APPROACHES TO INTEGRATED CONTROL OF COTTON PESTS IN THE MID-WESTERN STATE OF NIGERIA

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ABSTRACT

The cotton plant in Nigeria is subject to the depredations of numerous insect pests which have limited its potential yield. In the Mid-West State, efforts to control these pests have concentrated on the use of conventional sprays.

With the awareness of the hazards posed by the use of organochlorine compounds and the high mammalian toxicity of some organophosphates, there is need to review chemical control of insect pests to increase crop yield. The present study aimed at designing suitable approaches to integrated control of cotton pests on small-scale farms in Mid-Western State of Nigeria, by limiting the use of chemicals and enhancing the effect of natural enemies. The effects of mixed cropping systems was investigated. The major pests of cotton and some of their natural enemies were identified in different areas of the Mid-West State.

A comparison of some available insecticides against pests of cotton was made in the field in the hope that those with selective action properties could be identified for detailed studies, using a conventional spraying method with the aid of the knapsack sprayer. Spraying of insecticides began nine weeks after plant emergence in most of the trials. In the final conventional spray trial, different rates of the wettable powder formulation of the most promising insecticide, endosulfan, were compared, and carbaryl was applied as a selective killer of the natural enemies. Numbers of the major cotton pests and their natural enemies were estimated by sampling from randomly selected plants from September to December. Damage caused by pink and spiny

bollworms was assessed. The efficiency of the various insecticides tested were evaluated from the counts of insect numbers, damage caused and the yields of seed cotton per each treatment.

An ultra-low volume (ULV) spraying technique was investigated using a suitable hand-carried sprayer for small farmers which minimizes the burden of water transportation to cotton fields. The highest rate of 0.75 kg a.i/ha ULV endosulfan applied was as effective as the conventional carbaryl sprays in reducing cotton pests and increasing yield of seed cotton/ha. It also exhibited selectivity in favour of the aphid predators (1974-75 season).

Mixed cropping systems were studied by intercropping cotton with food crops. Numbers of insect pests, their natural enemies and yields of crops were recorded in cotton and associated food crops.

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SECTION I

GENERAL INTRODUCTION

1. BACKGROUND TO THIS STUDY

Cotton has been grown in Nigeria particularly the Northern States for many years and was an important export crop. With the development of local textile industries, production by small scale farmers has become insufficient and Nigeria is now an importer of cotton lint. Government policy is to encourage production in Nigeria, including the Mid-Western State where production is limited to the Northern areas 60-90 miles north of Benin City, the State's capital.

The Federal Republic of Nigeria has twelve States of which, the Mid-Western State is situated between latitudes 6° and 9° North and longitudes 3° and 6° East.

According to the 1963 census, the population was $2\frac{1}{4}$ million people, 80 percent of which depend on agriculture for their means of livelihood.

A feasibility study of cotton production in Mid-Western State by Dennison (1966), for the Food and Agricultural Organization (FAO) concluded that insect pests were a major factor responsible for low cotton yields. He recommended that research should concentrate on controlling these pests.

Cotton supports a wide range of insect species (Hargreaves, 1948) in all areas of the world where the

crop is grown; but high yields can be obtained if the pests are controlled.

As Principal Research Officer (Entomologist) Ministry of Agriculture and Natural Resources, Mid-Western State, the author decided to study the insect pests of cotton, their natural enemies and the possibilities of integrating different methods of pest control which is the most sensible approach to cotton pest control (Falcon and Smith, 1973).

Little work on cotton in Western State of Nigeria (then Centre for Cotton Research Development in Southern Nigeria) was done until Golding, Lean and Laycock (1927) studied growing of G. hirsutum and of Ishan cotton which is a variety of Gossypium barbardense. The latter originated in Ishan in the Mid-Western State and was subsequently cultivated in Southern Nigeria. Pomeroy (1925) working on cotton pests discovered that the duration of the pupal period of Diparopsis castanea in Nigeria is very variable at the end of the cotton season, some pupae remaining dormant in the soil for as long as 300 days or more.

As early as 1927, Golding described the infestation by cotton plants in Nigeria by numerous insect pests. Golding et al (1921) conducted a series of experiments at Moor Plantation, Ibadan, in Western State of Nigeria, and showed that in Southern Nigeria, the variety Allen cotton (G. hirsutum) compared very unfavourably with the local G. barbardense.

Allen cotton was more

susceptible in all stages of development to insect attack, especially Dysdercus species. Golding (1928) studying the bionomics of cotton stainers in Nigeria, recorded seven species of Dysdercus but only D. superstitiosus, D. fasciatus, and D. melanodenes can be considered as major pests of cotton. Of these three, D. superstitiosus is certainly the most important on account of its abundance and ubiquity; the other two species were localised in their seasonal distribution and irregular in their occurrence upon the cotton crop.

In order to improve cotton production, entomologists in Nigeria have concentrated efforts at controlling these numerous pests by the use of chemical insecticides and to a lesser degree by the use of cultural methods. Some of the cultural methods investigated were the utilization of time of planting to avoid infestation at a critical period (Hayward, 1967) and the replacement of the exotic cotton in the Southern Nigeria by an improved indigenous strain bred by Lewin (1927). Although these chemical and cultural methods were promising, they were not readily and fully adopted by the native farmers, because of the constraints they imposed on farmers viz:- the hazards of spraying dangerous chemicals, the costs (even though subsidized) of buying chemicals and the labour involved in spraying these chemicals in large volumes of water.

During the trade recession in 1932, Ishan cotton production in Southern Nigeria suffered a great set back. Its lint was found to be very rough and this made spinning

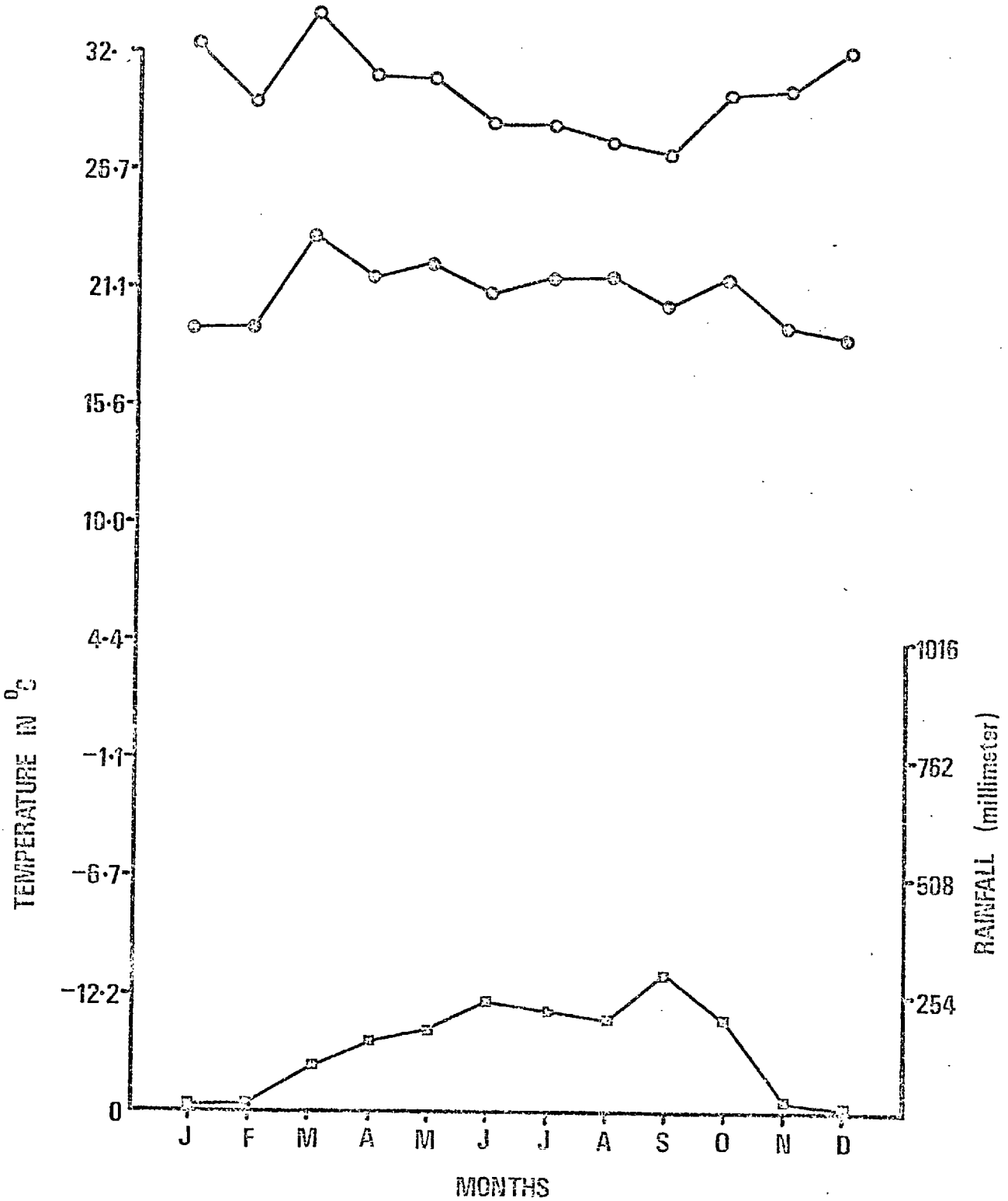
a very difficult operation. Neither selection, nor cross breeding with a smooth linted variety (Montserrat Sea Island) effected reduction in this roughness. Consequently interest in cotton growing in Nigeria moved to the North where a variety of G. hirsutum had proved superior to G. barbardense, and there prospects for a large export crop seemed better and was more promising. However, when cotton development was again revived in Southern Nigeria, G. hirsutum variety Allen 26J was introduced from Northern Nigeria. Hayward and Lee who worked under the Empire Cotton Growing Corporation in the North, were posted through the Department of Technical Co-operation to take charge of cotton research development in Southern Nigeria. Hayward (1966) sited demonstration plots in the Mid-Western State to study yield effects from fertilizer application. The first study on pests is that reported here by the writer.

2. CLIMATE, VEGETATION AND CROPS OF THE MID-WESTERN STATE

During the rainy season from March to October, warm moist air blows in from the Atlantic. The Harmattan brings the dry dust-laden winds from the north during November to early March. Annual rainfall in the State increases from 102 cm in the north to more than 254 cm in the south coastal area. In the cotton-growing areas 127 cm to 152 cm is usual with a break at the end of July or early August. The skies are often overcast and the diurnal fluctuation in temperature (Lee, 1966) commonly does not exceed about 9.4°C. Monthly mean maximum and minimum temperatures remain mostly within the range of 16 to 32°C throughout the year. The monthly mean maximum and minimum temperatures at Irrua Research Station (one of the sites used in this study) are shown in Figure 1 ; the mean monthly rainfall for 1952-1974 including the period covered by this study is given in Figure 1.

The vegetation of the Mid-Western State of Nigeria reflects the climate and is mainly tropical lowland dry forest between a coastal strip of wet forest swamps and Guinea Savannah zone. The cotton-growing areas are predominantly derived savannah, a humid climate with a well defined three months dry season. The crop ecological zones of the State (Fig. 2) illustrate this well. In addition to cotton, farmers in the cotton-growing areas also cultivate yam, cassava, cowpeas, groundnuts, upland rice, tomato, pepper, maize and sorghum. In general, these crops are often interplanted, except in the Government projects where crops are planted in succession (e.g. early maize followed by cotton etc.).

FIG.1 MEAN MONTHLY MAXIMUM AND MINIMUM TEMPERATURE AND RAINFALL AT IRRUA RESEARCH STATION



Rainfall – Irrua Research Station 1952 – 1974

Minimum Temperature °C
Maximum Temperature °C
} Irrua Research Station 1964 – 1974

KEY (CLASSIFICATION NUMBERS ARE THOSE OF A WORLD WIDE SYSTEM; PAPADAKIS 1961)

H4 GUINEA SAVANNA CLIMATE WITH 4 DRY MONTHS

D10 TRANSITION FOREST/SAVANNAH CLIMATE WITH 4 DRY MONTHS (deep sandy soils)

D4a DERIVED SAVANNA 50"–60" rainfall } HUMID CLIMATE WITH 3 DRY MONTHS

D4b FOREST 60"–70" rainfall } TYPICAL COCOA BELT

D8a HUMID FOREST CLIMATE WITH 2 DRY MONTHS (rather too humid for cocoa, deep sandy soils) 70"–90" rainfall

D8b AS D8a BUT LOWER RAINFALL (most below 70" per annum)

C9 HUMID FOREST CLIMATE WITH LESS THAN 2 MONTHS DRY SEASON. (soils from tertiary sands) 90"–120" rainfall

B3 MANGROVE SWAMPS WITHOUT DRY SEASON (humid climate rice harvest and drainage difficult) 100"–160" rainfall

B2 FRESH WATER SWAMPS AND DELTA MEANDER BELT 1–2 MONTHS ARE DRY (rice harvest difficult)

B1 FRESH WATER SWAMPS AND DELTA MEANDER BELT WITHOUT DRY SEASON (rice harvest difficult)

(NOTE: PAPADAKIS DIVIDES THE YEAR INTO DRY, INTERMEDIATE AND HUMID SEASONS BASED ON THE HUMIDITY INDEX)

M.A.N.R. RESEARCH BRANCH, BENIN.

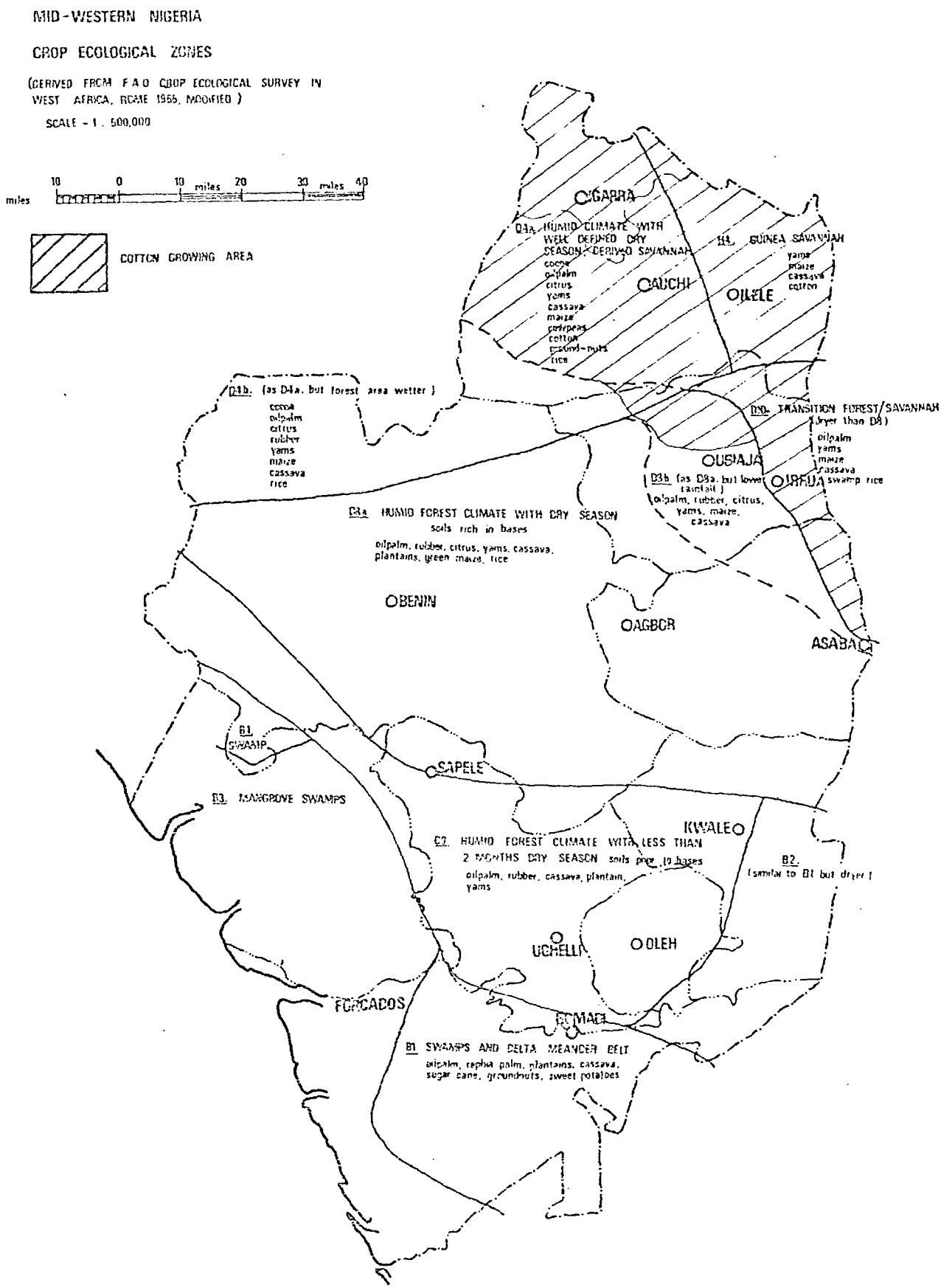

MID-WESTERN NIGERIA
CROP ECOLOGICAL ZONES
(DERIVED FROM F A O CROP ECOLOGICAL SURVEY IN WEST AFRICA, SCALE 1955, MODIFIED)
SCALE - 1 . 500,000
10 0 10 miles 20 30 miles 40
miles
COTTON GROWING AREA
OGARRA
D4a HUMID CLIMATE WITH WELL DEFINED DRY SEASON - DERIVED SAVANNAH
cocoa oilpalm citrus yams cassava maize cowpeas cotton ground-nuts rice
OAUCHI
OILELE
H4 GUINEA SAVANNAH
yams maize cassava cotton
D4b (as D4a, but forest area wetter)
cocoa oilpalm citrus rubber yams maize cassava rice
D4c TRANSITION FOREST/SAVANNAH (drier than D4)
oilpalm yams maize cassava swamp rice
OUSIAJA
IRRUA
D3b (as D3a, but lower rainfall)
oilpalm, rubber, citrus, yams, maize, cassava
D4a HUMID FOREST CLIMATE WITH DRY SEASON
soils rich in bases
oilpalm, rubber, citrus, yams, cassava, plantains, green maize, rice
OBENIN
OAGBOR
ASABA
B1 SWAMP
SAPELE
B3 MANGROVE SWAMPS
C2 HUMID FOREST CLIMATE WITH LESS THAN 2 MONTHS DRY SEASON soils poor in bases
oilpalm, rubber, cassava, plantain, yams
KWALE
B2 (similar to B1 but drier)
UCHELLI
OLEH
FORCADOS
ECMAEL
B1 SWAMPS AND DELTA MEANDER BELT
oilpalm, raphia palm, plantains, cassava, sugar cane, groundnuts, sweet potatoes

FIG. 2

3. MAJOR COTTON PESTS IN THE MID-WESTERN NIGERIA

The main cotton pests in the Mid-Western State of Nigeria are spiny bollworm (*Earias biplaga*, Wlk. Noctuidae), pink bollworm (*Pectinophora gossypiella*, Saund. Gelachidae), cotton stainers (*Dysdercus superstitiosus*, (F) Pyrrhocoridae), aphids (*Aphis gossypii* Glov. Aphidae) and flea beetles (*Podagrica* spp.). Where tomato is interplanted with cotton, the 'American' bollworm (*Heliothis armigera*, Hb. Noctuidae) appears as a pest. Although these pests are important in limiting yields of cotton in Mid-Western Nigeria, the relative importance of the individual species varies between seasons and localities.

E. biplaga and *H. armigera* are present in large numbers in some areas and almost entirely absent from others. Pomeroy (1925), Golding *et al* (1927) and Hayward (1967) recorded variations in infestations which may be due to the presence or absence of alternative host plants. In the 1974-75 season, for example, *H. armigera* was rare in sole cropped cotton while *E. biplaga* and *P. gossypiella* occurred quite commonly (Table 1); *E. biplaga* was abundant throughout the cotton growing season reaching a 'Peak' of 72.4% of the total moths collected from a light trap of Ilele (Site I) 16-17 weeks after germination of the cotton crop.

The biology of the major pests of cotton, their natural enemies and other host plants have been summarised by Pearson (1958) and Liby (1968).

TABLE 1. PERCENTAGE OF BOLLWORM LIGHT-TRAP CATCHES AT ILELE RESEARCH STATION, MID-WESTERN NIGERIA

MONTHS	SEPTEMBER		OCTOBER		NOVEMBER	
BOLLWORM	PERCENTAGE AND NUMBER CAUGHT		PERCENTAGE AND NUMBER CAUGHT		PERCENTAGE AND NUMBER CAUGHT	
EARIAS BIPLAGA	194	71.0%	370	72.0%	152	72.4%
PECTINOPHORA GOSSYPIELLA	79	29.1%	143	28.1%	58	28.6%

4. PEST INFESTATION IN RELATION TO COTTON CROP DEVELOPMENT IN MID-WESTERN STATE OF NIGERIA

High yields are obtained from cotton sown in July (Lee, 1966; Hayward, 1966); although most farmers sow their cotton later. Cotton sown after July has a shorter growing period before the end of the rains in October.

Cotton sown early in July begins to flower about nine to ten weeks later in September, and flowering reaches its peak in October. Some flowers may still be produced in December and early January. Flowers formed after the end of the rains seldom develop to mature bolls, as the majority shed within 10 days (Pearson, 1958). The peak number of green bolls is by the end of October and the earliest bolls begin to split open during November. Picking starts at this time and is ended by January. For convenience, pest infestation of cotton from the time of germination to harvest can be classified into Pre-flowering and Flowering stages:-

Pre-flowering Stage

The only insects that cause a serious problem are flea beetles (Podagrica spp.) which can destroy the entire crop at the seedling stage as observed in one of the experimental plots planted close to a source, - kenaf.

Adult flea beetles eat numerous small holes on leaves so delaying plant development.

A single early spray application with carbaryl has suppressed this initial pest attack.

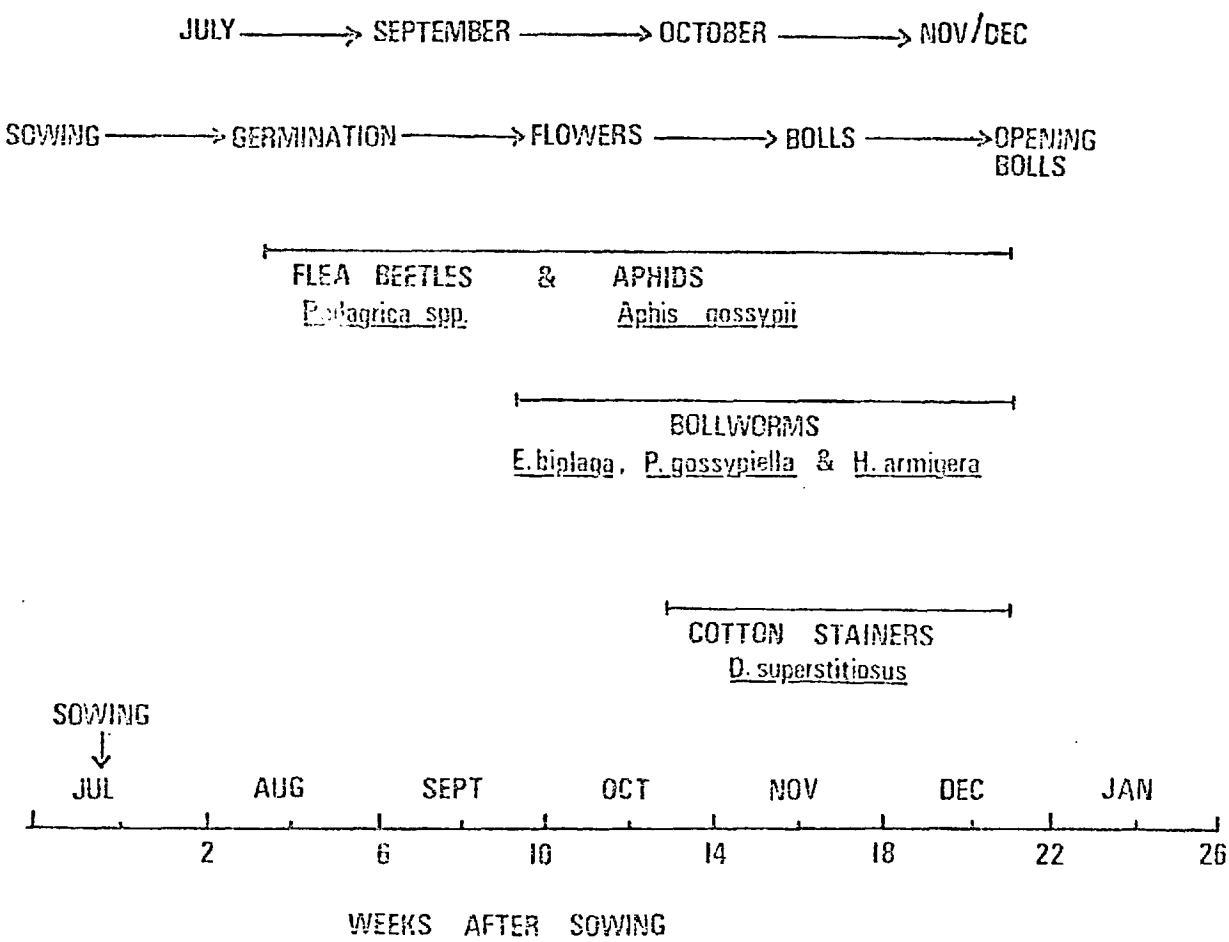
Infestation of A. gossypii Glov. occur regularly and can build up to large populations throughout the season. Early E. biplaga tip boring rarely seems to be important.

Flowering Stage

Populations of the major pests (bollworms and cotton stainers) begin to build up from September with the onset of flowering. The populations increase to give a peak in November. The few D. superstitiosus found on crops in Mid-October cause shedding of buds and young bolls. Apart from P. gossypiella, no diapause has been demonstrated for E. biplaga and H. armigera in the Mid-Western State; hence infestation by the latter two pests, no doubt originates always from alternate host crops. Populations of these bollworms reach a 'Peak' between October and November, thus coinciding with a critical period of the crop development when 'Peak' boll formation occurs.

Figure 3 represents the development of the cotton crop with time and the major occurrence of the pests.

FIG. 3 DIAGRAMATIC REPRESENTATION OF THE DEVELOPMENT OF COTTON CROP WITH TIME AND OCCURENCE OF THE MAJOR INSECT PESTS IN MID-WESTERN STATE OF NIGERIA



5. COTTON PEST CONTROL WITH SPECIAL REFERENCE TO NIGERIA

(i) General pest problems and conventional spray approach

In early years most of the cotton pest control measures investigated were mainly biological. For example Lewin (1927) working at Moor Plantation, Ibadan, bred cotton for growing in the Southern Provinces of Nigeria; with the objective of conferring resistance to the pest complex. Since then many trials have examined the effectiveness of various chemicals in controlling cotton pests.

Geering and Baillie (1954) working at Samaru in Northern Nigeria, established the annual cycle of activity and found that egg and larval population of red bollworm reached a peak in October or November. Geering (1951), Baillie and Geering (1952) and Baillie (1953) sprayed and dusted cotton crops with DDT against the red bollworm between October and November. Yields obtained were low, between 400-500 kg seed cotton per hectare. Although the yields were low, the small increases above the peasant farmers level of production, were a result of the chemical sprays applied. The uneconomic yield obtained was attributed to poor soil conditions and the fact that no fertilizers were applied.

Isobenzan, carbaryl, monocrotophos, dicrotophos, DDT plus BHC, fenitrothion, dimethioate plus DDT were effective against bollworm complex and Dysdercus (Choyce and Lyon, 1965; Hayward, 1967; Fadare, 1974), but carbaryl was considered the best in terms of effectiveness and safety.

It was commercially available, and even when marketed as a wettable powder with 85% active ingredient it can be used with little supervision. A major disadvantage of carbaryl is that mite infestations are induced. Also it would be easily washed off by rains unless it is deposited on the underside of the leaves (Matthews, 1966; Hayward, 1967). Therefore additional sprays might be required during the rainy season, and this would increase the cost.

(ii) Chemical control by ultra-low volume approach

The trials described above used conventional methods of spraying. Recently, a new application technique has been introduced, namely, the ULV (Ultra-Low Volume) spray, which has been defined (Anon, 1971) as the minimum amount of liquid per unit area compatible with economic requirements of achieving control.

Joyce (1955) applied about 4 litres DDT concentrate per hectare to control cotton jassid, Empoasca lybica (De Berg) in the Sudan Gezira. Messenger (1964) controlled Anthonomus grandis with undiluted ULV malathion. Wene and Sheets (1965) who compared undiluted malathion with an aqueous emulsion aerially sprayed at a dosage rate of 1.4 kg insecticide per hectare, confirmed that effective control of cotton pests except for bollworms would be possible. Other cotton pests that have been successfully controlled by malathion sprayed as the undiluted chemical are the carmine spider mites (Tetranychus telarius) and Aphis gossypii Hopkins et al, (1967).

Control of cotton pests with ULV application of DDT has been studied in East Africa (Sayer, 1967; Johnstone, 1970; Parish and Robertson, 1967). DDT combined with malathion and toxaphene were also effective.

In Malawi, Matthews (1973) sprayed ULV formulations of carbaryl and DDT and obtained best control of bollworms, Diparopsis castenea (Hmp) and Heliothis armigera (Hbn) with 10% sprays at 5 l/ha. Lindley (1969) has used ULV to control a great number of pests on citrus, date palm, wheat and cotton. Although this new approach to chemical control of cotton pests has not been widely used in Nigeria, the first attempt was made at Samaru and Kadawa in Northern Nigeria by Beeden (1974) and by Usenbo (1974) in Mid-Western State of Nigeria.

Usenbo obtained control of A. gossypii and D. superstitiosus by spraying a ULV formulation of 25% endosulfan on cotton crop.

Unlike in the U.S.A. and Sudan where cotton is grown on a large scale, and pesticide usage and pesticide problems are widespread; in Nigeria, cotton production is on a small scale by peasant farmers who have so far used few pesticides. In order to avoid the future risk of harmful side effects from intensive use of chemicals, an integrated control approach is urgently needed in Nigeria. This aspect of pest control is reviewed below.

6. THE INTEGRATED CONTROL APPROACH IN RELATION TO INSECT PEST CONTROL ON COTTON

Many problems have arisen as a result of the intensive use of chemical pesticides to control insect pests. There is the well-documented phenomenon of insect resistance with over 228 insect species in the world reported as resistant to chemical pesticides. Several pests of cotton including bollworms and leafworms are involved. A clear African example is the red spider mite in Rhodesia which developed resistance to dimethioate and related organophosphate chemicals (Duncombe, 1973). Pesticides applied to other target species usually eliminate the natural enemies, and thereby allowing unrestrained increase of the mites (Huffaker, Van de Vrie and McMurtry, 1969). Georghion (1972) reported that the heavy use of pesticides for cotton pest control in Central America has led to selection of resistance and cross resistance by a malaria-transmitting mosquito, Anopheles albimanus which inhabits many kinds of vegetation including cotton.

Another example of pesticide induced resistance is found in the cotton production work at the Canete Valley. Resistance of many important cotton damaging insects to insecticides in the Canete Valley was discussed by Barducci (1972). A. gossypii proved resistant to BHC, Anomis texana to toxaphene and Heliothis virescence to DDT and mixtures of DDT and BHC.

In Mid-Western Nigeria, the areas that are grown to cotton lie in the guinea savannah (Mid-West Ecological map Figure 2) region where alternative host crops grow to provide shelter and food to cotton pests and their natural enemies. On the contrary, in the Canete Valley cotton is cultivated in irrigated arid land. There are few alternative host plants; thus intensive use of chemicals has induced heavy selection pressure on the pests. Pests like the leaf roller which web themselves within the leaves required more sprays to develop resistance. Similarly, the major leafworms that feed on the leaves were among other insects to develop resistance in the valley.

In Mid-West State, the "closed season" is observed for cotton from February 11th to July of every growing season. This is provided to stop a carry over of P. gossypiella and other insect pests from the previous season. Although similar regulations were enacted in Peru (e.g. the ban on ratooning) this was broken due to the lower cost of ratoon cultivation in comparison with new cotton plantings.

A list of undesirable effects caused by indiscriminate use of chemical pesticides have been given by Smith and Falcon (1973) and these include among others, the flareback or resurgence of the target pests following application of pesticides, the release of non-target species by the destruction of natural enemies which otherwise hold their population in check; the problems of environmental disruption outside the pesticide treated area, human health

hazard and hazards due to the presence of chemical pesticide residues on food crops and the problems of the accummulation of harmful pesticide residues in wild life species.

The integrated control approach aims to minimise the ills caused by such use of chemical pesticides.

"Integrated control is a pest management system that in the context of the associated environment and population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury" (Doutt and Smith, 1971). Smith et al (1967) states that this system achieves this ideal by harmonizing techniques in an organized way, by making techniques compatible and blending them into a multifaceted, flexible, evolving system. Each control has a potential role to play in harmony with others.

An evolving example of integrated control of cotton pests is illustrated by the Nicaraguan integrated pest control programme for cotton.

The objectives of this programme were: to reduce the excessive use of insecticides and minimize associated undesirable effects especially those causing insect resistance and pesticide residue problems; to lower cotton production costs; and to increase cotton production.

Promising achievements are being made through this programme and thus cotton industry was once again revitalized in Nicaragua (Falcon and Smith, 1973).

In East and Central Africa a foundation for integrated control was laid in 1920's with host cottons resistant to jassid and also a closed season, established in the 1930's. Superimposed on this, scouting procedures (Matthews and Tunstall, 1968) were developed to minimize the use of pesticides. Thus a basis for integrated control concepts were formed (Matthews, 1968).

Insecticides will continue to be used by small-scale farmers in Mid-Western Nigeria and in Africa as a whole, as a cheap and reliable means of checking pest damage. Fortunately, there is the prospect in most countries in Africa of developing and implementing integrated methods, involving the rational use of insecticides before the onset of severe pesticide-induced problems as witnessed in Nicaragua and Canete Valley, although even in these cases, it was reported that the locally harmful effects of indiscriminate insecticide use are not irreversible.

7. OBJECTIVES OF THE STUDY

The major objectives were to determine whether a greater understanding of pest ecology would indicate whether improvement could be made by limiting the use of selective insecticides and by developing alternative crop systems which could be used to increase cotton yield economically whilst also decreasing pest damage.

Although it is recognised that insecticides play an essential role in crop protection, their use in agro-ecosystem has led to drastic reduction of natural enemies in these systems. As already mentioned some of the undesirable effects of the use of pesticides have been demonstrated (e.g. Smith *et al*, 1973; Reed, 1965; Matthews and Tunstall, 1968). There is every reason, therefore to believe that similar ecological disruption and pest out-break due to heavy use of insecticides might occur with time in the Mid-Western State of Nigeria.

Hence in developing this study, the author has as one of his objectives, the limited use of chemical pesticides for the control of the major insect pests of cotton (e.g. *Earias* and *Dysdercus*) such that pest infestations e.g. of aphids are not made worse.

A second objective of this study was to evaluate certain mixed cropping systems. Mixed cropping has been used successfully under indigenous technology to increase crop production in Northern Nigeria by Norman (1971). Reports from IRRI (1973) in crop combination and insect

interactions, showed that the traditional intercropping (mixed cropping system) of peanuts with corn decreased corn borer infestation. Way (1973) has stated that in Asia and Africa, the bollworm H. armigera a major pest of cotton, caused insignificant damage to cotton in the Sudan Gezira until the mid-1960's. Since then, however, this pest has increased its damaging activities as a result of a change in cropping practices to include ground-nuts. The inclusion of ground-nuts in the cropping system coincided with a decrease in the cropping of Dolichos, which is known to act as a "diversionary" host plant.

In part of Tanzania and elsewhere, it was reported Smith (1973) that intercropping of maize with cotton apparently increases Heliothis damage to cotton, whereas in Peru the same kind of diversity is reported to be an aid in management of Heliothis. However, the reason for this is not known; it may be ascribed to differences in the cotton variety grown and could also be due to differences in the species making up the Heliothis complex; for example, H. zea may prefer maize, whereas Heliothis armigera oviposits on wherever crop is flowering at the time, that is, a generation may breed up on maize and later transfer to the cotton crop.

Hence there is the need to understand why incidence is increased or decreased in a mixed cropping system.

Some guidelines to the understanding of this phenomenon are well outlined by Way (1973), and these include,

for example; possible enhancement due to natural enemy action, presence of diversionary hosts, camouflaging effects of other plants, lack of contact between plants of the same species so decreasing the success in plant-to-plant colonization; lack of coincidence of pests with the at-risk stage of the crop or conditions detrimental to dormant season survival. A full grip of the knowledge of these attributes of the mixed cropping system would lead to the third objective, that is, further understanding of cotton pest ecology so that better control measures can be devised for the pest complexes in an integrated control programme.

Thus the ultimate realisation of these objectives would make increased cotton production more likely.

SECTION II

CHEMICAL CONTROL BY CONVENTIONAL SPRAYING

1. INTRODUCTION

As a first approach in the development of an integrated control programme against cotton pests in the Mid-Western State of Nigeria, a comparison of some available insecticides against the insect pest complex was made in the field so that those with properties such as selective action (i.e. reduced kill of natural enemies) could be chosen for more detailed studies. Such detailed studies would include an examination of dosage rates, timing and number of insecticide applications which hopefully would optimise the selective action needed for a successful integrated control programme.

In the second season (1972-73), the dominant bollworms causing yield decreases were identified and the damage they cause assessed.

Finally, in the 1973-74 season, a study of a range of dosages of the readily available endosulfan wettable powder formulation was undertaken; to compare its possible selective effects in terms of natural enemies, most of which are predacious on aphids and other cotton pests.

There was evidence from the earlier work (1971-72 season) that endosulfan may be selective especially at low doses (e.g. kills aphids but not predators). The problem was therefore to assess how much control of pests was

exerted by the natural enemies spared by the low doses of endosulfan and whether or not lowering the dosage had undesirable repercussions in control of the total pest complex on cotton.

2. MATERIALS AND METHODS

The insecticides used in the first and second trials (1971-73 seasons) were endosulfan, monocrotophos and carbaryl belonging to the different chemical groups namely; organochlorine, organophosphate and carbamate. Their choice was based on reasons explained in the introductory passage (Section II). Two formulations each of endosulfan and carbaryl were used.

The treatments and rates of application were based on recommendations of Choyce et al (1963) and Hayward (1967) for control of cotton pests in Northern and Western States of Nigeria. Different rates were used in order to obtain possible selectivity in favour of the natural enemies, thus:-

i) Endosulfan 5% granules at 2.8 kg a.i/ha
ii) Endosulfan 35 E.C. at 0.39 kg a.i/ha
iii) Carbaryl 85 W.P. at 0.95 kg a.i/ha
iv) Carbaryl 20 E.C. at 0.22 kg a.i/ha
v) Monocrotophos 60 W/V at 0.39 kg a.i/ha
vi) Untreated control

The insecticides were made up in water and sprayed at 224 litres per hectare.

At the time the emulsifiable concentrate (e.c.) formulation of carbaryl and endosulfan insecticides were not readily available commercially in the Mid-West State. They were however compared with the more readily available and cheaper wettable powder carbaryl formulation (the

recommended spray in the State) especially as they provide better deposits on the leaf surface for bollworm control (Matthews, 1966).

In the final conventional spray trial conducted in the 1973-74 season, Endosulfan 50 and Carbaryl 85, both wettable powders, were used at higher rates than previously applied. Carbaryl was included in this trial because it was hoped that it would act as a selective killer of predators and so indicate the level of pest damage reached when predators were excluded.

The treatment and rates of application in 224 litres of water per hectare were:-

i) Endosulfan 50 W.P. at 1.12 kg a.i/ha
ii) " " at 0.56 kg a.i/ha
iii) " " at 0.28 kg a.i/ha
iv) Carbaryl 85 W.P. at 1.12 kg a.i/ha
v) Untreated Control

The cotton variety Allen 26J was sown in all the trials. It was planted during the first week of July in the 1971-73 seasons but in the last week of July in the 1973-74 season.

In all the trials 22.5 kg seed were sown per hectare treated with "Agrosan" chemical which was to act against seed borne diseases. Six seeds per hole were sown about 2.5 cm deep in ridges 90 cm apart. On germination, plants were thinned to one plant per hole. The trials received nitrogen fertilizer as calcium ammonium nitrate (26% N)

27m

27m

18m

9m 18m

GUARD ROW

CONTROL	CARBARYL 20 E.C.	ENDO-SULFAN GRANULE	ENDO-SULFAN 35 E.C.	MONO-CROTO-PHOS	CARBARYL 85 W.P.
MONO-CROTO-PHOS	ENDO-SULFAN 35 E.C.	CONTROL	CARBARYL 20 E.C.	CARBARYL 85 W.P.	ENDO-SULFAN GRANULE
CARBARYL 20 E.C.	ENDO-SULFAN GRANULE	ENDO-SULFAN 35 E.C.	CARBARYL 85 W.P.	CONTROL	MONO-CROTO-PHOS
CARBARYL 85 W.P.	CONTROL	MONO-CROTO-PHOS	ENDO-SULFAN GRANULE	CARBARYL 20 E.C.	ENDO-SULFAN 35 E.C.
ENDO-SULFAN 35 E.C.	CARBARYL 85 W.P.	CARBARYL 20 E.C.	MONO-CROTO-PHOS	ENDO-SULFAN GRANULE	CONTROL
ENDO-SULFAN GRANULE	MONO-CROTO-PHOS	CARBARYL 85 W.P.	CONTROL	ENDO-SULFAN 35 E.C.	CARBARYL 20 E.C.

Fig. A. A 6 x 6 LAYOUT PLAN FOR 1971-73 SEASONS.

TREATMENTS

1. ENDOSULFAN GRANULE
2. " 35 E.C.
3. CARBARYL 85 W.P.
4. " 20 E.C.
5. MONOCROTOPHOS
6. UNTREATED CONTROL

applied as a side dressing at 225 kg per hectare, 2-3 weeks after sowing and immediately after thinning.

A 6 x 6 latin square design was used and the experiments duplicated at two sites in the 1971-72 season, Site I at Ilele and Site II at Irrua Government Farm Centre. In the 1972-3 season only Site II was used. In both sets of trials the plots were 0.07 hectare in area but all counts and yield were taken from a central area of 0.03 hectare (Figure A). At the final trial in 1973-74 season, a 5 x 5 latin square design was used and it was located at Site I only. Plots were 0.07 hectare in area and all biological data were taken from the central 0.03 hectare in each plot.

All insecticide applications began from the first week of October in the 1971-73 trials, i.e. 12th week after germination contrary to the 9th week, which is the recommended period to commence spraying. However, the 12th week after sowing was chosen in this trial, as a time to begin spraying in order to compare the effect of delayed spraying with the recommended period. Endosulfan granules were applied by hand, by sprinkling them over the top of the plant, with care, so that as few as possible dropped directly to the ground. Most of the granules did not stay on the leaves, rather they collected behind the bracts; on most occasions wind shook many of the granules to the ground which must have reduced the effectiveness of this treatment.

A simple syringe type lancet sprayer (Manufactured by Cooper Pegler & Co.) was used to apply the sprays. The sprayer consists of a tank which is usually fitted on the back of the operator when in use, a hand-operated pump and a pressure chamber to reduce changes in pressure with each pump stroke. There is a variation in this sprayer which includes piston and diaphram pumps operated left or right handed by underarm or overarm levers. The sprayer also has a lance with trigger valve and a nozzle for the distribution of the insecticide droplets. Separate lancet sprayers was used to spray the different insecticides so as to avoid cross contamination of chemicals. Care was taken to avoid spray droplets drifting to adjacent plots, also spray was directed sideways between the rows to obtain some underleaf and stem cover. In the 1973-74 trial, spraying began in the 3rd week of September nine weeks after sowing. As in the previous trials, separate lancet sprayers were used to apply each of the treatments and the plants were sprayed both above and beneath the leaves with the endosulfan treatments only. The carbaryl was applied from above to kill predators but hopefully have minimal effects on aphids. The sprays were applied six times at weekly intervals; thus the spray operation was terminated in the last week of October when the cotton crop was 14 weeks old. Six spraying occasions were observed in this trial to cover the early and late pest infestation during crop development (Figs. 11-17).

Treatments in all trials were assessed on the basis of:-

(i) (a) the number of lepidopterous larvae, mostly Pink bollworm (P. gossypiella) and Spiny bollworm (E. biplaga),

(b) adults and nymphs of cotton stainers (D. superstitiosus),

(c) cotton aphids (A. gossypii),

(d) syrphid larvae

(e) coccinellids (C. lunata and P. ferruginea) and

(f) spiders found by examining in the field 40 randomly selected plants/plot in the 1971-73 trials and 64 randomly selected plants per plot in the 1973-74 trial.

(ii) total yields of seed cotton of the sampled areas of the plot.

Sampling for insect pests and predators began two days before the first insecticide treatment (i.e. Pre-spray sample) and was then done weekly two days after each treatment and weekly during the post-spray periods.

The sampling procedure adopted for A. gossypii was as given by Banks (1954). Each plant sampled was examined carefully for aphids. When the population on a plant was below about 700 and evenly distributed, direct counting using a hand counter was done. Where the population was larger, estimates were made. These were obtained by

first counting the actual number of aphids on 2 cm of the stem, then noting the length of the stem surface covered and multiplying accordingly.

More aphids were found on the stem than on the undersides of the leaves, contrary to the conclusions of Pearson (1958) who observed that more aphids were found on the underleaf surfaces.

The populations of bollworms, cotton stainers and natural enemies were assessed by directly counting the numbers found on the randomly selected plants. Three pickings of seed cotton were made at two-week intervals.

The total fruiting bodies (squares, bolls and flowers) produced during the 1973-74 trial were recorded and damage to unshed bolls caused by bollworms and cotton stainers was also recorded. This was assessed by counting all bolls damaged from the sixty-four randomly selected plants sampled for pests. In the 1972-73 trial, damage assessments were taken from 30 bolls and 30 flowers per plot examined for damage caused by either E. biplaga or P. gossypiella. A total of 180 bolls and 180 flowers was examined for each treatment. Bollworm larvae characteristically damage bolls by boring a tunnel in the bolls. Openings in the bolls often predispose affected bolls to secondary infections which may lead to boll shedding. Damage by E. biplaga was easier to recognise than by P. gossypiella; the tunnels made were usually blocked with excrement in both the flowers and green bolls. The bores

or tunnels are usually made at an angle to the Penduncle. In the case of the smaller larvae of P. gossypiella damage is very difficult to identify from the outside. However, the bolls and flowers are usually attacked below the calyx. The bolls and flowers were dissected and any larvae caught was identified and recorded against the treatment.

The data on population counts, damage assessments and yield were analysed by analysis of variance and subsequently finding the least significant range (LSR) between the means of the treatment at the 5% probability level for numbers of the insect pests, numbers of natural enemies and yields (Duncan's New Multiple Range Test; Steel & Torrie, 1960).

3. RESULTS

(A) Comparison of candidate insecticides for control of cotton pests in Mid-Western State of Nigeria, 1971-72 season

(i) Effects on Pectinophora gossypiella

At Site I, P. gossypiella numbers were approximately halved by endosulfan e.c., monocrotophos and the carbaryl 85 treatment compared to the untreated plots and endosulfan granule (Table 2). This represents a significant reduction ($P < 0.05$) of population size by 52, 50 and 48 percent respectively. Similarly, carbaryl 20 e.c. also significantly ($P < 0.05$) lowered P. gossypiella numbers below those in endosulfan granule and untreated controls (Table 2). At Site II, fewer larvae were recorded from insecticide treatments during spraying. Mean number of larvae recorded per plant from monocrotophos, endosulfan e.c. and carbaryl treatments were significantly lower ($P < 0.05$) than in untreated control plots. There was as in Site I no difference ($P = 0.05$) between endosulfan granule treatment and untreated controls (Table 2). Also carbaryl 20 e.c. did not differ significantly ($P < 0.05$) from endosulfan granule treatment.

The mean number per plant of P. gossypiella larvae recorded during the post-spray period (Table 2) was 0.305 from the untreated control in Site I. At this same site cotton treated with carbaryl 85, monocrotophos, carbaryl 20 and endosulfan e.c. had the lowest population

TABLE 2. MEAN NUMBERS OF PINK BOLLWORM (P. GOSSYPIELLA) LARVAE/PLANT DURING CONVENTIONAL SPRAY TRIAL, 1971-72 SEASON

			Carbaryl		Endosulfan		Untreated Control
		Monocrotophos	W.P.	E.C.	E.C.	Granule	
WHOLE SEASON	Site I	0.87	0.86	1.02	0.93	1.68	1.75
	Site II	0.072	0.13	0.21	0.20	0.26	0.35
SPRAYING PERIOD	Site I	0.16	0.16	0.20	0.15	0.30	0.32
	Site II	0.042	0.067	0.16	0.066	0.24	0.33
POST-SPRAY PERIOD	Site I	0.16	0.15	0.16	0.23	0.30	0.31
	Site II	0.046	0.079	0.086	0.17	0.069	0.116

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

of 0.15, 0.16, 0.16 and 0.23 per plant respectively and this meant a significant reduction ($P < 0.05$) of population by 52, 48, 48 and 26 percent over untreated control. However, monocrotophos and the two carbaryl treatments significantly depressed P. gossypiella numbers ($P < 0.05$) more than endosulfan e.c. Again no differences occurred in larvae numbers recorded from endosulfan granule and untreated controls (Table 2). Similar results were obtained at Site II, except surprisingly that endosulfan e.c. had no effect whereas the endosulfan granule treatment significantly reduced ($P < 0.05$) P. gossypiella numbers than untreated controls.

This lowering of P. gossypiella by endosulfan granules was perhaps due to some of the granules being retained on the small plants in Site II, and subsequently picked up by the newly emerging larvae.

The differential effects of treatments were demonstrated clearly at Site II (Table 2, Figure 4) where the P. gossypiella population was kept lower by monocrotophos, endosulfan e.c. and carbaryl 85 than at Site I where the population tended to rise even during the spraying period. However, at Site II, the population rose after the last spray application (Figure 4).

At both sites, the population pattern was similar in the untreated controls and in the plots treated with endosulfan granules (Table 2) except at Site II during the post-spray period when endosulfan granules

significantly lowered ($P \leq 0.05$) the *P. gossypiella* population.

Despite sprays, *P. gossypiella* numbers increased at both sites over the period of 9–13 weeks after germination (Fig. 4). This could probably have been due to later generations of *P. gossypiella* larvae produced in the crop at this time, which were less affected by sprays due to the diluting effect of the more luxuriant vegetative growth of the crop.

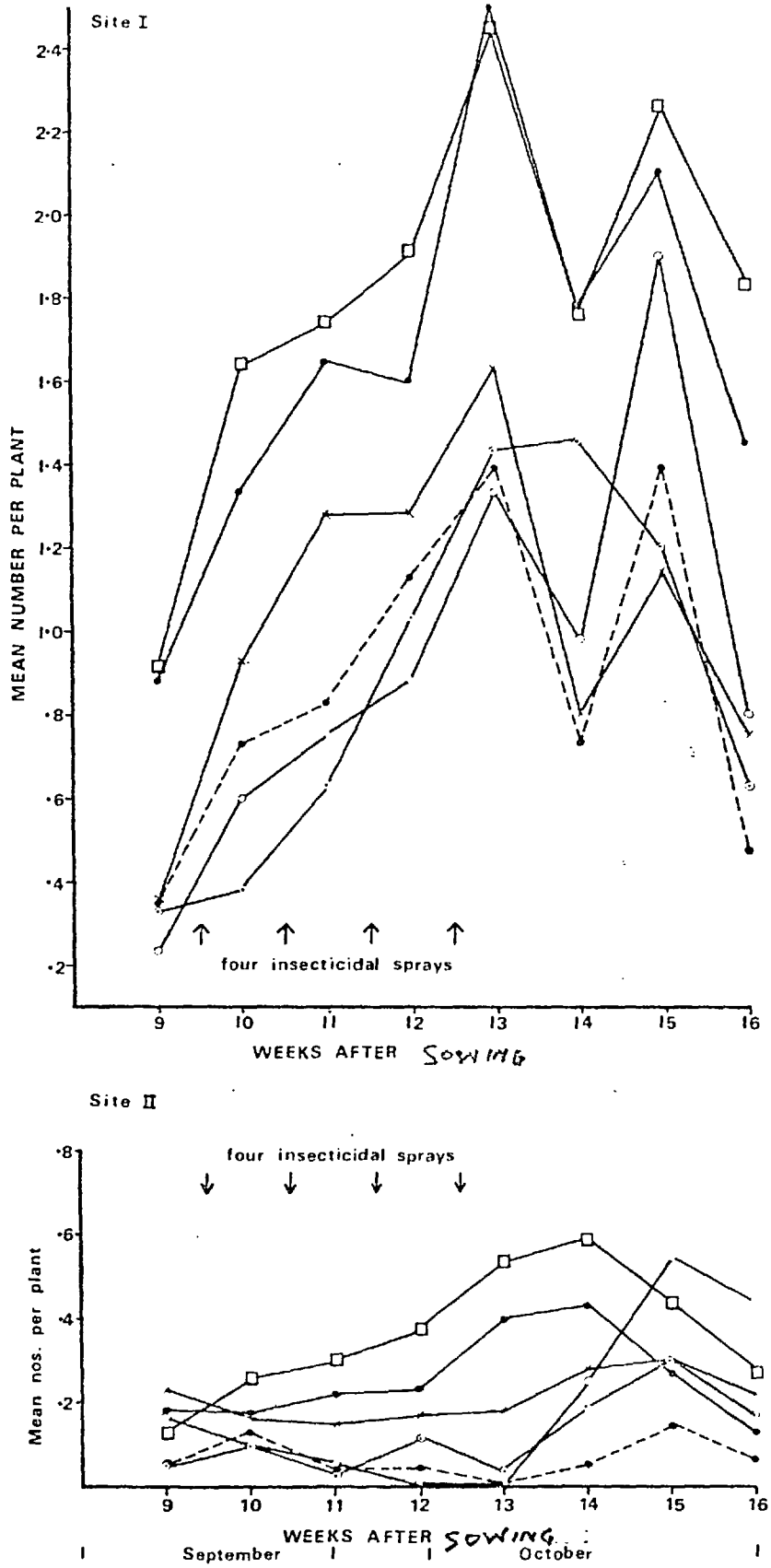


Fig. 4. Mean numbers of (Pectinophora gossypiella) larvae per plant recorded in weekly counts from sprayed and unsprayed plots in Mid-Western State of Nigeria.

1971-72 SEASON

KEY:

- Endosulfan Granules
- Endosulfan 35 E.C
- Carbaryl 85 W.P
- Carbaryl 20 E.C
- Monocrotophos
- Control

(ii) Effects on spiny bollworm (E. biplaga)

1971-72 season

Although monocrotophos, carbaryl 85, endosulfan 35 e.c. and carbaryl 20 e.c. kept E. biplaga low (Table 3, Fig. 5), the major difference between sprayed and unsprayed treatments was in week 14 after germination (Fig. 5). At both sites I and II there was no significant difference between untreated control and endosulfan granule treatments throughout the season.

