CONTROL OF INSECT PESTS OF COTTON IN COTTON-MAIZE MIXTURE

BY

ONOLEMHEMHEN O. PATRICK

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FACULTY OF AGRICULTURE
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DECLARATION

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

15-5-86

ONOLEMHEMHEN O. PATRICK

CANDIDATE

DATE: : MAY, 1986

The above declaration is confirmed.

DR. OLUPOMI AJAYI

MAJOR SUPERVISOR

CERTIFICATION

This thesis entitled 'CONTROL OF INSECT PEST OF COTTON IN COTTON-MAIZE MIXTURE' by PATRICK ONOLEMHEMHEN meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to Scientific knowledge and literary presentation.

DR. O. . AJAYI
CHAIRMAN,
SUPERVISORY COMMITTEE. DATE: 21/07/86

DR. V. KUMAR
MEMBER,
SUPERVISORY COMMITTEE. DATE: 28/8/86

PROFESSOR A.M. EMECHEBE
HEAD, DEPARTMENT OF CROP PROTECTION. DATE: _____

PROFESSOR G.E. OSUIDE
DEAN, POSTGRADUATE SCHOOL. DATE: 25/V/87

DEDICATION

This thesis is dedicated to my parents, MR. ONOLEMHEMHEN, AUGUSTINE and MRS. REGINA ONOLEMHEMHEN, whose foresight, sacrifice and support, has helped me to become what I am today.

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ABBREVIATIONS AND SYMBOLS

WAP	-	Weeks after planting
LV	-	Low volume
ULV	-	Ultra low volume
ED	-	'Electrodyn'
ANOVA	-	Analysis of variance
LSD	-	Least significant difference
NS	-	Not significant
P_1	-	Regular row arrangement
P_2	-	Paired row arrangement
S_0	-	No spray
S_1	-	Low volume spray
S_2	-	Ultra low volume spray
S_3	-	'Electrodyn' spray

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CHAPTER 1

INTRODUCTION

Cotton (Gossypium hirsutum L.) is a major cash crop of the northern states of Nigeria. It is also an important raw material for the country's textile industry.

The annual production of seed cotton in Nigeria lies between 150 to 300kg and 200,000 to 300,000 bales of cotton lint (Faulkner, 1974; Kumar and Ogunlela, 1982). This low yield is attributed to non-adoption of recommended practices such as early planting and chemical protection of the crop from insect pest damage. Added to the low yield, cotton production has been on the decline over the years in Nigeria. Production levels fell from 502,640 bales of lint in 1969/70 to 150,000 bales in 1980 (Kumar and Ogunlela, 1982). This represents a decrease of about 70.0 per cent in total production. With the prevailing low yield and declining cotton production the attainment of the national goal of 950,000 bales per year by 1990 would be impossible and this might result in the use of scarce financial resources in importing cotton lint for our textile industries.

Against this background, research efforts have been directed over the years at increasing cotton production in Nigeria. It is believed that increased

cotton production can better be achieved by increased yield/ha rather than increasing the hectarage devoted to the crop (Kumar and Ogunlela, 1982). Cultural control of insect pests by intercropping, in addition to chemical protection against insect pest attack and improved crop husbandry has been identified as a possible way of achieving increased yields per hectare.

A cotton-maize mixture has been reported to be more productive and profitable than sole cotton or cotton intercropped with millet, groundnut, sorghum and cowpea (Kumar, 1980; Kumar, et al, 1982). Bhuyemusoke (1984) observed that the mixture was fast becoming an important one in the Samaru-Zaria area, where cotton has been a long-standing cash crop and maize a relatively new, but increasingly important food and cash crop.

The high yield obtained from this mixture is possible, if the crops are sown early with the first rains and the cotton plants are protected from insect pest damage (Kumar and Raheja, 1984).

Cotton-maize mixture is grown in the conventional plant arrangement, with cotton plants alternating with the maize plants. Under such crop situations, the tall maize constitutes the top canopy, with the cotton plants as the under can opy. Sprayed insecticides are therefore trapped by maize and prevented from reaching the target cotton plants, thus resulting in increased

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pest populations. The tall maize also restricts the movement of the sprayer (Bhuyemusoke, 1984; Kumar and Paheja, 1984).

Alternating paired rows of cotton and maize, on the other hand, gives a better exposure of their canopies and is more likely to provide higher light interception for the cotton and less smothering effect of maize (Kumar and Ogunlela, 1982).

Information is presently lacking on efficient methods of insecticide spraying in crop mixtures. Results obtained with the recommended ultra-low volume method of insecticide application, have been poor, because the tall maize in the mixture traps some of the insecticide droplets.

Other methods of insecticide application, including the use of the low volume and electrodyn sprayers, have not been adequately investigated and thus no information is available on their efficacy in such crop situations.

The research was therefore an attempt at integrated control utilizing insecticides and mixed cropping. It was designed primarily to compare the spray performance of the three methods (low volume, ultra-low volume and electrodyn) in the control of insect pests of cotton in cotton-maize mixtures. It was also aimed at testing

(i) the comparative ease of use and spray efficacy of the spray methods on regular row arrangement and paired row arrangement of cotton plants and (ii) effect of intercropping on the level of insect damage.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Taxonomy and Geographical Distribution of Cotton in West Africa

Cotton (Gossypium spp.) belongs to the family Malvaceae and is the world's most important fibre crop. It is grown on more than 30 million hectares of land in about eighty countries of the world including Nigeria (Reynolds et al., 1982).

Commercially cultivated cotton in Africa is believed to have originated from introductions of the new world species, as well as from the development of barbadense cotton in Egypt in the 19th century (Pearson, 1958). In West Africa, cotton is grown in Ivory Coast, Ghana, Togo, Niger and Nigeria, among others. In Nigeria, the Ishan type of cotton, G. barbadense L., is grown in the south, while the upland cotton, G. hirsutum Linn, is grown in the north (Hayward, 1967).

The Nigerian cotton crop of about 500,000 hectares is almost entirely raingrown on small farms (Faulkner, 1974). The main centres of cotton production in Nigeria are located north of latitude 7^{o} 30' North, a region characterised by pronounced fluctuations in geographical and seasonal rainfall distribution (Anon., 1976). The rainy season lasts from May to September, with a rainfall of

600 - 750 millimetres per annum. The northern and eastern cotton growing areas account for about 93 per cent of the total cotton produced, with the northern area to which Zaria belongs, accounting for 60-65% of the total amount of cotton produced (Faulkner, 1974; Anon., 1976). Other areas of cotton production in Nigeria include Ibadan, Oyo, Irrua and Uromi (Hayward, 1967; Usenbo, 1977).

2.2 Reasons for Poor Yield of Cotton in Nigeria

Many reasons have been advanced for the low cotton yield and declining production in Nigeria. They are:

i. Its competition for farmer's time with food crops like millet, cowpea, sorghum and groundnuts (Anon. 1976).

ii. Non-adoption of recommended practices, as very little inputs (fertilizer and insecticide) are used by the farmers for cotton production (Anon. 1976).

iii. Damage by insect pests, which in some cases has led to a complete collapse of the cotton production programme in southern Nigeria. By their direct feeding, insects reduce cotton yield and by transmitting rot causing organisms-bacteria and fungi they indirectly reduce crop yield (Choyce, 1966; Hayward, 1967).

2.3 Insect Pests of Cotton

Cotton is pre-eminent among tropical field crops in its susceptibility to attack by a wide range of insect pests. This is due to the nutrient value of the readily accessible fruiting bodies which serve as a source of food for the pests.

The developing flower buds are rich in protein which constitutes about 20 - 38% of its dry weight. The bolls have a high proportion of reducing sugars during the first half of the bolls' life and their dry weight at maturity contains 23% protein and 21% oil (Rainey, 1948).

Hargreaves (1948), listed 1,326 species of insects as pests of cotton, 482 of which were recorded in Africa. Of the 482 insect species, only 150 are pests of significance in a cotton crop (Pearson, 1958).

Pearson (1958) reported Helopeltis sp., Bemisia sp., Diparopsis sp., Cryptophlebia sp., Heliothis sp. and Dysdercus spp. as the principal pests of cotton in the moist equatorial region to which Nigeria belongs. Libby (1968) reported about twenty insect species as pests of cotton in Nigeria, and regarded the mirids (Helopeltis sp.), the cotton stainers (Dysdercus spp.) and the bollworns as the major pests. Helopeltis schoutedeni Reut, Cryptophlebia leucotreta Meyr and Dysdercus spp. are

the major pests to the more humid south, while Diparopsis watersi Roths and Dysdercus spp. are the most important insect pests to the north (Libby, 1968; Caswell and Raheja, 1977), although Heliothis armigera Hubner and C. leucotreta have been reported to be of increasing importance in Nigeria (Anon., 1983). Over the years, more insect pests have been recorded and their effect on yield assessed. Such other insects are the Jassids (Empoasca spp.), the Fleabeetles (Podagrica spp.), Whitflies (Bemisia sp.), aphids (Aphis sp.) and to some extent the leaf roller (Sylepta sp.).

For a better understanding of the pest status in relation to plant growth, the insect pests will be treated in relation to the part or growth phase of the plant it attacks, with a brief mention of its biology which is essential in effective control of pests. Insect pests may thus be grouped into (a) pests of the vegetative phase and (b) pests of the reproductive phase, although some pests in the absence of their preferred feeding parts may utilize the available plant parts.

2.4 Pests of the Vegetative Phase

Insect pests of the vegetative phase are the leaf beetles (Podagrica spp. and Syagrus sp.), the cotton leaf roller (Sylepta sp.), the cotton whitefly (Bemisia sp.) and aphids (Aphis sp.) Libby, 1968; Anon., 1976).

2.4.1 Leaf beetles (Coleoptera: Chrysomellidae).

The leaf beetles include Podagrica uniformis Jacobi and P. sjostedti Jacobi commonly referred to as the fleabeetles and Syagrus calcaratus F. all of which are early season pests of cotton. The adults make feeding holes in the leaves, while the larvae feed on the roots. Egg plants and okra are also hosts of these pests (Libby, 1968; Anon., 1976).

2.4.2 Jassids (Hemiptera: Ci cadellidae).

Two common cicadellids, Empoasca dolichi Paoli and Empoasca facialis Jacobi are important pests of cotton in Africa (Pearson, 1958). The nymphs and adults attack 15 - 20 days old seedlings, feeding on the leaves from which they suck out sap. In addition to sap loss, they cause the 'hopper burn' symptom on leaves. Attacked leaves show pale yellow margins which turn red colour, and roll downward, turning brown as if scorched. In severe cases leaves and cotton buds are shed (Libby, 1968).

2.4.3 Mirids (Heteroptera: Miridae).

Mirid pests of cotton include Lygus voselleri Popp; Campylomma subflava Odhiambo and C. anguistor Poppius (Pearson, 1958; Lyon, 1972). Campylomma spp. are prevalent on cotton fields in Nigeria, where the adults and nymphs feed on the growing point and new growth tissues of cotton plants, causing leaf

Nymphs and adult colonies develop on new growth of shoots and leaves, feeding on them and causing curling of the leaves and stunted plant growth. Aphids secrete some honey dew, which apart from staining the lint, also enhance fungal growth and makes picking operation messy (Usenbo, 1980 and Raheja, 1981). The aphids also attack okra, tomato and maize (Libby, 1968). Its natural enemies on the field include the ladybird beetles Chilomenes spp., Platynaspis ferruginea (Coleoptera: Coccinelidae), spiders (Usenbo , 1977 and 1980) and ants (Camponotus acvapimensis Mayr.) (Anon., 1983).

Other important foliage pests include the whitefly, Bemisia tabacci Genadium (Hemiptera: Aleyrodidae) the grasshoppers (Orthoptera) and the cutworms - Spodoptera spp. (Lepidoptera).

The whitefly - B. tabacci affects cotton production by transmitting the leaf curl virus disease, producing honey dew which contaminates the lint, and decreasing plant growth (Ripper and George, 1965). The leaf curl disease is more severe on G. barbadense.

2.5 Pests of the Reproductive Phase

The reproductive phase of cotton is the most critical phase in cotton pest management (Lyon, 1972; Caswell and Raheja, 1977) as a result of which many control measures are aimed at controlling pests of

this phase of crop growth. Insect pest of this phase are the plant bugs - Helopeltis schoutedeni Reut, Dysdercus superstitiosus Fabricius, D. fasciatus Signoret and the bollworms.

2.5.1 Cotton stainer Dysdercus spp. (Hemiptera: Pyrrhocoridae).

There are about ten species of the genus Dysdercus in Africa, nine of which are pests of cotton (Pearson, 1958). However D. superstitiosus and D. fasciatus are the only species recorded as pests of cotton in Nigeria (Libby, 1968). The cotton stainers also feed on maize, millet, sorghum, rice, cowpea, sugar-cane, tomato and okra (Libby, 1968).

The nymphs and adults with a reddish body, marked with white, are responsible for the damage which may be direct and indirect. The main damage, which is direct, is the injury done to the developing seeds. Secondary damage, which is indirect, is the transmission of nematospora fungus which causes boll rot and lint staining. Its feeding nature (piercing and sucking) also results in bud shedding and abortion of young bolls. Early adult infestation comes from susceptible host crops like millet, okra and maize, which are harvested at the end of August or early September (Lyon, 1972).

Cotton stainers breed profusely on the later stages of the cotton crop. The young nymphs feed on seeds in newly opened bolls, while the older nymphs and adults feed on both the green and open bolls (Libby, 1967; Lyon, 1972).

Natural enemies of Dysdercus spp. on the field are Alophora multisetosa Villen, A. nasalis Bezzi, Bogosia helva Wied (Hemiptera: Sarcophagidae) and Phonoctonus nigrofasciatus Stal, P. lutescens S. and P. (Hemiptera: Reduviidae) (Pearson, 1958).

Helopeltis schoutedeni R. (Hemiptera: Miridae) is an important pest of cotton in moist areas of the tropics (Pearson, 1958). They are slender insects, the nymphs and adults of which resemble mosquitoes, with long legs and a pair of antennae that are twice as long as the body.

The nymphs and adults attack plant shoots, and green bolls. The shoots become distorted, while attacked bolls open pre-maturely. It is presently not a very common pest of cotton in northern Nigeria (Libby, 1968; Anon., 1983), although it is a major and common pest in the more humid south.

2.5.2 Bollworms

The fruiting bodies (flower buds or squares, flowers and bolls) are attacked by the bollworms

(Pearson, 1958; Choyce, 1966; Lyon, 1972) which constitute the major late season pests of cotton in Nigeria. The bollworm insect pests are the red bollworm - Diparopsis watersi Roths (Lepidoptera: Noctuidae); the American bollworm - Heliothis armigera Hubner (Lepidoptera: Noctuidae); the false codling moth - Cryptophlebia leucotreta Meyr. (Lepidoptera: Olethreutidae); the pink bollworm - Pectinophora gossypiella Saund (Lepidoptera: Gelechidae) and the spiny bollworms Earias insulana Boisd, E. biplaga Walk (Lepidoptera: Noctuidae). The spiny bollworm and red bollworm occur earlier in the season than the other bollworms, with red bollworm peak emergence in September - October.

2.5.2.1 Red bollworm

D. watersi is a major pest of cotton in the cotton growing areas of the world (Pearson, 1958). It is the most important bollworm in terms of population, incidence and level of damage of cotton in northern Nigeria (Caswell and Raheja, 1977), although recent pest surveys have indicated the increasing importance of H. armigera and C. leucotreta (Anon., 1983).

Damage to the cotton crop is caused by the larvae, the young of which feed on flower buds and bolls, or occasionally on immature bolls, which are consequently shed (Libby, 1968). The larva completely enters the bud or green boll, using the

excrement to block the entrance hole from within, while it feeds on the bud or boll content. The larvae are red, later becoming green with red markings, a red head capsule and a black prothoracic shield.

Its natural enemies in the field include Carcelia evolans Wied (Diptera: Tachnidae), Apanteles spp. and Bracon brevicornis Wesm (Hymenoptera: Braconidae) (Pearson, 1958; Libby, 1968).

2.5.2.2 Spiny bollworm

Two species, E. biplaga and E. insulana, are recorded as being major pests of cotton in Nigeria. E. insulana predominates in the northern cotton fields, while E. biplaga is more prevalent to the south where it is also a pest of cocoa (Libby, 1968). Raheja (1981) reported E. biplaga as an early season pest which occurs at the beginning of the wet season, and E. insulana as a late season pest which occurs at the end of the wet season.

The larva which does the damage is stout, spindle shaped, with characteristic long hairs and two pairs of fleshy spines on each segment. It attacks buds, flowers and unripe fruits (Libby, 1967; Raheja, 1981). Unlike other bollworms, its larva has a marked propensity for stem boring, resulting in the wilting of growing points and poor plant growth

(Ripper and George, 1965). Attacked buds and unripe bolls are shed. Its population on the field are attacked by parasites and predators like Apanteles diparopsidis Lyle, Phanerotoma hendecasisella Cam. (Hymenoptera: Brac onidae) and Rygchium ventrale Sauss (Hymenoptera: Eumenidae) (Pearson, 1958).

2.5.2.3 American bollworm

H. armigera is one of the major pests of maize, tomato, tobacco, citrus and vegetables (Libby, 1968). Damage to cotton plants is caused by the larva which feeds on the buds and flowers and consumes their contents. It occurs throughout the season. The larvae vary in colour from green to brown or black, with alternating dark stripes and a mid-dorsal line which runs the length of the body. Attacked buds and young bolls are shed, with neat, round entrance holes (Pearson, 1958; Libby, 1968). Older bolls, when attacked, may mature with one or two locks damaged, unless they are further affected by rot pathogens.

