harvest compared with the maximum obtained with IT86D-843. In 1992, Alectra inoculation caused significant reduction in cowpea stand count at harvest compared to Alectra free plots. Among the varieties, IT84S-2246-4, Kano 1696, TN 121-80, TVX 3236, IT82D-849, IT89KD-245, IT81D-985, IT81D-994, VITA-3, IT89KD-245-1 and SAMPEA-7, all had significantly lower crop stand count at harvest compared with the maximum obtained with B 301.

4.1.5 Number of days to first crop flowering

Alectra infection significantly decreased days to crop flowering (Table 8). Number of days to flowering only differed significantly among cowpea varieties in 1992. Among the varieties, days to crop flowering was earliest with IT86D-843, while it was late in Kano 1696. IT90K-76, IT81D-985, IT86D-534 were however comparable to IT86D-843 in number of days to flowering.

4.1.6 Number of pods

In 1992, Alectra infection significantly reduced pod number in cowpea (Table 9). In the two years, cowpea varieties differed significantly in pod number (Tables 7 and 9). In 1991, TN 93-80, IT89KD-245-1, TVX 3236, IT90K-59, IT90K-76, IT86D-534

and TN 121-80 produced number that were comparable to the maximum obtained with B 301 and signficantly higher than the lowest number produced by IT82D-849 (Table 5). In 1992, among the varieties, IT89KD-245-1, IT90K-59, IT90K-76, B301, SAMPEA-7 and VITA-3 produced pod numbers that were comparable to the maximum with Kano 1696 and significantly higher than those of IT84S-2246-4, IT89KD-245, IT82D-849 and SUVITA-2.

The interaction of variety and Alectra on number of pods was also significant (Table 9). No infected cowpea variety produced pod number comparable to the maximum with un-infected IT89KD-245-1 and Kano 1696. Alectra infection significantly depressed pod number in Kano 1696, IT89KD-245-1, IT90K-76, IT89KD-245, and IT86D-843 compared with corresponding non-infected crop.

4.1.7 Weight of Pods

Alectra infection significantly decreased cowpea pod weight in 1992 (Table 10). In the two years, cowpea varieties differed significantly with respect to weight of pods (Tables 7 and 10). In 1991, only varieties IT82D-849 and IT84S-2246-4 produced significantly lower pod weight than the highest obtained with TN93-80. Pod weight of IT82D-849 was only comparable to that of IT84S-2246-4. In 1992, result indicates that un-infected plots had significantly more pod weight than Alectra infested plots. Among the varieties B301 and its derivatives, IT90K-59 and IT90K-76, produced pod weights that were comparable to the maximum with VITA 3. The least were produced by SUVITA-2, TN 121-80, IT82D-849 and IT84S-2246-4.

Interaction of variety and Alectra infection on weight of

Table 7: Reaction of cowpea varieties to Alectra at Tasha Zomo, 1991 wet season

Varieties	Stand count at harvest	Weight of pods (Kg/ha)	Number of pods/plot^2	Grain yield (Kg/ha)
IT84S-2246-4	19 abc	540 bc	282 cd	378 bc
Kano 1696	19 abc	1324 a	256 cd	894 ab
IT89KD-245-1	19 abc	1354 a	374 abc	1099 a
TVX 3236	16 bcd	829 ab	364 abc	664 abc
IT90K-59	19 abc	1142 a	435 abc	974 a
IT90K-76	18 abc	1142 a	541 ab	981 a
IT86D-534	17 abc	902 ab	315 ab	648 abc
IT89KD-245	20 ab	1271 a	297 bcd	987 a
IT82D-849	13 d	238 c	88 d	161 c
B 301	18 abc	1229 a	612 a	860 ab
IT81D-985	20 ab	1064 ab	272 cd	821 ab
IT81D-994	18 abc	1013 ab	304 bcd	757 ab
IT86D-843	21 a	918 ab	259 cd	650 abc
TN 93-80	19 abc	1482 a	598 a	1122 a
TN 121-80	19 abc	918 ab	418 abc	714 ab
VITA 3	19 abc	1036 ab	207 cd	777 ab
SUVITA 2	15 cd	818 ab	244 bc	643 abc
	19 abc	804 ab	321 bc	624 abc
S.E ±	1.20	201.0	76.7	156.15

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

2 = Plot size = 4.5m^2

Table 8: Effect of Alectra inoculation on days to flowering, stand count and weight of 1000 grain of cowpea varieties at Samaru, 1992 wet season

Treatments	Number of days to crop flowering	Stand count at harvest	Weight of 1000 grains (g)
Infection (I)			
Infected	48 b	21 b	188.1 b
Un-infected	49 a	23 a	191.4 a
S.E ±	0.29	0.29	2.72
Variety (V)			
IT84S-2246-4	48 bcd	19 d	180.0 efg
Kano 1696	64 a	22 bc	224.2 abc
IT89KD-245-1	50 b	20 cd	213.3 a-d
TVX3236	50 b	20 cd	131.7 i
IT90K-59	47 cde	23 ab	170.0 gh
IT90K-76	44 fg	23 ab	166.7 gh
IT86D-534	45 efg	23 ab	196.7 def
IT89KD-245	49 bc	21 bcd	230.0 a
IT82D-849	48 bcd	21 bcd	191.7 d-g
B 301	47 cde	25 a	121.7 j
IT81D-985	45 efg	21 bcd	228.3 ab
IT81D-994	46 c-f	21 bcd	205.0 b-e
IT86D-843	42 g	23 ab	190.0 d-g
TN 93-80	50 b	23 ab	171.7 fgh
TN 121-80	49 bc	22 bc	151.7 hi
VITA 3	50 b	22 bc	238.3 a
SUVITA 2	50 b	23 ab	205.o b-e
SAMPEA 7	47 cde	21 bcd	199.8 cde
S.E ±	0.86	0.88	8.17
Interactions			
I x V	N.S	N.S	N.S

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

cowpea pods was significant (Table 10). With infection all the varieties produced lower pod weight than the maximum obtained with un-infected B301. Even without infection only varieties IT90K-59, IT89KD-245-1, TVX3236, IT90K-76 and VITA-3 produced yield comparable to the maximum. Unlike the other varieties, Alectra infection did not depress pod yield in IT84S-2246-4, IT90K-59, IT90K-76, IT86D-534, IT82D-849 and TN 121-80.

4.1.8 Weight of 1000 grains

Alectra infection significantly reduced weight of 1000 grains of cowpea in 1992. Similarly, cowpea varieties differed singificantly in weight of 1000 grains only in the same year (Table 8). Among the cowpea varieties, Kano 1696, IT89KD-245-1, IT89KD-245, IT81D-985 produced grain sizes that were comparable to the maximum with VITA-3. B 301 produced smaller grain size compared with other varieties.

4.1.9 Cowpea grain yield

In 1992, un-infected plants resulted in significantly higher grain yield by 53.2% compared with Alectra infected situation (Table 11). In the two years cowpea varieties differed significantly with respect to grain yield (Tables 7 and 11). In 1991, varieties IT84S-2246-4, TVX3236, IT86D-534, IT86D-843, SUVITA-2 and SAMPEA-7 resulted in grain yields comparable to the least with IT82D-849. In 1992, VITA 3 produced significantly higher cowpea grain yield than all the other varieties evaluated in the trial, including B 301. Varieties IT90K-59 and IT90K-76 however produced yield comparable to that of B 301. SUVITA-2 produced grain yields comparable to the least with IT82D-849.

Table 9: Interaction of cowpea variety and Alectra on number of pods of cowpea at Samaru, 1992 wet season

Varieties	Number of pods/plotsS^2 Infection: Infected	Un-infected	Mean
IT84S-2246-4	252 ijk[1]	251 ijk	251 fg
Kano 1696	562 e-f	840 a	701 a
IT89KD-245-1	459 efg	938 a	699 a
TVX 3236	410 e-i	483 e-g	447 b-e
IT90K-59	521 b-g	666 bc	594 abc
IT90K-76	405 e-i	688 b	547 a-d
IT86D-534	461 efg	473 d-g	467 b-e
IT89KD-245	225 jki	440 e-h	333 efg
IT82D-849	357 g-j	364 g-j	361 ef
B 301	548 b-g	667 bc	608 ab
IT81D-985	384 f-j	462 efg	423 cde
IT81D-994	538 b-g	366 b-g	452 b-e
IT86D-843	268 h-k	525 c-g	397 def
TN 93-80	452 efg	515 b-g	483 b-e
TN 121-80	375 f-j	494 b-g	434 cde
VITA 3	640 bcd	507 c-g	574 abc
SUVITA 2	183 ki	217 j-k	200 g
SAMPEA 7	595 b-e	529 b-g	562 a-d
(Int.) S.E ±	74.54	(V) S.E +	52.69
Mean	424 b	524 a	
(I) S.E ± 17.59			

1 Means followed by the same letter(s) within a treatment group in the marginal means and within the first order of interactions are not different statistically by DMRT at 5% level

(Int.) = Interaction, (V) = Variety, (I) = Infection

2. Plot size = $4.5m^2$

Table 10: Interaction of cowpea variety and Alectra on weight of pods of cowpea at Samaru, 1992 wet season

	Weight of pods/plots[2] (Kg/ha)		
	Infection		
Varieties	Infected	Un-infected	Mean
IT84S-2246-4	860 J-M[1]	1160 i-l	1020 fg
Kano 1696	1420 hij	2420 b-e	1930 bc
IT89KD-245-1	1110 jkl	2690 a-d	1910 bc
TVX 3236	730 j-m	2760 abc	1760 cd
IT90K-59	2190 c-g	2330 b-f	2270 ab
IT90K-76	2070 efg	2530 a-e	2310 a
IT86D-534	1360 h-k	1310 h-l	1360 de
IT89KD-245	760 klm	2270 c-g	1510 de
IT82D-849	620 m	870 J-m	760 g
B 301	1710 ghi	3090 a	2390 a
IT81D-985	790 klm	2190 c-g	1510 de
IT81D-994	870 j-m	2130 d-g	1490 de
IT86D-843	790 klm	2110 d-g	1490 de
TN 93-80	840 j-m	2110 d-g	1310 ef
TN 121-80	760 klm	980 J-M	870 g
VITA 3	2190 c-g	2890 ab	2530 a
SUVITA 2	390 m	1090 jkl	760 g
SAMPEA 7	1110 jkl	2390 b-e	1760 cd
(Int.) S ±	180	(V) S.E ±	130.0
Mean	1160 b	2070 a	
(I) S.E ± 40.0			

1 Means followed by the same letter(s) within a treatment group in the marginal means and within the first order of interactions are not different statistically by DMRT at 5% level

(Int.) = Interaction, (V) = Variety, (I) = Infection

2 Plot size = $4.5m^2$

Table 11: Interaction of cowpea variety and Alectra on grain yield and % yield reduction at Samaru, 1992 wet season

Varieties	Grain yield (Kg/ha) Infection Infected	Un-infected	Mean	Reduction in grain yield due to Alectra (%)
IT84S-2246-4	541 i-m[1]	765 h-k	653 fg	29.3
Kano 1696	830 g-j	1066 e-h	948 def	22.1
IT89KD-245-1	708 h-l	1679 ab	1194 cd	57.8
TVX 3236	237 m	1570 abc	904 def	84.9
IT90K-59	1011 e-h	1715 a	1363 bc	41.1
IT90K-76	1006 e-h	1794 a	1400 bc	43.9
IT86D-534	950 e-i	953 e-i	952 de	0.4
IT89KD-245	475 j-m	1534 a-d	1004 de	69.1
IT82D-849	211 m	327 lm	269 h	35.5
B 301	1032 e-h	1919 a	1476 b	46.3
IT81D-985	478 j-m	1335 b-e	907 def	64.2
IT81D-994	570 i-m	1206 c-g	888 ef	52.7
IT86D-843	586 J-m	1269 b-f	877 ef	61.7
TN 93-80	461 J-m	1127 d-h	794 efg	59.1
TN 121-80	398 klm	748 h-l	573 g	46.7
VITA 3	1934 a	1804 a	1869 a	-7.2
SUVITA 2	188 m	852 f-j	520 gh	77.9
SAMPEA 7	747 h-l	1370 b-e	1058 de	45.5
(Int.) S ±	132.60	(V) S.E ±	193.78	
Mean	681 b	1280 a		
(I) S.E ± 31.26				

1 Means followed by the same letter(s) within a treatment group in the marginal means and within the first order of interactions are not different statistically by DMRT at 5% level

(Int.) = Interaction, (V) = Variety, (I) = Infection

Interaction of variety and Alectra infection was significant on grain yield of cowpea (Table 11). Infected VITA-3 produced the highest cowpea grain yield in the trial. Under Alectra infection, no variety produced grain yields that were comparable to the highest while IT90K-59, IT90K-76, B 301, IT89KD-245-1, IT89KD-245, TVX3236 and VITA 3 were comparable under Alectra free condition. Unlike in all the other varieties, Alectra infection Kano 1696, IT84S-2246-4, IT86D-534, IT82D-849 and TN 121-80 grown in inoculated field which gave significantly similar grain yields irrespective of Alectra infection, all other varieties gave significanly higher grain yield under un-infected condition relative to infected plots. Significant grain yield reduction of 41.1 to 77.9% occured in all varieties except IT84S-2246-4, Kano 1696, IT82D-849 which experienced non significant reduction by 29.3, 22.1 and 35.5%, respectively. No yield reduction occured in IT86D-534 and VITA-3.

4.1.10 Correlation

In the two years, association of various parameters with grain yield production are presented in correlation matrices in Tables 12 and 13.

In 1991, correlation analysis indicated significant negative relationships between grain yield production and number of plants infected with Alectra at 8, 9 WAS and harvest (r = -0.35, -0.39, -0.35): Alectra shoot count at 8, 9 WAS and harvest (r = -0.34, -0.41, -0.37) and crop damage symptom score at 9 WAS (r = -0.53). However, number of pods and crop stand at harvest was significantly positively correlated to grain yield (r = 0.96,

0.42). There was a stronger relationship between cowpea grain yields and Alectra parameters at 9 WAS than other stages of crop growth (r = -0.39 and -0.41) for number of plants infected and Alectra shoot count, respectively.

In 1992, there was a significant negative relationship between grain yield and number of plants infected with Alectra at 9 and 10 WAS (r = -0.32, -0.30); days to Alectra emergence (r = -0.35). However, number of pods was significantly positively correlated to grain yield (r = 0.86).

Table 12: Correlation between cowpea grain yield and various parameters in the screening of cowpea varieties for Alectra tolerance at Tasha Zomo, 1991 Wet Season

	1	2	3	4	5	6	7	8	9	10	11
1	1.0										
2	-0.35**	1.0									
3	-0.34*	0.90**	1.0								
4	-0.35**	0.88**	0.76**	1.0							
5	-0.41**	0.83**	0.86**	0.85**	1.0						
6	-0.39**	0.86**	0.77**	0.93**	0.85**	1.0					
7	-0.37**	0.84**	0.87**	0.80**	0.95**	0.82**	1.0				
8	-0.96**	-0.33*	-0.31*	-0.36**	-0.39**	-0.36**	-0.35**	1.0			
9	-0.10	0.38**	0.30*	0.51**	0.35**	0.50**	0.29*	-0.08	1.0		
10	-0.53**	-0.68**	-0.63**	-0.77**	-0.70**	-0.61**	-0.61	-0.39**	0.59**	1.0	
11	0.42**	-0.26	-0.34*	-0.18	-0.36**	-0.24	-0.37**	0.43**	-0.03	-0.24	1.0

1 Grain yield
2 Number of plants infected at 8 WAS
3 Alectra count at 8 WAS
4 Number of plants infected at 9 WAS
5 Alectra count at 9 WAS
6 Number of plants infected at harvest
7 Alectra count at harvest
8 Weight of pods
9 Number of days to Alectra emergence
10 Crop damage symptom score at 9 WAS
11 Crop stand count at harvest
* Significant at 5% of probability (r = 0.27)
** Significant at 1% level of probability (r = 0.35)

Table 13: Correlation between grain yield and various parameters under Alectra infestation in the screening of cowpea varieties for Alectra resistance/toleance, at Samaru, 1992 wet season

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.0												
2	-0.29*	1.0											
3	-0.25*	0.86**	1.0										
4	-0.32*	0.90**	0.79**	1.0									
5	-0.32*	0.85**	0.87**	0.87	1.0								
6	-0.30*	0.88**	0.78**	0.97**	0.89**	1.0							
7	-0.26	0.84**	0.85**	0.87**	0.98**	0.84**	1.0						
8	-0.17	0.71**	0.73**	0.80**	0.89**	0.82**	0.87**	1.0					
9	-0.14	0.63**	0.86**	0.71**	0.86**	0.73**	0.89**	0.88**	1.0				
10	0.86**	-0.37**	-0.24	-0.39**	-0.31*	-0.37**	-0.27*	-0.22	-0.13	1.0			
11	-0.35**	0.17	0.08	0.25	0.09	0.21	0.09	0.09	0.03	-0.63**	1.0		
12	-0.18	-0.63*	0.55**	0.69**	0.64**	0.73**	0.61**	0.61**	0.45**	-0.34**	0.11	1.0	
13	0.26	-0.19	-0.18	-0.24	-0.24	-0.24	-0.26	-0.24	-0.24	0.36**	-0.38**	-0.24	1.0

1 Grain yield
2 Number of plants infected at 8 WAS
3 Alectra count at 8 WAS
4 Number of plants infected at 9 WAS
5 Alectra count at 9 WAS
6 Number of Plants infected at 10 WAS
7 Alectra count of 10 WAS
8 Number of plants infected at harvest
9 Alectra count at harvest
10 Weight of pods
11 Number of days to Alectra emergence
12 Crop damage symptom score at 9 WAS
13 Crop stand count at harvest

* = Significant at 5% level of probability (r = 0.27)

** = Significant at 1% level of probability (r = 0.35)

4.2 Green house experiment (Expt. 1)

Reaction of cowpea varieties on Alectra emergence and count, crop growth and nodulation are shown in Tables 14 to 17.

4.2.1 Alectra emergence and count

Cowpea varieties differed significantly in respect of number of days to Alectra emergence, emerged and un-emerged Alectra (Table 14). Cowpea varieties TVX 3236 and SAMPEA-7 which initiated Alectra emergence very early at 48 and 46 days after sowing (DAS), respectively, also recorded maximum emergence at 60 and 70 DAS, respectively. Variety Kano 1696 initiated late emergence of Alectra which increased with time until 80 DAS when the experiment was terminated. No emergence or attachment was observed on B 301, IT90K-59, IT90K-76 and IT81D-985. Despite non-emergence of Alectra on IT84S-2246-4, it had the highest number of un-emerged Alectra plants and total number of un-emerged Alectra plants and total number of Alectra per pot at harvest. Varieties TVX 3236, IT82D-849, SUVITA-2 and SAMPEA-7 as well as Kano 1696 supported high number of Alectra attachement (> 4.79/Plant), while TN 121-80, VITA-3, IT86D-534 and IT89KD-245 supported moderate attachment of 1.5 to 2.5 Alectra per plant. Varieties IT86D-843, TN 93-80 and IT89KD-245-1 supported an average of less than one per plant.