During spraying and post-spray periods monocrotophos, endosulfan 35, carbaryl 85 and 20 e.c. treatments recorded significantly lower ($P \leq 0.05$) E. biplaga population than untreated controls at both sites (Table 3).

Monocrotophos and carbaryl 85 w.p. recorded the lowest pest infestation compared to the other treatments (Table 3). The mean number of E. biplaga larvae found per plant during post-spray counts for these two chemicals were respectively 0.027 and 0.046, at Site I and 0.015 and 0.008 at Site II. Whereas from untreated control crops 0.084 and 0.107 larvae/plant were taken from Sites I and II respectively.

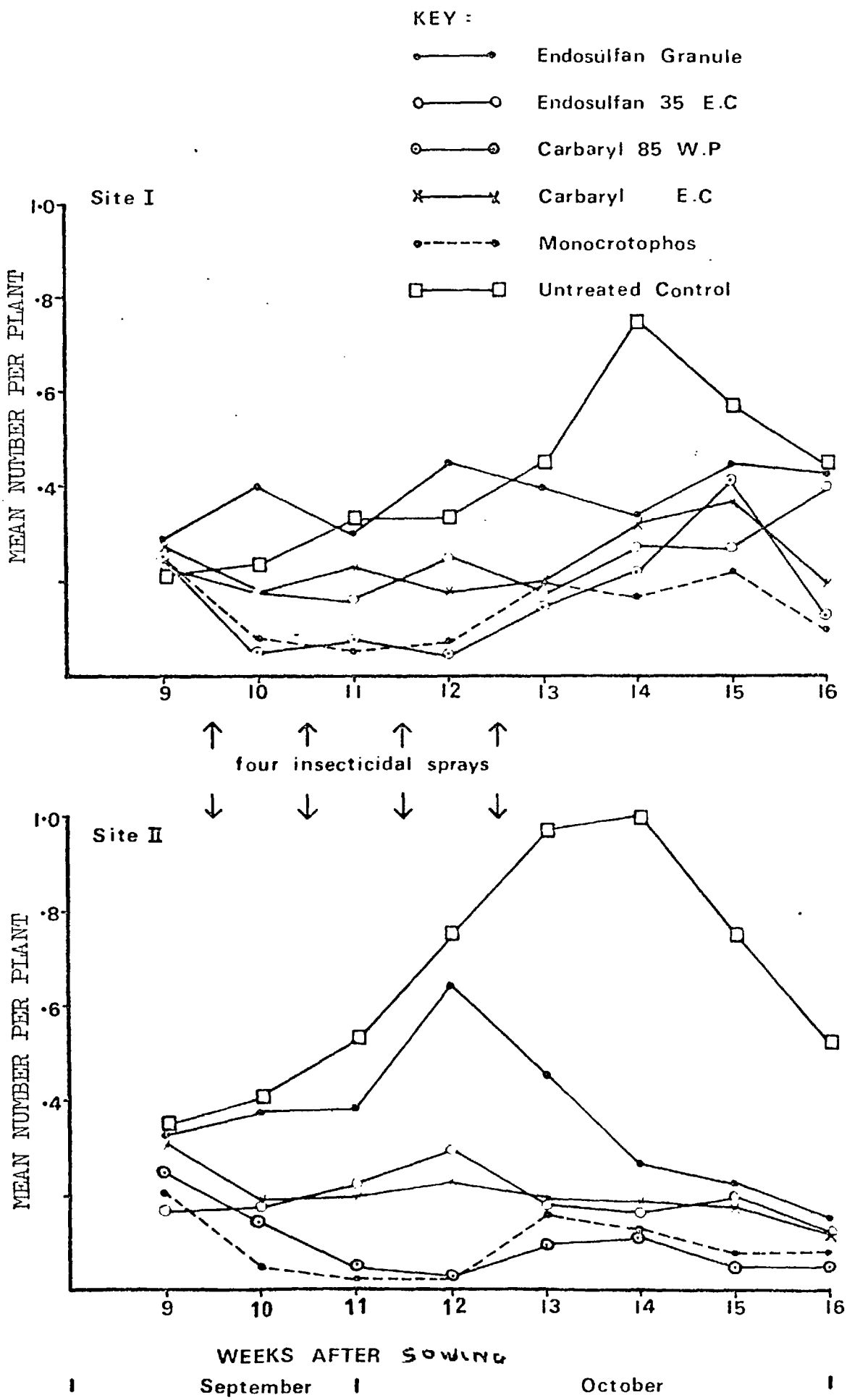
These results again confirmed the persistent effect of monocrotophos and carbaryl 85 w.p. However, in Site I there was a more rapid resurgence of the pest after spraying than at Site II (Fig. 5, Table 3). Endosulfan 35 e.c. was about as good as the monocrotophos and carbaryl 85 w.p. (Table 3, Fig. 5).

TABLE 3. MEAN NUMBER OF SPINY BOLLWORM (E. BIPLAGA)/PLANT DURING CONVENTIONAL SPRAY TRIAL, 1971-72 SEASON

			Carbaryl		Endosulfan		Untreated Control
		Monocrotophos	85 w.p.	20 e.c.	e.c.	granule	
WHOLE SEASON	Site I	.088	.108	.131	.129	.182	.190
	Site II	.061	.065	.107	.091	.228	.284
SPRAYING PERIOD	Site I	.019	.020	.037	.035	.063	.069
	Site II	.013	.015	.032	.034	.138	.123
POST-SPRAY PERIOD	Site I	.027	.046	.048	.056	.073	.084
	Site II	.015	.008	.025	.028	.036	.107

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

Fig. 5. Mean numbers of Earia$biplaga larvae per plant recorded in weekly counts from sprayed and unsprayed plots in Mid-Western State of Nigeria. 1971-72 SEASON



(iii) Effects on cotton stainers (D. superstitiosus)

1971-72 season

Cotton stainer numbers were low in all the treatments until week 17 after germination (Fig. 6) after which population rose.

Results of counts (Table 4) showed that during spraying monocrotophos and carbaryl 85 w.p. significantly reduced ($P < 0.05$) D. superstitiosus population compared with untreated controls at both sites; both treatments were not significantly different from each other. Similarly, during the spraying period there was no difference between the controls and endosulfan granule treatment in Site II (Table 4).

In the post-spray period, all treatments but endosulfan granules significantly lowered D. superstitiosus numbers below those in the control at Site I (Table 4).

At Site II during this same period, the numbers in the two carbaryl treatments and endosulfan 35 e.c. were not significantly different ($P = 0.05$) from each other and as in Site I was less than in the controls and endosulfan applied as granules.

More D. superstitiosus were recorded during the post-spray period than during spraying especially from unsprayed plots (Table 4, Fig. 6). At Sites I and II, unsprayed cotton had D. superstitiosus numbers of 2.1 and 0.85 per plant respectively at post-spray and sprayed

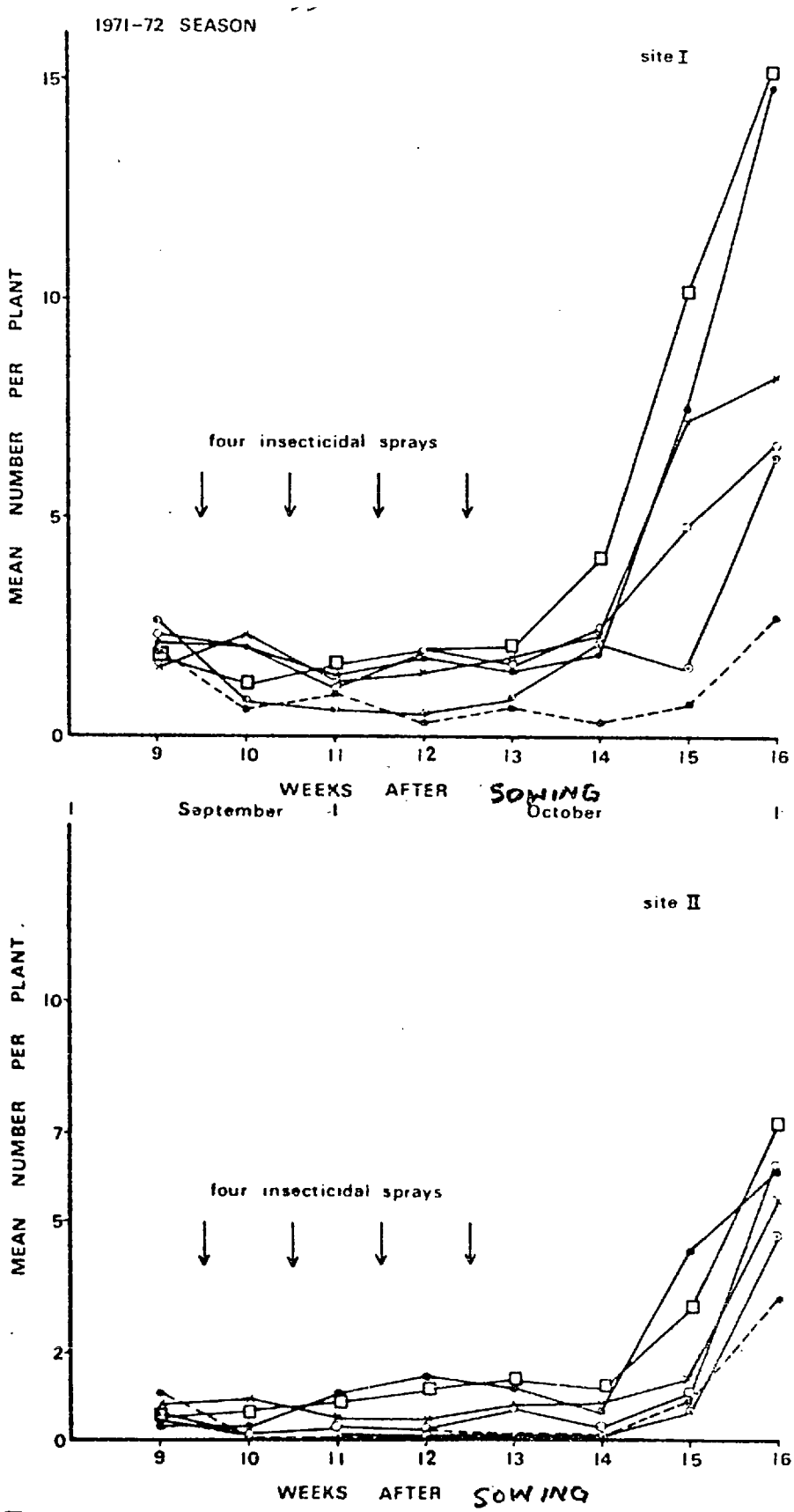


Fig.6. Mean numbers of Dysdercus superstitiosus recorded per cotton plant in weekly counts from sprayed and unsprayed plots

KEY :

- Endosulfan Granule
- Endosulfan 35 E.C
- Carbaryl 85 W.P
- Carbaryl 20 E.C
- Monocrotophos
- Control

TABLE 4. MEAN NUMBER OF COTTON STAINER (D. SUPERSTITIOSUS)/PLANT DURING CONVENTIONAL SPRAY TRIAL 1971-72 SEASON

			Carbaryl		Endosulfan		Untreated Control
		Monocrotophos	W.P.	E.C.	E.C.	Granule	
WHOLE SEASON	Site I	0.73	1.29	1.85	1.65	2.50	2.81
	Site II	0.53	0.51	0.71	0.71	1.07	1.09
SPRAYING PERIOD	Site I	0.10	0.17	0.30	0.31	0.29	0.36
	Site II	0.01	0.02	0.10	0.07	0.16	0.18
POST-SPRAY PERIOD	Site I	0.30	0.68	1.29	0.97	1.86	2.11
	Site II	0.35	0.45	0.52	0.61	0.87	0.85

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

crops with the lowest cotton stainer population corresponding to the two sites had 0.68 and 0.45 stainers per plant. The increase in numbers of D. superstitiosus found in untreated plots may have been a result of late immigrants from other host plants to the plots, or it may have been due to the insecticides repelling the late arrivals to the treated plots. The late fruiting of unsprayed cotton may also have caused this increased population by making the crop more attractive than treated plots at a later stage.

(iv) Effects on cotton aphids (A. gossypii)

1971-72 season

During the spraying period all treatments including untreated controls showed significantly ($P < 0.05$) lower aphid numbers than carbaryl 20 e.c. at Site I, monocrotophos and the two endosulfan treatments gave significantly ($P < 0.05$) lower aphid numbers than the untreated controls and the high carbaryl treatment (Table 5). At Site II monocrotophos and endosulfan 35 e.c. gave best control but were not significantly ($P = 0.05$) different during the spraying period. Similarly, endosulfan granules and the untreated controls showed no difference in aphid numbers.

However, at Site II monocrotophos and the two endosulfan treatments, carbaryl 85 w.p. and the control significantly ($P < 0.05$) reduced aphid population compared with carbaryl 20 e.c. (Table 5). In general, monocrotophos probably gave best control followed closely by endosulfan 35 e.c.

During post-spray, the aphid numbers recorded at Site I, from monocrotophos and endosulfan 35 e.c. treated plots were significantly ($P < 0.05$) lower than untreated control, carbaryl treatments, and endosulfan granules (Table 5). The untreated control and the carbaryl treatments were not different.

Although there was seasonal increase in aphid population in all the treatments at Site II (Table 5),

TABLE 5. POPULATION OF APHID (A. GOSSYPII)/PLANT DURING CONVENTIONAL SPRAY TRIAL 1971-72 SEASON

			Carbaryl		Endosulfan		Untreated Control
		Monocrotophos	85 w.p.	20 e.c.	e.c.	granule	
WHOLE SEASON	Site I	1.07	18.8	44.07	3.25	13.25	25.21
	Site II	3.97	9.49	42.88	8.32	36.48	33.13
SPRAYING PERIOD	Site I	0.21	6.65	29.92	1.25	3.91	5.86
	Site II	0.43	1.44	9.29	0.70	3.49	3.63
POST-SPRAY PERIOD	Site I	0.08	10.38	10.97	1.02	7.13	17.97
	Site II	2.56	7.50	33.18	7.12	32.89	28.82

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

numbers recorded in monocrotophos, endosulfan 35 e.c. and carbaryl 85 w.p. treatments reached significantly much ($P \leq 0.05$) lower than carbaryl 20 e.c., endosulfan granule and untreated control; these latter three treatments were not different ($P = 0.05$). Similarly, monocrotophos, endosulfan 35 e.c. and carbaryl 85 w.p. were also not different.

In contrast monocrotophos and endosulfan 35 e.c. gave protection even for about three weeks after spraying ceased in Site I (Fig. 7).

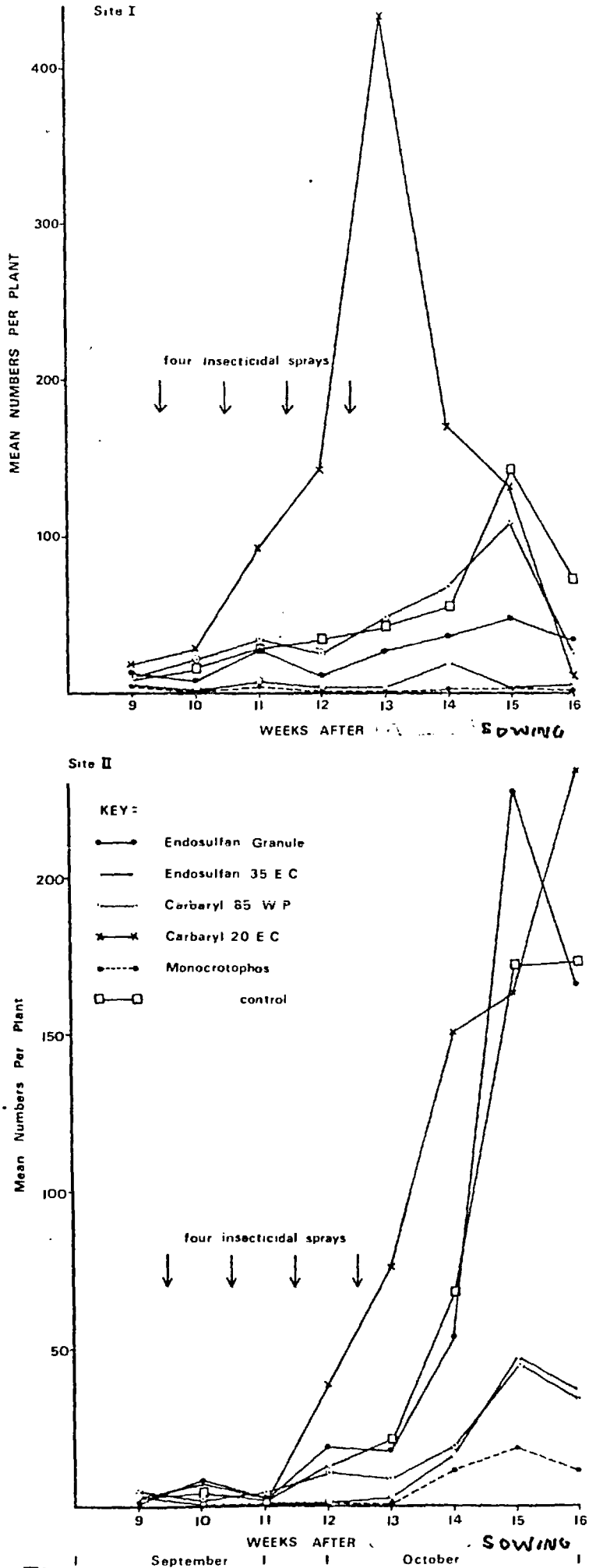


Fig.7. Mean numbers of aphid(A.gossypii) recorded per cotton plant in weekly counts from sprayed and unsprayed plots

1971-72 SEASON

(v) Effects on natural enemies

1971-72 season

The only natural enemies recorded in appreciable numbers were spiders and ladybirds (C. lunata). All insecticide treatments reduced C. lunata population in both sites.

During spraying monocrotophos, carbaryl 85 w.p. and endosulfan 35 e.c. recorded significantly ($P \leq 0.05$) lower numbers of C. lunata at both Sites I and II than in untreated controls, endosulfan granules and carbaryl 20 e.c. treatments. The effect of monocrotophos, carbaryl 85 and endosulfan 35 e.c. persisted throughout the post-spray period in Site I for the three insecticides and at site for only monocrotophos and carbaryl treatments only not endosulfan e.c. C. lunata numbers recorded from these treatments at Site I, were significantly ($P \leq 0.05$) lower than numbers obtained from untreated plots; and at Site II, they were similarly lower than endosulfan 35 e.c. and the controls.

With the exception of the endosulfan granule treatment and untreated control (Fig. 8) the population of C. lunata was low during spraying occasions. After the last spray, the population was still kept low by carbaryl treatment and much lower in the monocrotophos treated plots. This was more obvious at Site II than in Site I. Although the C. lunata population dropped in endosulfan treated plots at the penultimate counts at both

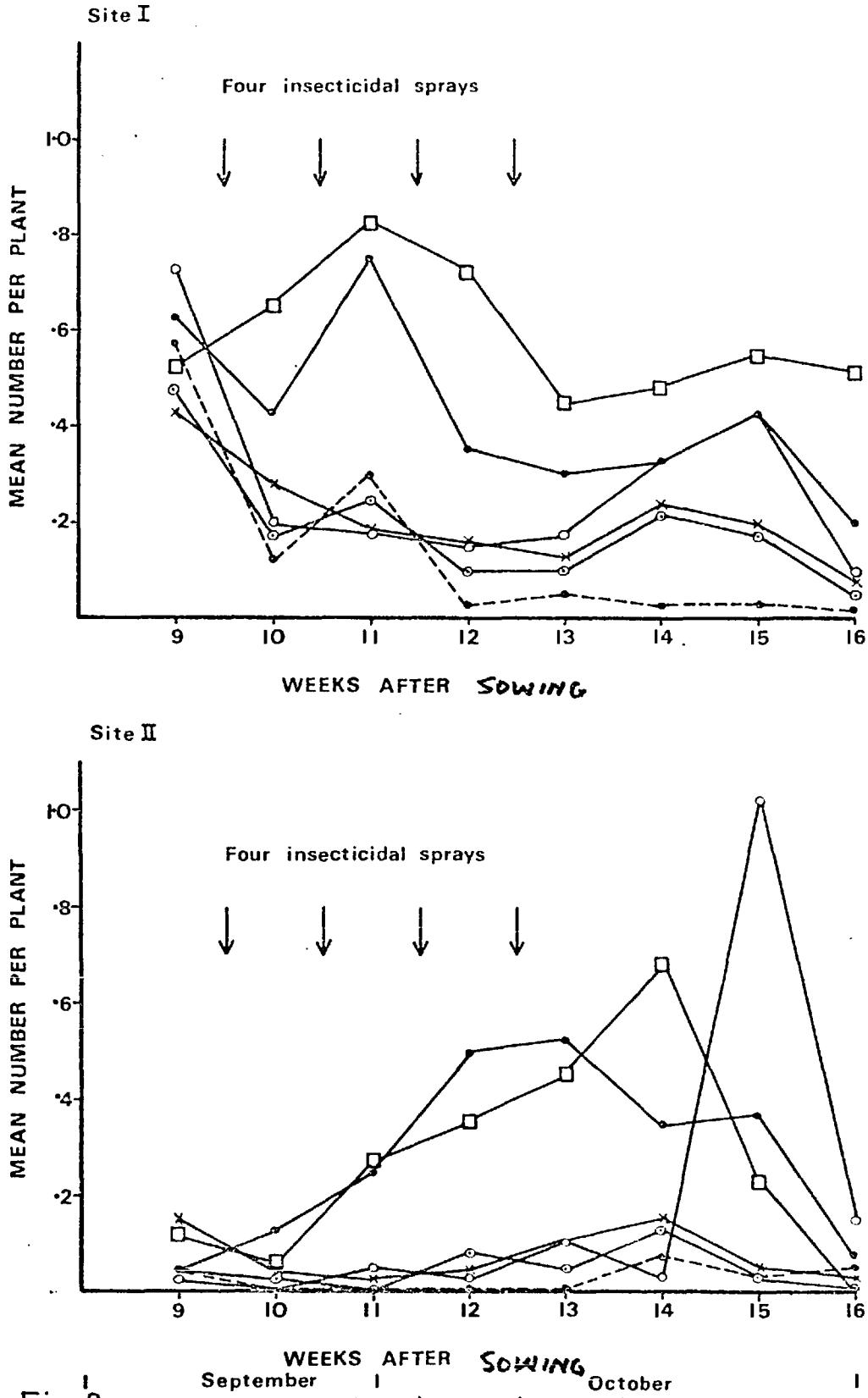


Fig.8. Mean number of ladybird (C.lunata) recorded per cotton plant in weekly counts from sprayed and unsprayed plots.

1971-72 SEASON

KEY:

- Endosulfan Granule
- Endosulfan 35 E.C
- Carbaryl 85 W.P
- Carbaryl 20 E.C
- Monocrotophos
- Control

TABLE 6 . MEAN NUMBERS OF LADYBIRD (C. LUNATA)/PLANT DURING CONVENTIONAL SPRAY TRIAL, 1971-72 SEASON

			Carbaryl		Endosulfan		Untreated Control
		Monocrotophos	85 w.p.	20 e.c.	e.c.	granule	
WHOLE SEASON	Site I	.19	.26	.68	.38	.57	.79
	Site II	.03	.06	.36	.23	.37	.35
SPRAYING PERIOD	Site I	.09	.14	.46	.17	.36	.52
	Site II	.01	.05	.26	.03	.29	.30
POST-SPRAY PERIOD	Site I	.01	.04	.15	.09	.10	.18
	Site II	.01	.00	.07	.20	.07	.04

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

sites, they were still higher than in monocrotophos and carbaryl treatments.

As with C. lunata, all insecticide sprays decreased spider numbers. At Site I during the spray period, monocrotophos, carbaryl 85 and 20 e.c. and endosulfan 35 e.c., significantly ($P < 0.05$) lowered spider numbers below the untreated controls and endosulfan granules (Table 7). In Site II, spider populations were significantly ($P < 0.05$) reduced in monocrotophos, and carbaryl treated crops compared with endosulfan and untreated controls. Both untreated controls and endosulfan treatments were not different (Table 7); nor also were the carbaryl treatments. During the post-spray period, apart from the endosulfan granule treatment in Site II, spider numbers were decreased throughout by the other treatments including untreated controls at both sites (Table 7). This decrease may be associated with residual effects of the insecticide in the treated plots, which either exerted direct mortality effect on the natural enemies or by causing reduction in the numbers of aphid and other prey made the plots less attractive or suitable for predator reproduction.

Throughout the season, spider population dropped in Site II, following each spray application (Fig. 9), however, the numbers increased gradually after spraying ceased; but in Site I spider population fluctuated during post-spray possibly as a result of inter crop movements of the natural enemies in search of prey.

TABLE 7. MEAN NUMBERS OF SPIDER PER PLANT DURING CONVENTIONAL SPRAY TRIAL, 1971-72 SEASON

			Carbaryl		Endosulfan		Untreated Control
		Monocrotophos	W.P.	E.C.	E.C.	Granule	
WHOLE SEASON	Site I	.45	.85	.83	.91	.15	1.38
	Site II	.13	.20	.20	.39	.51	.25
SPRAYING PERIOD	Site I	.29	.59	.64	.72	.81	1.14
	Site II	.04	.09	.10	.26	.17	.12
POST-SPRAY PERIOD	Site I	.02	.06	.07	.05	.14	.13
	Site II	.01	.04	.05	.03	.23	.06

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

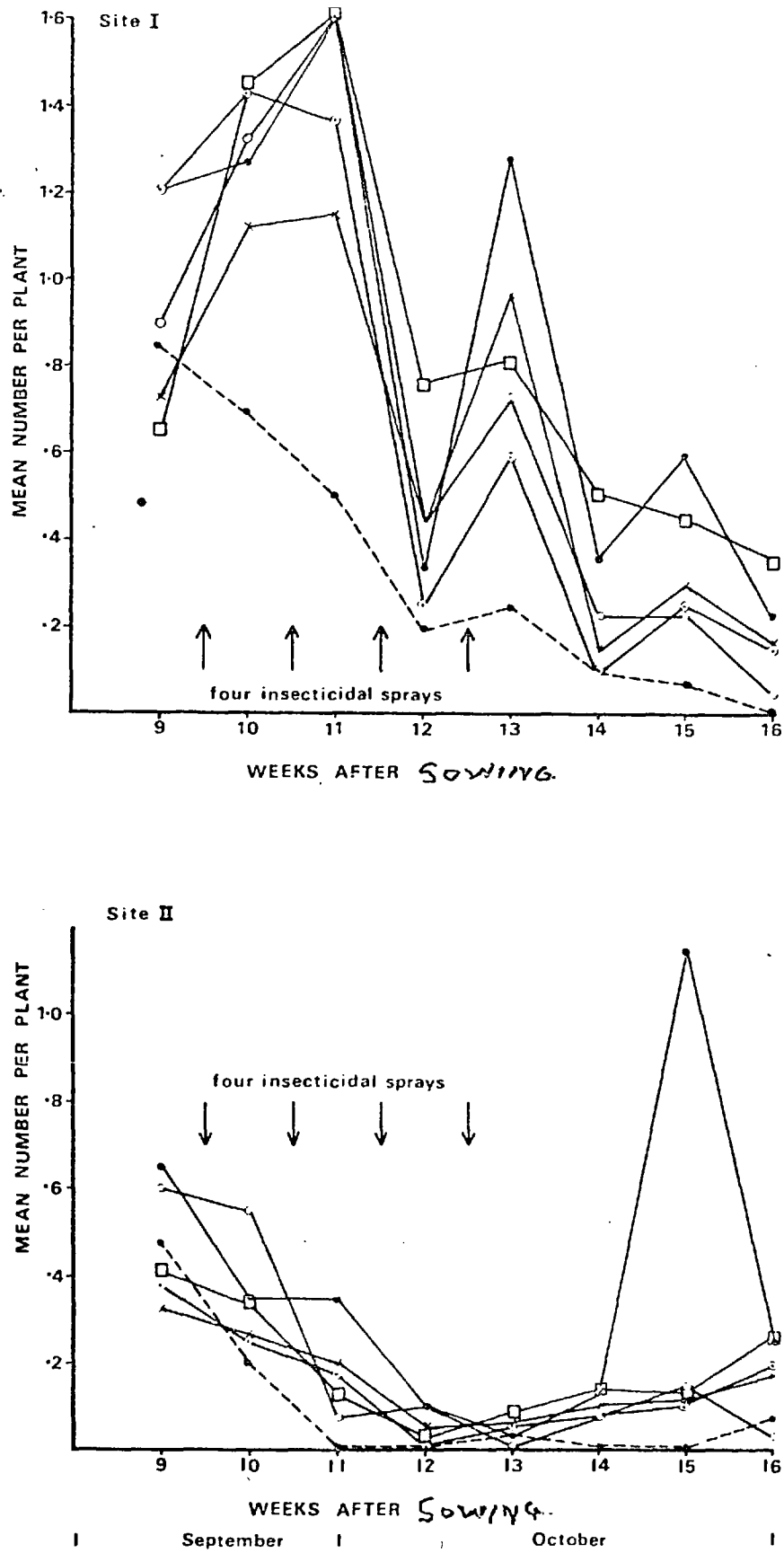


Fig.9. Mean numbers of spider recorded per plant in weekly counts from sprayed and unsprayed plots.

1971-72 SEASON

KEY:

- Endosulfan Granule
- Endosulfan 35 E.C
- Carbaryl 85 W.P
- Carbaryl 20 E.C
- Monocrotophos
- Control

(vi) Yields - 1971-72 season

The cotton was picked three times at two week intervals, from the 19th week after sowing. Data on mean percentage seed cotton picked (both sites combined) in the sprayed and unsprayed plots are shown in Figure 10. The sprayed cotton gave more early and less late crop than the unsprayed control.

Spraying resulted in a significant increase in the potential yield. Cotton sprayed with carbaryl w.p., monocrotophos and endosulfan 35 e.c. significantly out-yielded ($P < 0.05$) cotton treated with carbaryl e.c., endo-sulfan granule and the untreated controls at Site I (Table 8). But yields from the carbaryl e.c. treatment were significantly ($P < 0.05$) higher than those in endo-sulfan granule and untreated controls. The three insect-icides (carbaryl w.p., monocrotophos and endosulfan 35 e.c.) were not significantly ($P = 0.05$) different. Similarly, yields obtained from endosulfan granule did not differ from those in the untreated controls (Table 8).

At Site II, yields recorded in monocrotophos and carbaryl w.p. treatments were significantly ($P < 0.05$) higher than those from the other treatments and also from untreated control. There were no significant ($P = 0.05$) differences between yields in monocrotophos and carbaryl w.p. treatments. So also were differences not observed in yields from carbaryl e.c. and endosulfan e.c. treatments, and between endosulfan granules and untreated controls (Table 8). Generally, yields were higher in Site I than in Site II.

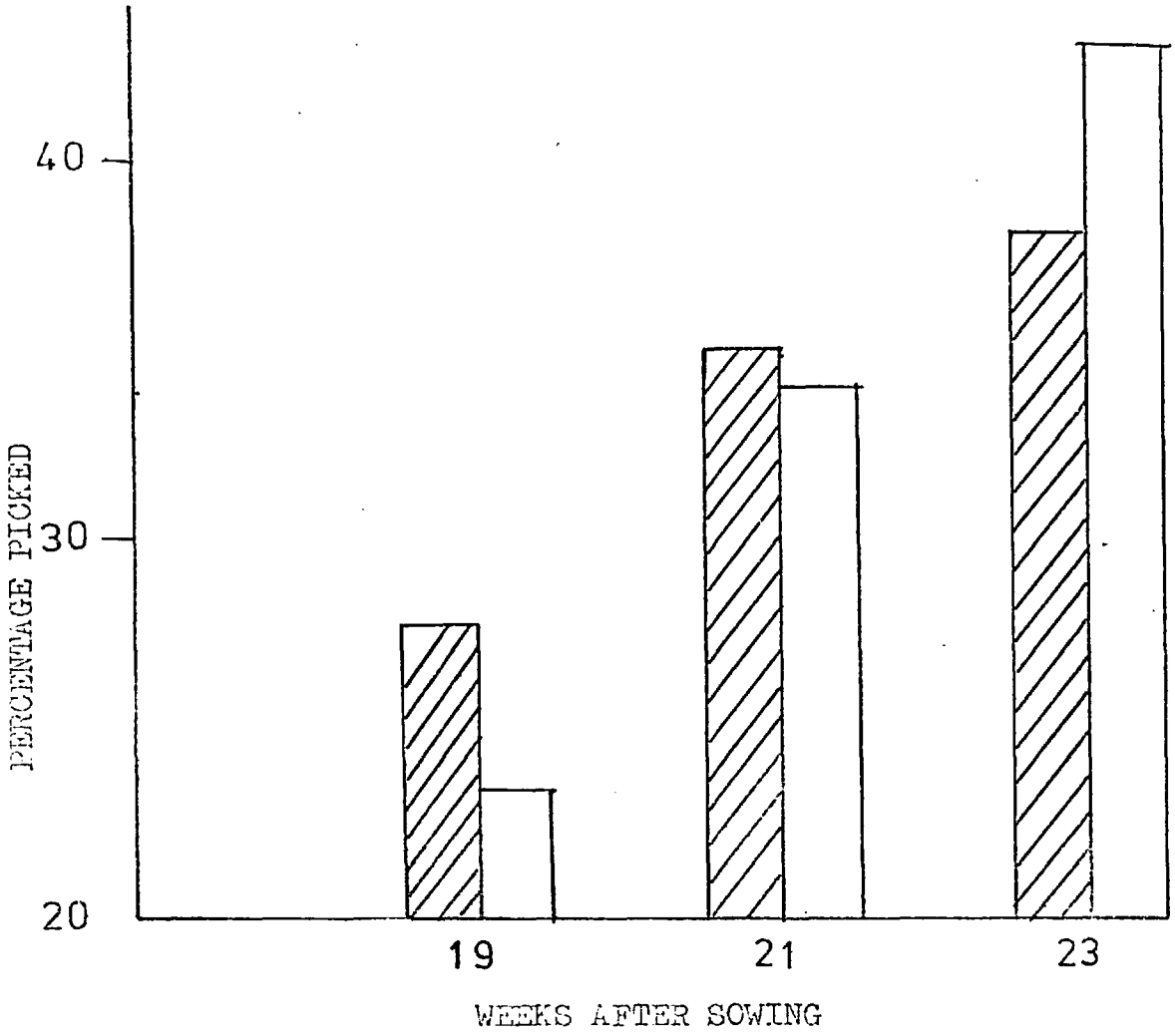
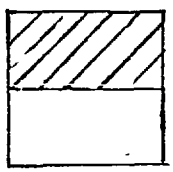


Fig.10. MEAN PERCENTAGE SEED COTTON FROM SITES I AND II IN THE SPRAYED AND UNSPRAYED PLOTS, MID-WESTERN STATE OF NIGERIA.



SPRAYED COTTON

UNSPRAYED COTTON

TABLE 8. MEAN YIELD SEED COTTON KG/HA IN A CONVENTIONAL SPRAY TRIAL, 1971-72 SEASON

	Monocrotophos	Carbaryl 85 w.p.	Carbaryl 20 e.c.	Endosulfan 35 e.c.	Endosulfan Granule	Untreated Control
Site I	955	1008	463	914	191	179
Site II	746	668	408	434	239	271

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

(B) Assessments of damage caused by P. gossypiella and E. biplaga in sprayed and unsprayed cotton, 1972-73 season

(i) Damaged bolls and flowers (fruiting bodies)

It is apparent from the results given in Tables 9 - 11 that the insecticide treatments had substantially different effects. Table 9 indicates that monocrotophos and carbaryl 85 w.p. reduced bollworm damage greatly. The damage caused in these two treatments was significantly ($P < 0.05$) less than that in the two endosulfan treatments, carbaryl 20 e.c. and the untreated control. The endosulfan and carbaryl 20 e.c. treatments were not significantly better from the untreated controls (Table 9) in terms of boll protection. Similar effects were shown on the bases of percentage damaged flowers (Table 10) except, that the e.c. formulations of carbaryl and endosulfan indicated significantly ($P < 0.05$) less damage than in the endosulfan granule treatment and the untreated control.

Details of damage to sampled fruiting bodies are shown in Table 11.

Monocrotophos and carbaryl 85 w.p. consistently reduced the percentage damage throughout the sampling period, and this resulted in a significantly ($P < 0.05$) lower percentage damage to the fruiting bodies than in untreated controls and the other treatments (Table 11).

TABLE 9. (A) PERCENTAGE DAMAGED BOLLS IN FOUR SPRAY TREATMENTS, 1972-73 SEASON

	Carbaryl		Endosulfan		
Monocrotophos	85 w.p.	20 e.c.	35 e.c.	Granule	Untreated Control
13.3	16.6	29.2	31.8	31.4	35.5

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

TABLE 10. (B) PERCENTAGE DAMAGED FLOWERS IN FOUR SPRAY TREATMENTS, 1972-73 SEASON

Monocrotophos	Carbaryl 85 w.p.	Carbaryl 20 e.c.	Endosulfan 35 e.c.	Endosulfan Granule	Untreated Control
10.7	11.5	19.9	19.4	27	26.2

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

TABLE 11. MEAN % DAMAGED TOTAL FRUITING POINTS SAMPLED FROM COTTON IN FIELD TRIAL IN MID-WESTERN STATE OF NIGERIA 1972-73

TREATMENTS	% DAMAGED BUDS							% DAMAGED BOLLS							MEAN % DAMAGED TOTAL FRUITING POINTS SAMPLED
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	
ENDOSULFAN GRANULES	28.33	26.66	23.33	30.00	28.88	28.88	22.77	31.11	48.88	30.00	38.88	20.55	19.44	31.11	58.402
ENDOSULFAN 35 E.C.	30.55	27.77	16.66	15.55	17.77	11.11	16.66	57.77	58.88	36.11	31.11	6.66	13.88	18.33	51.258
CARBARYL 85 W.P.	21.11	16.66	8.33	12.22	8.88	7.77	5.55	37.77	32.77	17.22	10.00	8.33	6.33	4.00	28.133
CARBARYL 20 E.C.	30.55	23.33	11.11	21.66	17.22	16.66	18.88	48.88	52.77	35.22	20.00	13.33	13.33	20.55	49.069
MONOCROTO-PHOS	18.88	23.33	5.55	9.44	7.77	7.22	2.66	31.11	22.77	16.11	8.71	6.00	5.55	3.11	24.029
CONTROL	35.55	25.00	26.11	31.66	20.00	21.66	23.33	50.55	61.66	41.66	38.33	21.11	21.11	13.88	61.658

(ii) Bollworm populations found within the fruiting bodies sampled

The bollworm numbers found within the fruiting bodies sampled are recorded in Tables 12 - 15. The numbers of P. gossypiella recorded from the fruiting bodies were similar to the percentage damage fruiting bodies obtained, except that fewer P. gossypiella were found within bolls in the crops treated with carbaryl than monocrotophos treated crops. The P. gossypiella numbers found in bolls treated either with carbaryl or monocrotophos were significantly ($P < 0.05$) fewer than numbers obtained from untreated control plots. Numbers of P. gossypiella found within flowers (Table 13) were not significantly ($P = 0.05$) different as between carbaryl e.c., endosulfan e.c. and granule treatments and the untreated controls.

E. biplaga recorded from the fruiting bodies followed a similar pattern as P. gossypiella, in that fewer E. biplaga numbers were found on monocrotophos and carbaryl 85 w.p. treatments.

From counts taken within the flower buds sampled, E. biplaga numbers in carbaryl 85 and monocrotophos treatments were less than on the untreated control and the difference was significant ($P = 0.05$), very highly significant ($P = 0.01$) in the case of counts of larvae within the bolls (Table 14).

TABLE 12. PINK BOLLWORM (P. GOSSYPIELLA) LARVAE FOUND WITHIN 180 GREEN BOLLS IN FOUR SPRAYING TREATMENTS, MID-WESTERN STATE OF NIGERIA, 1972-73 SEASON

Monocrotophos	Carbaryl 85 w.p.	Carbaryl 20 e.c.	Endosulfan 35 e.c.	Endosulfan Granule	Untreated Control
9.7	8.6	12.7	12.7	13.7	16.1

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

TABLE 13. PINK BOLLWORM (P. GOSSYPIELLA) LARVAE FOUND WITHIN 180 FLOWERS IN FOUR SPRAYING TREATMENTS, MID-WESTERN STATE OF NIGERIA 1972-73 SEASON

	Carbaryl		Endosulfan		Untreated Control
Monocrotophos	85 w.p.	20 e.c.	35 e.c.	Granule	
2.3	2.9	5.1	4.4	4.4	6.3

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

TABLE 14 . (A) SPINY BOLLWORM (E. BIPLAGA) LARVAE FOUND WITHIN 180 BOLLS IN FOUR SPRAYING TREATMENTS, MID-WESTERN STATE OF NIGERIA, 1972-73 SEASON

	Carbaryl		Endosulfan		Untreated Control
Monocrotophos	85 w.p.	20 e.c.	35 e.c.	Granule	
0.43	0.14	2.1	1.3	2.9	3.4

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

TABLE 15. (B) SPINY BOLLWORM (E. BIPLAGA) LARVAE FOUND WITHIN 180 FLOWERS IN FOUR SPRAYING TREATMENTS, MID-WESTERN STATE OF NIGERIA, 1972-73 SEASON

Monocrotophos	Carbaryl 85 w.p.	Carbaryl 20 e.c.	Endosulfan 35 e.c.	Endosulfan Granule	Untreated Control
2.9	3.3	5.1	4.7	5.3	6.4

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

More E. biplaga were recovered within the flowers than P. gossypiella, whereas inside the bolls P. gossypiella predominated. The fewer E. biplaga found in the bolls is to be expected as they frequently move about on the plant boring holes into stems and flowers as well as bolls. The high numbers of P. gossypiella found within the bolls agree with the suggestion of Pearson et al (1958) that this species has affinity for bolls which they use as diapausing sites, and besides, they also feed on seeds within the bolls.

The low pest population found from the fruiting bodies treated with carbaryl 85 w.p. and monocrotophos suggest that these two treatments were efficient in the control of bollworms.

(iii) Yield - 1972-73 season

The yields summarised in Table 16 showed no significant differences between treatments though carbaryl 85 w.p. and monocrotophos gave the highest yields. Yields were however very low in this trial, due to poor rainfall conditions during growing season (Table 17). In July, the monthly total rainfall was extremely low, thus making it difficult for early establishment of the crops. Rainfall was below average in August and even smaller in October which is the month when maximum water demand is needed to support heavy boll formation. There was also a heavy initial attack by grasshoppers and crickets which considerably reduced the plant stand to below 100 plants

TABLE 16. YIELD RESULTS OF FIELD TRIAL OF CONVENTIONAL SPRAY, 1972-73 SEASON

TREATMENT	SPRAY CONCENTRATION a.i/ha	YIELD IN KG. SEED COTTON/ha
MONOCROTOPHOS 60 W/V	0.39 kg	442.5
CARBARYL 85 W.P.	0.95 kg	453.4
CARBARYL 20 E.C.	0.22 kg	387.2
ENDOSULFAN 35 E.C.	0.39 kg	397.9
ENDOSULFAN GRANULE	2.8 kg	382.2
UNTREATED CONTROL		387.0

	Carbaryl		Endosulfan		Untreated
Monocrotophos	85 w.p.	20 e.c.	35 e.c.	Granule	Control
442.5	453.4	387.2	397.9	382.2	387

(Means joined by line are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

TABLE 17. RAINFALL IN IRRUA GOVERNMENT FARM CENTRE (SITE II)

MONTHLY MEANS FOR MONTHS OF GROWING PERIOD OF COTTON 1972-73 SEASON

Month	Rainfall (mm)
July	65.5
August	239.5
September	136.4
October	127.5
November	0.0
December	0.0
Total July-December	568.9

per plot. The replants supplied later to replace those destroyed by the early pests did not mature to give open bolls at the time of harvest. Finally, some of the bolls from the plots were removed as samples.

The trend in yields, although differences were not significant, reflect the damage to total fruiting bodies (Table 11), where the least damage occurred in carbaryl 85 w.p. and monocrotophos treated plots; and from these plots highest yields were obtained. These results confirmed the work of Hayward (1967) who sprayed carbaryl 85 w.p. at a rate of 1.5 lb a.i/acre to reduce percentage damage to bolls from 50% to 20%. In Malawi, the efficacy of carbaryl in protecting fruiting points has been well demonstrated. Matthews and Tunstall (1967) reported a significant reduction in the number of green bolls shed and bollworm-damaged bolls from sprayed treatment using 0.5 percent active ingredient of carbaryl against Diparopsis. Similar results were also obtained in Uganda by Davies (1963) when he sprayed carbaryl at 1.5 and 2 lb a.i/acre to reduce the damage caused by bollworms especially H. armigera.

(C) Study on dosage variation as a possible means of obtaining selective toxicity, 1973-74 season

(i) Effects on pink bollworm (P. gossypiella) 1973-74 season

As a result of insufficient cotton seed, only Site I was used in the 1973-74 studies.

Endosulfan 50 w.p. and carbaryl 85 w.p. sprayed at the same rate of 1.12 kg a.i/ha reduced the P. gossypiella population to an average of 0.07 - 0.08 larvae per plant and never more than 0.13 larvae per plant (Fig. 11, Table 18) during spraying period (i.e. until week 14 after germination). These numbers were significantly ($P < 0.05$) lower than those recorded in untreated controls 0.48 larvae per plant and in the two lower dosages of endosulfan 0.31 and 0.40 larvae per plant (Table 18); which were 0.56 and 0.28 kg a.i/ha respectively.

From analysis of variance these three treatments (endosulfan applied at 0.56 and 0.28 kg a.i/ha and untreated controls) were not significantly ($P = 0.05$) different (Table 18).

The P. gossypiella population increased after spraying had been terminated, probably as a result of later generation of pink bollworm developing on the crops, but P. gossypiella numbers in endosulfan and carbaryl treated plots at the rate of 1.12 kg a.i/ha were significantly ($P < 0.05$) lower than in the two lower endosulfan

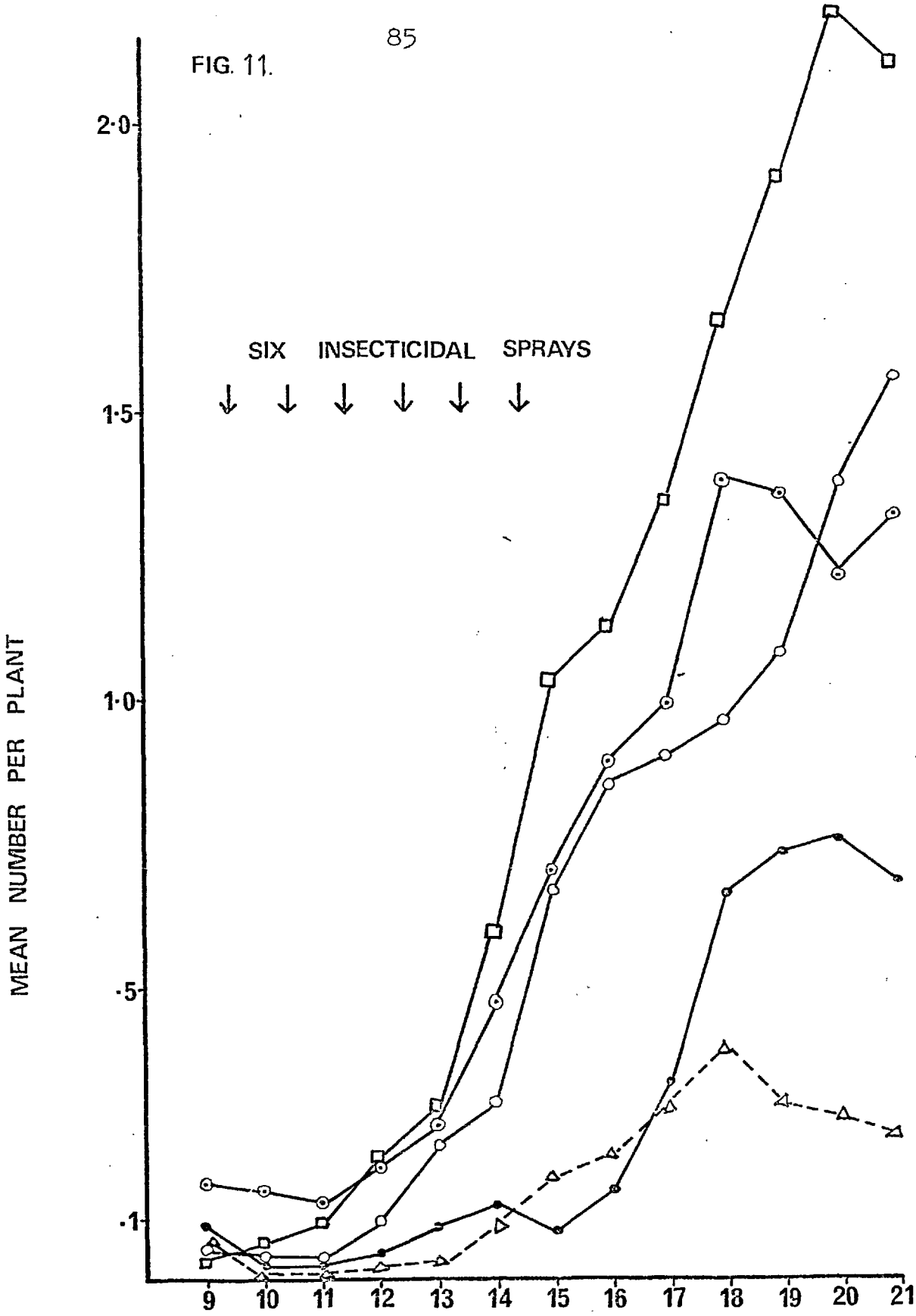
treatments and the untreated controls during the post-spray period (Fig. 11 , Table 18). Results for the two lower endosulfan treatments were not different. However, significantly ($P < 0.05$) lower pink bollworm numbers were found in them than in untreated controls (Table 18).

TABLE 18. MEAN NUMBERS OF PINK BOLLWORM (P. GOSSYPIELLA) LARVAE PER PLANT DURING CONVENTIONAL SPRAYING, 1973-74 SEASON

	Carbaryl 1.12 kg/ha	Endosulfan 1.12 kg/ha	Endosulfan 0.56 kg/ha	Endosulfan 0.28 kg/ha	Untreated Control
WHOLE SEASON	0.450	0.806	1.533	1.810	2.353
SPRAYING PERIOD	0.080	0.071	.313	.400	.482
POST-SPRAY PERIOD	0.308	0.641	1.174	1.254	1.840

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

FIG. 11.



MEAN NUMBER Pectinophora gossypiella LARVAE RECORDED PER COTTON PLANT FROM SPRAYED AND UNSPRAYED PLOT 1973-74

ENDOSULFAN	50	W.P.	1·12 Kg/ha
"	"	"	0·56 Kg/ha
"	"	"	0·28 Kg/ha
CARBARYL	85	"	1·12 Kg/ha
	CONTROL		

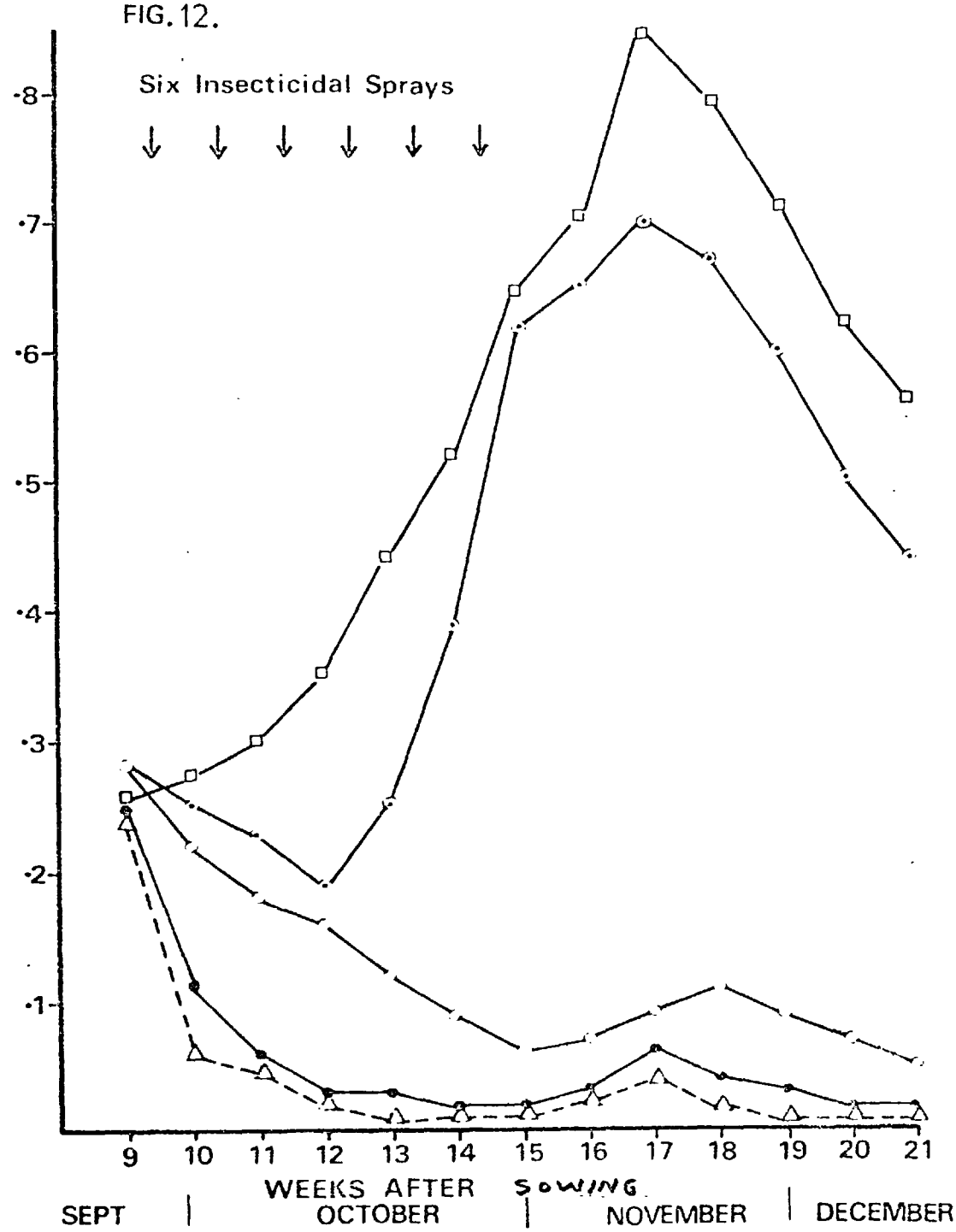
(ii) Effects on spiny bollworm (*E. biplaga*)

1973-74 season

During the spraying period carbaryl and the two higher endosulfan treatments significantly ($P < 0.05$) lowered spiny bollworm population below those found in untreated controls and in the plots treated with endosulfan applied at the lowest dosage rate of 0.28 kg a.i/ha. This effect was clearly indicated especially from week 13 (Fig. 12) after germination, though 0.56 kg a.i/ha endosulfan had comparatively little effect. There was no significant difference between untreated controls and endosulfan applied at 0.28 kg a.i/ha. Population trends in these two treatments were similar (Fig. 12).