The larva is an extremely voracious and polyphagous feeder which moves about the cotton plant considerably, thus damaging many fruiting bodies, with only one lock fed on (Ripper and George, 1965). H. armigera infestations originate from alternative dry season hosts as it has no diapausing pupae (Lyon, 1972).

2.5.2.4 False codling moth

C. leucotreta is one of the major pests of cotton in Africa (Pearson, 1958). In Nigeria, it is a late season pest and occurs at the end of the rainy season in the main cotton growing areas (Anon., 1976). In the more humid southern cotton fields, it is the most injurious bollworm (Libby, 1968). The insect attacks the mature green bolls. The body of the larva is plain coloured with shinning dark spots which give it a spotted appearance. The younger larvae feed almost entirely inside the boll wall, while the older ones penetrate the boll cavity to feed on the developing seeds and lint. It is also a pest of cucumber, squash, citrus, tomato and okra (Libby, 1968).

2.5.2.5 Pink bollworm

P. gossypiella is a primary pest of cotton in all cotton growing areas of the world (Pearson, 1958). Damage to the green boll is caused by the larvae, which feed on the seeds, eating out the kernel and damaging the immature lint. In heavily infested fields, many bolls are damaged and they fail to open or open prematurely with very dirty lint. Although a major pest of cotton, it is only of primary importance in the more humid cotton fields of southern Nigeria (Libby, 1968; Raheja, 1981).

Other insect pests of this growth phase of cotton include Oxycarenus dudgeoni Dist. and

especially the cotton stainers, in the absence of chemical control (Faulkner, 1974).

Cultural practices such as time of planting, crop spacing and intercropping, among others, have been observed to have some potential for reducing populations of many pest species and capable of increasing those of beneficial insects - natural enemies (Perrin, 1977; Usenbo, 1977; Lawani, 1982; Uvah, 1983).

2.6.1 Crop Diversity: Its effect on pest population and control

The principle and mechanism of insect pest incidence and population control by increased crop diversity of an agroecosystem have been discussed by many researchers including Way (1976) and Perrin (1977). The mechanisms of such control are barrier effects by the intercropped systems on the pest, visual effects, diversionary effect, chemical effect and natural enemy action.

Crop diversity enhances stability and control of pest populations in an agro-ecosystem (Usenbo, 1977) as host-plant diversity encourages year round activities of the pest, which are essential for biological control (Way, 1976).

Assessing pest damage to cowpea intercropped as a relay crop with millet in sorghum in the Zaria

area of Nigeria, Uvah (1983) reported 44.7%, 35% and 90% reduction in the abundance of Maruca testulalis Seyer, Megalurothrips sjostedti Trybon and pod sucking bugs, respectively, on intercropped cowpea, compared to the monocrop. The cowpea is believed to be partially protected by the sorghum, which acts as a non-host physical barrier, thus confusing landing insect pests of cowpea. Intercropping cotton with okra, tomato and maize have similarly been reported to have marked effects on pest infestation (Usenbo, 1977). Usenbo observed that cotton interplanted with tomato or okra had fewer pests than when cultivated as a sole crop. He concluded from his trial that natural enemy build up was high in the intercrop and thus accounted for the low pest infestation, in addition to serving as diversionary host plants for colonising insect pests of cotton such as aphids and cotton stainers.

Crop diversity can be achieved within the cultivated main crop or in the areas adjoining the habitat, which may serve as a reservoir of crop pests and their natural enemies (Dempster and Coaker, 1974). Crop diversity by intercropping however, may or may not affect pest population stability depending on the types of crops and particular growth stage of each crop in the mixture (Perrin, 1977).

Intercropping as a method of pest control is based on the pest population stability principle of

the diversity/stability theory. Intercropping which is synonymous with mixed cropping, describes those cropping patterns whereby more than one crop is simultaneously grown on the same land. The crops may be on different but proximate rows or on the same row or just intermingled with no distinct row arrangement (Abalu, 1984). Taylor (1976), on the other hand, defined mixed cropping as the cultivation of a secondary short duration crop, which is sown after the main crop and harvested before it. He also defined interplanting as the cultivation of a secondary crop which is sown after the main crop and harvested after it. Thus intercropping means cultivation of two or more crops, such that the plants in the mixture overlap temporarily and spatially during most of their growth.

Intercropping, with its pest and disease regulatory effect, can be said to be a desirable feature in increased food production with minimum input, as it is capable of increased yield without additional control measure (Perrin, 1977. Uvah, 1983). This is achieved via some features which influence insect pest populations and control. These include (i) visual unattractiveness of the host crops; (ii) unsuitable micro-climate or habitat for insect development; (iii) obstacles to dispersal; (iv) favourable environment for the development of natural enemies and (v) chemical factors such as odour confusion.

2.6.2 Cotton and cereals intercropping

Intercropping of cotton with cereals is extensively practiced in Africa, as it economises labour by making one clearing operation serve two crops (Pearson, 1958). In Nigeria, cotton is intercropped with cereals like millet, sorghum to the north (Baker, 1979), while to the south it is intercropped with maize (Usenbo, 1977).

From studies on cereal/cotton mixtures in northern Nigeria, Baker (1979) reported that the yields of cereals are not affected by the presence of cotton, but that yields of cotton are affected by both delayed sowing and intersowing between cereals. Comparing cotton intercropped with maize and legumes to sole cotton, intercropped cotton/maize has been observed to give a higher yield than sole cotton (Kumar, 1980; Kumar et al., 1983). Productivity of maize is not affected by cotton, while the frame of cotton in mixtures is comparable to that of sole cotton, provided the cotton is planted early along with maize or soon after and protected from pest damage by insecticide spraying.

Growing of maize and cotton (which are hosts to some common pests) on the same piece of land, has been reported in the literature to influence pest population and level of damage in such mixture. The particular growth stages of maize and cotton at the time of pest invasion determine whether or not diversion from

cotton occurs. This has been reported for H. armigera and Dysdercus spp. whose attack on cotton varies according to the growth stage and amount of maize relative to cotton at the time cotton is susceptible to attack (Pearson, 1958; Lawani, 1982).

In Peru, the cotton-maize mixture has been successfully used in the control of H. armigera on cotton, whereas such combinations have been observed to lead to increased H. armigera damage on cotton in California, Ivory Coast, Sudan and Tanzania (Pearson, 1958; Lawani, 1982). The failure of cotton-maize mixture in these instances was attributed to the absence of an attractive growth stage of maize (tasselling to cob formation) when H. armigera and Dysdercus spp. are abbundant and destructive (Perrin, 1977).

Thus intercropping of cotton with maize, although capable of leading to increased cotton yield, is also capable of creating more pest problems, unless a suitable cropping sequence is employed, such that the maize crop tasselling to cob formation stages coincide with early stages of boll formation.

2.7 Chemical Control of Insect Pests of Cotton

Chemical protection of the cotton crop using insecticides has remained an important component of pest management programmes geared towards increased cotton production. Kumar et al., (1982) observed

that yield increases resulting from early planting, use of fertilizers and herbicides are dependent to a large extent on the efficiency of pest control.

Investigations into the use of insecticides for the control of insect pests of cotton in Nigeria date back to 1949 (Choyce, 1957). Such early trials in the main cotton growing areas of Nigeria were designed to control the bollworms, particularly the red bollworm (D. watersi), a major pest of cotton which passes the dry season as a diapausing pupa (Lyon, 1972).

Insecticides used in Nigeria for cotton insect pest control include DDT, BHC, DDT/BHC mixture, aldrin, chlordane (Choyce, 1957 and 1966; Caswell, 1973). Others are endosulfan, carbaryl, monocrotophos and synthetic pyrethroids like cypermethrin and decamethrin (Caswell and Raheja, 1977).

Choyce (1957) observed that DDT was effective in reducing bollworm population, although with no corresponding increase in yield. From other trials using toxaphene, dieldrin and endrin formulation, which were equally effective against the bollworms, he concluded that for increased yield to be obtained, other pests in addition to the bollworms should be controlled in a cotton agro-ecosystem. Choyce (1966) similarly observed increased yield with insecticide spraying to control pests of cotton - the bollworms and the cotton stainers.

Coaker (1957) reported DDT and toxaphene at 0.2% mixture to be effective against the bollworm larvae and Lygus vosseleri Popp., noting that late bollworm attack was most important in yield reduction in Uganda. Like Choyce (1966), he concluded that insect pests control in agro-ecosystems results in increased early yields, as against the low and late yields of unsprayed plots. Other workers like Caswell and Raheja (1977), Raheja (1981) and Kumar et al., (1982) have similarly reported that protected cotton gave early and higher yields of cotton than the unprotected cotton.

Six sprays at weekly intervals, starting from the 9 - 10th week after planting with 5.6 litres of DDT or BHC and 1.1 kg of carbaryl wettable powder in 225 litres of water per ha, have been recommended and used to control insect pests of cotton in Nigeria (Anon. 1976; Raheja, 1981). Choudry (1982) observed that monocrotophos and endosulfan at 3 litres/ha were effective against some of the bollworms had no marked effect on the incidence of cotton stainers and H. armigera. This suggests that the insecticides were ineffective against the cotton stainers and H. armigera.

Owing to the high mammalian toxicity and persistence of the early insecticides such as DDT and lindane, the trend in pesticide usage in Nigeria is towards the use of the relatively safe synthetic

pyrethroids like cypermethrin and Decamethrin (Caswell and Raheja, 1977). Synthetic pyrethroids, in the main, combine high insecticidal activity with low mammalian toxicity. They have an additional advantage of a rapid knockdown effect and unlike the earlier used insecticides (DDT/BHC, Carbaryl) only three spray applications at bi-weekly intervals are needed for a cotton crop, starting from the tenth week after planting. Compared against DDT, BHC and Carbaryl, 5% cypermethrin at 2.5 litres/ha has been reported to give a better control and a resultant increased yield which is about three times that of the unsprayed plots (Kumar et al., 1982). Cypermethrin at 100g a.i./ha and Decamethrin at 10g a.i./ha in 200 litres of water are recommended as E.C. formulations, while 2.5 litres and 1 - 2 litres of ULV/ha respectively are recommended for ULV application (Raheja, 1981; Anon., 1983).

2.8 Insecticide Application Methods

Different methods have been recommended for the application of insecticides under the Nigerian environment (Beeden, 1974; Bindra, 1980). These include the use of (a) conventional low volume spraying, (b) ultra-low volume spraying and very recently (c) electrodyn spraying (Raheja et al., 1984).

2.8.1 Low volume application (LV)

LV application equipment used in Nigeria include the lancelet sprayer, the falcon, losa-3, Tenama and C P-3 knapsack sprayers (Bindra, 1980). The C P-3 knapsack sprayer with a capacity of 20 litres is commonly used, as fewer fillings are required for spray application.

The C P-3 knapsack sprayer is a hydraulic energy sprayer, with a manually operated hand pump. It requires no medium of transportation to the target crop. As a traditional spray method, it is observed to be a versatile and effective spray method (Anon. 1976). However, it is an inefficient spray process, since much of the pesticides are not deposited in the target plant, thus leading to contamination on non-target areas (Bals, 1978; Raheja et al., 1984). In addition, large volumesof water are needed.

2.8.2 Ultra low volume (ULV)

ULV spraying is defined as the application of the minimum volume of pesticide per unit area compatible with economically desired goals (W.H.O., 1971).

The technique of ultra low volume (ULV) spraying is an improvement over the traditional methods (LV sprayers) with smaller droplets (80 - 120 um), higher recovery and reduced active ingredient and volume applied per hectare (Raheja et al., 1984).

Compared with the conventional method of insecticide application, a principal feature of ULV application is reduction of costs associated with transporting, mixing and application of the non-toxic portion of the spray mixture (diluent) (Beeden, 1974).

The spray technique has been extensively used in Africa, including Nigeria, to control pests of cotton. Seed cotton yields of upto 1,643 kg/ha have been obtained using 2.5 litres/ha, of the ULV formulation as against 1,435 kg/ha using 200 litres/ha for the conventional spray method (Beeden, 1974; Bals, 1978).

However, the main disadvantage of the ULV method is the fact that small droplets are very drift prone and wind direction is crucial for deposition of pesticides on the target crop (Raheja et al., 1984). In addition, power (battery) consumption is high, with weak batteries giving ineffective coverage as it affects atomization and thus droplet size (Beeden, 1974).

2.8.3 'Electrodyn' application method

Electrodynamic spraying (ED) is a new method of pesticide application which uses an electric field effect to charge the spray droplets and thus an improved method of controlled droplet application of pesticides with increased efficacy (Coffee and Kohli, 1982).

The 'Electrodyn' sprayer, designed to produce electrically charged droplets, differs from the popular

ULV applicators since the small droplets produced (40 - 60 microns) are electrically charged and attracted to the earthed target. Thus, like the knapsack sprayer, it is a placement sprayer which does not require an extra medium for its transportation to the target crop.

The electrodyn method has been used in different crop situations including cotton and cowpea, although its initial objective was pest control in cotton (Morton, 1982).

On cotton pests, with its low flow rate of 0.05 - 0.1 ml/sec., 'ED' sprays at 0.5 litres/ha have been observed to give a good control of the major bollworm pests, using a two row swath. In a 3-year trial (1981 - 1983) conducted at the Institute for Agricultural Research, Samaru, using some synthetic pyrethroids - Cymbush ED; Cymbush + dimethoate, ED spraying gave a good control of insect pests of cotton and cowpea (Raheja et al., 1984). However the method is believed to be of limited value in intercropping situations. Compared to the other spray methods, the 'ED' sprayer has the following advantageous features:

(a) production of droplets, control of their size and entrainment to the target crop by electrical means.

(b) simplicity and low energy requirement of the machine as four U-2 batteries are used as against (eight) for ULV sprayers.

(c) an improved spray recovery and distribution over hidden surfaces of the target plants. This ensures no contamination of the environment, as no pesticide is lost to the non-target areas.

(d) cost of pesticide application is cheaper than the ultra low volume and low volume application methods (Raheja et al., 1984).

From the various trials conducted in Nigeria, the three methods of spray application above have been found to be effective against the insect pests of cotton, although each method has one disadvantage or another. The use of LV, knapsack sprayer is handicapped by the large volume of water needed, while the ULV application, being wind dependent, is effective only in a situation of cross-wind effect. The 'ED' spray method has limited use in an intercrop situation.

CHAPTER 3

MATERIALS AND METHODS

3.1 Experimental Site

The research work was carried out in the 1984 and 1985 cropping seasons, on plot E_3 in the Agronomy Field, Institute for Agricultural Research, Samaru, Zaria (Lat 11° 11' N, Long 07° 38' E, 686 M) in the northern Guinea savanna ecological zone of Nigeria.

3.2 Crop Varieties

Maize variety 'TZB' and cotton variety 'Samaru 71' were used.

3.3 Fertilizer and Fertilizer Application

Calcium ammonium nitrate (200 kg/ha), boronated superphosphate (300 kg/ha) and muriate of potash (100 kg/ha) were applied by broadcasting on the harrowed plot which was later split into ridges.

A side dressing of 250 kg/ha CAN (1.9 kg/plot) was applied five weeks after planting in the 1984 cropping season and four weeks after planting in the 1985 cropping season.

3.4 Planting and Plant Arrangement

Planting Commenced as soon as the field was ready. In 1984, planting commenced on 31 May and

ended on 6 June, while in 1985 planting started on 22 May and ended on 28 May.

The cotton-maize mixtures were sown in two types of plant row arrangement:

(a) regular row arrangement and

(b) paired row arrangement.

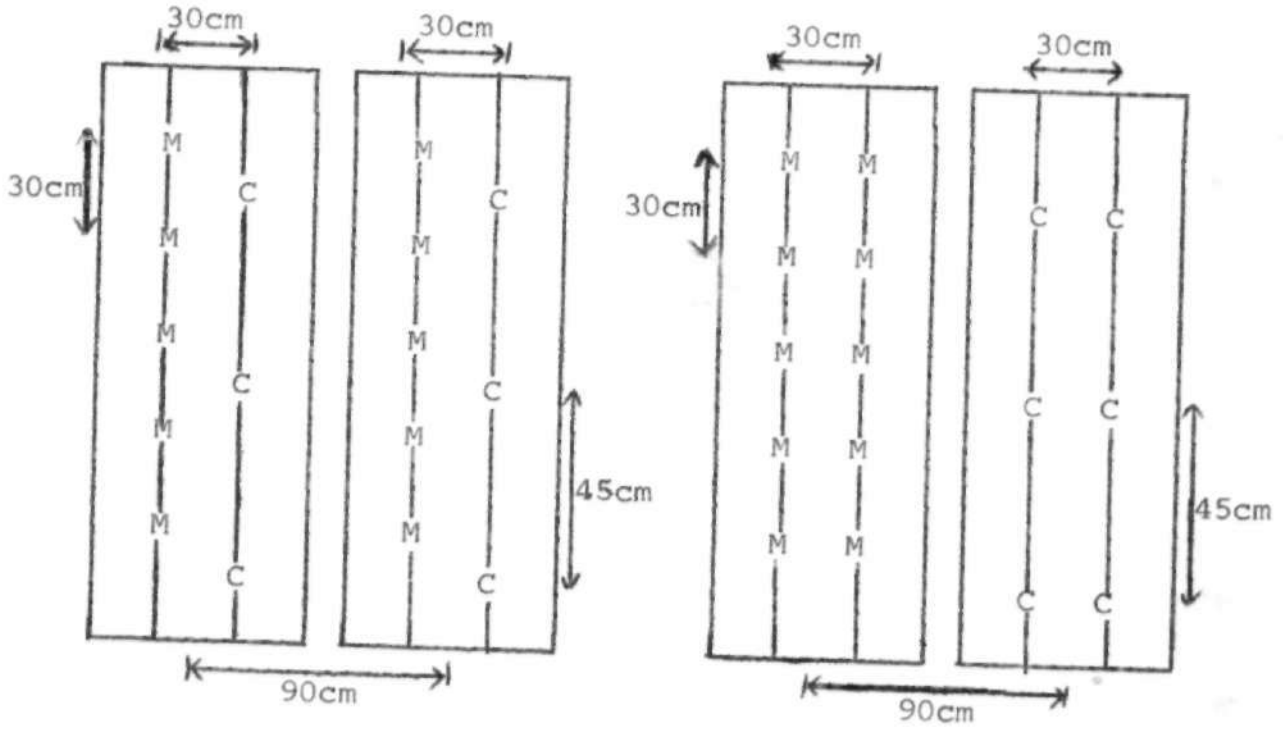
In the regular row arran gement, cotton and maize were sown in alternate rows on either side of the same ridge, while in the paired row arrangement, two rows of cotton on a ridge alternated with two rows of maize on a different ridge (Fig. 1). The ridges were spaced 90cm apart. Two to three seeds of maize were sown per hole 30cm apart and thinned to one plant/stand at two weeks after planting (a total of 180 plants/plot). Cotton seeds were sown six per hole 45cm apart. At three to four weeks after planting (WAP), cotton seedlings were thinned to two plants/stand and four plants/stand (in cases of poor germination) to obtain a total population of 120 plants/plot. This spacing gave dense planting of cotton plants as suggested by Kumar and Ogunlela (1982).