4.2.2 Crop Growth

Alectra infection significantly decreased number of days to crop flowering in cowpea (Table 15). Among the varieties IT86D-843 and IT90K-59 resulted in significantly more number of days to crop flowering while IT82D-849 and TVX 3236, flowered earliest.

Table 14: Effect of Alectra infection on number of days to Alectra emergence, total Alectra at harvest, emerged and unemerged Alectra, 1992 in the green house

Treatment	Emerged Alectra/pots			Unemerged Alectra/ Plant at harvest	Total Alectra at harvest	Number of days to first Alectra emergence
	60 DAS[1]	70 DAS	Harvest			
IT84S-2246-4	0.0 e[2]	0.00f	0.00 f	2.53 a	10.12 a	-
Kano 1696	0.67cde	2.00c	3.33c	1.10c	7.73c	61 a
IT89KD-245-1	0.33de	0.67def	0.67def	0.00f	0.67g	62a
TVX 3236	6.67a	6.67a	6.67a	6.67d	9.07ab	48de
IT90K-59	0.00e	0.00f	0.00f	0.00f	0.0g	-
IT90K-76	0.00e	0.00f	0.00f	0.00f	0.0g	-
IT89KD-245	1.00cde	1.33cde	1.33cde	0.43de	3.05f	58ab
IT8(2D-849	1.67c	2.33c	2.33c	1.60b	8.73b	59a
B 301	0.00e	0.00f	0.00f	0.00f	0.00g	-
IT81D-985	0.00e	0.00f	0.00f	0.00f	0.00g	-
IT81D 994	0.33de	0.33ef	0.33ef	0.43de	2.05f	51cd
IT86D-843	0.00e	0.00f	0.00f	0.17ef	0.68g	-
TN 93-80	0.33de	0.33ef	0.33ef	0.10ef	0.73g	52cd
TN 121-80	1.33cd	1.67cd	1.67cd	0.33def	2.99f	49de
VITA-3	1.00cde	1.33cde	2.33cde	0.10ef	2.73f	58ab
SUVITA-2	3.00b	3.33b	4.00b	0.60d	6.40d	54bc
SAMPEA-7	3.67b	4.00b	4.00b	1.03c	4.79e	46e
IT86D 534	0.33de	0.67def	0.67def	0.43de	2.39f	45e
S.E ±	0.35	0.35	0.36	0.37	0.39	1.61

1 Days after sowing

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

Table 15: Effect of *Alectra* infection on nodulation, reduction in nodulation due to *Alectra* and number days to first crop flowering at Samaru, 1992 in the green house

Treatment	Average number of nodules per plant			Reduction in nodulation due to Alectra (%)	Number of days to first crop flowering
Infection (I)					
Infected	1.6 b[1]				26 b
Un-infected	3.2 a			50.0	37 a
S.E +	0.21				0.35
Variety (V)					
	Infected	Un-infected	Mean		
IT84S-2246-4	1.2	3.1	2.2b-e	61.3	49
Kano 1696	4.3	7.8	6.0a	44.7	-2
IT89KD-245-1	0.0	1.0	0.5 e	100.0	47
TVX 3236	0.0	2.6	1.3de	100.0	26
IT90K-59	1.7	3.0	2.4b-e	43.9	71
IT90K-76	0.3	1.2	0.7 e	76.9	47
IT89KD-245	0.4	1.3	0.9 e	66.1	48
IT82D-849	1.0	2.3	1.7 cde	54.6	25
B 301	3.4	4.4	3.9 b	21.5	-
IT81D-985	0.6	1.6	1.1 de	83.1	-
IT81D 994	0.6	1.6	1.1 de	72.5	61
IT86D-(43	0.7	2.3	1.5 de	69.2	73
TN 93-80	4.4	8,4	6.4 a	47.5	-
TN 121-80	1.0	4.0	2.5 b-e	75.2	-
VITA 3	3.4	2.8	3.1 bcd	-21.	-
SUVITA 2	0.9	1.6	1.2 de	45.6	33
SAMPEA 7	3.3	3.8	3.6 bc	12.4	31
IT86D 534	0.8	3,5	2.1 b-e	77.8	52
S.E ± (Int)	0.89	(V)	0.63		1.04

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

2 Did not flower at termination of the experiment
(Int) = Interaction, (V) = Variety

Varieties of Kano 1696, B 301, IT81D-985, TN 93-80, TN121-80 and VITA-3 did not flower during the 80 days of experimentation.

Interaction of variety and Alectra infection on number of days to crop flowering was significant (Table 16). Cowpea varieties Kano 1696, IT81D-985, B 301, TN 93-80, TN 121-80 and VITA 3 did not flower during the 80 days of experimentation with or without infection. Although without infection, SAMPEA-7, IT81D-849 and SUVITA-2 flowered at 62, 50 and 66 days respectively, while the plants in the infected pots did not flower throughout the period of experimentation. In contrast Alectra infection increased the number of days to cowpea flowering in varieties IT84S-2246-4, IT89KD-245-1, IT90K-59, IT90K-76, IT89KD-245 and IT86D-534 by 8, 5, 3, 4, 6 and 1, respectively (Table 16).

4.2.3 Nodulation

Alectra infection significantly decreased nodulation in cowpea (Table 15). Generally, Alectra infection reduced nodulation by 12.4 to 100% in all the varieties except VITA-3. The most promiscuous varieties were Kano 1696 and TN 93-80, while IT89KD-245-1, IT89KD-245 and IT90K-76 produced the least number of nodules which were comparable to IT84S-2246-4, TVX 3236, IT90K-59, IT81D-849, IT81D-985, IT81D-994, IT86D-843, IT86D-534, TN 121-80 and SUVITA-2 (Table 15).

4.2.4 Correlation

Number of nodules was negatively correlated with the number of emerged and un-emerged Alectra at 80 DAS, and number of days

to crop flowering (r value = -0.16, -0.05, and -0.41, respectivley). However, it was positively correlated with number of days to Alectra emergence (r value = 0.01) (Table 17).

Table 16: Interaction between variety and infection on number of days to first crop flowering at Samaru, 1992 in the green house

Variety	Number of days to crop flowering	
	Infected	Un-infected
IT84S-2246-4	58 e	50 f
Kano 1696	-	-
IT89KD-245-1	50 f	45 g
TVX 3236	45 g	51 f
IT90K-59	72 ab	69 bc
IT90K-76	49 fg	45 g
IT89KD-245	51 f	45 g
IT82D-849	-	50 f
B 301	-	-
IT81D-985	-	-
IT81D 994	58 e	63 de
IT86D-(43	72 ab	74 a
TN 93-80	-	-
TN 121-80	-	-
VITA 3	-	-
SUVITA 2	-	66 cd
SAMPEA 7	-	62 de
IT86D 534	52 f	51 f
S.E ±	1.47	

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

Table 17: Correlation between various parameters in the screening of cowpea varieties for Alectra resistance in the green house at Samaru, 1992

	1	2	3	4	5	6	7
1	1.0						
2	-0.16	1.0					
3	-0.04	0.55**	1.0				
4	-0.19	0.82**	0.13	1.0			
5	0.01	0.67**	0.49**	0.57**	1.0		
6	-0.05	0.38**	0.21	0.31**	0.44**	1.0	
7	-0.41**	-0.39**	-0.19	-0.33*	0.01	-0.04	1.0

* = Significant at 5% level of probability (r = 0.27)

** = Significant at 1% level of probability (r = 0.35)

1 Average number of nodules/plant
2 Alectra count at 80 days (Expt. terminated)
3 Number of alive Alectra at 80 days
4 Number of death Alectra at 80 days
5 Number of days to Alectra emergence
6 Un-emerged Alectra/plant at 80 days
7 Number of days to crop flowering

4.3 Effect of nitrogen and phosphorus combination on the reaction of cowpea to Alectra

Effect of nitrogen and phosphorus combinations on Alectra parameters viz number of plants infected, Alectra shoot count, days to Alectra emergence; crop growth and yield and yield attributes are presented in Tables 18 to 33.

4.3.1 Number of plants infected and Alectra shoot count

In the two trials, cowpea varieties differed significantly in their reaction to Alectra (Tables 18 & 19). In 1991, number of plants infected and Alectra shoot count were significantly higher for VITA-3 than TN 93-80. In 1992, SAMPEA-7 had the highest number of plants infected and Alectra shoot count, while the least was obtained with IT89KD-245. Varieties differed in the number of plants infected by Alectra following the order SAMPEA-7 > VITA-3 > TN 93-80 > IT89KD-245-1.

In the two trials, phosphorus levels did not have an effect on number of plants infected and Alectra shoot count, while nitrogen levels had significant effect at 9 WAS in 1991 and Alectra count only in 1992. The number of plants infected decreased with N levels in 1991 and non-significantly in 1992. Nitrogen at 60 Kg N/ha reduced the Alectra count significant as compared with 0 Kg and 30 Kg N/ha in both two years.

The interactions of nitrogen X variety and variety x phosphorus x nitrogen number of plants infected with Alectra at 9 WAS were significant in 1991 and 1992, respectively. In 1991, number of plants infected with Alectra decreased with N-levels in TN 93-80 while it only occured with 60 Kg N/ha in VITA-3 (Table 20). In 1992, interaction of variety x phosphorus x nitrogen on

Table 18: Effect of nitrogen and phosphorus on number of plants infected, the time of Alectra emergence, Alectra shoot count and crop damages score at Tasha Zomo, 1991 wet season

Treatments	Number of plants infected/ $6m^2$ 9 WAS[1]	Alectra count/ $6m^2$ 9 WAS	Number of days to first Alectra emergence	Crop damage[2] symptom score 9 WAS
Variety (V)				
B 301	0.0 c	0.0 c	-	1.0 b
TN 93-80	6.5 b	16.3 b	57 a	3.2 a
VITA 3	10.4 a	38.2 a	56 b	3.6 a
S.E ±	0.58	1.43	0.35	0.21
Phosphorus (Kg P/ha)				
0	5.9	17.2	38	2.4 b
20	5.3	16.0	38	2.4 b
40	5.7	21.4	38	3.0 a
S.E ±	0.58	3.06	0.68	0.18
Nitrogen (Kg N/ha)				
0	7.7 a	24.8 a	37	2.6
30	5.8 b	19.1 a	38	2.9
60	3.5 c	10.6 b	37	2.3
S.E ±	0.58	3.06	0.68	0.18
Interactions				
V x P	NS	NS	NS	NS
V x N	**	NS	NS	NS
N x P	NS	NS	NS	NS
V x P x N	NS	NS	**	NS

1 Weeks after sowing

2 Crop damage symptom score scale (1-5), where 1 = normal crop plant growth, no chlorosis, no blotching, no leaf scorching and 5 = total leaf scorching or/and obviously stunted or dead plants.

3 Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

Table 19: Effect of nitrogen and phosphorus on number of plants infected, the time of emergence, number of shoot count of Alectra and crop damage score under Alectra infestation at Samaru, 1992 wet season

Treatments	Number of plants infected/ $6m^2$ 9 WAS[1]	Alectra count/ $6m^2$ 9 WAS	Number of days to first Alectra emergence	Crop damage[2] symptom score at 9 WAS
Variety (V)				
IT89KD-245-1	2.0 d	4.9 c	53 a	1.2 b
TN 93-80	4.4 c	30.4 b	43 b	2.0 a
VITA 3	7.1 b	30.6 b	44 b	1.7 ab
SAMPEA-7	9.4 a	68.8 a	44 b	2.3 a
S.E ±	0.56	6.55	1.18	0.26
Phosphorus (Kg P/ha)				
0	5.1	26.8	47	1.6 b
20	5.9	37.4	44	1.9 a
40	6.1	36.8	46	1.8 ab
S.E ±	0.44	5.21	0.63	0.08
Nitrogen (Kg N/ha)				
0	6.5	40.1 a	46 ab	1.9
30	5.9	35.8 a	45 b	1.7
60	4.7	25.2 b	47 a	1.7
S.E ±	0.44	5.21	0.63	0.08
Interactions				
V x P	NS	NS	*	NS
V x N	NS	NS	*	NS
N x P	NS	NS	NS	NS
V x N x P	*	NS	*	NS

1 Weeks after sowing

2 Crop damage symptom score scale (1-5), where 1 = normal crop plant growth, no chlorosis, no blotching, no leaf scorching and 5 = total leaf scorching or/and obviously stunted or dead plants.

3 Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

Table 20: Interaction of nitrogen and variety on number of plants infected with Alectra at Tasha Zomo, 1991 wet season

Variety	Number of plants infested with Alectra/6m^2 at 9 WAS Nitrogen (Kg N/ha) 0	30	60
B 301	0.0 e	0.0 e	0.0 e
TN 93-80	8.9 b	6.3 c	3.3 d
VITA 3	13.1 a	11.0 ab	7.2 c
S.E ±	0.89		

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

number of plants infected by Alectra at 9 WAS was highest in SAMPEA-7 treated with 40 Kg P/ha alone. Only combination of 30 Kg N and 20 Kg P/ha in the same variety was comparable to the maximum (Table 21).

4.3.2 Number of days to Alectra emergence

Number of days to Alectra emergence differend significantly among cowpea varieties in the two years (Tables 18 & 19). Alectra emergence on cowpea variety TN 93-80 was significantly delayed in 1991 while IT89KD-245-1 delayed emergence with TN93-80, VITA-3 and SAMPEA-7 in 1992. Nitrogen only had significant effect on days to Alectra emergence in 1992 when 30KgN/ha significantly reduced it compared with 0 and 60 Kg N/ha.

In 1992, under artificial infestation, interaction of variety x nitrogen and variety x phosphorus were significant (Tables 22 and 23). Number of days to Alectra emergence was significantly increased in IT89KD-245-1 when no nitrogen and 60 Kg N/ha were applied compared with other variety x nitrogen interactions (Table 22). Similarly, without P and with 40Kg P/ha, IT89KD-245-1 also increased the number of days to Alectra emergence compared with other varieties. The use of 20 Kg P/ha also resulted in earlier emergence of Alectra compared with 20Kg P/ha in the same variety (Table 23). The application of 20 Kg P/ha reduced number of days to Alectra emergence in TN 93-80 compared with IT89KD-245-1.

There was significant interaction between variety, nitrogen and phosphorus on number of days to Alectra emergence in 1991 and 1992 (Tables 24 and 25). In 1991, combinations of 60Kg N/ha and

40Kg P/ha increased days to Alectra emergence in TN93-80, compared with combination involving the same rate of phosphorus and zero or 30Kg N/ha. The use of either 30Kg N/ha, 20 Kg P/ha or 40Kg P/ha alone in VITA-3 reduced days to Alectra emergence compared with the maximum in TN 93-80 (Table 24). In 1992, the 3-way interactions, indicatres that, maximum number of days to first Alectra emergence was obtained with IT89KD-245-1 given 40Kg P/ha only. The same variety given 60 Kg N/ha only and combination of the 60 Kg N/ha and 40 Kg P/ha also resulted in days comparable to the maximum. Among all varieties tested, Alectra emergence was only delayed in IT89KD-245-1 by phosphorus at 40Kg P/ha alone or in combination with 30 Kg N/ha compared with 0 and 20 Kg P/ha (Table 25).

4.3.3 Number of days to first crop flowering

Infection by Alectra significantly reduced number of days to crop flowering. Cowpea varieties differed significantly among themselves (Table 26). SAMPEA-7 had significantly shorter period than the other three varieties. Application of phosphorus and nitrogen significantly decreased days to crop flowering. Higher rates of N and P. (30 Kg N and 40 Kg P) did not significantly affect number of days to crop flowering compared with the lower rates. The interactions of various factors on number of days to crop flowering were not significant.

4.3.4 Crop stand at harvest

Of all the factors evaluated only phosphorus had significant effect on crop stand count in 1992. Phosphorus application at 20 Kg P/ha resulted in higher cowpea stand count than 0 and 20 Kg

Table 21: Interaction of phosphorus, nitrogen and variety on number of plants infected with Alectra at 9 WAS at Samaru, 1992 wet season

Varieties	Nitrogen (Kg N/ha)	Number of plants infected with Alectra/6m^2 at 9 WAS[1] Phosophorus (Kg P/ha) 0	20	40
IT89KD-245-1	0	3.0e-i	2.7f-i	1.0i
	30	0.7i	2.7f-i	3.0e-i
	60	1.7hi	1.7hi	1.7hi
TN 93-80	0	8.7cd	4.0d-i	5.0c-i
	30	2.7f-i	3.7d-i	6.3c-h
	60	2.3ghi	4.0d-i	2.7f-i
VITA-3	0	5.7c-i	9.3bc	6.7c-h
	30	7.7c-f	8.3cd	7.3c-g
	60	8.0cde	5.0c-i	5.7c-i
SAMPEA-7	0	7.0c-g	8.7cd	16.7a
	30	7.3c-g	13.3ab	7.7c-f
	60	6.3c-h	8.0cde	9.3bc
S.E ±		1.55		

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

Table 22: Interaction of nitrogen and variety on number of days to Alectra emergence at Samaru, 1992 wet season

Varieties	Number of days to Alectra emergence Nitrogen (Kg N/ha) 0	30	60
IT89KD245-1	54 a[1]	47 b	55 a
TN 93-80	42 b	43 b	44 b
VITA-3	44 b	44 b	45 b
SAMPEA-7	45 b	45 b	44 b
S.E ±	1.57		

Table 23: Interaction of phosphorus and variety on number of days to Alectra emergence at Samaru, 1992 wet season

Varieties	Number of days to Alectra emergence Phosphorus (Kg P/ha) 0	20	40
IT89KD245-1	52 ab	49 bc	56 a
TN 93-80	46 cd	42 d	42 d
VITA-3	45 cd	44 cd	44 cd
SAMPEA-7	46 cd	43 cd	44 cd
S.E ±	1.57		

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

Table 24: Interaction of variety, nitrogen and phosphorus on days to first Alectra emergence at Tasha Zomo, 1991 wet season

Variety	Phosphorus Kg P/ha	Days to first Alectra emergence Nitrogen Kg N/ha 0	30	60
	0	-[2]	-	-
B 301	20	-	-	-
	40	-	-	-
	0	57 ab	57 ab	56 ab
TN 93-80	20	59 ab	57 ab	56 ab
	40	53 b	53 b	62 a
	0	58 ab	53 b	56 ab
VITA-3	20	53 b	56 ab	59 ab
	40	54 ab	59 ab	56 ab
S.E (±)		1.96		

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

2 Alectra did not emerge

Table 25: Interaction of phosphorus nitrogen and variety on number of days to Alectra emergence at Samaru, 1992 wet season

Varieties	Nitrogen (Kg N/ha)	Phosophorus (Kg P/ha) 0	20	40
IT89KD-245-1	0	50bcd	51bcde[1]	61a
	30	46cde	43de	53bc
	60	60a	50bcd	54ab
TN 93-80	0	43de	43de	44de
	30	46cd	43de	41e
	60	48b-e	39e	46cde
VITA-3	0	44de	43de	44de
	30	44de	44de	44de
	60	44de	44de	44de
SAMPEA 7	0	48b-e	43de	44de
	30	46cde	45de	43de
	60	44de	41e	45debc
S.E ±	2.38			

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

Table 26: Effect of nitrogen and phosphorus on number of days to crop flowering, weight of pods and grain yield under Alectra infestation at Samaru, 1992 wet season

Treatment	Number of days to crop flowering	Weight of pods (Kg/ha)	Grain yield (Kg/ha)	% yield reduction
Infection (I)				
Infected	51 b	1200	1029	
Un-infected	52 a	1450	1155	11.1
S.E ±	0.20	270.0	197.28	
Variety (V)				
IT89KD-245-1	52 a	1400 ab	1275 a	11.7
TN 93-80	53 a	1030 c	849 b	13.5
VITA 3	52 a	1620 a	1345 a	0.9
SAMPEA	49 a	1270 bc	895 a	21.5
S.E ±	0.52	100.0	58.76	
Phosphorus (Kg P/ha)				
0	52 a	1220 b	990 b	7.9
20	51 b	1420 a	1131 a	16.7
40	51 b	1350 ab	1152 a	8.0
S.E ±	0.23	50.0	39.25	
Nitrogen (Kg N/ha)				
0	52 a	1300 ab	1041 b	18.0
30	51 b	1450 a	1239 a	2.9
60	51 b	1230 b	993 b	13.3
S.E ±	0.23	50.0	39.25	
Interactions				
V x I	NS	NS	NS	NS
V x N	NS	NS	NS	NS
I x N	NS	NS	NS	NS
V x P	NS	NS	NS	NS
P x N	NS	NS	NS	NS
V x I x N	NS	NS	NS	NS
V x P x N	NS	NS	NS	NS
I x P x N	NS	NS	NS	NS

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

P/ha (Table 30). Although not statistically different, it was apparent that Alectra infestation caused crop stand reduction as compared with Alectra free condition.