During the post-spray period, effects similar to those experienced during the spraying period persisted. *E. biplaga* numbers recorded from carbaryl and the two higher doses of endosulfan were significantly ($P < 0.05$) lower than numbers found in untreated controls and in endosulfan sprayed as 0.28 kg a.i/ha (Fig. 12 , Table 19). Endosulfan at 0.56 kg a.i/ha seemed poorly better than untreated controls.

FIG. 12.



MEAN NUMBERS Earias biplaga LARVAE RECORDED PER COTTON FROM SPRAYED AND UNSPRAYED PLOT 1973-74

●——●	ENDOSULFAN	50	W.P	1·12 Kg/ha
○——○	"	"	"	0·56 Kg/ha
⊙——⊙	"	"	"	0·28 Kg/ha
△----△	CARBARYL	85	"	1·12 Kg/ha
□——□	CONTROL			

TABLE 19 . MEAN NUMBERS OF SPINY BOLLWORM (E. BIPIAGA) LARVAE PER PLANT DURING CONVENTIONAL SPRAYING, 1973-74 SEASON

	Carbaryl 1.12 kg/ha	Endosulfan 1.12 kg/ha	Endosulfan 0.56 kg/ha	Endosulfan 0.28 kg/ha	Untreated Control
WHOLE SEASON	0.304	0.327	0.501	1.231	1.414
SPRAYING PERIOD	0.036	0.43	0.129	0.369	0.460
POST-SPRAY PERIOD	0.018	0.034	0.092	0.582	0.704

(Means joined by line are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

(iii) Effects on cotton stainers (D. superstitiosus)

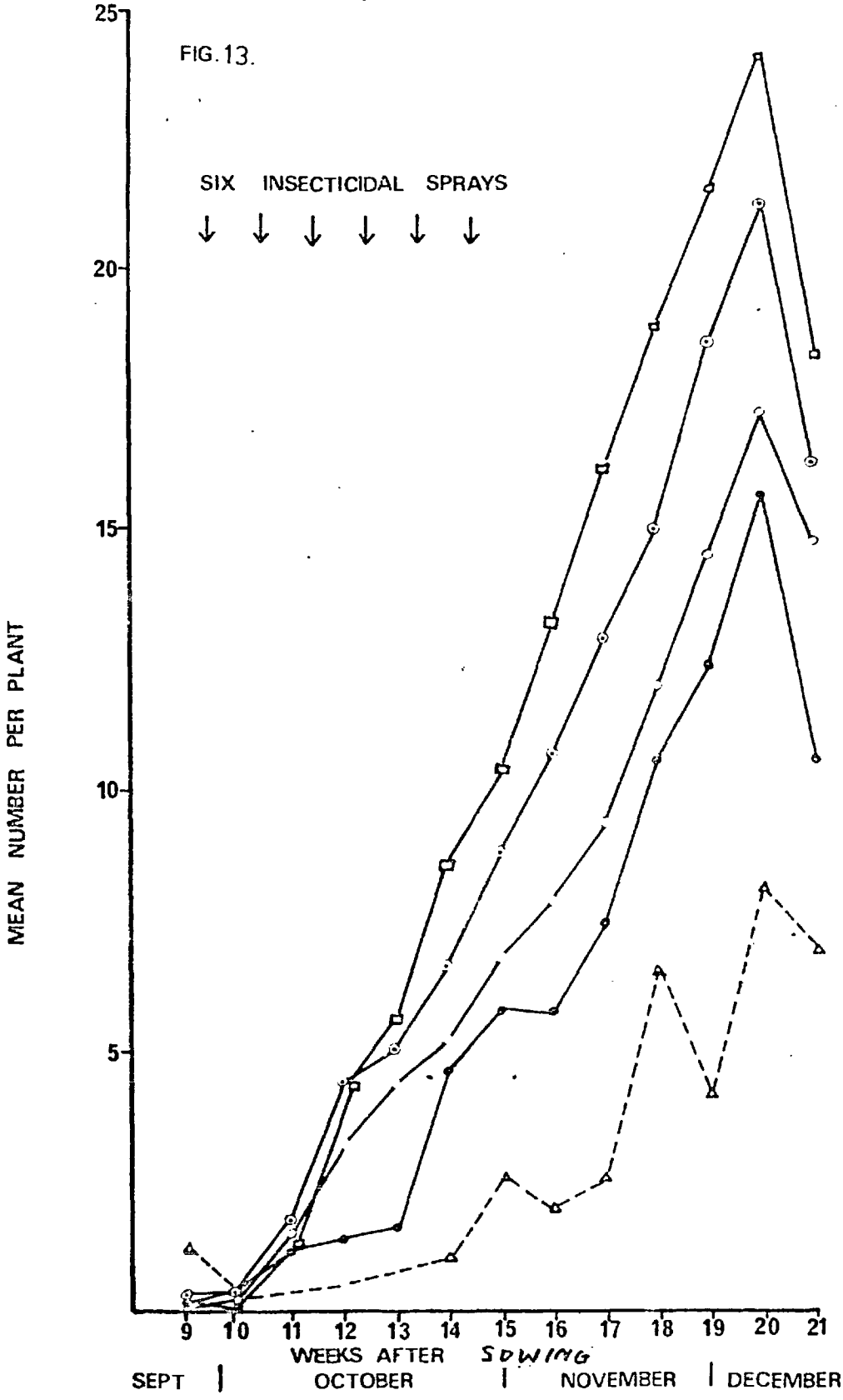
1973-74 season

During the season populations of D. superstitiosus rose in all the treated plots and also in the untreated controls (Fig. 13). However, statistically, carbaryl 85 applied at 1.12 kg a.i/ha significantly greatly reduced cotton stainer numbers during spraying; and the population recorded per plant was significantly ($P \leq 0.05$) lower during the whole season than that in the endosulfan treatments and in the untreated control (Table 20). The endosulfan treatments also showed significant control except the lowest and also the 0.56 kg a.i/ha treatment during the spraying period.

During the post-spray period, carbaryl and the two higher endosulfan treatments recorded significantly ($P \leq 0.05$) lower D. superstitiosus number than in the untreated control and endosulfan applied at 0.28 kg a.i/ha, and this effect persisted throughout the season (Table 20).

The effects of treatments on D. superstitiosus (Fig. 13) show that endosulfan was less well protecting cotton than carbaryl from cotton stainers. The plot design no doubt gives a false impression of inefficiency because D. superstitiosus is a very active species moving from plot to plot as an adult and also as a larva. So plots could be readily recolonized unlike a larger field.

FIG. 13.



MEAN NUMBER Dysdercus superstitiosus RECORDED PER COTTON PLANT FROM SPRAYED AND UNSPRAYED PLOT 1973-74

●—●	ENDOSULFAN	50	1·12 kg/ha
○—○	"	"	0·56 kg/ha
⊙—⊙	"	"	0·28 kg/ha
△—△	CARBARYL	85	1·12 kg/ha
□—□	CONTROL		

TABLE 20. MEAN NUMBERS OF COTTON STAINERS (D. SUPERSTITIOSUS) PER PLANT DURING CONVENTIONAL SPRAYING, 1973-74 SEASON

	Carbaryl 1.12 kg/ha	Endosulfan 1.12 kg/ha	Endosulfan 0.56 kg/ha	Endosulfan 0.28 kg/ha	Untreated Control
WHOLE SEASON	8.33	14.46	17.88	22.37	26.24
SPRAYING PERIOD	1.34	2.93	4.14	5.37	6.27
POST-SPRAY PERIOD	5.73	11.30	13.60	16.83	19.81

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

(iv) Effects on Aphis gossypii

1973-74 season

During the spraying and post-spray periods, all the insecticide treatments significantly ($P < 0.05$) reduced aphid numbers per plant compared with the untreated controls (Table 21), and they were all significantly ($P = 0.05$) different from one another. The lowest aphid population at the spraying and post-spray occasions was recorded from endosulfan applied at 1.12 kg a.i/ha. This was followed by carbaryl 85 w.p. applied at 1.12 kg a.i/ha. Figure 14 also confirmed that carbaryl 85 effectively reduced aphid numbers in this trial, contrary to results obtained elsewhere e.g. in Rhodesia (Tunstall and Matthews, 1966), in Western State of Nigeria (Hayward, 1967) and in Northern States of Nigeria (Choyce and Lyon, 1965).

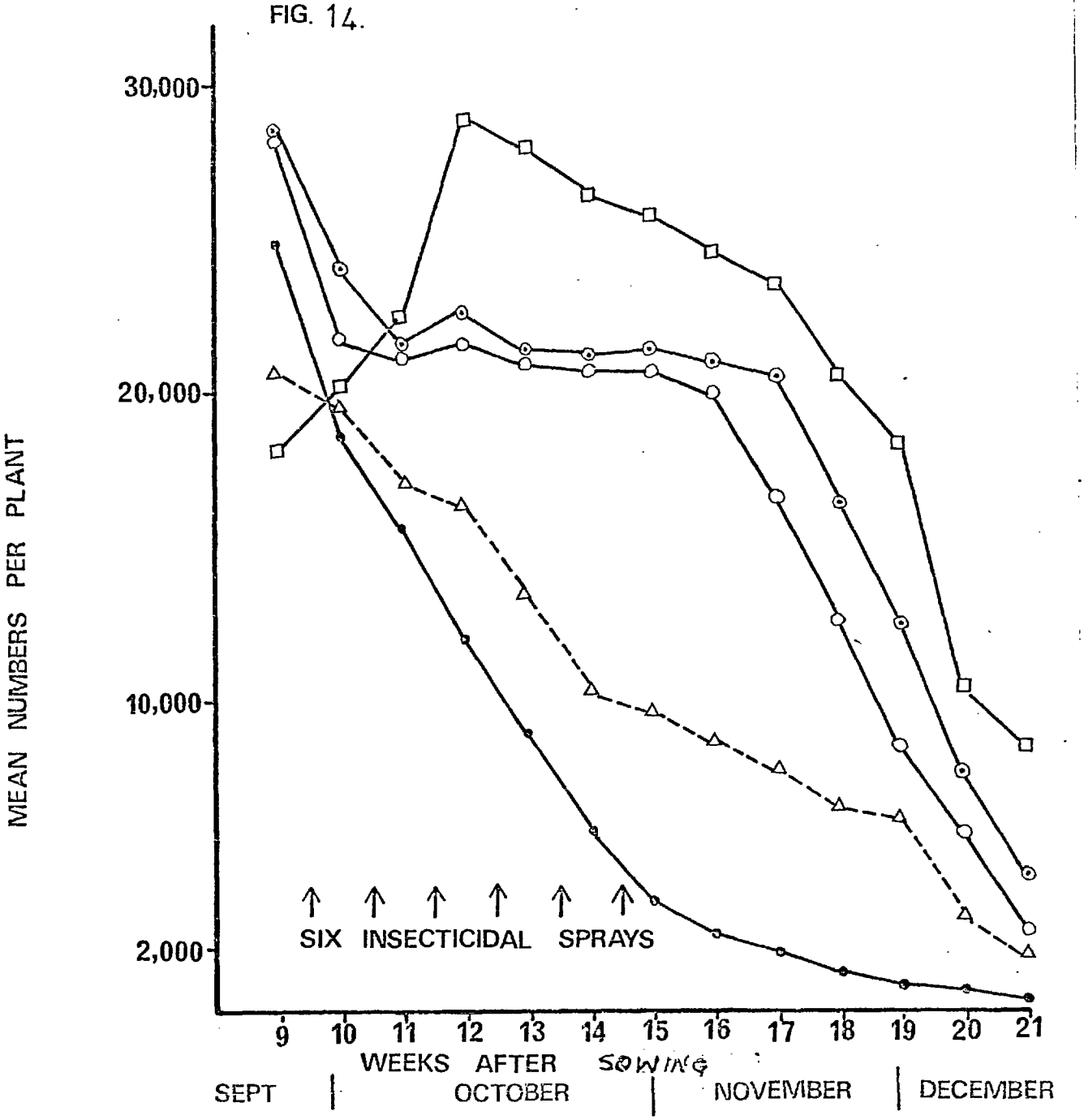
The low aphid numbers found on the crops treated with carbaryl 85 could be partly explained by the fact that this chemical applied only to the top of the crops, was not selectively killing off the natural enemies that were found on the surfaces of the leaves; infact many larvae of the predators P. ferruginea and C. lunata and spiders were found buried within the aphid colonies underneath the leaves and were not affected by carbaryl spray. These natural enemies may have been partly responsible for the aphid reduction in the carbaryl treated plots but, even so, carbaryl may have had a direct effect on the aphids especially at the highest dosage (Fig. 14).

There was a gradual decline in aphid numbers in all plots after spraying ceased (Fig. 14). This is probably due to the fact that either the crops were matured and were therefore not providing enough food to support increasing aphid population or the natural enemies were common enough to exert a direct effect on the aphid preys. It is also possible that the combined effects of insecticide sprays and natural enemies were affecting aphid numbers during post-spray period.

TABLE 21. MEAN NUMBER OF APHIS GOSSYPII PER PLANT DURING CONVENTIONAL SPRAYING, 1973-74 SEASON

	Carbaryl	Endosulfan 1.12 kg/ha	Endosulfan 0.56 kg/ha	Endosulfan 0.28 kg/ha	Untreated Control
WHOLE SEASON	39597	35518	53051	62322	59459
SPRAYING PERIOD	13662	9629	21051	21859	25134
POST-SPRAY PERIOD	5175	1039	9140	12373	6325

FIG. 14.



MEAN NUMBER Aphis gossypii RECORDED PER COTTON PLANT FROM SPRAYED AND UNSPRAYED PLOT 1973-74

●——●	ENDOSULFAN	50	W.P.	1·12 Kg/ha
○——○	"	"	"	0·56 Kg/ha
⊙——⊙	"	"	"	0·28 Kg/ha
△----△	CARBARYL	85	"	1·12 Kg/ha
□——□	CONTROL			

(v) Effects on natural enemies

1973-74 season

A. Platymaspis ferruginea

P. ferruginea numbers were higher than all the other predators sampled during the trial.

During spraying, P. ferruginea numbers per plant in the treated plots were significantly ($P < 0.05$) lower than in untreated controls, though treatments were not significantly ($P = 0.05$) different between themselves (Table 22).

However, the post-spray population of P. ferruginea in the carbaryl treated plots remained significantly ($P < 0.05$) much lower than numbers in the untreated controls and in the three endosulfan treatments (Table 22, Fig. 15), but numbers fell in the controls and in all treatments after the 4th spraying.

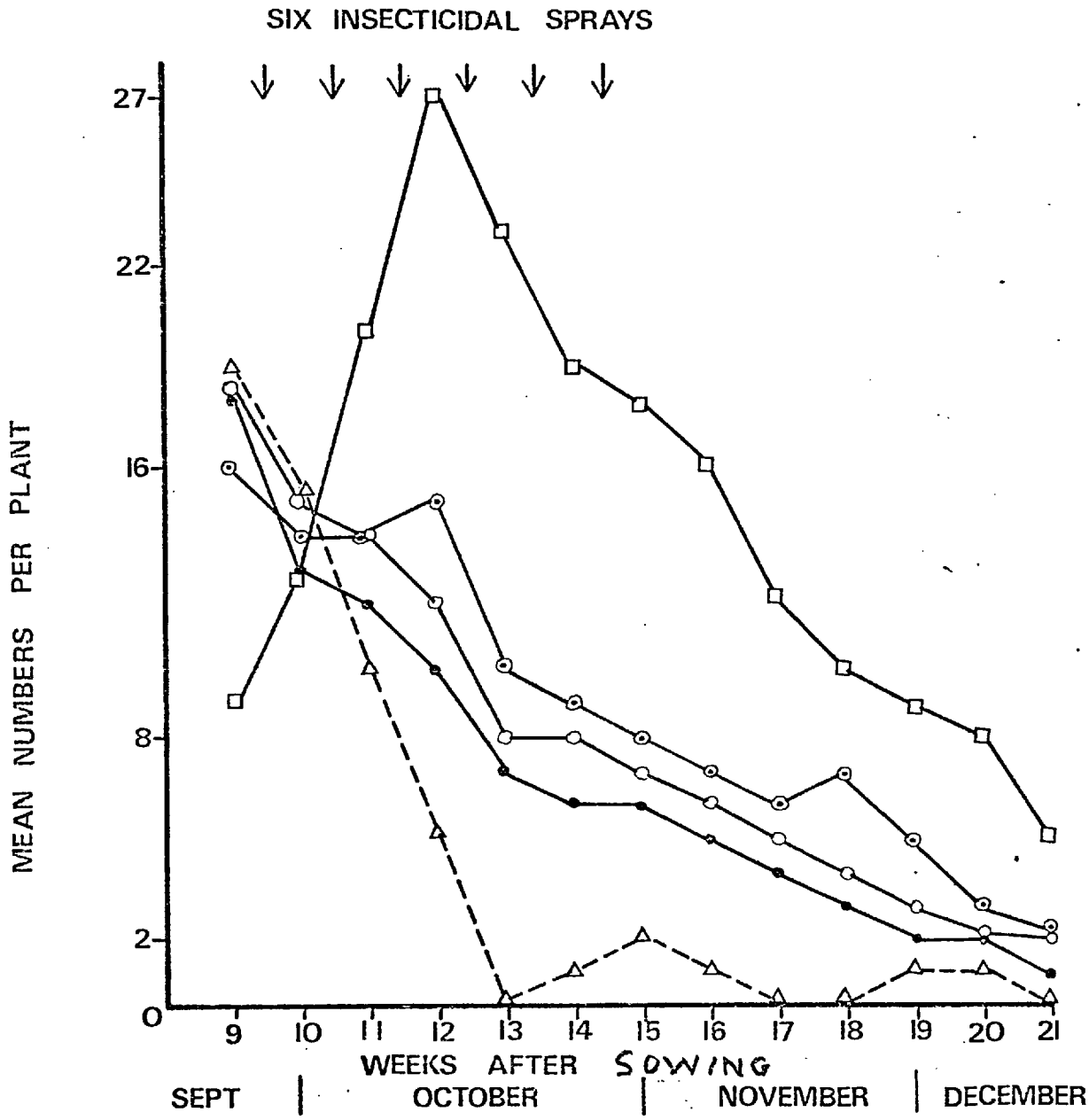
'Peak' P. ferruginea was attained in the untreated control 12 weeks after germination (Fig. 15), thereafter population declined gradually to less than 6 number/plant at week 21. This decline may have been due to a number of factors e.g. either low prey population, or direct mortality effects or to the combination of these two factors. Carbaryl 85 seemed definitely the most toxic. Endosulfan applied at 1.12 kg a.i/ha was by far more selective in favour of the natural enemies than carbaryl applied at the same rate of 1.12 kg a.i/ha (Table 22).

TABLE 22. MEAN NUMBERS OF PLATYNASPIS FERRUGINEA PER PLANT DURING SPRAYING, 1973-74 SEASON

	Carbaryl 1.12 kg/ha	Endosulfan 1.12 kg/ha	Endosulfan 0.56 kg/ha	Endosulfan 0.28 kg/ha	Untreated Control
WHOLE SEASON	28.8	32.4	31.2	31.6	37.2
SPRAYING PERIOD	8.4	9.6	10	11	19.4
POST-SPRAY PERIOD	2.4	3.8	3.2	4.6	8.8

(Means joined by line are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

FIG.15.



MEAN NUMBER Platynaspis ferruginea RECORDED PER COTTON FROM SPRAYED AND UNSPRAYED PLOT.

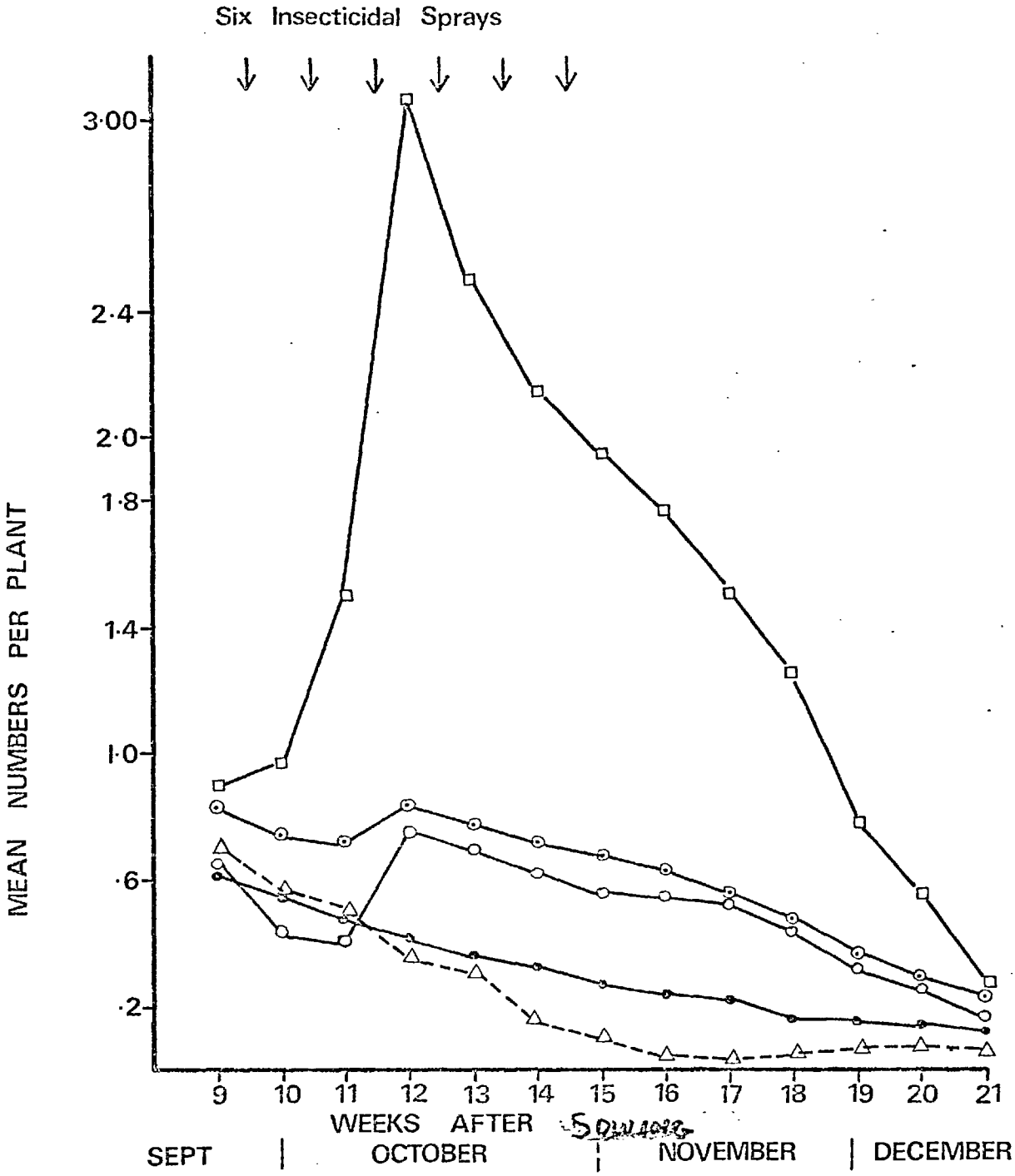
●——●	ENDOSULFAN	50	W.P.	1·12 Kg/ha
○——○	"	"	"	0·56 Kg/ha
⊙——⊙	"	"	"	0·28 Kg/ha
△----△	CARBARYL	85	"	1·12 Kg/ha
□——□	UNTREATED CONTROL			

B. Chilomines lunata

Like P. ferruginea, C. lunata populations recorded per plant in all the treated plots were significantly lower ($P < 0.05$) than in untreated control during spraying period. There was no difference ($P = 0.05$) between numbers of C. lunata recorded in carbaryl and endosulfan applied at the rate of 1.12 kg a.i/ha, similarly, the two lower endosulfan rates did not differ significantly ($P = 0.05$) either during spraying or at post-spray.

Throughout the post-spray period fewer C. lunata were recorded, indicating persistence of insecticide in the case of the treated plots or fewer prey. Again, numbers of C. lunata taken from the treatments were significantly ($P < 0.05$) fewer than in untreated controls. The lowest C. lunata population was found in the carbaryl treated plots, followed by endosulfan applied at 1.12 kg/ha. The fewer numbers of C. lunata recorded at the post-spray in the untreated control and in the treated plots may be directly due to scarcity of aphid preys, which at this time of plant development were reduced owing to maturity of the crops or were small because of predation (Fig. 16 , Table 23). C. lunata may be more sensitive to scarcity of prey than P. ferruginea and spiders.

FIG. 16.



MEAN NUMBER *C. lunata* beetle RECORDED PER COTTON PLANT FROM SPRAYED AND UNSPRAYED PLOT.

ENDOSULFAN	50	W.P.	1·12 Kg/ha
"	"	"	0·56 Kg/ha
"	"	"	0·28 Kg/ha
CARBARYL	85	"	1·12 Kg/ha
CONTROL			

TABLE 23 . MEAN NUMBERS OF CHILOMINES LUNATA PER PLANT DURING SPRAYING, 1973-74 SEASON

	Carbaryl 1.12 kg/ha	Endosulfan 1.12 kg/ha	Endosulfan 0.56 kg/ha	Endosulfan 0.28 kg/ha	Untreated Control
WHOLE SEASON	1.03	1.20	1.54	1.92	3.84
SPRAYING PERIOD	.297	.391	.585	.734	2.03
POST-SPRAY PERIOD	.063	.185	.350	.359	.875

(Means joined by line are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

C. Spiders

No significant difference (P = 0.05) was observed in the number of spiders during spraying in carbaryl 85 and endosulfan treatments sprayed as 1.12 kg a.i/ha. Similarly, was there no difference between spider numbers recorded in the two lower endosulfan treatments (Table 24). However, all the insecticide treatments significantly reduced ($P \leq 0.05$) spider population compared to the numbers found in untreated plots. These insecticide effects persisted into the post-spray period.

Figure 17 shows that population of spiders also dropped in all the treated plots after spraying ceased, but in the untreated control, population increased to a 'Peak' of 1.35 spider per plant four weeks of cessation of spray; and this number dropped to 5.5 spider/plant at week 21 after germination.

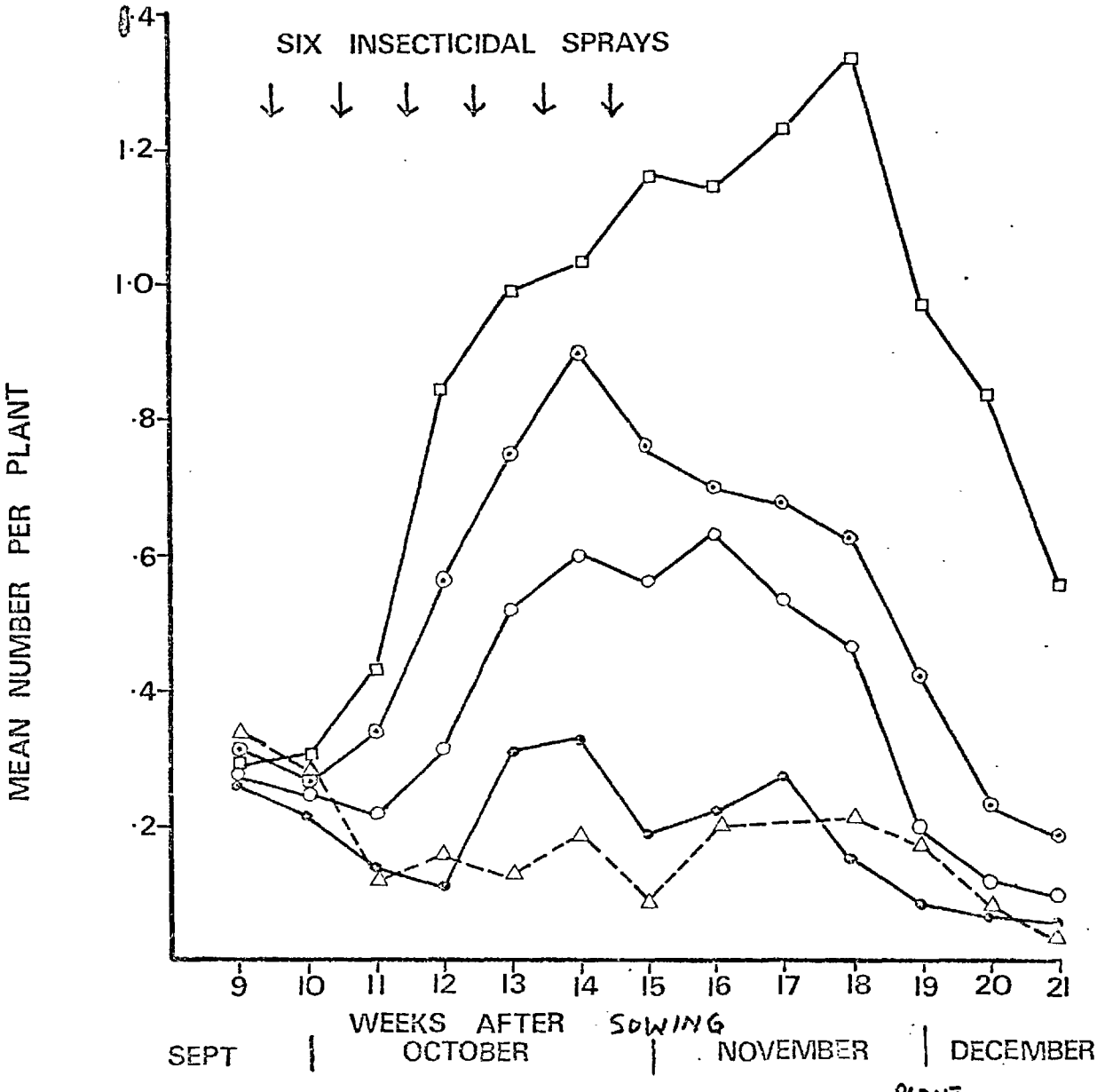
The higher spider and other predator numbers recorded from endosulfan (especially at the lower dosages) over carbaryl treatments throughout the season (Tables 22 , 23 and 24) suggest that endosulfan treatments had selective effects for the natural enemies. This was further supported by the results of the ratio of predators to prey (Table 29) from samples taken from the untreated controls, carbaryl and endosulfan treatments applied at the same rate of 1.12 kg a.i/ha. Here the effect of carbaryl treatments was seen to be most drastic on the natural enemies during the six post-spray occasions, which resulted to lower ratios compared with the highest endosulfan rate used.

TABLE 24. MEAN NUMBER OF SPIDERS PER PLANT DURING CONVENTIONAL SPRAYING, 1973-74

	Carbaryl	Endosulfan			Untreated Control
		Carbaryl 1.12 kg/ha	0.56 kg/ha	0.28 kg/ha	
WHOLE SEASON	.595	.611	1.008	1.347	2.106
SPRAYING PERIOD	.161	.216	.444	.607	.839
POST-SPRAY PERIOD	.100	.130	.283	.428	.986

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

FIG. 17.



MEAN NUMBER Spider RECORDED PER COTTON PLANT FROM SPRAYED AND UNSPRAYED PLOT.

ENDOSULFAN	50	W.P.	1·12 Kg/ha
"	"	"	0·56 Kg/ha
"	"	"	0·28 Kg/ha
CARBARYL	85	"	1·12 Kg/ha
			CONTROL

(vi) Yields - 1973-74 season

The data on Table 25 shows that yields obtained from carbaryl and endosulfan treatments at 1.12 kg a.i/ha were significantly ($P < 0.05$) higher than from the untreated control and the two lower endosulfan treatments. This reflects degree of pest control. Although yields obtained from carbaryl treated crops were higher than yields from endosulfan applied at similar rates (1.12 kg/ha), the difference was not significant. Similarly, yields from untreated control plots and endosulfan applied at 0.56 and 0.28 kg a.i/ha did not differ significantly ($P = 0.05$) from each other.

The percentage bolls damaged per plant was taken from the 11th to the 20th week after germination (Table 26). The lowest percentage damage was recorded from crops treated with carbaryl. This was followed in that order by the highest endosulfan rate and latter followed by the two lower endosulfan treatments, thus reflecting the same sequence of significance as was found in the pest population (Table 27) and yields (Table 25). Although there was no significant difference between endosulfan treatments in the total buds and flowers sampled (Table 28), results from this trial demonstrated that doubling the endosulfan rates resulted in significantly increased yield (Table 25). Subsequently, low endosulfan dosages did not stop significant increases and in some cases doubling of pest numbers during spraying and post-spray periods (Tables 18 - 21).

TABLE 25. MEAN YIELD SEED COTTON KG/HA IN A CONVENTIONAL SPRAY TRIAL, 1973-74 SEASON

	Endosulfan			
Control	0.28 kg	0.56 kg	1.12 kg	Carbaryl
371	446	502	833	935

(Means joined by line are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

TABLE 26 . PERCENTAGE DAMAGED BOLLS DURING CONVENTIONAL SPRAY TRIAL, 1973-74 SEASON

	Carbaryl	Endosulfan 1.12 kg/ha	Endosulfan 0.56 kg/ha	Endosulfan 0.28 kg/ha	Untreated Control
WHOLE SEASON	8.6	18.3	40.5	37.8	48.3

(Means joined by line or with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

TABLE 27 . MEAN PEST AND PREDATOR NUMBERS PER PLANT DURING CONVENTIONAL SPRAY TRIAL, 1973-74 SEASON AND YIELDS

TREATMENT	MEAN NUMBER PESTS PER PLANT				MEAN NUMBER PREDATORS PER PLANT			YIELD SEED COTTON kg/ha
	PINK BOLLWORM	SPINY BOLLWORM	COTTON STAINER	APHIDS	SPIDER	LADYBIRD	PLATYNASPIS FERRUGINEA	
ENDOSULFAN 50 W.P. 1.12 kg	0.292	0.055	5.942	7495.7	0.186	0.392	6.846	833.3
ENDOSULFAN 50 W.P. 0.56 kg	0.623	0.122	7.471	16608.8	0.370	0.496	8.000	502.5
ENDOSULFAN 50 W.P. 0.28 kg	0.710	0.448	9.375	18682.6	0.516	0.597	8.932	446.3
CARBARYL 85 W.P. 1.12 kg	0.166	0.043	3.020	10944.0	0.151	0.238	4.230	935.2
CONTROL	0.969	0.538	11.009	21197.3	0.852	1.499	14.538	371.6

TABLE 28. MEAN TOTAL FRUITING BODIES SAMPLED DURING CONVENTIONAL SPRAY TRIAL, 1973-74 SEASON AND % DAMAGED BOLLS

TREATMENT		TOTAL BUDS SAMPLED	TOTAL FLOWER SAMPLED	TOTAL BOLLS SAMPLED	% BOLL DAMAGED
ENDOSULFAN 50	1.12 kg/ha	60.5	6.8	68.7	32.5
ENDOSULFAN 50	0.56 kg/ha	56.7	6.8	88.8	41.0
ENDOSULFAN 50	0.28 kg/ha	60.3	7.3	85.6	41.4
CARBARYL 85	1.12 kg/ha	54.7	7.3	53.0	25.2
UNTREATED CONTROL		53.9	7.1	89.9	48.7
	P.	0.05	N.S.	.05	0.05

TABLE 29 . RATIO OF PREDATORS TO PREY A. GOSSYPII IN SPRAYED AND UNSPRAYED COTTON PLOTS DURING CONVENTIONAL SPRAY TRIAL (Ratios X 10^3) 1973-74 SEASON

POST-SPRAYING OCCASIONS	ENDOSULFAN 1.12 kg/ha			CARBARYL 1.12 kg/ha			UNTREATED CONTROL		
	C. lunata	P. ferruginea	Spiders	C. lunata	P. ferruginea	Spiders	C. lunata	P. ferruginea	Spiders
1	0.1	2	0.09	0.005	0.9	0.02	0.07	.7	0.05
2	0.1	2	0.13	0.004	0.8	0.03	0.06	.5	0.05
3	0.2	3	0.13	0.007	0.9	0.02	0.06	0.5	0.07
4	0.2	2	0.09	0.009	0.5	0.01	0.04	0.5	0.08
5	0.2	3	0.09	0.03	0.7	0.02	0.05	0.8	0.08
6	0.4	3	0.17	0.04	1	0.03	0.03	0.6	0.06

DISCUSSION

The 1971-72 season's trial produced evidence to show that carbaryl w.p., monocrotophos and endosulfan e.c. gave increases in cotton yield under the prevailing conditions in the Mid-Western State of Nigeria. In the yield of crops, and in the degree of infestation by insect pests, plots sprayed with monocrotophos, carbaryl 85 w.p. and endosulfan 35 e.c. received better protection and out yielded the unsprayed cotton and cotton treated with either carbaryl 20 e.c. or endosulfan granule. The highest yield was produced by cotton treated with carbaryl 85 w.p. followed in that order by yields from monocrotophos and endosulfan 35 e.c. treated plots.

Although carbaryl 20 e.c. reduced pest infestation as endosulfan 35 e.c., it could not be compared with it against aphids. Against carbaryl 85 w.p. and endosulfan 35 e.c., monocrotophos is a fast-acting insecticide with both systemic and contact action; and in this trial it effectively reduced aphids and the other pests. But it has a rather high mammalian toxicity the acute dermal LD_{50} for rabbit being between 149 to 709 mg/kg. It is also very expensive, a litre bottle costing between 18 to N20 (Twenty Naira, Nigerian Money; compared with carbaryl w.p. costing N1.87/1 kilogram weight). Thus it cannot be recommended to the peasant farmers in the State, whose low level of education cannot cope with handling toxic chemicals and their financial resources cannot afford such costly insecticide.

In view of these results and having due regards to the toxicity of carbaryl 85 w.p. to natural enemies together with its poor aphid control and the scarcity of endosulfan 35 e.c. in the State, it was decided to carry out the 1973-74 trials comparing only different rates of endosulfan 50 w.p., and using carbaryl 85 w.p. as a possible selective killer of predators.

The choice of endosulfan wettable powder was based on the investigation of Matthews (1966) that wettable powder might remain more readily available to the pests as a contact insecticide compared to the emulsifiable concentrate sprays which are absorbed to some extent by the leaves or may even collect at the base of the hairs.

In addition the wettable powder formulation of endosulfan was now easily available to the farmers in the State just as carbaryl 85 w.p. and is also quite cheap and relatively safe to handle.

Results from 1973-74 trial showed that all the major cotton pests (pink and spiny bollworms and D. superstitiosus) in the State were significantly reduced (P = 0.05) by carbaryl 85 w.p. and endosulfan 50 w.p. sprayed at the same rate of 1.12 kg/ha. But endosulfan sprayed as 0.56 kg/ha was still significantly better (P = 0.05) than the untreated controls in reducing the E. biplaga population during spray and post-spray period (Table 19).

Apart from E. biplaga, the other pests investigated were found to be high in population in the plot treated

with the two lower endosulfan rates and in the untreated control plots, indicating their ineffectiveness at those rates of application. Carbaryl was toxic to natural enemies, but was effective against the bollworms and Dysdercus. Therefore in addition to causing direct mortality on the predators, carbaryl also imposes indirect effect on natural enemies through its supression of the pests preys on which the later feed.

Crops treated with carbaryl nevertheless produced the highest yield of seed cotton per hectare, and the least damage to the fruiting bodies (Table 26). The effects of carbaryl on yield in this report supports the results obtained by Hayward (1967) in the Western State of Nigeria.

Although endosulfan applied at 1.12 kg/ha, 0.56 kg/ha and 0.28 kg/ha was less severe on the natural enemies than carbaryl 85 w.p. treatment, indicating potentiality for integrating it (endosulfan treatments) in control work, but their ability to control cotton pests was poorer than carbaryl 85. The population of cotton pests rose gradually in the crops treated with endosulfan treatments during post-spray. Thus it is apparent that the reduced mortality of pests due to the smaller rates (0.56 and 0.28 kg/ha) of endosulfan applied was not adequately compensated for by the enhanced activity of the natural enemies compared to plots where the full rate of endosulfan (1.12 kg/ha) was sprayed.

However, further investigations have to be conducted to assess the potentials of these dosage variations in carbaryl and endosulfan with particular references to their effects on the pest complex of cotton, their natural enemies and finally on yield, as these would determine their inclusion in integrated control programme.

In particular, the potential of ULV sprays as a means of obtaining selective insecticide action is worth investigating and this is reported in the next section.

SECTION III

CHEMICAL CONTROL BY ULTRA-LOW VOLUME (ULV) SPRAYING

1. INTRODUCTION

The recommended method of chemical control of Lepidoptera attacking cotton in the Mid-West State of Nigeria is carbaryl (Vetox 85) at 1.5 lbs active ingredient per acre in 20 gals of water (i.e. 1.7 kg a.i/ha in 224 litres of water) based on the conclusions from work done in Western State of Nigeria by Hayward (1967).

The decision to investigate ultra-low volume spraying as a new technique in the Mid-West State was based on the following considerations:-

1) Suitable hand-carried sprayers for the small farmers are now available (e.g. the Micron sprayer).

2) The area where cotton is grown in the Mid-West State is prone to drought e.g. the drought of 1971-72 which occurred especially in the Northern States of Nigeria with which the Mid-West State has a common boundary.

   As in Malawi (Matthews, 1973) the provision of large quantities of water to spray cotton farms as recommended by Hayward (1967) and Beeden (1974) poses a big problem to cotton farmers in

the Mid-West State, where the nearest source of water to cotton plots can vary from a distance of about 1-3 kilometres. There is therefore considerable incentive to minimize the heavy burden of water transport to cotton fields as well as decreasing the burden of carrying heavy weights of water during spraying.

3) When ULV sprays are properly applied by drifting droplets downwind away from the operator, there is less danger of contaminating him than from a conventional sprayer.

   Furthermore, ULV application involves less handling and mixing of the concentrate in the farm compared with water-based sprays, so the operator is less likely to be exposed to contamination during this process.

4) Evidence from elsewhere (Maas, 1971; Matthews 1973; Beeden, 1974 and Bals, 1970) indicates that ULV application can give good control of some cotton pests.

A preliminary Ultra-low Volume application trial was therefore undertaken to test different rates of endosulfan, and then in the following season two more trials were done to compare in more detail ULV endosulfan and a relatively high volume carbaryl spray. Endosulfan was chosen because a ULV formulation was available, unlike

carbaryl at that time, and because there is evidence that it exhibits a degree of selectivity (Huttenbach, 1969), and therefore is likely to be more selective in saving natural enemies than is carbaryl.

2. MATERIALS AND METHODS

In the preliminary field trial in the 1973-74 season a randomized block design was used with four replications. The overall plot size was 24 m x 24 m (0.06 ha). All biological data and yields were taken from a central sampling area of 18 m x 18 m (0.034 ha).

In 1974-75 season, each trial was 5 x 5 latin square design. The gross and the nett plot size was the same as in the previous season. Each plot was surrounded with a 0.9 metre path and the blocks were 1.8 metres apart.

In all trials, a small battery-driven spinning disc sprayer, the ULVA made by Micron Sprayers, U.K. and designed by Bals (1970) was used to apply endosulfan.

The sprayer had a centrifugal energy nozzle consisting of two plastic discs which atomized the spray fluid into droplets with a volume median diameter (VMD) of 70-120 microns. Droplet size increases with a decrease in the voltage applied. The discs were driven by a small electric motor (12 volt D.C) powered by two sets of eight 1.5 volt batteries. On the sprayer, flow rate into the spinning disc was altered by interchanging feed tubes; thus a yellow feed tube had an orifice diameter 1 mm, red 1.5 mm and grey 2 mm. The nominal flow rates of these were 0.5, 1 and 2 ml/s respectively.

In these experiments, the red stem was used and the flow rate of endosulfan was 1.12 ml/s, similar to the

flow rate used at Samaru in the Northern States of Nigeria (Beeden, 1974). A 6 metre swath-width was adopted in these trials.

The preliminary experiment was conducted at Irrua site II but the 1974-5 season's experiment was duplicated in two locations: Ilele site I and Irrua site II. Details of the two locations are already given in Section I.

A 25% W/V active ingredient ULV formulation of endosulfan supplied by the Hoeschst company, was used in the preliminary trial at two rates namely, 2.5 kg a.i/ha applied by walking four times along each spray swath and on 0.625 kg a.i/ha applied by walking once along each spray swath.

During the 1974-5 season, the rates of endosulfan 0.75 kg a.i/ha, 0.38 kg a.i/ha and 0.19 kg a.i/ha were applied by walking four times, twice and once respectively along each spray row. The carbaryl wettable powder was applied at 1.9 kg a.i/ha in 224 litres of water per hectare using a knapsack sprayer with a single nozzle. This was sprayed above and beneath the leaves. In both years' trials the insecticides were applied six times at weekly intervals from nine weeks after sowing.

The cotton variety was Allen 26J (G. hirsutum). This was sown using seeds treated with 'Agrosan' a copper fungicide to control seedling diseases (e.g. Xanthomonas malvecearum). Sowing was late, on the 4th of August 1973

for the preliminary trial, due to late arrival of seeds; but in the second week of July 1974 for the season 1974-5. 22.5 kg/ha of seeds were drilled about 4 per hole, with holes 2.5 cm deep on top of ridges which were 1 m apart. Seedlings were later thinned to 1 or 2 per hole. Calcium ammonium nitrate was applied as a basal fertilizer at 251 kg/ha.

Sampling procedures were as described in Section II. The following insects were sampled in the preliminary studies:- aphids (Aphis gossypii), cotton stainer (Dysdercus superstitiosus), lady birds (Chilomines lunata) and spiders.

In the 1974-5 trials insects sampled were pink bollworm (Pectinophora gossypiella), spiny bollworm (Earias biplaga), cotton stainers (Dysdercus superstitiosus) and aphids. Predators sampled included the lady birds Chilomines lunata and Platynas[illegible]s ferruginea, spiders and syrphid larvae.

All insects data were analysed, using analysis of variance and Duncan's New Multiple Range Test.

Bollworm numbers in the preliminary trial were very scarce and were not recorded. Counts of buds, healthy and damaged medium sized bolls retained on 40 plants sampled per plot were recorded on sprayed and unsprayed cotton at both sites during the main trial. Yields were recorded and analysed as for the insect data.

3. RESULTS

(A) Preliminary experiment with a ULV formulation of endosulfan applied at two dosage rates - 1973-4 season (Usenbo, 1974b)

(i) Aphis gossypii

Unfortunately the population of A. gossypii in the untreated plots was higher (600 per plant) than sprayed plots (300 per plant) before spraying. However, after the first and second sprays, the aphid numbers declined to almost 100 in the untreated controls and to less than 10 in plots treated at the higher rate of endosulfan. After week 16, aphid populations began to rise in the controls and low endosulfan treatment despite continued application of endosulfan. Numbers in the lower endosulfan treatment remained less than in the untreated control. In plots treated with ULV endosulfan at 2.5 kg a.i/ha the aphid numbers remained below 50 per plant until just before the last spraying when there was a rise to about 150 followed by a fall coinciding with spraying. The drop in aphid numbers recorded on untreated control plots during most of the spraying period may have been caused by rainfall and possibly in part by spray drifts from treated plots, though great care was taken and this is unlikely especially as the increase in numbers towards the end of the experiment cannot be explained on this basis whereas it coincided with the end of the wet season. By comparison endosulfan applied as 2.5 kg/ha drastically

reduced aphid numbers and kept them very significantly less ($P < 0.05$) than those in untreated plot as well as in plots treated with 0.625 kg endosulfan.

(ii) D. superstitiosus

Population of D. superstitiosus was low initially in all treatments and did not begin to rise until after the third spray application when there was a steady increase. Numbers initially kept lower in the 2.5 kg/ha endosulfan than in the untreated and 0.625 endosulfan treatment which was similar until after the fourth spraying, when numbers in untreated controls rose considerably to 90 per plant compared with about 60 per plant in the endosulfan treatments which appeared similar in their efficiency. The significant control ($P < 0.01$) suggests that endosulfan was very effective, the live individuals caught being immigrants which seemingly later died.

The increase in numbers of D. superstitiosus despite spraying was probably due to fresh migration from the surrounding host plants (e.g. Okra farms cultivated by native farmers and maize cobs left to dry on the Government demonstration plots). Adults of D. superstitiosus also hide in the leaf litter at the base of plants and so may not have contacted the spray deposit on the aerial parts of the plant until after eggs were laid.

(iii) Natural enemies

The natural enemies sampled were adults and

larvae of Chilomines lunata (Cocciullidae) and spiders. Numbers of C. lunata in plots treated with the higher endosulfan rate were less ($P < 0.05$) than those in unsprayed plots, as well as in plots treated with 0.625 kg endosulfan which did not differ significantly. No significant difference was observed between treatments in the total number of spiders.

It is important that endosulfan exhibited differential selectivity in favour of spiders over aphids when compared with the ratio of spiders to aphids in untreated controls. Thus the ratio ranged from 11-41 per 1000 aphids for 2.5 endosulfan compared with only 2-20 per 1000 aphids in untreated controls. The ratio of numbers of C. lunata and spiders to D. superstitiosus in treated and untreated plots varied considerably between sampling periods (Reprint, Table 2, page 73). However, more predators to prey were found in untreated controls, with the ratio of predators to prey in the 0.625 kg/ha treatment next in rank to the control. The worst ratio was recorded from 2.5 kg endosulfan treatment; thus implying a higher toxicity of the latter treatment to predators relative to toxicity to the D. superstitiosus prey.

CONCLUSIONS

As a preliminary study, the trial indicated that significant control of aphids and cotton stainers was obtained at 2.5 kg/ha but not at 0.625 kg/ha ULV endosulfan. 2.5 kg/ha endosulfan also resulted in a significantly (P 0.05) higher yield of seed cotton/ha than 0.625 kg/ha and untreated control (Table 38); however, it was rather toxic to the natural enemies and reduced their numbers compared with 0.625 and untreated control (Usenbo, 1974b).

0.625 kg/ha endosulfan did not result in significant depression on abundance of the predatory spiders and caused less mortality of C. lunata than 2.5 kg/ha, thus suggesting its suitability for inclusion in an integrated programme, but this tolerance to natural enemies did not compensate for the increased pest infestation recorded on 0.625 kg/ha treated plots and also the yield losses (Table 38). However 2.5 kg/ha endosulfan showed a valuable differential protection of predators relative to aphids. The ratio predators/aphids being greater than in the lower endosulfan treatment and the untreated (Usenbo, 1974b).

(B) Main experiment - to compare the effects on cotton pests and their natural enemies of different rates of an endosulfan ULV formulation and a carbaryl wettable powder - 1974-5 season

The results are given for both sites in the following order:- effects on Pectinophora gossypiella, effects on Earias biplaga, effects on Dysdercus superstitiosus, effects on Aphis gossypii, effects on natural enemies and effects on yields.

(i) Effects on Pectinophora gossypiella

Prior to spraying which began nine weeks after sowing, the mean numbers of P. gossypiella larvae were extremely low, less than 0.1/plant, and showed no discernible change in either treated or untreated plots until the 12th week after sowing.

In the untreated controls, there was a notable increase in numbers after week 15 with a 'Peak' of 2.5 larvae/plant in week 20 at Site I and 2.0 larvae/plant in week 18 at Site II followed at the latter site by a rapid decline to 1.0 larvae/plant in week 21 after sowing (Figure 18). In Site I harvesting was completed in week 20, so it was not possible to sample subsequently.

The insecticides had similar effects at both sites. Carbaryl at 1.9 kg/ha, ULV endosulfan at 0.75 kg a.i/ha and ULV endosulfan at 0.38 kg a.i/ha kept

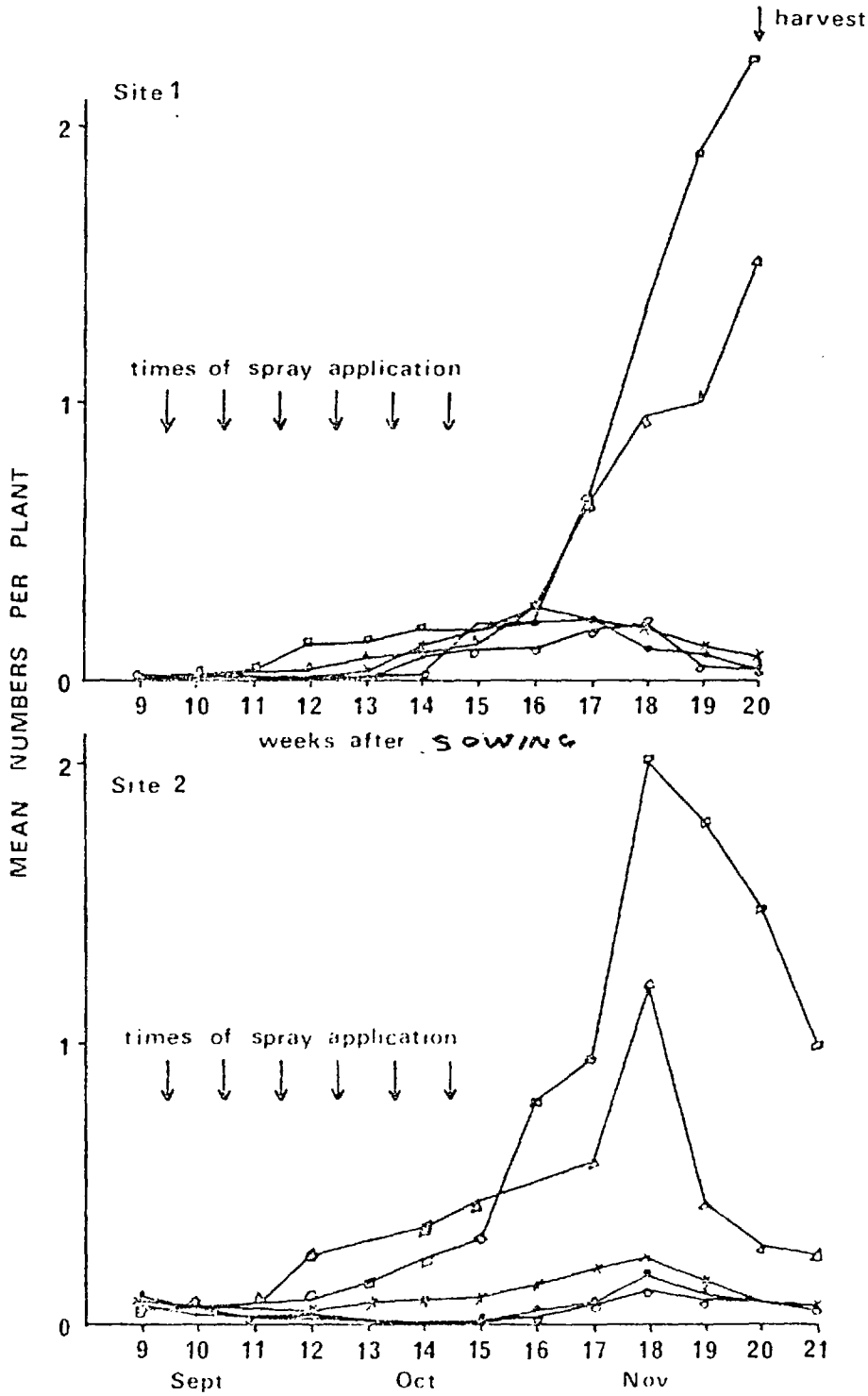


Fig. 18. Weekly counts of Pink Bollworm larvae (mean no per plant) in ULV Endosulfan and conventional volume Carbaryl treated cotton plots

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o	o	CARBARYL	1·9Kg a.i./ha
⊙	⊙	ENDOSULFAN	0·75Kg " "
X	X	"	0·38Kg " "
Δ	Δ	"	0·19Kg " "
□	□		CONTROL

population significantly lower ($P < 0.05$) than in the untreated control (Table 30). The carbaryl treatment was possibly the most effective but numbers of P. gossypiella larvae were not significantly less than in the two higher endosulfan treatments.