In all 32 plots were used for the trial and each plot was made up of six ridges of 9 metres long and 90 centimetres wide (Fig. 2). In the 1984 cropping season, each plot in a replicate was separated from the other by two guard rows which

were sown to maize, to minimise insecticide drift from adjoining plots. Two ridges at each end of the plot (ridges 1, 2, 5, 6) served as the sample rows for insect bionomics and growth parameters data, while ridges 3 and 4 were marked and used for yield data collection.

In 1985, the control (unsprayed) plots were separated from the insecticide spray plots. In this layout, the plant arrangements were randomised, while the control plots were placed at the two extremes of the replicate layout, separated from the sprayed plots by guard plots sown to maize.

In both years, about 0.260 hectares of land was used to carry out the research. Throughout the research period, normal field operations such as thinning, and weeding, were carried out manually. Three hoe weeding operations were carried out in each year of the trial.



Regular row arrangement.

M = Maize

Paired row arrangement.

C = Cotton

Fig. 1. Diagramatic representation of row arrangments used to compare cotton + maize mixtures on regular row and paired row arrangement.

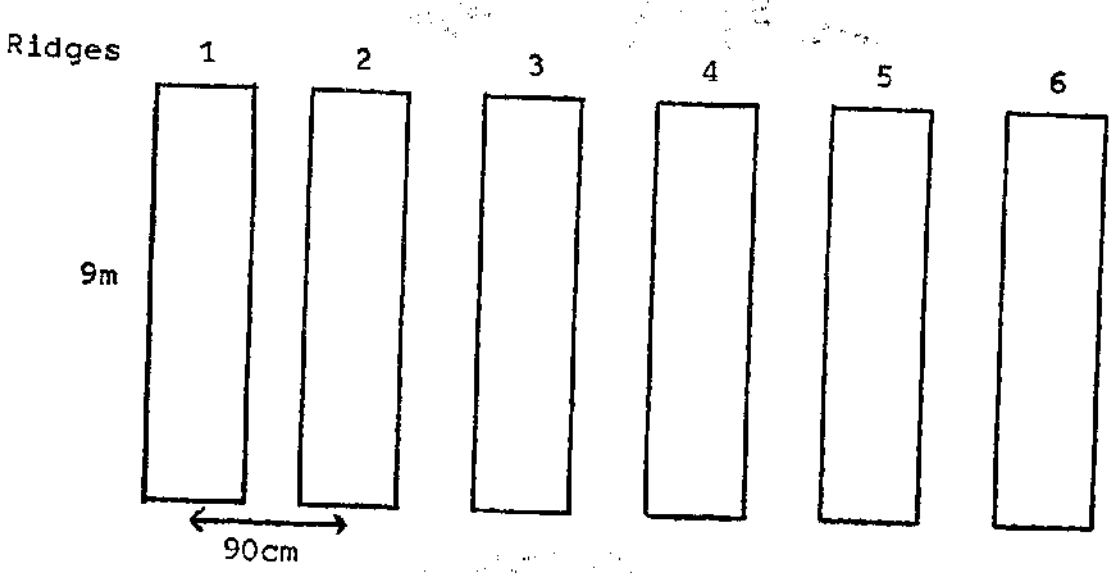


Fig. 2. Diagramatic representation of a plot showing the rows used for sampling and recording yield data.

3.5 Insecticides and their Application

In the 1984 cropping season, cypermethrin (Cymbush 10% EC) a product of Imperial Chemical Industry Ltd. (ICI), available from Chemical and Allied Products (CAP) Ltd., Nigeria, was used. In 1985, sherpa plus EC a mixture of cymbush (from ICI) and dimethoate (Perfekthion 40% E.C. available from BASF, Nigeria) was used owing to the non-availability of 'ED' cymbush formulation when spraying commenced.

Three insecticide application methods were used (i) low volume (LV) application with a CP-3 knapsack sprayer (a product of Cooper and Pegler Co. Ltd., supplied by G.B. Olivant - U.A.C., Nigeria); (ii) Ultra low volume (ULV) application with a Micron 'ULVA' sprayer (a product of Micron Sprayers Ltd., supplied by Nigerian Hoechst Ltd.) and (iii) 'Electrodyn' (ED) application with the Electrodyn sprayer (supplied by ICI Ltd., U.K.).

3.5.1 Low volume (LV) application

In the 1984 cropping season trial, the formulation used was Cymbush 10 E.C. (100g/l) applied at the rate of 1 litre (100g a.i.) in 200 litres of water/ha. In the 1985 season, a combination of 50g a.i. cymbush plus

200g a.i. dimethoate was used i.e. 500 ml of Cymbush 10 E.C. (100g/l) plus 500 ml of dimethoate 40 E.C. (400g/l) was sprayed in 100 litres of water/ha. The one row swath recommended for knapsack sprayers was used.

3.5.2 Ultra low volume (ULV) application

In the 1984 season, ULV formulation of Cymbush containing 3% a.i. cypermethrin (30g a.i./l) was applied at the rate of 2.5 litres/ha (i.e. 75g a.i./ha). In 1985, Sherpa plus ULV (available from Rhone - Total Nigeria Ltd.) containing 12g a.i./l of cypermethrin and 100g a.i./l of dimethoate was applied at the rate of 2.5 l/ha (i.e. 30g cypermethrin plus 250g dimethoate). In each year of the trial, the ULV applicator with a yellow stem (nominal flow rate of 0.5 ml/sec.) was used with a swath width of two rows as suggested by Kumar et al (1983).

3.5.3 'Electrodyn'(ED) Application

Cymbush 3 ED (30g a.i./l) formulation was applied at the liquid rate of 500 ml/ha (15g a.i./ha) in 1984. In 1985, Cymbush 3 super/ED containing 30g a.i./l cypermethrin + 50g a.i./l dimethoate was applied at the rate of 500 ml/ha (i.e. 15g a.i. cypermethrin + 25g a.i. dimethoate/ha). The nominal flow rate was 0.05 - 0.1 ml/s and the swath width was two rows.

Insecticide spraying commenced on 23 August (11 WAP) for the 1984 cropping season and 2 August (10 WAP) for the 1985 cropping season, when 40-50% of the cotton plants had flowered. Three spray applications at two weeks interval were used commencing at 10 - 11 WAP.

3.6 Treatments

There were eight treatments made up of two types of plant arrangements (regular row and paired row) and four spray treatments (control, low volume, ultra low volume and electrodyn).

The treatments were completely randomised with four replications (Fig. 3). Thus the completely randomised block design was used to carry out the research work.

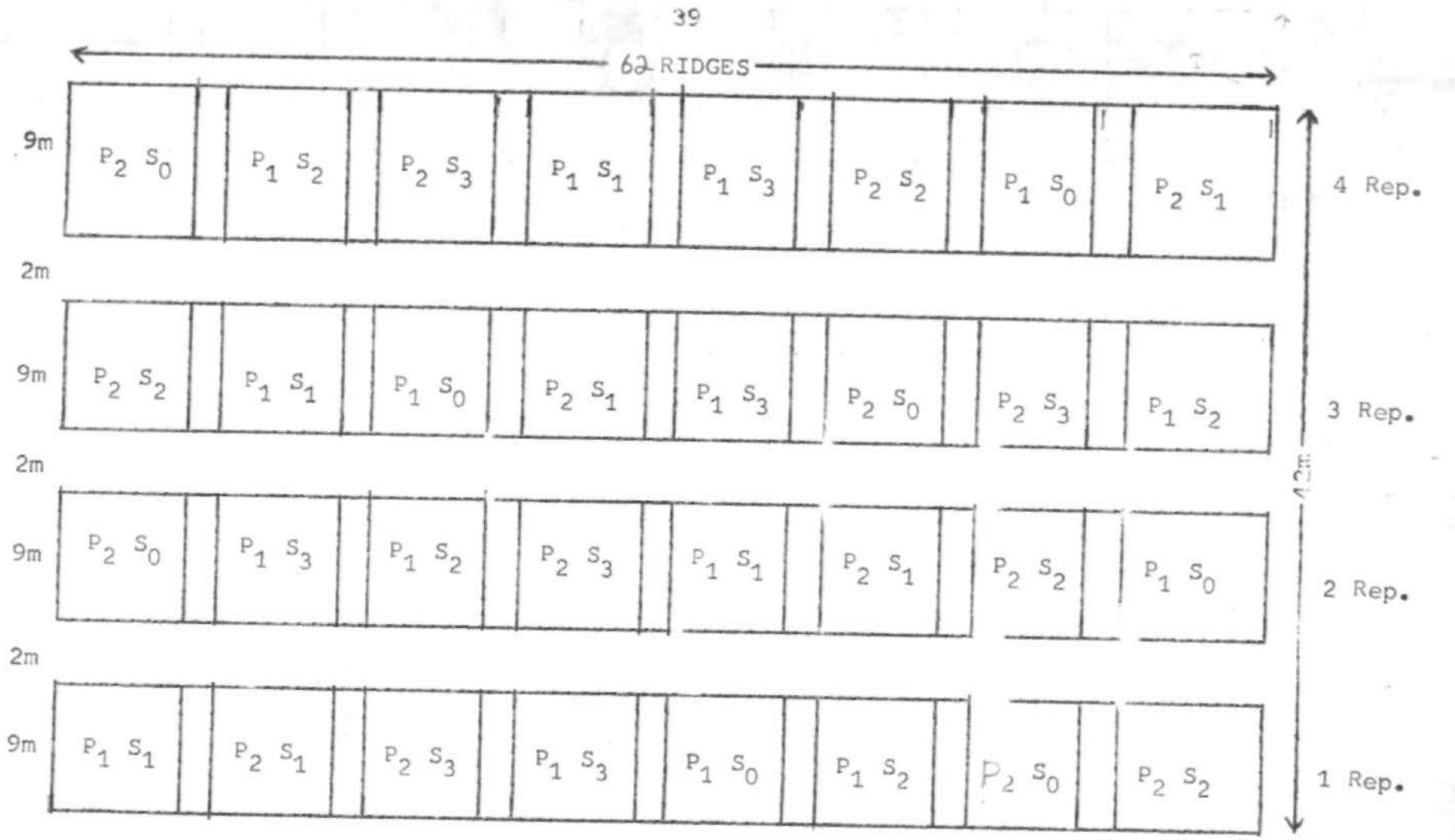


Fig. 3. General layout of the field showing random allocation of treatments.

Treatment symbols

$P_1 S_0$ = Regular row/control.

$P_1 S_1$ = Regular row/Low Volume Spray.

$P_1 S_2$ = Regular row/Ultra - Low Volume Spray.

$P_1 S_3$ = Regular row/'Electrodyn' Spray.

$P_2 S_0$ = Paired row/Control.

$P_2 S_1$ = Paired row/Low Volume Spray.

$P_2 S_2$ = Paired row/Ultra - Low Volume Spray.

$P_2 S_3$ = Paired row/'Electrodyn' Spray.

3.7 Sampling Methods For Insect Incidence and Assessment of Damage

The population dynamics of several insect pests of cotton were studied from the first true leaf stage (4 - 5 weeks after planting - WAP), until bolls opened up (16 - 17 WAP). Emphasis was placed on (1) aphids and their coccinellid predators, (2) cicadellids, (3) whiteflies, (4) the cotton leaf roller, (5) the cotton stainer and (6) the bollworm complex.

The following methods were used in collecting data on the insects

(a) Handpicking (cotton stainers, coccinellids).

(b) Use of ground cloth technique (ants, aphids, coccinellids).

(c) Use of polythene bags (aphids, cicadellids).

(d) Use of sweep net (cotton stainer, coccinellids, cicadellids, whiteflies).

(e) Direct physical count (leaf roller, cotton stainer, whiteflies) and

(f) Use of damage indices (bollworms and sucking pest damage).

The sample rows (ridges 1, 2, 5 and 6) were used for insect counts. In each plot ten stands of cotton

were randomly selected from the sample rows each week of sampling and the numbers of each insect present were noted in the proforma. The insect count commenced at 4 - 5 WAP and ended 16 - 17 WAP when the cotton bolls opened up for picking.

3.7.1 Aphids and coccinellid predators

Aphids were physically counted using the colony method (Usenbo, 1980). Polythene bags were used to collect samples for identification. The ground cloth technique was used for ants and coccinellid beetles. The plants were gently tilted over the spread cloth (1.0 x 1.0 Sq. m.) and hit or shaken to dislodge the beetles and ants. The insects thus collected were counted and samples were taken for identification.

For the maize aphids Rhopalosiphum maidis Fitch, the tassels were randomly selected, cut off and shaken unto the ground cloth.

3.7.2 Cicadellids

The Cicadellids which rested on the undersurface of the leaves were counted directly and polythene bags used to collect some for identification. Nymphs and adults were counted together.

3.7.3 Whiteflies

The direct count method was used after gently raising the leaves to expose the undersurface of the leaves on which the whiteflies fed.

3.7.4 The cotton leaf roller

The number of rolled leaves per stand was used as an index for assessing leaf roller incidence and rolled leaves were occasionally opened up to see if the parasite Apanteles spp. was present.

3.7.5 The cotton stainer

The nymphs of the cotton stainer were handpicked and counted, while the adults were counted insitu.

During the first two weeks of sampling the sweep net was used. It was swept over ten stands from the sample rows and the insects caught were counted and identified. As the plants grew larger this method became unsuitable and other methods like handpicking and direct physical count were used.

3.7.6 Fruiting body damage assessment

Damage to the Fruiting bodies (Flower buds, flowers and green bolls) was estimated from 9 - 10 WAP by counting the total number of fruiting bodies produced as well as the number damaged by insects. Damaged fruiting bodies were visually assessed using

damage indices (sucking points and feeding holes) and grouped into (a) those caused by the sucking pests and (b) those caused by the bollworms. The number of damage fruiting bodies was then expressed as a percentage of the total fruiting bodies produced.

Since most of the fruiting body damage is internal and thus not obvious on the outside, internal fruiting bodies damage assessment was carried out in the 1985 cropping season. Starting from 9 WAP until 15 WAP, three stands/plot were randomly selected every two weeks and their fruiting bodies were stripped, bagged and labelled. In the laboratory, the fruiting bodies were cut open and damage indices used to assess insect damage. Stained lint (yellow) or boll rot with sucking points indicated sucking pest damage while feeding holes and tunnelling indicated bollworm attack. Live bollworm larvae when found were collected and identified.

3.7.7 Shed fruiting bodies

During the spray period, fruiting bodies shed by the cotton plants were also collected and assessed for insect and non-insect damage. Shed fruiting bodies were collected on a 3m x 3m mark and examined for damage by sucking and bollworm pests and by non-insect pests.

3.7.8 Sampling sprayed plots

One week before the first insecticide application (pre-spray sample) and two days after each insecticide application, ten stands of cotton were randomly selected from the sample rows and the incidence of and damage due to insects were assessed as described above. This sampling ended two weeks after the last spray (14 - 15 WAP). From the data obtained, the efficacy of the three spray methods was determined.

3.8 Yield Data

At 16 - 17 WAP (for maize) and 19 - 20 WAP (for cotton), four stands per row in the sample rows were selected and the following parameters were measured

Maize: Plant height, number of green leaves, fresh plant weight and number of cobs.

Cotton: Plant height, number of green leaves, fresh plant weight and number of fruiting bodies.

The mature maize cobs were harvested when over 70% of the maize plants had no greenleaf (17 - 18 WAP). In each plot, the cobs of maize in the yield rows were harvested, bagged and labelled according to the plots

and weighed. After removing the cobs, the maize stalks were uprooted and the cotton, which was still growing, was left in the field.

Owing to poor cotton stand establishment, 10 stands of cotton were randomly selected from the yield rows and tagged, as from 16 - 17 WAP, when the bolls started opening. Two pickings of seed cotton were made at two to three weeks interval starting from 20 - 21 WAP. The split bolls were hand picked, bagged and labelled. The remaining cotton plants in the yield rows were also handpicked, bagged and labelled.

The seed cotton was weighed and graded into grades "A" (good quality lint and seed) and "B" (lint and seeds which showed insect damage).