There was significant interaction between cowpea variety x infection on crop stand count at harvest (Table 27). Among all the varieties only IT89KD-245-1 did not have significant stand count depression under Alectra infection compared with Alectra free condition.

4.3.5 Number of Pods

In the two trials, cowpea varieties differed significantly in respect to number of pods (Tables 28 & 29). In 1992, although not significant, Alectra infection caused lower pod number production than no Alectra condition. Cowpea varieties B 301 and VITA 3 had significantly more number of pods in 1991 and 1992, respectively. In 1991; both 20 and 40Kg P/ha similarly increased pod number compared with no phosphorus application. But in 1992, althogh not significant, 20 Kg P/ha gave more pod number than the 0 and 40 Kg P/ha. In the two trials, 60KgN/ha, resulted in more pod number when compared to 60 Kg N, although not significant statistically in 1991.

There was significant interaction of nitrogen x phosphorus on the number of pods of cowpea in 1991 and 1992 (Tables 30 & 29). In 1991 maximum pod number was produced by phosphorus alone at 40Kg P/ha.

Application of 20 Kg P and 60 Kg N, 20 Kg P and 30 Kg N, 40 Kg P and 30 Kg N and 60 Kg N and 40 Kg P/ha resulted in pod number comparable to the maximum. Without N, 206 Kg P resulted

in higher pod number than 0 and 20 Kg P while with 30 Kg N, 40 Kg P only had higher pod number than no P-application. However, with 60 Kg N both 20 and 40 Kg P had higher number of pods than no P-application. Nitrogen at 60 Kg N only significantly increased pod number compared with 0 Kg N when combined with 20 Kg P (Table 30). In 1992, variety x nitrogen indicates that VITA 3 irrespective of N-levels resulted in the highest pod numbers which was comparable to SAMPEA 7 at all N-levels, IT89KD-245-1 at zero N-level and TN 93-80 at 30 Kg N/ha (Table 29). Simlarly, in the variety x phosphorus interaction, 40 Kg P/ha gave the highest pod number which was comparable to other P-levels, SAMPEA 7 at 0 and 40 Kg/ha, IT89KD-245-1 at 20 Kg P/ha and TN 93-80 at 40 Kg P/ha.

4.3.6 Weight of Pods

Although not significant, Alectra infection depressed yield in 1992. In the two years cowpea varieties differed significantly with respect to pod weight (Tables 28 & 26). In the two years, VITA-3 produced significantly higher pod yield than TN 93-80. In 1991, pod yield with B 301 was also higher than that of TN 93-80. In 1992, SAMPEA-7 also produced lower pod yield than VITA-3, while IT89KD-245-1 was comparable to VITA-3. In the two trials, 20 Kg P/ha significantly increased pod weight compared with no phosphorus application. Application of 40 Kg P/ha did not result in significant increase in pod weight. Application of 30 Kg N/ha resulted in higher pod weight than 0 and 60 Kg N/ha in 1992. Although, N-levels did not affect weight of pods in 1991, the trend showed that 30 Kg N/ha resulted in higher pod weight compared with 0 and 60 Kg N/ha.

Table 27: Effect of nitrogen and phosphorus on stand count at harvest under artificial Alectra infestation at Samaru, 1992 wet season

Variety	Infection: Infected	Un-infected	Mean	Nirogen (Kg/ha)	Phosphorus (Kg P/ha): 0	20	40	Mean
IT89-245-1	20 d[1]	20 d	20	0	**21**	21	21	21
TN 93-80	19 e	21 c	21	30	21	22	21	21
VITA-3	20 d	24 a	22					
SAMPEA-7	19 e	22 b	21	60	20	21	20	21
(Int.) S.E ± 0.3				(Int.) S.E ± 0.35				
Mean	**20**	22	(V) S.E ± 0.80	Mean	20 b	21 a	20 b	(N) S.E ± 0.20
(I) S.E ±	0.17			(P) S.E ± 0.20				

1 Means followed by the same letter(s) within the same treatment group in the marginal means and within the first order of interactions are not different statistically by DMRT at 5% level.
(Int) = Interaction, (P) = phosphorus (N) = Nitrogen, (I) = Infection
(V) = Variety

4.3.7 Weigth of 1000 grains

Cowpea varieties differed significantly with respect to weight of 1000 grains only in 1992 trial (Table 31). Among the varieties tested, IT89KD-245-1 resulted in significantly heavier grains than all the other varieties. Varieties differed in grain weight folllowing the order IT89KD-245-1 > VITA-3 > SAMPEA-7 > TN 93-80. Phosphorus and nitrogen levels did not have significant effect on weight of 1000 grains in the trial.

There was significant interactions of variety x nitrogen, variety x phosphorus, variety x infection and nitrogen x infection on weight of 1000 grains (Table 31). In the variety x nitrogen interaction, application of 60 Kg N/ha significantly depressed 1000 grain weight compared with 0 and and 30 Kg N in IT89KD-245-1. In contrast, 60 Kg N depressed 1000 grain weight compared with 0 Kg N in TN 93-80. In the phosphorus x variety interaction, 20 Kg P had significantly higher weight of 1000 grains in TN 93-80 compared to 0 and 40 Kg P/ha, while in SAMPEA-7, 0 and 20 Kg P/ha was higher than 40 Kg P/ha. The variety x infection interaction, indicates that infection significantly depressed 1000 grain weight in IT89KD-245-1 and VITA-3. In the nitrogen x infection interaction, without infection, 60 Kg N depressed 1000 grain weight compared with 0 Kg N. With infection, 30 and 60 Kg N/ha resulted in higher 1000 grain weight compared to 0 Kg N/ha.

4.3.8 Cowpea grain yield

In 1992, although not significant, Alectra infection reduced cowpea grain yield compared with Alectra free condition. Varieties only different significantly in cowpea production

Table 28: Effect of nitrogen and phosphorus on number, weight of pods and grain yield at Tasha Zomo, 1991 wet season

Treatments	Number of pods/6m^2	Weight of pods (Kg/ha)	Grain yield (Kg/ha)
Variety (V)			
B 301	575 a	943.3 a	641
TN 93-80	336 b	688.3 b	532
VITA-3	253 c	881.7 a	660
S.E ±	12.73	60.7	44.20
Phosphorus (Kg P/ha)			
0	272 b	533.3 b	390 b
20	415 a	925.0 a	685 a
40	477 a	1055.0 a	759 a
S.E ±	25.53	57.52	45.76
Nitrogen (Kg N/ha)			
0	359	833.3	613 a
30	425	945.0	694 a
60	370	743.3	526 b
S.E ±	25.53	57.52	45.76
Interactions			
V x P	NS	NS	NS
V x N	NS	NS	NS
N x P	**	NS	NS
V x P x N	NS	NS	NS

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

Table 29: Interaction of variety Effect of nitrogen and phosphorus on number of pods/4.5m^2 under artificial Alectra infestation at Samaru, 1992 wet season

Variety	Nirogen (Kg/ha) 0	30	60	Phosphorus (Kg P/ha) 0	20	40	Infection Infected	Unfected	Mean
IT89-245-1	459ab1	384bcd	384bcd	325d	512ab	390bcd	345	473	409b
TN 93-80	299d	497ab	338cd	337d	364d	432a-d	373	383	378b
VITA 3	526a	518a	512a	521ab	506abc	528a	498	539	519a
SAMPEA 7	415abc	442abc	409abc	443a-d	408bcd	416a-d	390	454	442ab
(Int) S.E ±	36.92				36.9		(V) S.E ±		23.69
Mean	425ab	460a	411b	407	448	442	402	462	
	(N) S.E ± 17.33			(P) S.E ± 17.33			(I) S.E ± 58.48		

1 Means followed by the same letter(s) within the same treatment group in the marginal means and within the first order of interactions are not different statistically by DMRT at 5% level

(Int.) = Interaction, (N) = Nitrogen, (V) = Variety, (P) = Phosphorus, (I) = Infection

Table 30: Interaction of nitrogen and phosphorus on number of pods at Tasha Zomo, 1991 wet season

Phosphorus (Kg P/ha)	Number of pods/6m² Nitrogen (Kg N/ha) 0	30	60
0	261 c	337 bc	219 c
20	348 bc	405 ab	492 a
40	499 a	533 a	398 ab
S.E ±	44.20		

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

Table 31: Effect of nitrogen and phosphorus on weight of 1000 grain (g) under artificial Alectra infestation at Samaru, 1992 wet season

Variety	Nitrogen Kg/ha			Phosphorus Kg P/ha			Infection			Mean
	0	30	60	0	20	40	Infected	Un-effected	Mean	
ITS9KD-245-1	245.6a	250.6a	231.7b	242.2a	239.4a		246.1a	230.7b	254.4a	242.6a
TN 93-80	163.9f1	180.0ef	176.7e	164.4f	176.7e		169.4f	174.4f	165.9g	170.2d
VITA 3	216.1c	208.9c	213.3c	213.3bc	205.0bcd		220.0b	207.4d	218.1c	212.8b
SAMPE 7	189.4d	192.8d	193.9d	198.9d	200.6cd		176.7e	195.9e	188.1e	192.0c
(Int) S.E ±	3.98			3.98			2.91		(V) S.E ± 1.76	
Mean	203.8	205.6	203.9	204.7	205.4		203.1	202.1	206.7	
(N) S.E ± 2.19			(P) S.E ± 2.19			(I) S.E ± 1.94				

Nitrogen (Kg/ha)	Infection	
	Infected	Uninfected
0	194.2c	213.3a
30	204.4b	206.7ab
60	207.7ab	200.0bc
(Int) S.E ± 3.19		

1 Means followed by the same letter(s) within the same treatment group in the marginal means and within the first order of interactions are not different statistically by DMRT at 5% level

(Int.) = Interaction, (N) = Nitrogen, (V) = Variety, (P) = Phosphorus, (I) = Infection

in 1992. Both IT89KD-245-1 and VITA-3 produced highr grain yield than TN 93-80 and SAMPEA-7. In 1991, although not significant, B 301 and VITA-3 produced higher grain yields than TN 93-80 (Tables 28 & 26). In the trial, grain of VITA-3 was only reduced by Alectra of 0.9% compared with 21.5%, 13.5% and 11.7% for SAMPEA-7, TN93-80 and IT89KD-245-1, respectively. In the two trials, grain yield was significantly increased by phosphorus application at 20 Kg P/ha. In 1992, under artificial infestation, Alectra caused 16.7% reduction in cowpea grain yield with application of 20 Kg P/ha compared with 7.9 and 8.0% obtained with 0 and 40 Kg P/ha, respectively. Application of 30 KgN/ha resulted in significantly higher cowpea grain yield compared with 60 Kg N/ha in 1991 and 0 and 60 Kg N/ha in 1992. In 1992, under artificial infestation, Alectra only caused 2.9% reduction in cowpea grain yield with the application of 30 Kg N/ha compared with 18.0% and 13.3% obtained with 0 and 60 Kg N/ha, respectively.

4.3.9 Correlation

Grain yield was positively correlated with weight of pods and crop stand at harvest in the two trials (r values = 0.96, 0.09 respectively in 1991 and 0.68, 0.21, respectively in 1992). However, it was negatively correlated to number of plants infeced and Alectra shoot count at 8, 9, 10 WAS and at harvest. The r values were higher in 1991 than 1992 (Tables 32 & 33).

Table 32: Correlation between cowpea grain yield and varieties parameters as affected by nitrogen and phosphorus combinations at Iasha Izoo, 1991 wet season

	1	2	3	4	5	6	7	8	9	10	11
1	1.0										
2	-0.10	1.0									
3	-0.13	0.35**	1.0								
4	-0.13	0.89**	0.73**	1.0							
5	-0.14	0.93**	0.85**	0.89**	1.0						
6	-0.05	0.88**	0.70**	0.95**	0.89**	1.0					
7	-0.09	0.92**	0.80**	0.90**	0.95**	0.93**	1.0				
8	0.96**	-0.02	-0.06	-0.05	-0.07	-0.01	0.02	1.0			
9	0.09	0.53**	0.39**	0.68**	0.51**	0.68**	0.54**	-0.20	1.0		
10	-0.01	0.77**	0.70**	0.77**	0.70**	0.75**	0.67**	-0.10	0.69**	1.0	
11	0.09	0.17	0.17	0.24*	0.21	0.25*	0.23*	0.08	0.14	0.24*	1.0

1 Grain yield
2 Number of plants infected at 8 WAS
3 Alectra count at 8 WAS
4 Number of plants infected at 9 WAS
5 Alectra count at 9 WAS
6 Number of plants infected at harvest
7 Alectra count at harvest
8 Weight of pods
9 Number of days to Alectra emergence
10 Crop damage symptom score at 9 WAS
11 Crop stand count at harvest

* Significant at 5% level of probability ($r = 0.22$)

** Significant at 1% level of probability ($r = 0.28$)

Table 33: Correlation between cowpea grain yield and various parameters under Alectra infestation as affected by nitrogen and phosphorus combinations at Samaru, 1992 wet season

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.0												
2	-0.21*	1.0											
3	-0.29**	0.83**	1.0										
4	-0.15	0.94**	0.79**	1.0									
5	-0.26**	0.85**	0.96**	0.84**	1.0								
6	-0.15	0.81**	0.70**	0.85**	0.75	1.0							
7	-0.29**	0.73**	0.72**	0.78**	0.79**	0.54**	1.0						
8	-0.06	0.76**	0.59**	0.81**	0.65**	0.89**	0.77**	1.0					
9	-0.08	0.69**	0.63**	0.76**	0.73**	0.82**	0.95**	0.80**	1.0				
10	0.68**	-0.09	-0.12	-0.05	-0.12	-0.04	-0.06	-0.06	-0.01	1.0			
11	-0.13	0.46**	-0.43**	-0.41**	-0.42**	-0.29**	-0.25**	-0.27**	-0.20	-0.002	1.0		
12	-0.26**	-0.54**	0.60**	0.52**	0.57**	0.49*	0.41**	0.44**	0.32**	-0.04	-0.44**	1.0	
13	0.21*	-0.19*	-0.15	-0.16	-0.15	-0.15	-0.16	-0.20*	-0.12	0.30**	-0.07	-0.21	1.0

1 Grain yield
2 Number of plants infected at 8 WAS
3 Alectra count at 8 WAS
4 Number of plants infected at 9 WAS
5 Alectra count at 9 WAS
6 Number of Plants infected at 10 WAS
7 Alectra count of 10 WAS
8 Number of plants infected at harvest
9 Alectra count at harvest
10 Weight of pods
11 Number of days to Alectra emergence
12 Crop damage symptom score at 9 WAS
13 Crop stand count at harvest

* = Significant at 5% level of probability (r = 0.19)

** = Significant at 1% level of probability (r = 0.25)

4.4 Evaluation of herbicide combinations for the control of Alectra in Cowpea

Effect of herbicide combinations on Alectra parameters viz number of plants infected, Alectra shoot count, number of days to first Alectra emergence crop damage score and cowpea yield and yield attributes are shown in Tables 34 to 39.

4.4.1 Number of plants infected with Alectra

In the two field trials, treatments differed significantly with respect to the number of plants infected with Alectra at 9 WAS (Tables 34 & 35). In both years, all pre-emergence applications of mixtures containing Pree followed by Imazaquin at 0.18 kg a.i./ha resulted in significantly lower number of plants infected. Similarly, in 1991, pendimethalin plus imazaquin at 0.87 + 0.15 and 1.09 + 0.19 kg a.i./ha, and pendimethalin plus in imazethapyr at 1.58 - 0.12 kg a.i./ha all followed by imazaquin at 0.18 kg a.i./ha, resulted in lower number of plants infected compared with the weedy check. However, in 1992 post-emergence application of Pree plus imazethapyr at 1.0 + 0.075 kg a.i./ha, as well as pre-emergence application of Pree plus imazethapyr at 1.0 + 0.05 kg a.i./ha and Pree plus imazaquin at 1.0 + 0.36 kg a.i./ha both fb supplementary hoe-weeding (SHW) resulted in lower number of infected plants compared with the maximum obtained with pendimethalin plus imazaquin at 1.09 + 0. 19 kg a.i./ha fb SHW. Both the hoe-weeded control and weedy check also had lower number of infected plants than the maximum.

4.4.2 Alectra shoot count

In the two field trials, treatments differed significantly

with respect to Alectra shoot count at 9 WAS (Tables 34 & 35). In 1991 Pree plus imazethapyr at 1.0 + 0.075 Kg a.i./ha fb imazaquin or the same pre-emergence treatment applied potst-emergence at 3 WAS as well as Pree plus imazaquin at 1.0 + 0.36 Kg a.i/ha fb imazaquin at 0.18 kg a.i./ha reduced Alectra shoot count significantly compared with weedy check. In addition to those indicated, Pree plus imazaquin at 1.0 + 0.05 Kg a.i./ha applied post-emergence, Pree plus imazaquin at 1.0 + 0.18 Kg a.i/ha either fb SHW or imazaquin at 0.18 Kg a.i./ha. Pree plus imazethapyr at 1.0 + 0.075 and pendimethalin plus imazaquin at 1.09 + 0.19 Kg a.i./ha, each followed by imazaquin at 0.18, resulted in lower Alectra shoot count than the maximum obtained with pendimethalin plus imazethapyr fb SHW (Table 35).