Endosulfan was probably more effective when applied at a rate of 0.75 kg/ha than at 0.38 kg/ha. Plots treated with carbaryl and endosulfan at the highest dosage had a mean infestation of less than 0.2 larvae/plant for the whole season. At 0.19 kg a.i/ha endosulfan did not significantly ($P < 0.05$) reduce the total infestation (Table 30) and at Site II, this treatment resulted in more larvae during the spraying period than on control plots though the difference was not significant.

Differences in P. gossypiella population between treated and untreated plots arose largely in the Post-spray period, since during the spraying period there was little increase in numbers even in the treated plots (Fig. 18).

Among treated plots the bollworm population rose in the second half of the season only in the plots treated with the lowest endosulfan dosage where the rise was comparable to though less than that on the untreated control plots.

Only the medium sized larvae were counted. The majority of the small ones were difficult to find or see and this may explain the apparently low populations early in the season.

TABLE 30. MEAN NUMBERS/PLANT OF PINK BOLLWORM LARVAE DURING ULV INSECTICIDE TRIAL 1974-5

		TREATMENT				
			Endosulfan			
		Carbaryl 1.9 kg/ha	0.75 kg/ha	0.38 kg/ha	0.19 kg/ha	Untreated Control
WHOLE SEASON	Site I	0.15	0.18	0.25	0.95	1.39
	Site II	0.14	0.15	0.28	0.96	1.81
SPRAYING SEASON	Site I	0.06	0.09	0.13	0.13	0.15
	Site II	0.004	0.004	0.016	0.06	0.05
POST-SPRAY SEASON	Site I	0.09	0.09	0.12	0.82	1.23
	Site II	0.016	0.018	0.03	0.11	0.29

(Means joined by line are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

(ii) Effects on Earias biplaga

Just before spraying commenced, the mean numbers of E. biplaga larvae recorded in the plots were very low, less than 0.1 larvae/plant. A notable increase in numbers of larvae occurred in the untreated control plots at Site I, and in Site I plots treated with 0.19 kg a.i/ha of ULV endosulfan from week 13 after germination (i.e. after the fourth spray application). A 'Peak' of 2.1 larvae/plant was reached in the control plots in week 18 (Fig. 19). At Site II, an increase in population in untreated controls at the 10th week after germination and reached a 'Peak' of 3.2 larvae/plant in week 18 followed by a decline to 1.1 larvae/plant in week 21 (Fig. 19).

The numbers of E. biplaga kept very low following application of carbaryl, and ULV endosulfan at Site II. However, after the last spray application (Fig. 19) the larval population in the ULV endosulfan applied at 0.19 kg a.i/ha increased as in the untreated control.

Throughout the whole sampling period (Table 31) significantly fewer larvae per plant ($P < 0.05$) were recorded from plots treated with the insecticide than from the control plots; numbers in carbaryl and the two highest ULV endosulfan treatments were least and did not differ significantly (Table 31).

During the spraying period (Table 31) carbaryl, ULV endosulfan at 0.75 kg a.i/ha and at 0.38 kg/ha kept E. biplaga larval numbers significantly less ($P < 0.05$) than in the control plots.

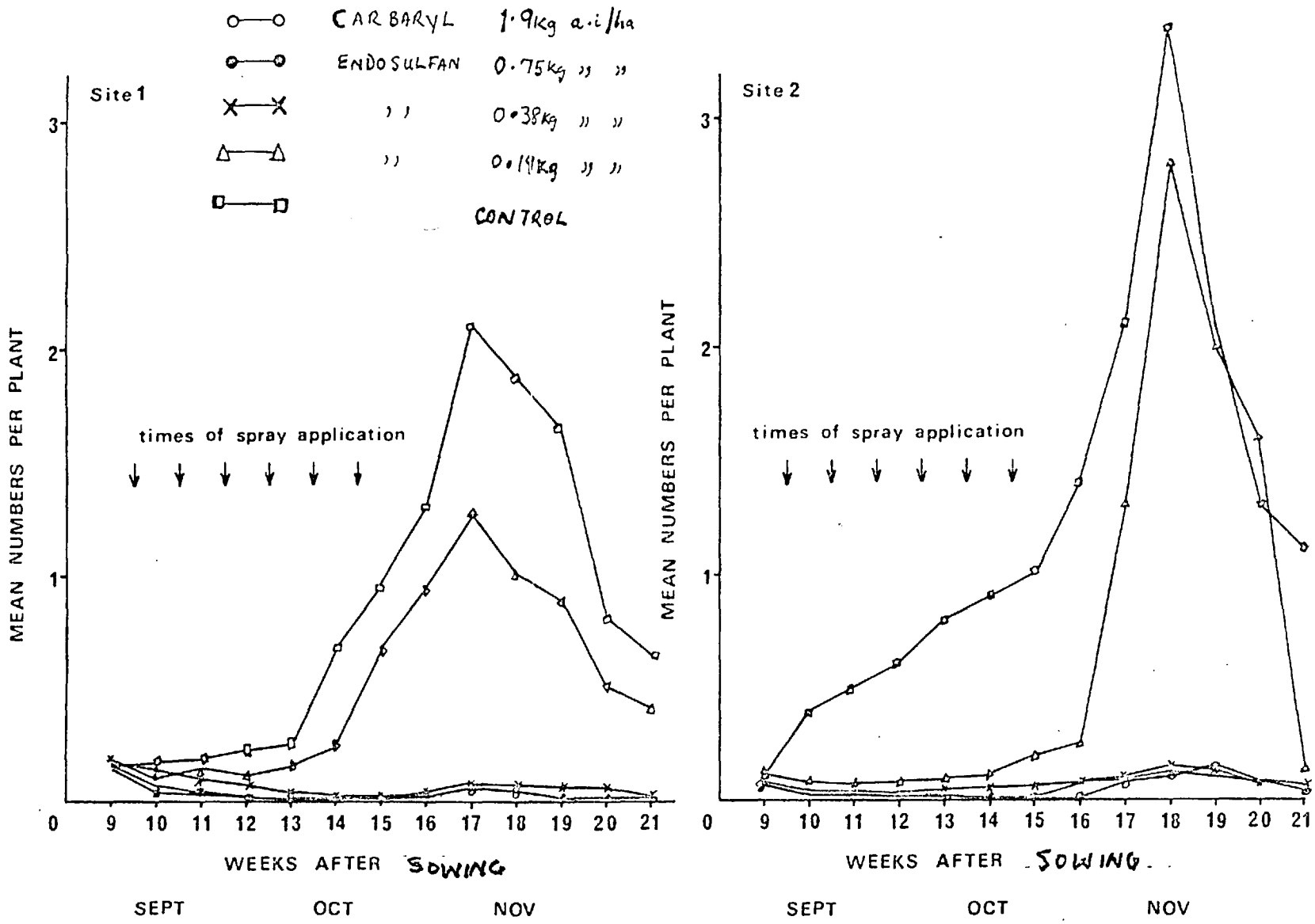


Fig. 19. Weekly counts of Spiny Bollworm larvae (mean number per plant) in ULV Endosulfan and conventional volume Carbaryl treated cotton plots.

1974-75 SEASON

TABLE 31 MEAN NUMBER/PLANT OF EARIAS BIPLAGA LARVAE DURING ULV APPLIED INSECTICIDE TRIAL 1974-5 SEASON

		TREATMENT				
			Endosulfan			
		Carbaryl 1.9 kg/ha	0.75 kg/ha	0.38 kg/ha	0.19 kg/ha	Untreated Control
WHOLE SEASON	Site I	0.09	0.10	0.18	1.36	2.20
	Site II	0.036	0.034	0.044	0.352	0.580
SPRAYING SEASON	Site I	0.03	0.04	0.09	0.49	0.76
	Site II	0.002	0.004	0.01	0.04	0.16
POST-SPRAY SEASON	Site I	0.026	0.028	0.056	0.83	1.41
	Site II	0.018	0.018	0.020	0.30	0.40

(Means joined by line are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

Endosulfan at 0.19 kg a.i/ha significantly ($P < 0.05$) decreased the bollworm numbers except in the post-spray period in Site II (Table 31), so except for ULV endosulfan applied as 0.19 kg a.i per hectare (Table 31) at Site II during the post-spray period, E. biplaga number was always significantly less in all treated plots compared with untreated ones.

Overall the controlling effect of the insecticides was more pronounced in Site I than at Site II (Fig. 19) e.g. in the post-spray period in Site I there are about 50 times more larvae per plant in the untreated plots than in the carbaryl treatments compared with about 20 times more on equivalent plots at Site II.

(iii) Effects on Dysdercus superstitiosus

At Site I, the mean numbers of D. superstitiosus in the pre-spray period was less than 1 per plant, and except for the untreated control, there was no rise in population (Fig. 20) in the treated plots until after the last spray treatment which was applied in the 14th week after sowing. At Site I, the numbers in untreated controls rose steadily to a 'Peak' of 178 stainers/plant at week 18 and then dropped to 80/plant in week 21 (Fig. 20) when harvesting was complete. The numbers reached a 'Peak' in the treated plots of Site I in week 20 with the highest peak of 180 stainers per plant in ULV endosulfan at 0.19 kg a.i/ha, and the least in carbaryl and endosulfan at 0.75 kg a.i/ha where the peak number was about 110/plant.

At Site II, the mean population of D. superstitiosus prior to spraying, varied from 30-60 per plant (Fig. 20). The numbers decreased during the treatment period in plots treated with carbaryl and ULV endosulfan at 0.75 kg/ha. There was increase in numbers in the plots treated with ULV endosulfan at both 0.38 and 0.19 kg/ha only after the third spray was applied i.e. 12 weeks after germination. Numbers in untreated control increased steadily from the beginning and the 'Peak' was 129 per plant in week 18, declining to 101/plant in week 21 (Fig. 20) when harvest was completed.

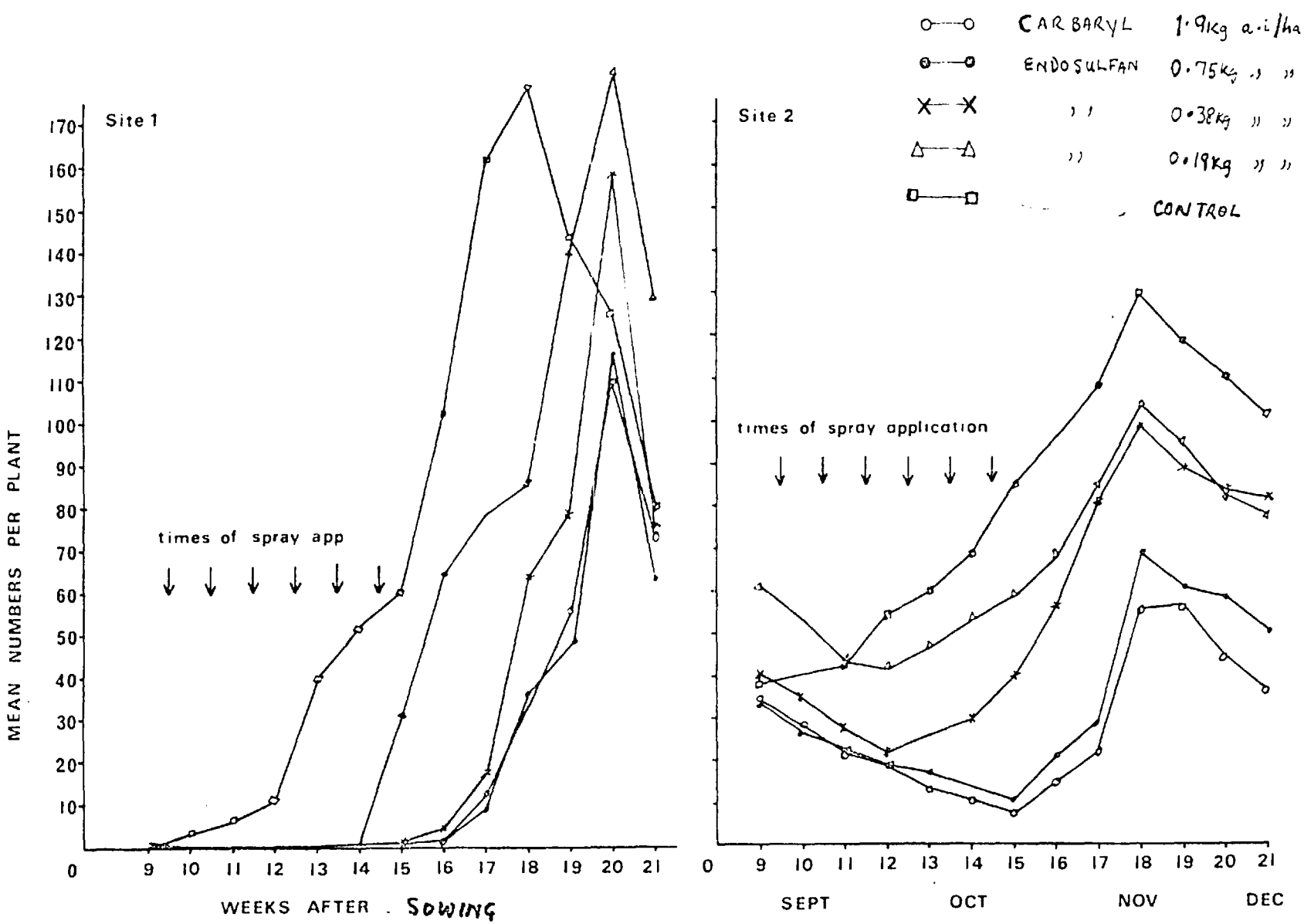


Fig. 20. Weekly counts of cotton stainer (mean numbers per plant) in ULV Endosulfan and conventional volume Carbaryl treated Plot

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The insecticide treatments showed somewhat different effects at the two sites, perhaps related to initially greater infestation in Site II, and latterly greater in Site I. In both sites all treatments exerted control during the spray period especially in the less intensely infested Site I. Subsequently, numbers of D. superstitiosus rose in all plots but least in carbaryl and the highest endosulfan ULV treatments though even with these, the numbers rose to probably unacceptably high levels by week 20 (about 110/plant). The delayed peak in treated plots at Site I (Fig. 20) is probably related to attractiveness of bolls in such plots in relation to the untreated controls.

At Site II, D. superstitiosus were colonising the crops throughout the spray period and were not kept so low in treated plots as at Site I. However, in the post-spray period there was less build-up than at Site I (Fig. 20). This however was not due to greater persistence of the insecticides but to less overall infestation as indicated by numbers on the untreated controls. Again the carbaryl and highest endosulfan treatments gave best control, though seemingly carbaryl was better in the post-spray period in Site II, though not in Site I (Table 32).

TABLE 32. MEAN NUMBER OF COTTON STAINER DURING ULV INSECTICIDE TRIAL 1974-5 SEASON

		TREATMENT				
			Endosulfan			
		Carbaryl 1.9 kg/ha	0.75 kg/ha	0.38 kg/ha	0.19 kg/ha	Untreated Control
WHOLE SEASON	Site I	57.2	55.2	79.8	139.8	192.0
	Site II	18.5	21.1	31.7	40.1	43.4
SPRAYING PERIOD	Site I	0.56	0.56	1.27	19.06	54.36
	Site II	3.2	3.6	6.6	10.3	13.2
POST-SPRAY PERIOD	Site I	56.5	54.6	78.2	120.8	137.7
	Site II	8.5	11.0	17.1	17.6	22.6

(Means joined by line are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

(iv) Effects on *Aphis gossypii*

Before treatment, nine weeks after germination, the mean numbers of *A. gossypii* were less than 200/plant at Site I. Numbers increased in untreated plots to 1300 per plant at week 17. In the plots treated with endosulfan at 0.19 kg/ha and 0.38 kg/ha spraying reduced numbers but after the spray period there was a rise to about 1000 and 700 aphids per plant respectively (Fig. 21). However, aphid numbers kept low (below 200/plant) throughout the season in the carbaryl and the highest endosulfan treatments.

At Site II (Figure 21), there was a general decrease in aphid numbers in the treated plots during the treatment period except on the plots given the lowest dosage of endosulfan where numbers remained fairly constant.

In the untreated controls, numbers rose from the beginning and reached a 'Peak' of 1800 aphids per plant in week 18 followed by a decline to 1400 aphids/ plant in week 22 (Fig. 21).

Throughout the whole season, the aphid populations in the treated plots at both sites were significantly ($P < 0.05$) smaller than those in the untreated control plots. Carbaryl and endosulfan at 0.75 kg/ha gave the best control and their effects did not significantly differ ($P = 0.05$) throughout the whole season

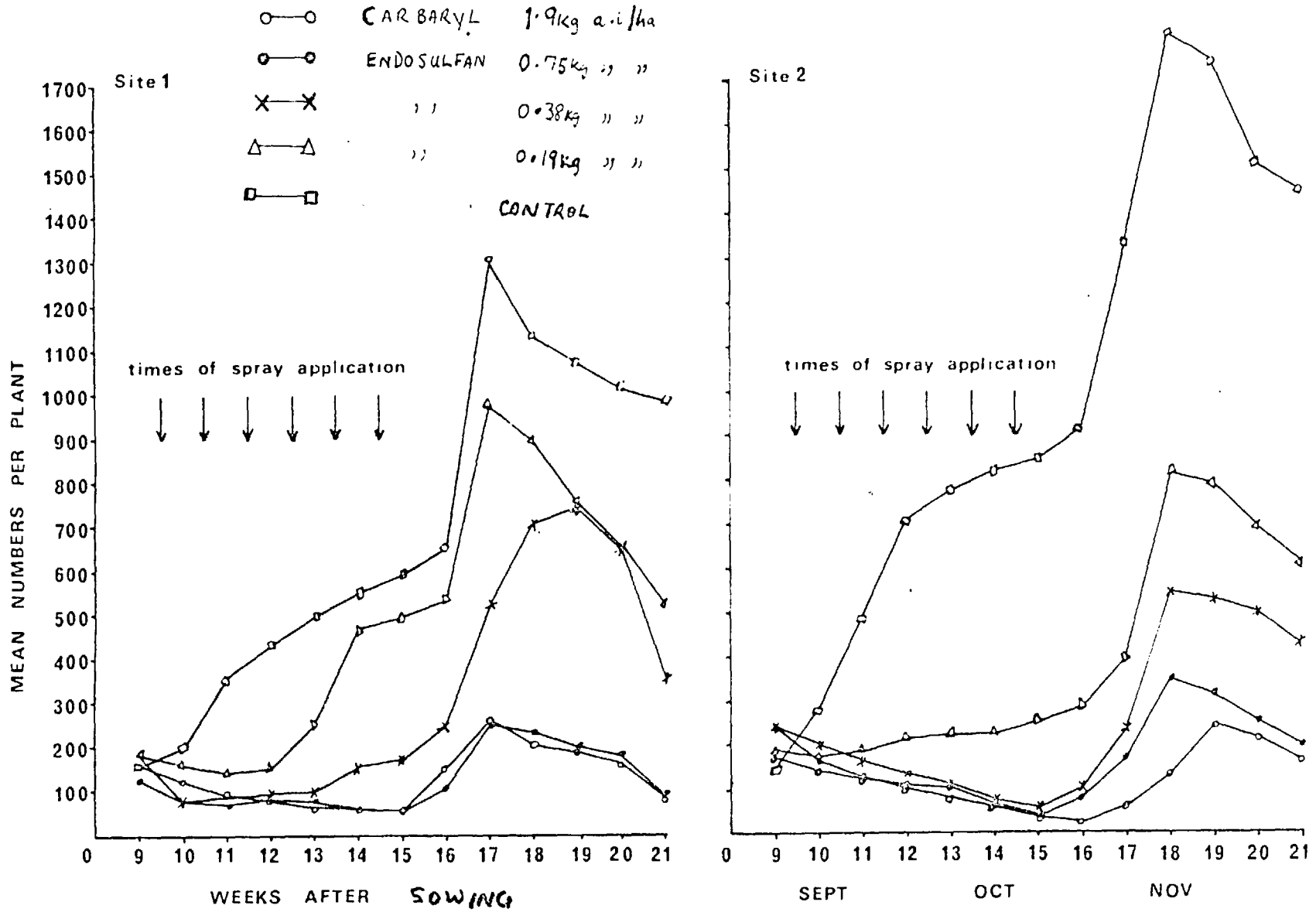


Fig. 21. Weekly counts of cotton aphids (mean numbers per plant) in ULV Endosulfan and conventional volume Carbaryl treated cotton plots.

1974-75 SEASON

(Table 33). These two treatments had a seasonal mean infestation of less than 200 aphids/plant at both sites.

In view of its relatively poor aphicidal action in many other conditions carbaryl gave surprisingly good control while endosulfan was less good than expected, good at the highest dosage but probably inadequate at the lowest dosage of 0.19 kg a.i/ha.

TABLE 33. MEAN NUMBERS OF COTTON APHIDS (A. GOSSYPII) PER PLANT DURING ULV INSECTICIDE TRIAL 1974-5 SEASON

		TREATMENT				
			Endosulfan			
		Carbaryl 1.9 kg/ha	0.75 kg/ha	0.38 kg/ha	0.19 kg/ha	Untreated Control
WHOLE SEASON	Site I	85.2	78.6	180.5	250.8	344.1
	Site II	82.3	117.4	160.5	214.4	471.6
SPRAYING PERIOD	Site I	17.8	15.0	26.6	63.0	96.6
	Site II	16.6	18.1	23.8	43.6	137.5
POST-SPRAY PERIOD	Site I	35.5	37.9	118.9	151.8	219.4
	Site II	32.2	50.9	88.7	131.6	304.9

(Means joined by line are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

(v) Effects on Natural Enemies

A. Syrphidae

Syrphids were scarce in Site II, so were not counted there. A mean of less than one syrphid larvae per plant was present in Site I before spraying (Fig. 22). The population increased slightly in the untreated plots during the spraying period but, increased more quickly after spraying ceased except in plots where carbaryl was applied where numbers remained below 0.5/plant until the end of the experiment. A 'peak' population of 2.4 syrphids per plant was attained in the untreated plots at week 17 after sowing, and this gradually declined to about 1.9 syrphids/plant at harvest.

All insecticide treatments gave significantly fewer (P 0.05) syrphids/plant compared with untreated control during spraying and in the post-spray period (Table 34). In general, numbers significantly decreased with increase in dosage of endosulfan and were least in the carbaryl treated plots.

The effect of carbaryl treatment persisting after the last application could be related to a persistent residue of carbaryl or to relative scarcity of prey, notably aphids, on the carbaryl treated plots, or perhaps to a combination of both. That carbaryl is persistent is indicated by its effects on some of the pests (Tables 31 - 33 and Figs. 18 - 20) and likewise it could remain toxic to syrphid larvae. Furthermore, there

was lowest aphids in the carbaryl treated plots. However, syrphid numbers rose in the highest endosulfan treatment despite similarly fewer aphids (Fig. 22). It seems possible therefore that the persistence of carbaryl residue was then more important. Endosulfan could have been more selective in favour of the predator or it may have persisted less.

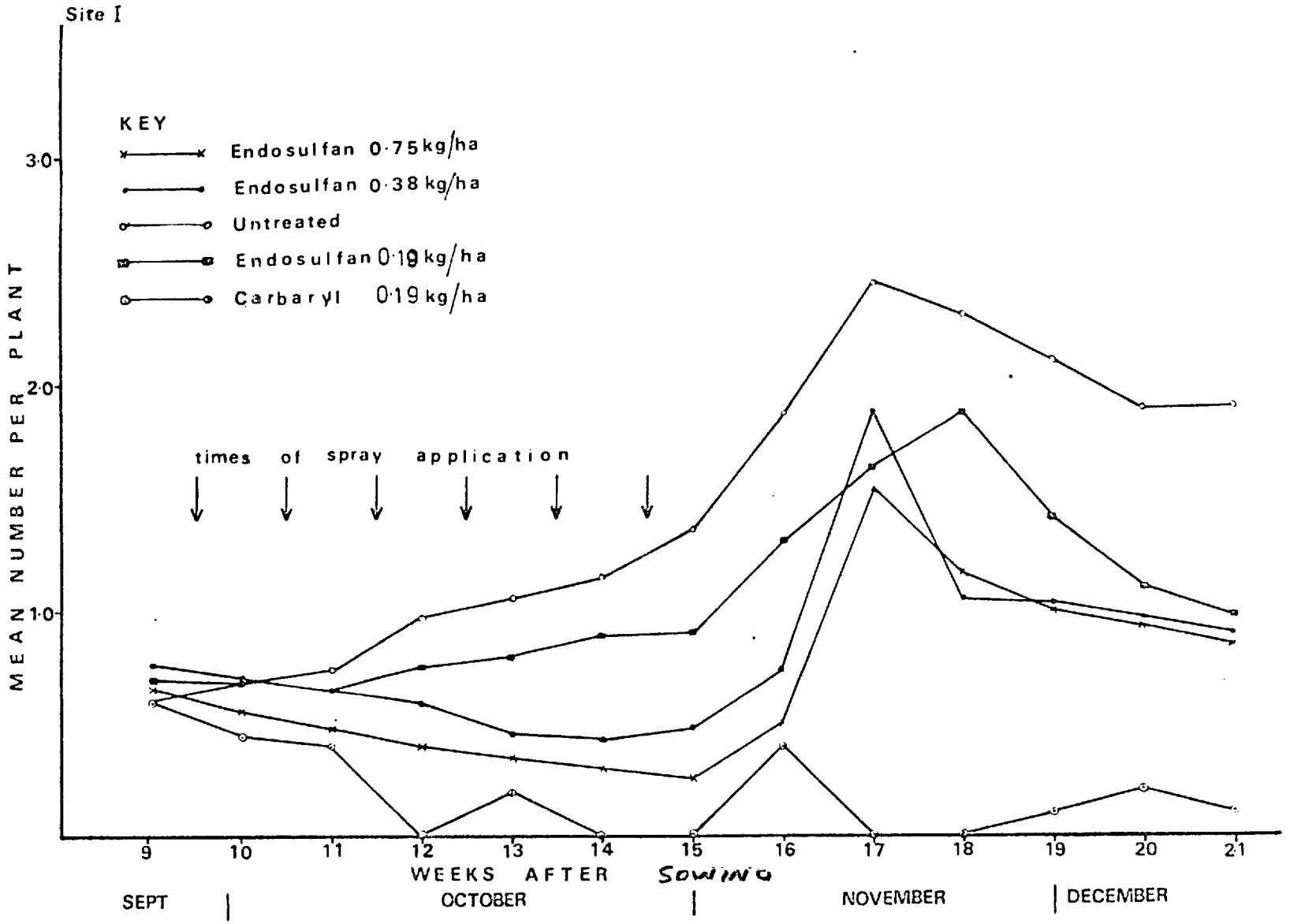


Fig 22. Weekly counts of Syrphid fly larvae (Mean no. per/plant) in ULV Endosulfan and Conventional Volume Carbaryl treated Cotton plots, 1974-75 season.

TABLE 34. POPULATION OF SYRPHID PLANT DURING ULV INSECTICIDE TRIAL 1974-5 SEASON

		TREATMENT				
			Endosulfan			
		Carbaryl 1.9 kg/ha	0.75 kg/ha	0.38 kg/ha	0.19 kg/ha	Untreated Control
WHOLE SEASON	Site I	0.51	1.78	2.12	2.73	3.82
SPRAYING PERIOD	Site I	0.29	0.57	0.81	1.19	1.56
POST-SPRAY PERIOD	Site I	0.08	1.08	1.17	1.40	2.13

(Means joined by line are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

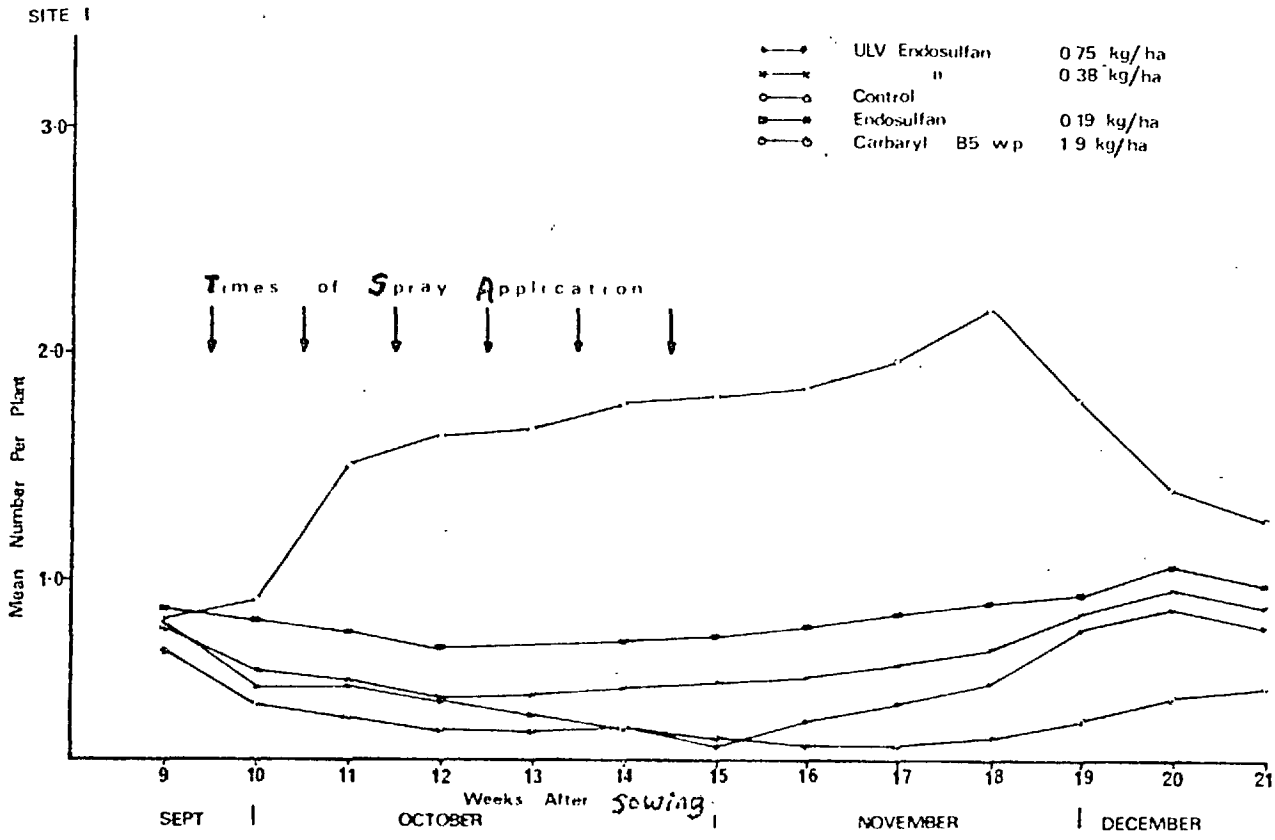
B. Spiders

Spiders were scarce in treated plots than in untreated throughout the spraying period, and very little increase in numbers occurred after spraying stopped (Fig. 23). A 'peak' number of 2.2 spider per plant was obtained in untreated plots at Site I in week 18, and 2.6 spiders/plant in Site II at week 17. Population trends were similar in all the ULV endosulfan treated plots at both sites. Endosulfan at 0.19 kg/ha had least effect on the spiders followed by endosulfan at 0.38 kg/ha. The 'peak' population recorded in these two lower endosulfan treatments were slightly higher than that obtained in 0.75 kg/ha ULV endosulfan treated plots.

Carbaryl seemed notably the most toxic to spiders. On plots treated with carbaryl, the population recorded was consistently significantly lower than in the other plots (Table 35).

All treatments resulted in significantly lower ($P < 0.05$) spider populations compared with the untreated control during both the spraying and post-spray periods at both sites.

It is again difficult to judge the causes of differences during the post-spray period. Persistence of the chemicals and relative scarcity of prey may be important as well as delay in build-up by the pest from the small population left after destruction of spiders during the spray period.



WEEKLY COUNTS OF SPIDER (MEAN NUMBER/ PLANT) IN ULV ENDOSULFAN AND CONVENTIONAL VOLUME CARBARYL TREATED COTTON PLOTS 1974-75 SEASON

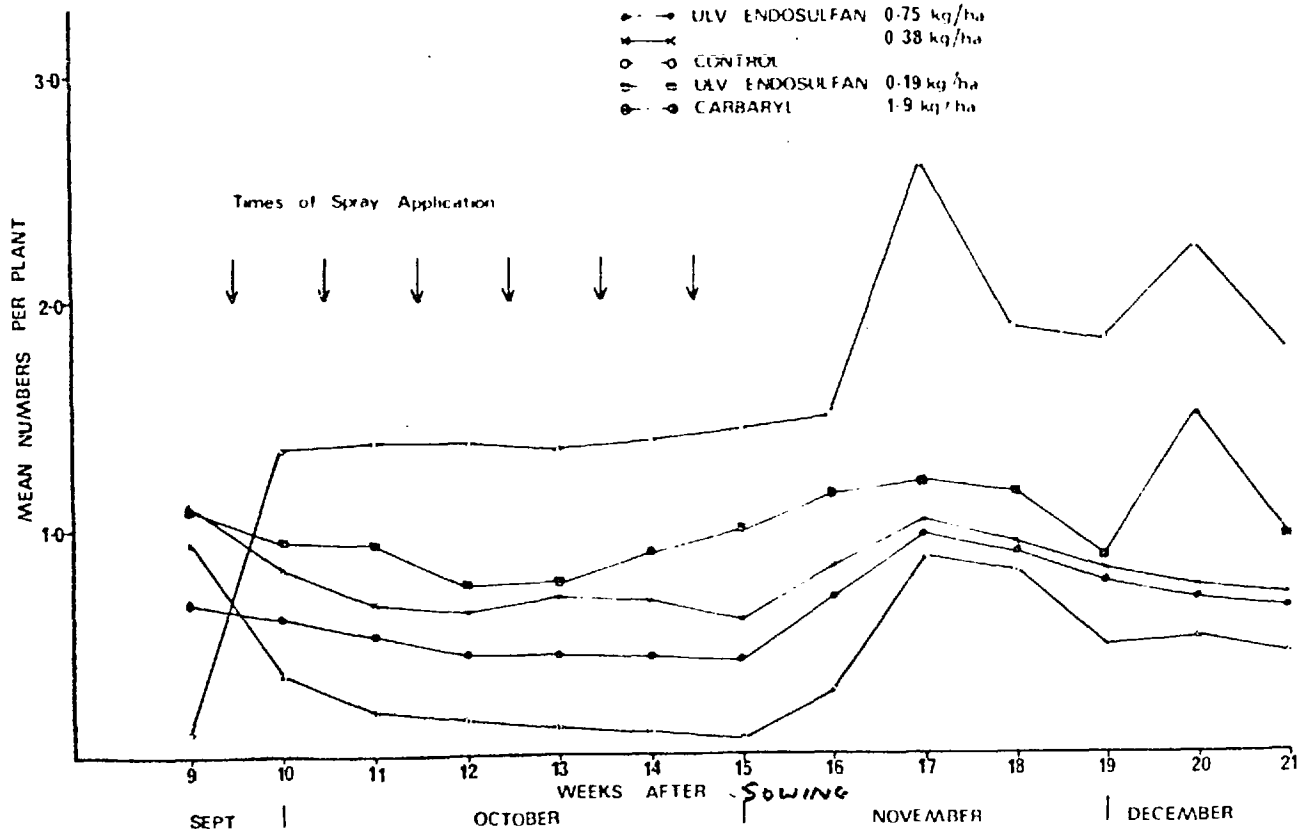


Fig.23. WEEKLY COUNTS OF SPIDER (MEAN NUMBER PER PLANT) IN ULV ENDOSULFAN AND CONVENTIONAL VOLUME CARBARYL TREATED COTTON PLOTS 1974-75 SEASON SITE II

TABLE 35. POPULATION OF SPIDER DURING ULV INSECTICIDE TRIAL 1974-5 SEASON

		TREATMENT				
			Endosulfan			
		Carbaryl 1.9 kg/ha	0.75 kg/ha	0.38 kg/ha	0.19 kg/ha	Untreated Control
WHOLE SEASON	Site I	1.02	1.44	1.73	2.23	4.13
	Site II	0.35	0.39	0.54	0.62	0.71
SPRAYING PERIOD	Site I	0.49	0.59	0.76	1.11	2.23
	Site II	0.04	0.10	0.14	0.19	0.28
POST-SPRAY PERIOD	Site I	0.39	0.69	0.81	0.95	1.73
	Site II	0.12	0.16	0.17	0.22	0.41

(Means joined by line are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

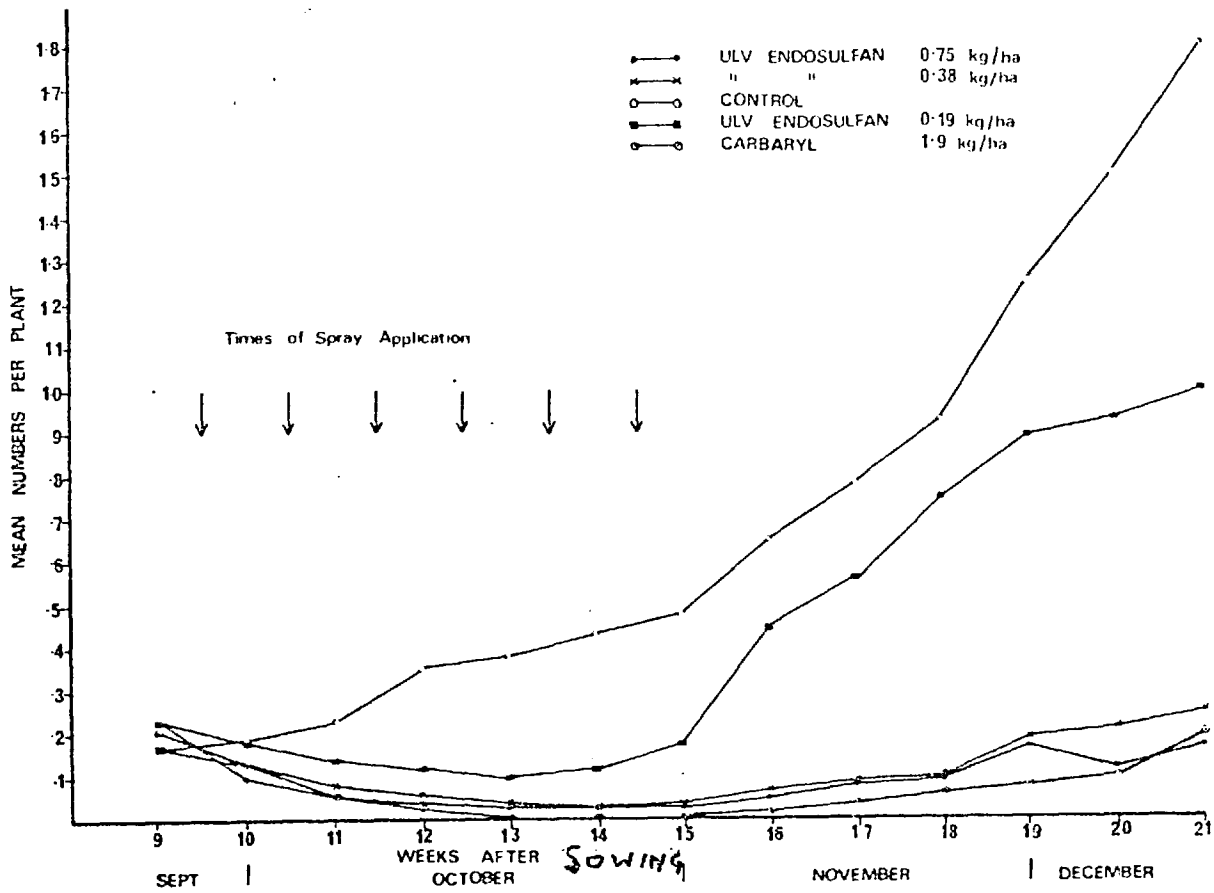
C. Platynaspis ferruginea

The population of P. ferruginea larvae in the plots treated with ULV endosulfan applied as 0.19 kg/ha at Site I followed a similar pattern as that in the untreated control plots (Fig. 24) in which numbers increased after the last spraying date at both sites reaching a 'peak' number in week 22. Otherwise, numbers remained low in other treatments.

The insecticide treatments gave similar trends in both sites. All treatments showed significant (P = 0.05) lower larvae in treated compared with untreated control plots (Table 36). Carbaryl exerted the most drastic reduction on the predator population and the mean number was less than 0.2/plant throughout the season (Table 36).

During the spraying period all treatments gave mean numbers significantly ($P < 0.05$) less than that in untreated plots. But during spraying and post-spray periods the effects of carbaryl and higher endosulfan rates on P. ferruginea were similar at both sites.

No doubt, as with syrphid larvae the post-spray differences are related both to insecticide persistence and abundance of aphid prey.



WEEKLY COUNTS OF Platynaspis ferruginea (MEAN NUMBERS/PLANT) IN ULV ENDOSULFAN AND CONVENTIONAL VOLUME CARBARYL TREATED COTTON PLOTS 1974-75 SEASON SITE I

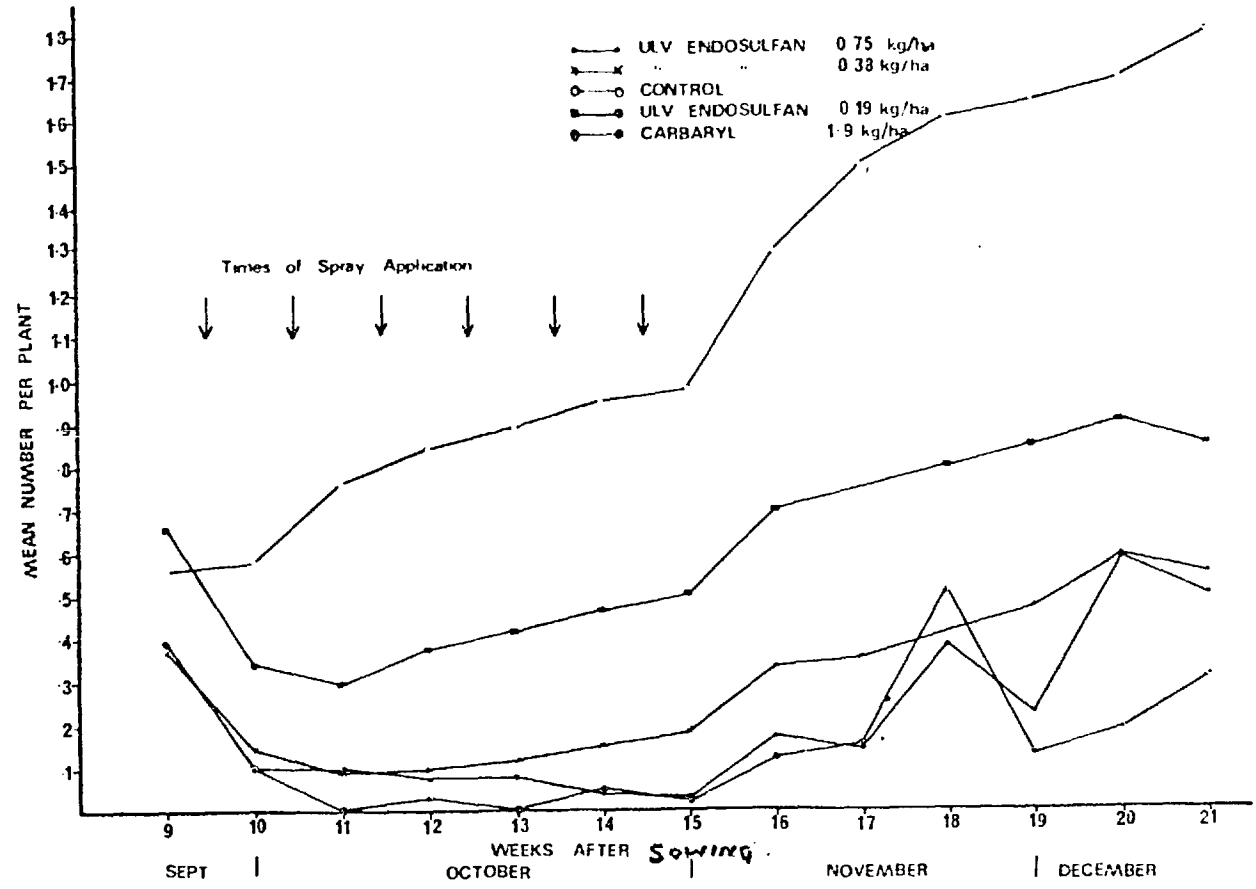


Fig.24. WEEKLY COUNTS OF Platynaspis ferruginea (MEAN NUMBERS/PLANT) IN ULV ENDOSULFAN AND CONVENTIONAL VOLUME CARBARYL TREATED COTTON PLOTS 1974-75 SEASON SITE II

TABLE 36. MEAN NUMBER OF PLATYNASPIS FERRUGINEA/PLANT DURING ULV INSECTICIDE TRIAL 1974-5 SEASON

		TREATMENT				
			Endosulfan			
		Carbaryl 1.9 kg/ha	0.75 kg/ha	0.38 kg/ha	0.19 kg/ha	Untreated Control
WHOLE SEASON	Site I	0.19	0.24	0.29	1.13	2.32
	Site II	0.14	0.17	0.20	0.39	0.62
SPRAYING PERIOD	Site I	0.05	0.07	0.09	0.26	0.71
	Site II	0.01	0.02	0.03	0.09	0.18
POST-SPRAY PERIOD	Site I	0.10	0.12	0.17	0.83	1.58
	Site II	0.05	0.07	0.09	0.17	0.33

(Means joined by line are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

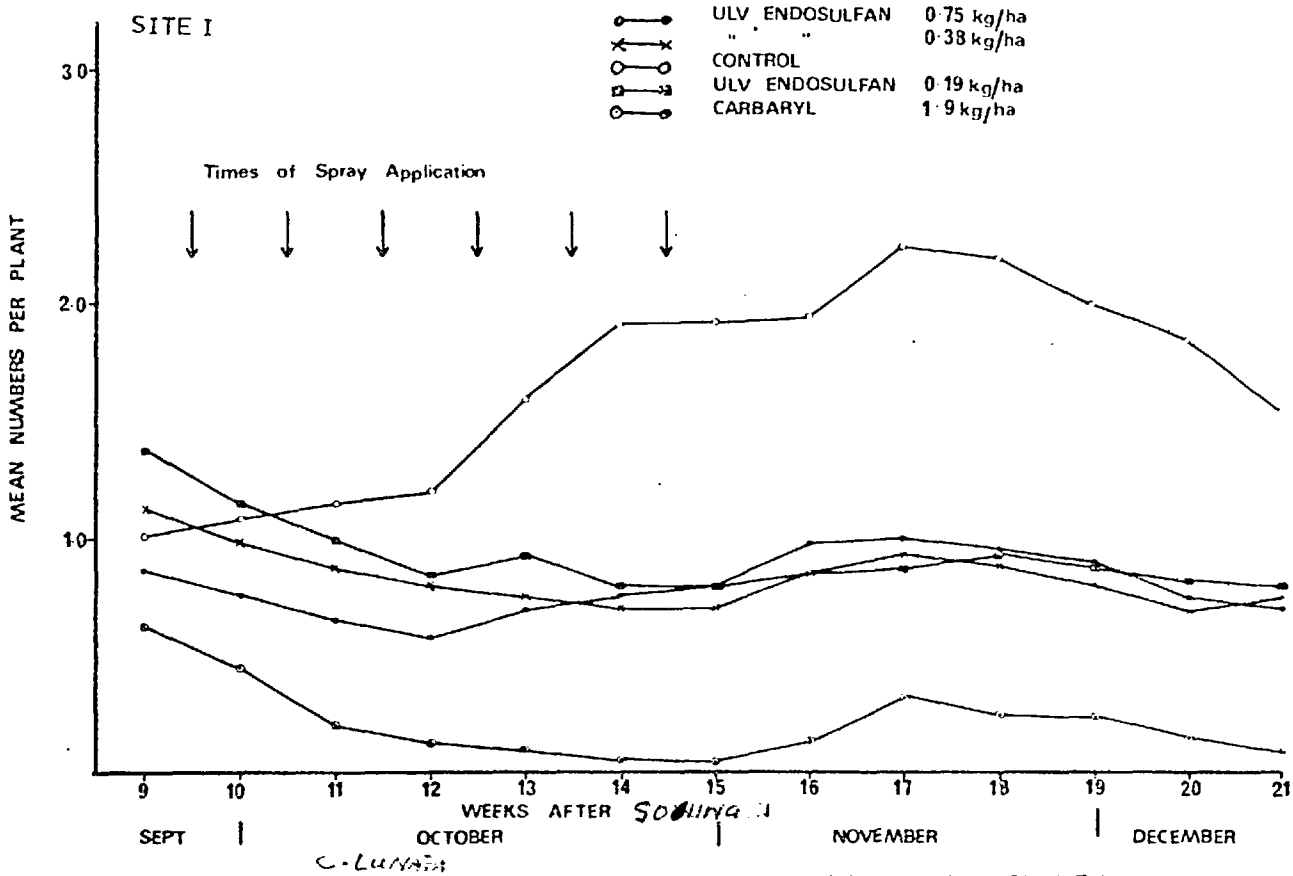
D. Chilomines lunata

The population of C. lunata adults and larvae decreased during the application of insecticides in the treated plots (Figure 25). Very few C. lunata; an average of less than 0.6/plant remained on plants treated with carbaryl. Once spraying had started (Table 37) the endosulfan treatments were less harmful and supported averages of more than three C. lunata per plant.

More C. lunata were found in the plots treated with the three dosage rates of ULV endosulfan than on the carbaryl plots. The population in the untreated plots showed gradual increase reaching a 'Peak' of 2.2 C. lunata per plant at Site I and 1.77/plant at Site II in week 17 after germination (Figure 25).

At both sites during the spraying and post-spray period treatments reduced the population of C. lunata compared with the untreated plots on which numbers increased to 10.8 and 1.8, at Sites I and II respectively. Nevertheless numbers of C. lunata were greater on the endosulfan treated plots than in carbaryl plots.

Thus carbaryl was shown to have more effect either directly or indirectly, or both, on populations of this predator (Table 37).



WEEKLY COUNTS OF Lady bird C. LUNATA MEAN NUMBER PLANT IN ULV ENDOSULFAN AND CONVENTIONAL VOLUME CARBARYL TREATED COTTON PLOTS 1974-75 SEASON

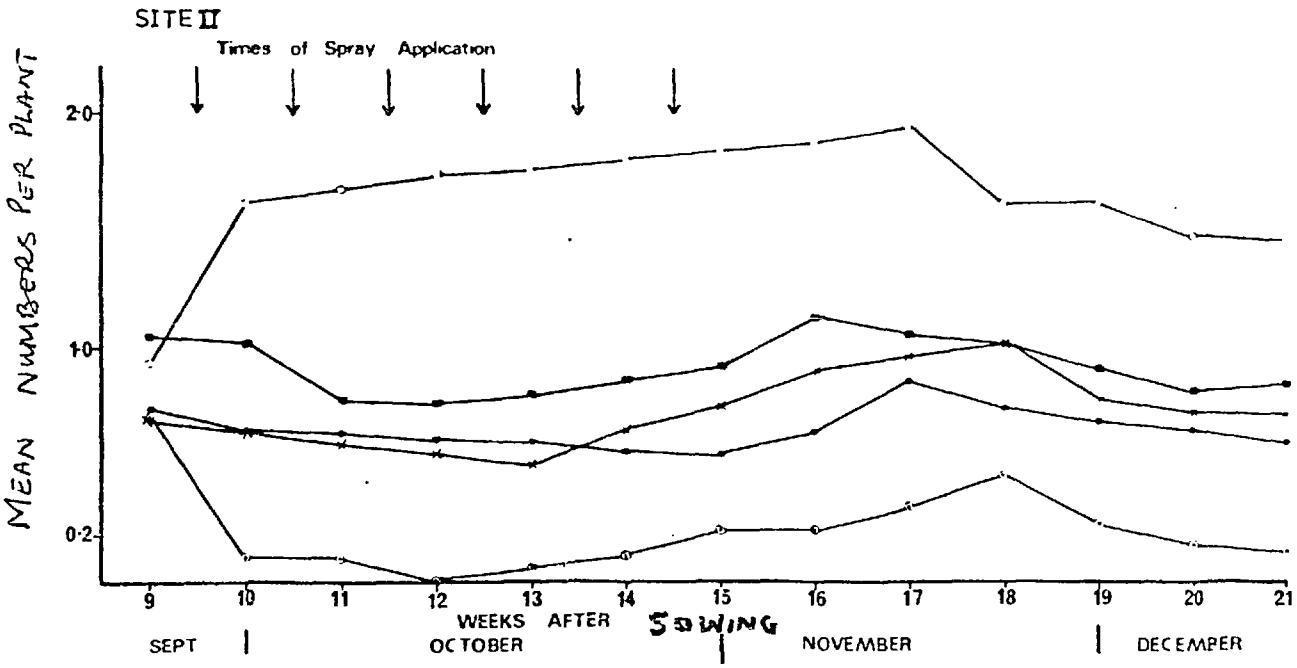


Fig. 25. WEEKLY COUNTS OF C. LUNATA MEAN NUMBERS PLANT IN ULV ENDOSULFAN AND CONVENTIONAL VOLUME CARBARYL TREATED COTTON PLOTS 1974-75 SEASON

TABLE 37 . MEAN NUMBER OF CHILOMINES LUNATA/PLANT DURING ULV INSECTICIDE TRIAL 1974-75 SEASON

		TREATMENT				
			Endosulfan			
		Carbaryl 1.9 kg/ha	0.75 kg/ha	0.38 kg/ha	0.19 kg/ha	Untreated Control
WHOLE SEASON	Site I	2.82	10.34	10.83	12.15	21.69
	Site II	2.94	8.59	9.49	11.95	21.43
SPRAYING PERIOD	Site I	1.13	5.17	5.65	6.39	10.83
	Site II	0.11	0.62	0.66	0.90	1.77
POST-SPRAY PERIOD	Site I	1.06	4.22	4.05	4.30	9.85
	Site II	.28	0.71	0.85	0.93	1.64

(Means joined by line are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

(vi) Yield

In the preliminary trial, endosulfan applied at 2.5 kg/ha resulted in a significant doubling (P 0.05) in yield of clean seed cotton over the lower dosage rate of ULV endosulfan which did not differ from that of the untreated control (Table 38).