3.9 Statistical Analysis of Data

The insect counts and yield data were statistically analysed, using analysis of variance (ANOVA) and standard error for some of the treatments (effect of plant row arrangement on the number of aphids, cicadellids, whitefly, leaf roller, cotton stainer). The least significant difference (LSD) at the 5% level, was used to compare the means of the spray treatments. Some of the data was also illustrated graphically.

CHAPTER 4

RESULTS

4.1 Effects of Plant Row Arrangement and Spray Treatments on Cotton and Maize Growth Parameters

The maize (2 - 2.2 m) was much taller than the cotton (0.9 - 1.3 m). The cotton was overshadowed more in the regular row arrangement than in the paired rows (Plates I and II).

Cotton: The effects of plant row arrangement and spray treatments on the growth parameters of cotton and maize are shown in tables 1 and 2. In 1984, there was no significant difference in the height of cotton between the paired row (1.3m) and the regular row (0.9m) arrangement (Table 1). There was also no significant difference between the two row arrangements in the number of green leaves. However fresh plant weight and the number of fruiting bodies per plant were significantly higher in the paired row than in the regular row arrangement. None of the growth parametres was significantly affected by the method of insecticide application (Table 1).

In 1985, all the parameters measured had significantly higher values in the paired row than in the regular row arrangement (Table 1). As with 1984, none of the parameters was signifactly affected by the method of spraying (Table 1).



Plate I. Regular row arrangement of Plants (Cotton and Maize).



Plate II. Paired row arrangement of Plants (Cotton and Maize).

Table 1. Effects of plant row arrangement and spray treatments on some growth parameters of cotton.

Treatments	1984				1985			
	Plant height (m)	No. green leaves/ plant	Fresh plant wt. kg/plant	No. of fruiting bodies/ plant	Plant height (m)	No. green leaves/ plant	Fresh plant wt. kg/plant	No. of fruiting bodies/ plant
Plant arrangement								
Regular rows	0.9	17.9	1.0	69.0	1.0	13.1	1.3	60.3
Paired rows	1.3	19.6	1.9	87.0	1.4	21.3	2.8	96.3
LSD (P = 0.05)	NS	NS	0.6	16.0	0.2	6.5	0.7	32.9
Spray Treatments*								
No. spray	1.2	19.5	1.5	69.0	1.2	13.5	1.9	80.3
Low volume	1.1	16.6	1.3	73.0	1.3	17.5	2.4	87.3
Ultra-low volume	1.2	21.6	1.5	76.0	1.3	21.4	2.0	67.7
Electrodyn	1.1	17.0	1.4	73.0	1.4	16.5	1.9	77.8
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS. = Not Significant. *Data pooled for plant arrangement.

Table 2. Effects of plant row arrangement and spray treatments on some growth parameters of maize.

Treatments	1984				1985			
	Plant height (m)	No. green leaves/ plant	No. cobs/ plant	Fresh plant wt. kg/plant	Plant height (m)	No. green leaves/ plant	No. cobs/ plant	Fresh plant wt. kg/plant
Plant arrangement								
Regular row	2.2	7.6	1.9	2.2	2.7	2.9	1.7	2.2
Paired row	2.0	6.6	1.6	1.9	2.1	3.5	1.5	1.9
LSD (P =0.05)	NS	NS	NS	NS	0.4	NS	NS	NS
Spray treatments								
No spray	2.0	6.4	1.2	1.8	2.2	3.6	1.5	2.1
Low volume	2.2	8.0	1.3	2.1	2.1	2.7	1.4	2.2
Ultra-low volume	2.1	7.2	1.5	2.2	2.2	3.7	1.7	2.1
Electrodyn	2.1	6.7	1.5	2.1	2.0	2.7	1.7	2.0
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Maize: For maize (Table 2), the effect of plant arrangement was the reverse of that observed for cotton. The growth parameters had higher values in the regular than in the paired row arrangement, although the difference was significant for plant height only. The method of insecticide application did not significantly influence any of the parameters.

4.2 Effect of Plant Row Arrangement on the incidence of Insect Pest of Cotton

Many insects were found associated with cotton in the cotton-maize mixture. Some of the insects fed on the leaves, while others fed on the squares (flower buds) or bolls or both, or the growing points. These insects are listed in Appendix A.

4.2.1 Cotton aphids

Aphis gossypii were first seen at 4 WAP each year of the trial. The effect of plant row arrangement on the population of the aphid is shown in Figue 4. Ants and coccinellid beetles were found associated with the aphids; the beetles preyed on the aphids while the ants fed on the honey dew secretions of the aphids.

There were fewer aphids in the regular row arrangement than in the paired row arrangement (Appendix B). In 1984, the peak population of aphids occurred in the second week of August (9 WAP) with a

mean of 402.5 in the regular row and 987.5 in the paired row arrangement. The difference was statistically significant (P = 0.05).

Prior to the commencement of spraying (10 WAP) the mean number of aphids per week (averaged over 7 weeks) was 170.1 for the regular row arrangemnt and 349.8 for the paired row arrangement. These numbers fell to 5.0 for the regular row and 10.6 for the paired row arrangement after the first spray at 11 WAP. The difference was not statistically significant (P = 0.05). At the end of spraying four weeks later, mean number of aphids (averaged over 5 weeks) was 12.8 for the paired row arrangement and 10.1 for the regular row arrangement. Post spray data showed that the paired rows had a mean of 11.5 as against 3.2 aphids in the regular rows.

In 1985 when seeds were sown earlier, the peak population of aphids occurred in the second week of August (11 WAP), with 198.8 in the paired rows and 131.3 in the regular rows (Appendix B). Differences between the two arrangements was, however, not significant (P = 0.05).

The pre-spray mean number of aphids was 32.1 for the paired rows. Spraying decreased the aphid numbers to 17.5 and 42.5 respectively for the regular and paired rows, but these numbers increased to a peak of 131.3 and 198.8 at 11 WAP and decreased thereafter.

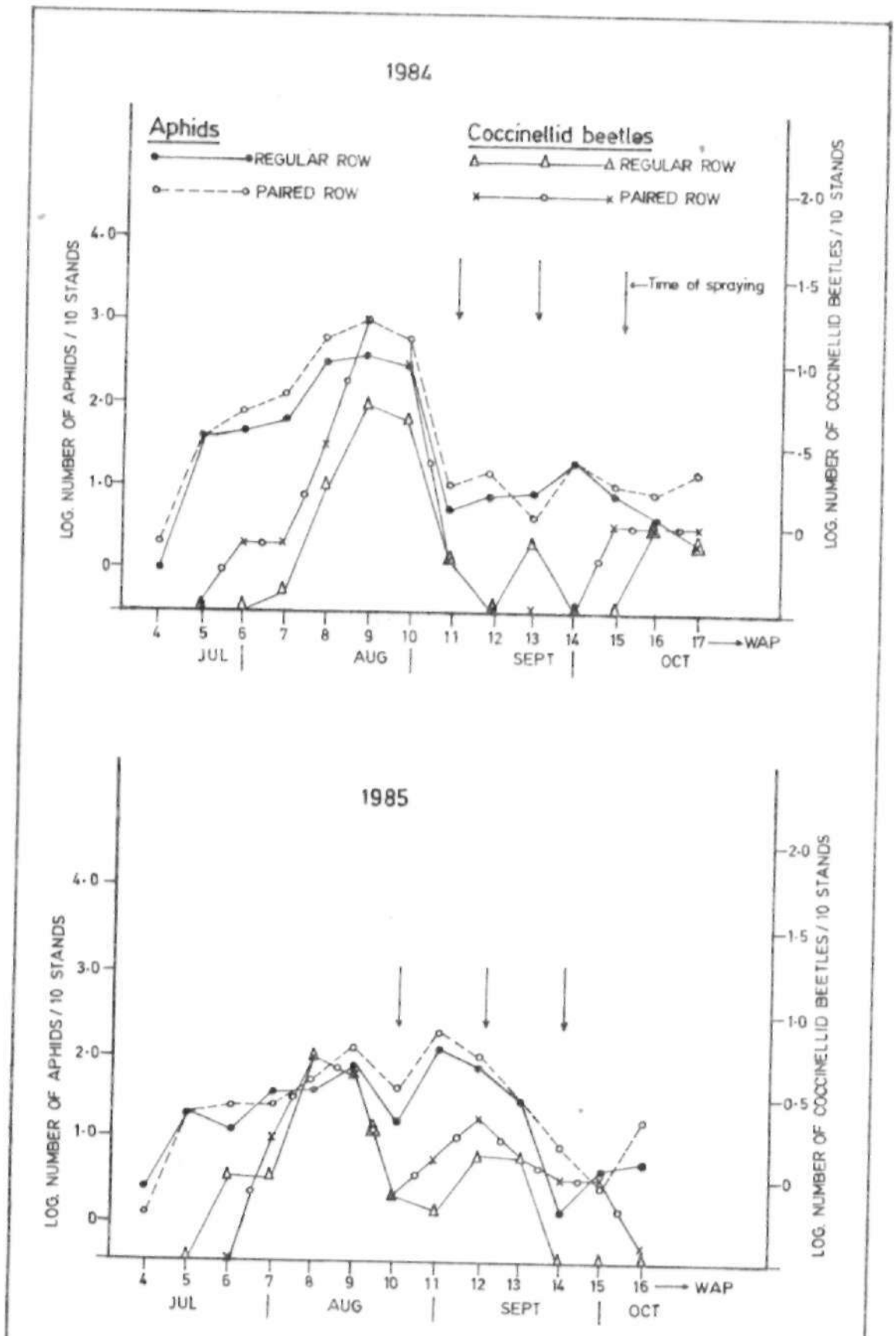


Fig. 4. Effect of plant row arrangement on the number of aphids and coccinellid beetles on cotton in 1984 and 1985.

The ant species found associated with the aphids were Camponotus perrisi For, C. macularus Fab. and C. acvapimensis Meyr (Hymenoptera: Vespidae).

4.2.2 Predatory coccinellid beetles

Coccinellid beetles Exochomus flavipes Thugh, Cheilomenes vicinia Muls and Cheilomenes sulphurea Olive (Coleoptera: Coccinelidae) were first seen preying on the aphids at 5 WAP in both years (Appendix B). Peak populations of the beetlesoccurred at 9 WAP in 1984 with a mean of 6.9 and 15.4 in the regular and paired rows respectively (Fig. 4). The difference between these means was significant. In 1985, the beetles attained peak populations at 8 WAP with a mean of 5.6 in the regular rows and 7.0 in the paired rows. The difference between the means was not statistically significant (P = 0.5).

The mean numbers of ladybird beetles 1 week before spraying commenced were 2.2 for the regular rows and 5.8 for the paired rows in 1984, 2.0 for the regular rows and 2.5 for the paired rows in the 1985 cropping season. The ratio of ladybird beetles to aphids in 1984 during this period was 1 : 77 for the regular row and 1 : 61 for the paired row plant arrangement. In the 1985 cropping season, the ratio for the same period was 1 : 17 for the regular row and 1 : 32 for the paired row.

The number of coccinellid beetles decreased as the number of aphids decreased in both years.

4.2.3 Cicadellids and whiteflies

Empoasca spp. and *Bemisia tabacci* were encountered on the field in both years as early season foliage pests which however persisted until the end of sampling. The weekly mean numbers of cicadellids and whiteflies are shown in Tables 3 and 4 respectively.

More cicadellids were recorded in 1985 than in 1984. In both years, the paired row arrangement supported a higher population of *Empoasca* spp. and *B. tabacci* than did the regular row arrangement.

In 1984, cicadellids were first encountered at 5 WAP with means of 0.2 for both regular rows and paired rows (Table 3). The pest attained its pre-spray peak of 3.7 for the regular row and 4.2 for the paired row arrangement at 10 WAP and a second peak of 5.0 for the regular row and 8.3 for the paired row arrangement at 12 WAP. The difference was significant at 12 WAP ($P = 0.05$).

In 1985 the peak population of the Cicadellids occurred at 8 WAP with a mean of 22.6 in the paired rows and 17.6 for the regular rows. A second peak was recorded at 11 WAP with a mean of 9.6 in the paired rows and 3.1 in the regular rows.

Table 3. Effect of plant row arrangement on the population of Cicadellids on cotton in 1984 and 1985.

Number of Cicadellids/10 Stands

Sampling period (weeks after planting)	1984			1985		
	Regular row arrangement	Paired row arrangement	Variance (F)	Regular row arrangement	Pairedrow arrangement	Variance (F)
Pre-spray data						
5	0.2	0.2		0	0.3	
6	3.3	3.1		2.0	2.5	
7	1.3	2.5		12.4	14.5	
8	0.9	2.5		17.8	22.6	2.7*
9	2.9	4.4		13.1	13.4	0.1 (NS)
10	3.7	4.2	1.8 (NS)			
Total	12.3	16.9		45.3	53.3	
Mean	2.1	2.8		9.1	10.7	
Spray data						
10				2.5	6.4	13.6*
11	0.1	0.4	0.6 (NS)	3.1	9.6	
12	5.0	8.3	2.9*	2.8	3.6	0.3 (NS)
13	0.3	0.3	0.0 (NS)	2.5	3.4	
14	0.2	0.1		0.6	0.6	1.3 (NS)
15	0.5	0.6	0.7 (NS)			
Total	6.1	9.7		11.5	23.6	
Mean	1.2	1.9		2.3	4.7	
Post-spray data						
15				0.6	0.9	
16	0.2	0.3		0.3	0.5	0.8 (NS)
17	0.2	0.6	1.4 (NS)			
Total	0.4	0.9		0.9	1.4	
Mean	0.2	0.5		0.5	0.7	
s.e. ±	0.4	0.6		1.6	2.0	

* = Significant
NS = Not significant

Table 4. Effect of plant arrangement on the population of Whiteflies on cotton in 1984 and 1985.

Number of Whiteflies/10 stands

Sampling period (weeks after planting)	1984			1985		
	Regular row arrangement	Paired row arrangement	Variance (F)	Regular row arrangement	Paired row arrangement	Variance (F)
Pre-spray data						
5	0.3	0.6		0.5	0.3	
6	2.3	4.0		5.1	5.5	
7	7.5	11.3		5.4	6.4	
8	8.6	12.9		15.0	17.0	0.8 (NS)
9	6.8	11.9		4.8	11.0	12.9*
10	15.9	18.9	3.6*			
Total	41.4	59.5		28.8	40.2	
Mean	6.9	9.9		5.8	8.0	
Spray data						
10						
11	2.4	2.4	0.0 (NS)	2.6	7.0	15.3*
12	6.6	4.5		2.0	6.3	
13	3.4	3.1	0.7 (NS)	2.8	4.6	1.8 (NS)
14	2.6	3.1		1.9	3.5	
15	0.6	1.3	1.9 (NS)	1.1	1.3	0.3 (NS)
Total	15.6	14.4		10.4	22.7	
Mean	3.1	2.9		2.1	4.5	
Post-spray data						
15						
16	0.2	0.4		1.0	0.4	4.3*
17	1.6	1.4	1.0 (NS)	0	0	
Total	1.8	1.8		1.0	0.4	
Mean	0.9	0.9		0.5	0.2	
s.e. ±	1.2	1.6		1.1	1.4	

* = Significant
NS = Not significant

There were more whiteflies in 1984 than in 1985 (Table 4).

4.2.4 Leaf roller

Sylepta derogata, a mid season pest of cotton was first recorded at 8 - 9 WAP. The numbers of larvae recorded are shown in Table 5.

In 1984, leaf rollers were first encountered at 8 WAP with means of 0.5 and 0.3 for regular row and paired row arrangements respectively. The peak population occurred 13 WAP with a mean of 18.4 in the regular rows as against 17.2 in the paired rows. The difference was not statistically significant ($P = 0.05$).

There were fewer leaf rollers in the regular row arrangement than in the paired row arrangement in the pre-spray and spray periods. In the post-spray period however, the paired row arrangement had more leaves rolled than the regular row arrangement.

In 1985, leaf rollers were first recorded with 0.5 in the paired rows and 0.0 in the regular rows (9 WAP). The peak population occurred 14 WAP with mean numbers of 12.8 leaf rollers for paired row arrangement and 17.6 for regular row arrangement. The difference between the means was not significant ($P = 0.05$). Post spray data showed that there were more leaf rollers on the paired row arrangement.

Table 5. Effect of plant row arrangement on the number of cotton leaves rolled by Sylepta derogata in 1984 and 1985.

Number of leaves rolled/10 stands

Sampling period (Weeks after planting)	1984 Regular row arrangement	1984 Paired row arrangement	1984 Variance (F)	1985 Regular row arrangement	1985 Paired row arrangement	1985 Variance (F)
Pre-spray data						
8	0.5	0.3	0.4 NS	0	0	
9	3.3	8.8		0	0.5	1.9 NS
10	8.7	18.7	3.8*			
Total	12.5	27.8		0	0.5	
Mean	4.2	9.3		0	0.2	
Spray data						
10				0.8	0	1.4 NS
11	14.1	19.1	1.5 NS	0.8	0	
12	12.5	19.3		5.0	5.4	0.1 NS
13	18.4	17.2	0.1 NS	10.0	5.8	
14	6.3	4.3		17.6	12.8	0.7 NS
15	3.3	3.6	0.3 NS			
Total	54.6	63.5		32.6	24.0	
Mean	10.9	12.7		6.5	4.8	
Post-spray data						
15				2.5	11.4	6.9*
16	1.3	0.3	3.6*	13.1	9.7	
17	0.0	0.1				
Total	1.3	0.4		15.6	21.1	
Mean	0.66	0.2		7.8	10.6	
s.e. ±	1.9	2.5		2.0	1.7	

* - Significant
NS - Not significant

4.2.5 Cotton stainers

Dysdercus superstitiosus and D. fasciatus were encountered during the trial. D. superstitiosus was the main cotton stainer.