4.4.3 Number of days to Alectra emergence

In both years, Pree plus imazaquin at 1.0 + 0.36 fb imazaquin at 0.18 resulted in the maximum number of days to Alectra emergence (Tables 34 & 35). The shortest days to Alectra emergence were with weedy check and Galex in 1991 and 1992, respectively. In 1991, all the other Pree containing treatments, except Pree plus imazethapyr at 1.0 + 0.05 fb imazaquin at 0.18 as well as pendimthalin plus imazaquin at 0.18 and Galex at 2.5 Kg a.i/ha resulted in number of days to emergence comparable to the maximum of days to emegence comparable to the maximum, and more than the least with weedy check (Table 34). In 1992, no treatment resulted in days comparable to the maximum. However, Pree plus imazethapyr at 1.0 + 0.075 either applied pre-emergence and fb imazaquin at 0.18 kg a.i/ha or applied post-emergence at 3

WAS Pree plus imazaquin at both rates and pree plus imazethapyr at 1.0 + 0.05, all applied post-emergence as well as Pree plus imazaquin at 1.0 + 0.36 fb SHW reduced the number of days to Alectra emergence compared with the least in the trial (Table 35).

4.4.4 Crop damage symptom score

Treatments were only significantly affected by crop damage syndrome score in 1991 at 9 WAS (Table 34). The weedy check had the highest crop damage syndrome score which was comparable to all pendimethalin containing treatments except pendimethalin plus imazaquin at 1.09 + 0.19 fb imazaquin at 0.18 as well as Pree plus imazethapyr at 1.0 + 0.05 fb imazaquin at 0.18 or same rate applied post emergence; post-emergence application of Pree plus imazaquin at 1.0 + 0.36 and Pree plus imazaquin at the same fb SHW.

4.4.5 Weight of Pods

Treatments differed significantly with respect to pod weight in the two trials (Tables 36 & 37). The highest pod weight was obtained with pendimethalin plus imazaquin at 1.09 + 0.19 fb SHW and pendimethalin plus imazethapyr at 1.58 + 0.12 fb SHW in 1991 and 1992, respectively. In the two years, the recommended herbicide for cowpea (Galex) gave lower pod weight compared with the highest in the two years. The hoe-weeded control also Produced lower pod weight than the maximum in 1992. In 1991, Pree plus imazethapyr at 1.0 + 0.05 Kg a.i/ha and 1.0 + 0.075 Kg a.i/ha and pendimethalin plus imazaquin at 1.0 + 0.19 Kg a.i/ha, all followed by SHW resulted in significantly higher pod weight

Table 34: The effect of herbicide on number of plants infected, Alectra emergence and Alectra shoot count at Tasha Zomo, 1991 wet season

Pre-emergence	Rate Kg a.i/ha	Post-emergence	Number of plants infected with Alectra/ 6M^2 9 WAS[1]	Alectra count/6m^2 9 WAS	Number of days to Alectra emergence	Crop damage[2] score at 9 WAS
Pree+Imazethapyr	1.0+0.05	SHW	6.7d-h	34.3a-e	58abc	2.3def
" + "	1.0+0.05	Imazaquin at 0.18	6.3e-h	22.7a-e	54b-f	3.3a-f
" + "	-	1.0+0.05 at 3WAS	6.7e-h	17.0cde	55a-e	3.7a-e
" + "	1.0+0.075	SHW	4.0gh	15.0cde	59a-e	2.3def
" + "	1.0+0.075	Imazaquin at 0.18	3.7gh	5.3e	59ab	2.3def
" + "	-	1.0+0.075 at 3WAS	5.0fgh	9.0de	57a-d	3.0b-f
Pree+Imazaquin	1.0+0.18	SHW	7.3d-h	17.3b-e	55a-e	2.7e-f
" + "	1.0+0.18	Imazaquin at 0.18	3.7gh	13.7cde	58abc	3.3a-f
" + "	-	1.0+0.18 at 3WAS	9.0b-h	22.0a-e	58abc	4.0a-d
" + "	1.0+0.36	SHW	8.0c-h	25.3a-e	59ab	3.7a-e
" + "	1.0+0.36	Imazaquin at 0.18	1.3h	3.3e	60a	2.0ef
" + "	-	1.0+0.36 at 3WAS	15.3a-d	48.7abc	56a-d	3.7a-e
Pendimethalin + Imazaquin	0.87+0.15	SHW	15.7abc	51.0ab	51efg	3.7a-e
" + "	0.87+0.15	Imazaquin at 0.18	8.3c-h	21.0a-e	49fg	3.7a-e
" + "	-	0.87+0.15 at 3WAS	13.7a-e	39.3a-e	53c-g	3.3a-f
" + "	1.09+0.19	SHW	11.3a-g	40.0a-d	51efg	3.3a-f
" + "	1.09+0.19	Imazaquin at 0.18	5.3f-h	17.3b-e	56a-d	1.7f
" + "	-	1.09+0.19 at 3WAS	17.0ab	40.3a-d	50efg	4.0a-d
Pendimethalin + Imazethapayr	1.27+0.096	SHW	12.3a-f	26.0a-e	52d-g	4.0a-d
" + "	1.27+0.096	Imazaquin at 0.18	14.3a-e	33.3a-e	49fg	4.0a-d
" + "	-	1.27+0.096 at 3WAS	15.3a-d	42.3a-e	49fg	5.0a
" + "	1.58+0.12	SHW	14.3a-e	52.3a	51efg	4.3abc
" + "	1.58+0.12	Imazaquin at 0.18	8.3c-h	25.3a-e	54b-f	3.3a-f
" + "	-	1.58+0.12 at 3WAS	15.7abc	43.0abc	51efg	4.3abc
Metolachlor + Metobromuron	2.5		10.3a-g	21.0a-e	55a-e	3.3a-f
Hoe weeded 3&6 WAS			17.0ab	41.0a-d	52d-g	4.7ab
Unweeded check			18.0a	43.3abc	48g	5.0a
S.E ±			2.52	9.93	1.72	0.55

1 Weeks after sowing

2 Crop damage score scale (1-5), where 1 = normal crop plant growth, no chlorosis, no blotching no leaf scorching and 5 = total leaf socrching or/and obviously stunted or dead plants

3 Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

Table 35: The effect of herbicide on number of plants infected, Alectra shoot count and number of days to first Alectra emergence at Samaru 1992 wet season

Pre-emergence	Rate Kg a.i/ha	Post-emergence	Number of plants infected with Alectra/ $6M^2$ 9 WAS	Alectra count/$6M^2$ 9 WAS[1]	Number of days to Alectra emergence	Crop damage score at 9 WAS
Pree+Imazethapyr	1.0+0.05	SHW	6.7bc	29.3cde	47b-f	2.0
" + "	1.0+0.05	Imazaquin at 0.18	5.0bcd	11.7de	49b-f	1.7
" + "	–	1.0+0.05 at 3WAS	8.7abc	42.7a-e	50b-e	1.7
" + "	1.0+0.075	SHW	10.0abc	51.4a-e	48b-f	1.7
" + "	1.0+0.075	Imazaquin at 0.18	5.3bcd	21.3de	53bc	1.3
" + "	–	1.0+0.075 at 3WAS	6.4bcd	25.3de	52bcd	1.7
Pree+Imazaquin	1.0+0.18	SHW	7.7abc	25.3de	44c-f	1.7
" + "	1.0+0.18	Imazaquin at 0.18	7.0abc	58.7a-e	44c-f	2.0
" + "	–	1.0+0.18 at 3WAS	5.7bcd	28.7cde	52bcd	1.7
" + "	1.0+0.36	SHW	5.3bcd	15.7de	56b	1.7
" + "	1.0+0.36	Imazaquin at 0.18	1.0d	4.7e	67a	1.0
" + "	–	1.0+0.36 at 3WAS	5.7bcd	42.3a-e	50b-e	1.3
Pendtmethalin + Imazaquin	0.87+0.15	SHW	11.0abc	94.3ab	44c-f	2.0
" + "	0.87+0.15	Imazaquin at 0.18	9.3abc	45.0a-e	41ef	2.3
" + "	–	0.87+0.15 at 3WAS	10.0abc	59.0a-e	43c-f	2.0
" + "	1.09+0.19	SHW	13.7a	91.7ab	40ef	2.3
" + "	1.09+0.19	Imazaquin at 0.18	11.3abc	102.7a	40ef	2.3
" + "	–	1.09+0.19 at 3WAS	10.7abc	68.7a-d	42def	1.7
Pendimethalin + Imazethapayr	1.27+0.096	SHW	9.7abc	77.3a-d	49b-f	2.3
" + "	1.27+0.096	Imazaquin at 0.18	8.0abc	41.0a-e	40ef	2.3
" + "	–	1.27+0.096 at 3WAS	10.3abc	56.7a-e	49b-f	4.0
" + "	1.58+0.12	SHW	11.0abc	98.7a	46c-f	2.7
" + "	1.58+0.12	Imazaquin at 0.18	10.3ab	47.0a-e	44c-f	1.7
" + "	–	1.58+0.12 at 3WAS	13.7abc	89.3abc	46c-f	2.3
Metolachlor + Metobromuron	2.5		11.7ab	73.3a-d	39f	2.0
Hoe weeded 3&6 WAS			4.7cd	32.3b-e	44c-f	1.7
Unweeded check			6.3bcd	44.7a-e	45c-f	1.2
S.E ±			2.00	18.65	3.03	0.45

1 Weeks after sowing
Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)

Table 36: The effect of herbicide on weight of pods and grain yield at Tasha Zomo, 1991 wet season

pre-emergence	Kg	Rate a.i/ha	Post-emergence	Weight of pods (Kg/ha)	Grain yield (Kg/ha)
Pree+Imazethapyr		1.0+0.05	SHW	515abc	326bc
" + "		1.0+0.05	Imazaquin at 0.18	395a-d	298bc
" + "		-	1.0+0.05 at 3WAS	342a-d	221bc
" + "		1.0+0.075	SHW	568ab	402ab
" + "		1.0+0.075	Imazaquin at 0.18	421a-d	314bc
" + "		-	1.0+0.075 at 3WAS	293a-d	194bc
Pree+Imazaquin		1.0+0.18	SHW	498a-d	363abc
" + "		1.0+0.18	Imazaquin at 0.18	413a-d	391abc
" + "		-	1.0+0.18 at 3WAS	178cd	176bc
" + "		1.0+0.36	SHW	155cd	166bc
" + "		1.0+0.36	Imazaquin at 0.18	253a-d	191bc
" + "		-	1.0+0.36 at 3WAS	325a-d	244bc
Pendtmethalin + Imazaquin		0.87+0.15	SHW	403a-d	285bc
" + "		0.87+0.15	Imazaquin at 0.18	431a-d	315bc
" + "		-	0.87+0.15 at 3WAS	256a-d	187bc
" + "		1.09+0.19	SHW	788a	598a
" + "		1.09+0.19	Imazaquin at 0.18	256a-d	183bc
" + "		-	1.09+0.19 at 3WAS	208a-d	152bc
Pendimethalin + Imazethapayr		1.27+0.096	SHW	241a-d	181bc
" + "		1.27+0.096	Imazaquin at 0.18	123d	84c
" + "		-	1.27+0.096 at 3WAS	136d	95c
" + "		1.58+0.12	SHW	378a-d	290bc
" + "		1.58+0.12	Imazaquin at 0.18	485a-d	388abc
" + "		-	1.58+0.12 at 3WAS	341a-d	252bc
Metolachlor + Metobromuron		2.5		156cd	112c
Hoe weeded 3&6 WAS				210a-d	155bc
Unweeded check				313a-d	125bc
S.E ±				111.03	83.95

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

Table 37: The effect of herbicide on weight of pods and grain yield at Samaru 1992 wet season

pre-mergence	Rate Kg a.i/ha	Post-emergence	Weight of pods (Kg/ha)	Grain yield (Kg/ha)
Pree+Imazethapyr	1.0+0.05	SHW	2920b-e	1420bc
" + "	1.0+0.05	Imazaquin at 0.18	3360bcd	1420abc
" + "	–	1.0+0.05 at 3WAS	3040b-e	1381bc
" + "	1.0+0.075	SHW	2960b-e	1396bc
" + "	1.0+0.075	Imazaquin at 0.18	3080b-f	1287bcd
" + "	–	1.0+0.075 at 3WAS	3000b-e	1372bc
Pree+Imazaquin	1.0+0.18	SHW	2920b-e	1213b-e
" + "	1.0+0.18	Imazaquin at 0.18	3320bcd	1369bc
" + "	–	1.0+0.18 at 3WAS	3680ab	1578abc
" + "	1.0+0.36	SHW	3640ab	1596abc
" + "	1.0+0.36	Imazaquin at 0.18	2800b-e	1505abc
" + "	–	1.0+0.36 at 3WAS	2520b-e	1272bcd
Pendtmethalin + Imazaquin	0.87+0.15	SHW	3000b-e	1422bc
" + "	0.87+0.15	Imazaquin at 0.18	2480b-e	1329bc
" + "	–	0.87+0.15 at 3WAS	2120cde	1114c-e
" + "	1.09+0.19	SHW	3360bcd	1322bc
" + "	1.09+0.19	Imazaquin at 0.18	2200cde	1227b-e
" + "	–	1.09+0.19 at 3WAS	1640e	724de
Pendimethalin + Imazethapayr	1.27+0.096	SHW	3440abc	1547abc
" + "	1.27+0.096	Imazaquin at 0.18	3440abc	1650abc
" + "	–	1.27+0.096 at 3WAS	2640b-e	1408bc
" + "	1.58+0.12	SHW	4720a	2032a
" + "	1.58+0.12	Imazaquin at 0.18	3040b-e	1627abc
" + "	–	1.58+0.12 at 3WAS	1920de	1108c-e
Metolachlor + Metobromuron	2.5		1760e	688e
Hoe weeded 3&6 WAS			2120cde	1729ab
Unweeded check			2040cde	741de
S.E ±			440.0	18.06

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

than the least in the trial. In 1992, Pree plus imazaquin at 1.0 + 0.36 and pendimethalin plus imazethapyr at 1.27 + 0.96 and 1.58 + 0.12 Kg a.i/ha, all fb SHW, Pree plus imazaquin at 1.0 + 0.18 applied post-emergence and pendimethalin plus imazethapyr at 1.27 + 0.096 fb imazaquin at 0.18 also produced significantly higher pod yields than the least in the trial.

4.4.6 Cowpea grain yield

In the two years cowpea grain yield was significantly affected by various herbicide treatments (Tables 36 & 37). The cowpea grain yields of 1991 was generally low compared with that 1992. In 1991, pendimethalin plus imazaquin at 1.09 + 0.19 and Pree plus imazethapyr at 1.0 + 0.075 both fb by SHW resulted in significantly higher cowpea grain yields than the least in the trial. In 1992, pendimethalin plus imazethapyr at 1.27 + 0.96 and 1.58 + 0.12 each fb SHW or imazaquin at 0.18 Kg a.i/ha, Pree plus imazethapyr at 1.0 + 0.05 and Pree plus imazaquin at 1.0 + 0.36 Kg a.i/ha each fb imazaquin at 0.18 Kg a.i/ha, Pree plus imazaquin at 1.0 + 0.36 fb SHW as well as the same mixture at 1.0 + 0.18 applied post-emergence 3 WAS resulted in grain yields comparable to the maximum and significantly higher than the least. The hoe weeded control also produced grain yields comparable to the maximum in the trial.

4.4.7 Correlation

Grain yield was positively correlated with weight of pods, crop stand at harvest and number of days to Alectra emergence, weight of pods and crop stand at harvest in 1991 and 1992, respectively (r values = 0.96, 0.51 and 0.03, 0.78, 0.07)

respectively. However, it was negatively correlated to number of plants infected and Alectra shoot count at 8, 9, 10 WAS and at harvest. There was a stronger relationship between cowpea grain yield and Alectra parameters at 9 WAS than other stages of crop growth (Tables 38 and 39).

Table 38: Correlation between cowpea grain yield and various parameters under Alectra infestation as affected by different herbicide mixtures at Yasha Zomo, 1991 wet season

	1	2	3	4	5	6	7	8	9	10	11
1	1.0										
2	-0.18	1.0									
3	-0.15	0.95‡‡	1.0								
4	-0.22‡‡	0.88‡‡	0.83‡‡	1,0							
5	-0.03	0.83‡‡	0.55‡‡	0.85‡‡	1.0						
6	-0.06	0.76‡‡	0.70‡‡	0.87‡‡	0.77‡‡	1.0					
7	-0.05	0.84‡‡	0.85‡‡	0.85‡‡	0.87‡‡	0.84‡‡	1.0				
8	0.96‡‡	-0.13	-0.11	-0.15	0.02	-0.02	0.11	1.0			
9	0.16	-0.66‡‡	-0.65‡‡	-0.64‡‡	-0.62‡‡	-0.59‡‡	-0.58‡‡	0.12	1.0		
10	-0.50‡‡	0.63‡‡	0.58‡‡	0.62‡‡	0.48‡‡	-0.58‡‡	0.48‡‡	-0.46‡‡	-0.58‡‡	1.0	
11	0.51	-0.07	-0.07	-0.01	0.03	0.24‡	0.18	0.55‡‡	0.12	-0.29‡‡	1.0

1 Grain yield
2 Number of plants infected at 8 WAS
3 Alectra count at 8 WAS
4 Number of plants infected at 9 WAS
5 Alectra count at 9 WAS
6 Number of plants infected at harvest
7 Alectra count at harvest
8 Weight of pods
9 Number of days to Alectra emergence
10 Crop damage symptom score at 9 WAS
11 Crop stand count at harvest

‡ Significant at 5% level of probability (r = 0.22)

‡‡ Significant at 1% level of probability (r = 0.28)

Table 39: Correlation between cowpea grain yield and various parameters under Alectra infestation as affected by different herbicide mixtures at Samaru 1992 wet season

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.0												
2	-0.11	1.0											
3	-0.12	0.89‡‡	1.0										
4	-0.29‡‡	0.86‡‡	0.77‡‡	1,0									
5	-0.22‡‡	0.82‡‡	0.85‡‡	0.87‡‡	1.0								
6	-0.25‡	0.73	0.71‡‡	0.78‡‡	0.77‡‡	1.0							
7	-0.13	0.67	0.66‡‡	0.75‡‡	0.81‡‡	0.84‡‡	1.0						
8	0.28‡‡	-0.66	-0.62‡‡	-0.76‡‡	0.71‡‡	-0.93‡‡	0.84‡‡	1.0					
9	0.15	-0.67	-0.66‡‡	-0.76‡‡	-0.80‡‡	-0.85‡‡	-0.99‡‡	0.03	1.0				
10	-0.78‡‡	0.03	0.06	-0.06	-0.04	-0.13	-0.07	-0.13	-0.08	1.0			
11	0.23‡	-0.66	-0.55‡‡	-0.67‡‡	-0.54‡‡	-0.55‡‡	-0.46‡‡	-0.54‡‡	-0.47‡‡	0.17	1.0		
12	0.06	0.52	-0.36‡‡	0.56‡‡	0.51‡‡	0.39‡‡	0.38	0.33‡‡	0.37‡‡	0.12	-0.36‡‡	1.0	
13	0.07	0.52	-0.36‡‡	0.56‡‡	0.51‡‡	0.39‡‡	0.38	0.38	0.33‡‡	0.37‡‡	0.12	-0.36‡‡	1.0

1 Grain yield
2 Number of plants infected at 8 WAS
3 Alectra count at 8 WAS
4 Number of plants infected at 9 WAS
5 Alectra count at 9 WAS
6 Number of plants infected at harvest
7 Alectra count at harvest
8 Number of plants infected at harvest
9 Alectra count at harvest
10 Weight of pods
11 Number of days to Alectra emergence
12 Crop damage symptom score at 9 WAS
13 Crop stand at harvest

‡ Significant at 5% level of probability (r = 0.22)

‡‡ Significant at 1% level of probability (r = 0.28)

4.5 Green house experiments (II & III)

4.5.1 Developing an appropriate technique for evaluating cowpea varieties for their reaction to Alectra

Effect of Alectra seed concentrations, preconditioning period and cowpea varieties on Alectra parameters viz number of emerged, un-emerged, total Alectra, days to Alectra emergence and crop growth such as crop damage score, nodulation and shoot dry matter production are presented in Tables 40 to 54.