All the insecticide treatments in the main trial gave significant increases (P 0.05) in the yield of seed cotton compared to the untreated control (Table 39) with the relative increase greater at Site II than at Site I.

Carbaryl was the most effective insecticide, producing a 1½ - fold increase in yield at Site I and 2½ - fold increase at Site II. Overall, at Site I there was significantly higher (P = 0.05) yields than at Site II.

The overall yields of clean seed cotton were greater at Site I where the plant population was higher than at Site II (500 plants/plot V. 300 plants/plot); at both sites treatments were ranked in the following order according to yield: Carbaryl endosulfan 0.75 kg/ha endosulfan 0.38 kg/ha endosulfan 0.19 kg/ha untreated control (Table 39).

Figure 28 shows the mean numbers of the fruiting parts of cotton per plant during the 1974-5 growing season in sprayed irrespective of insecticide and unsprayed cotton. These data indicate that the insecticides were

protecting the plant from a pest which affected bud production either by debilitating the plant or by attacking the buds direct. Aphids could cause this but it seems likely that an unrecorded pest was also involved. Otherwise it is difficult to explain the much greater number of buds in treated plants, since buds are less attractive than bolls to Earias, Pectinophora or Dysdercus. The data also indicate that very many green bolls were produced on treated than in untreated plants; more than would explain the yield increase. No doubt, many of the "green bolls" were already attacked or could be damaged later. Furthermore many of the bolls were unripe at the time of final harvesting when the crop had to be uprooted. Much value of the chemical treatments in particular at late crops is therefore lost because of closed season regulations.

'Peak' boll production occurred in this in October at week 13. This is in accordance with July sown cotton and it was also observed in Western State (Lee, 1966) and in Northern States of Nigeria (Choyce et al, 1963), coinciding with increasing numbers of the major pests of cotton.

There was excellent correlation between pest numbers in the post-spray period and yield. Thus linear regressions (Figures 26 & 27) indicate that at both sites, higher pest numbers were associated with lower yield. Multiple regression analysis (Appendix Tables 4 & 5).

indicate correlations between insect numbers and yield in both sites I and II, at the post-spray period, particularly with aphids and cotton stainers. Significant correlation occurred during spraying period, but less strong. This was better for P. gossypiella at Site I (Figure 26) and D. superstitiosus Site II (Figure 27).

Although aphid attack is generally associated with the early stages of plant development, aphids can be common or later as in the present experiment so, increase in numbers of aphids in the post-spray period may perhaps critically affect the crop. Most of the sugar that aphids take as sap is excreted in the form of honey-dew. This sticky substance forms a cover to the leaf surface and obscures respiration and retards photosynthetic activity. Honey-dew and associated fungi also discolour the seed cotton and therefore reduces its quality.

The increase in numbers of D. superstitiosus in the post-spray could cause serious damage which could be critical in determining yield. First, by feeding on the young developing seeds inside the green bolls, the insects may kill the embryos and consequently cause the bolls to rot; secondly, they introduce pathogens into the unopened bolls which may invariably destroy the cotton lint and thirdly, their feeding on the ripe seeds may reduce their germinating potential and their quality as a source of oil and cotton seed cake (Pearson, 1958).

TABLE 38 . YIELD OF SEED COTTON FROM PRELIMINARY ULV INSECTICIDE TRIAL 1973-74 SEASON

	TREATMENT		
	Endosulfan ULV		
	2.5 kg a.i/ha	0.625 kg a.i/ha	Untreated Control
Mean Yield Seed Cotton kg/ha	809	437	411

(Yields joined by line are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test)

TABLE 39. TOTAL YIELDS OF CLEAN SEED COTTON FROM MAIN ULV INSECTICIDE TRIAL 1974-75 SEASON

	Carbaryl W.P.	0.75 kg/ha	0.38 kg/ha	0.19 kg/ha	Untreated Control
Mean Yield Seed Cotton kg/ha					
Site I	1001	959	777	721	672
Site II	932	858	599	543	364
Increase in yield over untreated control					
Site I	x 1.5	x 1.4	x 1.5	x 1.2	
Site II	x 2.6	x 2.4	x 1.6	x 1.5	

Means which are joined by line and with similar underlining are not significantly different at P = 0.05 according to Duncan's New Multiple Range Test.

Fig. 26. LINEAR REGRESSION YIELD Vs INSECT ATTACK IN ULV ENDOSULFAN AND CONVENTIONAL VOLUME CARBARYL TREATED COTTON 1974-75

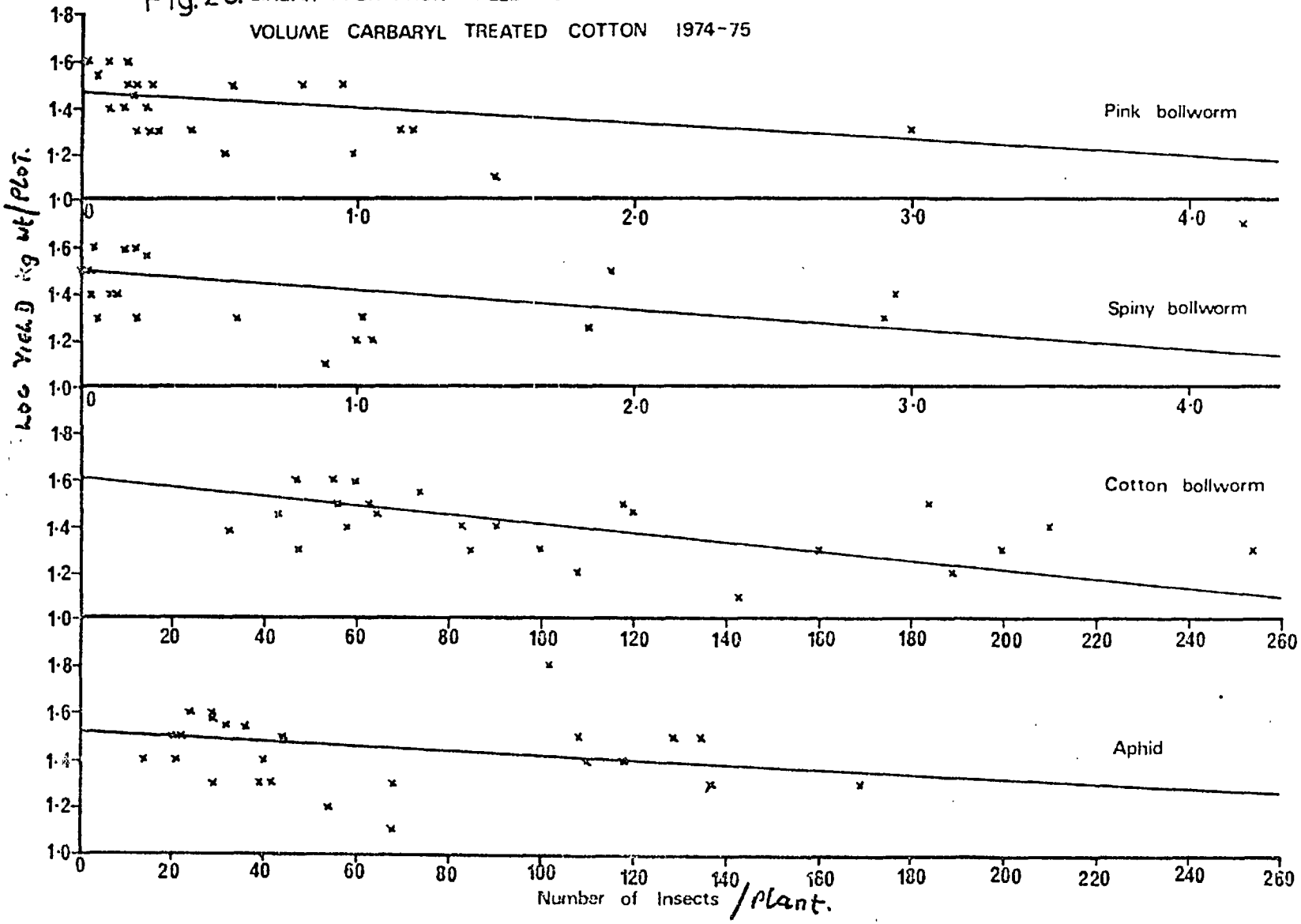


Fig. 27. LINEAR REGRESSION YIELD Vs INSECT ATTACK IN ULV ENDOSULFAN AND CONVENTIONAL VOLUME CARBARYL TREATED COTTON 1974-75

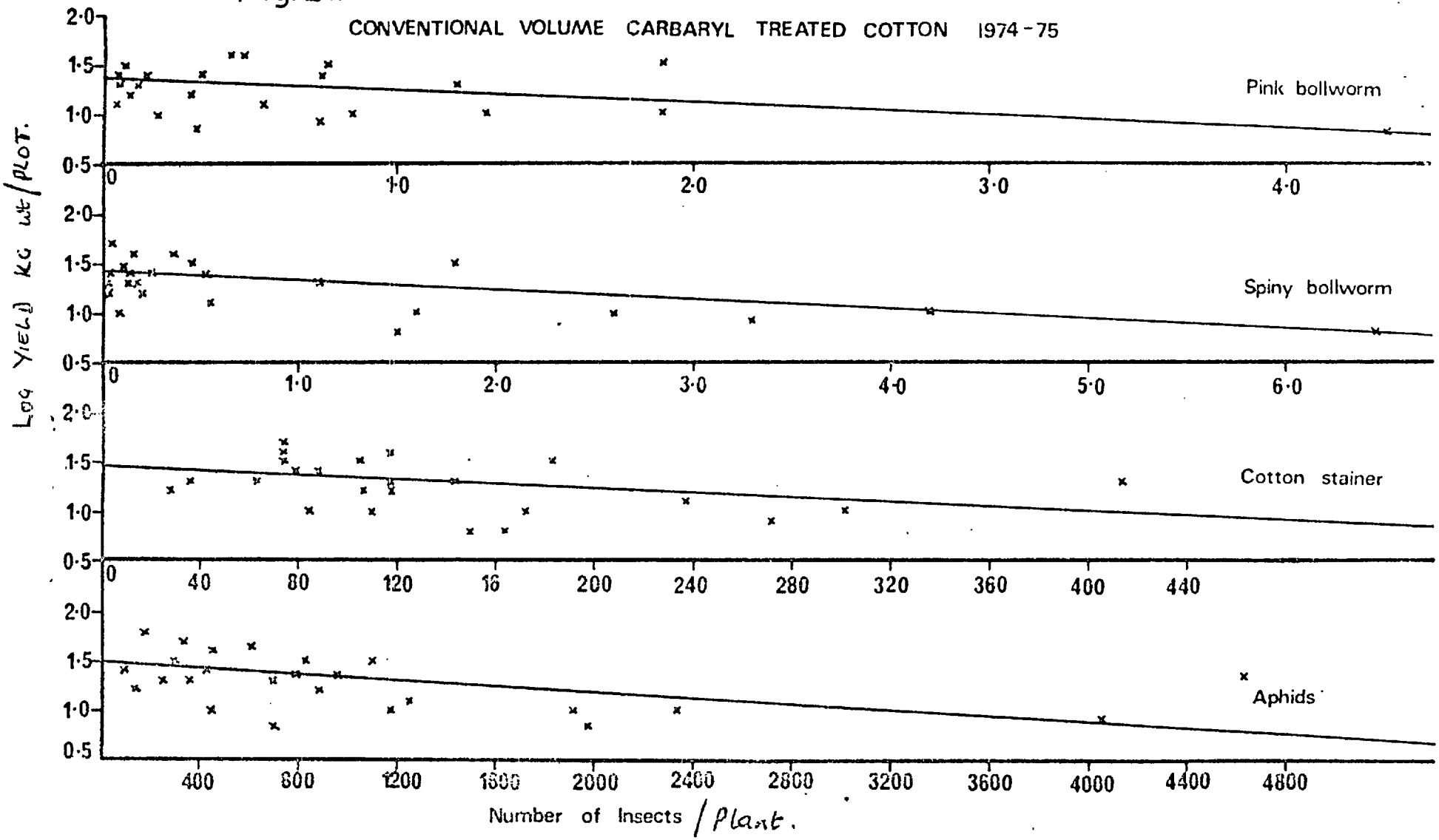
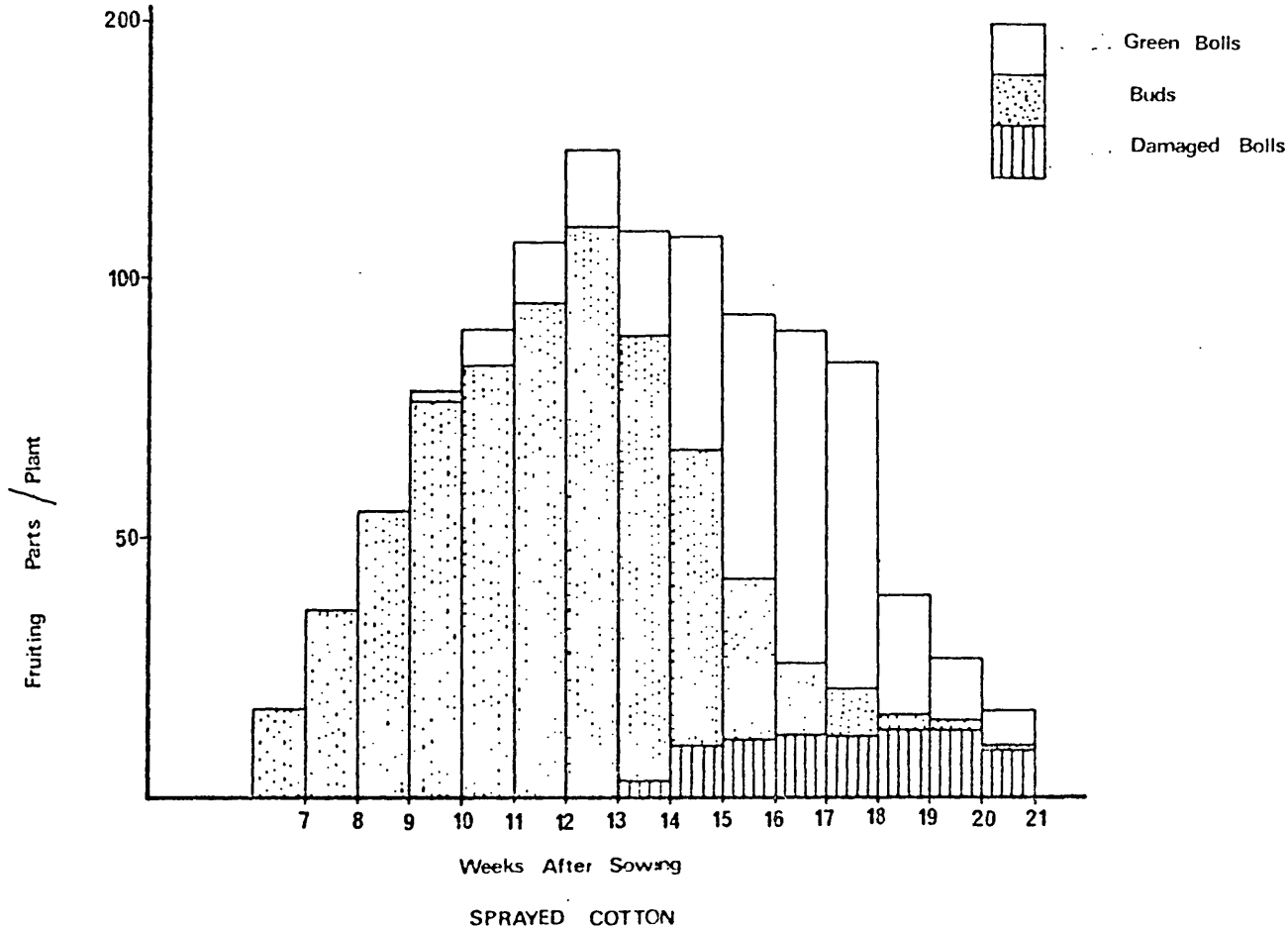


Fig. 28. FRUITING BODIES IN SPRAYED AND UNSPRAYED COTTON

SITE I

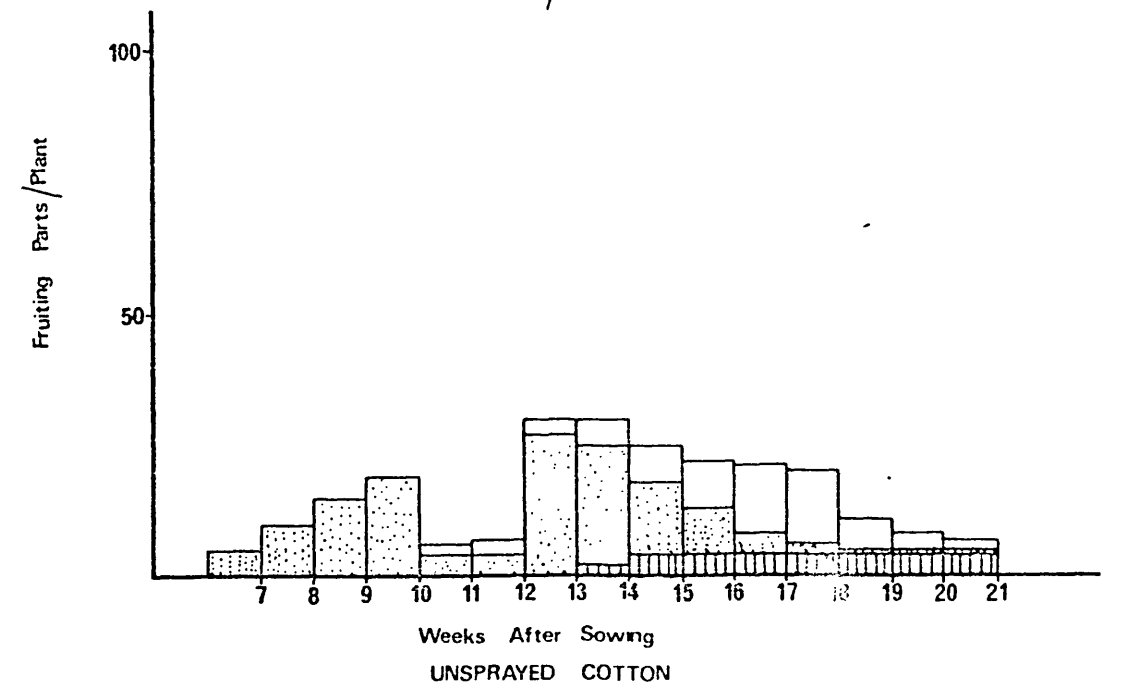
MEAN NUMBER FRUITING PARTS/PLANT IN SPRAYED PLOTS 1974-75 SEASON



SPRAYED COTTON

SITE II

MEAN NUMBER FRUITING PARTS/ PLANT IN UNSPRAYED PLOTS 1974-75 SEASON



UNSPRAYED COTTON

DISCUSSION

Briefly, the preliminary studies indicated that good control of A. gossypii and D. superstitiosus was achieved at 2.5 kg/ha but not at 0.625 kg/ha endosulfan ULV.

Similarly, 0.625 kg/ha endosulfan seemingly had no significant control of spiders and caused less mortality of C. lunata than 2.5 kg. Endosulfan at 0.625 kg/ha therefore seems a suitable concentration for use in an integrated programme, where natural enemies need to be preserved; but yields obtained from plots treated with endosulfan 0.625 kg/ha were significantly ($P < 0.05$) less (Table 38) than that from 2.5 kg/ha endosulfan. Thus, the dosage which is least harmful to beneficial insects is not necessarily the best for higher yield and for the control of the pests.

The main studies (1974-5 season) showed very significant decreases of P. gossypiella, E. biplaga, D. superstitiosus and A. gossypii numbers with ULV sprays of endosulfan at the two highest dosage (0.75 kg/ha) and also with LV sprays of carbaryl. The lowest dosage of 0.19 kg/ha endosulfan was much less effective or ineffective. This was probably due basically to the low dosage of active ingredient used but may have been influenced by uneven distribution across the 6 metre swath when plants were over 100 cm high. Control with 0.38 kg/ha endosulfan was as good (statistically) as 0.75 kg/ha ULV endosulfan and LV carbaryl both during

the spraying and post-spray periods against E. biplaga. Control by 0.38 kg/ha endosulfan of A. gossypii at Site II and of cotton stainers (D. superstitiosus) at Site I was as good as by 0.75 kg/ha endosulfan during spraying period (Section III, Tables 32 & 33). However, significantly greater resurgence of aphids occurred in the post-spray period in the lower ULV endosulfan treatments at both sites compared with ULV endosulfan applied at 0.75 kg/ha and carbaryl (Table 33).

The total predator populations were reduced by all spray treatments perhaps partly because of direct mortality due to the pesticides used, but also indirectly as fewer predators and parasites were attracted to the sprayed plots when populations of the prey had been reduced (Table 40). During the spraying period, significantly lower pest populations were recorded from plots treated with carbaryl and the highest dosage of endosulfan where also the lowest predator populations were found. After spraying the predator numbers failed to increase on these plots perhaps because there were no increase in the numbers of aphid prey to justify their presence.

The predator-prey ratio (Table 41) in the plots treated with ULV endosulfan at 0.75 kg/ha was higher than in plots sprayed with either of the two lower dosages of endosulfan or the untreated control. This may have occurred as a result of intercrop movements of the predators. The effect of carbaryl was more drastic in

killing off both preys and predators, and this resulted in the lower ratios of predators to preys found on plots treated with endosulfan treatments.

At 0.75 kg/ha ULV endosulfan, there was evidence of differential selectivity in favour of C. lunata, spiders, syrphids and P. ferruginea over aphids as compared to the ratios of these predators to aphids in carbaryl, the two lower endosulfan ULV and the untreated control plots. However, in the untreated control plots, the ratios of the natural enemies to aphids were similarly higher compared with carbaryl and the lower endosulfan treatments (Table 41).

0.75 kg/ha ULV endosulfan thus appeared to provide satisfactory level of pest control while sparing natural enemies (predators) to a higher degree than LV carbaryl. This conservation of natural enemies could be important in the long-term particularly if partial insecticide-resistance appears in pest management.

Matthews (1971) has discussed different swath widths for a ULV ground sprayer with particular reference to cotton.

Basically, he emphasized that, as the speed and direction of the wind are variable, wide swaths are liable to result in uneven distribution of spray. When plants are 25 cm (10 ins.) high, he recommended six metres swath since at this stage of plant growth, less restriction of air movement occurs within the foliage. Four metres swath

is recommended for plant 25-30 cm high and two metres swath for plants over 50 cm (20 in) high when row-spacing is 0.91 metre apart.

In the 1974-5 season's (main trial) ULV trial, a narrow swath could easily have been adopted as the spray operator had to walk along each spray line four times to achieve the required dosage using a 6 metre swath when only one concentration of spray was applied. So apart from differences in droplet distribution due to fluctuations in wind speed and turbulence, droplets were deposited over approximately the same rows, droplet distribution would have been different, and no doubt coverage of the plots would have been more even. Thus, with relatively few droplets deposited on some rows, i.e. those furtherest from the spray line, control was not as good as in the rows nearer the spray operator. Conversely, with a higher wind velocity, rows nearest the spray operator may have had poor coverage. This effect of reduced coverage was probably in part the cause of poorer pest control and lower yield from the lowest dosage of endosulfan.

The lowest dosage might therefore have given better pest control when applied at narrow swath width and also do no more harm to predators. This needs further study.

In the Mid-West State experiments using 6 metre swath for the ULV endosulfan treatments throughout the spraying period may have been one factor which resulted in lower, though not significantly, yield compared with

carbaryl treatment. Much better control might have been obtained if 1.8 metre swath had been used especially on the older cotton which reached a height of 100 cm and for which Matthews (1971) recommends 1.8 metres swath in Malawi. In these circumstances the same dosage/ha is applied, but the flow rate from the sprayer is decreased approximately.

A yield increase of 400 kg seed cotton/ha over the untreated control was obtained from the highest ULV endosulfan treatment. This compared favourably with the average yield increase of 466 kg seed cotton obtained in a ULV application trial at Daudawa and Malumfashi in Northern Nigeria (Beeden, 1974). Although low swath width (4.5 metres) was used in Northern Nigeria, yield increase was considered to be relatively low and was attributed to the luxuriant crop growth which resulted in inferior spray coverage. But in Malawi Matthews, (1973) obtained an average yield increase of 961 kg seed cotton over untreated control.

In Mid-West State trials, the dosages of endosulfan (0.75 kg, 0.38 kg and 0.19 kg/ha) applied at a flow rate of 1.12 m/s were somewhat higher than the range (0.5, 0.25 and 0.125 kg/ha) of ULV endosulfan used in Malawi, but these high dosage rates were not reflected by corresponding yield increases over control.

Differences in yield obtained from Malawi, Northern Nigeria and Mid-West State due to spraying may have been

due to differences in swath width, as well as plant growth and density and many other factors like plant variety, intensity and differing weather, soil moisture and soil fertility factors.

TABLE 40. MEAN NUMBERS OF PREDATORS/PLANT 1974-75 ULV TRIAL

	SITE I.				SITE II.		
TREATMENT	SPIDER	SYRPHID	CHILOMINES LUNATA	PLATYNASPIS FERRUGINEA	SPIDER	CHILOMINES LUNATA	PLATYNASPIS FERRUGINEA
ENDOSULFAN 0.75 kg/ha	7.23	8.74	10.34	1.18	8.11	8.59	2.80
ENDOSULFAN 0.38 kg/ha	8.65	10.61	10.83	1.46	10.24	9.49	3.93
ENDOSULFAN 0.19 kg/ha	10.37	13.66	12.15	5.66	12.96	11.95	7.92
CARBARYL 1.9 kg/ha	5.08	2.55	2.82	1.03	5.32	2.94	2.00
UNTREATED CONTROL	20.65	19.08	21.69	9.14	20.76	21.43	15.13

TABLE 41. RATIO OF PREDATORS TO PREY A. GOSSYPII IN SPRAYED AND UNSPRAYED PLOTS DURING ULV SPRAY TRIAL 1974-75 SEASON

RATIOS X 10^3

POST-SPRAY OCCASIONS	0.75 kg/ha ULV Endosulfan				0.38 kg/ha ULV Endosulfan				0.19 kg/ha ULV Endosulfan				1.9 kg/ha Carbaryl				Untreated Control			
	Ladybird	Spider	Syrphid	Platynaspis ferruginea	Ladybird	Spider	Syrphid	Platynaspis ferruginea	Ladybird	Spider	Syrphid	Platynaspis ferruginea	Ladybird	Spider	Syrphid	Platynaspis ferruginea	Ladybird	Spider	Syrphid	Platynaspis ferruginea
1	9	3	4	.4	3	2	3	.3	2	1	2	.8	1	2	3	.1	3	3	3	1
2	4	1	6	.3	2	1	4	.2	.9	.9	2	.6	1	1	0	.2	2	2	2	.6
3	4	2	4	.3	1	1	1	.1	1	1	2	.8	1	1	0	.3	2	2	2	.8
4	4	3	5	.8	1	1	1	.3	1	1	2	1	1	2	.5	.4	2	2	2	1
5	4	4	5	.6	1	1	1	.3	1	2	2	1	.2	3	1	.6	2	2	1	1
6	7	8	9	2	2	3	3	.7	2	2	2	2	1	7	.5	3	2	2	1	2

SECTION IV

MIXED CROPPING IN INTEGRATED CONTROL PROGRAMME

1. INTRODUCTION

(A) General effects of mixed cropping

Mixed cropping has been defined by Kassam (1973) as a husbandry system whereby an area is sown or planted with more than one crop type, and where the growth of some or all of the component crop types overlap in space and time. This system also covers practices such as intercropping, interplanting or intersowing.

There are other systems where crops are grown on the same land but do not overlap significantly in space namely, relay-cropping and multiple cropping, which is defined by Harwood (1973) as the growing of crops in succession on the same piece of ground in one year. These systems have been described by Norton (1975) as characteristic of many subsistence economies.

Wilson and Burton (1938) stated, "Although mixed cropping has long been in use in agriculture little progress has been made towards an understanding of the origin of the benefits arising from the practice". Even now little information is available on the comparative merits of different forms of intercropping and monoculture cropping. However, with more research on increased food production to provide for the increasing world population,

interest in mixed cropping has been renewed.

Fisher (1972) reviewed productivity of mixed cropping in the tropics from a plant physiologist viewpoint; and in 1974 in Tanzania Finlay et al embarked on a programme to study and improve intercropping systems through plant breeding, agronomy and crop protection.

In Nigeria, mixed cropping is a cropping system of traditional agriculture. A study by Norman (1971) in the Northern States of Nigeria in indigenous conditions showed that in general, the profitability of annual crop mixtures over monocultures was about 60%. Norman suggested that under the existing agricultural technology in Nigeria, the practice of mixed cropping was not only consistent with both profit maximisation and security of subsistence but was founded on sound biological attributes.

Some of these attributes include:-

(i) Increase in the utilization of environmental factors. This has both space and time dimensions. With reference to space, some crops need more space between plants than others (Aiyer, 1949) while different species have different nutritional requirements and different rooting systems (Russell, 1961; Wards, 1965). Thus from his work on mixed cropping, Igbozurike (1971) has suggested that growing crops in mixtures can maximise utilization of light, water and nutrients for any given area at one point in time. In terms of time, under-sowing

and overlapping of crops enables full use to be made of light by spreading the period of leaf cover and in maximizing the leaf area over time.

(ii) Reduction of adverse conditions in the ecosystem. Although sole cropping tends to attract fewer types of diseases and insect pests these are individually likely to be present in such quantities as to cause greater damage. In mixed cropping, however, a greater variety of disease and insect pests is likely to be present, but the overall damage is not likely to be as great (Aiyer, 1949). Furthermore, the denser plant population which usually results from crop mixtures helps to control the incidence of weeds (F.A.O., 1968; Geerte, 1963).

(iii) Soil Protection. Since many of the crops in mixed cropping overlap in the times they are in the ground, they extend the period of the year in which the soil is protected by leaf cover and root systems (Igbozurike, 1971) together with some economic advantages:-

(a) A reduction of inputs and an increase in output. Results of work done by Andrews (1972), Anthony and Willimott (1957), Evans (1960), Evans et al (1962) have concluded in general that mixed cropping results in greater gross returns per acre.

(b) Insurance against total crop failure. Mixed cropping has the advantage of assuring farmers of getting some return from their efforts on a given piece of land in any one year since not all crops are likely to be equally affected adversely by environmental conditions including weather, variation, diseases and pests (Webster and Wilson, 1966).

In the United States some studies conducted, using mixed cropping systems have produced positive results, e.g. intercropping corn and soy-beans in alternate pairs of rows (Alexander et al, 1962), alternating strips of corn and soy-beans as solid planting (Pendleton et al, 1963), mixed cropping corn as a windbreak for soy-bean, (Radka, 1968) and mixed cropping which takes advantage of nitrogen fertilizer from leguminous plants (Wilson and Wyss, 1936) have all demonstrated the potential of mixed cropping systems. Mixed cropping has also been practised in Europe for silage production e.g. good yields of dry matter and feed value have been obtained with inter-cropping maize and soy-bean by Kalaidzhieva (1969). In general, beans and oats, cereals with clover or other forage crops are common mixed cropping practices in Europe.

A considerable body of literature exists in Africa on mixed cropping. Evans (1960) in Tanganyika, showed that

over a wide range of populations intercropping maize or sorghum with groundnuts generally leads to a greater overall crop production per acre than by growing these crops in pure stands. This was shown for two sites of contrasted levels of soil fertility and in two years of differing rainfall, one favourable, the other less favourable (Table 42). At both sites the production of both crops was appreciably greater from intercropping at comparable levels of plant population. Evans et al (1962) interplanted castor-bean with soy-bean or groundnuts and obtained an overall gain in production per acre (Table 43).

Since insect pests attack can reduce castor-bean yield drastically, intercropping with other crops may give a compensatory yield of the other crops as indicated in Table 43.

Anthony and Willimott (1957) conducted a feasibility study on mixed cropping in South-West Sudan, to determine the possibility of growing cotton in association with other crops (legumes) planted at the beginning of the cropping season, so that cotton grew for some weeks prior to harvest. Despite reduction in the cotton stand and set back in growth with delayed budding by early planting of the legumes and cotton, good crops of both were obtained. Intercropping of cotton in later-sown crops resulted in a significant loss in cotton yield but was compensated for by the yield of the other crops.

TABLE 42. COMPARISON OF YIELDS (LB) FROM ONE ACRE OF INTERCROPPING AND TWO HALF-ACRES OF PURE STANDS - SOUTHERN PROVINCE, 1958* - TANZANIA

POPULATION LEVEL		INTERCROP		PURE STANDS	
MAIZE	GROUNDNUTS	MAIZE	GROUNDNUTS	MAIZE	GROUNDNUTS
MTAMA:-					
H	L	923	575	552	465
L	H	1,134	862	567	654
Significant Difference at 5%		270	80	135	40
MNACHO:-					
H	L	1,644	192	1,163	101
L	H	1,550	151	877	61
Significant Difference at 5%		238	64	119	34

H = high population L = low population

* East African Agricultural and Forestry Journal (1960).

TABLE 43. *COMPARISON OF YIELD (LB) FROM ONE ACRE OF INTERCROPPING WITH TWO HALF-ACRES OF PURE STANDS - SOUTHERN PROVINCE, 1960* - TANZANIA

CASTOR	PURE STAND		INTERCROP WITH GROUNDNUTS		GAIN OR LOSS FROM INTERCROPPING	
Planting Date	Castor	G'nuts	Castor	G'nuts	Castor	G'nuts
Early	268	468	476	500	208	32
Medium	279	468	350	1146	71	678
Late	300	468	295	1096	-5	630
	With Soya-bean					
	Castor	G'nuts	Castor	Soya	Castor	Soya
Early	268	807	473	994	205	187
Medium	279	807	84	1708	-195	901
Late	300	807	26	1700	-274	893

* East African Agricultural and Forestry Journal (1962)

(B) Effects of mixed cropping on insects and other pests

Evidence of the potential effects of mixed cropping on insects and other pests was demonstrated in the United States. Interplanting alfalfa with cotton was shown to reduce damage by Lygus hesperus which is one of the most destructive insect pests of cotton, beans, and many seed crops in California.

Strip harvesting of alfalfa (Stern et al, 1964, 1967, 1969) has been shown to produce greater stability in alfalfa environment. This process in turn, prevents emigration of certain species during the harvest period and brings about improved spatial and temporal synchrony between pest populations and those of their natural enemies. This eventually results in a dual benefit from strip cutting: (1) reduction in the population of Lygus in susceptible crops e.g. cotton and (2) alfalfa strips serve as an 'insectary' for natural enemies which later migrate from the alfalfa into cotton, where they attack eggs and small larvae of bollworms and other insect pests.

Dempster and Coaker (1974) in U.K., showed that clover interplanted with brussels sprouts greatly reduced numbers of the cabbage caterpillar, Pieris [illegible]ae, on the brussel crop. Similarly, O'Donnell and Coaker (1975) have demonstrated the effect of intra-crop diversity on insect pest populations on brassicas by undersowing brussel sprouts with clover. Cabbage aphid infestations were reduced by over 80% due to interference with their immigration into the crop. Soil dwelling predatory

arthropods were enhanced by the additional shelter provided by the clover and were responsible for the lower survival of cabbage caterpillars (30%) and cabbage root fly (60%). Although clover competed severely with brussels sprouts on light soil, this effect was remedied by irrigation.

Much observational information has been recorded in Africa (Pearson, 1958) which suggests the role that mixed cropping could play in insect pest management. In Rhodesia considerable oviposition by H. armigera occurred in maize and beans, so Peat (1932) considered these two crops as potential trap crops in a mixed cropping system with cotton. Maize just coming into tassel and silking was more attractive to H. armigera at that time than were cotton plants. Similarly, Bebbington and Allan (1933) confirmed the usefulness of maize as diversionary crop for the American bollworm (H. armigera) in Zambia. Maize thus used, is attractive for only a short period, say for 15-20 days as suggested by Pearson (1958). So as a diversionary crop, sequential sowings are required to ensure that some are in tassel throughout the period when cotton plants are prone to attack by bollworms.

Results so far known provide little factual evidence of the effect of mixed cropping on pest control management, especially in Africa where scanty work has been done and little quantitative data have been published. The main aims of this study, therefore, were to determine the

extent to which insect pests would be attracted to, diverted away from or otherwise affected cotton in a mixed cropping system, considering these underlying factors which have been indicated by Way (1973) as sound requisites to ecological research needs in relation to population dynamics and control of insect pests:

(i) the possibility that mixed stands produce a favourable environment to enhance natural enemies action,

(ii) the presence of diversionary hosts in the mixtures which could serve to attract pests from the target crop,

(iii) lack of contact between plants of the same species, so decreasing success in plant-to-plant colonization; and lack of coincidence of pests with the at-risk stage of the crop or conditions less favourable to dormant season survival; and

(iv) the attractive properties of crops in the mixtures, as this can affect the visual and olfactory stimuli that attract insect pests into the crops or prevent them from finding the crops.

Furthermore, it was desirable to assess the possible benefits from mixed cropping systems in terms of increased yields.

2. MATERIALS AND METHODS

Treatments were:-

(1) Rows of cotton (Allen 26J) planted as 100% crop population per plot spaced at 45 cm on ridges 90 cm apart.

(2) Rows of cotton interplanted with maize as 50% cotton crop population per plot. Here cotton was planted at 90 cm spacing on ridges 90 cm apart and maize 90 cm on ridges 90 cm apart i.e. 45 cm between different crops.

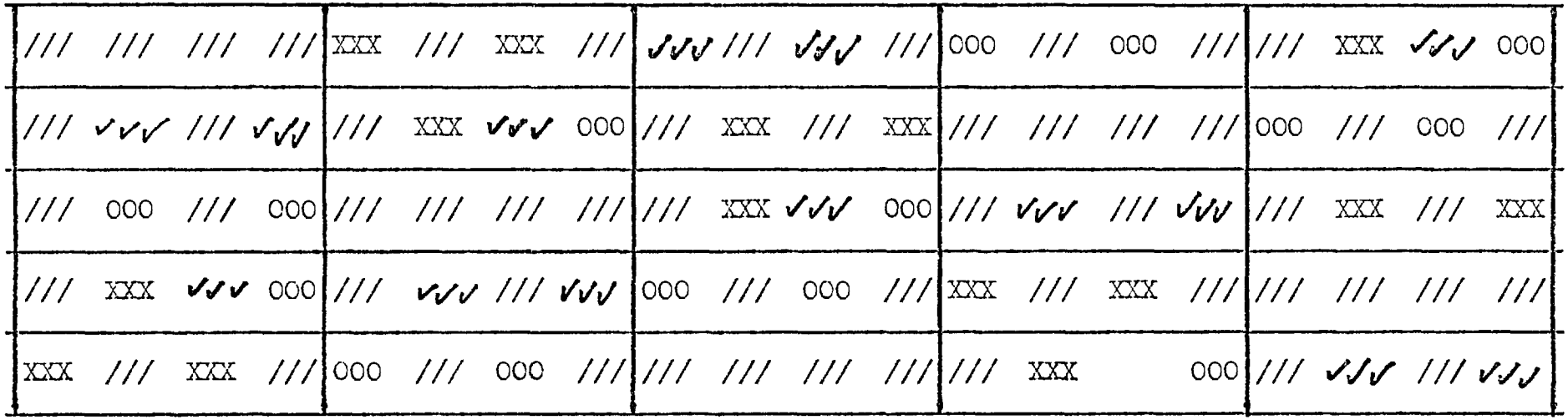
(3) As treatment (2) but okra interplanted instead of maize.

(4) As treatment (2) but cotton interplanted with tomato instead of maize.

(5) Cotton interplanted into maize, okra and tomato and cotton as 25% crop population per plot of each species. Each crop was planted at 180 cm spacing on 90 cm ridge i.e. 45 cm apart between the different crop species.

The five treatments were replicated five times in a 5 x 5 latin square design (Fig. B). All biological data including yields were collected from the inner portion of each plot, a nett area of 72 sq. metres. Sowing dates for the three trials were the first week of July 1972, the beginning of the second half of July 1973 and 1974. The sowing dates were rather late for crops like maize, tomato

FIGURE B . SCHEMATIC DIAGRAM OF A MIXED CROPPING LAYOUT FOR 1972-74 SEASON



Rows are spaced 45 cm apart on 90 cm wide ridges. Plot size = 18 m x 18 m

/// ///	COTTON ALONE
/// XXX	COTTON + MAIZE
/// ✓✓✓	COTTON + OKRA
000 ///	COTTON + TOMATO
/// XXX ✓✓✓ 000	COTTON + MAIZE + OKRA + TOMATO

and okra which would normally be sown as early as April for uptimum yield, but they were chosen to coincide with the cotton sowing time recommended by Hayward (1967), Choyce and Lyon (1965). For the trials, tomatoes were sown into trays and transplanted into the field two weeks after sowing. All plants of all species were thinned to two per hole 2-3 weeks after planting. Artificial fertilizer was applied to cotton at the rate of 225 kg/ha of 26% N calcium ammonium nitrate while the other crops were treated with 15% : 15% : 15% N.P.K. compound fertilizer at 225 kg/ha. No insecticide sprays were applied to the mixed cropping trial.

Treatments were assessed on the basis of the total number of larvae mostly P. gossypiella and E. biplaga, and of adults of flea beetles essentially Podagrica spp, cotton stainers (D. superstitiosus) and ladybird adults and larvae C. lunata and P. ferruginea taken from eight randomly selected plants per ridge in the 1972-3 and 1973-4 trials. In the 1974-75 trials samples were taken from 84, 42 and 14 randomly selected plants to correspond to cotton planted in the proportion of 100 : 50 : 16.6% (Tables 44 - 50).

Sampling for insect pests, natural enemies and yields were from the nett plots and methods of sampling and analysis were similar to those used in the insecticidal trials (Sections II and III). Four separate trials were conducted.

First, a preliminary survey of the use of a mixed cropping system was undertaken in 1972-73 season, to study the numbers and species of insect pests and their natural enemies in a cotton growing community (Usenbo, 1974a). Four crops used in this trial were cotton G. hisurtum (var. Allen 26J), maize Zea mays (var. N.S 1), tomato Lycopersicum esculentum (var. Ife 1) and okra Hibiscus esculentus. The trial was repeated in 1973-74 season. In 1974-75 season, two separate trials were conducted; one in which the crops were combined as in the two previous (Fig. C) seasons (1972-73) and in the other in which the different crop species were sown as sole crops in strips with a view to collecting yield data used for determining the land equivalent ratios for each crop.

In these final trials, sorghum and cowpeas which were now available were included. Numbers of insect pests and their natural enemies were also counted as per previous trials.

FIGURE C . SCHEMATIC DIAGRAM OF A MIXED CROPPING LAYOUT ON THE FIELD. 1974-75 SEASON

Layout:- 7 x 6 complete randomized block

O	W	O	W	O	W	O	⊙	X	//	✓✓	W
W	O	W	O	W	O	W	✓✓	//	X	⊙	O
⊙	W	⊙	W	⊙	W	X	W	X	W	X	W
W	⊙	W	⊙	W	⊙	W	X	W	X	W	X
X	W	X	W	X	W	✓✓	W	✓✓	W	✓✓	W
W	X	W	X	W	X	W	✓✓	W	✓✓	W	✓✓
//	W	//	W	//	W	⊙	W	⊙	W	⊙	W
W	//	W	//	W	//	W	⊙	W	⊙	W	⊙
✓✓	W	✓✓	W	✓✓	W	O	W	O	W	O	W
W	✓✓	W	✓✓	W	✓✓	W	O	W	O	W	O
O	⊙	X	//	✓✓	W	W	W	W	W	W	W
W	✓✓	//	X	⊙	O	W	W	W	W	W	W
W	W	W	W	W	W	//	W	//	W	//	W
W	W	W	W	W	W	W	//	W	//	W	//

Plot size = 18 m x 18 m

O W	SORGHUM + COTTON
⊙ W	COWPEA + COTTON
X W	MAIZE + COTTON
// W	TOMATO + COTTON
✓✓ W	OKRA + COTTON
O ⊙ X // ✓✓ W	SORGHUM + COWPEA + MAIZE + TOMATO + OKRA + COTTON
W W	COTTON ALONE

3. RESULTS

(A) Mixed cropping 1972-73 season

(i) Effects on bollworms (P. gossypiella and E. biplaga)

The populations of these two species were relatively low on the crops throughout the season, and both were patchily distributed.

First larvae were recorded on samples during the first week of September, and the subsequent changes in larval populations (Fig. 30) indicate three possible phases of attack perhaps corresponding to peaks of oviposition in late September, at the end of October and in the third week of November.

The numbers of larvae per plant, per plot and per hectare of P. gossypiella and E. biplaga are shown in Tables 44 & 45 respectively. Analysis of variance of the mean larvae recorded per cotton plant either of pink bollworm or spiny bollworm showed significant ($P = 0.05$) effects of the treatments, and on per plot or per hectare bases more of both species were found on cotton planted as monoculture than in mixed situations (Tables 44 & 45). Thus except in the treatment where cotton was interplanted with okra and in the four crop mixture (i.e. cotton with maize, okra and tomato) the mean numbers of P. gossypiella larvae on cotton in the cotton/maize and cotton/tomato treatments were significantly ($P < 0.05$) less than in the

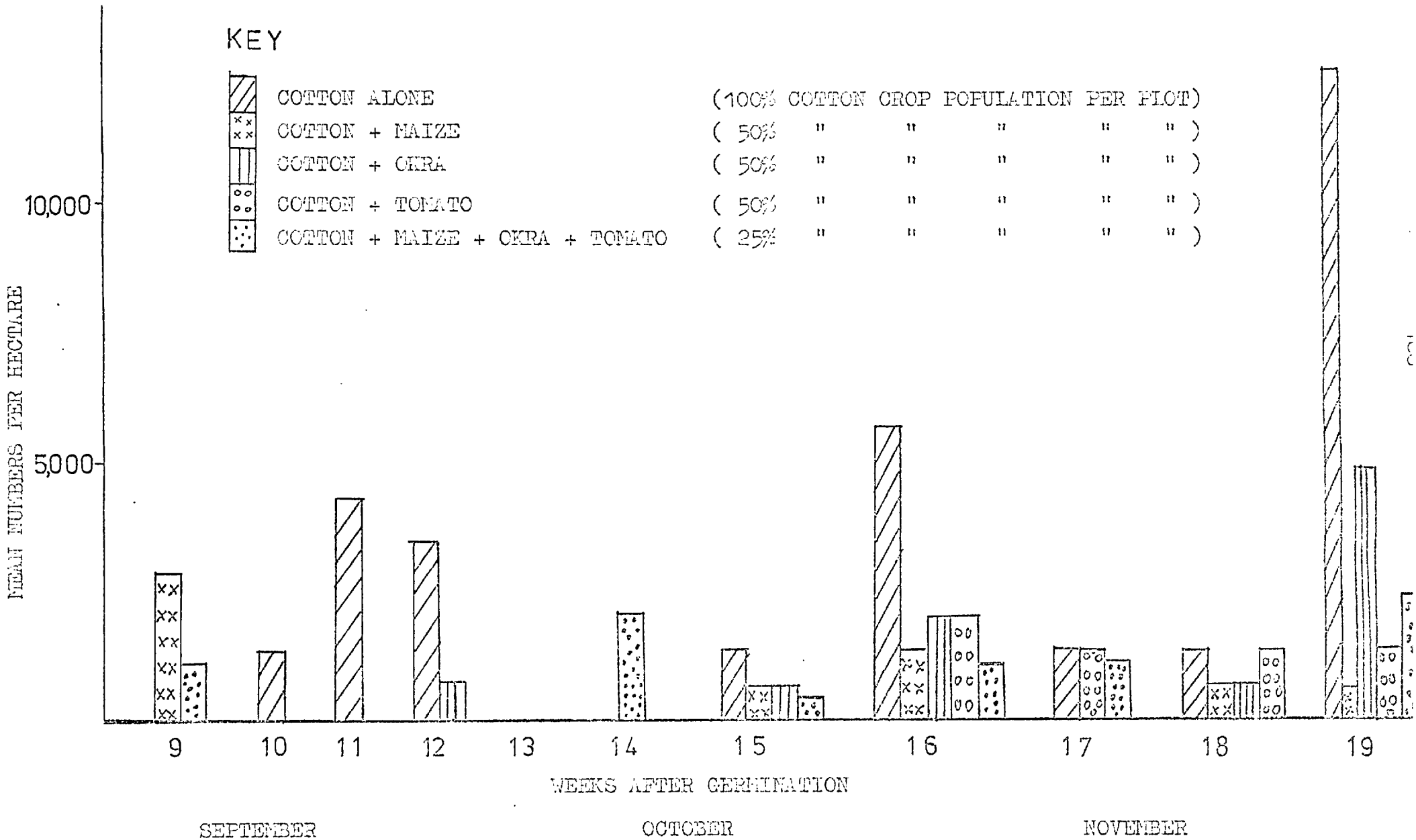


Fig. 30. MEAN NUMBERS OF (P. gossypiella) ON COTTON IN MIXED CROPPING SYSTEMS. 1972-73 SEASON

TABLE 44 . POPULATIONS OF PINK BOLLWORM (P. GOSSYPIELLA) IN MIXED CROPPING SYSTEM 1972-73 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		2.0 **	200	2857
50	COTTON + MAIZE	COTTON	0.82*	40	571
		MAIZE	0	0	0
50	COTTON + OKRA	COTTON	1.3 **	64	914
		OKRA	.91	46	657
50	COTTON + TOMATO	COTTON	0.82*	40	571
		TOMATO	0.09	5	71
25	COTTON + MAIZE + OKRA + TOMATO	COTTON	2.1 **	52	742
		MAIZE	0	0	0
		OKRA	0.18	5	71
		TOMATO	0.09	2	28

** Means are not significantly different at P = 0.05

* Means are not significantly different at P = 0.05, but are significantly different from **

pure cotton (Table 44). It would therefore, seem advantageous to interplant cotton especially with maize or tomato to reduce P. gossypiella infestation.

Unlike P. gossypiella, the mean numbers of E. biplaga larvae/cotton plant (Table 45) were significantly ($P < 0.05$) higher in cotton planted with tomato than in the other crop combinations though it was not significantly ($P = 0.05$) different from numbers found on cotton interplanted with okra or as a sole crop (Table 45) and on a per plot basis they were significantly fewer on cotton in all the crop mixtures. The numbers of E. biplaga larvae found on okra were four times those on tomato crop in the two crop mixtures (Table 45). The fewer numbers of E. biplaga found on tomatoes compared to the other combined crop (cotton) indicate that intercropping of cotton with tomato enhances the buildup of spiny bollworm. It must be noted however, that the presence of E. biplaga on tomato is by chance as this crop is not a known host to Earias spp.

Overall, the best combination seemed to be the 50/50 cotton/maize mixture (Table 45; Fig. 31)

TABLE 45 . POPULATIONS OF SPINY BOLLWORM (E. BIPLAGA) IN MIXED CROPPING SYSTEM 1972-73 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		1.28***	128	1828
50	COTTON + MAIZE	COTTON	0.73**	37	528
		MAIZE	0	0	
50	COTTON + OKRA	COTTON	1.09***	55	785
		OKRA	0.73	37	528
50	COTTON + TOMATO	COTTON	1.46***	73	1042
		TOMATO	0.18	9	128
25	COTTON + MAIZE + OKRA + TOMATO	COTTON	0.36*	9	128
		MAIZE	0	0	0
		OKRA	0.36	9	128
		TOMATO	0.18	5	71

*** Means are not significantly different at P = 0.05; but significantly different from ** and *

** Means are significantly different from * at P = 0.05

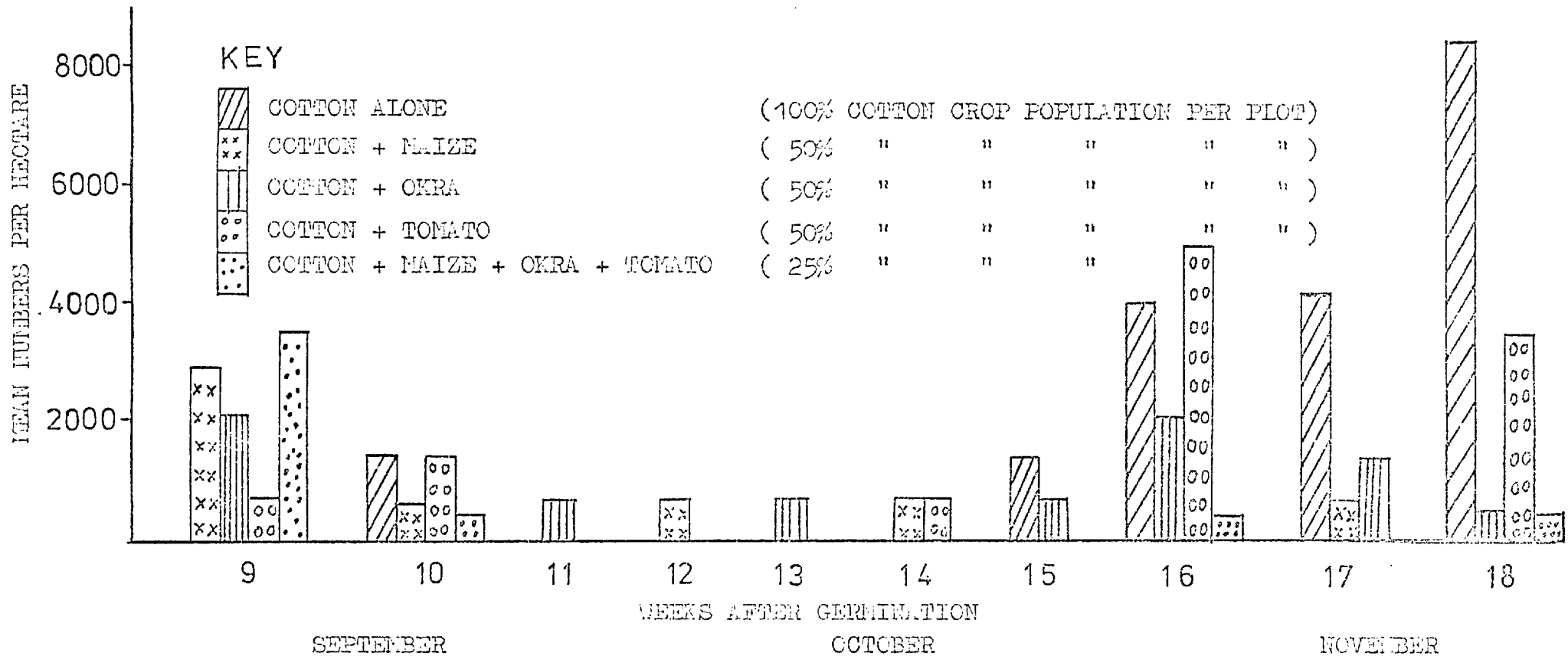


FIG. 31. MEAN NUMBERS OF SPINY BOLLWORM (E. biplaga) ON COTTON PER HECTARE IN MIXED CROPPING SYSTEMS, 1972 - 73 SEASON

(ii) Effects on cotton stainers (D. superstitiosus)

Cotton stainers were fairly uniformly distributed throughout the treatments (Fig. 32). The highest peak number/plant was recorded in the middle of October on cotton interplanted with okra. On per hectare basis, the mean number of D. superstitiosus found on cotton planted as a sole crop (i.e. 100% crop population per plot) was in the order of nearly half a million (Table 46) and this was notably more than numbers on cotton in the crop combinations (Table 46).