In 1984, the cotton stainers (adults) were first recorded 10 WAP with means of 0.1 for the regular row and 0.3 for the paired row arrangement. The pest attained its peak 14 WAP with means of 1.6 and 1.0 in the regular and paired rows respectively (Table 6). Difference between their means was significant at P = 0.05. At the end of spraying, mean numbers of Dysdercus spp. (averaged over 5 weeks) was 0.9 for the regular row and 0.7 for the paired row arrangement. Post spray data (averaged over 2 weeks) showed that the paired rows had a mean of 2.3 as against 1.6 cotton stainers in the regular rows.

In 1985, incidence of Dysdercus spp. was first recorded 11 WAP with a regular row mean of 0.8 and paired row mean of 0.1. The peak population of Dysdercus spp. occurred 14 WAP with 17.6 in the regular rows and 12.8 in the paired rows (Table 6). Difference between the two arrangements was, however, not significant (P = 0.05). Post spray data showed a mean of 7.8 in the paired row and 5.0 in the regular row arrangements.

Table 6. Effect of plant row arrangement on the population of cotton stainers on cotton in 1984 and 1985.

Number of cotton stainers/10 stands

Sampling period (weeks after planting)	1984 Regular row arrangement	1984 Paired row arrangement	1984 Variance (F)	1985 Regular row arrangement	1985 Paired row arrangement	1985 Variance (F)
Pre-spray data						
9	0	0		0	0	0 (NS)
10	0.1	0.3	1.3 (NS)			
Total	0.1	0.3		0	0	
Mean	0.1	0.2		0	0	
Spray data						
10				0	0	0 (NS)
11	0.3	0.8	1.3 (NS)	0.8	0.1	
12	0.3	0.7		5.0	5.4	0.1 (NS)
13	1.2	0.7	1.8 (NS)	10.0	5.8	
14	1.6	1.0	4.2*	17.6	12.8	0.7 (NS)
15	0.1	0.2	1.2 (NS)			
Total	4.4	3.4		33.4	24.1	
Mean	0.9	0.7		6.7	4.8	
Post-spray data						
15				2.5	11.4	
16	3.0	1.9		7.5	4.3	1.0 (NS)
17	0.3	2.8	3.8*			
Total	3.3	4.7		10.0	15.7	
Mean	1.6	2.3		5.0	7.8	
s.e. ±	0.3	0.3		2.0	1.7	

* = Significant
NS = Not significant

By early September, the nymphs of D. superstitiosus emerged with a few adults and the population continued to build up until the split cotton bolls were picked. Phonoctonus spp. were found preying on the cotton stainer adults and nymphs.

4.2.6 Bollworms

The bollworms were rarely encountered on the field, although their damage indices were observed. The spiny bollworm (Earias spp.) and the American bollworm (Heliothis sp.) were the only bollworms encountered before spraying commenced 10 - 11 weeks after planting (Appendix C). Other bollworms found as spraying progressed were the red bollworm (Diparopsis sp.) and the false codling moth (Cryptophlebia sp.). The early instars of C. leucrotreta appeared 14 - 15 weeks after planting. More bollworms were found on the paired row arrangement than the regular row arrangement (Appendix C).

4.2.7 Shed fruiting bodies

Weekly means of shed fruiting bodies are shown in table 7. The paired row arrangement had more shed fruiting bodies than the regular row arrangement. On opening up the shed fruiting bodies, it was observed that the sucking pests and bollworms accounted for 35.7% and 47.8% total fruiting bodies shed in 1984 and 1985 respectively (Table 8).

Table 7. Effect of plant row arrangement on cotton fruiting bodies shed/9m^2 in 1984 and 1985.

Sampling period (weeks after planting)	1984			1985		
	Regular row arrangement	Paired row arrangement	Variance (F)	Regular row arrangement	Paired row arrangement	Variance (F)
Pre-spray data						
9	1.0	0.5		1.1	0.8	0.3 (NS)
10	3.5	4.0	0.4 (NS)			
Total	4.5	4.50		1.1	0.8	
Mean	2.3	2.3		1.1	0.8	
Spray data						
10				1.9	3.2	2.3 (NS)
11	4.3	5.8	1.3 (NS)	1.9	5.7	
12	5.3	7.9		3.3	8.1	4.3*
13	6.0	9.8	3.2 (NS)	4.2	12.0	
14	6.8	12.8		5.8	14.9	4.3*
15	7.3	16.1	4.9*			
Total	29.7	52.4		17.1	43.9	
Mean	5.9	10.5		3.4	8.8	
Post-spray data						
15				6.0	15.3	4.6*
16	7.5	20.6	5.6*			
Total	7.5	20.6		6.0	15.3	
Mean	7.5	20.6		6.0	15.3	
s.e. ±						

* - Significant
NS - Not significant

Table 8. Causes of fruiting bodies shed/$9m^2$ in 1984 and 1985.

Sampling period (weeks after planting)	1984 T.F.B.[1] shed	1984 S.P.[2] shed	1984 B.W.[3] shed	1984 N.I.D.[4] shed	1985 T.F.B. shed	1985 S.P. shed	1985 B.W. shed	1985 N.I.D. shed
Pre-spray data								
9					2.7	0.4	0.6	1.7
10	1.5	1.0	0	0.5				
Total	1.5	1.0	0	0.5	2.7	0.4	0.6	1.7
Mean	1.5	1.0	0	0.5	2.7	0.4	0.6	1.7
Spray data								
10					5.8	1.4	1.2	3.2
11	7.5	0.8	0.4	6.3	7.6	2.4	0.7	4.5
12	10.1	3.0	3.1	4.0	11.4	3.0	1.5	6.8
13	13.2	3.6	1.7	7.9	16.2	5.1	2.6	8.5
14	15.8	2.0	4.0	9.8	20.7	7.0	3.8	9.9
15	19.6	2.7	2.0	14.9				
Total	66.2	12.1	11.2	42.9	61.7	18.9	9.9	32.9
Mean	13.2	2.4	2.2	8.6	12.3	3.8	2.0	6.6
Post-spray data								
15					21.3	6.3	4.9	10.1
16	23.4	3.2	4.9	15.5				
Total	23.4	3.2	4.9	15.5	21.3	6.3	4.9	10.1
Mean	23.4	3.2	4.9	15.5	21.3	6.3	4.9	10.1
s.e. ±	2.6	0.4	0.6	1.9	2.5	0.9	0.6	1.2

1 T.F.B. - Total fruiting body shed.
2 S.P. - Shed due to sucking pest damage.
3 B.W. - Shed due to bollworm damage.
4 N.I.D. - Shed due to non-insect damage.

Sucking pests accounted for 17.9% and 30.0% shed fruiting bodies in 1984 and 1985 respectively, while the bollworms accounted for 17.7% insect damage in 1984 and 18.0% damage in 1985 (Table 8).

4.2.8 Fruiting body damage

Results of the effect of plant row arrangement on percentage fruiting body damage are shown in Table 9. In both years, more fruiting bodies were damaged in the regular rows than the paired rows during the spray period (10 - 15 WAP). More fruiting bodies were, however, damaged in the paired rows in the pre-spray (9 - 10 WAP) and post spray (15 - 17 WAP) periods.

In 1984, the prespray mean percentage fruiting body damage (by sucking pests and bollworms) was 1.1 for the regular rows and 1.6 for the paired rows. At the end of spraying (15 WAP), mean percentage fruiting body damage was 1.4 in the regular row and 1.1 in the paired row arrangements. Post spray data showed that the regular rows had a mean of 1.0 as against 1.4 in the paired rows.

In 1985, the peak damage of fruiting bodies (by sucking pests and bollworms) occurred 14 WAP with means of 4.3 in the regular rows and 3.3 in the paired rows. Difference between the two types of plant arrangement was, however, not statistically significant ($P = 0.05$). The pre-spray (9 WAP) mean numbers of

Table 9. Effect of plant row arrangement on percentage fruiting body damage by sucking pests and bollworms in 1984 and 1985.

	1984			1985		
Sampling period (weeks after planting)	Regular row arrangement	Paired row arrangement	Variance (F)	Regular row arrangement	Paired row arrangement	Variance (F)
Pre-spray data						
9				1.5	1.2	0.2 (NS)
10	1.1	1.6	1.6 (NS)			
Total	1.1	1.6		1.5	1.2	
Mean	1.1	1.6		1.5	1.2	
Spray data						
10				0.8	1.0	0.2 (NS)
11	1.7	1.0	1.8 (NS)	2.6	2.2	
12	1.3	1.2		2.1	1.3	0.1 (NS)
13	2.0	1.1	3.8*	2.8	2.6	
14	1.0	1.7		4.3	3.3	1.9 (NS)
15	1.1	0.5	4.1*			
Total	7.1	5.5		12.6	10.4	
Mean	1.4	1.1		2.5	2.1	
Post-spray data						
15				3.3	3.2	
16	0.9	1.5		3.4	3.8	2.0 (NS)
17	1.1	1.3	1.3 (NS)			
Total	2.0	2.8		6.7	7.0	
Mean	1.0	1.4		3.3	3.5	
s.e. ±	0.1	0.2		0.6	0.5	

* = Significant
NS = Not significant

of percentage fruiting body damage was 1.5 for the regular rows and 1.2 for the paired rows. At the end of spraying (14 WAP), mean percentage fruiting body damage (averaged over 5 weeks) was 2.5 in the regular rows and 2.1 in the paired rows. Post spray data (averaged over 2 weeks) showed that the paired rows had a mean of 3.5 as against 3.4 for the regular rows.

4.3 Pest Control

Insecticide application commenced 10 - 11 weeks after planting. Weekly means for the spray performance of the different spray treatments on the insect pests of cotton and predators of aphids are shown in Tables 10 - 15. The pest population generally decreased with insecticide application, although individual insect data showed some variations with the spray treatments.

4.3.1 Effect of spray treatments on aphids and their predators (Coccinellid beetles)

All spray methods (LV, ULV, ED) gave good control of aphids (Table 10). In 1984, pre-spray (10 WAP) mean numbers of aphids was 376.2 for the control, 590.0 for the low volume, 485.0 for the ultra low volume and 442.0 for the electrodyn spray treatments. Difference between their means was not significant (P = 0.05). The mean numbers of aphids fell to 16.3 for the control, 2.5 for the low volume, 6.3 for the ultra low volume and electrodyn spray

treatments 11 WAP, when spraying commenced. At the end of spraying (15 WAP) mean numbers of aphids (averaged over 5 weeks) was 16.3 for the control, 7.9 for the low volume, 12.8 for the ultra low volume and 9.9 for the electrodyn spray treatments. This indicated a 95.7% decrease in mean numbers of aphids for the control as against 98.7%, 97.4, 97.8, decrease for low volume, ultra low volume and electrodyn spray methods respectively. Post spray data, similarly showed low aphid means for the different spray methods (LV, ULV and ED).

In 1985 mean numbers of aphids before spraying commenced (9 WAP) were 82.5 for the control, 37.5 for the low volume, 125.0 for the ultra low volume and 51.3 for the electrodyn spray treatments. Difference between their means was not significant (P = 0.05). The aphid population increased to 105.0 in the control and decreased to 0.0 in the low volume and 7.5 each in the ultra low volume and electrodyn spray treatments respectively at 10 WAP when spraying commenced. Difference between their means was significant (P = 0.05). At the end of spraying four weeks later, mean numbers of aphids (averaged over 5 weeks) was 172.0 for the control, 11.0 for the low volume, 55.0 for the ultra low volume and 24.1 for the electrodyn spray treatments (Table 11).

Post spray data showed that the control had a mean number of aphids of 18.8 as against 0.0 in the low

Table 10. Effect of spray treatments on the population of Aphids on cotton in 1984 and 1985.

	Number of Aphids/10 stands									
	1984					1985				
Sampling period (weeks after planting	Control	LV	ULV	ED	LSD (P = 0.05)	Control	LV	ULV	ED	LSD (P = 0.05)
Pre-spray data										
9						82.5	37.5	125.0	87.5	NS
10	376.2	590.0	485.0	442.0	NS					
						82.5	37.5	125.0	87.5	
Total	376.2	590.0	485.0	442.0		82.5	37.5	125.0	87.5	
Mean	376.2	590.0	485.0	442.0						
Spray data										
10						105.0	0.0	7.5	7.5	33
11	16.3	2.5	6.3	6.3	NS	410.0	17.5	182.5	50.0	97
12	21.3	7.5	12.5	3.8	9.2	292.5	15.0	55.0	30.5	66.5
13	6.3	5.0	8.8	6.3	NS	37.5	22.5	27.5	32.5	NS
14	26.3	12.6	26.3	20.0	NS	15.0	0	2.5	0	NS
15	11.3	11.3	10.0	13.1	NS					
Total	81.5	38.9	63.9	49.5		860.0	55.0	275.0	120.5	
Mean	16.3	7.8	12.8	9.9		172.0	11.0	55.0	24.1	
Post-spray data										
15						5.0	0	7.5	2.5	NS
16	10.0	1.3	6.3	6.3	NS	32.5	0	5.0	7.5	10.8
17	11.3	10.0	8.8	5.0	NS	18.8	0	6.3	5.0	
						37.5	0	12.5	10.0	
Total	21.3	11.3	15.1	11.3		18.8	0	6.3	5.0	
Mean	10.6	5.7	7.6	5.7						

LV - Low volume
ULV - Ultra low volume
ED - Electrodyn

volume, 6.3 in the ultra low volume and 5.0 in the electrodyn spray methods. Difference between the treatment means was significant at 16 WAP (P = 0.05).

In both years the low volume gave the best control of aphids, followed by the electrodyn spray method.

Aphid predators (Coccinellid beetles)

The performance of the spray treatments on coccinellid beetles is shown in Table 11. There were more coccinellid beetles in the control than in the sprayed plots in both years (Table 11).

In both years, of the three spray methods, the ultra low volume method recorded the highest number of coccinellid beetles and was closely followed by the electrodyn spray method during and after spraying. In 1984 differences between the spray treatment means were not significant, while in 1985, differences were statistically significant at 10 and 12 WAP (P = 0.05).

Table 11. Effect of spray treatments on the population of Coccinellid beetles on cotton in 1984 and 1985/10 stands.

Sampling period (weeks after planting)	1984 Control	LV	ULV	ED	LSD (P = 0.05)	1985 Control	LV	ULV	ED	LSD (P = 0.05)
Pre-spray data										
9										
10	11.1	8.9	11	10.3	NS	6.8	4.3	4.8	5.3	NS
Total	11.1	8.9	11	10.3		6.8	4.3	4.8	5.3	1.05
Mean	11.1	8.9	11	10.3		6.8	4.3	4.8	5.3	
Spray data										
10						3.0	0	0	0	1.05
11	0.6	0.5	0.8	0.5	NS	2.8	0.5	0.8	0.3	NS
12	1.6	0.0	0.4	0.1	NS	5.5	0.5	1.0	1.0	2.6
13	0.1	0	0	0.1	NS	.5	0	0.8	1.0	NS
14	0.7	0	0	0	NS	.5	0	0	0	NS
15	0.3	0	0	0	NS	.1	.1	0.5	0	NS
Total	3.3	0.5	1.2	0.7		16.9	1.1	3.1	2.3	
Mean	0.7	0.1	0.2	0.1		3.4	0.2	0.6	0.5	
Post-spray data										
15						0.3	0	0	0	NS
16	0	0	0	0	NS	0	0	0	0	NS
17	0.2	0	0	0	NS					
Total	0.2	0	0	0		0.3	0	0	0	
Mean	0.1	0	0	0		0.1	0	0	0	

LV - Low volume
ULV - Ultra low volume
ED - Electrodyn

4.3.2 Cicadellids and whiteflies

Results of the efficacy of the spray treatments on cicadellids and whiteflies are shown in Tables 12 and 13. The three spray methods generally gave a good control of the cicadellids and whiteflies in both years. More cicadellids were recorded in 1985.

In 1984, the pre-spray mean numbers of cicadellids was 4.1 for the control, as against 4.3 for the low volume, 3.6 for the ultra low volume and 3.8 for the electrodyn spray treatments. Spraying decreased the cicadellids to 0.3, 0.0 0.6 and 0.0 respectively for the control, ultra low volume, low volume and electrodyn spray treatments at 11 WAP. At the end of spraying (15 WAP) mean numbers of cicadellids (averaged over 5 weeks) was 0.4 in the control as against 0.1 in the low volume, 0.5 in the ultra low volume and 0.3 in the electrodyn spray treatments. Post-spray data showed that the control had a mean of 0.7 cicadellids as against 0.1 for the low volume, 0.3 for the ultra low volume and 0.2 for the electrodyn spray treatments.

In 1985, the pre-spray mean numbers of cicadellids was 15.8 for the control as against 16.5 for the low volume, 13.3 for the ultra low volume and 7.5 for the electrodyn spray methods. At the end of spraying 14 WAP, spray data (averaged over 5 weeks) showed that spraying decreased the cicadellid mean numbers to 0.6, 1.1, 1.0 respectively for the low volume, ultra low volume and

Table 12. Effects of spray treatments on the population of Cicadellids on cotton in 1984 and 1985/10 stands.