4.5.1.1 Number of emerged Alectra

In the two trials, cowpea variety TVX3236 had more number of emerged Alectra compared with all the other varieties, except TN93-80 in the first trial (Table 40). Among the varieties evaluated B 301 and the derivative of cross with IT84S-2246-4 (IT90K-76) did not have emergence of Alectra, while IT89KD-245-1 recorded the least Alectra emergence in the two trials. Alectra emergence increased with Alectra seed concentrations in the first trial while 10cc/pot Alectra seed gave the highest number of emerged Alectra when compared to other Alectra seed concentrations in the second trial. Pre-conditioning period had no significant effect on emerged Alectra, but Alectra emergence increased with pre-conditioning period of 7 and 14 days.

There was significant interaction betwen Alectra seed concentration and cowpea varieties on number of emerged Alectra in the two trials (Tables 44 & 45). In the first trial, among the varieties, TVX3236 supported the highest emergence in Alectra seed concentrations 5cc and 20cc while TN93-80 had highest emergence at concentration of 10cc.

Within each variety, maximum Alectra emergence occured with

20cc concentration on TVX 3236, IT89KD-245-1, VITA-3 and IT81D-985 while TN93-80 and IT84S-2246-4 had their maximum under concentration 10cc and 5cc, respectively (Table 44). In the second trial, among the varieties VITA-3, IT84S-2246-4 and TVX 3236 supported the highest emergence in 5cc concentration while VITA-3 and TVX3236 had the highest under 10cc and 20cc respectively. Within each variety, IT84S-2246-4 had the highest in 5cc. TN93-80, VITA-3 and IT81D-985 in 10cc and TVX 3236 in 20cc (Table 45).

4.5.1.2 Number of un-emerged Alectra

Cowpea varieties differed significantly with respect to number of un-emerged Alectra in the two trials (Table 40). Among the varieties evaluated B 301 and IT90K-76 did not support any attachment of Alectra. The highest number was recorded with TN93-80 and TVX3236 in the first and second trials, respectively. In the second trial, IT89KD-245-1, IT84S-2246-4 and IT81D-985 had the least while in the first trial VITA-3 and IT84S-2246-4 had the least number of un-emerged Alectra

Generally, increasing the Alectra seed concentration increased the number of un-emerged Alectra in the two trials. However, preconditioning period did not give a clear trend on un-emerged Alectra. Pre-conditioning for 14 DAS may not be necessary.

There were significant interactions of Alectra seed concentrations x variety, preconditioning period x variety in the two trials, Alectra seed concentration x preconditioning period and 3-way interaction of preconditioning period x Alectra

seed concentration x variety only in the second trial (Tables 46 to 51).

In the first trial, TN93-80 at the highest Alectra seed concentration gave significantly higher number of un-emerged Alectra, which was followed by TVX3236 at Alectra seed concentrations. Among the varieties, TVX3236 had the highest un-emerged Alectra in concentrations of 5 and 10cc while TN93-80 had the highest in 20cc. All the varieties had the highest attachment of un-emerged Alecta at the 20cc concentration with exception of IT81D-985 at 10cc (Table 46). In the second trial at all concentrations TVX3236 had the highest number of un-emerged Alectra. Within each variety maximum number of unemerged Alectra occured in 10cc for TVX3236, IT89KD-245-1 and TN93-80, in 5cc for IT84S-2246-4 and IT81D-985 and 20cc for VITA-3 (Table 47).

Cowpea variety TN93-80 that was not pre-conditioned prior to sowing had significantly more number of un-emerged Alectra than all the other varieties at all periods in the first trial. The other cowpea varieties supported their maximum un-emerged Alectra at 7 DAS except IT89KD-245-1. In the second trial, TVX3236 pre-conditioned for 14 day shad the highest number of un-emerged Alectra. All other varieties except IT89KD-245-1 and VITA-3 had their maximum emergence without pre-conditioning. IT89KD-245-1 and VITA-3 required 3 and 7 DAS, respectively for maximum emergence. Interaction between pre-conditioning period x Alectra seed concentration in the second trial indicated that highest Alectra seed level at the control and 7 days pre-conditioning period had the highest un-emerged Alectra which was comparable to 5cc/pot level at control pre-conditioning period

(Table 50). The 3-way interaction indicated that TVX3236 at 10cc/pot preconditioned for 14 days gave the highest number of un-emerged Alectra, this was folowed by TN93-80 and TVX3236 in which there was no pre-conditioning prior to sowing and VITA-3 pre-conditioned for 7 days all at the highest Alectra seed concentrations (Table 51).

4.5.1.3 Total number of Alectra

In the two trials, cowpea variety TVX3236 had the highest total number of Alectra. Cowpea variety TN93-80 had similar number to the highest in the first trial. Increasing Alectra seed concentration generally increased total number of Alectra up to 20cc and 10cc in the first and second trials, respectively. Pre-conditioning period did not affect total number of Alectra significantly (Table 40).

Interaction of Alectra seed concentration and varieties on total Alectra at harvest was significant in the two trials (Tables 51 & 53). In the first trial, cowpea variety TN93-80 at the highest Alectra seed concentration had significantly higher total Alectra than all the other varieties, this was followed by TVX3236 also at the highest level of Alectra seed concentration. All the varieties that supported Alectra has the maximum number at 20cc Alectra seed concentration with the exception of IT81D-985 which had the highest at 10cc (Table 52). At all Alectra seed concentration, TVX 3236 supported the highest Alectra infection in the second trial, among all varieties. Within each variety, maximum emergence occured with TVX 3236 in 20cc, IT89KD-245-1, TN93-80 and VITA-3 in 10cc and IT84S-2246-4 and IT81D-985 in 5cc

(Table 53).

4.5.1.4 Number of days to Alectra emergence

Number of days to Alectra emergence was significantly affected by cowpea varieties (Table 41). In the two trials, variety TVX3236 initiated early emergence of Alectra; VITA-3 also initiated early emergence comparable to TVX 3236 in the first trial. In general, Alectra emergence was earlier in the second trial than the first trial. In the second trial number of day to Alectra emergence followed the order IT81D-985 > TN 93-80 > IT84S-2246-4 > VITA 3 > TVX 3236. Generally, Alectra seed concentrations significantly increased number of days to emergence in the two trials. Pre-conditioning period only had significant effect in the first trial. Pre-conditioning period prior to cowpea sowing for 14 days initiated early Alectra emegence which was comparable to that of control. In the second trial, although not significant, it was apparent that increase in pre-conditioning period reduced the number of days to Alectra emergence.

4.5.1.5 Crop damage score

Crop damage score at 50 DAS was significantly affected by cowpea varieties in the second trial (Table 41). Among the varieties tested, crop damage score was significantly high for TVX3236 which was followed by VITA-3. Cowpea varieties B301, IT90K-76 and IT89KD-245-1 were observed to have the least damage score. Crop damage score was lowest with no Alectra inoculant and significantly higher with 5cc/pot of Alectra seeds compared with the 10cc/pot and 20cc/pot which are similar. Less

significant damage score on crop plants was observed with 3 and 7 days pre-conditioning period compared with the control and 14 days pre-conditioning.

4.5.1.6 Nodulation

Cowpea varieties differed significantly in nodulation per plant with Alectra inoculation. Nodulation as percentage of the control was only suppressed in IT89KD-245-1 at 5 and 10cc/pot Alectra seed concentrations in the first trial. But in the second trial only TVX3236 and VITA-3 at all Alectra seed inoculations had suppressed nodulation as percentage of the control was generally increased with increase in Alectra seed inoculation in the two trials, but more pronounce in the first trial. Pre-conditioning of Alectra seeds prior to cowpea sowing for 14 days reduced nodulation in plants in the first trial and 7 days in the second trial.

4.5.1.7 Shoot dry matter production

Alectra inoculation suppressed shoot dry matter production in TVX3236 and VITA-3 especially at higher levels of Alectra seed concentrations compared to other varieties tested in the second trial (Table 43). Shoot dry weight as percentage of the control increased with increase in Alectra seed inoculant. The effect of pre-conditioning period on shoot dry matter production is however not consistant in this trial.

4.5.1.8 Correlation

Crop shoot dry matter production was negatively correlated to number of emerged, un-emerged and total number of *Alectra* at termination of experiment. It was however, positively correlated to number of nodules/plant (Table 54).

Table 40: Alectra infection at harvest as influenced by Alectra seed concentration, pre-conditioning period and cowpea variety, in the at green house at Samaru, 1993

Treatments	Number of emerged Alectra per pot		Number of un-emerged Alectra per pot		Total number of Alectra per pot	
Varieties	1st trial	2nd trial	1st trial	2nd trial	1st trial	2nd trial
IT90K-76	0.0d[1]	0.0e	0.0e	0.0e	0.0d	0.0g
TVX3236	0.6a	2.1a	1.9b	1.2a	2.6a	3.3a
IT89-245-1	0.1bc	0.0e	0.1e	0.3cd	0.2d	0.3f
TN93-80	0.6a	0.9c	2.2a	0.7b	2.5a	1.6c
VITA-3	0.3bc	1.7b	0.4d	0.4c	0.8c	2.1b
B 301	0.0d	0.0e	0.0e	0.0e	0.0d	0.0g
IT84S-2246-4	0.2bc	1.0c	0.4d	0.3cd	0.8c	1.3d
IT81D-985	0.3b	0.4d	0.6c	0.2d	1.3b	0.6e
S.E ±	0.04	0.06	0.06	0.04	0.08	0.06
Concentration (c.c/pot)						
0	0.0d	0.0c	0.0d	0.0c	0.0d	0.0c
5	0.3b	0.9b	0.6c	0.4b	0.9c	1.3b
10	0.2c	1.3a	0.8b	0.5a	1.2b	1.8a
20	0.5a	0.8b	1.4a	0.5a	2.0a	1.4b
S.E ±	0.03	0.04	0.04	0.03	0.05	0.04
Pre-conditioning Period (DAS)						
0	0.2	0.6	0.7b	0.5a	1.0	1.1
3		0.8		0.3b		1.2
7	0.3	0.7	0.9a	0.4ab	1.2	1.0
14	0.3	0.9	0.6b	0.3b	0.9	1.3
S.E ±	0.03	0.04	0.04	0.03	0.15	0.04
Interactions						
C x V	*	*	*	*	*	*
P x V	NS	NS	*	*	NS	NS
P x C	NS	NS	NS	*	NS	NS
P x C x V	NS	NS	NS	*	NS	NS

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

DAS = Days after sowing

Table 41: Number of days to Alectra emergence and crop damage score as influenced by Alectra seed concentration pre-conditioning period and cowpea variety in the green house at Samaru, 1993

Treatments	Number of days to Alectra emergence		Crop damage Score[3] (50 DAS)
Varieties	1st trial	2nd trial	2nd trial
IT90K-76	-	-	0.0e
TVX3236	46b[1]	34d	1.9a
IT89KD-245-1	-2	-	1.0e
TN93-80	47a	36b	1.4c
VITA-3	46b	35c	1.7b
B 301	-	-	1.oe
IT84S-2246-4	47a	36b	1.4c
IT81D-985	47a	38a	1.1d
S.E ±	0.02	0.04	0.03
Alectra seed oncentration (c.c/pot)			
0	-	-	1.0e
5	38b	29c	1.5a
10	39a	30b	1.4b
20	39a	31a	1.4b
S.E ±	0.02	0.03	0.02
Pre-conditioning Period (DAS)			
0	29b	23	1.4a
3		23	1.3b
7	30a	22	1.3b
14	29b	22	1.4a
S.E ±	0.01	0.03	0.02
Interactions			
C x V	NS	NS	NS
P x V	NS	NS	NS
P x C	NS	NS	NS
P x C x V	NS	NS	NS

1 Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT)
2 No Alectra emergence
3 Damage symptoms on crop plants using scale (1-5), where 1 = normal crop plant growth, no chlorosis, no blotching, no leaf scorching and 5 = total leaf scorching or/and obviously stunted or dead plants.

Table 42: Nodulation (as percentage of the control) as influenced by Alectra seed concentration, pre-conditioning period and cowpea varietty in the green house at Samaru, 1993

Treatments	Percentage nodulation (%)							
Concentration (c.c/pot)	1st trial				2nd trial			
0	100				100			
5	94.1				82.3			
10	102.6				82.6			
20	106.2				82.7			
Pre-conditioning period	0	5	10	20	0	5	10	20
0	100	102.5	108.6	101.0	100	97.4	111.6	113.7
3	-	-	-	-	100	101.6	103.3	81.6
7	100	95.2	103.5	87.8	100	78.3	64.6	74.8
14	100	92.9	94.0	94.6	100	62.2	66.1	74.1
Varieties								
IT90K-76	100	135.1	109.6	113.3	100	114.9	123.1	104.2
TVX3236	100	84.4	119.1	69.6	100	48.9	52.9	59.6
IT89KD-245-1	100	64.4	59.9	94.7	100	99.9	82.0	107.3
TN93-80	100	86.4	85.1	84.7	100	86.6	69.6	108.2
VITA-3	100	101.4	113.8	81.3	100	66.2	44.6	54.8
B 301	100	127.1	138.1	151.4	100	89.2	107.6	88.6
IT84S-2246-4	100	91.7	92.8	102.9	100	65.1	79.5	81.9
IT81D-985	100	67.8	84.1	185.8	100	59.4	80.1	71.8

1 Means following by the same letter(s) are not significantly different at 5% level of probability (DMRT)

DAS = Days after sowing

Table 43: Shoot dry weight production (as percentage of the control) as influenced by Alectra concentration, preconditioning period and cowpea variety in the green house at Samaru, 1993

Treatments	Shoot dry matter production (% of the control)			
Concentration (c.c/pot)	2nd trial			
0	100			
5	111.5			
10	120.7			
20	132.8			
Pre-conditioning period	0	5	10	20
0	100	80.9	95.2	130.9
3	100	122.2	153.2	144.4
7	100	136.7	136.7	144.4
14	100	100.0	89.5	236.4
Varieties				
IT90K-76	100	145.8	112.5	112.5
TVX3236	100	105.3	100.0	131.5
IT89KD-245-1	100	104.3	130.4	152.2
TN93-80	100	100.0	120.0	155.0
VITA-3	100	100.0	104.5	113.6
B 301	100	126.3	126.3	136.8
IT84S-2246-4	100	113.6	127.3	131.8
IT81D-985	100	116.0	140.0	132.0

DAS = Days after sowing

Table 44: Interaction between cowpea varieties and Alectra seed concentration on number of emerged Alectra in the first green house trial at Samaru, 1993

Varieties	Emerged Alectra			
	Concentration (c.c/pot)			
	0	5	10	20
IT90K-76	0.0g	0.0g	0.0g	0.0g
TVX3236	0.0g	0.9b	0.1fg	1.4a
IT89KD-245-1	0.0g	0.0g	0.1fg	0.2efg
TN93-80	0.0g	0.4de	1.2a	0.8bc
VITA 3	0.0g	0.1fg	0.0g	0.7bc
B 301	0.0g	0.0g	0.0g	0.0g
IT84S-2246-4	0.0g	0.4de	0.1fg	0.3ef
IT81D-985	0.0g	0.3ef	0.2efg	0.6cd
S.E (±)	0.08			

Table 45: Interaction of cowpea varieties and Alectra seed concentration on number of emerged Alectra in the second green house trial at Samaru, 1993

Varieties	Emerged Alectra			
	Concentration (c.c/pot)			
	0	5	10	20
IT90K-76	0.0g	0.0g	0.0g	0.0g
TVX3236	0.0g	1.9d	2.8b	3.7a
IT89KD-245-1	0.0g	0.0g	0.0g	0.0g
TN93-80	0.0g	0.9e	2.4c	0.4f
VITA 3	0.0g	1.9d	3.1b	1.8d
B 301	0.0g	0.0g	0.0g	0.0g
IT84S-2246-4	0.0g	1.9d	1.7d	0.5f
IT81D-985	0.0g	0.5f	0.6e	0.3fg
S.E (±)	0.11			

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

Table 46: Interaction of cowpea varieties and Alectra seed concentration on number of un-emerged Alectra in the first green house trial at Samaru, 1993

Varieties	Un-Emerged Alectra Concentration (c.c/pot) 0	5	10	20
IT90K-76	0.0i	0.0i	0.0i	0.0i
TVX3236	0.0i	2.6b	2.6b	2.7b
IT89KD-245-1	0.0i	0.0i	0.2hi	0.3ghi
TN93-80	0.0i	1.0de	2.0c	5.7a
VITA 3	0.0i	0.3ghi	0.3ghi	1.0de
B 301	0.0i	0.0i	0.0i	0.0i
IT84S-2246-4	0.0i	0.6fg	0.2hi	0.8ef
IT81D-985	0.0i	0.4gh	1.2d	0.9de
S.E (±)	0.12			

Table 47: Interaction of Alectra seed concentration on cowpea varieties on number of un-emerged Alectra in the second green house trial at Samaru, 1993

Varieties	Un-emerged Alectra Concentration (c.c/pot) 0	5	10	20
IT90K-76	0.0	0.0g[1]	0.0g	0.0g
TVX3236	0.0	1.3b	1.8a	1.7a
IT89KD-245-1	0.0	0.3f	0.7d	0.3f
TN93-80	0.0	0.8cd	1.3b	0.6de
VITA-3	0.0	0.3f	0.3f	1.0c
B 301	0.0	0.0g	0.0g	0.0g
IT84S-2246-4	0.0	0.6de	0.0g	0.4ef
IT81D-985	0.0	0.3f	0.3f	0.3f
S.E (±)	0.08			

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

Table 48: Interaction of cowpea varieties and preconditioning period on number un-emerged Alectra in the first green house trial at Samaru, 1993