The analysis of variance of the means of D. superstitiosus per cotton plant (Table 46) showed that D. superstitiosus recorded from cotton planted as sole crop and cotton interplanted with okra were significantly ($P < 0.05$) higher than numbers counted from cotton interplanted with the other crop combinations. There was no significant difference ($P = 0.05$) between cotton stainers recorded from cotton sown as 100% crop population/plot (i.e. cotton as sole crop) and cotton planted with okra. Similarly, no differences were observed in cotton stainer numbers found cotton interplanted with either maize, tomato or in the four crop mixtures (Table 46).

The low numbers of stainers found on cotton interplanted with maize, okra and tomato or cotton with okra or maize, suggest that these crops could be interplanted with cotton as crop combination as against cotton sole cropping, in order to reduce stainer incidence on

cotton crop. The high stainer population on cotton mixed with okra was probably because this combination of host plant was exerting a great attractive effect from the second half of October, a period which coincided with the peak boll formation and early opening of the first formed bolls. Okra had also matured and the adult stainers could feed on their seeds while the young nymphs took shelter within the loculi of the ripe fruits. A cotton/ okra mixture was therefore behaving like a pure cotton stand. In maize, the adults and nymphs of D. superstitiosus were attracted to the early formed tassels which they sucked as nutrients; but this did not coincide with the period of maximum attractiveness of cotton.

Examinations of the green bolls for amount of staining were not carried out, hence the damage effect due to the fungus Nematospora was not assessed.

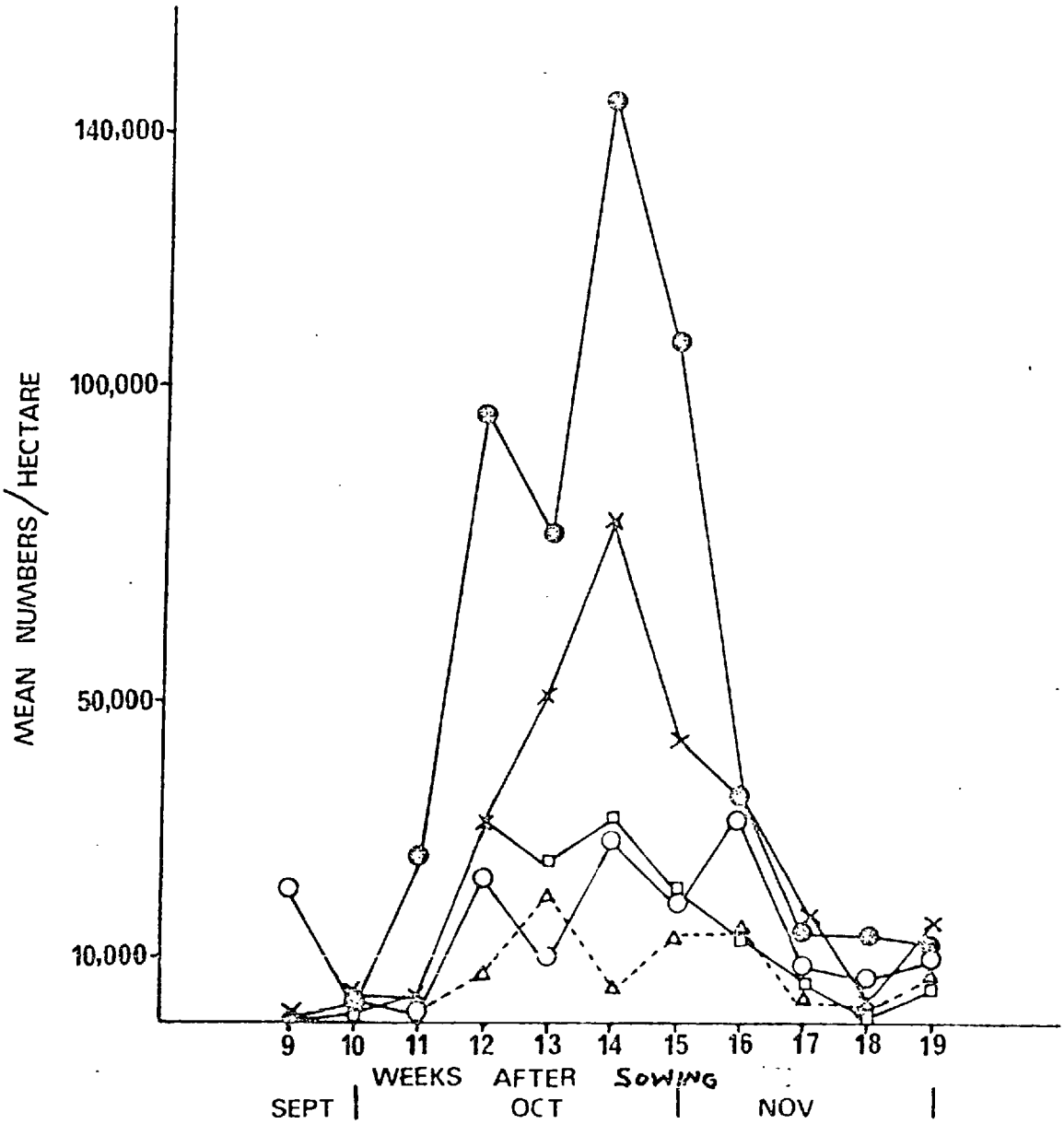


FIG. 32. MEAN NUMBER OF COTTON STAINERS (D. Superstitiosis) PER HECTARE IN A MIXED CROPPING SYSTEM 1972-73 SEASON

⊙—⊙	Cotton alone	(100% Cotton Crop Population Plot)
○—○	Cotton and Maize	(50% " " " ")
×—×	Cotton and Okra	(50% " " " ")
□—□	Cotton and Tomato	(50% " " " ")
△---△	Cotton, Maize, Okra and Tomato	(25% " " " ")

TABLE 46. POPULATION OF COTTON STAINER (D. SUPERSTITIOSUS) IN MIXED CROPPING SYSTEM 1972-73 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		33.9**	3400	47,200
50	COTTON + MAIZE	COTTON	21.1*	1100	15,300
		MAIZE	14.6	730	10,100
50	COTTON + OKRA	COTTON	35.6**	1800	25,000
		OKRA	29.8	1500	20,800
50	COTTON + TOMATO	COTTON	18.3*	900	12,500
		TOMATO	4.7	230	3,200
25	COTTON + MAIZE + OKRA + TOMATO	COTTON	19.8*	480	6,670
		MAIZE	9	200	2,780
		OKRA	12.4	300	4,170
		TOMATO	2.9	70	970

** Means are not significantly different at P = 0.05

* Means are not significantly different at P = 0.05, but are significantly different from **

(iii) Effects on flea beetle (Podagrica spp.)

Flea beetles were the earliest pests to arrive on the crops. The population trends are shown in Fig. 33 . The highest peak number per plant was observed on cotton planted as a sole crop (Fig. 33), followed by cotton interplanted with maize. Numbers of flea beetle in both treatments increased in a similar pattern, although numbers decreased more on cotton planted with maize after week 11.

The analysis of variance of the mean flea beetle per cotton plant showed that all the treatments were significantly different at P = 0.05 (Table 47). Cotton planted as 100% crop population or as crop combination except with tomato recorded mean numbers of flea beetle significantly higher ($P < 0.05$) than the numbers found on cotton mixed with tomato.

In the mixtures, the highest mean numbers per cotton plant/hectare was again on cotton planted as sole crop. This was followed by those on cotton in the cotton-maize combination (Fig. 33). These results indicate that tomatoes give very notable protection to cotton against flea beetle attacks.

Evidence from Table 47 shows that okra carried the most flea beetle per plant and this therefore, suggests okra as the most favoured host for flea beetles.

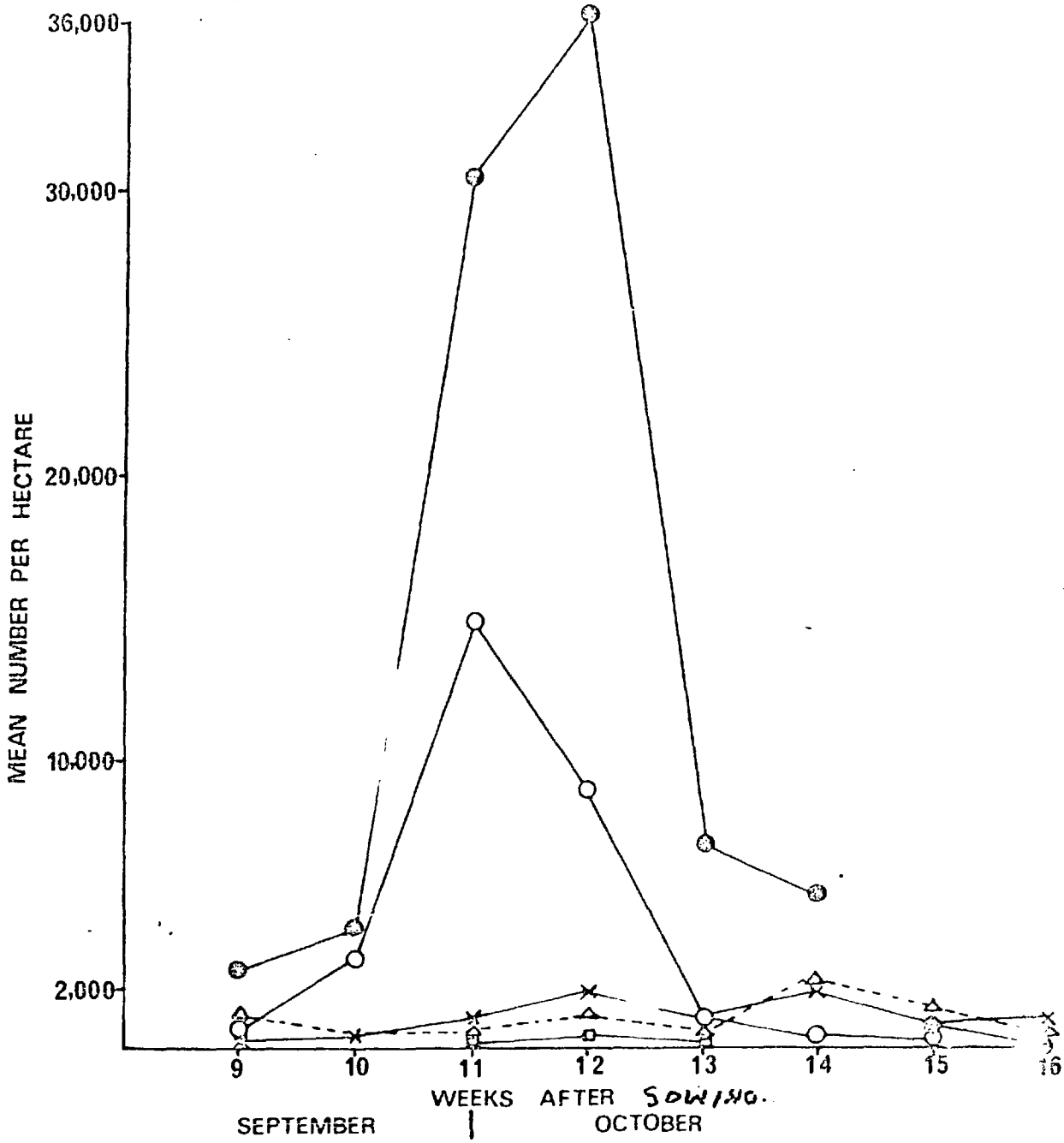


FIG. 33. MEAN FLEA BEETLE PER HECTARE IN A MIXED CROPPING SYSTEM. 1972 - 73 SEASON.

○—○	Cotton alone	(100% Cotton Crop Population/Plot)
○—○	Cotton and Maize	(50% " " " ")
×—×	Cotton and Okra	(50% " " " ")
□—□	Cotton and Tomato	(50% " " " ")
△---△	Cotton, Maize, Okra, Tomato	(25% " " ")

TABLE 47. POPULATIONS OF FLEA BEETLE IN MIXED CROPPING SYSTEM 1972-73 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Flea Beetle/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		78.6***	7860	11228
50	COTTON + MAIZE	COTTON	52.5***	2625	37500
		MAIZE	3.3	165	2357
50	COTTON + OKRA	COTTON	15.6**	780	11142
		OKRA	344.6	17230	246142
50	COTTON + TOMATO	COTTON	0.50*	25	357
		TOMATO	1.6	80	1142
25	COTTON + MAIZE + OKRA + TOMATO	COTTON	25 **	625	8928
		MAIZE	0.75	19	271
		OKRA	106.5	2700	38571
		TOMATO	5.3	133	1900

*** Means are not significantly different at P = 0.05

** Means are not significantly different at P = 0.05, but significantly different from *** and *

(iv) Effects of mixed cropping on predators

Figure 34 represents the predator numbers in the plots. All tended to fluctuate from the beginning of sampling and this resulted in many 'Peaks'. This fluctuation is perhaps associated with movement of the natural enemies from one plant species to another in search of prey.

Analysis of variance showed that the mean numbers of P. ferruginea larvae recorded from cotton interplanted with either tomato, okra or into the four crop mixtures were significantly higher ($P < 0.05$) than those found on cotton interplanted with maize or with cotton as sole crop (Table 48). However, on per hectare basis numbers of P. ferruginea taken from cotton planted as monoculture, and from the mixtures of cotton with either okra, tomato and maize were not significantly different ($P = 0.05$), but these were significantly higher ($P < 0.05$) than those sampled from cotton in the four crop mixtures (Table 48). The highest mean number of P. ferruginea per cotton plant and hence per hectare found cotton/tomato mixtures indicates tomato crop as possible attractant of natural enemies. Similarly okra and maize could act as attractants for P. ferruginea because cotton intercropped with either maize or okra, carried proportionately higher numbers of this predator. However, as associated crops, few predators were recorded on tomato, okra and maize. Yet, the high peak numbers of P. ferruginea recorded on cotton interplanted with either okra or tomato are

probably influenced by the presence of these other associated crops (Fig. 34).

The mean numbers/cotton plant of Chilomenes lunata showed significant differences at P = 0.05. Mean numbers of C. lunata recorded from cotton as sole crop, cotton interplanted with okra or tomato gave significantly ($P < 0.05$) higher numbers than those found on cotton planted with maize or in the four crop mixtures (Table 49). There was no significant difference (P = 0.05) between C. lunata numbers found on cotton planted as 100% crop population and cotton interplanted with okra (Table 49). Similarly, there were no differences between cotton/maize treatment and the four crop mixtures (cotton/maize/okra/tomato). Cotton/maize and the four crop mixtures seemingly carried low C. lunata numbers on cotton (Fig. 34).

Spiders were not identified but most of them were Lycosa spp. associated with bottom leaves of the plant. They were far more abundant on the crops than the other predators samp l. High numbers of spiders were recorded per cotton plants and these were very significantly (P = 0.01) more than on other associated crops (Table 50). The spider numbers per cotton planted as 100% population/plot and per cotton interplanted with tomato, maize and okra were not significantly different (P = 0.05) though significantly higher ($P < 0.05$) than those on cotton in the four crop mixtures (Table 50). In general, the other crops, maize, okra and tomato,

especially tomatoes seemed to be attracting some of these natural enemies but less than did cotton (Table 50).

The rise in population numbers of these natural enemies during week 14 after crop germination (Fig. 34) was possibly responsible for the drastic fall in bollworm numbers at the same period (Fig. 34). Conversely, the drop in predator numbers at weeks 16 and 19 might have permitted rise in bollworm numbers at the same time in the plots.

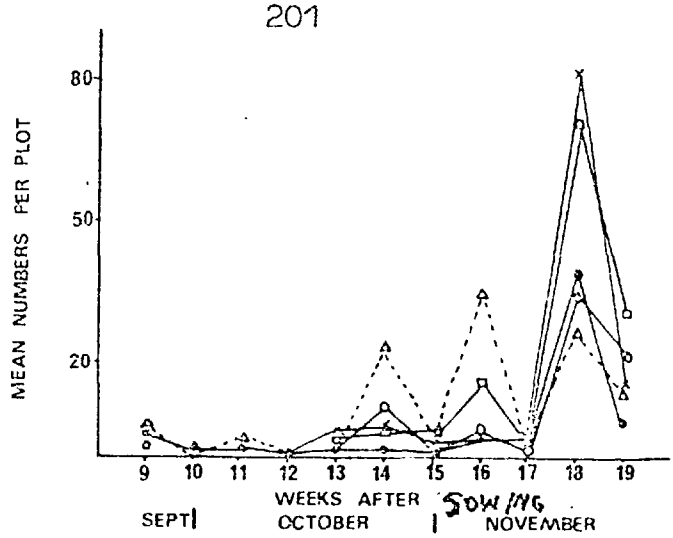


FIG MEAN NUMBERS OF P FERRUGINEA ON COTTON IN A MIXED CROPPING SYSTEM 1972-73 SEASON

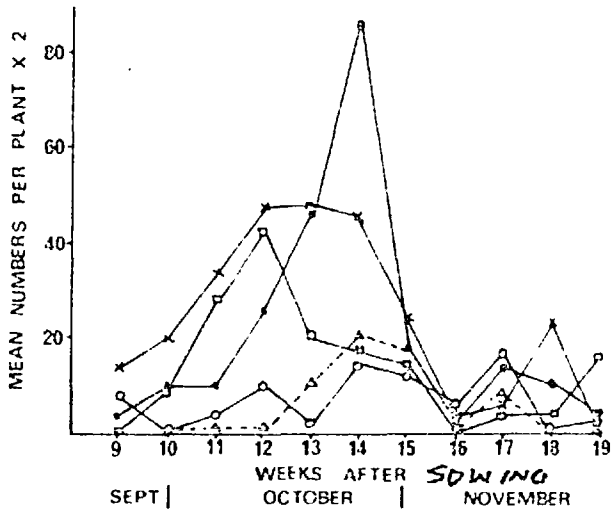


FIG MEAN NUMBERS OF C. LUNATA ON COTTON IN A MIXED CROPPING SYSTEM 1972-73 SEASON

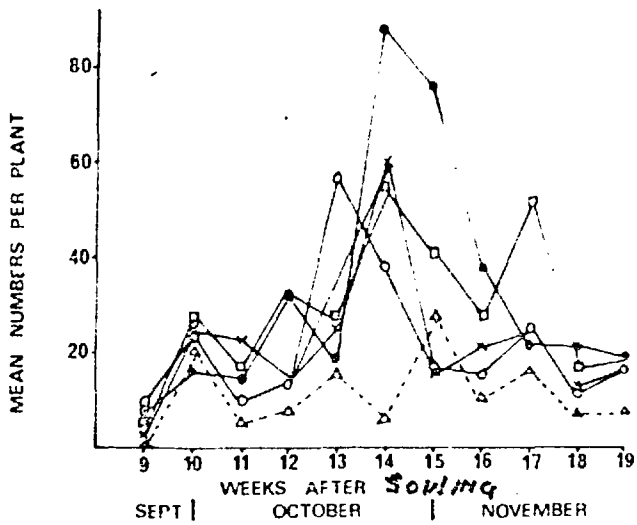


FIG 34. MEAN NUMBERS OF SPIDER ON COTTON IN A MIXED CROPPING SYSTEM 1972-73 SEASON

Cotton alone	(100% Cotton Crop Population/Plot)
" and Maize	(50% " " " ")
" and Okra	(50% " " " ")
" and Tomato	(50% " " " ")
" , Maize, Okra & Tomato	(25% " " " ")

TABLE 48 . POPULATIONS OF THE LADYBIRD BEETLE (P. FERRUGINEA) IN MIXED CROPPING SYSTEMS 1972-73 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		6 *	600	8570
50	COTTON + MAIZE	COTTON	7.2 *	360	5120
		MAIZE	0.09	4.5	64
50	COTTON + OKRA	COTTON	11.3 **	560	8050
		OKRA	0.73	36	521
50	COTTON + TOMATO	COTTON	12.3 **	610	8760
		TOMATO	0.45	23	
25	COTTON + MAIZE + OKRA + TOMATO	COTTON	10.1 **	250	3600
		MAIZE	0.18	4.5	64
		OKRA	0.82	21	293
		TOMATO	0	0	0

** Means are not significantly different at P = 0.05

* Means are not significantly different at P = 0.05, but are significantly different from **

TABLE 49. POPULATIONS OF THE LADYBIRD BEETLE (C. LUNATA) IN MIXED CROPPING SYSTEMS 1972-73 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. adults larvae/plant/sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		10.5 ***	1045	14929
50	COTTON + MAIZE	COTTON	3.4 *	168	2400
		MAIZE	0.64	32	457
50	COTTON + OKRA	COTTON	12.1 ***	605	8635
		OKRA	1.6	78	1100
50	COTTON + TOMATO	COTTON	7.1 **	355	5060
		TOMATO	0.45	23	321
25	COTTON + MAIZE + OKRA + TOMATO	COTTON	2.7 *	68	975
		MAIZE	0.64	16	228
		OKRA	0.36	9	128
		TOMATO	0.73	18	261

*** Means are not significantly different at P = 0.05

** Means are not significantly different at P = 0.05, but significantly different from *** and *

TABLE 50. POPULATIONS OF SPIDERS IN MIXED CROPPING SYSTEMS 1972-73 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		32.3 **	3227	46100
50	COTTON + MAIZE	COTTON	21.7 **	1086	15520
		MAIZE	5	250	3571
50	COTTON + OKRA	COTTON	21.8 **	1090	15580
		OKRA	4.4	218	3114
50	COTTON + TOMATO	COTTON	28.3 **	1400	20190
		TOMATO	7.1	355	5064
25	COTTON + MAIZE + OKRA + TOMATO	COTTON	11.6 *	289	4125
		MAIZE	0.55	14	190
		OKRA	2.6	66	942
		TOMATO	9.6	240	3442

** Means are not significantly different at P = 0.05

* Means are significantly different from **

(B) Mixed cropping 1973-74 season

(i) Effects on pink bollworm (P. gossypiella)

Cotton planted as sole crop and cotton inter-planted with maize as well as in the four crop mixture had a higher pink bollworm infestation than cotton planted either with okra or tomato (Table 51). After the 11th week of germination, (Fig. 35), the P. gossypiella numbers increased significantly in cotton planted as mono-culture and this increase came up distinctly in cotton/ okra mixture from week 14 (Fig. 35), both periods thus coinciding with boll formation; and this increase was fairly constantly maintained through the remaining sampling period. The high numbers of P. gossypiella recorded on okra per se (Table 51) indicate this crop as a host to pink bollworm which could act as reservoir from whence P. gossypiella can migrate to infest cotton plants.

Analysis of variance of the mean numbers of P. gossypiella per cotton showed significance between treat-ments. Cotton planted as sole crop recorded mean numbers significantly ($P < 0.05$) higher than numbers on cotton in the other treatments. Similarly, mean numbers P. gossypiella on cotton in the cotton/maize, cotton, cotton/ okra and on cotton planted as 25% crop population per plot were significantly ($P < 0.05$) higher than those taken from cotton in cotton/tomato treatment (Table 51). Thus from the results (Table 51) it is possible to interplant cotton with tomato which seemingly had some repellent effects as in the 1972-73 season.

TABLE 51. POPULATION OF PINK BOLLWORM (P. GOSSYPIELLA) IN COTTON MIXED CROPPING SYSTEM 1973-74 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		0.35***	35	500
50	COTTON + MAIZE	COTTON	0.13**	6.3	90
		MAIZE	00	00	0
50	COTTON + OKRA	COTTON	0.08**	4	57
		OKRA	0.15	8	114
50	COTTON + TOMATO	COTTON	0.03*	1.3	18
		TOMATO	00	00	0
25	COTTON + MAIZE + OKRA + TOMATO	COTTON	0.13**	3.1	44
		MAIZE	00	00	0
		OKRA	00	00	0
		TOMATO	00	00	0

*** Means are significantly different from ** and *

** Means are not significantly different at P = 0.05 but are significantly different from *

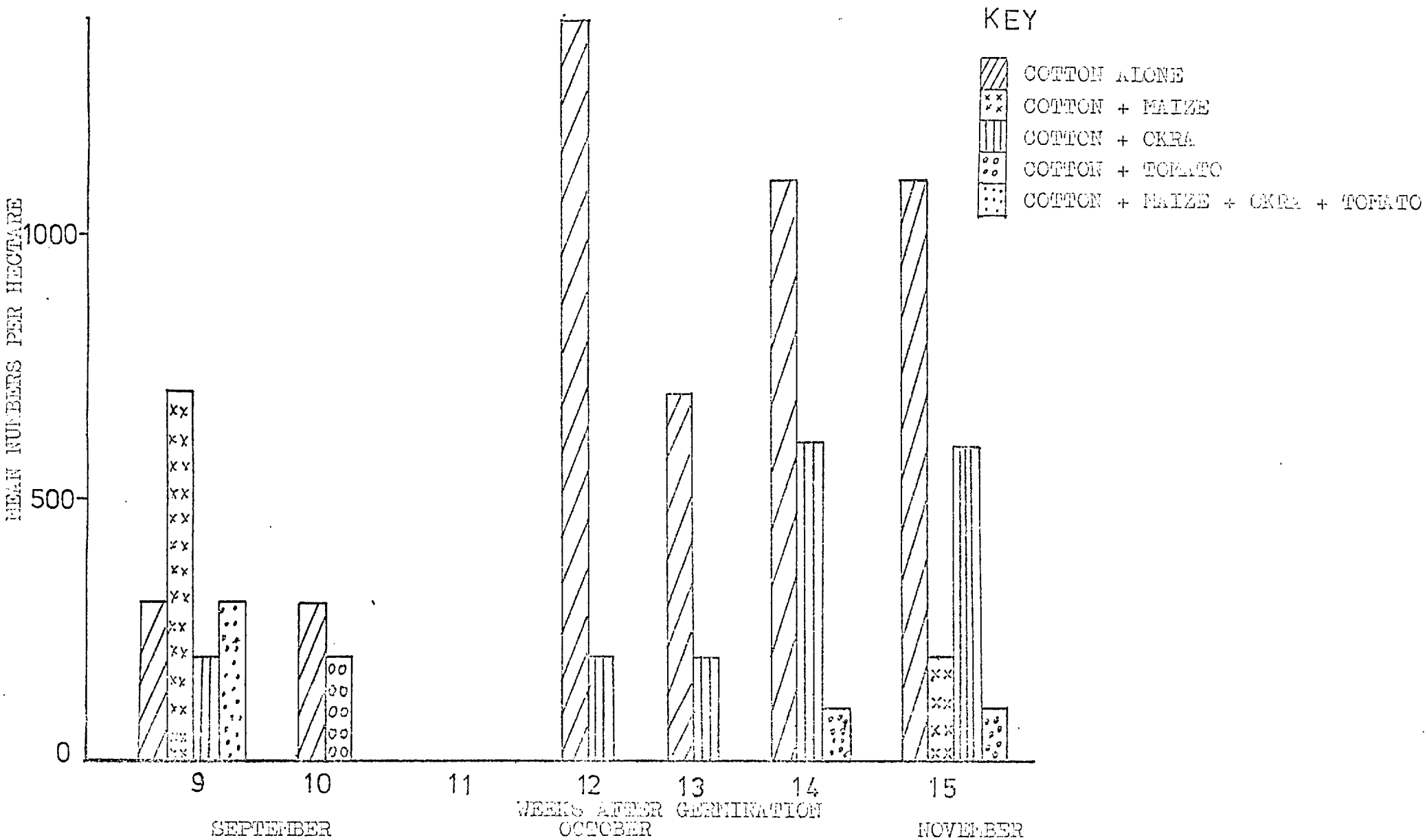


Fig. 35. MEAN NUMBER OF (P. gossypiella) IN COTTON PER HECTARE IN MIXED CROPPING SYSTEMS 1973-74 SEASC

(ii) Effects on spiny bollworm (E. biplaga)

As with P. gossypiella larvae, numbers of E. biplaga larvae recorded per cotton plant was significantly affected by treatment. Numbers of E. biplaga were generally higher than those of P. gossypiella (Table 52).

The mean numbers of E. biplaga sampled from cotton planted as sole crop were significantly (P 0.05) higher than those from the other treatments. Numbers of E. biplaga taken from cotton in cotton/maize, cotton/okra and cotton/tomato were not different (P = 0.05) but were significantly more than those from cotton in the four crop mixture (Table 52).

Except in week 9 (Fig. 36) when Earias infestation was high in cotton/maize and cotton/okra mixtures, throughout the season the highest E. biplaga numbers and hence the greatest infestation was generally observed from cotton planted solely (Fig. 36). Unlike the P. gossypiella whose presence in cotton was most noticeable from the second-half of October, E. biplaga numbers were fairly evenly distributed throughout the season (Fig. 36).

TABLE 52. POPULATION OF SPINY BOLLWORM (E. BIPLAGA) IN A MIXED CROPPING SYSTEM 1973-74 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		0.38***	38	542
50	COTTON + MAIZE	COTTON	0.18**	9	128
		MAIZE	00	00	0
50	COTTON + OKRA	COTTON	0.15**	8	114
		OKRA	0.03	1.3	18
50	COTTON + TOMATO	COTTON	0.10**	5	71
		TOMATO	00	00	C
25	COTTON + MAIZE + OKRA + TOMATO	COTTON	0.05*	1.3	18
		MAIZE	00	00	0
		OKRA	00	00	0
		TOMATO	00	00	0

*** Means are significantly different from ** and *

** Means are not significantly different at P = 0.05, but are significantly different from *

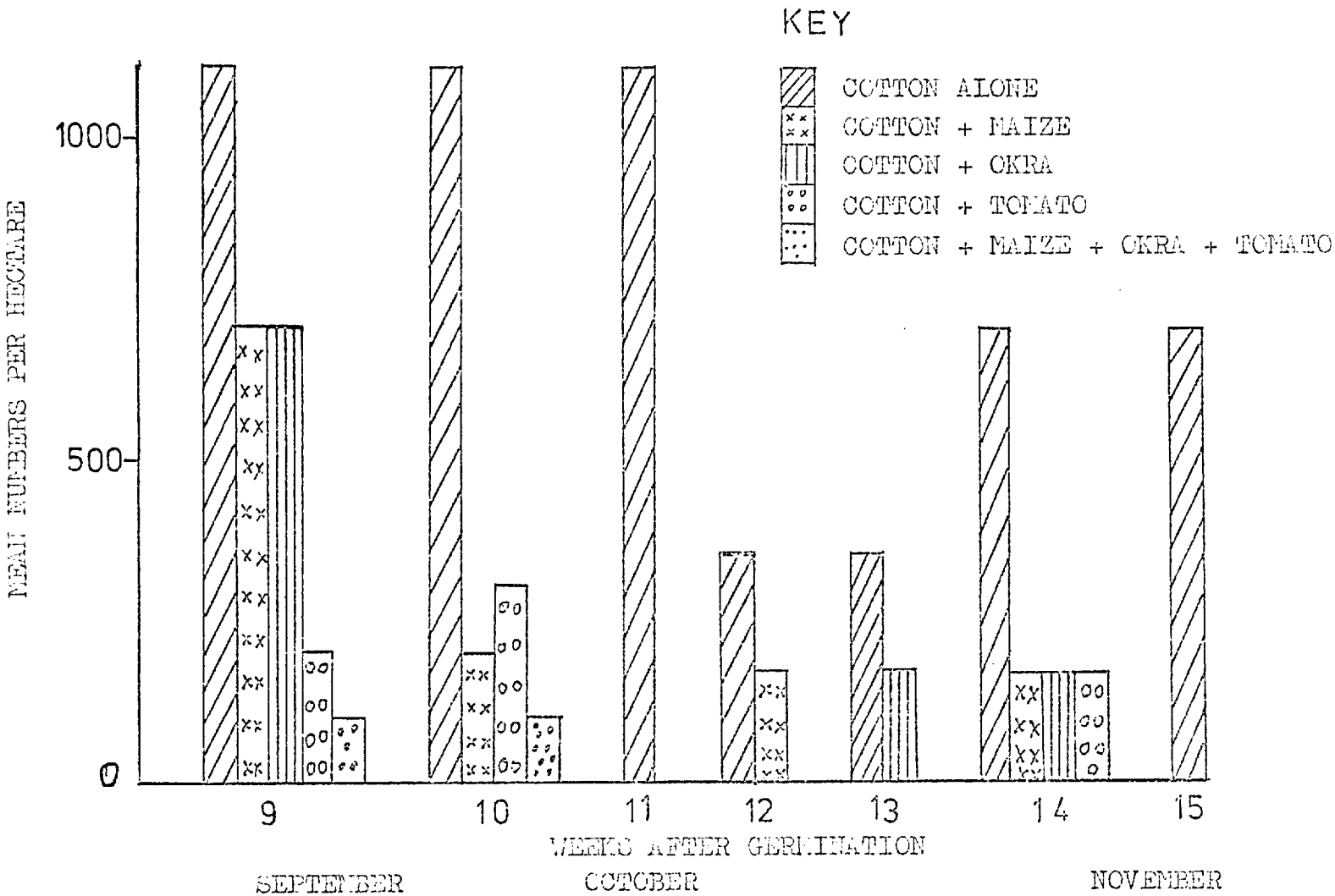


Fig. 36. MEAN NUMBERS OF SPINY BOLLWORM (E. biplaga) ON COTTON PER HECTARE IN MIXED CROPPING SYSTEMS. 1973-74 SEASON

(iii) Effects on cotton stainers (D. superstitiosus)

The mean numbers of cotton stainers/cotton planted with okra were significantly higher ($P < 0.05$) than numbers on cotton in the other crop combinations except cotton planted as sole crop (i.e. 100% crop population/plot), (Table 53). There was no difference in stainer numbers in the cotton/maize and cotton/tomato combinations (Table 53).

Against the mean stainer numbers/cotton plant found on cotton interplanted with cotton, the greatest stainer infestation per plot and hence per hectare was found from cotton sown as 100% crop population per plot (i.e. as sole crop); this was followed by infestation observed on cotton interplanted with okra (Table 53). The level of cotton stainer infestation per plant and per plot in the cotton/okra treatment (Table 53 , Fig. 37) was at least significently ($P < 0.05$) double the infestation numbers on cotton in the mixtures of cotton/maize or cotton/tomato. This high number of stainers on cotton in the cotton/okra treatment as in 1972-73 indicates that okra is not serving as a diversionary crop but as an attractant equivalent to that of cotton alone.

Figure 37 shows that maize and tomato crops carried some D. superstitiosus. The high cotton stainer numbers found on the crops began to build up from week 12 (Fig. 37) and this coincided with boll formation in cotton and maturation of okra which are then being harvested.

TABLE 53. POPULATION OF COTTON STAINERS (D. SUPERSTITIOSUS) IN A MIXED CROPPING SYSTEM

1973-74 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. nymphs and adults/plant/sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		7.4 **	738	10542
50	COTTON + MAIZE	COTTON	4.6 *	230	3285
		MAIZE	3.1	154	2200
50	COTTON + OKRA	COTTON	9.50**	474	6771
		OKRA	6.20	310	4428
50	COTTON + TOMATO	COTTON	4.1 *	204	2914
		TOMATO	1.2	62	885
25	COTTON + MAIZE + OKRA + TOMATO	COTTON	3.5 *	88	1257
		MAIZE	2.5	63	900
		OKRA	3.4	85	1214
		TOMATO	0.80	19	271

** Means are not significantly different

* Means are not significantly different at P = 0.05, but are significantly different from **

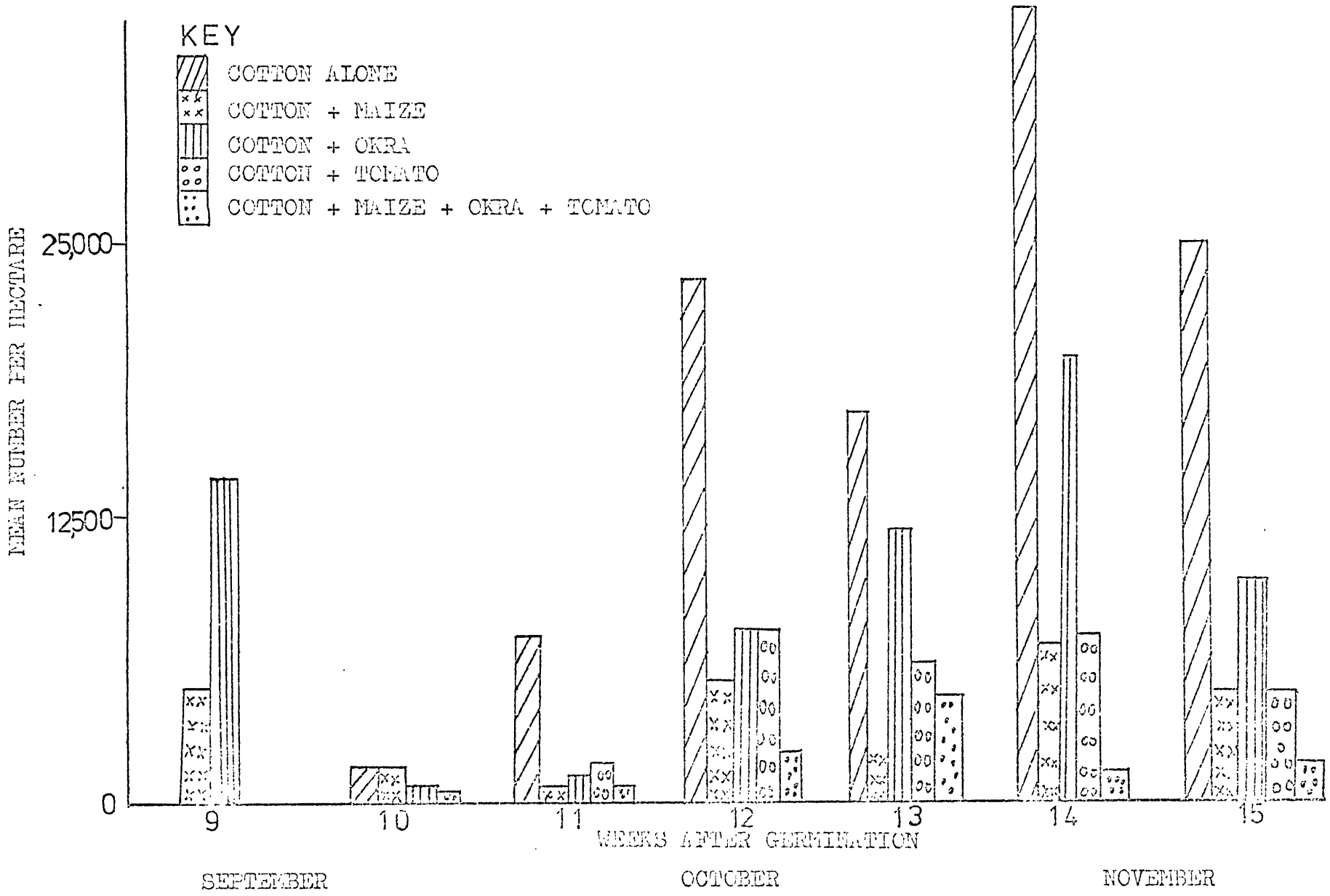


Fig.27 MEAN NUMBERS OF P. superbidiensis IN A MIXED CROPPING SYSTEM, 1973-74 SEASON

(iv) Effects on flea beetles (Podagrica spp.)

As in 1972-73 flea beetle infestation was highest on okra and on cotton interplanted with okra (Table 54 , Fig. 38). The mean numbers of flea beetle counted on cotton interplanted with okra was significantly greater ($P < 0.05$) than numbers recorded from cotton planted either as sole crop or in combination with either of the associated crops (maize or tomato) (Table 54). Flea beetle numbers recorded on cotton planted as monoculture and in cotton/maize and cotton in the three crop mixture were not different ($P = 0.05$), but were significantly higher ($P < 0.05$) than numbers taken from cotton in cotton/tomato mixture (Table 54).

The high population of flea beetle (Table 54) on okra indicates that this pest had a greater preference for okra than cotton and the other associated crops on the mixtures (Table 54 , Fig. 38).

It has been suggested Pearson (1958) that if alternative hosts of flea beetles were well grown by the time the cotton germinated, they tended to act as traps. Thus if this tendency of flea beetle to develop on other host crops is exploited, by establishing okra crops before cotton germinated; then the former can be used to trap or divert flea beetles away from cotton. In addition, okra plants remain longer on the ground producing fresh food to support pests; and thus by this provision pests (flea beetles) are prevented from migrating to infest cotton crops.

TABLE 54. POPULATION OF FLEA BEETLE (PODAGRICA SPECIES) IN A MIXED CROPPING SYSTEM 1973-74 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. adults/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		.250**	25	3571
50	COTTON + MAIZE	COTTON	.375**	18.8	2685
		MAIZE	.675	33.8	4828
50	COTTON + OKRA	COTTON	2.68 ***	133.8	19142
		OKRA	69.15	3452.3	493142
50	COTTON + TOMATO	COTTON	0.10 *	5	714
		TOMATO	0.43	21.5	3142
25	COTTON + MAIZE + OKRA + TOMATO	COTTON	0.250**	6.3	857
		MAIZE	0.12	3.1	428
		OKRA	20.51	512.8	73142
		TOMATO	1.03	25.7	3714

** Means are not significantly different at P = 0.05, but are significantly different from *** and *

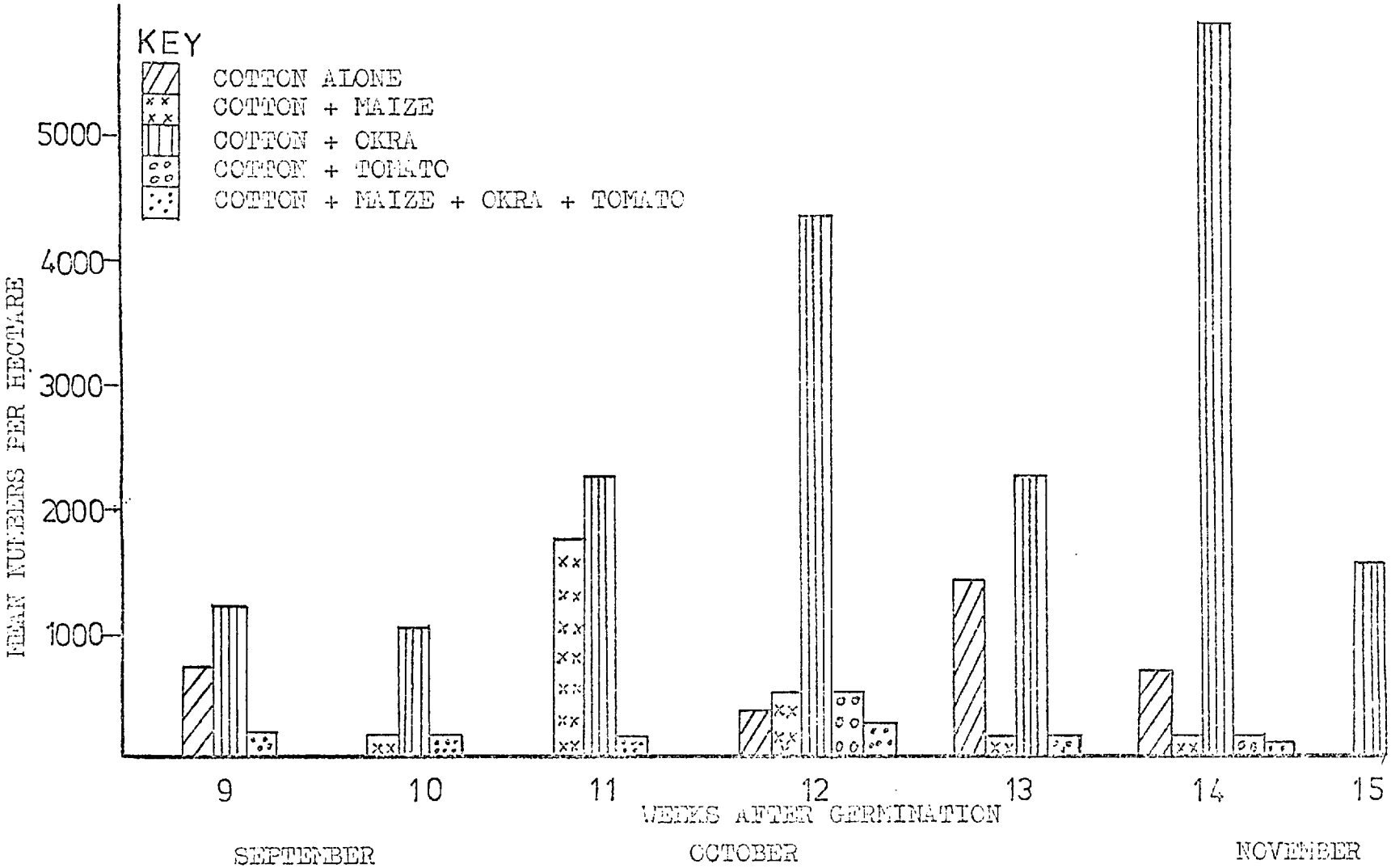


Fig. 38. MEAN NUMBERS OF FLEA BEETLES (Podagrica spp) IN COTTON PLANT/HECTARE IN MIXED CROPPING SYSTEMS. 1973-74 SEASON.

(v) Effects of mixed cropping on predators

Spiders and the coccinellids Chilomenes lunata (adults and larvae), and Platynaspis ferruginea (mainly larvae) were the common predators sampled during the season, and their numbers are represented in Tables 55, 56 & 57. Spiders and C. lunata were more numerous than P. ferruginea.

With the exception of P. ferruginea, the mean numbers of predators counted on cotton planted as 100% crop population per plot were significantly higher ($P < 0.05$) than numbers taken from cotton planted in crop combinations (Tables 55).). Spider numbers per cotton planted as sole crop were significantly greater ($P < 0.05$) than numbers sampled from cotton planted as 25% crop population per plot (Table 57), but were not different from the other crop mixtures. Similarly, C. lunata numbers/ cotton planted as sole crop (i.e. 100% crop population/ plot) and per cotton interplanted with okra or tomato (i.e. as 50% cotton population/plot) were not different ($P = 0.05$) but were significantly higher ($P < 0.05$) than those recorded from cotton interplanted with maize and in the three crop mixtures (i.e. 25% cotton population/plot) (Table 56).

In general, with the exception of P. ferruginea, C. lunata and especially spider numbers recorded per cotton planted as 50% crop population/plot (Figs. 39 - 41) significantly ($P < 0.05$) doubled the numbers sampled from cotton sown as 25% crop population/plot. This indicates

that a combination of cotton crop with more than one associated crop mixtures reduces predator populations on cotton and thus enhances pest development. Just as in the 1972-73 trial and except for the P. ferruginea, the predator populations recovered were high on cotton sown as sole crop and in the combinations of cotton with either okra, tomato or maize. However, more predator numbers were sampled during the 1972-73 season than in the 1973-74 trials.

TABLE 55 . POPULATION OF LADYBIRD (P. FERRUGINEA) IN A MIXED CROPPING SYSTEM 1973-74 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. P. ferruginea/plant/sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		0.050*	5.8	83
50	COTTON + MAIZE	COTTON	0.08 *	4	57
		MAIZE	0.018	0.9	12
50	COTTON + OKRA	COTTON	0.08 *	3.8	54
		OKRA	0.041	2.1	30
50	COTTON + TOMATO	COTTON	0.10 *	5.0	71
		TOMATO	0.022	1.1	15
25	COTTON + MAIZE + OKRA + TOMATO	COTTON	0.19 *	4.6	65
		MAIZE	0.014	0.4	5
		OKRA	0.017	0.4	6
		TOMATO	0.018	0.5	6

* Means are not significantly different at P = 0.05

TABLE 56. POPULATION OF LADYBIRD BEETLE (C. LUNATA) IN A MIXED CROPPING SYSTEM 1973-74 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. C. lunata/plant/sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		0.50 **	49.8	7,11
50	COTTON + MAIZE	COTTON	0.12 *	6	85
		MAIZE	0.044	2.2	31
50	COTTON + OKRA	COTTON	0.60 **	29.3	4,18
		OKRA	0.087	4.4	62
50	COTTON + TOMATO	COTTON	0.40 **	18.3	2,61
		TOMATO	0.033	1.7	24
25	COTTON + MAIZE + OKRA + TOMATO	COTTON	0.130*	3.3	47
		MAIZE	0.015	.40	5
		OKRA	0.057	1.4	20
		TOMATO	0.030	0.8	10

** Means are not significantly different at P = 0.05 but are significantly different from *

TABLE 57 . POPULATION OF SPIDERS IN A MIXED CROPPING SYSTEM 1973-74 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. spider/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		1.170**	117	1671
50	COTTON + MAIZE	COTTON	0.900**	44	628
		MAIZE	0.268	13.4	185
50	COTTON + OKRA	COTTON	0.840**	41.8	600
		OKRA	0.251	12.6	185
50	COTTON + TOMATO	COTTON	1.0 **	49.8	711
		TOMATO	0.397	19.9	284
25	COTTON + MAIZE + OKRA + TOMATO	COTTON	0.48 *	11.9	170
		MAIZE	0.219	5.5	78
		OKRA	0.202	5.1	72
		TOMATO	0.280	7	100

** Means are not significantly different at P = 0.05, but are significantly different from *

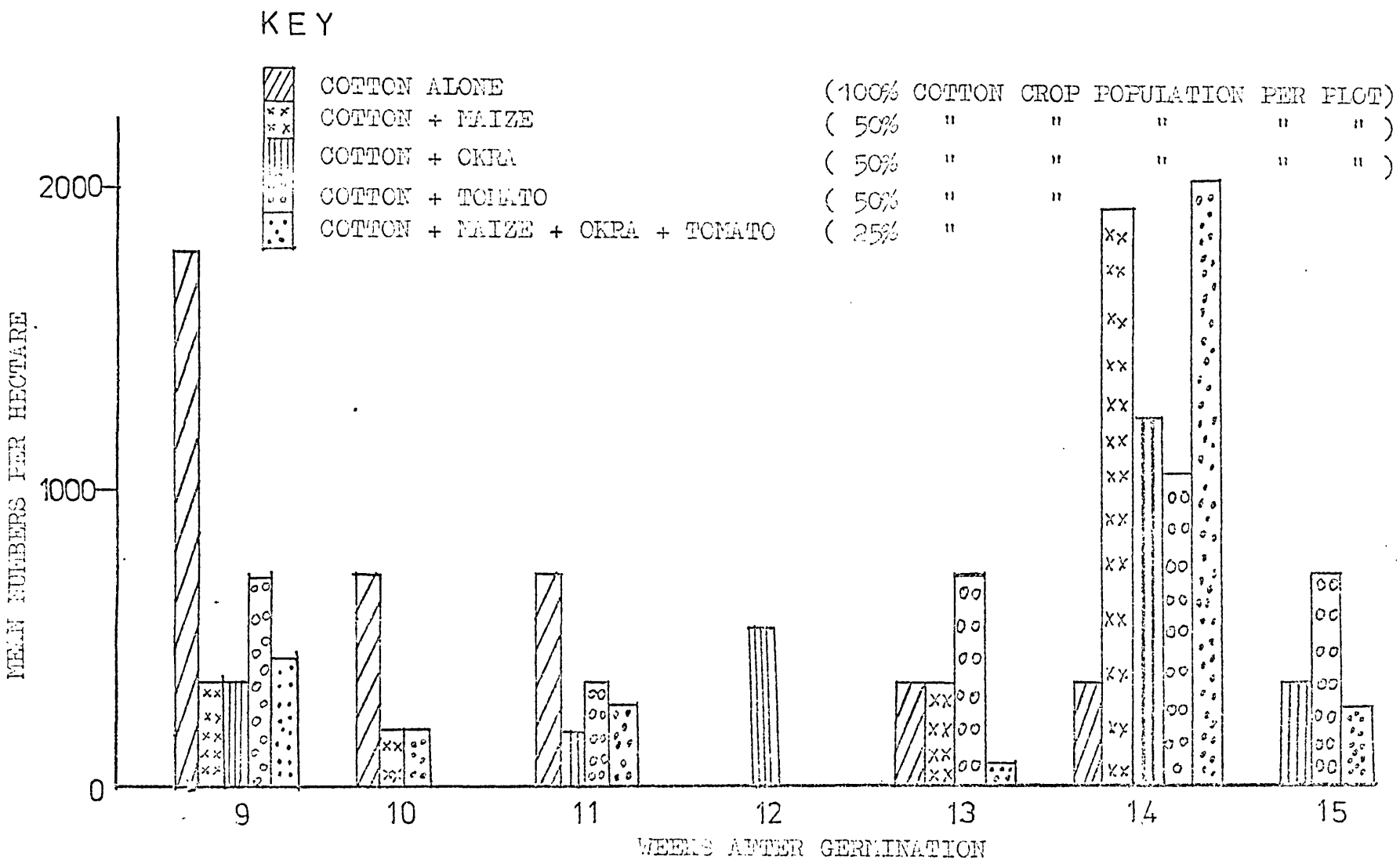


Fig.39. MEAN NUMBERS OF Platymaspis fernuginea IN COTTON PER HECTARE IN COTTON MIXED CROPPING SYSTEMS. 1973-74 SEASON.