	1984					1985				
Sampling period (weeks after planting)	Control	LV	ULV	ED	LSD (P = 0.05)	Control	LV	ULV	ED	LSD (P = 0.05)
Pre-spray data										
9						15.8	16.5	13.3	7.5	NS
10	4.1	4.3	3.6	3.8	NS					
Total	4.1	4.3	3.6	3.8		15.8	16.5	13.3	7.5	
Mean	4.1	4.3	3.6	3.8		15.8	16.5	13.3	7.5	
Spray data										
10						16.3	0.3	0.8	0.5	3.8
11	0.3	0.0	0.6	0.0	NS	21.0	1.3	1.3	2.0	5.6
12	0.5	0.1	0.6	0.6	NS	9.8	0.5	2.8	1.0	3.1
13	0.3	0.3	0.3	0.0	NS	9.5	0.8	0.5	1.0	3.0
14	0.6	0.8	0.8	0.8	NS	6.5	0	0	0.3	1.6
15	0.4	0	0	0	NS					
Total	2.1	0.5	2.3	1.5		63.1	2.9	5.4	4.8	
Mean	0.4	0.1	0.5	0.3		12.6	0.6	1.1	1.0	
Post-spray data										
15						1.0	0.3	0.3	1.0	NS
16	0.5	0.1	0	0.5	NS	8.3	3.8	3.8	3.3	NS
17	0.9	0	0.6	0	NS					
Total	1.4	0.1	0.6	0.5		9.3	4.1	4.1	4.3	
Mean	7.0	0.1	0.3	0.2		4.6	2.05	2.05	2.15	

LV - Low volume
ULV - Ultra low volume
ED - Electrodyn

electrodyn spray methods as against 12.6 for the control treatment. This represent a decrease of 96.4%, 91.7%, 86.7% and 20.3% for the low volume, ultra low volume, electrodyn and control treatments respectively. Post-spray data showed an increase in the mean numbers of cicadellids in the sprayed plots compared to the spray period.

In both years the low volume gave the best control of cicadellids closely followed by the electrodyn spray method.

Whiteflies:

Results in respect of the spray performance on whiteflies on table 13, showed that the three spray methods were effective. The low volume, however, was the most effective against B. tabacci closely followed by the ultra low volume spray method.

In 1984, pre-spray mean numbers of whiteflies was 16.0, 18.8, 18.3 and 16.6 for the control, low volume, ultra low volume and electrodyn spray.treatments respectively, which decreased to 4.3, 1.7, 2.9 and 3.3 for the control, low volume, ultra low volume and electrodyn spray treatments at the end of spraying (15 WAP). Post spray data showed that the control had a mean number of 1.2 whiteflies as against 0.8 each for the low volume and ultra low volume and 0.9 for the electrodyn spray methods. Differences between the means of the spray treatments were not significant

(P = 0.05) throughout the sampling period in 1984.

In 1985, pre-spray data 9 WAP (Table 14) indicated no marked level of difference between the treatment means. With insecticide application (10 WAP) mean numbers of whiteflies decreased by 100%, 76.9% and 85.6% respectively in the low volume, ultra low volume and electrodyn sprayed plots as against 61.3% increase in the control treatment (Table 14). At the end of spraying four weeks later, the mean numbers of the whitefly (averaged over 5 weeks) was 9.5, 0.8, 1.7 and 1.4 for the control, low volume, ultra low volume and electrodyn spray treatments respectively. Post spray data (averaged over 2 weeks) showed that the mean numbers of whiteflies was 0.5 for the control, as against 0.2, 1.2 and 0.3 for the low volume, ultra low volume and electrodyn spray methods respectively. Based on the data shown in table 13, the low volume spray method gave the best control of B. tabacci in 1984, closely followed by the ultra low volume method, while in 1985 the electrodyn spray method gave the best control, closely followed by the low volume spray method.

Table 13. Effect of spray treatments on the population of Whiteflies on cotton in 1984 and 1985/10 stands.

	1984					1985				
Sampling period (weeks after planting)	Control	LV	ULV	ED	LSD (P = 0.05)	Control	LV	ULV	ED	LSD (P = 0.05
Pre-spray data										
9						6.3	8.8	7.8	9.0	NS
10	16.0	18.8	18.3	16.6	NS					
Total	16.0	18.8	18.3	16.6		6.3	8.8	7.8	9.0	
Mean	16.0	18.8	18.3	16.6		6.3	8.8	7.8	9.0	
Spray data										
10						16.3	0.0	1.8	1.3	2.3
11	3.9	1.6	1.6	2.5	NS	13.5	0.5	2.3	0.3	2.02
12	8.6	1.6	7.3	4.8	NS	8.5	1.8	1.8	2.8	2.9
13	4.3	2.1	1.4	5.4	NS	5.3	1.5	2.0	2.0	1.8
14	3.5	2.3	2.9	3.1	NS	4.0	0.0	0.8	0.8	1.0
15	1.0	0.8	1.1	0.9	NS					
Total	21.3	8.4	14.3	16.7		47.6	3.8	8.7	0.5	
Mean	4.3	1.7	2.9	3.3		9.5	0.8	1.7	0.0	
Post-spray data										
15						1.0	0	1.3	0.5	NS
16	0.1	0.1	0.6	0.4	NS	0.0	0.3	1.0	0.0	NS
17	2.3	2.5	0.9	1.3	NS					
Total	2.4	1.6	1.5	1.7		1.0	0.3	2.3	0.5	
Mean	1.2	0.8	0.8	0.9		0.5	0.2	1.2	0.3	

LV - Low volume
ULV - Ultra low volume
ED - Electrodyn

4.3.3 Leaf roller (S. deroqata)

Effect of spray treatments on the population of the leaf roller is shown in table 14. In both years (1984 and 1985), the three spray methods significantly lowered the leaf roller population below that of the control treatment.

In 1984, pre-spray (10 WAP) mean numbers of leaf rollers was 9.5, 5.4, 3.3 and 6.0, for the control, low volume, ultra low volume and electrodyn spray treatments respectively. Difference between their means was not significant (P = 0.05). The population means rose to 17.3 in the control, 9.0 for the low volume, 21.0 for the ultra low volume and 7.5 in the electrodyn spray treatments, after the first spray application at 11 WAP. Difference between their means was not significant (P = 0.05).

At the end of spraying (15 WAP) mean numbers of leaf rollers (averaged over 5 weeks) was 20.7, 10.9, 15.0, and 8.4 for the control, low volume, ultra low volume and electrodyn spray treatments respectively. Differences between the treatment means was significant at 13 WAP (P = 0.05). Post-spray data showed that the control treatment had a mean of 5.8, as against 0.1, 2.0 and 0.4 for the low volume, ultra low volume and electrodyn spray methods.

In 1985, the mean numbers of leaf rollers 1 week before spraying commenced, were 0.5 for the control,

zero each for the low volume and electrodyn and 0.5 for the ultra low volume spray treatments. Difference between their means was not statistically significant ($P = 0.05$). With commencement of insecticide application (10 WAP), the mean numbers of leaf rollers rose to 1.3 for the control and decreased to 0.3 for the ultra low volume spray treatments. Low volume and electrodyn spray methods had no leaf roller infestation. Difference between the treatment means was not significant ($P = 0.05$). At the end of insecticide application four weeks later, mean numbers of leaf rollers (averaged over 5 weeks) was 19.3 for the control as against 1.5, 2.3 and 0.3 for the low volume, ultra low volume and electrodyn spray treatments respectively. Post spray data 15 - 16 WAP, indicated significant level of difference between the treatment means ($P = 0.05$) with the three spray methods of the same range and statistically different from the control.

In both years, the electrodyn spray method gave the best control of S. derogata, followed by the low volume spray method.

Table 14. Effect of spray treatments on number of cotton leaves rolled by S. derogata in 1984 and 1985/10 stands.

Sampling period (weeks after planting)	1984 Control	LV	ULV	ED	LSD (P = 0.05)	1985 Control	LV	ULV	ED	LSD (P = 0.05)
Pre-spray data										
9						0.5	0	0.5	0	NS
10	9.5	5.4	3.3	6.0	NS					
Total	9.5	5.4	3.3	6.0		0.5	0	0.5	0	
Mean	9.5	5.4	3.3	6.0		0.5	0	0.5	0	
Spray data										
10						1.3	0	0.3	0	NS
11	17.3	9.0	21.0	7.5	NS	1.5	0.0	0.2	0	0.61
12	25.9	16.1	13.8	10.5	NS	16.3	2.0	2.5	0	10.4
13	21.3	14.3	16.8	9.6	7.9	23.3	1.3	6.0	1.0	11.9
14	28.6	12.3	18.9	11.4	NS	54.0	4.0	2.5	0.3	12.2
15	10.4	3.0	4.6	3.1	NS					
Total	103.5	54.7	75.1	42.1		96.4	7.3	11.5	1.3	
Mean	20.7	10.9	15.0	8.4		19.3	1.5	2.3	0.3	
Post-spray data										
15						24.0	2.0	0.8	1.0	11.08
16	9.1	0.2	3.8	0.9	7.6	43.8	0	2.0	0	20.3
17	2.6	0	0.1	0	NS					
Total	11.7	0.1	3.9	0.9		67.8	2.0	2.8	1.0	
Mean	5.8	0.1	2.0	0.4		33.9	1.0	1.4	0.5	

LV - Low volume
ULV - Ultra low volume
ED - Electrodyn

4.3.4 Cotton stainers (Dysdercus spp.)

Data in respect of the performance of the spray treatments are shown in Table 15. In both years, the electrodyn and low volume spray methods gave the best control of cotton stainers.

In 1984, the mean numbers of cotton stainers before spraying commenced 11 WAP, were 0.3, 0.0, 0.4 and 0.4 for the control, low volume, ultra low volume and electrodyn spray treatments respectively. Difference between their means was not significant (P = 0.05). All through the spray period, there was no marked difference between the sprayed and unsprayed plots (Table 15). At the end of the spray period (15 WAP), mean numbers of cotton stainers (averaged over 5 weeks) was 1.0 for the control as against 0.5 each, for the low volume and ultra low volume and 0.2 for the electrodyn spray treatments. Post spray data showed that the control had a mean of 3.4 as against 0.2 for the low volume and 0.5 each for the ultra low volume and electrodyn spray spray treatments.

In 1985, no cotton stainers were recorded before spraying commenced (10 WAP). From low infestations at 11 WAP, the population increased to 2.3 for the control, 0.3, 0.5, 0.3 for low volume, ultra low volume and electrodyn spray methods respectively 12 WAP. Differences between the treatment means were not

Table 15. Effect of spray treatments on the population of cotton stainers on cotton in 1984 and 1985/10 stands.

Sampling period (weeks after planting)	1984 Control	LV	ULV	ED	LSD (P = 0.05)	1985 Control	LV	ULV	ED	LSD (P = 0.05)
Pre-spray data										
9						0.0	0.0	0.0	0.0	
10	0.3	0.0	0.4	0.3	NS					
Total	0.3	0	0.4	0.3		0	0	0	0	
Mean	0.3	0	0.4	0.3		0	0	0	0	
Spray data										
10						0	0	0	0	
11	1.5	0.0	0.4	0.4	NS	1.5	0.3	0	0	NS
12	1.6	1.3	0.6	0.3	NS	2.3	0.3	0.5	0.3	NS
13	0.9	0.4	0.4	0.3	NS	2.3	0.0	0.5	0	1.0
14	0.8	0.7	0.9	0.1	NS	3.0	0.0	0	0	0.84
15	0.3	0.0	0.1	0.1	NS					
Total	5.1	2.4	2.4	1.7		9.1	0.6	1.0	0.3	
Mean	1.0	0.5	0.5	0.2		1.8	0.1	0.2	0.10	
Post-spray data										
15						21.8	0.8	1.8	0	5.96
16	5.0	.1	0.0	0.0	NS	9.0	5.5	3.6	2.8	NS
17	1.8	0.3	1.0	1.1	NS					
Total	6.8	0.4	1.0	1.1		30.8	6.3	5.4	2.8	
Mean	3.4	0.2	0.5	0.5		15.4	3.1	2.7	1.4	

LV - Low volume
ULV - Ultra low volume
ED - Electrodyn

significant (P = 0.05). At the end of spraying (14 WAP), the mean numbers of cotton stainers (averaged over 5 weeks) were 1.8 for the control as against 0.1 each for the low volume and electrodyn and 0.2 for the ultra low volume spray treatments. Post spray data (averaged over 2 weeks) showed that the control had mean numbers of Dysdercus spp. of 15.4, as against 3.1, 2.7 and 1.4 for the low volume, ultra low volume and electrodyn spray treatments respectively.

4.4 Effect of Spray Treatments on Level of Fruiting Body Damage

In the two-year trial (1984 and 1985) it was observed that the performance of the three spray methods (LV, ULV and ED) were markedly different from the control. The low volume and electrodyn spray methods generally performed better than the ultra low volume spray method (Table 16).

In 1984, mean percentage fruiting body damage was 1.1, 1.4, 1.3, 1.6 for the control, low volume, ultra low volume and electrodyn spray treatments respectively at 10 WAP. Differences between the treatments were not significant (P = 0.05). With insecticide application (11 WAP) the level of fruiting body damage rose to 1.3, 1.5 and 1.8 respectively for the control, ultra low volume and electrodyn spray treatments and decreased to 0.8 in the low volume spray treatment. Difference between treatment means was

however not significant. At the end of spraying four weeks later, level of fruiting body damage (averaged over 5 weeks) were 2.0 for the control as against 0.8, 1.3 and 0.9 for the low volume, ultra low volume and electrodyn spray methods.

Post spray data (averaged over 2 weeks) showed that the control had a mean fruiting body damage of 3.4 as against 1.3, 1.6 and 1.7, for the electrodyn, low volume and electrodyn spray methods respectively. Differences between the treatment means were statistically significant at 15 and 16 WAP ($P = 0.05$).

In 1985, pre-spray (10 WAP) mean percentage fruiting body damage was 4.1, 1.0, .3 and 0.0 for the control, low volume, ultra low volume and electrodyn spray treatments respectively. Differences between the means was statistically significant ($P = 0.05$). The three spray methods (LV, ULV, ED) were at par and different from the control (LSD = 2.7). During the spray period (10 - 14 WAP) there were marked differences between the control and sprayed plots (Table 16). The mean of percentage fruiting body damage was 2.6, 1.6 for the control and ultra low volume and zero each for the low volume and electrodyn spray treatments respectively, during the first week of spraying (10 WAP). At the end of the spraying period four weeks later, mean of percentage fruiting body damage (averaged over 5 weeks)

was 5.1 for the control as against 0.6, 0.8 and 1.6, for the electrodyn, low volume and ultra low volume spray methods. Post spray data (averaged over 2 weeks) with means of 6.1, 2.3, 3.3, 1.6 for the control, low volume and electrodyn spray treatments respectively, showed an increase over their spray period means.

Internal fruiting body damage assessment data in Table 17, showed that the spray treatments gave a good control of fruiting body pests. Pre-spray data (9 WAP) showed that the mean percentage fruiting body damage were 7.6, 11.9, 3.0 and 3.9 for the control, low volume, ultra low volume and electrodyn spray treatments respectively. Difference between the means was not significant (P = 0.05). Spray period data at 12 WAP in Table 17, indicated a statistically significant level of difference among the treatments. Similarly, post spray data (15 WAP) showed a marked level of difference between the control and the three spray methods with an LSD value of 6.3. The electrodyn and low volume spray methods gave the best protection against fruiting body damage.

Table 16. Effect of spray treatments on percentage fruiting body damage in 1984 and 1985/10 stands.

Sampling period (weeks after planting)	1984 Control	LV	ULV	ED	LSD (P = 0.05)	1985 Control	LV	ULV	ED	LSD (P = 0.05)
Pre-Spray data										
9						4.1	1.0	0.3	0	2.7
10	1.1	1.4	1.3	1.6	NS					
Total	1.1	1.4	1.3	1.6		4.1	1.0	0.3	0	
Mean	1.1	1.4	1.3	1.6		4.1	1.0	0.3	0	
Spray data										
10						2.6	0	1.6	0	1.2
11	1.3	0.8	1.5	1.8	NS	3.2	0.5	0.9	0.2	1.1
12	2.3	1.1	1.4	0.6	1.36	5.2	6.2	1.1	0.5	2.7
13	2.5	0.9	1.5	1.1	NS	5.8	0.8	2.8	1.1	1.5
14	2.4	1.0	1.3	0.7	1.6	8.9	2.3	2.8	1.4	1.5
15	1.5	0.4	0.7	0.5	1.04					
Total	10.0	4.2	6.4	4.7		25.7	3.8	9.2	3.2	
Mean	2.0	0.8	1.3	0.9		5.1	0.8	1.8	0.6	
Post-spray data										
15						6.1	2.3	3.3	1.6	1.7
16	2.5	0.8	0.7	0.9	1.5					
17	4.2	2.3	2.6	1.7	1.2					
Total	6.7	3.1	3.3	2.6		6.1	2.3	3.3	1.6	
Mean	3.4	1.6	1.6	1.3		6.1	2.3	3.3	1.6	

LV - Low volume
ULV - Ultra low volume
ED - Electrodyn

Table 17. Effects of plant row arrangement and spray treatments on percentage fruiting body damage in 1985, (internal assessment).

Treatments	Sampling period weeks after planting		
	9	12	15
Plant row Arrangement			
Regular row	4.6	5.7	3.5
Paired row	8.5	5.4	5.5
LSD (P = 0.05)	NS	NS	NS
Spray treatment			
'0' spray (control)	7.6	10.7	10.8
LV spray	11.9	3.4	1.2
ULV spray	3.0	4.3	3.5
ED spray	3.9	1.9	2.5
LSD (P = 0.05)	NS	6.5	6.3

'0' treatment = Control.
LV " = Low volume spray
ULV " = Ultra low volume spray
ED " = Electrodyn spray

4.5 Yield Data

4.5.1 Seed cotton yield

The paired row arrangement of cotton outyielded the regular row arrangement in both years (Table 18). In 1984, the paired rows yielded about 2.6 times the yield of regular rows and about 2.2 times for the 1985 trial. Difference. between their means was signficant (P = 0.05).