Varieties	Un-Emerged Alectra Preconditioning period (DAS) 0	7	14
IT90K-76	0.0g	0.0g	0.0g
TVX3236	1.4d	2.3b	2.2b
IT89KD-245-1	0.2fg	0.0g	0.3f
TN93-80	3.3a	1.8c	1.5d
VITA 3	0.1fg	0.8e	0.3f
B 301	0.0g	0.0g	0.0g
IT84S-2246-4	0.3f	0.8e	0.1fg
IT81D-985	0.2fg	1.4d	0.3f
S.E (±)	0.10		

Table 49: Interaction of cowpea varieties and pre-conditioning period on number of un-emerged Alectra in the second green house trial at Samaru, 1993

Varieties	Un-emerged Alectra Pre-conditioning period (DAS) 0	3	7	14
IT90K-76	0.0h	0.0h	0.0h	0.0h
TVX3236	1.3b	0.9c	0.6de	1.9a
IT89KD-245-1	0.0h	0.8cd	0.3fg	0.1gh
TN93-80	1.3b	0.4ef	0.8cd	0.2fgh
VITA 3	0.3fg	0.1gh	0.9c	0.2fg
B 301	0.0h	0.0h	0.0h	0.0h
IT84S-2246-4	0.6de	0.0h	0.3fg	0.1gh
IT81D-985	0.3fg	0.3fg	0.1gh	0.2fgh
S.E (±)	0.08			

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

DAS = Days after sowing

Table 50: Interaction of Alectra seed concentration and pre-conditioning period on number of un-emerged Alectra in the second green house trial at Samaru, 1993

Concentration (c.c/Pot)	Un-emerged Alectra Pre-conditioning (DAS)			
	0	3	7	14
0	0.0g[1]	0.0g	0.0g	0.0g
5	0.7ab	0.3ef	0.3ef	0.5cd
10	0.4de	0.7ab	0.5cd	0.6bc
20	0.8a	0.3ef	0.8a	0.2f
S.E (±)	0.06			

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

DAS = Days after sowing

Table 51: Interaction of cowpea varieties, Alectra seed concentration and pre-conditioning period of number of un-emerged Alectra in the second green house trial at Samaru, 1993

		Un-emerged Alectra			
		Pre-conditioning period (DAS)			
Varieties	Concentration (c.c/Pot)	0	3	7	14
IT90K-76	0	0.0i	0.0i	0.0i	0.0i
	5	0.0i	0.0i	0.0i	0.0i
	10	0.0i	0.0i	0.0i	0.0i
	20	0.0i	0.0i	0.0i	0.0i
TVX3236	0	0.0i	0.0i	0.0i	0.0i
	5	1.7de	0.3h	0.3h	2.0cd
	10	1.0fg	2.0cd	0.3h	4.3a
	20	2.7b	1.0fg	1.7de	1.3ef
IT89KD-245-1	0	0.0i	0.0m	0.0i	0.0i
	5	0.0i	0.3h	0.7gh	0.3h
	10	0.0i	2.0cd	0.7gh	0.0i
	20	0.0i	1.0fg	0.0i	0.0i
TN93-80	0	0.0i	0.0i	0.0i	0.0i
	5	2.0cd	0.0i	1.0fg	0.3h
	10	1.0fg	1.7de	2.0cd	0.3h
	20	2.3bc	0.0i	0.0i	0.0i
VITA-3	0	0.0i	0.0i	0.0i	0.0i
	5	0.0i	0.0i	0.0i	0.0i
	10	0.3h	0.0i	0.7gh	0.3h
	20	0.7gh	0.3h	2.7b	0.3h
B 301	0	0.0i	0.0i	0.0i	0.0i
	5	0.0i	0.0i	0.0i	0.0i
	10	0.0i	0.0i	0.0i	0.0i
	20	0.0i	0.0i	0.0i	0.0i
IT84S-2246-4	0	0.0i	0.0i	0.0i	0.0i
	5	2.0cd	0.0i	0.0i	0.3h
	10	0.0i	0.0i	0.0i	0.0i
	20	0.3h	0.0i	1.3ef	0.0i
IT81D-985	0	0.0i	0.0i	0.0i	0.0i
	5	0.0i	0.3h	0.0i	0.7gh
	10	0.7gh	0.7gh	0.0i	0.0i
	20	0.3h	0.3h	0.3h	0.0i
S.E ±	0.16				

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

DAS Days after sowing

Table 52: Interaction of cowpea varieties and Alectra seed concentration on total number of Alectra in the first green house trial at Samaru, 1993

	Total Alectra			
	Concentration (c.c/pot)			
Varieties	0	5	10	20
IT90K-76	0.0i	0.0i	0.0i	0.0i
TVX3236	0.0i	3.1c	3.1c	4.3b
IT89KD-245-1	0.0i	0.0i	0.3hi	0.3hi
TN93-80	0.0i	1.8f	2.7cd	5.4a
VITA-3	0.0i	0.7gh	0.2i	2.3de
B 301	0.0i	0.0i	0.0i	0.0i
IT81D-985	0.0i	0.8g	2.4d	2.0ef
S.E (±)	0.15			

Table 53: Interacxtion of cowpea varieties and Alectra seed concentration on total number of Alectra in the second green house trial at Samaru, 1993

	Total Alectra			
	Concentration (c.c/Pot)			
Varieties	0	5	10	20
IT90K-76	0.0	0.0i	0.0i	0.0i
TVX3236	0.0	3.3c	4.6a	5.3a
IT89KD-245-1	0.0	0.3h	0.8fg	0.3h
TN93-80	0.0	1.8e	3.6b	1.0f
VITA-3	0.0	2.2d	3.3c	3.1c
B 301	0.0	0.0i	0.0i	0.0i
IT84S-2246-4	0.0	2.5d	1.7e	0.9fg
IT81D-985	0.0	0.8fg	0.9fg	0.6gh
S.E (±)	0.13			

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

Table 54: Correlation between cowpea shoot dry weight and various parameters in the evaluation of Alectra seed concentration and pre-conditioning periods on cowpea varieties in the green house at Samaru, 1993

	1	2	3	4	5	6
1	1-0					
2	-0.08	1.0				
3	-0.11	0.26**	1.0			
4	-0.12	0.61**	0.69**	1.0		
5	-0.20*	0.41**	-0.26**	0.73**	1.0	
6	0.17	-0.13	-0.11	-0.26*	-0.36**	1.0

* = Significant at 5% level of probability (r = 0.19)
** = Significant at 1% level of probability (r = 0.25)

1 Shoot dry weight
2 Number of un-emerged Alectra at termination of experiment
3 Number of emerged Alecta at termination of experiment
4 Total number of Alectra at termination of experiment
5 Crop damage score
6 Average number of nodules/plant

5.0 DISCUSSION

The higher grain yields of 1.9t/ha, 1.3t/ha and 2.0t/ha obtained in the two years trials conducted in this study are lower than 2.2t/ha earlier reported at Samaru (Tanko, 1990) for the same crop. High Alectra infestation at the sites of the trials was probably responsible for the low yields of cowpea obtained in these trials. Generally, yields of 1991 trials were lower than that of 1992. This could be because, in 1992 under artificial Alectra infestation, the Alectra seed concentration was not high enough to cause yield reduction as the case of natural but heavily infested situation of 1991 trials.

5.1 Reaction of cowpea varieties to Alectra

In all the trials, variety B 301 and the derivatives of crosses with IT84S-2246-4 (IT90K-59 and IT90K-76) did not support the emergence of Alectra in the field and in the green house. The varieties also produced cowpea grain yields that were comparable to the maximum in the trial of 1991 and significantly higher than the least in two years under Alectra infection. However, the nodulation of these varieties were reduced in the pot by 21.2, 43.9 and 76.9% for B 301, IT90K-59 and IT90K-76, respectively (Table 15). This was probably responsible for the reduction in the yield of the varieties observed with artificial inoculation in 1992. While B301 did not flower within 80 days of experimentation in the green house, significant reduction in the number of days to flowering was caused by Alecta infection in the other varieties; the effect was however not observed in the field in 1992. Earlier reports have indicated that any factor which

inhibits nodulation(Dart and Mercer, 1965) and growth period (Whitney, 1975) of cowpea would definetely reduce grain yield in the crop. However, it was apparent that the reduction in nodulation was less in B301 than the derivatives, IT90K-59 and IT90K-76. This could be attributed to the fact that the other parent of these varieties IT84S-2246-4 while delaying Alectra emergence supported high level of root infection and experienced higher reduction in nodulation than B 301. Line B 301, a local variety, which was initially identified for resistance to Alectra vogelii in Botswana has since been observed to exhibit combined resistance to various strains of Striga and Alectra at various locations in Africa, including Nigeria (Riches, 1984; Emechebe and Singh, 1989). However, Emechebe and Singh (1989) have reported that other two sources of resistance to S. gesnerioides (SUVITA-2 and IT82D-849) are susceptible to Alectra. Resistance to Striga in the genotype B 301 has been reported to be controlled by one dorminant gene and resistance to Alectra by two dominant genes (Signh and Emechebe, 1990a, 1990b; Atokple et al. 1991). This then indicates there are differences in mechanism of resistance and the genes controlling resistance to these parasitic weeds in different varieties. The mechanism of resistance of S. gesnerioides in cowpea is still not clearly known. Several forms have been observed, but few reported for Striga species. These includes low stimulant production and mechanical barriers to establishment and penetration after germination, which both functions in cowpea (Obilana, 1987). In addition, some cowpea cultivars stimulated the Striga to

germinate and the seedlings were allowed to penetrate the cowpea root tissues, but failed to develop further (BA, 1983). Lane and Bailey. (1991) and Lane et al. (1991) have observed similar mechanism with B 301 variety in the laboratory, which reveals that there is actual stimulation and germination of the Striga seeds, as well as formation of haustoria which fail to develop any further possibly through antibiosis. The anatomical studies further shows that the haustoricum remains in the endodermis and never develops any further.

However, from this study, it is apparent that the varieties (B301, IT90K-59 and IT90K-76) are not completely immuned from the effect of the parasite since important aspects of crop growth such as nodulation and phenology as well as crop yields were interfered with in these resistant varieties. The reasons for this needs further investigation. However, the fact that no Alectra emergence occurred in IT90K-59 and IT90K-76 further indicates the compatability of relevant genes in the two parents i.e B 301 an IT84S-2246-4. In contrast, IT89KD-245-1 and IT89KD-245, both of which are derivatives of B 301 and local variety kananado still supported low emergence of Alectra. The varieties still produced cowpea grain yields that were comparable to the maximum in 1991 and significantly higher than the least in the two years. Alectra inoculation in the pot completely prevented nodulation in IT89KD-245-1, and reduced nodualtion by 66.2% in IT89KD-245, both of which are low nodulators. In addition to increase in number of days to flowering in the two varieties due to Alectra, cowpea grain yield reduction of 57.8% and 69.1% were obtained with IT89KD-245-1 and IT89KD-245, respectively (Table

11). Variety IT86D-534 presents an interesting and useful reaction to Alectra. Inspite of high reduction of nodulation in the pot by Alectra, and support for Alectra infection in all the trials, it did not suffer any reduction in cowpea grain yield in 1992. The variety was observed to delay Alectra emergence and possible attack. The delay in Alectra might be the mechanism of tolerance which enables it to produce adequate grain yield under infection inspite of reduced nodulation, moderate yield potentials. Possible delay in the production of adequate stimulant or/and high production of germination inhibitor might be suggested as being responsible for the reaction of the variety to Alectra (Berner personal communication). However, the major limitation of the variety is its low yield when there is no Alectra infection. IT86D-843 did not support emergence in the greenhouse but had very low underground infection. Although Alectra did affect number of days to flowering in the variety, both nodulation in the pot and cowpea grain yield in the field were reduced by 69.2% and 61.7%, respectively. Both TN93-80 and Kano 1696 which were promiscuous nodulators had 47.5% and 44.7% reduction in nodules count due to Alectra infection. The former variety however supported very low Alectra emergence in the green house, while both exhibited similar reaction to Alectra with respect to shoot count, number of plants infected and number of days to emergence in 1992 field trial. However, TN93-80 suffered a higher loss of 55% in cowpea grain yield than Kano 1696 in the year. On the other hand, in 1991 wet season, Kano 1696 supported more Alectra shoots than IT81D-843. Kano 1696 produced

low pod number, but acceptable grain yield in 1991 and low reduction in 1992 inspite of high and moderate infestation respectively. This may be attributed to tolerance reaction which it does through reduction in pod number but compensated for in seed size which consequently increases the grain yield of the crop. Being a late maturing, it would still produce adequate photosynthetic apparatus for the production of assimilates for grain filling at the later stage of life-cycle inspite of the initial adverse effect of Alectra infection. VITA 3 has exhibited a high degree of tolerance in this study. This is because VITA-3 produced significantly higher cowpea grain yield than all the other varieties evaluated inspite of hig Alectra incidence (Tables 4 and 5). Since the variety combines high yield with tolerance, it could be used to improve the genetic base of the varieties being developed for Alectra tolerance/resistance. Both TVX3236 and SAMPEA 7, the two recommended varieties in northern Guinea savanna supported high Alectra infection with consequent high susceptability to the parasite. SAMPEA-7 is however less susceptible than TVX 3236 as reflected in low reduction in nodulation and grain yield and low emergence of Alectra shoots under Alectra infection. In the pot, Alectra prevented nodulation in TVX3236 and caused 84% reduction in grain yield in the 1992 trial.

A major consideration in the adoption of cowpea varieties are the sizes of the seeds, the texture of the seed coat which affect cookebility and the colour. In Nigeria, rough coated white black eyed or brown large size seeds will be accepted easily by the farmers. High yield potential inspite of Alectra infestation

would be major agronomic and economic consideration in variety's adoption. All the varieties tested including B 301 had lower grain yield than VITA 3, the only one which did not have cowpea grain yield reduction due to Alectra. Similarly, many other promising varieties have rough coats and the acceptable colour. However, seeds of IT90K-59 which are normally rough-coated and brown are considered very small by the farmers. There is therefore the need to broaden the genetic base of the existing resistant materials by incorporating the high yield potential, tolerance and big sizes of seeds observed in varieties like Kano 1696 and VITA 3 and other sources of resistance in IT86D-534 into some of them. This will definetely improve the sustainability of the technical performance and yield potential as well as the varieties level. However, in order to further ensure a sustainable solution to the problem of parasitic weed, the varieties will only be used as component of intergrated package for control and be validated at farmers level.

5.1.1 Interactions

Interaction of cowpea varieties x infection was significant on crop vigour score at 9 WAS, number of pods, weight of pods and cowpea grain yield. In the Alectra infected plots, plants of B 301 under Alectra infection did not differ in vigour score from those of Alectra-free situation. Conversely, Alectra infection significantly depressed crop growth vigour in TVX 3236 compared with corresponding Alectra free plants. Line B 301 has been reported to be resistant to both Striga and Alectra (Riches, 1984; Emechebe and singh 1990; Lagoke et al. 1991) while TVX 3236

reported to be susceptible.

Under Alectra infection, no variety produced grain yields that were comparable to the highest obtained with VITA 3, while IT90K-59, IT90K-76, B 301, IT89KD-245-1, IT89KD.-245, TVX 3236 and VITA 3 were similar in yields under Alectra free condition. The high yield of VITA 3 inspite of moderate infestation may be attributed to its tolerance to the parasite which may be further investigated.

In the green-house, interaction of variety and Alectra infection on number of days to crop flowering, indicates that Kano 1696, IT81D-985, B 301, TN93-80, TN 121-80 and VITA 3 did not flower during the 80 days of experimentation with or without infection. This may probably because of the varieties are late-maturing and photoperiod sensitive. Although without infection, SAMPEA -7, IT81D-849 and SUVITA-2 flowered, the plants in the infected pots did not flower. These varieties are susceptible to Alectra, therefore, it is possible that the attack had adverse effect on crop growth and thus not allowing it to flower as compared with the un-infected condition.

5.1.2 Correlation

The negative correlations between cowpea grain yield and Alectra shoot count, number of plants infected, days to Alectra emergence and crop damage symptom score measured inthe two trials indicated that Alectra parasitism reduced cowpea grain yield seriously. Similar observation has been reported (Atokple et al 1991). The positive correlation observed between grain yield and weight of pods revealed this as an important yield component and

determinant of cowpea grain yield. The result confirms with (Sule 1988) who also observed positive correlation between grain yield and other yield components. There was stronger relationship between cowpea grain yield and Alectra parameters at 9 WAS than other stages of crop growth. This could probably be explained by the fact that maximum Alectra emergence occured at 9 WAS which probably cause serious damage at the critical grain filling stage of the crop. Subsequent emergence are either less damaging on the crop. In addition many of the earlier emerged shoots of Alectra senesce and die after 9 WAS and escape assessment.

5.2 Effect of nitrogen and phosphorus combinations on the reaction of cowpea varieties to Alectra

In the two trials, cowpea varieties differed significantly in their reaction to Alectra. In 1991, number of plants infected and Alectra shoot count was significantly higher for VITA-3 than TN93-80. Alectra did not emerge at all in B301 and thus exhibiting high level of resistane as earlier indicated by Riches (1984) and later confirmed by Emechebe and Singh (1991); while in 1992, SAMPEA-7 had significantly higher plants infected and Alectra shoot count, the least was obtained with IT89KD-245-1. It was unnecessary to subject B 301 to these treatments, since it did not support Alectra emergence at all in 1991. Cowpea varieties TN93-80 and IT89KD-245-1 delayed Alectra emergence compared with VITA-3 in 1991 and 1992, respectively (Tables 18 & 19). Inspite of higher number of plants infected and Alectra shoot count VITA-3 produced comparable grain yield to the

maximum with IT89KD-245-1. This could be attributed to high tolerance by the variety to Alectra. Both nodulation and cowpea grain yield were not reduced in this variety by Alectra infection at Samaru (Lagoke personal communication).