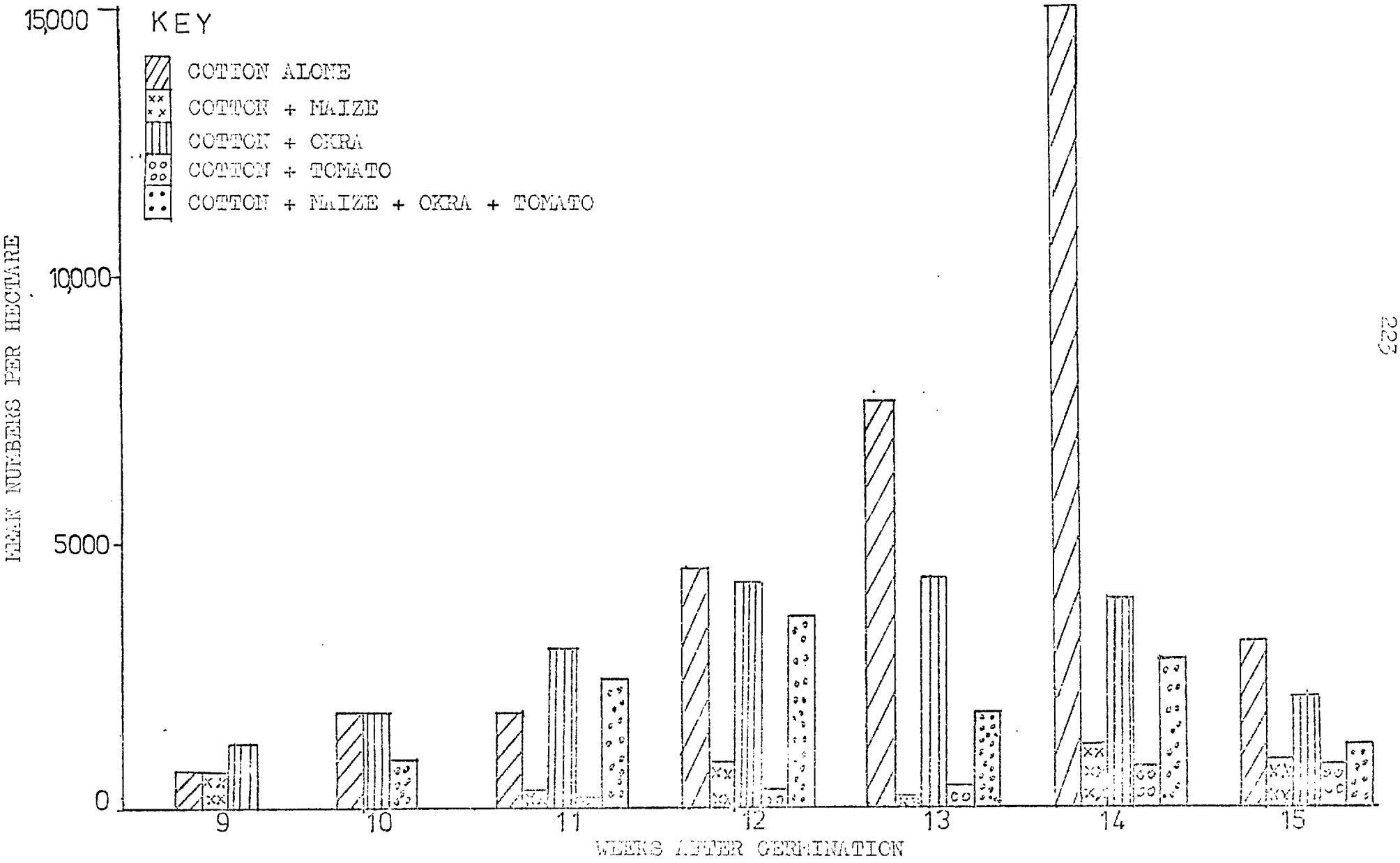


Fig 40 MEAN NUMBERS OF C. lunata PER COTTON/HECTARE IN MIXED CROPPING SYSTEMS - 1975-76 SEASON

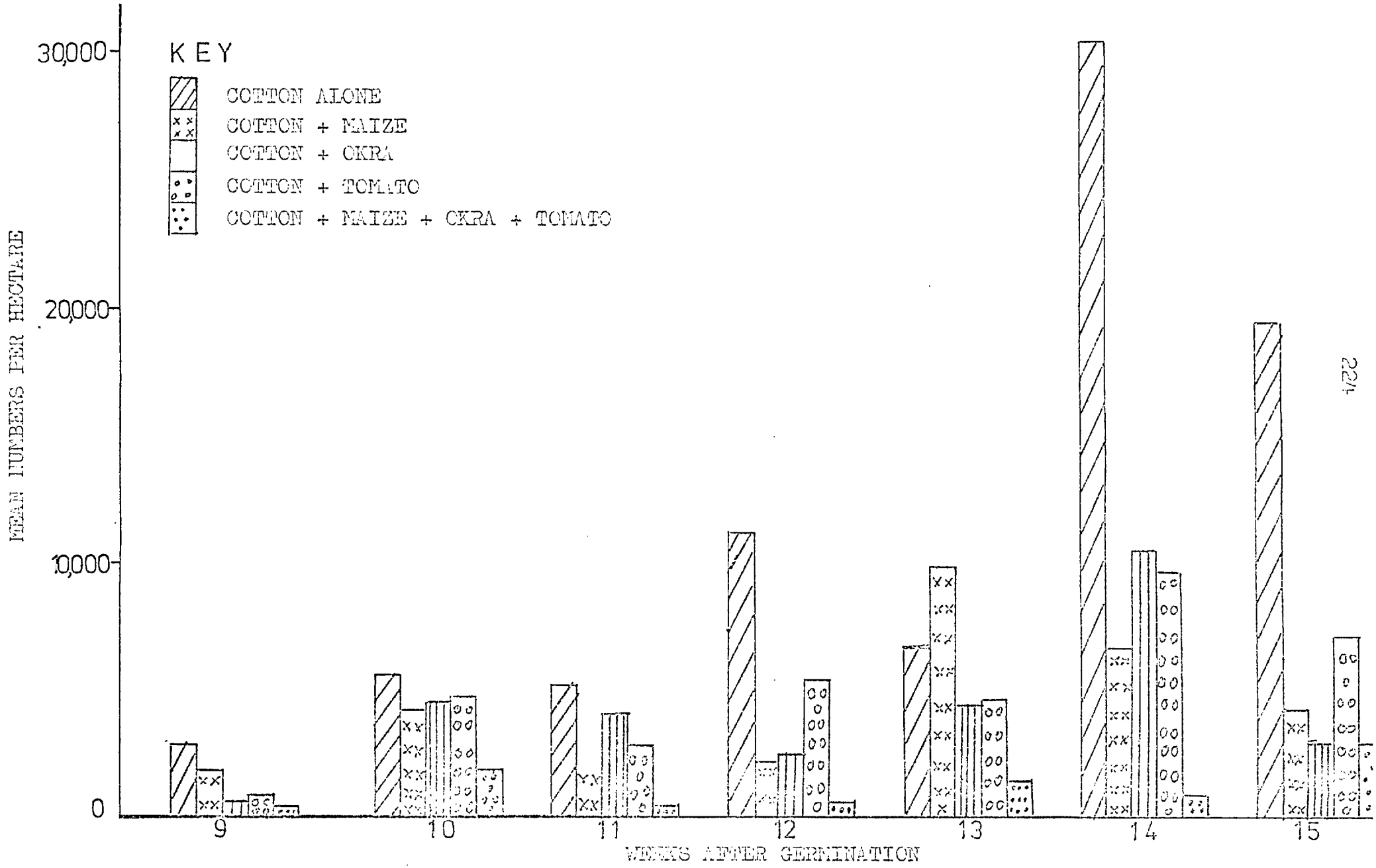


Fig 41 MEAN NUMBERS OF SPIDER PER HECTARE IN A MIXED CROPPING SYSTEM. 1973-74 SEASON

(vi) Effects of mixed cropping on yields

Yield data are tabulated in Table 58. From cotton cultivated as 100% crop population/plot, yield was not high but comparable to typical yields from unsprayed crops. However, cotton yields were significantly greater ($P < 0.01$) than yields obtained from the other treatments (Table 58). Yields obtained from cotton intercropped with either okra or tomato were significantly higher ($P < 0.05$) than yields taken from cotton/maize and cotton interplanted with the three crops mixture. Only in one mixture, the cotton/okra combination were yields of seed cotton more than half the yields derived from cotton sown as sole crop (Table 58). The significantly lower yields of seed cotton obtained from cotton/maize and cotton/ tomato treatments were perhaps due to the fact that maize overshadowed cotton and possibly tomato plants grew more rapidly and also shaded the cotton crops. However, a satisfactorily high yields of the associated crops were realised from the treatments where cotton was intersown with okra and tomato (i.e. as 50% crop population/plot). Table 58 further showed that the yields from the component crops were good, and the maize yield was as good in the four crops mixture as in the 50:50 cotton/maize mixture.

The values obtained from cotton crop reflected differences in the treatments. In terms of Naira, cotton planted as sole crop significantly out-weighted the values obtained from cotton interplanted in the other treatments (Table 58). The value of cotton interplanted with okra

was about half and that from cotton/tomato mixtures less than half the value obtained from cotton sown as sole crop. Although high populations of insect pests developed on the four crop and six crop mixtures, the total values of crops per hectare from these treatments (Table 58) , were comparable to the highest values obtained tomato/cotton combination and were also higher than the values realised from the other treatments. The high yields/values obtained from the combination of cotton and tomato also suggest this latter combination is promising.

TABLE 58. MEAN YIELDS IN Kg/Ha OF CROPS HARVESTED FROM MIXED CROPPING SYSTEMS 1973-74 SEASON

CROP COMBINATIONS		YIELDS IN Kg/Ha	VALUE OF CROPS IN (N/ha)	Totals
COTTON ALONE		671.4	89	89
COTTON + MAIZE	COTTON	134.3	18	93
	MAIZE	474.3	75	
COTTON + OKRA	COTTON	366.7	48	76
	OKRA	279.4	28	
COTTON + TOMATO	COTTON	271.4	36	178
	TOMATO	1162.3	142	
COTTON + MAIZE + OKRA + TOMATO	COTTON	71.4	9	115
	MAIZE	457.1	72	
	OKRA	83.7	8	
	TOMATO	214.6	26	

N = Nigerian Naira. (N) = 100 Kobo

The official Marketing Board price of grade I seed cotton in 1973-4 season was 13.2 Kobo per kilogram in Mid-West State. All cotton picked from the nett plots were virtually grade I. Prices of the other associated food crop varied within localities in the State, but the ones given here were the prevailing prices during 1973-74 season. These are given in Kobo/Kg:- Maize 15.7, Okra 10, Tomato 12.2, Sorghum 6.62 and Cowpea 22.6.

(C) Mixed cropping 1974-75 season

(i) Effects on pink bollworm (P. gossypiella)

At Site I (Fig. 42) cotton planted as sole crop recorded the highest 'Peak' number of 0.73 larvae per cotton plant in October. There was however, a sudden rise in number of P. gossypiella on cotton in the six crop mixture at the beginning of November, when cotton was maturing and had bolls to support pink bollworm larvae. P. gossypiella showed a consistent increase in population on cotton sown as single crop/plot (Fig. 42). This pattern was similarly followed in cotton/sorghum and cotton/tomato treatments.

In Site II (Fig. 42) the general 'Peak' was distinctly shown for all treatments except cotton/tomato. The highest 'Peak' number of P. gossypiella/cotton plant was found in the six crop mixture treatment. The high numbers recorded in this treatment is perhaps associated with the presence of the other crops attracting pink bollworm to the plot. However, populations decreased steadily throughout the month of November.

Analysis of variance showed that the mean numbers of P. gossypiella/cotton in treatments for cotton planted as sole crop and where five other crops are combined with cotton were not different, though they were significantly more ($P < 0.05$) than those recorded in the other treatments at Site I (Table 59). Similarly, at Site II (Table 60), the larvae of P. gossypiella recorded

/cotton in treatment, for cotton planted as sole crop, was significantly higher ($P < 0.05$) than numbers found on cotton in the other treatments except in the combination of six crop mixtures (i.e. where cotton is interplanted with sorghum, cowpea, maize, okra and tomato).

Okra was the only associated crop on which P. gossypiella was found breeding.

Fig. 42. Mean numbers of P. gossypiella in a cotton mixed cropping system.

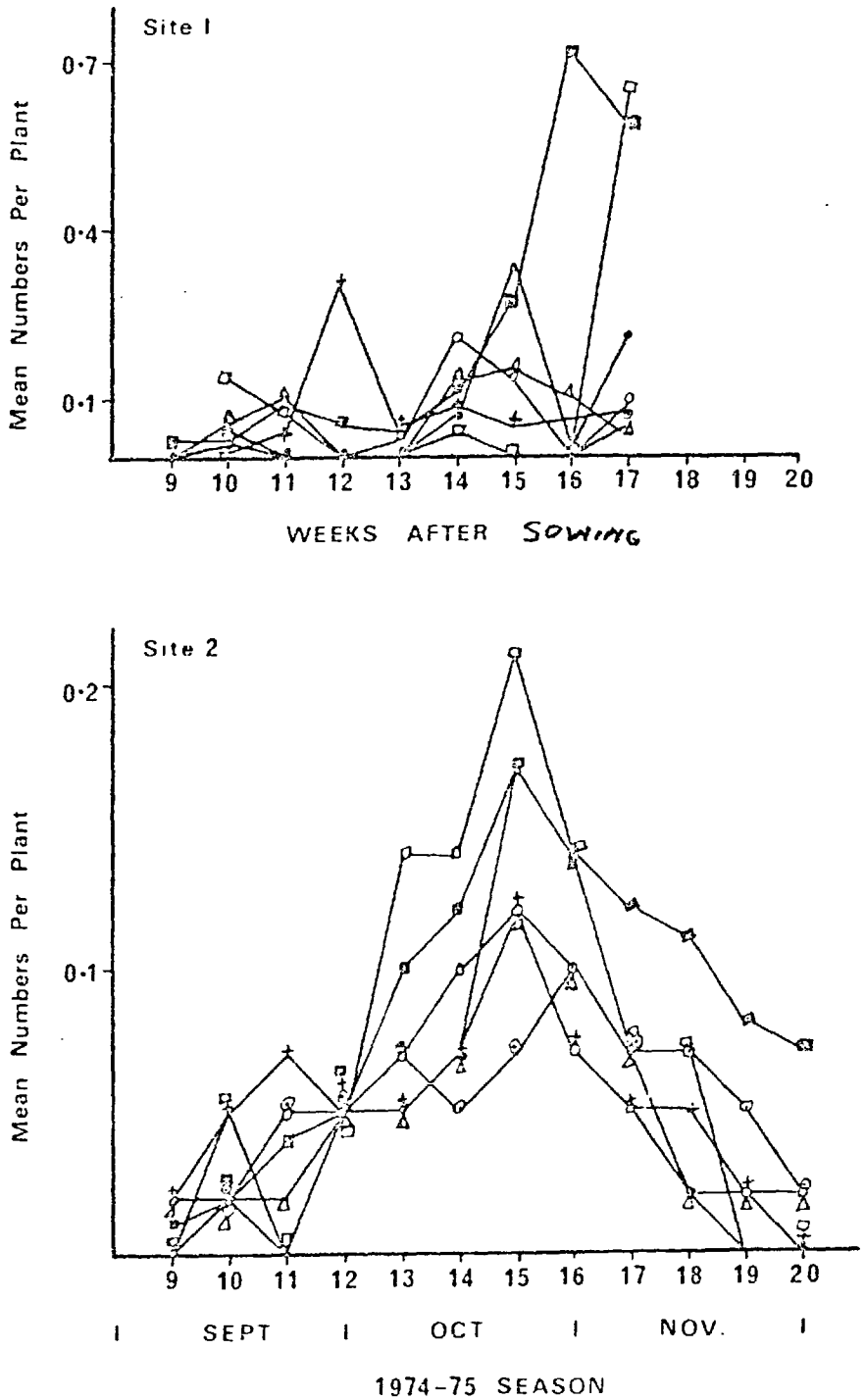


TABLE 59. POPULATION OF PINK BOLLWORM (P. GOSSYPIELLA) IN A MIXED CROPPING SYSTEM.

SITE I. 1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		0.13 **	13	186
50	COTTON + SORGHUM	COTTON	0.07 *	4	57
		SORGHUM	0	0	0
50	COTTON + COWPEA	COTTON	0.05 *	3	43
		COWPEA	0	0	0
50	COTTON + MAIZE	COTTON	0.04 *	2	29
		MAIZE	0	0	0
50	COTTON + OKRA	COTTON	0.06 *	3.1	44
		OKRA	0.002	.1	1
50	COTTON + TOMATO	COTTON	0.06 *	3.2	46
		TOMATO	0	0	0
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	0.10 **	2	29
		SORGHUM	0	0	0
		COWPEA	0	0	0
		MAIZE	0	0	0
		OKRA	0	0	0
		TOMATO	0	0	0

** Means are not significantly different at P = 0.05 but are significantly different from *

TABLE 60. POPULATION OF PINK BOLLWORM (P. GOSSYPIELLA) IN A MIXED CROPPING SYSTEM. SITE II.

1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		0.09**	8.7	124
50	COTTON + SORGHUM	COTTON	0.05*	2.5	35
		SORGHUM	0	0	0
50	COTTON + COWPEA	COTTON	0.05*	2.6	37
		COWPEA	0	0	0
50	COTTON + MAIZE	COTTON	0.05*	2.7	39
		MAIZE	0	0	0
50	COTTON + OKRA	COTTON	0.05*	2.6	37
		OKRA	0.04	2.2	31
50	COTTON + TOMATO	COTTON	0.05*	2.4	34
		TOMATO	0	0	0
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	0.08**	1.3	19
		SORGHUM	0	0	0
		COWPEA	0	0	0
		MAIZE	0	0	0
		OKRA	0.08	1.4	20
		TOMATO	0	0	0

** Means are not significantly different at P = 0.05, but are significantly different from *

(ii) Effects on spiny bollworm (E. biplaga)

Spiny bollworm distribution throughout the season is shown in Figure 43 for Sites I and II respectively. The highest E. biplaga populations occurred in September and October in both sites; and as for P. gossypiella, most E. biplaga were found on cotton planted as sole crop as a treatment of six crop mixture in Site I; but in Site II, numbers recorded from treatment of six crop mixture were highest followed by those found in treatments of cotton/sorghum and cotton planted as sole crop (Figure 43). There was however, a third rise in population found in November at Site I (Fig. 43) from cotton/cowpea, cotton/okra and cotton/maize treatments. This later peak population may have been caused as a result of late sowing of cotton giving rise to late flower and boll production which attracted a new generation of E. biplaga. As in Site I, there was a decline in E. biplaga numbers during the month of November (Fig. 43).

Apart from treatment of cotton planted as sole crop, Site II (Table 62), high E. biplaga infestations were also found in the treatment of cotton/okra, cotton/sorghum and six crop mixture. The high number of spiny bollworm found on okra and on cotton in the treatment of cotton/okra suggests okra as a favourable host crop. Seemingly, the low E. biplaga larvae recorded from cotton in cotton/cowpea, cotton/maize and cotton/tomato combinations indicates that these other crops were possibly helping to reduce spiny bollworm infestation on

the cotton crop (Table 62), but in Site II (Table 62) only tomato seemed to show this reducing effect.

At Site I, the mean numbers of E. biplaga sampled from cotton in the treatment of cotton sown as sole crop were significantly more ($P < 0.05$) than numbers found from the other treatments. Numbers recorded from cotton in cotton/cowpea, cotton/maize, cotton/okra, cotton/tomato and six crop mixture treatments were not different, but were significantly higher ($P < 0.05$) than those from cotton/sorghum (Table 61).

But at Site II (Table 62) all treatments were not different except cotton/tomato where they were significantly less ($P > 0.05$). This indicates the possible reduction of E. biplaga infestation by intercropping cotton with tomatoes.

Fig.43. Mean numbers of E.biplaga per plant in a cotton mixed cropping system.

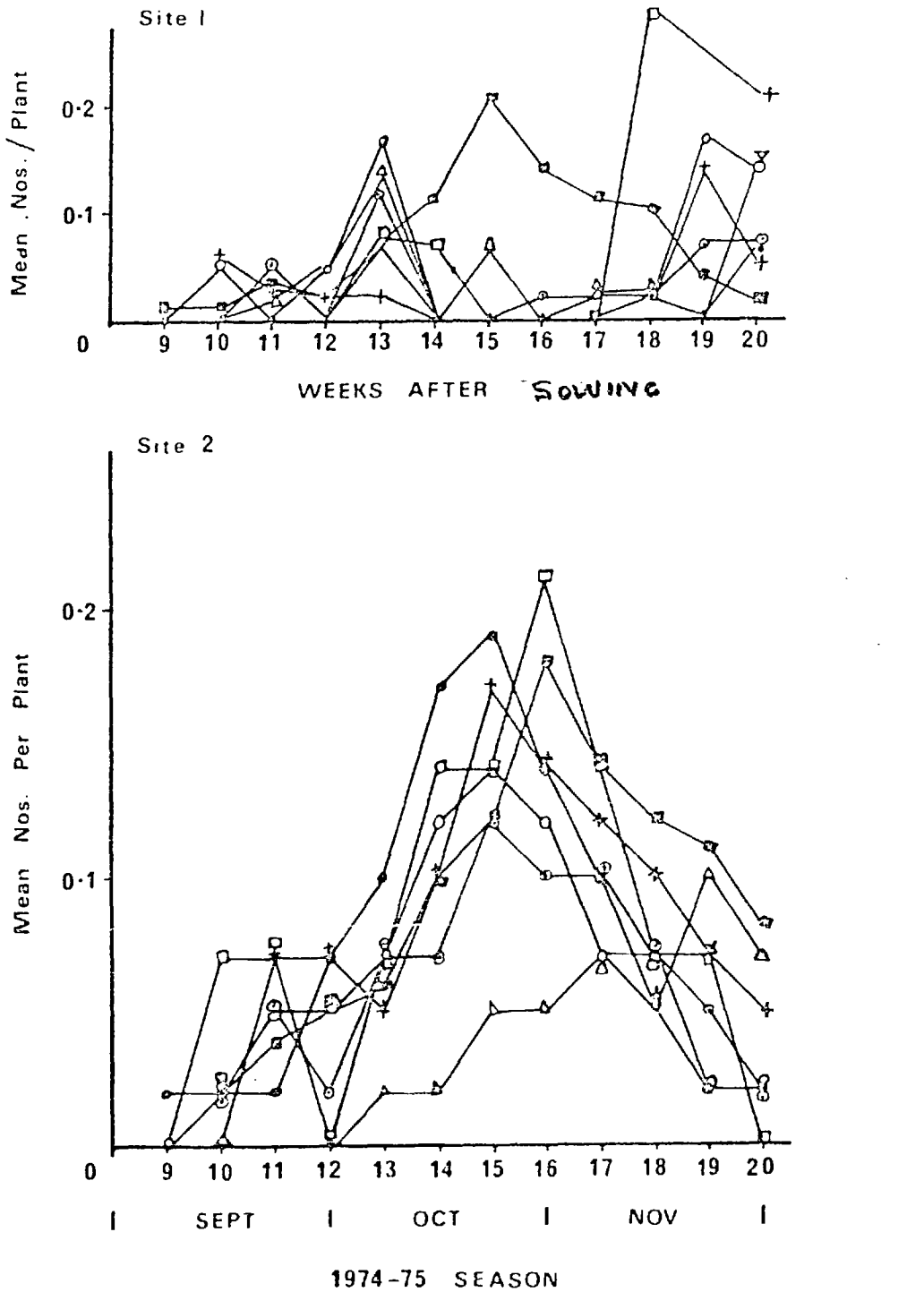


TABLE 61. POPULATION OF SPINY BOLLWORM (E. BIPLAGA) IN A MIXED CROPPING SYSTEM. SITE I.

1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		0.07***	7.3	104
50	COTTON + SORGHUM	COTTON	0.01*	.65	9
		SORGHUM	0	0	0
50	COTTON + COWPEA	COTTON	0.05**	2.6	37
		COWPEA	0	0	0
50	COTTON + MAIZE	COTTON	0.03**	1.6	23
		MAIZE	0	0	0
50	COTTON + OKRA	COTTON	0.03**	1.6	23
		OKRA	.02	1.2	17
50	COTTON + TOMATO	COTTON	0.04**	1.9	27
		TOMATO	0	0	0
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	0.05**	.89	13
		SORGHUM	0	0	0
		COWPEA	0	0	0
		MAIZE	0	0	0
		OKRA	0	0	0
		TOMATO	0	0	0

*** Means are not significantly different at P = 0.05, but are significantly different from ** and *

TABLE 62. POPULATION OF SPINY BOLLWORM (E. BIPLAGA) IN A MIXED CROPPING SYSTEM. SITE II.

1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		0.11**	11.3	161
50	COTTON + SORGHUM	COTTON	0.08**	3.9	56
		SORGHUM	0	0	0
50	COTTON + COWPEA	COTTON	0.06**	3.2	46
		COWPEA	0	0	0
50	COTTON + MAIZE	COTTON	0.06**	3.0	43
		MAIZE	0	0	0
50	COTTON + OKRA	COTTON	0.08**	3.9	56
		OKRA	0.08	4.2	60
50	COTTON + TOMATO	COTTON	0.04*	1.8	26
		TOMATO	0	0	0
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	0.08**	1.4	20
		SORGHUM	0	0	0
		COWPEA	0	0	0
		MAIZE	0	0	0
		OKRA	0.08	1.3	19
		TOMATO	0	0	0

** Means are not significantly different at P = 0.05, but are significantly different from *

(iii) Effects on American bollworm (H. armigera)

Heliothis armigera population was generally low at both sites, but was higher at Site I. At Site I, (Table 63) the highest numbers of H. armigera larvae were recorded in the treatment where cotton was interplanted with tomato followed by numbers recorded from the treatments of cotton planted as 100% crop population/plot and cotton interplanted with sorghum.

Although the numbers of H. armigera in the plots were low, generally less than 0.1/plant, analysis of variance showed that at Site II (Table 64) mean numbers of Heliothis sampled/cotton from treatments of cotton planted as sole crop and cotton interplanted with tomato were not significantly different (P = 0.05), but were significantly more than those in the other treatments. But at Site I (Table 63), the mean numbers of H. armigera from treatment cotton/tomato and the six crop mixture were significantly greater ($P < 0.05$) than those from the other treatments.

The high numbers of H. armigera sampled from cotton interplanted with tomato and the amount taken from tomato plants, suggests that this crop is a favourable host to Heliothis. Similarly, some of the Heliothis numbers recorded on okra, maize, cowpea and sorghum at both sites indicates them as hosts and as probable diversionary crops.

TABLE 63. POPULATION OF AMERICAN BOLLWORM (H. ARMIGERA) IN A MIXED CROPPING SYSTEM.

SITE I. 1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		0.01*	1	14
50	COTTON + SORGHUM	COTTON	0.01*	0.45	6
		SORGHUM	0.01	.65	9
50	COTTON + COWPEA	COTTON	0.01*	.30	4
		COWPEA	0	0	0
50	COTTON + MAIZE	COTTON	0.01 *	.25	4
		MAIZE	0.002	.10	1
50	COTTON + OKRA	COTTON	0.01	.60	9
		OKRA	0.002	.10	1
50	COTTON + TOMATO	COTTON	0.04 **	2.1	30
		TOMATO	0.01	.65	9
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	0.04 **	.63	9
		SORGHUM	0.01	.18	3
		COWPEA	0	0	0
		MAIZE	0.01	.08	1
		OKRA	0.01	.18	3
		TOMATO	0.04	.63	9

** Means are not significantly different at P = 0.05, but are significantly different from *

TABLE 64. POPULATION OF AMERICAN BOLLWORM (H. ARMIGERA) IN A MIXED CROPPING SYSTEM.

SITE II. 1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		0.003***	.3	4
50	COTTON + SORGHUM	COTTON	0.002**	.1	1
		SORGHUM	0	0	0
50	COTTON + COWPEA	COTTON	0	0	0
		COWPEA	0.002*	.1	1
50	COTTON + MAIZE	COTTON	0 *	0	0
		MAIZE	0	0	0
50	COTTON + OKRA	COTTON	0	0	0
		OKRA	0.001*	.4	6
50	COTTON + TOMATO	COTTON	0.004***	.2	3
		TOMATO	0.004	.2	3
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	0 *	0	0
		SORGHUM	0	0	0
		COWPEA	0.012	.2	3
		MAIZE	0.012	.2	3
		OKRA	0	0	0
		TOMATO	0.01	.1	1

*** Means are not significantly different at P = 0.05 but are significantly different from ** and *

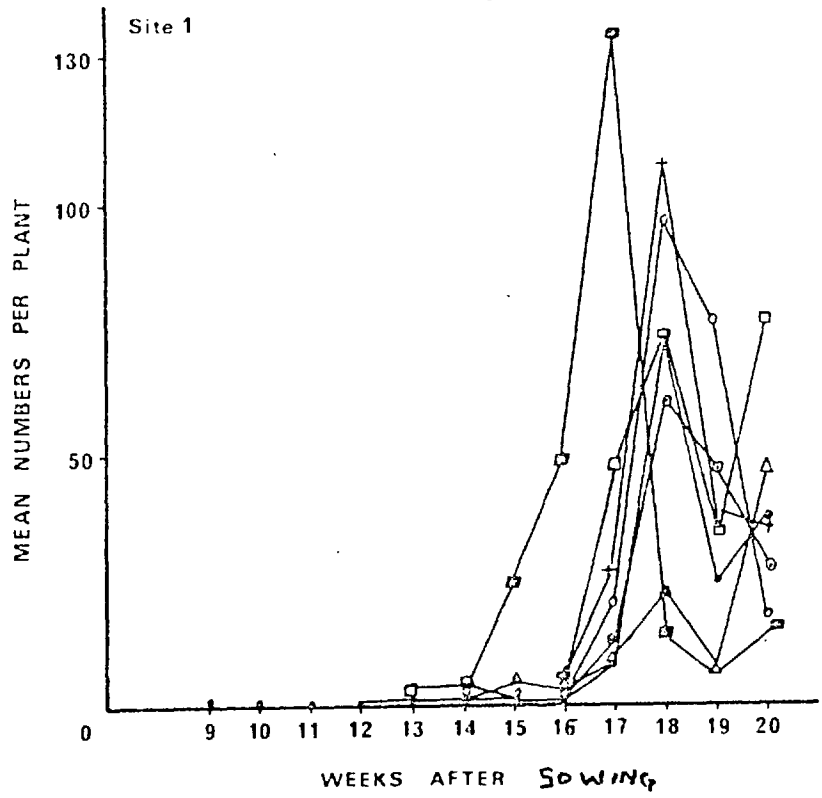
(iv) Effects on cotton stainers (D. superstitiosus)

D. superstitiosus did not appear in the plots at Site I until October. Populations gradually built up, and the highest population was recorded in treatments of cotton sown as sole crop in the middle of November with a mean number of 134 stainers/cotton plant (Fig. 44). 'Peak' populations were recorded on cotton in the other treatments a week later. Besides treatment where cotton is cultivated as sole crop, the 'Peak' population recorded from the other treatments followed the order of cotton/ okra, cotton/cowpea, six crop mixture, cotton/sorghum and cotton/maize.

Against Site I, the highest 'Peak' population of D. superstitiosus was observed in cotton planted as mono-culture in Site II during the last week of October. The 'Peak' generation found on cotton in the other treatments occurred irregularly, each appearing at different times between October and November (Fig. 44).

On per plot basis the mean numbers of D. superstitiosus found in the treatment of cotton planted as 100% crop population/plot were highest in treatment and these were followed by numbers recorded in cotton/cowpea, cotton/ okra, cotton/sorghum, cotton/maize and cotton/tomato treatments (Table 65). Similarly at Site II (Table 66) stainers numbers found per cotton in treatments of cotton/ okra, cotton/cowpea, cotton/tomato, cotton/sorghum and cotton/maize followed numbers found in cotton planted as

sole crop in that descending order; thus indicating that these other crops, okra, tomato, cowpea, sorghum could possibly reduce stainers incidence on cotton crops.



Mean numbers of D superstitiosus per plant in Mixed Cropping System

1974-75 SEASON

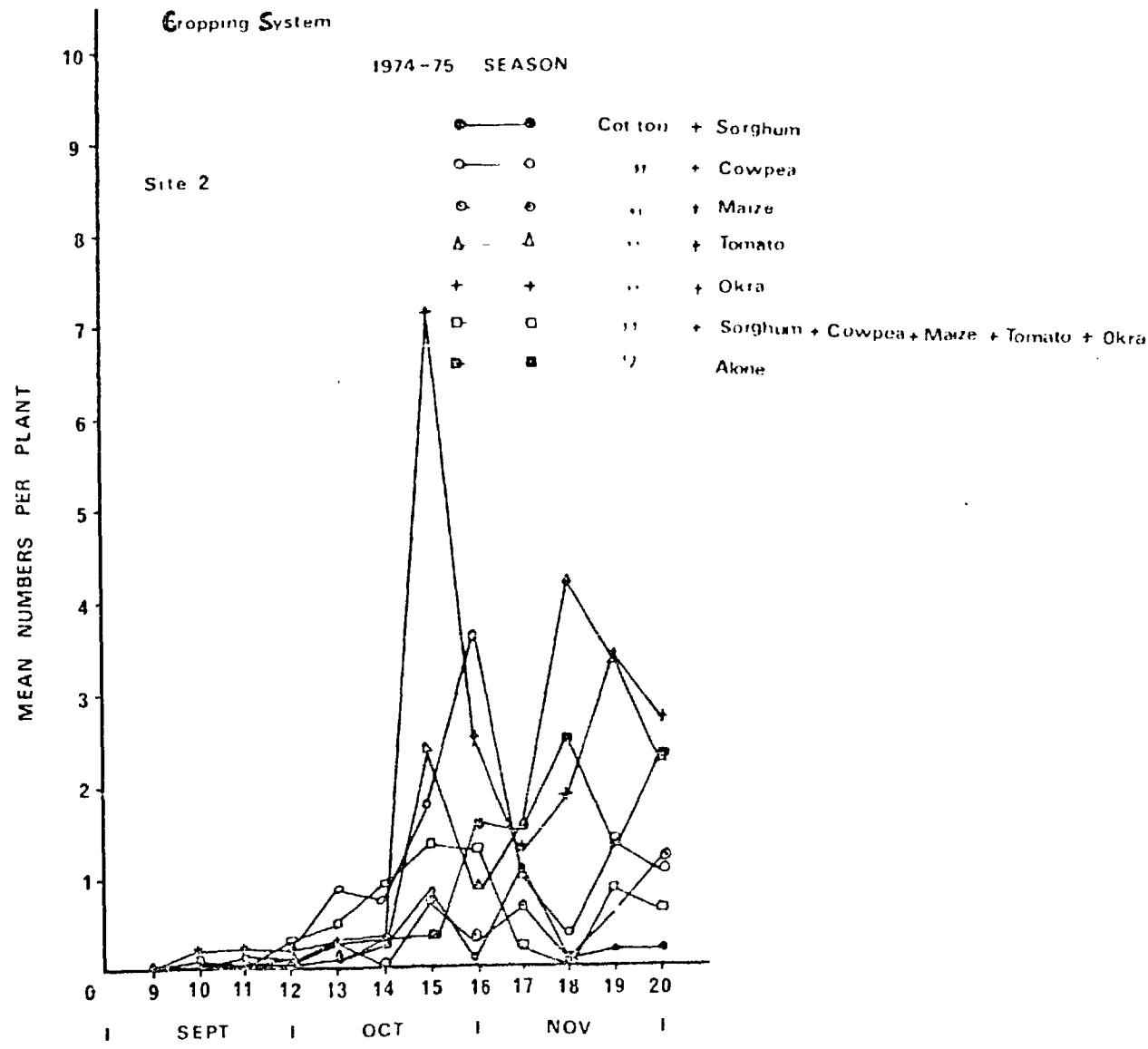


Fig.44. Mean numbers of D superstitiosus per plant in a Mixed Cropping System 1974-75 SEASON

TABLE 65. POPULATION OF COTTON STAINERS (D. SUPERSTITIOSUS) IN A MIXED CROPPING SYSTEM.

SITE I. 1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		9.41 **	941	13442
50	COTTON + SORGHUM	COTTON	5.60 **	288	4114
		SORGHUM	.675	34	486
50	COTTON + COWPEA	COTTON	8.30 **	416.5	5950
		COWPEA	.432	21.6	309
50	COTTON + MAIZE	COTTON	5.89 **	250	3571
		MAIZE	.632	32	457
50	COTTON + OKRA	COTTON	8.32 **	416	5942
		OKRA	2.49	125	1785
50	COTTON + TOMATO	COTTON	3.53 *	177	2528
		TOMATO	.065	3.3	47
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	9.38 **	157	2242
		SORGHUM	3.96	66	942
		COWPEA	5.22	87	1242
		MAIZE	.72	12.0	171
		OKRA	5.07	85.7	1224
		TOMATO	.087	2	29

** Means are not significantly different at P = 0.05 but are significantly different from *

TABLE 66. POPULATION OF COTTON STAINERS (D. SUPERSTITIOSUS) IN A MIXED CROPPING SYSTEM.

SITE II. 1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		2.182***	218	3/ 3114
50	COTTON + SORGHUM	COTTON	0.248*	12	171
		SORGHUM	0.150	8	114
50	COTTON + COWPEA	COTTON	0.928**	46	657
		COWPEA	0.208	10	142
50	COTTON + MAIZE	COTTON	0.328*	16	229
		MAIZE	0.038	2	29
50	COTTON + OKRA	COTTON	1.716***	86	1229
		OKRA	1.400	70	1000
50	COTTON + TOMATO	COTTON	1.272***	64	914
		TOMATO	0.046	2	29
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	0.494*	8	114
		SORGHUM	0.472	8	114
		COWPEA	0.450	8	114
		MAIZE	0.238	4	57
		OKRA	1.978	33	471
		TOMATO	0.071	1	14

*** Means are not significantly different at P = 0.05 but are significantly different from ** and *

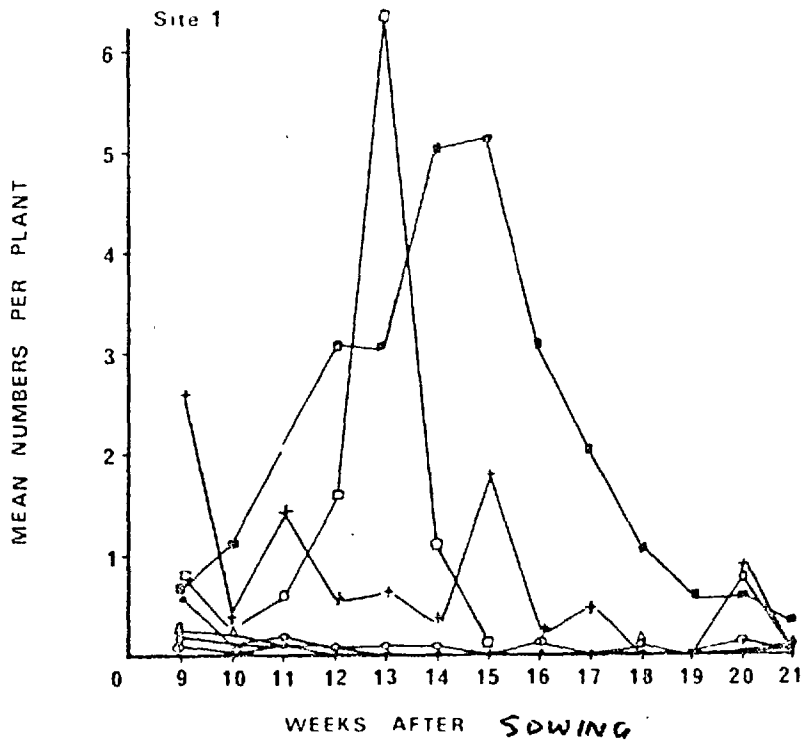
(v) Effects on flea beetles (Podagrica spp.)

Flea beetle population build-up was more pronounced in treatment cotton/okra. At both sites (Figure 45) three 'Peak' populations were recorded on cotton planted into treatment cotton/okra. The high population recorded in the treatment of six crop mixture was definitely due to the presence of okra. The highest Podagrica spp numbers recorded from treatments of cotton/okra and cotton sown as sole crop occurred in the month of October at both Sites I and II (Fig. 45).

On per plot basis the mean number of flea beetles sampled on cotton from cotton/okra treatment was 50 in Site II (Table 68) but in Site I (Table 67), the highest mean flea beetle numbers found on cotton was from the treatment of cotton planted as 100% crop population/plot and this was followed by numbers recorded from cotton in treatments of cotton/okra and cotton sown as six crop mixture. Numbers of flea beetle/cotton in cotton/okra and cotton/tomato treatments Site I (Table 67) were not different, similarly, numbers found from the treatments of cotton as sole crop, cotton/sorghum and cotton/cowpea were not significantly different ($P = 0.05$) although they were significantly greater ($P < 0.05$) than those from cotton in cotton/maize treatment (Table 67).

The high flea beetle numbers from cotton inter-planted with okra further confirmed earlier season's work where very heavy flea beetle infestation was found on the

cotton/okra treatment suggesting okra as a favoured host which does not act as a diversionary crop but as an attractant which causes cotton to be more infested than in other crop mixtures.



Mean numbers of Flea Beetles (Podagrica spp.) in a Mixed Cropping System

1974-75 SEASON

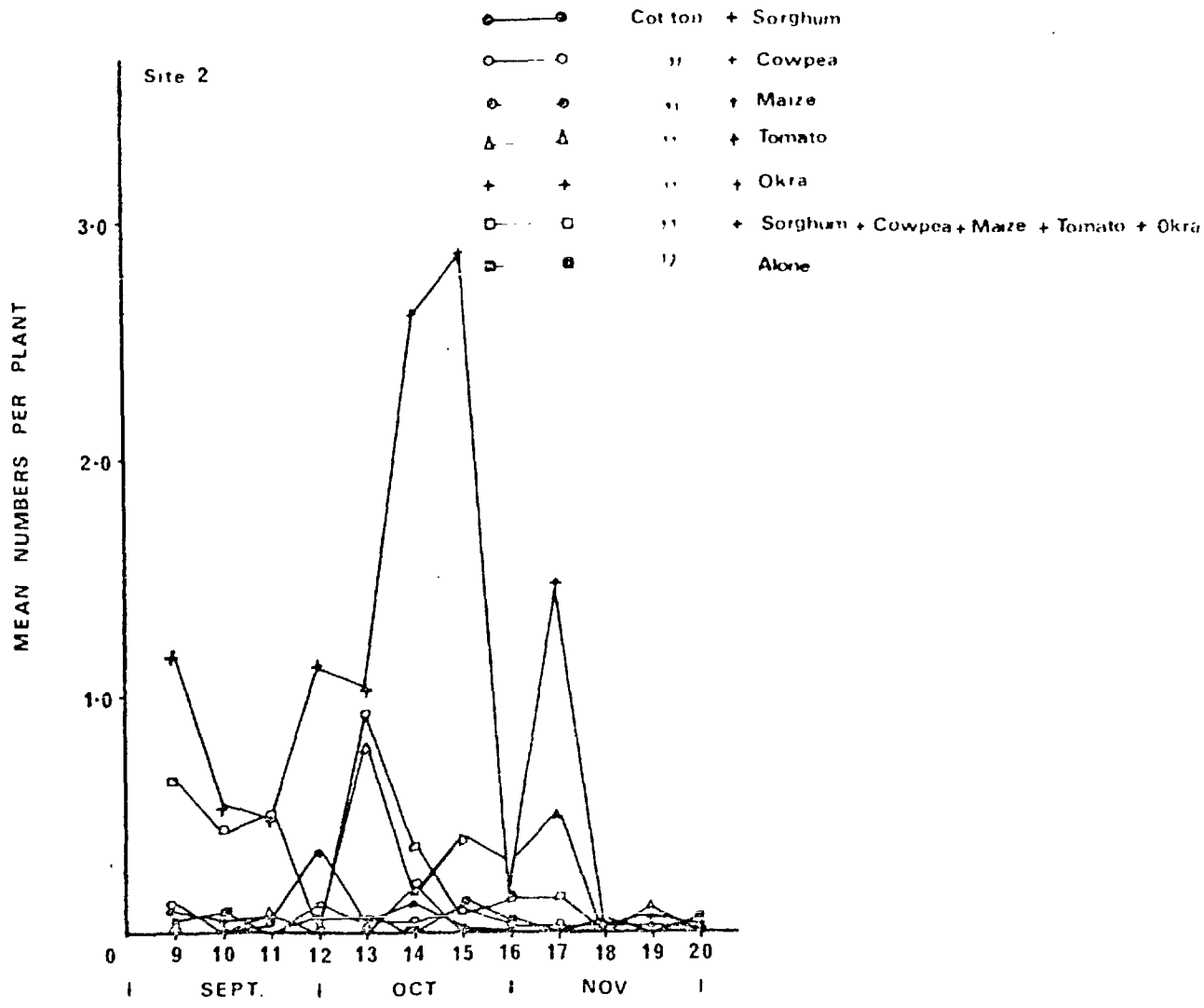


Fig. 45. Mean numbers of Flea Beetles (Podagrica spp) in a Mixed Cropping System

1974-75 SEASON

TABLE 67. POPULATION OF FLEA BEETLES (PODAGRICA SPP.) IN A MIXED CROPPING SYSTEM.

SITE I. 1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		2.135****	214	3057
50	COTTON + SORGHUM	COTTON	0.060*	3.1	44
		SORGHUM	0.067	3.4	49
50	COTTON + COWPEA	COTTON	0.124**	6.2	89
		COWPEA	0.088	4.4	63
50	COTTON + MAIZE	COTTON	0.040*	2.9	41
		MAIZE	0.054	3	43
50	COTTON + OKRA	COTTON	0.697***	35	500
		OKRA	19.175	960	13714
50	COTTON + TOMATO	COTTON	0.041*	2.1	30
		TOMATO	0.165	8.3	119
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	0.830***	14	200
		SORGHUM	0.373	6	86
		COWPEA	0.159	3	42
		MAIZE	0.104	2	28
		OKRA	24.10	402	5742
		TOMATO	0.132	2.2	31

*** Means are not significantly different at P = 0.05, but are significantly different from ****, ** and *

TABLE 68. POPULATION OF FLEA BEETLES (PODAGRICA SPP.) IN A MIXED CROPPING SYSTEM.

SITE II. 1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		0.040**	4	57
50	COTTON + SORGHUM	COTTON	0.066**	3.3	47
		SORGHUM	0.127	6.4	91
50	COTTON + COWPEA	COTTON	0.043**	2.2	31
		COWPEA	0.096	5	71
50	COTTON + MAIZE	COTTON	0.022*	1.1	16
		MAIZE	0.067	3.4	49
50	COTTON + OKRA	COTTON	0.999****	50.0	714
		OKRA	16.344	817.2	11674
50	COTTON + TOMATO	COTTON	0.193***	9.7	138
		TOMATO	0.053	2.7	39
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	0.268***	4.5	64
		SORGHUM	0.102	1.7	24
		COWPEA	0.107	1.8	26
		MAIZE	0.065	1.1	16
		OKRA	11.411	191	2728
		TOMATO	0.101	1.7	24

*** Means are significantly different at P = 0.05, but are significantly different from ****, ** and *

(vi) Effects on predators

A. C. lunata

Figure 46 represents C. lunata distribution in the plots. Treatments of cotton planted as sole crop and the six crop mixture harboured the most C. lunata per cotton plant and at Site I, (Fig. 46) the sole cropped cotton treatment had the highest numbers of C. lunata, 4 larvae per plant, at the middle of November; thereafter the population dropped gradually to zero at the last sampling date in December.

Similarly, at Site II (Fig. 46) 'Peak' populations recorded in the treatments of cotton sown as sole crop and the six crop mixture were more than peak numbers taken from the other crop combinations.

Analysis of variance showed that the mean numbers of C. lunata found per cotton sown into treatment of six crop mixture Site II were significantly higher ($P < 0.05$) than numbers recorded from cotton in either of the remaining five treatments (Table 70). However, in treatment of cotton cultivated as 100% crop population/plot C. lunata numbers/cotton were significantly greater ($P < 0.05$) than those taken from treatments of cotton/sorghum, cotton/cowpea, cotton/maize, cotton/okra and cotton/tomato.

Unlike in Site II, the mean larvae of C. lunata sampled from cotton in treatment of cotton planted as sole crop at Site I, were significantly more ($P < 0.05$) than

numbers sampled on cotton grown in combination with the other crops (Table 69); and with the exception of cotton/tomato treatment, these other treatments were not different from each other at P = 0.05. At both sites the treatments of cotton/cowpea, cotton/sorghum (Table 69) and cotton/tomato and cotton/cowpea (Table 70) carried higher C. lunata population per hectare compared to the other treatments. The number of C. lunata per cowpea only per hectare (Table 69) was at least twice the numbers per hectare taken from each of the other crops grown in combination with cotton; thus suggesting cowpea as better host for C. lunata than the other associated crops.

The general increase in C. lunata numbers found on the crops in Site I was associated with the luxuriant growth of the cotton crop at this site compared to Site II. The higher C. lunata numbers recorded on cotton in the six crop mixture is probably due to growth differential of cotton crop in the mixture, and also to the presence of the other associated crops (Table 70). On the contrary, at Site I (Table 69) high C. lunata numbers were sampled from cotton planted as sole crop compared to the treatment of six crop mixture. This is probably accounted for by the fact that the greater crop population in the treatment where cotton was sown as 100% crop population/plot was well established to attract more predators than in the six crop mixture treatment where cotton was grown as 25% crop population/plot.

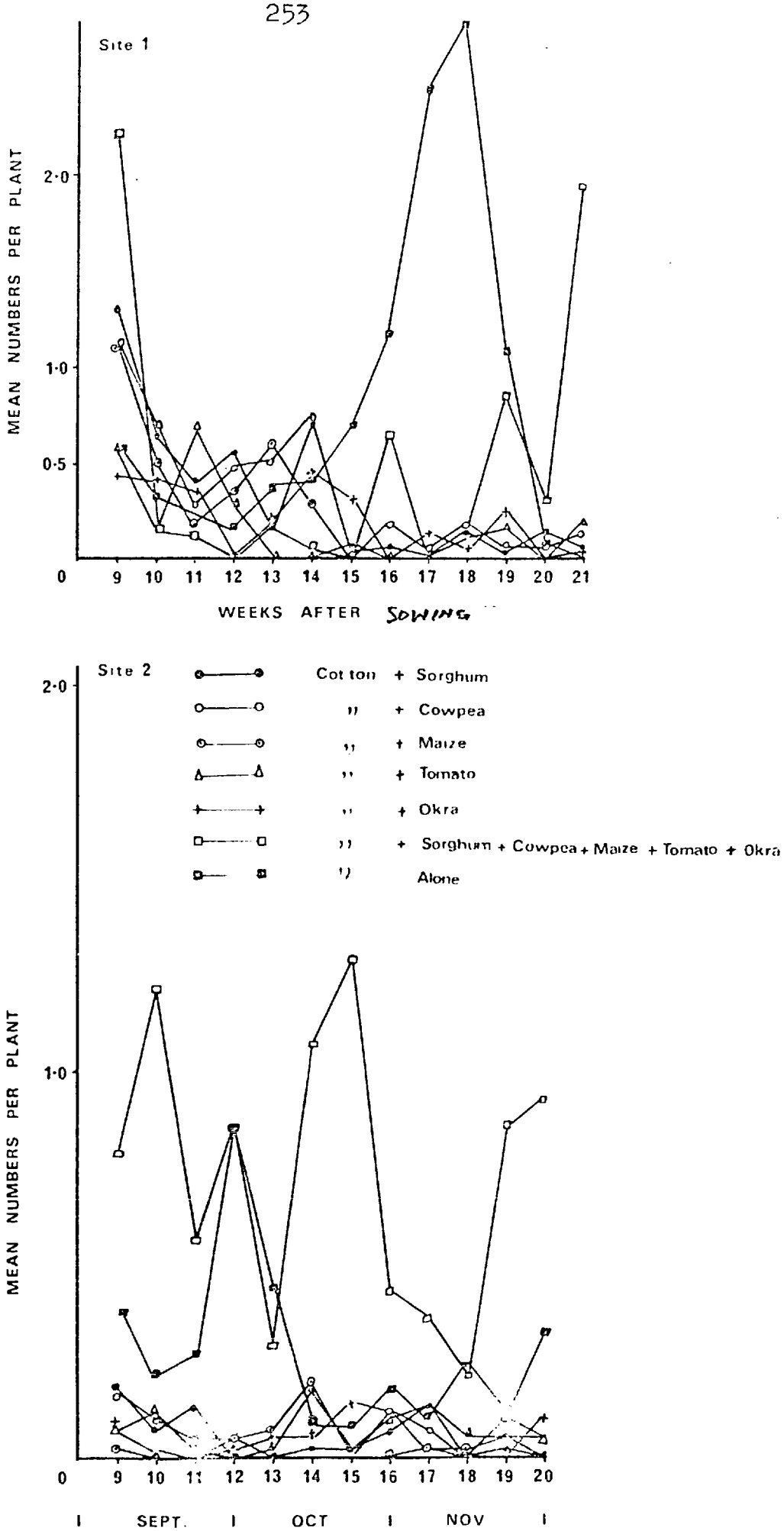


Fig. 46. Mean numbers of Ladybird Beetle (C lunata) larvae in a cotton mixed cropping system.

1974-75 SEASON

TABLE 69. POPULATION OF LADYBIRD (C. LUNATA) IN A MIXED CROPPING SYSTEM. SITE I.

1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		.936***	93.6	1337
50	COTTON + SORGHUM	COTTON	.337**	16.9	241
		SORGHUM	.205	10.3	147
50	COTTON + COWPEA	COTTON	.346	17.3	247
		COWPEA	.384	19.2	274
50	COTTON + MAIZE	COTTON	.235**	11.8	168
		MAIZE	.192	9.6	137
50	COTTON + OKRA	COTTON	.205**	10.3	147
		OKRA	.145	7.5	107
50	COTTON + TOMATO	COTTON	.174*	8.7	124
		TOMATO	.138	6.9	98
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	.494**	8.2	117
		SORGHUM	.248	4.1	59
		COWPEA	.062	1.0	14
		MAIZE	.110	1.8	25
		OKRA	.044	.73	10
		TOMATO	.055	.92	13

** Means are not significantly different at P = 0.05, but are significantly different from *** and *

TABLE 70. POPULATION OF LADYBIRD (C. LUNATA) IN A MIXED CROPPING SYSTEM. SITE II

1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		.274**	27.4	391
50	COTTON + SORGHUM	COTTON	.056*	2.8	40
		SORGHUM	.168	8.4	120
50	COTTON + COWPEA	COTTON	.059*	3.0	42
		COWPEA	.045	2.3	33
50	COTTON + MAIZE	COTTON	.035*	1.8	26
		MAIZE	.026	1.3	18
50	COTTON + OKRA	COTTON	.049*	2.5	36
		OKRA	.060	3.0	43
50	COTTON + TOMATO	COTTON	.068*	3.4	49
		TOMATO	.099	5.0	71
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	.739***	12.3	176
		SORGHUM	.110	1.8	26
		COWPEA	.083	1.4	20
		MAIZE	.125	2.1	30
		OKRA	.088	1.5	21
		TOMATO	.157	2.6	37

* Means are not significantly different at P = 0.05, but are significantly different from ** and ***

B. P. ferruginea

P. ferruginea were irregularly distributed in the plots. Several 'Peaks' were formed especially at Site I (Fig. 47); and these may have been caused by intercrop movements of this predator. At both sites the highest predator numbers were taken from treatment in the six crop mixture. At Site I, this treatment was followed by numbers recorded from treatment of cotton planted as sole crop; but at Site II, the treatments cotton/okra and cotton/maize came next to the six crop mixture.