The spray treatments had no significant effect on seed cotton yield (Table 18). On percentage basis, however, the sprayed plots outyielded the unsprayed plots by 11% and 29% in 1984 and 1985 respectively. In both years the low volume spray method gave the highest seed cotton yield of 772.0, and 994.9 kg/ha for 1984 and 1985 respectively, closely followed by the electrodyn spray methods with 769.0 and 964.1 kg/ha respectively for 1984 and 1985 cropping seasons.

4.5.2 Seed cotton quality

Results of the seed cotton quality graded into grades A and B are shown on Table 19. In 1984, the spray treatments had no significant effect on Grade A seed cotton (P = 0.05). In 1985 however, there was a significant level of difference between the spray treatments. The control with a mean of 887.0 gm, was

Table 18. Effects of plant row arrangement and spray treatments on maize and seed cotton yield.

Treatment	1984 Maize grain yield kg/ha	1984 Seed cotton yield kg/ha	1985 Maize grain yield kg/ha	1985 Seed cotton yield kg/ha
Plant row arrangement				
Regular row	4772.0	410.0	6148.0	543.6
Paired row	3877.0	1065.0	5777.9	1185.0
LSD (P = 0.05)	697.5	128.4	376.5	216.0
Spray treatments				
'0' No spray	3973.0	673.0	4080.4	660.5
LV - Low volume spray	4452.0	772.0	4586.5	994.9
ULV - Ultra low volume spray	4683.0	758.0	4648.3	830.4
ED - Electrodyn spray	4192.0	769.0	4555.0	964.1
LSD (P = 0.05)	NS	NS	NS	NS

statistically different from 1261.0, 1515.3 and 1446.0 gms for the ultra low volume, electrodyn and low volume spray methods respectively.

Grade B cotton

The grade B seed cotton yield for 1984 were 30.1, 12,3, 15.7 and 15.0 gms for the control, low volume, ultra low volume and electrodyn spray treatments respectively. Difference between the treatment means was significant (P = 0.05).

In 1985, there was also a marked difference between the control treatment and the spray methods (LV, ULV, and ED). The control treatment with 179 gms had the highest grade B cotton, followed by 83.6 gms for the ultra low volume as against 65.8 and 46.5 gms for the low volume and electrodyn spray methods respectively.

Of the three spray methods, the electrodyn with 3.1% grade B seed cotton had the lowest pest damaged seed cotton, followed by the low volume with 4.1% grade B cotton. The ultra low volume with 6.2% grade B cotton was least effective.

4.5.3 Maize yield

The regular row arrangement of maize outyielded the paired row arrangement to the tune of 18.8% in 1984 and 20.4% in 1985 (Table 18). Difference between their means was statistically significant (P = 0.05).

Table 19. *Effect of plant row arrangement and spray treatments on quality of seed cotton yield/ 10 stands.*

Treatments	1984 Grade A Cotton (g)	1984 Grade B cotton (g)	1985 Grade A cotton (g)	1985 Grade B cotton (g)
Plant row arrangement				
Regular row	323.7	8.1	408.4	32.0
Paired row	834.2	28.6	894.3	91.8
LSD (P = 0.05)	210.0	17.6	350.0	58.0
Spray treatments				
'0' No spray	514.8	30.1	887.0	179.0
Low volume spray	610.0	12.3	1546.0	65.8
Ultra low volume spray	592.5	15.7	1261.6	83.6
Electrodyn spray	600.3	15.6	1575.3	46.5
LSD (P = 0.05)	NS	17.6	350.0	58.0

The ultra low volume spray method gave the highest yield for both trials, thus suggesting a beneficial effect of insecticide spraying.

4.6 Insect Pests of Maize in the Cotton-Maize Mixture

Maize the secondary crop in the mixture was infested by a number of insect pests (Appendix A). The important foliage insects found associated with maize include Monolepta goldingi, Podagrica uniformis Jac., Empoasca sigmata Haupt, (Make feeding holes on the leaves); Cicadulina nr similis, C. storeyi (transmits maize streak virus disease). Other foliage pests include Poophilus costralis Walker, Locris rubens Erichson and Rhopalosiphum maidis Fitch.

Other insect pests which attacked the stalk and cobs were cotton stainer D. superstitiosus F., American bollworm H. armigera Hubn., false codling moth C. leucotreta Meyr and the stem borers Sesamia calamitis Hamp., and Busseola fusca Fuller.

CHAPTER 5

DISCUSSION

From the results and their analysis presented in Chapter Four, it was apparent that the plant row arrangement affected yield contributing factors (growth parameters), insect pest and their damage and consequently the cotton yield.

5.1 Growth and Yield Parameters

Of the two types of plant arrangement, the paired row arrangement favoured cotton plant height, number of green leaves and fresh plant weight (Table 1). The paired row arrangement yielded 21% and 40% more fruiting bodies in 1984 and 1985 respectively than the regular row arrangement. The better performance of the paired row arrangement was probably due to the fact that the cotton plants in this arrangement were more exposed to sunlight while those in the regular arrangement were smothered by the taller maize plants. Earlier work by Kumar (1980) and Kumar et al, (1983) have similarly shown that the growth parameters and vigour of cotton are affected when the crop is intersown with maize on the same ridge.

The paired row cotton with its more exposed leaves and shoot, had a more luxuriant growth than the shaded regular row cotton.

5.2 Effect of Plant Arrangement on Incidence and Population of Cotton Pests

Of the two types of plant row arrangement, the paired row cotton supported more aphids, cicadellids and whiteflies, which fed on the young leaves and shoot, sucking the plant juice. The high population of pests on paired rows could be due to the near monocrop situation with its luxuriant growth. With insecticide application at 10-11 WAP, the pest population trend remained the same, with paired rows still supporting more foliage pests of cotton although the pest numbers decreased.

5.2.1 Aphids and their predatory beetles

The fewer aphids found on the regular row arrangement compared to the paired rows, could have resulted from a number of factors which include visual and olfactory stimuli and reduced mobility of the aphids due to the tall obstructive maize (Perrin, 1977; Uvah, 1983).

Aphids are naturally controlled in the field by some coccinellid beetles - Cheilomines vicinia and C. sulphurea (Libby, 1968; Usenbo, 1977). They were found preying on the aphids, with populations which fluctuated with that of aphids and subsequently declined 13 weeks after planting. Four possible

reasons may account for the fluctuating trends of aphids and their predators. Firstly heavy rains in the months of August and September (Appendix D), during which the aphids perhaps got washed away; secondly the feeding activities of the natural enemies; thirdly the absence of young tender shoots and leaves which are preferred sites for feeding; and fourthly, the application of insecticides.

The cicadellids and whiteflies were found throughout the sampling period. The paired row arrangement supported more number of the pest than the regular row, perhaps due to the luxuriant plant growth which shaded the pests.

5.2.2 Leaf roller

It is a mid-season major pest of cotton in Nigeria (Anon., 1976). Appearing late in the season, they rapidly rolled up the leaves of the cotton plant, feeding from within, the end result of which was skeletonized cotton stands. Of the two types of plant row arrangement, it was found that the paired row cotton had more leaves rolled during most of the growth period of the plant. This was perhaps due to the luxuriant growth of cotton which attracted more leaf roller adults. The higher means for the regular row arrangement in the post spray period may be due to the spray efficacy. This perhaps, was the case,

as the more exposed cotton on the paired rows got better pesticide coverage than the regular row cotton.

Apanteles spp. are natural enemies of leaf rollers in the field (Libby, 1968) and were found parasitizing the leaf roller larvae. The ratio of Apanteles spp. to leaf roller was 1 leaf roller to 3.4 Apanteles spp. at 13 weeks after planting.

5.2.3 Cotton stainers

The regular row cotton supported more of the pest than the paired row and this was also reflected in the percentage fruiting body damage. Kumar and Ogunlela (1982) reported more pests on regular row cotton than on paired row cotton with insecticide application. This was attributed to better pesticide coverage of the more exposed canopy of the paired row arrangement. Added to the above is the proximity of the regular row cotton to maize which also sheltered some cotton stainers, thus increasing the number of cotton stainers on cotton.

Comparing the 1984 and 1985 cropping season data, it was observed that except for aphids and leaf rollers, 1985 had more pests than the 1984 season. This was perhaps due to the field arrangement and cymbush/dimethoate mixture used in the 1985 cropping season. The cymbush/dimethoate mixture has

a low amount of dimethoate (25g a.i./ha) and thus not effective for the control of sucking pests in situations of heavy infestation (Raheja et al., 1984).

The generally low population of cotton stainer was perhaps due to insecticide application and Phonoctonus spp. preying on them.

5.3 Effect of Plant Arrangement on Shed Bodies and Level of Damage

The cotton plant produces a lot of fruiting bodies (squares), flowers and bolls, most of which are shed either due to moisture stress, insect pest damage or physiological disorders (Pearson, 1958; Libby, 1968).

The paired row arrangement with its high number of fruiting bodies, also shed more of them than the regular row. Intra-row competition for soil moisture and effect of feeding activities of the pests on leaves and shoots led to shedding of fruiting bodies. The sucking pests and bollworms accounted for most of the insect damaged shed fruiting bodies while other shed bodies were due to the feeding activities of the insect pests. This agrees with Libby's (1968) view that feeding activities apart from affecting plant growth, also lead to shedding of fruiting bodies.

More fruiting bodies were shed due to sucking pest damage, compared to that due to the bollworms.

This agrees partly with the views of Faulkner (1974) and Kumar et al. (1982), that the sucking pests constitute a major problem in early sown cotton.

5.4 Pest Control

Control of insect pests of cotton using insecticides is regarded as one of the most rapid and successful methods of control (Lyon, 1972; Caswell and Raheja, 1977). Insecticide application during the two season trials showed that the spray methods markedly reduced pest populations compared to control treatment.

5.4.1 Efficacy of the different spray methods on Aphids and Coccinellid beetles

The spray application methods (LV, ULV and ED) gave a good control of the aphids. However, of the three spray methods used, the low volume spray method gave the best control, closely followed by the electrodyn and ultra low volume spray methods respectively. In earlier work at Samaru, it was found that the spray methods all gave good control of insect pests of cotton (Raheja et al., 1984). The electrodyn method was however said to be of limited use in intercrop situations, as its charged droplets are obstructed from the target plant, by the taller intercrop plants. From its observed performance

during this trial, it is evident that with improved plant arrangement, the electrodyn method will give a good plant coverage.

The observed better performance of the low volume spray method over the other methods in both seasons may be due to the one-row swath used. This makes for direct deposit of pesticides on the sprayed cotton plants. With the electrodyn and ultra low volume sprayers which have wider row swaths, it is possible that the tall maize trapped some of the insecticides, thus depriving the cotton plants of the sprayed insecticides. This leads to reduced spray performance as stated by Kumar and Raheja (1984).

The coccinellid beetles, like the aphids, were affected by insecticide application, resulting in higher population means for the no spray treatment. Of the three spray methods, the ULV had the least effect on the ladybird beetles, followed by the electrodyn spray method. This perhaps also occurred because of the different spray-swaths used (one row-swath for LV and two row-swath for 'ED' and ULV sprayers) respectively. The insects could have avoided the spray-row paths used and thus escape immediate contact with the pesticides. Added to the above, the wrap round effect of the electrodyn could also have ensured good pesticide coverage and coccinellid contact, more so as the aphids preyed on were on the underside

of the leaves. This observed performance agrees with the views of Usenbo (1977) who reported that the ultra low volume method contributed to the abundance of predators of aphids in a cotton agro-ecosystem.

5.4.2 Cicadellids and whiteflies

The cicadellids and whiteflies were better controlled with the LV spray method, than the ULV and 'ED' spray methods. This was perhaps due to the one-row swath used, which made for direct deposit of pesticides on the target plants.

5.4.3 Leaf roller

The electrodyn spray method gave the best control of leaf rollers. This performance is in accord with the performance of 'ED' sprayers as recorded by Morton (1982) and Raheja et al., (1984). Perhaps owing to its wrap round effect on the cotton plants, the ED insecticides penetrated the rolled cotton leaves, giving a good control of the pest. Other spray methods (LV and ULV) were also effective as they were statistically at par with the 'ED' spray method.

Contrary to the views expressed by Hayward (1967) that insecticide application increases leaf roller infestation and population build up, it was observed from the two-year trial, that insecticides markedly reduced the population of the leaf rollers.

This agrees with the views of Libby (1968) that leaf rollers are better controlled by the use of insecticides in addition to parasitism by Apanteles spp.

5.4.4 Cotton stainers

In the absence of insecticide application, the feeding activities of cotton stainers may considerably reduce seed cotton yield and quality (Faulkner, 1974; Kumar et al, 1982), thus making insecticide application against them imperative for good cotton yield. Chaudry (1982), however reported no marked effect of ULV insecticides on the cotton stainer (D. superstitiosus) in Niger State.

In the current study, insecticide application was effective against D. superstitiosus. Thus like Faulkner (1974) and Kumar et al, (1982), it was observed that spraying gave good control of the sucking pests in both seasons. The observed high performance of the electrodyn spray method was probably due to the wrap-round pesticide coverage of the fruiting bodies on which the cotton stainers fed as suggested by Morton (1982). The relatively high number of cotton stainers in the post-spray period, may be due to migration from other fields where millet and maize had perhaps matured.

5.5 Effect of Plant Arrangement and Spray Treatments on Fruiting Body Damage

Fruiting bodies produced by the cotton plants are fed on by the insects and consequently damaged in the process. The bollworms tunnel into the bolls, feeding on the contents and thereby introducing rot pathogens (Libby, 1968; Raheja, 1981). The sucking pests on the other hand suck the contents of the bolls and predispose the lint to Nematospora fungus.

From the result, it was observed that the paired row arrangement had more fruiting bodies damaged in the pre and post spray periods. This was perhaps due to the high proportion of fruiting bodies available to the pest in this arrangement.

With insecticide spraying commencing at 10 - 11 weeks after planting, the regular row arrangement had a higher proportion of fruiting bodies damaged than in the paired row arrangement. This trend remained so throughout the spray period.

Fruiting body damage was caused by the sucking pests (yellow stained lint) and the bollworms (tunnelling holes). Sucking pests on early sown cotton are responsible for poor cotton yield, especially at first picking (Faulkner, 1974; Kumar et al, 1982). The sucking pests accounted for over 51% and 65% of

total fruiting bodies damaged in 1984 and 1985 respectively, especially in the first half of the spray period. The bollworms emerged late (except Earias spp. and H. armigera which emerged early) and accounted for the rest of the damage to the fruiting bodies.

The high percentage of fruiting body damage in the regular row arrangement may be due to (i) the proximity of the cotton to maize plants, which harbour Dysdercus spp. and (ii) reduced efficacy of the insecticide, as some droplets are trapped by the upper canopy maize. The second reason seems to be more important since damage in the paired row arrangement increased at the end of insecticide application. It is also possible that as the maize cobs matured, the insect pests migrated to the paired row cotton.

Among the three insecticide spray application methods, there was no significant difference in the level of protection, thus indicating that all three spray application methods are effective in protecting the fruiting bodies from damage. However the low volume and electrodyn spray methods performed better than the ultra low volume method. This perhaps arose from the fact that they ensured better pesticide coverage of the fruiting bodies.

5.6 Yield Data and Seed Cotton Quality

The seed cotton yield was higher for the paired row arrangement and this may have resulted from a number of factors including plant populations, micro-climate and effect of pests on fruiting bodies. Yield parameters like plant height, number of green leaves and fruiting bodies, were consistently higher in the paired row arrangement, throughout the growth period of the plant.

At pre-harvest sampling (19 weeks after planting) plants in the paired row arrangement still had a lot of green growth compared to those in the regular rows. This indicates that the paired row plants had a longer growth period and perhaps compensated for damaged and shed fruiting bodies. Cotton as a plant produces more fruiting bodies than it can support (Pearson, 1958), thus ensuring minimal effect of pest damage on yield.

The extended growth period, better growth characters and the higher efficacy of the spray methods in the paired rows, perhaps collectively led to the higher yield of cotton in that arrangement. Kumar et al, (1983) similarly reported higher yields in paired row cotton.

Based on the yield data for the spray methods, the spray plots generally outyielded the unsprayed plots.

Caswell and Raheja (1977) and Kumar et al, (1982) similarly reported that insecticide spraying resulted in increased cotton yield. However, the differences between means of the three spray methods were not statistically significant. The higher yield of the sprayed plots compared to the control plots, was consistent with their efficacy, with the electrodyn and low volume spray methods recording higher cotton yield than the ultra low volume.

The observed close range between the seed cotton yield of the control and sprayed treatments indicate that pest populations and their effect on yield were controlled by factors other than insecticide application. Intercropping has a marked effect on pest populations since the survival of biological control agents is enhanced (Usenbo, 1977; Uvah, 1983). This perhaps was the case in the unsprayed plots, especially as the two component crops have some common pests and predators - aphids and Cheilomenes spp.; the cotton stainer and Phonoctonus spp.

Based on seed cotton quality data, the sprayed plots had significantly more grade A and less grade B cotton than the control ($P = 0.05$). Among the spray methods, the electrodyn and low volume gave less grade B cotton values (see table 19) than the ultra low volume and control spray treatments.

This was consistent with their observed performance on sucking pests and level of fruiting body damage.

Maize yields were higher in the regular row than the paired row arrangement. This finding agrees with that of Kumar et al., (1983), who similarly reported higher yields for the regular row maize as against the paired row maize. Maize plants in the regular row grew taller (2.2m) than the paired row (2.0m) and were more exposed to sunlight. Consequently they were able to utilize more light energy which resulted in higher yields.

Although insecticides were not directed at maize, they benefited from insecticide spraying as suggested by Taylor (1976).