In the two years, number of cowpea plants infected and Alectra shoot count were consistently reduced by 60 Kg N/ha, which also depressed cowpea grain yield compared with 0 and 30 Kg/ha. In a similar study in sand culture (Emechebe et al., 1991) showed that 140 ppm N applied as sodium nitrate (Na No_3) solution completely reduced the incidence of S. gesnerioides with a concomitant decrease in nodule numbers. However, Adu et al. (1989) reported that lower levels of N in combination with some host resistance would be appropriate to reduce Striga infection. The influence of N-fertilization and manuring as farm practices in the management of Striga are generally not consistent and repeatable. The use of N in controlling S. gesnerioides in cowpea seems to be limited due to its detrimental effect of high rates on nodulation with consequent yield reduction. In field studies in the U.S., outstanding control of Striga asiatica was obtained by using high rates of N as ammonium sulfate (Shaw et al., 1962). Similarly, in India, N applied to heavily infested Striga fields grown with pearl-millet reduced the incidence of Striga and doubled the yields of the crop (Mathur and Mathur, 1967). In Sudan, Last (1960) reported that on soil lightly infested with S. hermonthica, 90 kg N/ha trebled grain yields from 1278 to 3957 kg/ha while the relative effect was greater in highly infested soil with severe attack. In Nigeria, Mansfield (1982), showed that up to 150 kg N/ha may be needed to reduce

Striga infestation effectively, while in Gambia, Carson (1985) found that mineral fertilizers did not have any discernible effect on Striga population, although there was tendency for more Striga at the higher levels of NPK. The mechanism by which high N reduced Striga infestation could be attributed to the production of low germination stimulant by Sorghum under high N (Parker, 1984; Adeosun 1990; Ngawa 1992). This was confirmed by Gworgwor (1993) who reported that under high N low stimulant was produced for the first three weeks only, which was a clear indication of the inhibitory effect of high N on stimulant production. Earlier works by (Parker 1984), Sherif and Parker. (1986) and Raju et al. (1990) have shown that high N has the effect of reducing stimulant production from sorghum and can delay Striga emergence and reduce infestation of Striga compared with low N application. This reduction of stimulant produced by sorghum under high N might be through physiological changes in the growth rate of the cell tissues in the active stimulant producing area of the sorghum roots. It is known that the stimulant producing part of the crop utilizes back the stimulant for cell elongation (Sunderland, 1960), who further reported that the utilization of the chemo-stimulants is greatest during the growth in the length of the root cells, and consumption falls as the cells matures. It is possible that the high N encourages rapid and vigorous cell growth and elongation, which demands a lot of stimulants to perform such functions, consequently leading to a small quantity of the stimulant to be released into the soil medium. High N could also caused the reduction of radicle

elongation of the few germinated Striga seeds as observed by Pesch and Pieterse. (1982) providing an escape mechanism effect on the attachment of the Striga seedlings to the host.

Phosphorus levels did not have any effect on Alectra parameters while the damage symptoms on crop plants was more intense at 40 Kg P/ha compared with 0 and 20 Kg P/ha. This may be attributed to better establishment and increase number of nodules and lateral roots which could serve as haustorial attachment points for the parasite. Phosphorus application however increased weight of pods and grain yield compared with no phosphorus in 1991. The significant increase in number and weight of pods per unit area and grain yield with P-application has earlier been attributed to the fact that P promotes good establishment, nodulation and yield of legumes (Whitney, 1975).

In 1992, although not significant, un-infected plots had more grain yield than the infected (Table 26). Alectra infection only reduced grain yield of VITA-3 by 0.9% compared with 21.5%, 13.5% and 11.7% for SAMPEA 7, TN93-80 and IT89KD-245-1, respectively. With the low pod number, the acceptable yield of VITA-3 in 1991 and low reduction in yield in 1992 inspite of moderate infestation respectively can be attributed to tolerance reaction by the variety. This is done probably through reduction in pod number, compensated for by seed size with consequent increase in the grain yield of the crop. Being a late-maturing variety, it would still produce adequate photosynthetic apparatus for the production of assimilates for grain at the later stage of life-cycle.

5.2.1 Interactions

Interactions of variety x nitrogen, and variety x nitrogen x phosphorus were significant on number of plants infected at 9 WAS in 1991 and 1992, respeöctively. In 1991, number of plants infected decreased with N-levels, while it was highest with SAMPEA-7 treated with 40 Kg P alone (Table 21). This could be attributed to reduction in number of nodules on lateral roots thus reducing the incidence of infection as reported by Emechebe et al. (1983) and Adu et al. (1989).

Interaction of variety x phosphorus on number of days to Alectra emergence was significant in the two years (Tables 24 & 25). From the three-way interaction, it was apparent that varieties which exhibited moderate (TN93-80 in 1991) to high (IT89KD-245-1 in 1992) levels of resistance responded to high doses of N (60 Kg N/ha) and P (40 Kg P/ha) by delaying the emergence of Alectra. However, the high rate of N was detrimental to cowpea. It is possible that the high N encourages rapid and vigorous cell growth and elongation, which demands a lot of stimulants to perform such functions, consequently leading to a small quantity of the stimulant to be released into the soil medium.

Interaction of variety x phosphorus on number of pods was significant in the two years (Tables 29 & 30). Maximum number of pods was produced by phosphorus, alone at 40 Kg P/ha in 1991. However, with 60Kg N both 20 and 40 Kg P/ha had higher number of pods than no phosphorus application. Nitrogen at 60Kg N only significantly increased pod number compared with 0 Kg N when combined with 20 Kg P/ha. The use of N in controlling S.

gesnerioides in cowpea seems to be limited due to its detrimental effect on nodulation with high doses and consequent yield reduction. The significant increase on number of pods with phosphorus application has earlier been attributed to the fact that P promotes good establishment, nodulation and yield of legumes (Whitney, 1975).

The nitrogen x Alectra infection on weight of 1000 grains indicated that, without infection, 60 Kg N depressed 1000 grain weight compared with 0 Kg N (Table 31). This could be attributed to the detrimental effect of high N rate on cowpea (Emechebe et al. (1983) and Adu et al. (1989).

5.2.2 Correlation

The negative correlation between cowpea grain yield and number of plants infected and Alectra shoot count in the two trials confirms the high vulnerability of cowpea to Alectra with consequent reduction in grain yield. Similar observation have been reported by Gworgwor (1993) who found that Striga reduces both grain yield and 1000 grain weight.

5.3 Evaluation of herbicide combinations for the control of Alectra in cowpea

Generally, in the two trials, all pre-emergence herbicide mixtures containing Pree (metazachlor + antidote) as well as pendimethalin plus imazaquin at 0.87 + 0.15 and 1.09 + 0.19; pendimethalin plus imazethapyr at 1.58 + 0.12 all followed by imazaquin at 0.18 resulted in low number of plants infected and Alectra shoot count. (Lagoke personal communication) reported that pendimethalin plus imazaquin at 1.09 + 0.19 Kg a.i/ha

followed by one supplementary hoe-weeding (SHW) at 6 WAS resulted in lower Alectra shoot count and number of plants infected with consequent increase in cowpea grain yield. In the control of Orobanche crenata, Garcia et al (1992) reported effective control of the parasitic weed with imazaquin at 80/ha. However, early sowing/high yield cropping systems, which are normally subject to heavy and lasting parasite infestations, would require a combination of pre-emergence and post-emergence treatments. Results of experiments in developing a cowpea seed treatment in the Laboratory and Screenhouse in controlling both Striga gesnerioides and Alectra vogelii, that consisted of a 5 minute seed soak in solutions of imazaquin in concentrations ranging from 1.8 to 7.2 mg a.i/ml solution indicated that treatment concentrations of 3.6 to 7.2 imazaquin/ml solution reduced parasite attachment by 90% in comparison to untreated controls. The mechanism of control appears to be post-attachment mortality of the parasites with no reduction in parasite seed germination (Berner et al., 1993).

The highest pod weight and consequently cowpea grain yield were obtained with pendimethalin plus imazaquin at 1.09 + 0.19 fb SHW and pedimethalin plus imazethapyr at 1.58 + 0.12 fb SHW in 1991 and 1992, respectvely (Tables 36 & 37). The yields of Pree and imazaquin containing treatments are generally lower than those of pendimethalin containing mixtures although the former had lower number of plants infected and Alectra shoot count. This could be attributed to phytotoxicity on cowpea stand establishment (Berner et al; 1993). Similarly, with Striga,

Eplee et al. (1991) reported among dinitroanilines, pendimethalin have been found to act as barrier to Striga emergence. Pendimethalin, applied pre-emergence to the surface at 1.7 Kg a.i/ha, gave a 100% reduction in early Striga emergence. The mode of action of this herbicide in preventing early season Striga attachment is not yet known. In 1992, hoe-weeded control produced grain yields that was comparable to the maximum obtained in the trial with pendimethalin + imazethapyr at 1.58 + 0.12 fb SHW. Sule. (1988) reported good cowpea grain yield with two hoe-weedings at 3 and 6 WAS.

5.3.1 Correlation

The negative correlation between cowpea grain yield and number plants infected and Alectra shoot count confirms the high vulnerability of cowpea to Alectra with consequent reduction in grain yield. There was also negative correlation between Alectra parameters and weight of pods while grain yield was positively correlated to weight of pods (Tables 38 & 39). The result indicate that these parameters are critical determinants of cowpea grain yield and that the effect of Alectra on them was the main cause of yield reduction. Yield reduction of 100% due to Striga perasitism has been reported to occur in cowpea depending on the level of infestation (Emechebe et al., 1983). Similarly, Salako. (1984) reported 34-39% loss in pod yield for individual groundnut plants due to Alecta infestation.

5.4 Reaction of cowpea varieties to preconditioning period and concentration of seed inoculant of Alectra vogelii

In the two trials, cowpea variety TVX3236 had the highest

total number of Alectra compared to all other varieties. Alectra inoculation suppressed shoot dry matter production in TVX3236 especially at the higher levels of Alectra seed concentrations in the second trial. Among the varieties evaluated B 301 and the derivative of cross with IT84S-2246-4 (IT90K-76) did not have any attachment of Alectra, while IT89KD-245-1 recorded the least emergence in the two trials Table 40). Similar levels of resistance to Striga gesnerioides by B 301 have been reported by Lagoke et al. (1991) and Emechebe and Singh. (1991) and Alectra vogelii by Magani et al. (1991). B 301, a local variety, which was initially identified for resistance to Alectra vogelii in Botswana has been observed to exhibit multigenic resistance to both various strains of Striga and Alectra at various locations in West and Central Africa, including Nigeria (Riches, 1984; Emechebe and Singh, 1989). Resistance to Striga in the genotype B 301 has been reported to be controlled by one dominant gene and resistance to Alectra by two dominant genes (Singh and Emechebe, 1990a, 1990b). Lane. (1989) has however attributed the resistance in B 301 to its failure to low production of stimulants for the germination of Striga seeds as well as attachment and prevention of haustorial formation and subsequent development of the seedling of the parasite through antibiosis. The anatomical studies revealed that the haustorium remains in the endodermis without further development and penetration. The fact that no Alectra attachment occured in IT90K-76 further indicates the compatability of relevant genes in the two parents i.e B 301 and IT84S-2246-4. In the two trials, variety TVX 3236 initiated early emergence of Alectra, while delayed Alectra

emergnce was observed on IT89KD-245-1 as previously reported by Magani et al. (1992). Generally, Alectra emergence was earlier in the second trial than the first trial. This could be attributed to the favourable temperature for Alectra seed germination (July-September) during which the second was conducted as compared to that of first trial (February-May).

Nodulation as percentage of the control was only suppresed in IT89KD-245-1 at 5 and 10 c.c/pot Alectra seed concentrations in the first trial. IT89KD-245-1 has earlier been reported to be a poor nodulaton (Magani et al. 1992). But in the second trial only TVX 3236 and VITA-3 at all Alectra seed concentrations had suppressed nodulation as percentage of the control (Table 42). Shoot dry matter production as percentage of the control was suppressed in the susceptible variety TVX3236 as similarly reported by Stewart et al. (1988) and Kureh et al. (1994), They indicated that prior to emergence, Alectra entirely depended on its host for carbon but after emergence about two-third of its carbon requirements still come from the host. Another factor which may account for reduced growth of the host is the possible reduction in photosynthetic activity in infested plants as earlier reported by Press et al. (1987).

In the two experiments, inoculation with 10 c.c/pot of Alectra seeds resulted in higher Alectra infection than 20 c.c/pot probably due to competition among the attached parasite seedlings for the host resources. In effect it may not be necessary to increase the level of inoculation from 10 c.c/pot to 20 c.c/pot in order to induce reaction in cowpea in the green

house. The result confirmed the reports of Emechebe et al. (1991) on cowpea Alectra and Striga and Kureh et al. (1994) on soybean Alectra. They indicated that adequate exposure of plants to Alectra and Striga in pots can be achieved by inoculation with about 10 c.c/pot seeds of the parasites.

Pre-conditioning period only had significant effect in the first trial. Pre-conditioning period needs further investigation under controlled environment as Alectra infection seems to be related to environmental conditions which tended to vary even in the green house. With cowpea Striga Emechebe et al. (1991) observed that Striga symptom expression was related to environmental condition which vary even in the screen house and that the number of Striga shoot that emerged often vary greatly for replicates of the same cowpea lines grown during the same period in the screen house. However, in this study although only significant, in the first trial, pre-conditioning period prior to cowpea sowing 14 days initiated early Alectra emergence. In a study of the role of ethylene in germination of Striga asiatica in response to Strigol, Babiker et al. (1993) reported that unconditioned seeds and those conditioned for 3 days produced negligeble amounts of ethylene reponse to Strigol. However, extending the conditioning period to 5 and 8 days increased ethylene evolution by more than 10-fold. Thus it would appear that conditioning resulted in partial release of the ethylene biosynthetic pathway. Previous work demonstrated that germination of Striga asiatica is curtailed by the presence, in the seed, of mechanical barriers as well as germination and radicle elongation inhibitors (Kust, 1966; Egley, 1972; Sahai and

Shivana, 1982).

5.4.1 Interactions

Interactions of cowpea x Alectra seed concentrations was significant in the two trials on all Alectra parameters except number of days to Alectra emergence. Generally, increasing the Alectra seed concentration increased the number of un-emerged Alectra in the two trials. In the first trial variety TN 93-80 at the highest Alectra seed concentration had significantly higher total Alectra than all other varieties. All the varieties that supported Alectra has the maximum number at 20 c.c Alectra seed concentration with the exception of IT81D-985 which had th highest at 10 c.c. At all Alectra seed concentration, TVX3236 supported the highest Alectra infection in the second trial, among all varieties. This confirms the susceptibility of TVX 3236 as previously reported by Emechebe and Singh. (1991).

The 3-way interaction of variety x preconditioning period x Alectra seed concentration indicated that TVX 3236 at 10 c.c/pot pre-conditioned for 14 days gave the highest number of un-emerged Alectra. This indicates the need for further investigation in order to have the approriate pre-conditioning periods.

5.4.2 Correlations

Crop dry matter production was negatively correlated to number of emerged, un-emerged and total number of Alectra. This confirms the high vulnerability of cowpea to Alectra with consequent yield reduction. Similar observation has been reported by Kureh et al. (1994) in soybean.

CHAPTER 6

SUMMARY AND CONCLUSION

Field and green house trials were conducted to study the effects of fertilizers and herbicides on the reaction of cowpea varieties to Alectra vogelii (Benth.) at Samaru (11^{o} 11' N, 07^{o} 38' in the northern Guinea savanna ecological zone of Nigeria in 1991 and 1992 wet seasons and the green house trials in 1992 and 1993 dry seasons.

In the screening of cowpea varieties for their reactions to Alectra 18 cowpea varieties were planted out in a randomized complete block design in the field naturally infested by Alectra in 1991 and in both inoculated and Alectra free blocks in 1992. In the greenhouse in 1992, the same 18 cowpea varieties evaluated in the field were also evaluated in pots arranged on the greenhouse bench in a complete randomized design. Half of the pots were inoculated with approximately 2,000 Alectra seeds/pot.

In the fertilizer trial, three (B 301, TN 93-80, VITA-3) and four (IT89KD-245-1, TN93-80, VITA-3, SAMPEA-7) cowpea varieties were used in 1991 and 1992, respectively as main-plot treatments and three levels each of nitrogen at 0, 30 and 60 kg N/ha and phosphorus at 0, 103 and 206 Kg P/ha fertilizers in factorial combination were the sub-plot treatments laid out in a split-plot design.

In the herbicide evaluation trial, 25 herbicide treatments were compared with hoe-weeding at 3 and 6 weeks after sowing (WAS) and a weedy check in a randomized complete block desing, using a susceptible but recommended cowpea variety, SAMPEA-7.

In the green house trials to study the reaction of cowpea varieties to pre-conditioning and concentration of seed inoculant of Alectra, consisted of a factorial combination of eight cowpea varieties, four Alectra seed inoculant concentraitons (0, 5, 10, 20 c.c/pot) and three pre-conditioning periods (0, 7 and 14 days before crop planting) in the first trial and four pre-conditioning periods (0, 3, 7 and 14 days) in the second trial arranged on the green house bench in a complete randomized design.

Results indicated from the screening of cowpea varieties trials, variety B 301 and the derivatives of crosses with IT84S-224-4 (IT90K-59 and IT90K-76) did not support the emergence of Alectra in the field and in the green house. The varieties also produced cowpea grain yields that were comparable to the maximum in 1991 and significantly higher than the least in the two years under Alectra infection. However, the nodulation of these varieties were reduced in the pot by 21.2, 43.9 and 76.9% for B 301, IT90K-59 and IT90K-76, respectively. In contrast, IT89KD-245-1 and IT89KD-245, both of which are derivatives of B 301 and a local variety Kananado supported low emergence of Alectra. The varieties still produced cowpea grain yields that were comparable to the maximum in 1991 and significantly higher than the least in the two years.

In addition to increase in number of days to flowering in the two varieties due to Alectra cowpea grain yield reduction of 57.8% and 69.1% were obtained with IT89KD-245-1 and IT89KD-245, respectively. Variety IT86D-534, inspite of high reduction of nodulation in the pot by Alectra, and support for Alectra infection in all the trials, it did not suffer any reduction in

cowpea grain yield in 1992. The variety was observed to delay Alectra emergence and possible attack. IT86D-843 did not support emergence in the green house but had very low underground infection. Although Alectra did not affect number of days to flowering in the variety, both nodulation in the pot and cowpea grain yield in the field were reduced by 69.2% and 61.7%, respectively. Both TN93-80 and Kano 1696 which were promiscuous nodulators had 47.5% and 44.7% reduction in nodules count due to Alectra infection. The former variety however supported very low Alectra emergence in the green house, while both exhibited similar reaction to Alectra with respect to shoot count, number of plants infected and number of days to emergence in 1992 field trial. However, TN93-80 suffered a higher loss of 55% in cowpea grain yield than Kano 1696 in the year. On the other hand, in 1991 wet season, Kano 1696 supported more Alectra shoots than IT81D-843, Kano 1696 produced low pod number, but acceptable grain yield in 1991 and low reduction in 1992 inspite of high and moderate infestation, respectively. VITA-3 produced significantly higher cowpea grain yield than all the other varieties evaluated both in 1991 and even under Alectra infection in 1992. Both TVX3236 and SAMPEA-7, the recommended varieties in northern Guinea savanna supported high Alectra infection with consequent high susceptibility to the parasite. SAMPEA-7 is however less susceptible than TVX3236 as reflected in low reduction in nodulation and grain yield and low emergence of Alectra shoot under Alectra infection. In the pot, Alectra prevented nodulation in TVX3236 and caused 84% reduction in grain

yield in the 1992 trial.

In the fertilizer trial, in 1991 number of plants infected and Alectra shoot count was significantly higher for VITA-3 than TN93-80. Alectra did not emerge in B 301. In 1992, SAMPEA-7 had significantly higher than all other varieties number of plants infected and Alectra shoot count, the least was obtained with IT89KD-245-1. In the two years number of plants infected and Alectra shoot count were consistently reduced by 60 kg N/ha, which also depressed cowpea grain yield compared with 0 and 30 kg N/ha. Phosphorus levels did not have any effect on Alectra parameters while the damage symptoms on crop plants was more intense at 40 kg P/ha compared with 0 and 20 kg P/ha. In 1992, although not significant, un-infected plots produced a higher grain yield than the infected. Alectra infection only reduced grain yield of VITA-3 by 0.9% compared with 21.5%, 13.5% and 11.7% for SAMPEA-7, TN 93-80 and IT89KD-245-1, respectively.