The overall better yield performance of the electrodyn and low volume spray methods was probably due to the interaction between plant arrangement and spray application. Thus with the near monocrop situation of the paired row arrangement, these spray methods performed better than the ultra low volume method. This contradicts the general belief about the limitations of the electrodyn method in crop mixtures as stated by earlier workers like Morton (1982) and Raheja et al, (1984), perhaps due to the more exposed canopy of the paired row cotton.

CHAPTER 6

SUMMARY AND CONCLUSION

The results enumerated in Chapter four have shown that where growth requirements such as moisture, plant nutrients and micro-climate are optimal, insect pests particularly the sucking pests and bollworms, adversely affect the quantity and quality of seed cotton yield. This emphasises the need for suitable control measure(s) which can be easily adopted by the farmers if they are to grow cotton along with food crops like maize, sorghum and millet which have some common insect pests.

From the research work, three salient points emerge. First, plant arrangement has a marked effect on the incidence of insect pests of cotton. The paired row arrangement supported more insect pests than the regular rows. Secondly, all spray methods effectively controlled the insect pests of cotton as reflected in the seed cotton yield. Thirdly, intercropping maize and cotton has a marked effect on pest populations and the efficacy of the different spray methods.

Since all three spray methods (LV, ULV and ED) were effective, the availability of insecticide formulation, spray equipment, water and cost of application will to a large extent determine the method

of insecticide application used by the farmer in cotton-maize mixtures.

Although the work reported is preliminary in nature, it does point out some advantages that are inherent in crop mixtures and the integration of chemical and biological control. To fully understand the factors operating in such an integrated control measure, further studies should be undertaken of the different control measures. Such studies could help to identify the best time of spraying with limited use of insecticides as suggested by Taylor (1976) and Usenbo (1980).

From the high yields obtained for both maize and cotton and the higher efficacy of the spray treatments in the paired row arrangement, this arrangement, if adopted by the farmers, could considerably encourage them to produce more cotton along with maize.

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Appendix A. List of insects found associated with the cotton-maize mixture.

S/No.	Insect Species	(Order) /Family	Crop on which found	Part of plant	Nature of damage
		(COLEPTERA)			
1.	Monolepta kraatzi Jac.	(Chrysomelidae)	Maize	Foliage	Feed on leaves
2.	M. golding Bry.	"	Maize/cotton	Foliage	"
3.	M. elegans Allard.	"			
4.	Luperodes quaterous Frm.	"	Maize	Foliage	"
5.	Podagrica uniformis Jacobi.	"	Cotton	Foliage	leaf tattering
6.	Podagrica sjostedti J.	"	Cotton	Foliage	leaf tattering
7.	Syagrus calcaratus F.	"	Cotton	Foliage	Feed on leaves
		/Coccinelidae			
8.	Cheilomenes vicinia Muls.	"	Cotton/maize	On Aphids	Feeds on aphids
9.	Cheilomenes sulphurea Oliver.		Cotton/maize	On aphids	"
10.	Exocomus flavipes Thunb.		Cotton	On aphids	"
11.	Caryedon serratus Oliver.	/Bruchidae	Maize	Leaf	Found on foliage
12.	Nematocerus spp.	/Curculionidae	Maize	Foliage	Feed on leaves/ growing points.
13.	Alcidodes leucogrammus Er.		Maize/cotton	foliage/stem	"
14.	Hypolixus nubilosus Boh.		Maize/cotton	foliage/stem	"

Appendix A (Cont'd)

S/No.	Insect Species	(Order) /Family	Crop on which found	Part of plant	Nature of damage
		/Meloidae			
15.	Mylabris bifasciata Degeer & Var.	"	Maize/cotton	Tassel and flowers	Adults feed on tass
16.	Coryna hermanniae Fab.	"	Maize	Foliage; tassel	"
		/Scarabidae			
17.	Anomalia mixta F.	"	Maize	Tassel	"
18.	Pachnoda cordata Dry.	"	Maize/cotton	Foliage, tassel and buds	Adults feed on tass and also probably o injured bolls.
		(DIPTERA)			
19.	Musca spp.	/Muscidae	Cotton/maize	Foliage, flower	Feeds on aphids secretions
20.	Diopsis spp.		Maize	Foliage/Tunnel	Feeds on aphids
		(HEMIPTERA)			
21.	Empoasca dolichi Paoli.	/Cicadellidae	Cotton	Foliage	Feed on foliage, causes 'hopper' burn symptoms.
22.	Empoasca facialis Jacobi.	"	Cotton	Foliage	"
23.	Exicianus raeniariceps Kirch	"	Maize	Foliage	Found on foliage, may be a casual visitor.
24.	Hecalus sp.	"	Maize	Foliage	"
25.	Cicadulina trianqula Ruppel	"	Maize	Foliage	Transmits maize streak virus

Appendix A (Cont'd)

S/No.	Insect Species	(Order) /Family	Crop on which found	Part of plant	Nature of damage
26.	Cicadulina similis China.	/Cicadellidae	Maize	Foliage	Transmits maize streak virus.
27.	C. storeyi China	"	Maize	Foliage	"
		/Aphrophoridae			
28.	Poophilus costalis Walker.	"	Maize	Foliage	Feeds on leaves.
29.	Locris rubens Erichson.	"	Maize	Foliage	Feeds on leaves.
		/Aphididae			
30.	Aphis gossypii Slover.	"	Cotton	Foliage/stem	Cause leave curling and contaminates lint.
31.	A. croccivora Koch	"	Cotton	Foliage/funnel	"
32.	Rhopalosiphum maidis Fitch.	"	Maize	Funnel, tassel	Adults and nymphs on tassel retards growth.
		/Aleyrodidae			
33.	Bemisia tabacci G.	"	Cotton	Foliage	Transmits leaf curling virus diseases.
34.	Anoplocnemis curvipes Fabricius.	"	Maize	Foliage Cobs	Probably a visitor
		/Mirridae			
35.	Campylomma angustior Poppius.	"	Cotton	Foliage/stem	Attack young shoots and leaves. Causes leaf tattering and bud shedding.
36.	Campylomma subflava	"	Cotton	Foliage	"

Appendix A (Cont'd)

S/No.	Insect Species	(Order) /Family	Crop on which found	Part of plant	Nature of damage
		/Pyrrochoridae			
37.	Dysdercus superstitiosus Fabricius.	"	Cotton/maize	maize cobs, green bolls.	Suck miaze grains and green boll contents. Introduce Nematospora fungus.
38.	D. fasciatus Signoret.	"	Maize	Maize folliage	Plant sap.
		(HYMENOPTERA)			
39.	Camponotus perrisi For.	/Formicidae	Cotton	On Aphids	Feeds on Aphid secretions.
40.	C. macularus Fab.	"	Cotton/maize	On Aphids	"
41.	C. Acvapimensis Mayr.	"	Cotton/maize	On Aphids	"
42.	Apanteles spp.	/Braconidae	Cotton	On leaf rollers	Feed on S. derogata
43.	Phonoctonus lutescens (G & P)	/Reduvidae	Cotton/maize	foliage	Predators of cotton stainers (Dysdercus spp).
44.	P. nigrofasciatus	"	Cotton	Foliage	"
		(LEPIDOPTERA)			
45.	Diparopsis watersi Roths.	/Noctuidae	Cotton	Bolls.	Destroys green boll contents.
46.	Heliothis armigera Hubner	/Noctuidae	Cotton/maize	buds, bolls, Ears of maize cobs.	Consumes buds and flowers. Feed on silk of maize cob.
47.	Cryptophlebia leucotreta Meyr.	/Oletheridae	Cotton	Bolls	Tunnels into green mature green bolls.

Appendix A (Cont'd)

S/No.	Insect Species	(Order) /Family	Crop on which found	Part of plant	Nature of damage
48.	Earias insulana Boisd.	/Noctuidae	Cotton	Shoot, buds and bolls.	Attacks buds, Flowers and unripe fruit.
49.	E. biblaqa Walk.	/Noctuidae	Cotton	Shoot, buds and bolls.	"
50.	Sylepta derogata Fab.	/Pyralidae	Cotton	Foliage	Roll up leaves. Reduces leaf area.
51.	Spodoptera exempta Walk.	(Lepidoptera) /Nodtuidae	Cotton/maize	Foliage	Various feeder on folliage. Young plants stripped of leaves.
		(ORTHOPTERA)			
52.	Pyrgomorpha kraussi Uv.	/Pyrgomorphidae	Cotton/maize	Foliage	Eats foliage, stems, causing defoliation and death of seedlings.
53.	Acanthocris spp.	/Acrididae	maize	Foliage	"
		(LEPIDOPTERA)			
54.	Sesamia calamiti s Hamp.	/Noctuidae	Maize	Foliage/stem	Leaf feeding with small window holes bores in stem, injure growing point, kill plant or cause lodging.
55.	Busseola fusca Fuller	"	Maize	Foliage/stem	"

Appendix B. Effect of plant row arrangement on aphids and its predatory coccinellid beetles in 1984 and 1985. Number of aphids and coccinellid beetles/10 plants.

Sampling period (weeks after planting)	1984				1985			
	Aphids		Predatory beetles		Aphids		Predatory beetles	
	Regular rows	Paired rows	Regular rows	Paired rows	Regular rows	Paired rows	Regular rows	Paired rows
Pre-spray								
4	0	1.9	0	0	2.5	1.2	0	0
5	38.8	40.6	0.3	0.4	18.8	21.3	0.1	0.3
6	49.4	73.1	6.3	0.8	13.8	27.5	0	.3
7	63.8	112.5	0.4	0.8	37.5	26.2	1.0	1.9
8	322.5	600	2.2	3.0	43.8	46.3	5.6	7.0
9	402.5	987.5	6.9	19.8	76.3	127.5	5.1	5.4
10	313.8	633.1	5.3	15.4				
Total	1190.8	2448.7	15.4	40.2	192.7	250	12.2	14.8
Mean	170.1	349.8	2.2	5.7	32.1	41.6	2.0	2.5
During spray								
10					17.5	42.5	0.8	0.8
11	5	10.6	0.6	0.6	131.3	197.8	0.6	1.5
12	7.5	15.0	0.9	0.2	85.0	113.3	1.5	2.5
13	8.8	4.4	0.1	0.1	30	3	1.6	1.8
14	20	22.6	0.3	0.1	1.3	.3	0.3	0
15	9.1	11.3	0.1	0				
Total	50.4	63.9	2	1	265.1	386.9	4.8	6.6
Mean	10.1	12.8	0.4	0.2	53.0	77.0	1.0	1.3
Post-spray								
15					3.8	2.5	0.1	0
16	4.4	7.5	0	0	5.0	17.5	0.1	0.4
17	2.0	15.6	0.1	0				
Total	6.4	23.1	0.1	0	8.8	20.0	.2	0.4
Mean	3.2	11.5	0.05	0	4.4	10.0	.1	.2

Appendix C. Weekly number of bollworms/10 plants in 1984 and 1985.

Sampling period (weeks after planting)	1984				1985			
	Red boolworm	American bollworm	Spiny bollworm	False codling moth	Red bollworm	American bollworm	Spiny bollworm	False codling moth
8	0	0.3	0.1	0	0	0	0.3	0
9	0	0.0	0	0	0	0.1	0.2	0
10	0.2	0.1	0	0	0	0.2	0	0
11	0	0.1	0	0	0	0	0.1	0
12	0	0	0.1	0	0	0	0	0
13	0	0.2	0	0	0	0	0	0
14	0	0	0.2	0.3	0.2	0.2	0	0.4
15	0.2	0	0	0.2	0	0	0	0.2
16	0	0	0	0.6	0	0.1	0	0.1
17	0	0	0	0.3				

Appendix D. Meterological data from Institute for Agricultural Research, Meterological Station, Samaru.

Month	1984		1985	
	Rainfall (mm)	Temperature (°C)	Rainfall (mm)	Temperature (°C)
May	98.9	26.6	140.7	27.9
June	55.4	26.0	142.2	24.4
July	173.8	24.1	313.1	22.6
August	158.1	24.7	256.3	22.2
September	189.0	24.4	163.3	23.6
October	177.5	24.6	3.3	23.4

Appendix E. Analysis of variance (ANOVA) of cotton and maize growth parameters.

E. a(i) Cotton: 1984 data

Sources	Degree of freedom	Sum of square	Mean sum of square	Variance (F)	LSD (P=0.05)
Plant height					
Replicate	2	0.008	0.004	0.25	NS
Plant arrangement(P)	1	0.033	0.033	2.06	NS
Spray treatments(S)	3	0.015	0.005	0.31	NS
Interaction (PxS)	3	0.008	0.003	0.19	NS
Error	14	0.223	0.016		
Total	23	0.337			
Green leaves					
Replicate	2	28.91	14.45	0.40	NS
Plant arrangement(P)	1	16.73	16.73	0.46	NS
Spray treatments(S)	3	103.84	34.60	0.94	NS
Interaction (PxS)	3	110.07	36.69	1.02	NS
Error	14	508.40	36.00		
Total	23	768.69			
Fresh plant weight					
Replicate	2	0.26	0.13	1.13	NS
Plant arrangement(P)	1	4.04	4.04	35.0	0.59
Spray treatments(S)	3	0.14	0.05	0.43	NS
Interaction (PxS)	3	0.26	0.09	0.78	NS
Error	14	1.61	0.12		
Total	23	6.31			
Fruiting bodies					
Replicate	2	147.00	73.50	0.9	NS
Plant arrangement(P)	1	604.04	604.04	7.3	16.0
Spray treatments(S)	3	519.00	173.00	2.1	NS
Interaction (PxS)	3	190.16	63.40	0.76	NS
Error	14	1162.00	83.00		
Total	23	2622.20			

Appendix E. (Cont'd)

E. a(ii) Cotton: 1985 data

Sources	Degree of freedom	Sum of square	Mean sum of square	Variance (F)	LSD (P=0.05)
Plant height					
Replicate	2	0.07	0.004	2.10	NS
Plant arrangement(P)	1	0.40	0.40	26.70	0.18
Spray treatments(S)	3	0.04	0.01	0.87	NS
Interaction (PxS)	3	0.03	0.01	0.66	NS
Error	14	0.21	0.02		
Total	23	0.75			
Green leaves					
Replicate	2	245.80	122.89	6.3	6.5
Plant arrangement(P)	1	408.97	408.87	20.8	6.5
Spray treatments(S)	3	192.63	64.21	2.3	NS
Interaction (Px)	3	66.09	22.03	1.1	NS
Error	14	274.33	19.59		
Total	23	1187.72			
Fresh plant weight					
Replicate	2	1.00	0.50	2.17	NS
Plant arrangement(P)	1	12.90	12.90	56.00	0.7
Spray treatments(S)	3	0.76	0.25	1.09	NS
Interaction (PxS)	3	1.85	0.62	2.70	NS
Error	14	3.31	0.23		
Total	23	19.82			
Total fruiting bodies					
Replicate	2	150.01	75.01	0.13	NS
Plant arrangement(P)	1	7740.04	7740.04	15.42	32.9
Spray treatments(S)	3	1194.13	398.04	0.79	NS
Interaction (Px)	3	1544.80	514.93	1.03	NS
Error	14	7028.00	502.00		
Total	23	17656.98			

Appendix E. (Cont'd)

E. b(ii) Maize: 1985 data

Sources	Degree of freedom	Sum of squares	Mean sum of squares	Variance (F)	LSD (P=0.05)
Plant height					
Replicate	3	1.87	0.62	8.23	0.4
Plant arrangement(P)	1	0.58	0.58	7.25	0.4
Spray treatments(S)	3	0.12	0.04	0.50	NS
Interaction (PxS)	3	0.30	0.10	1.25	NS
Error	21	1.79	0.08		
Total	31	4.84			
Fresh plant weight					
Replicate	3	0.02	0.01	0.02	NS
Plant arrangement(P)	1	0.53	0.53	1.70	NS
Spray treatments(S)	3	0.73	0.24	0.77	NS
Interaction (PxS)	3	0.17	0.06	0.19	NS
Error	21	0.65	0.31		
Total	31	0.97			
Green leaves					
Replicate	3	46.04	15.34	4.90	2.60
Plant arrangement(P)	1	3.32	3.32	1.06	NS
Spray treatments(S)	3	7.25	2.42	0.77	NS
Interaction (PxS)	3	5.16	1.72	0.55	NS
Error	21	65.75	3.13		
Total	31	127.52			
No. of cobs					
Replicate	3	1.30	0.43	4.3	0.13
Plant arrangement (P)	1	1.14	1.14	11.40	0.13
Spray treatments (S)	3	1.06	0.35	3.5	0.13
Interaction (PxS)	3	0.04	0.01	0.1	NS
Error	21	2.10	0.10		
Total	31	5.64			

Appendix F. (Cont'd)

F.b. Maize yield analysis of variance.

F.b(i) 1984 data

Sources	Degree of freedom	Sum of squares	Mean sum of squares	Variance (F)	LSD (P=0.05)
Replicate	3	7.37	2.46	1.05	NS
Plant arrangement(P)	1	16.82	16.82	7.19	1.13
Spray treatments(S)	3	3.14	1.05	0.45	NS
Interaction (PxS)	3	6.74	2.25	0.96	NS
Error	21	49.15	2.34		
Total	31				

LSD (P = 0.05)/ha = 697.46

F.b(ii) 1985 data

Sources	Degree of freedom	Sum of squares	Mean sum of squares	Variance (F)	LSD (P=0.05)
Replicate	3	3.59	1.20	7.06	0.61
Plant arrangement(P)	1	2.85	2.85	16.76	0.61
Spray treatments(S)	3	1.05	0.35	2.05	NS
Interaction (PxS)	3	0.27	0.09	0.53	NS
Error	21	3.66	0.17		
Total	31	11.42			

LSD (P = 0.05)/ha = 376.51