In the herbicide evaluation trial, all pre-emergence herbicide mixtures containing Pree (metazachlor + antidote) as well as pendimethalin plus imazaquin at 0.87 + 0.15 and 1.09 + 0.19; pendimethalin plus imazethapyr at 1.58 + 0.12 all followed by imazaquin at 0.18 kg a.i/ha resulted in lower Alectra incidence. The highest pod weight and consequently cowpea grain yield were obtained with Pendimethalin plus imazaquin at 1.09 + 0.19 followed (fb) by supplementary hoe-weeding (SHW) and pendimethalin plus imazethapyr at 1.58 + 0.12 fb SHW in 1991 and 1992, respectively. The yields of pree containing treatments are generally lower than those of pendimethalin containing mixtures although the former had lower number of plants infected and

Alectra shoot count.

In the green house trials to study the reaction of cowpea varieties to pre-conditioning and concentration of seed inoculant of Alectra indicated that cowpea variety TVX3236 initiated early emergence of Alectra compared with all the other varieties. Variety B 301 and the derivative of it cross with IT84S-2246-4 (IT90K-76) did not allow emergence of Alectra, while IT89KD-245-1 recorded the least number of emerged Alectra in the two trials. Alectra emergence increased with Alectra seed concentrations in the first trial, while 10 c.c/pot Alectra seed gave the highest number of emerged Alectra when compared to other Alectra seed concentrations in the second trial. Pre-conditioning period had no significant effect on emerged Alectra, but Alectra emergence increased with pre-conditioning period of 7 and 14 days.

In conclusion, this investigation has shown that variety B 301 and the derivatives of its crosses with IT84S-2246-4 (IT90K-59 and IT90K-76) did not support the emergence of Alectra in the field and in the green house thus exhibiting resistance. However, cowpea varieties IT89KD-245-1 and IT89KD-245, both of which are derivatives of B301 and local variety kananado supported low emergence of Alectra with good cowpea grain yield thus exhibiting moderate resistance. Inspite of higher cowpea grain yield under free Alectra condition in the recommended varieties (TVX3236 ad SAMPEA 7), however under infestation, they supported high Alectra infection with consequent high susceptibility to the parasite. All the varieties tested including B 301 had lower grain yield than VITA-3, the only

variety (VITA-3) which did not have cowpea grain yield reduction due to Alectra and thus considered tolerant.

It is apparent that the highest nitrogen level used in this study (60 kg N/ha) significantly reduced Alectra incidence, but resulted in cowpea grain yield depression compared with 0 and 30 kg N/ha. Cowpea grain yield was significantly increased by phosphorus application at 20 kg P/ha without any significant effect of Alectra incidence, although the trend indicated that Alectra incidence increases with P-levels. Generally, a combination of 30 kg N/ha and 20 kg P/ha gave adequate suppression of Alectra with good cowpea grain yield.

All pre-emergence application of mixtures containing Pree followed by imazaquin at 0.18 kg a.i/ha resulted in significantly lower number of plants infected compared with the weedy check. Pendimethalin plus imazaquin at 1.09 + 0.19 and pendimenthalin plus imazethapyr at 1.58 + 0.12 both followed by supplementary hoe-weeding resulted in significantly higher cowpea grain yield than the weedy check.

Alectra emergence increased with Alectra seed concentration up to 10 c.c/pot when compared to other Alectra seed concentrations. Pre-conditioning period had no significant effect on emerged Alectra, but Alectra emergence increased with pre-conditioning period of 7 and 14 days.

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Appendix 1; Common, Chemical and trade names of the herbicides mentioned in the text.

Common Name	Chemical Name	Trade Name
Imazaquin	2-(4-Isopropyl-4-methyl-5-oxo-2 imidazolin -2-yl(quinoline -3- carboxylic acid	Scepter
Imazethapyr	5-ethyl-2-(4-isopropyl-4-methyl-5-oxo-2 -imidazolin-2-yl) nicotinic acid	Pursuit
Metazachlor	N-(2,6-Dimethylphenyl)-N-(1-Pyrazolyl methyl -chloroacetamide	Pree
Pendimethalin	(N-(1-ethylpropyl)-3,4-dmethyl-2-6 -dinitrobenzenamine	Stomp
Metolachlor	(2-chloro-N-(2-ethyl-6-methyl-pheny(-N- (2-methoxyl-1-methyl ethy) acetamide	Dual
Metobromuron	3-(4-bromophonyl)-1-methoxy-1-methylurea	Potoran

Appendix 2: Means squares of analysis of variance for number of plants infected, Alectra plant count, number of days to Alectra emergence and crop damage score as affected by the reaction of cowpea varieties to natural infestation of Alectra at Tasho Zomo in 1991 wet season

Source of variation	DF	Number of plants infected at 9 WAS	Alectra shoot count at 9 WAS	Number of days to Alectra emergence	crop damage score at 9 WAS
Replication	2	9.24	359.41	787.5	4.13
Treatments	17	52.25**	868.15**	1191.2**	4.40**
Error	34	5.91	98.70	341.1	0.87
Total	53	21.52	355.18	624.4	2.05

*/** = Significant at 5/1% level of probability

WAS = Weeks after sowing

Appendix 3: Means squares of analysis of variance for crop vigour score stand count weight of pods number of pods and grain yield as affected by the reaction of cowpea varieties to natural infestation of Alectra at Tasha Zamo in 1991 west season

Source of variation	DF	crop vigour score at 9 WAS	stand count at harvest	weight of pods	Number of pods	Grain yield
Replication	2	2.17	3.50	23862.0	16975.0	91534.0
Treatments	17	7.80**	10.82**	57450.0*	53531.0**	175783.0*
Error	34	1.38	4.32	24543.0	17383.0	73132.0
Total	53	3.52	6.49	35512.0	29433.0	107349.0

*/** = Significant at 5/1% level of probability

WAS = Weeks after sowing

Appendix 4; Means squares of analysis of variance for number of plants infected, Alectra plant count, number of days to Alectra emergence and crop damage score as affected by the reaction of cowpea varieties to natural infestation of Alectra at Tasho Zomo in 1992 wet season

Source of variation	DF	Number of plants infected at 9 WAS	Alectra shoot count at 9 WAS	Number of days to Alectra emergence	crop damage score at 9 WAS
Replication	2	2.74	218.7	10.24	1.56
Treatments	17	16.24**	599.5**	851.40**	1.29**
Error	34	3.35	132.8	19.63	0.36
Total	53	7.65	288.4	2964.89	0.67

*/** = Significant at 5/1% level of probability

WAS = Weeks after sowing

Appendix 5| Means squares of analysis of variance for crop vigour days to crop flowering, stand count number of pods weight of pods, weight of 1000 grains and grain yield as affected by the reaction of cowpea varieties under artificial Alectra infestation at Samaru in 1992 wet season

Source of variation	DF	Crop vigour 9 WAS	Number of days to crop flowering	Stand count at harvest	Number of pods	Weight of pods	weight of 1000 grains	Grain yield
Replication	2	2.23	11.36	18.08	2721.0	0.0009	1698.5	27491.0
Treatments	17	2,36**	123.59**	12.08**	115056.0*	0.375**	6576.2**	870918.0**
Infection	1	6.75**	13.37	147.00**	267705.0**	4.546**	280.3	9669007.0**
Treatment x Infection	17	0.80**	4.66	7.82	3866.0**	0.107**	338.9	227731.0**
Error	70	0.28	4.39	4.64	16578.0	0.021	398.1	52735.0
Total Error	107	0.76	23.82	7.71	38489.0	0.136	1387.6	305119.0

*/** = Significant at 5/1% level of probability

WAS = Weeks after sowing

Appendix 6: Means squares of analysis of variance for number of emerged Alectra, number of un-emerged Alectra and days to Alectra emergence as affected by reaction of cowpea varieties to Alectra in the green house at Samaru, in 1992 dry season

Source of variation	DF	Number of Emerged Alectra at 60 DAS	70 DAS	Harvest	Number of un/ emerged Alectra/ Plant	Number of days to Alectra emergence
Replication	2	0.96	0.91	1.18	0.03	443.7
Treatments	17	9.06*	9.64*	10.86*	1.36**	1394.2**
Error	34	4.77	5.14	5.71	0.27	549.3
Total	53	6.19	6.65	7.43	0.63	830.9

*/** = Significant at 5/1% level of probability

DAS = Days after sowing

Appendix 7: Means square of analysis of variance for average number of nodules/plant and number of days to crop flowering as affected by reaction of cowpea varieties to Alectra in the green house at Samaru in 1992 dry season

Source of variation	DF	Average number of nodules/plant at harvest	Number of days to crop flowering
Replication	2	1.52	4.731
Treatment	17	17.03**	4104.53**
Infection	1	75.33**	3278.01**
Treatment x Infection	17	2.17	1021.21**
Error	70	2.39	6.53
Total	105	5.42	865.45

*/** = Significant at 5/1% level of probability

DAS = Days after sowing

Appendix 9: Means squares of analysis of variance for weight of pods, number of pods and grain yield as affected by variety, nitrogen and phosphorus under natural Alectra infestation at Tasha Zomo in 1991 wet season

Source of variation	Df	Weights of pods	Number of pods	Grains yield
Replication	2	11722	54830	156519
Variety	2	172732*	754812**	129475
Error (a)	4	35753	4383	52727
Phosphorus	2	718369**	297590**	1028440**
Nitrogen	2	90622	27723	189368*
Variety x phosphorus	4	52213	37830	82115
Variety x Nitrogen	4	45322	19737	35930
Phosphorus x Nitrogen	4	72428	48060**	120884
Variety x Phosphorus x Nitrogen	8	27524	21237	42885
Error (b)	48	32203	17554	56463
Total	80	56441	28967	89510

*/** = Significant at 5/1% level of probability

WAS = Weeks after sowing

Appendix 10: Means squares of analysis of variance for number of plants infected, Alectra plant count, days to Alectra emergence and crop damage score as affected by variety nitrogen and phosphorus under artificial Alectra infestation at Samaru, in 1992 wet season

Source of variation	Df	Number of plants infected at 9 WAS	Alectra count at 9 WAS	Number of days to Alectra emergence	Crop damage score at 9 WAS
Replication	2	72.78	3768.9	35.11	0.68
Variety	2	277.36**	18769.7**	441.40**	5.69*
Error (a)	4	8.48	1151.2	37.88	1.88
Phosphorus	2	10.56	1278.5	89.36**	1.01*
Nitrogen	2	31.18**	2117.6	44.33**	0.59
Variety x phosphorus	4	4.31	1453.4	44.47**	0.47
Variety x Nitrogen	4	12.99	1261.5	37.02*	0.20
Phosphorus x Nitrogen	4	6.68	477.7	27.24	0.20
Variety x Phosphorus x Nitrogen	12	19.42*	1665.6	28.30*	0.36
Error (b)	64	6.98	969.4	14.27	0.27
Total	107	9.31	1114.8	22.06	0.31

*/** = Significant at 5/1% level of probability

WAS = Weeks after sowing

Appendix 11: Means square of analysis of variance for number of days to crop flowering, stand count and number of pods as affected by variety nitrogen and phosphorus under artificial Alectra infestation at Samaru, in 1992 wet season

Source of variation	Df	Number of days to crop flowering	Stand count at harvest	Number of pods
Replication	2	10.09	7.28	186346
Infection	1	26.74	234.38*	200324
Error (a)	2	4.51	3.13	368886
Variety	3	140.28**	38.46**	198969**
Infection x variety	3	4.46	39.65**	33540
Error (b)	12	14.34	3.68	30367
Phosphorus	2	7.09	1481*	35552
Nitrogen	2	4,06	4.79	46808
Variety x Nitrogen	6	4.09	3.11	64334**
Infection x Nitrogen	2	5.24	4.67	9511
Variety x phosphorus	6	3.12	3.80	59618*
Infection x phosphorus	2	0.62	5.28	719
Nitrogen x phosphorus	4	2.13	1.09	107844**
Infection x variety x Nitrogen	6	4.23	3.46	4426
Infection x variety x Phosphorus	6	3.02	4.80	5247
Variety x Nitrogen x Phosphorus	12	4.16	3.75	31297
Infection x Nitrogen x phosphorus	4	0.14	0.98	49381
Infection x variety x Nitrogen x phosphorus	12	2.94	3.04	17656
Error (c)	128	3.97	2.99	21668
Total	215	3.77	3.24	25921

*/** = Significant at 5/1% level of probability

WAS = Weeks after sowing

Appendix 12: Means square of analysis of variance for weight of pods, weight of 1000 grains variety, nitrogen and phosphorus under artificial Alectra infestation at Samaru in 1992 wet season

Source of variation	Df	Weight of pods	Weight of 1000 grains	Grain yield
Replication	2	0.34	325.5	320446
Infection	1	1.21	1111.6	878054
Error (a)	2	2.63	408.8	4200126
Variety	3	1.12**	51342.4**	3515865**
Infection x variety	3	0.11	3275.8**	98364
Error (b)	12	0.21	168.4	186415
Phosphorus	2	0,29*	106.0	558353**
Nitrogen	2	0.36**	72.7	1222427**
Variety x Nitrogen	6	0.08	907.3*	53606
Infection x Nitrogen	2	0.01	3339.4**	131328
Variety x phosphorus	6	0.08	907.3*	53606
Infection x phosphorus	2	0.01	3339.4**	131328
Nitrogen x phosphorus	4	0.15	483.8	131475
Infection x variety x Nitrogen	6	0.05	333.2	57493
Infection x variety x Phosphorus	6	0.05	276.7	148342
Variety x Nitrogen x Phosphorus	12	0.07	207.3	47473
Infection x Nitrogen x phosphorus	4	0.14	747.7	46561
Infection x variety x Nitrogen x phosphorus	12	0.05	628.5	66605
Error (c)	128	0.07	344.1	110857
Total	215	0.07	450.3	119067

*/** = Significant at 5/1% level of probability

WAS = Weeks after sowing

Appendix 13: Means squares of analysis of variance for number of plants infected, Alectra, plants count, crop damage score, number of days to Alectra emergence, weight of pods and grain yield as afected by herbicide treatments at Tasha Zomo in 1991 wet season

Source of variance	Df	Number of plants infected at 9 WAS	Alectra count at 9 WAS	Crop damage score at 9WAS	Number of days to Alectra emergence	Weight of pods	Grain yield
Replication	2	48.44	927.4	8.93	56.35	133667	216680
Treatments	26	72.96**	606.4*	2.21**	40.00**	25339*	38314*
Error	52	19.09	295.7	0.90	8.85	13315	21145
Total	80	37.04	389.3	1.34	19.23	17323	26868

*/** = Significant at 5/1% level of probability

WAS = Weeks after sowing

Appendix 14: Means squares of analysis of variance for number of plants infected, Alectra plants count, number of days Alectra emergence, crop damage score, number of pods, weight of pods and grain yield as affected herbicide treatments at Samaru in 1992 wet season

Source of variance	Df	Number of plants infected at 9 WAS	Alectra count at 9 WAS	Number of days to Alectra emergence	Crop damage score at 9WAS	Number of pods	Weight of pods	Grain yield
Replication	2	523.59	43349	300.11	8.16	2325	0.01	66686
Treatments	26	27.32**	2331*	105.85**	0.98	34435*	0.09**	274568**
Error	52	11.91	1037	27.42	0.59	15321	0.04	97745
Total	80	17.05	1468	53.56	0.72	21692	0.05	156686

*/** = Significant at 5/1% level of probability

WAS = Weeks after sowing

Appendix 15: Means squares of analysis of variance for number of days to Alectr emergence, emerged Alectra, un-emerged Alectra, total Alectra an average number of nodules as affected by variety, Alectra see concentration and pre conditioning period at Samaru in the firs green house trial 1993

Source of variance	Df	Number of days to Alectra emergence	Number of emerged Alectra	Number of un-emerged Alectra	Total number of Alectra	Average number of nodules/ plant
Replication	2	0.0006	0.04	0.09	0.18	57.17
Variety	7	120.25**	0.39**	3.13**	4.38**	50.41**
Alectra seed concentration	3	203.94**	0.58**	2.87**	5.48**	2.19
Precondition period	2	46.37**	0.15	0.28	0.20	77.57**
Variety x concentration	21	33.26**	0.14**	0.66**	0.76**	4.51
Variety x Preconditioning	14	27.22**	0.05	0.29*	0.14	5.18
Concentration x preconditioning	6	18.25**	0.06	0.06	0.06	1.18
Variety concentraion x precondition	42	14.25**	0.07	0.12	0.14	2.92
Error	190	0.01	0.06	0.13	0.21	3.15
Total	287	14.25	0.08	0.28	0.39	4.95

*/** = Significant at 5/1% level of probability

Appendix 16: Means squares of analysis of variance for number of days to Alectra emergence, unemerged, total Alectra, crop damage score, average number of nodules and shoot dry matter production as affected by variety, Alectra seed concentration and *preconditioning period* at Samaru *in the second green house trial* 1993

Source of variance	Df	Number of days to Alectra emergence	Number of unemerged Alectra	Number of emerged Alectra	Total Alectra	Crop damage score	Average number of nodules/ plant	Shoot dry matter per plant
Replication	2	0.07	0.01	2.51	1.75	0.25	4.78	0.003
Variety	7	197.56**	1.20**	4.00**	6.76**	6.59**	44.08**	0.04**
Alectra seed concentration	3	232.23**	1.08**	3.96**	7.30**	4.76**	29.32**	0.08**
Preconditioning period	3	18.23**	0.06	0.14	0.06	0.47*	12.22*	0.11**
Variety x concentration	21	25.61**	0.22**	0.67**	1,01**	0.77**	8.43**	0.01**
Variety x Preconditioning	21	10.16**	0.21**	0.13	0.18	0.10**	5.71	0.01*
Concentration x preconditioning	9	10.67**	0.15*	0.14	0.23	1.14**	16.30**	0.05**
Variety concentrion x preconditioning	63	7.04**	0.12	0.15	0.21	0.12**	7.09**	0.01
Error	254	0.06	0.07	0.15	0.19	0.04	3.96	0.003
Total	383	9.94	0.12	0.28	0.42	0.26	6.12	0.01

*/** = Significant at 5/1% level of probability

BIOGRAPHY

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PREVIOUS ACADEMIC QUALIFICATIONS

INSTITUTION ATTENDED	FROM	TO	CERTIFICATE/DEGREE AWARDED
Government Secondary School, Dengi	1974	1979	W A S C
School of Preliminary Studies,Keffi	1979	1981	I J M B
Ahmadu Bello University Zaria	1981	1985	B.Sc (Agric.)
Ahmadu Bello University Zaria	1989	1991	M.Sc (Agron.)

POSTS HELD SINCE AWARD OF FIRST DEGREE

ORGANIZATION	POSITION	FROM	TO
Fed. Govt. Girls' College, Sagamu	N.Y.S.C	1985	1986
University of Agriculture, Makurdi	Grad. Asst.	1986	1991
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