There were differences in the mean numbers of P. ferruginea larvae/cotton plant in Site I (Table 71), and this resulted in significant differences between some treatments. The mean numbers of P. ferruginea recorded from cotton in the treatment cotton/cowpea were significantly less ($P > 0.05$) than those taken from the other treatments which were themselves not different from each other. Similarly, in Site II (Table 72), the mean P. ferruginea numbers taken from treatments cotton/sorghum and cotton/cowpea were significantly lower ($P > 0.05$) than numbers in the other treatments. Although numbers from these latter two treatments were not significantly different ($P = 0.05$).

Fig.47. Mean numbers of Platynaspis ferruginea in a cotton mixed cropping system
1974-75 SEASON

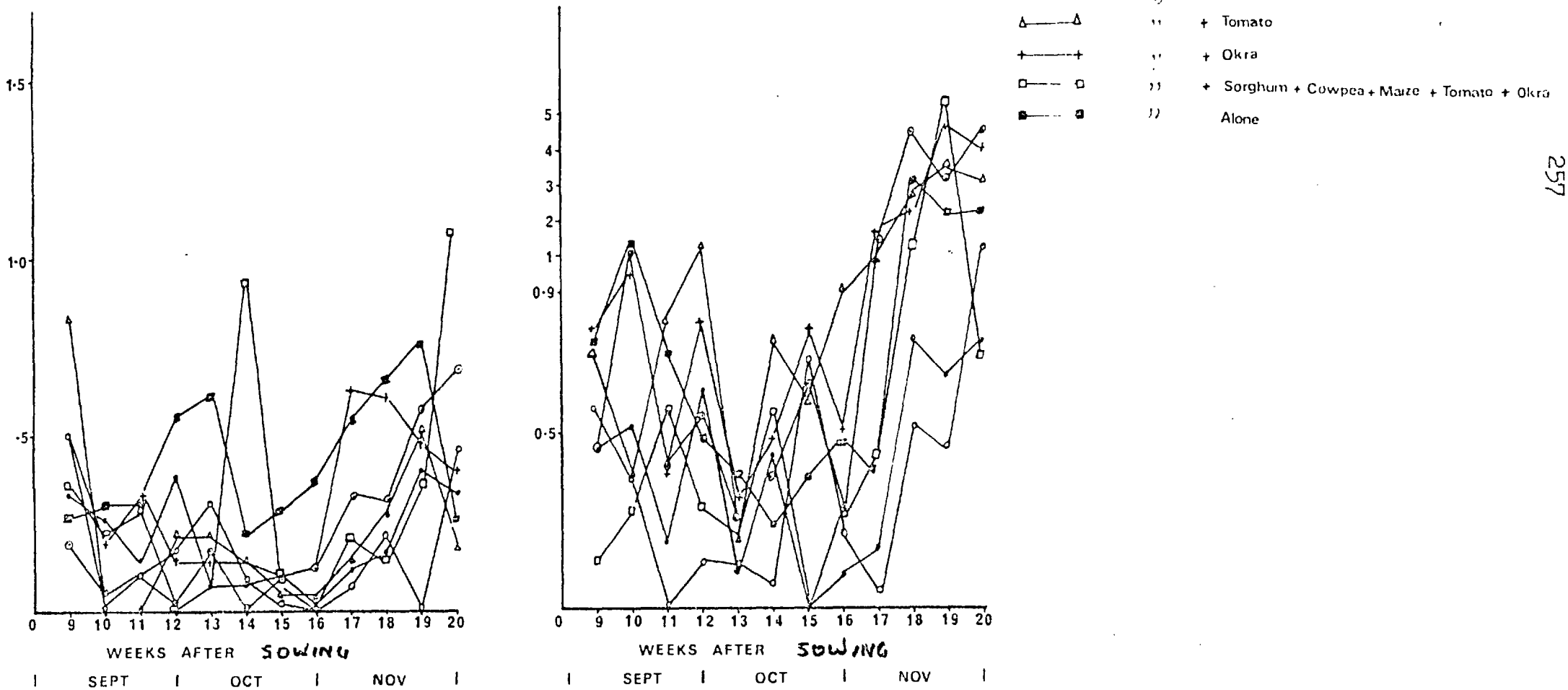


TABLE 71. POPULATION OF LADYBIRD BEETLE (P. FERRUGINEA) IN A MIXED CROPPING SYSTEM.

SITE I. 1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		.167**	16.7	238
50	COTTON + SORGHUM	COTTON	.199**	10	142
		SORGHUM	.138	6.9	98
50	COTTON + COWPEA	COTTON	.075*	3.8	54
		COWPEA	.033	1.7	24
50	COTTON + MAIZE	COTTON	.221**	11.1	158
		MAIZE	.070	3.5	50
50	COTTON + OKRA	COTTON	.312**	15.6	222
		OKRA	.034	1.7	24
50	COTTON + TOMATO	COTTON	.220**	11	157
		TOMATO	.040	2	29
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	.309**	5.2	74
		SORGHUM	.100	1.7	24
		COWPEA	.030	.50	7
		MAIZE	.029	.48	7
		OKRA	.042	.70	10
		TOMATO	.024	.40	6

** Means are not significantly different at P = 0.05, but are significantly different from *

TABLE 72. POPULATION OF LADYBIRD BEETLE (P. FERRUGINEA) IN A MIXED CROPPING SYSTEM.

SITE II. 1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		1.05 **	105	1500
50	COTTON + SORGHUM	COTTON	.398*	19.9	284
		SORGHUM	.138	6.9	98
50	COTTON + COWPEA	COTTON	.370*	18.5	264
		COWPEA	.026	1.3	18
50	COTTON + MAIZE	COTTON	1.450**	72.5	1036
		MAIZE	.029	1.5	21
50	COTTON + OKRA	COTTON	1.469**	73.5	1050
		OKRA	.158	7.9	113
50	COTTON + TOMATO	COTTON	1.321**	66.1	944
		TOMATO	.063	3.2	46
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	.833*	13.9	199
		SORGHUM	.274	4.6	66
		COWPEA	.059	.99	14
		MAIZE	.023	.38	5
		OKRA	.066	1.10	16
		TOMATO	.035	.58	8

** Means are not significantly different at P = 0.05, but are significantly different from *

C. Spiders

The spider population recorded throughout the season is shown in Figure 48. More spiders were found in Site I than in Site II. Like in the case of C. lunata, spider population built up higher in treatments of cotton planted as sole crop and in the six crop mixture than in the other crop combinations in Site I; but at Site II, spider population on cotton in the six crop mixture was distinctly higher than population on cotton and in the remaining crop combinations. At both sites, several 'Peak' generations were found, suggesting intercrop movements of spider within the plots.

At Site I, the mean numbers of spider recorded on cotton in the treatment of cotton sown as sole crop were significantly higher ($P < 0.05$) than numbers found on cotton in the other crop combinations; but numbers sampled from cotton on treatments of cotton/maize, cotton/tomato and in the six crop mixture were not different ($P = 0.05$), though were significantly greater ($P < 0.05$) than those in treatments of cotton/cowpea and cotton/okra (Table 73). In Site II, only the means of spiders taken from the treatment in the six crop mixture were significantly higher ($P < 0.05$) than means sampled from cotton in the treatment of cotton sown as sole crop and the other crop combinations (Table 74).

The relatively high numbers of spider recorded on sorghum, cowpeas, maize, tomato and okra intersown with cotton (i.e. in the six crop mixture) at both sites,

suggest that more prey were probably associated with cotton crops especially when interplanted with more crops which were seemingly attracting more predators to the plots.

Fig. 48. Mean numbers of spiders in a cotton mixed cropping system

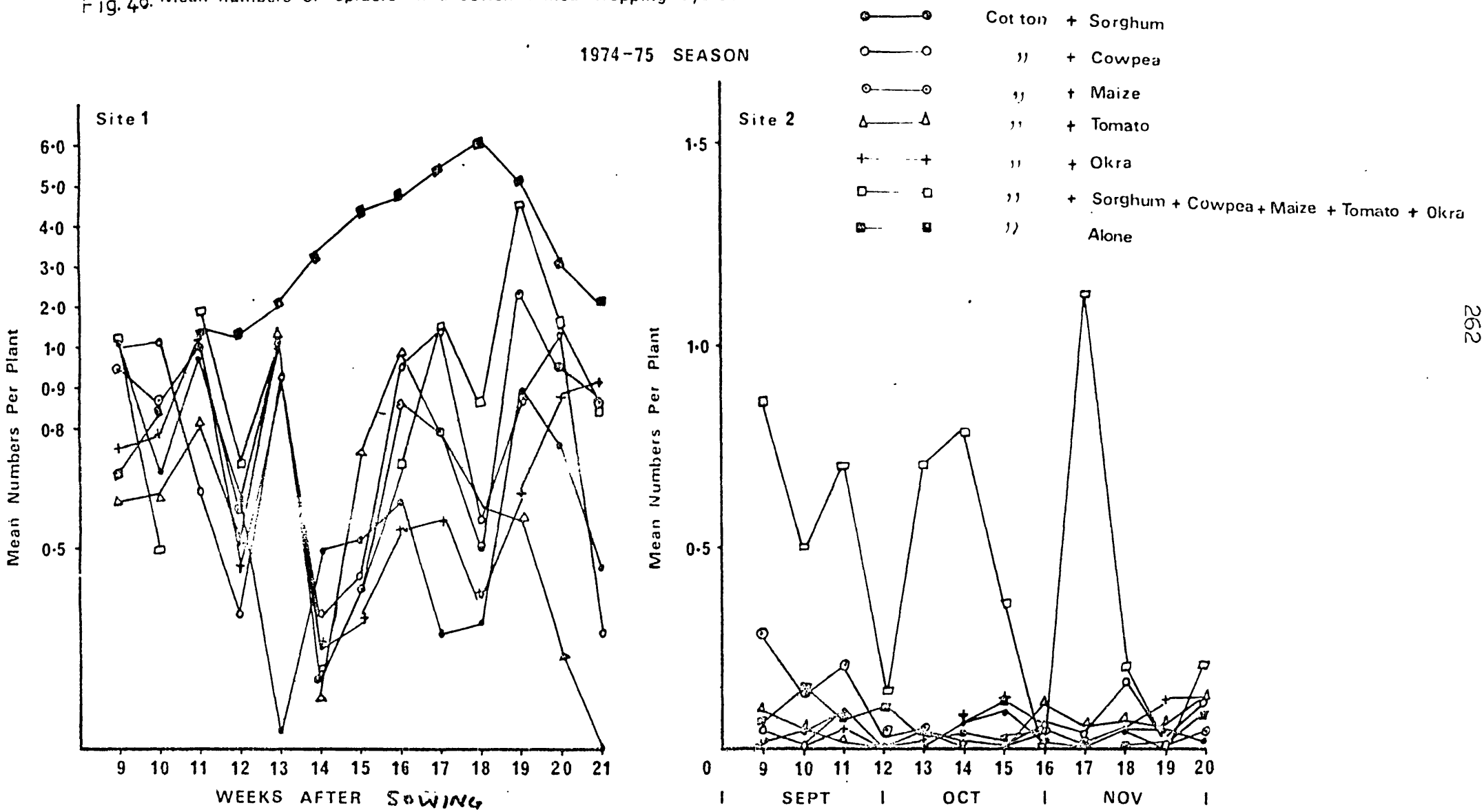


TABLE 73. POPULATION PREDATORY SPIDERS IN A MIXED CROPPING SYSTEM. SITE I.

1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		3.195***	319.5	4564
50	COTTON + SORGHUM	COTTON	.592*	29.6	423
		SORGHUM	.338	16.9	214
50	COTTON + COWPEA	COTTON	.785*	39.3	561
		COWPEA	.364	18.2	260
50	COTTON + MAIZE	COTTON	.881**	44.1	630
		MAIZE	.351	17.6	251
50	COTTON + OKRA	COTTON	.657*	32.9	470
		OKRA	.234	11.7	167
50	COTTON + TOMATO	COTTON	.989**	49.5	707
		TOMATO	.594	29.7	424
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	1.203**	20.1	287
		SORGHUM	.428	7.1	101
		COWPEA	.539	9	129
		MAIZE	.379	6.3	90
		OKRA	.566	9.5	136
		TOMATO	.682	11.4	163

*** Means are significantly different from ** and * at P = 0.05

TABLE 74 . POPULATION OF PREDATORY SPIDERS IN A MIXED CROPPING SYSTEM. SITE II.

1974-75 SEASON

% COTTON POPULATION PER PLOT	CROP COMBINATION		Mean Nos. larvae/Plant /sample	Mean Nos/Plot /sample	Mean Nos/Hectare /sample
100	COTTON ALONE		.054*	5.4	77
50	COTTON + SORGHUM	COTTON	.040*	2	29
		SORGHUM	.368	18.4	262
50	COTTON + COWPEA	COTTON	.056*	2.8	40
		COWPEA	.033	1.7	24
50	COTTON + MAIZE	COTTON	.073*	3.7	52
		MAIZE	.119	6.0	86
50	COTTON + OKRA	COTTON	.059*	3.0	43
		OKRA	.068	3.4	49
50	COTTON + TOMATO	COTTON	.048*	2.4	34
		TOMATO	.019	1.0	14
16.7	COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	.469**	7.8	111
		SORGHUM	.475	7.9	113
		COWPEA	.363	6.1	87
		MAIZE	.418	7.0	100
		OKRA	.165	2.8	40
		TOMATO	.298	5.0	71

** Means are significantly different from * at P = 0.05

(vii) Yields 1974-75 season

A comparison of yields from intercrop and pure stands of cotton, sorghum, cowpea, maize, okra and tomatoes on a production per hectare basis is given in Tables 75 - 79 .

As in 1973-74 there was clearly an all-round loss in cotton production from intercropping it with either sorghum, cowpea, maize, okra or tomato (Table 75). The percentage losses were very high in the treatments of cotton/sorghum, cotton/cowpea, cotton/maize and in the six crop mixture. At both sites comparable yields of seed cotton were obtained from cotton sown into okra and tomato. Although losses were also sustained from the two treatments (cotton/okra and cotton/tomato) these were less than in the other treatments. Yields of cotton from intercropping with okra were the most promising in the trial, followed by yields from cotton/tomato combination (Tables 75 and 76).

The yields from sorghum, cowpea, maize okra and tomato intercropped with cotton were compared with yields from the same crops planted in strips as pure stands (Table 79). Results obtained by comparing these yields (Table 79) showed that % gain was obtained by inter-cropping sorghum, maize and tomato with cotton (i.e. planting cotton as 50% crop population/plot); and increases in the yield of maize and cowpea when cotton is planted as in the treatment of six crop mixture in Site I. Similarly, at Site II (Table 79) there were overall

gains when sorghum, cowpea, maize and tomato but not okra were interplanted with cotton. Only in maize crops were increases obtained when cotton was planted as in the six crop mixture.

To evaluate efficiency of the crop combinations and in this study to increase total land productivity, land equivalent ratio which is the total land required using crop of pure stands to give total production of the same crops equal to that of one hectare of intercrop, was determined for each crop in the 1974-75 season.

Each land equivalent ratio (LER) was calculated by determining the ratio of the yields of each crop in the combination and compared with its yield in the pure stand trial kept under the same experimental conditions (i.e. weeding, fertility, thinning etc). The ratios of all the crops in the mixture were added to give the land equivalent ratio (LER) (Tables 80 and 81). Yields of cotton were taken from treatment where cotton was sown as 100% crop population/plot and those of sorghum, cowpea, maize, okra and tomato from the pure stand trial.

Ratios of cotton yield in the intercrop to cotton yields from the pure stands (Table 80) were less than 1 at both sites. The highest ratios were recorded from the treatments of cotton/okra and cotton/tomato (Tables 80 and 81). There was an overall increase in the total productivity in Site I except in the case of cotton mixed with cowpea where there was a loss of 22%

productivity. There was no loss in Site II. The marked high land equivalent from cotton/maize, cotton/tomato and in the six crop mixture treatments in Site I, and cotton/ sorghum, cotton/tomato and in the six crop mixture in Site II had been due to the high ratio values obtained from the other fine associated crops (sorghum, cowpea, maize, okra and tomato).

These results indicate however, that inter-cropping cotton with okra, tomato, maize sorghum and cowpea could be more productive although at Site I, there were losses from cotton sown into cowpea. Time of planting, other insect pests which were present, though not taken into account in this study together with other physiological factors may have affected the cotton/cowpea combinations and thus were probably responsible for these losses. Evidently, okra and tomatoes have come up very well as crops which can be mixed or intercropped with cotton to obtain increased productivity. The total value of crops/ ha for 1973-75 (Tables 58, 75 and 76) justified this.

Although high yields were obtained from cotton/ okra and cotton/tomato combinations which led to increased revenue (Section V) repeated trials must be carried out in the field for a longer period to justify these results, before these systems which lacked spray applications can be recommended to the farmers. Besides, educational compaign on the systems must be given to the farmers; as their acceptance or non-acceptance of this concept would determine its success or failure.

TABLE 75. MEAN YIELD IN Kg/Ha OF CROPS HARVESTED FROM MIXED CROPPING SYSTEMS, 1974-75 SEASON.

SITE I

CROP COMBINATIONS		YIELDS IN Kg/Ha.	VALUE OF CROPS IN (N)	TOTAL VALUE/Ha
COTTON ALONE		833	110	110
COTTON + SORGHUM	COTTON	225	30	
	SORGHUM	204	14	44
COTTON + COWPEA	COTTON	179	24	
	COWPEA	0	0	24
COTTON + MAIZE	COTTON	300	40	
	MAIZE	396	62	102
COTTON + OKRA	COTTON	758	100	
	OKRA	50	5	105
COTTON + TOMATO	COTTON	467	62	
	TOMATO	1975	241	303
COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	171	23	
	SORGHUM	83	6	
	COWPEA	13	3	
	MAIZE	183	29	
	OKRA	33	3	
	TOMATO	1063	130	194

TABLE 76 . MEAN YIELD IN Kg/Ha OF CROPS HARVESTED FROM MIXED CROPPING SYSTEMS, 1974-75 SEASON.

SITE II

CROP COMBINATIONS		YIELDS IN Kg/Ha	VALUE OF CROPS IN (N)	TOTAL VALUE/Ha
COTTON ALONE		350	46	46
COTTON + SORGHUM	COTTON	0	0	
	SORGHUM	750	50	50
COTTON + COWPEA	COTTON	4		
	COWPEA	129	29	30
COTTON + MAIZE	COTTON	17	2	
	MAIZE	300	47	49
COTTON + OKRA	COTTON	292	39	
	OKRA	15	2	41
COTTON + TOMATO	COTTON	158	21	
	TOMATO	1450	177	198
COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	COTTON	8	1	
	SORGHUM	104	7	
	COWPEA	56	13	
	MAIZE	288	45	
	OKRA	6	1	
	TOMATO	450	55	122

TABLE 77 . PERCENTAGE LOSS OR GAIN IN COTTON YIELD FROM INTERCROP AND PURE STANDS IN A COTTON MIXED CROPPING SYSTEMS.

1974-75 SEASON

SITE I

PURE STAND 100% CROP	COTTON INTERCROP WITH SORGHUM, COWPEA, MAIZE, OKRA AND TOMATO						% GAIN OR LOSS FROM INTERCROPPING					
Cotton	Sorghum	Cowpea	Maize	Okra	Tomato	Sorghum + cowpea + maize + okra + tomato	Sorghum	Cowpea	Maize	Okra	Tomato	Sorghum + cowpea + maize + okra + tomato
833.3	225	179.2	300	758.3	466.7	170.8	- 72.9	- 78.5	-64	- 9	- 44	- 80

SITE II

PURE STAND 100% CROP	COTTON INTERCROP WITH SORGHUM, COWPEA, MAIZE, OKRA AND TOMATO						% GAIN OR LOSS FROM INTERCROPPING					
Cotton	Sorghum	Cowpea	Maize	Okra	Tomato	Sorghum + cowpea + maize + okra + tomato	Sorghum	Cowpea	Maize	Okra	Tomato	Sorghum + cowpea + maize + okra + tomato
350	0	4.2	16.7	291.7	158.3	8.3	- 100	- 99	-95.2	- 17	- 55	- 98

TABLE 78. MEAN YIELD Kg/Ha OF CROPS FROM PURE STANDS.

1974-75 SEASON

% CROP POPULATION PER PLOT	CROP	SITE I	SITE II
100	SORGHUM	159	341.7
"	COWPEA	0	85.3
"	MAIZE	118.9	265.9
"	OKRA	55.6	39.0
"	TOMATO	1099.7	860.7
"	COTTON	758.3	952.1

TABLE 79 . COMPARISON OF YIELDS OF ASSOCIATED CROPS FROM INTERCROP AND PURE STAND IN A MIXED CROPPING SYSTEM.

1974-75 SEASON

SITE I

PURE STAND 100% CROP		INTERCROP WITH SORGHUM, COWPEA, MAIZE, OKRA, TOMATO										% GAIN OR LOSS FROM INTERCROPPING									
		Sorghum	Cowpea	Maize	Okra	Tomato	Sorghum	Cowpea	Maize	Okra	Tomato	Sorghum	Cowpea	Maize	Okra	Tomato	Sorghum	Cowpea	Maize	Okra	Tomato
Sorghum	159	204.2					83.3					+22.1					-91				
Cowpea	0		0					12.5					0					+100			
Maize	118.9			395.8					183.3					+70					+35.1		
Okra	55.6				50					33.3					- 11.2					-67	
Tomato	1099.7				1975						1062.5					+44.5					- 3.5

SITE II

Sorghum	341.7	750					104.2					+54.4					-228				
Cowpea	85.3		129.2					56.3					+34					-51.5			
Maize	265.9			300					287.5					+11.4					+ 7.5		
Okra	39				14.9					5.95					-161.7					-555	
Tomato	860.7					1450					450					+40.6					-913

TABLE 80 . TOTAL PRODUCTIVITY BASED ON EVALUATING YIELDS OF CROP COMBINATION. 1974-75 SEASON

SITE I

CROP COMBINATION	RATIOS	LAND EQUIVALENT	% TOTAL PRODUCTIVITY
COTTON + SORGHUM	.270 1.284	1.54	+ 54
COTTON + COWPEA	.215 .000	.22	- 78
COTTON + MAIZE	.360 3.329	3.69	+ 69
COTTON + OKRA	.910 .899	1.81	+ 81
COTTON + TOMATO	.560 1.796	2.36	+ 136
COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	.205 .524 .000 1.542 .599 .966	3.84	+ 284

TABLE 81. TOTAL PRODUCTIVITY BASED ON EVALUATING YIELDS OF CROP COMBINATION. 1974-75 SEASON

SITE II

CROP COMBINATION	RATIOS	LAND EQUIVALENT	% TOTAL PRODUCTIVITY
COTTON + SORGHUM	.000 2.195	2.20	+ 20
COTTON + COWPEA	.012 1.515	1.53	+ 53
COTTON + MAIZE	.048 1.128	1.18	+ 18
COTTON + OKRA	.833 .381	1.22	+ 22
COTTON + TOMATO	.452 1.685	2.14	+ 114
COTTON + SORGHUM + COWPEA + MAIZE + OKRA + TOMATO	.024 .305 .660 1.081 .153 .523	2.75	+ 175

On the other hand, cotton grown as sole crop and sprayed against insect pests would at the moment be considered advantageous for many reasons:-

i) In terms of economics, cotton is produced in Nigeria both for domestic consumption and possible export which earn the nation some foreign exchange; up to a value of more than 80 million Naira (Prentice, 1972) was gained by African cotton producing countries including Nigeria. As at now tomato or okra is mainly produced for local utilization and no foreign exchange earnings are derived from either of the crops. Unlike seed cotton, neither tomato nor okra can withstand long storage. The latter crops are prone to decay and hence cannot command high cash value in the market, especially, if they have to be stored against period of scarcity when prices are bound to be high.

ii) Oil with a high nutritional value is obtained from cotton seeds, and in addition, its byproducts are also converted to protein seed cake fed to livestocks to increase animal nutrition. These products command a premium, unlike tomato and okra, in the world market.

Cotton/maize mixture is a promising crop combination that could also be recommended, however, the revenue realised from it in this trial was less than those of either cotton/okra or cotton/tomato mixtures. However, a well grown maize could out-yield either okra or tomato under favourable weather conditions. Maize has a higher

quality value than okra or tomato, and because of its higher price many farmers grow it in Nigeria.

The yellow maize (variety Eijianthen Synthetic ESI) is popularly grown in Nigeria for livestock feed. It has an added advantage of the yellow pigment which contains caroteen content, a precursor of Vitamin A, needed for night vision.

(D) Discussion

A major problem of producing cotton in Mid-West State has been pests. Chemical insecticides by the use of conventional sprays have been the recommended practice for the control of these pests. This practice has not been embraced by farmers for reasons advanced earlier in the Introduction (Section I). As possible alternatives the results of three seasons' trial on the use of mixed cropping systems are hereby discussed.

Data from Table 82 showed that relatively high pink bollworm (P. gossypiella) populations developed on cotton planted as sole crop and on the four crop and six crop mixtures during the 1972-75 seasons. Simultaneously, the two lowest populations per plant of P. gossypiella were recorded on cotton interplanted with either tomato or maize during this same period. The low pink bollworm populations sampled from cotton interplanted with either maize or tomato indicate that these latter associated crops perhaps have the potentials to repel P. gossypiella and hence could be planted with a cotton crop to reduce pink bollworm infestation.

Similarly, the two lowest populations per plant of E. biplaga were consistently recorded on cotton interplanted with either maize or tomato for two out of the three seasons of trial (Table 83). The low population of E. biplaga seen in the four crop mixture (Table 83) is probably associated with the presence of tomato and maize.

Cotton planted as sole crop and cotton sown in the six crop mixture further recorded the highest E. biplaga population/cotton plant. Although only in the 1973-74 season was a bollworm population (Table 82) recorded as the lowest number/cotton plant interplanted with okra, numbers of E. biplaga and P. gossypiella sampled from the crop were highest on okra plants. This therefore confirmed the crop as a suitable host to these bollworms which could be effective in reinfesting cotton crops rather than as a diversionary crop.

Hayward (1967) working on the control of cotton pests in Western State of Nigeria found that P. gossypiella and E. biplaga were restricted in host preference to Malvales. Okra (H. esculentus) and kenaf (H. cannabinus) were mostly preferred. The survey of pests attacking food crops in Nigeria by Liby (1968) strongly supported the findings by Hayward. A similar situation has been observed in the Mid-West State. Of the five food crops interplanted with cotton, only okra, a malvaceous crop, was found to harbour all the major cotton pests (bollworms, cotton stainers and flea beetles) investigated, in a significantly higher numbers than the other associated food crops except for H. armigera which were significantly more on tomato crops. Furthermore, Hayward (1967) observed that in addition to malvales, various species of Bombacaceae (Ceiba pentandra, Andansonia digitata and Bombax spp.) found in forest zones could act as alternative host plants to bollworms. Unfortunately, forest zone plants and other uncultivated

crops were not sampled during this trial.

Although H. armigera numbers were low during the 1974-75 season (Tables 63 and 64), the populations sampled from the crops showed that cotton interplanted with tomato recorded higher Heliothis numbers than cotton grown as sole crop or interplanted with the other associated food crops. From these associated crops, tomatoes, okra and sorghum carried higher population of H. armigera at both Sites I and II (Tables 63 and 64).

The effects of diversionary crops on pests of cotton have been shown in many cotton growing zones of Africa. Reed (1965) working in Tanzania, demonstrated that the numbers of eggs laid by Heliothis on cotton which was sown next to silking maize, was significantly lower than on the rest of the cotton field; thus maize was acting as diversion crop to Heliothis. However, Reed concluded that a system of trap-cropping for cotton protection could not be feasible in Tanzania because of the rainfall pattern which did not allow sequence of trap crops to be cultivated.

In Botswana, Roome (1970) has shown that of the possible alternative crops which could be used as trap-crops, sorghum appeared to be most attractive to ovipositing H. armigera adults. He also observed that maize and sun-flower were successful trap crops for H. armigera.

A number of examples of the effects of trap crops on cotton pests are well exemplified by Pearson (1958).

Although maize was found as attractive as trap crop for Heliothis in Tanzania (1965), Botswana (1968) and in the lake Province of Tanganyika (1947), the story was the opposite in Sudan (1937) where maize crop failed as a diversionary crop.

In the mixed cropping experiments conducted in Mid-West State, the associated food crops (maize, okra and tomato used in 1972-74 seasons and repeated in 1974-75 season to include sorghum and cowpea) were interplanted with cotton as alternate crops spaced at 45 cm apart on top of ridges (Fig. C) thus showing that each associated crop was behaving exactly like a cotton monoculture, serving to attract insect pests rather than divert them away from cotton. Unlike in the examples of the effect of diversionary crops on insect pests cited in parts of Africa, tomato crops were found in Mid-West State to be most attractive to the ovipositing adults of H. armigera; and thus higher numbers of H. armigera larvae were found on cotton interplanted with tomato and also on tomato crop itself. Okra and sorghum crops were next in the order of attraction for this bollworm. Maize and cowpea came last.

Way (1970) stated 'that from field evidence diversity exemplified by a sequence of host plants may encourage pest build up and be directly responsible for damaging migrations to cotton. Hence, artificially decreasing this diversity can, by removing important alternate host plant, control the pest by dislocating its life cycle. On the

other hand, the maintenance or enhancement of host plant diversity can sometimes provide the all-the-year round continuity of breeding of pests and natural enemies which are needed to maintain effective biological control. For example, the all-the-year round continuity of breeding of H. armigera and its natural enemies in Uganda, in a sequence of many host plants is considered to be responsible for its relative minor pest status on cotton, Coaker (1960)'. Therefore, the presence of tomato, sorghum, okra and maize is thought to be responsible for the low numbers of H. armigera larvae sampled from cotton crops sown either as sole crop or interplanted with any of the other five associated crops during the 1974-75 season.

The success of tomato to attract insect pests would depend on the time of flowering, the latter which invariably depends on time of planting. At the time of peak boll formation in October, rainfall is usually very low in Mid-West State and cannot support tomato at this time when heavy demand for water is required for tomato fruit formation which is most attractive to Heliothis. Hence alternative means of water supply e.g. irrigation must be provided to support tomato development. For sorghum and maize to be effective as trap crops, a succession of them must be sown in order to have some in tassel throughout the period of danger to cotton. Besides, unless dwarf varieties of sorghum or maize is sown, there is the possibility that tall species when intersown, would over-grow cotton and therefore become a

total crop failure as was the case in 1974-75 mixed cropping trial at Site II (Table 76).

Adult cotton stainers first appeared in the crops from about the middle of September before any ripe bolls were present. Peak numbers occurred in October and November. So far, observations and counts taken, showed that the two highest D. superstitiosus populations developed on cotton grown as sole crops and on cotton interplanted with okra during 1972-75 seasons (Table 84). Within this same period the two lowest cotton stainer populations were found on cotton interplanted with tomato and in the four crop mixture (Table 84). The high numbers of D. superstitiosus recorded on okra and on cotton interplanted with okra, is a further confirmation of the ability of malvales to support cotton pests and could thus act as sources of infestation. The low population of D. superstitiosus taken from cotton sown with tomato demonstrates the possibility of intercropping cotton and tomato together to reduce cotton stainers infestation on cotton crops.

Cotton planted as 100% crop population/plot and cotton interplanted with maize consistently recorded the highest flea beetle population per cotton plant for two seasons (Table 85), and only from cotton interplanted with tomato crops were the lowest flea beetles populations recorded through three consecutive seasons. This indicates that tomato was probably repelling flea beetles; and thus could be interplanted with cotton to reduce the incidence of this pest on cotton.

Although cotton crops suffered heavy infestation from flea beetle, they are able to compensate for the leaf damage caused by these pests by additional vegetative growth with optimum rainfall; but if drought occurs, total crop loss could be envisaged from pest attack.

In general the high numbers of insect pests (Tables 82 - 85) recorded on cotton in the treatments of four crop and six crop mixture were indicative of the lower cotton crop population per plot (i.e. 25 and 16.6% cotton/plot) which were more easily or quickly colonized by the available pest species compared to the treatments of 50:50 combination (e.g. cotton/tomato and cotton/maize). Thus it would seem unjustifiable to adopt any system where cotton is grown with more than one crop in which insect infestation could develop to a status causing severe damage to the crops.

The counts of natural enemies mainly C. lunata, P. ferruginea and spiders taken from the crops, showed that the two highest population per plant of spiders were obtained from cotton planted as a monoculture and from cotton interplanted with tomato (Table 88). With C. lunata, the two highest population per cotton plant were recovered from cotton sown as sole crop and from cotton interplanted with okra (Table 86). But P. ferruginea two highest population/cotton were taken from cotton interplanted either with tomato or okra (Table 87). Cotton interplanted with maize and in the four crop mixture recorded the lowest predator population per plant

during the periods of trial (Tables 86, 87 and 88).

The results showed that of the associated crops in the mixtures, tomato and okra interplanted with cotton seemed the most 'preferred' hosts of these natural enemies; which they possibly serve as hibernation or ovipositing sites, from where they migrate to cotton crops to effect biological control of the insect pests.

It is therefore concluded that on the bases of the number of insect pests recorded per cotton plant, the yield of the associated food crops and the degree of hibernation or oviposition opportunities provided to the natural enemies, the results obtained from the three season trials on mixed cropping demonstrate that inter-cropping of cotton especially with tomato and maize and to some extent okra seemed a feasible system which can be harmonized with other techniques in an integrated control programme.

TABLE 82. THE TWO LOWEST AND TWO HIGHEST POPULATIONS PER PLANT OF P. GOSSYPIELLA ON COTTON IN CROP MIXTURE. 1972-75 SEASONS

COTTON COMBINED WITH:-

	YEAR	COTTON	SORGHUM	COWPEA	MAIZE	OKRA	TOMATO	FOUR CROPS	SIX CROPS
	1972-3	↑	-	-	↓	-	↓	↑	-
	1973-4	↑	-	-	-	↓	↓	↑	-
SITE I	1974-5	↑	-	↓	↓	-	-	-	↑
SITE II	1974-5	↑	-	↓	↓	-	-	-	↑

↓ = Lowest per plant

↑ = Highest per plant

TABLE 83 . THE TWO LOWEST AND TWO HIGHEST POPULATIONS PER PLANT OF E. BIPLAGA ON COTTON IN CROP MIXTURE. 1972-75 SEASONS

COTTON COMBINED WITH:-

	YEAR	COTTON	SORGHUM	COWPEA	MAIZE	OKRA	TOMATO	FOUR CROPS	SIX CROPS
	1972-3	↑	-	-	↓	-	↑	↓	-
	1973-4	↑	-	-	↑	-	↓	↓	-
SITE I	1974-5	↑	-	-	↓	-	↓	-	↑
SITE II	1974-5	↑	-	-	↓	-	↓	-	↑

↓ = Lowest per plant

↑ = Highest per plant

TABLE 84. THE TWO LOWEST AND TWO HIGHEST POPULATIONS PER PLANT OF D. SUPERSTITIOSUS ON COTTON IN CROP MIXTURE. 1972-75 SEASONS

COTTON COMBINED WITH:-

	YEAR	COTTON	SORGHUM	COWPEA	MAIZE	OKRA	TOMATO	FOUR CROPS	SIX CROPS
	1972-3	↑	-	-	-	↑	↓	↓	-
	1973-4	↑	-	-	-	↑	↓	↓	-
SITE I	1974-5	↑	↓	-	-	-	↓	-	↑
SITE II	1974-5	↑	↓	-	↓	↑	-	-	-

↓ = Lowest per plant

↑ = Highest per plant

TABLE 85 . THE TWO LOWEST AND TWO HIGHEST POPULATIONS PER PLANT OF FLEA BEETLES (PODAGRICA SPP) ON COTTON IN CROP MIXTURE. 1972-75 SEASONS

COTTON COMBINED WITH:-

	YEAR	COTTON	SORGHUM	COWPEA	MAIZE	OKRA	TOMATO	FOUR CROPS	SIX CROPS
	1972-3	↑	-	-	↑	↓	↓	-	-
	1973-4	-	-	-	↑	↑	↓	↓	-
SITE I	1974-5	↑	-	-	↓	-	↓	-	↑
SITE II	1974-5	↓	-	-	↓	↑	-	-	↑

↓ = Lowest per plant

↑ = Highest per plant

TABLE 86. THE TWO LOWEST AND TWO HIGHEST POPULATIONS PER PLANT OF C. LUNATA ON COTTON IN CROP MIXTURE. 1972-75 SEASONS

COTTON COMBINED WITH:-

	YEAR	COTTON	SORGHUM	COWPEA	MAIZE	OKRA	TOMATO	FOUR CROPS	SIX CROPS
	1972-3	↑	-	-	↓	↑	-	↓	-
	1973-4	↑	-	-	↓	↑	-	↓	-
SITE I	1974-5	↑	-	-		↓	↓	-	↑
SITE II	1974-5	↑	-	-	↓	↓	-	-	↑

↓ = Lowest per plant

↑ = Highest per plant

TABLE 87. THE TWO LOWEST AND TWO HIGHEST POPULATIONS PER PLANT OF P. FERRUGINEA ON COTTON IN CROP MIXTURE. 1972-75 SEASONS

COTTON COMBINED WITH:-

	YEAR	COTTON	SORGHUM	COWPEA	MAIZE	OKRA	TOMATO	FOUR CROPS	SIX CROPS
	1972-3	↓	-	-	↓	↑	↑	-	-
	1973-4	↓	-	-	↓	-	↑	↑	-
SITE I	1974-5	↓	-	↓	-	↑	-	-	↑
SITE II	1974-5	-	↓	↓	↑	↑	-	-	-

↓ = Lowest per plant

↑ = Highest per plant

TABLE 88 . THE TWO LOWEST AND TWO HIGHEST POPULATIONS PER PLANT OF SPIDERS ON COTTON IN CROP MIXTURE. 1972-75 SEASONS

COTTON COMBINED WITH:-

	YEAR	COTTON	SORGHUM	COWPEA	MAIZE	OKRA	TOMATO	FOUR CROPS	SIX CROPS
	1972-3	↑	-	-	↓	-	↑	↓	-
	1973-4	↑	-	-	-	↓	↑	↓	-
SITE I	1974-5	↑	↓	↓	-	-	-	-	↑
SITE II	1974-5	-	↓	-	↑	-	↓	-	↑

↓ = Lowest per plant

↑ = Highest per plant

SECTION V

ECONOMICS OF SPRAYING COTTON COMPARED WITH UNSPRAYED MIXED CROPPING

1. INTRODUCTION

The incentive of the subsistent farmer for growing any cash crop is geared to the returns he makes. This return depends almost entirely upon three major factors, namely the inputs involved, labour force and the market price offered for the produce. Therefore in recommending a control programme to the farmer these underlying factors must be taken into consideration. In the study of an approach to integrated control of cotton pests in the Mid-Western State of Nigeria, three different factors have been examined viz:- Conventional Spraying, Ultra-Low Volume Spraying and Mixed Cropping. The yield and revenue accruing from the use of these methods of control either singly or combined should determine to a large extent whether each is acceptable or not acceptable to the farmer.

Although the cropping systems used in the study were not developed sufficiently or studied over a sufficient number of years to obtain conditions to make it possible to do a comprehensive economic analysis but, nevertheless, the data obtained provide a basis for elaborating techniques and for assessing the future work that needs to be done to determine what is economically justified.

The present study compared the profitability of cultivating sprayed sole cotton crops with an unsprayed

cotton mixed cropping with a hope to recommending the more likely beneficial system to the farmer.

2. METHOD

The project was carried out at Ilele Government Farm Centre. Data for the cotton sole cropping were collected from Sections II and III, and those for the cotton mixtures from Section IV. Unlike in the cotton sole crop the cotton mixtures were not sprayed. Costs of seeds sown, fertilizer applied, the various insecticides and the labour involved in spraying are given in Table 89. The labour cost for establishing the land (i.e. cost of clearing, weeding, hoeing and burning including harvesting etc.) is not considered here, as this varies with the yield, which itself depends on weather and efficiency of the farmer. The family unit (including wives, children and young relatives) which forms the nucleus of the labour force at the disposal of most subsistent farmer is not costed. Besides, land was not a limiting factor.

3. RESULTS

(i) Comparison of insecticides

The use of endosulfan 50 wettable powder instead of carbaryl 85 w.p. increases the cost of spraying by N1.20 per hectare based on prices in the year 1973-74. Similarly, using endosulfan 25 ULV formulation also put in an increase of N3.50 per hectare (Table 90). These overall increases could be more or less especially if scouting for insect pests is done as a basis for judicious

spraying e.g. as practised in Malawi (Matthews, 1968).

Table 91 shows that the highest returns from one hectare of sprayed cotton was obtained from carbaryl 85 w.p. treatment. This was followed by the ULV endosulfan and endosulfan 50 w.p. treatment in that descending order. Although the difference in returns between carbaryl and endosulfan ULV treatment was not significant, safety devices are required for the endosulfan ULV formulation to be used e.g. face masks, protective gowns, gloves and boots would be needed; and so these can be an added overhead cost to spraying.

Whilst therefore, ULV endosulfan is promising there are difficulties which however could be minimized if the safer carbaryl is used at ULV; a ULV carbaryl formulation is now available.

(ii) Comparison of inputs and returns from sprayed sole cotton and unsprayed cotton mixed cropping

The costs and returns involved in growing one hectare of a sprayed sole cotton and unsprayed mixed cotton crop are shown in Table 91 . For convenience, these items are presented under three sub-headings:- Inputs, Gross Returns and Difference. Under sole cotton crop system, cotton was cultivated as 100% crop population/plot and in the mixed cropping, it was sown as 50% crop population/plot (Section IV).

Table 91 indicates that the lowest input involved in growing one hectare of cotton was obtained

from the treatment where sole cotton crops were sprayed with carbaryl 85 w.p. The total involvement was approximately N29. From the cotton mixtures, cotton/tomato and cotton/maize combinations gave the least inputs of approximately N7 per combination, and thus constitute 25% of the least total inputs of cultivating sole cotton crops sprayed with insecticides (Table 91). Conversely, the highest revenues from growing one hectare of cotton singly or in mixtures were realised from cotton/tomato, cotton/maize and cotton sole crop sprayed with carbaryl where the least was expended in the two systems.

Therefore, on the bases of input, yields and revenue, cotton mixtures especially, the cotton/tomato, cotton/maize and cotton/okra seemed the more promising systems than sole crop cotton; but sole crop cotton sprayed with carbaryl gave comparable revenue to either cotton/tomato or cotton/maize and would therefore be advocated. However, a combination whereby cotton in a mixed cropping system is sprayed with carbaryl would be most promising, and therefore requires further examination.

TABLE 89. COSTS OF SEEDS AND SPRAYING OF INSECTICIDES (EXCLUDING SUBSIDIES)

SOLE COTTON CROP					MIXED CROPPING						
With Knapsack Sprayer			With ULVA Spray		seeds						
		₦/ha for 6 sprays		₦	CROP COMBINATIONS	COSTS OF SEEDS/kg/ha					₦
i)	Labout at N0.89 per 7 hour day	2.20	15 litre ULV endosulfan @ N1.50/litre	22.50	Cotton + Sorghum	11.3 kg	seed/ha @	3.4	kobo/kg		0.38
ii)	Carbaryl 85 w.p.	18.00	16 batteries (PP 12 @ N0.2 each) (enough for at least 1.3 ha)	3.20		"	"	13.2	"		1.50
iii)	Depreciation of sprayer over 3 years (cost of sprayer N25) at 2 ha (x 6 sprays)	4.20	Depreciation of sprayer over 3 years (cost N13) at 2 ha (x 6 sprays/ season)	2.20	Cotton + Coupea	"	"	3.4	"		0.38
						"	"	35.3	"		4.00
iv)	Seeds 22.5 kg/ha at 3.4 kobo/kg	0.68	Seeds 22.5 kg/ha @ 3.4 kobo/kg	0.68	Cotton + Maize	"	"	3.4	"		0.38
						"	"	"	"		0.38
					Cotton + Okra	"	"	"	"		0.38
						"	"	112.4	"		3.00
					Cotton + Tomato	"	"	3.4	"		0.38
	TOTAL =	25.1	TOTAL =	28.6		"	"	27.1	"		0.6

TABLE 90. COMPARATIVE COSTS OF SPRAYING PROGRAMMES, EACH COMPRISING SIX APPLICATIONS PER HECTARE IN MID-WESTERN STATE OF NIGERIA 1973-74 SEASON

	Extra Cost in Naira (₦)$^{(\bar{x})}$
Using the Standard Recommended Carbaryl 85 w.p. at a cost of ₦25.1	
Using Endosulfan 50 w.p. instead of Carbaryl 85 w.p. (₦26.30)	1.20
Using ULV Endosulfan 25 instead of Carbaryl 85 w.p. (₦28.60)	3.50

($\bar{x}$) Extra cost of the alternative programme compared with the cost (₦25.1) of the Carbaryl 85 used in the State.

TABLE 91 . COMPARISON OF COSTS OF INPUTS AND RETURNS FROM GROWING ONE HECTARE OF COTTON

	SOLE CROP COTTON			COTTON MIXTURES				
	CONVENTIONAL SPRAY		ULV SPRAY	COTTON MIXED CROPPING				
	Carbaryl 85 w.p.	Endosulfan 50 w.p.	ULV Endosulfan 25	Cotton + Sorghum	Cotton + Cowpea	Cotton + Maize	Cotton + Okra	Cotton + Tomato
1. INPUTS (₦)								
Spraying	24.42	27.42	35.34	-	-	-	-	-
Seeds	0.68	0.68	0.68	1.88	4.38	0.76	3.38	0.98
Fertilizer:- Calcium Ammonium Nitrate	4	4	4	2	2	2	2	2
15 : 15 : 15 N : P : K	-	-	-	4	4	4	4	4
TOTAL	29.1	32.1	40.02	7.88	10.38	6.76	9.38	6.98
2. GROSS RETURNS								
Yield Seed Cotton kg/ha	(935)	(833)	(959)	(225)	(179)	(300)	(758)	(467)
Value of Cotton (₦)	123	110	127	30	24	40	100	62
Yield of other crops kg/ha				(204)	(0)	(396)	(50)	(1975)
Value of other crops (₦)				14	0	62	5	240
TOTAL	123	110	127	44	24	102	105	302
3. DIFFERENCE (Gross returns - Inputs)	94	78	87	36	14	95	96	295

SECTION VI

LABORATORY EXPERIMENTS ON THE EFFECTS OF ULV SPRAY FORMULATION, MIXED CROPPING AND NATURAL ENEMIES ON PESTS OF COTTON

Experiment I.

Laboratory tests to evaluate the effect of ULV endosulfan sprays on cotton bollworms: (*P. gossypiella*, *E. biplaga* and *H. armigera*)

1. INTRODUCTION

Several investigations have reported results of field experiments on toxicity of ULV insecticides to insect pests of cotton; however, little work of this nature has been conducted in the laboratory. Laboratory bioassays together with field trials (Matthews, 1966; Tunstall and Matthews, 1966) showed that carbaryl and DDT were the most effective insecticides for the control of red bollworm (*Diparopsis castenea* Hmps) and American bollworm (*Heliothis armigera* Hb) respectively.

Beeden (1974) has concluded from field studies that ULV formulations were very effective against pest complex attacking cotton in Northern States of Nigeria. Usenbo (1974b) observed that ULV endosulfan was effective against *A. gossypii* and *D. superstitiosus* in the Mid-Western State. Further assessments of ULV endosulfan formulation using laboratory bioassays are discussed in this Section, with particular reference to

dosage variation. The bioassay tests, conducted at Irrua farm centre (Site II) laboratory, were used to assess the toxicity of ULV endosulfan insecticide sprayed on cotton in the field against P. gossypiella, (Saund); E. biplaga, (Wlk) and H. armigera, (Hb).

2. MATERIALS AND METHOD

Mostly second instar larvae of P. gossypiella, E. biplaga and H. armigera were collected from cotton and tomato crops in the mixed cropping experiment where no insecticides were applied. Larvae of the different species are recognised by their characteristic colour. The second instar larva of P. gossypiella is distinctive by being yellowish, with a prominent dark brown head, becoming creamy-white with dark brown to chestnut-brown head. Those of E. biplaga are grey-brown with dark brown markings, paler dorsally, with characteristic spines in the segments; head and shield dark brown; hairs are almost black. Later instars are similar in colour but colours are non permanent. The larvae of H. armigera vary greatly in colour, from greenish to brown, some almost uniform in colour, others with distinct stripes.

A simple method of treatment was adopted, using plastic containers. Two openings were made, one each in the shorter opposite sides of plastic containers measuring 12 x 9 x 6 cm high. One opening was covered with fine linen using an adhesive (Evostick) to allow air into the container; the other end carried a "six inch" long test tube filled with water to half the capacity, and then



Fig. 49. LABORATORY BIOASSAY TESTS USING P. gossypiella, E. biplaga and H. armigera

plugged with fine cotton wool. The plugged end pushed into the container and the cotton wool absorbed water which served to cool the chamber and its contents.

After spraying with the different ULV endosulfan rates in the field, bolls or flowers were collected from the plots and five bolls or flowers are placed in each of the plastic containers. Ten of each species of bollworm were introduced into the plastic containers. Each treatment was replicated three times (Fig. 49).

In this study, two dosage levels of insecticide were compared, the highest and the lowest ULV endosulfan rates (0.75 and 0.19 kg a.i/ha). All tests were conducted at room temperatures ranging from 24°C to 28°C. The mortality was recorded every 24 hours throughout a seven day period.

3. RESULTS

As can be seen in Table 92 and Figures 50 and 52 ULV endosulfan applied at the higher rates gave consistently higher kills of the bollworms. Although the highest control kill was recorded in H. armigera (Figure 52) at the 6th and 7th day of exposure to the treated bolls, the lower ULV endosulfan rate (0.19 kg a.i/ha) applied did not show any effect on H. armigera confined till after the 4th day when the number of H. armigera killed remained at 10%. As against this result, E. biplaga confined to bolls treated with 0.19 kg a.i/ha of ULV endosulfan gave a kill of 20% after 24 hours of exposure, and 70% kill at the

end of the 7th day; thus indicating E. biplaga to be more susceptible to ULV endosulfan treatment at this lower rate of application. However, there was consistent difference shown in the % kill between the higher and lower rates of ULV treatments throughout the period of experiment (Table 92 , Fig. 50).

Higher % kill were recorded in the higher ULV endosulfan rate applied to H. armigera and E. biplaga than P. gossypiella (Table 92 and Figs. 50 - 52), and at the lower rate of application, only E. biplaga bollworm showed more % kill than H. armigera and P. gossypiella; and at the 5th day of exposure % kill recorded from the latter two species (10%) was similar but less than in E. biplaga (Table 92). The high cumulative % kill obtained in H. armigera and E. biplaga at the higher dosage rate suggests that both species are more susceptible to control by ULV endosulfan treatment than P. gossypiella.

During the 2nd day of exposure, 20% of P. gossypiella were killed in 0.75 kg/ha ULV endosulfan against zero percent kill recorded in 0.19 kg/ha treatment; and only at the 5th day was 10% kill of P. gossypiella observed in the 0.19 kg/ha treatment, and this did not change till the experiment was terminated.

Thus at the 6th and 7th day there was a difference of 10% kill of P. gossypiella between the higher and lower endosulfan rates sprayed into the bolls (Table 92). But with E. biplaga the difference was 20%, and in H. armigera

90% kill (Table 92 , Figs. 50 - 52). Thus further confirming that E. biplaga was susceptible and that H. armigera was even more susceptible to endosulfan control.

The results obtained from the bioassay tests may not necessarily be the same on the field. Weather conditions, crop development, droplet size and distribution of the chemicals on the crop; size and age of the bollworms and their feeding habits are factors that could further influence the % kill by the toxicant in the sprays.

The higher endosulfan rate gave a good kill especially in the case of E. biplaga, that could be further studied in the field. The 100% kill observed in H. armigera is perhaps not the ideal needed in integrated control programme. Such situations may affect the natural enemies that integrated control is out to conserve but could otherwise be affected through direct mortality or by starvation through total extinction of the natural enemies food by the chemical sprays.

Therefore a further investigation into the higher, intermediate and the lower rates of the ULV endosulfan may help define the ideal dosages that may be included in integrated control system.

The bioassay results agree with those obtained during field application (Section III) where ULV endosulfan applied at the rate of 0.75 kg a.i/ha and not 0.19 kg significantly ($P < 0.05$) reduced the bollworm (E. biplaga and P. gossypiella) population compared to the untreated

controls during spray and post-spray periods. There was no difference in E. biplaga numbers between untreated controls and endosulfan sprayed at 0.19 kg a.i/ha (Table 31 , Section III).

Although no statistical analysis was performed with the bioassay data, the results (Table 92) showed that the cumulative % kill recorded from 0.75 kg/ha treatment were higher than the kills obtained from 0.19 kg/ha for all the bollworms tested. However, kills from 0.19 kg/ha treatment were clearly shown to be higher than in untreated controls especially in the case of E. biplaga and to some extent in P. gossypiella and H. armigera.

TABLE 92. CUMULATIVE PERCENTAGE KILLS OF BOLLWORM IN A LABORATORY BIOASSAY TEST IN A SPRAYED AND UNSPRAYED COTTON

Treatment	Cumulative percentage kill of *E. biplaga*						
	Days of exposure						
	1	2	3	4	5	6	7
0.75 kg a.i/ha	30	60	70	70	80	90	90
0.19 kg a.i/ha	20	40	60	60	70	70	70
Untreated Control	0	0	0	0	0	0	0

Treatment	Cumulative percentage kill of *P. gossypiella*						
	Days of exposure						
	1	2	3	4	5	6	7
0.75 kg a.i/ha	0	20	20	20	20	20	20
0.19 kg a.i/ha	0	0	0	0	10	10	10
Untreated Control	0	0	0	0	0	0	0

Treatment	Cumulative percentage kill of *H. armigera*						
	Days of exposure						
	1	2	3	4	5	6	7
0.75 kg a.i/ha	0	30	50	50	60	100	100
0.19 kg a.i/ha	0	0	0	0	10	10	10
Untreated Control	0	0	10	10	10	10	10

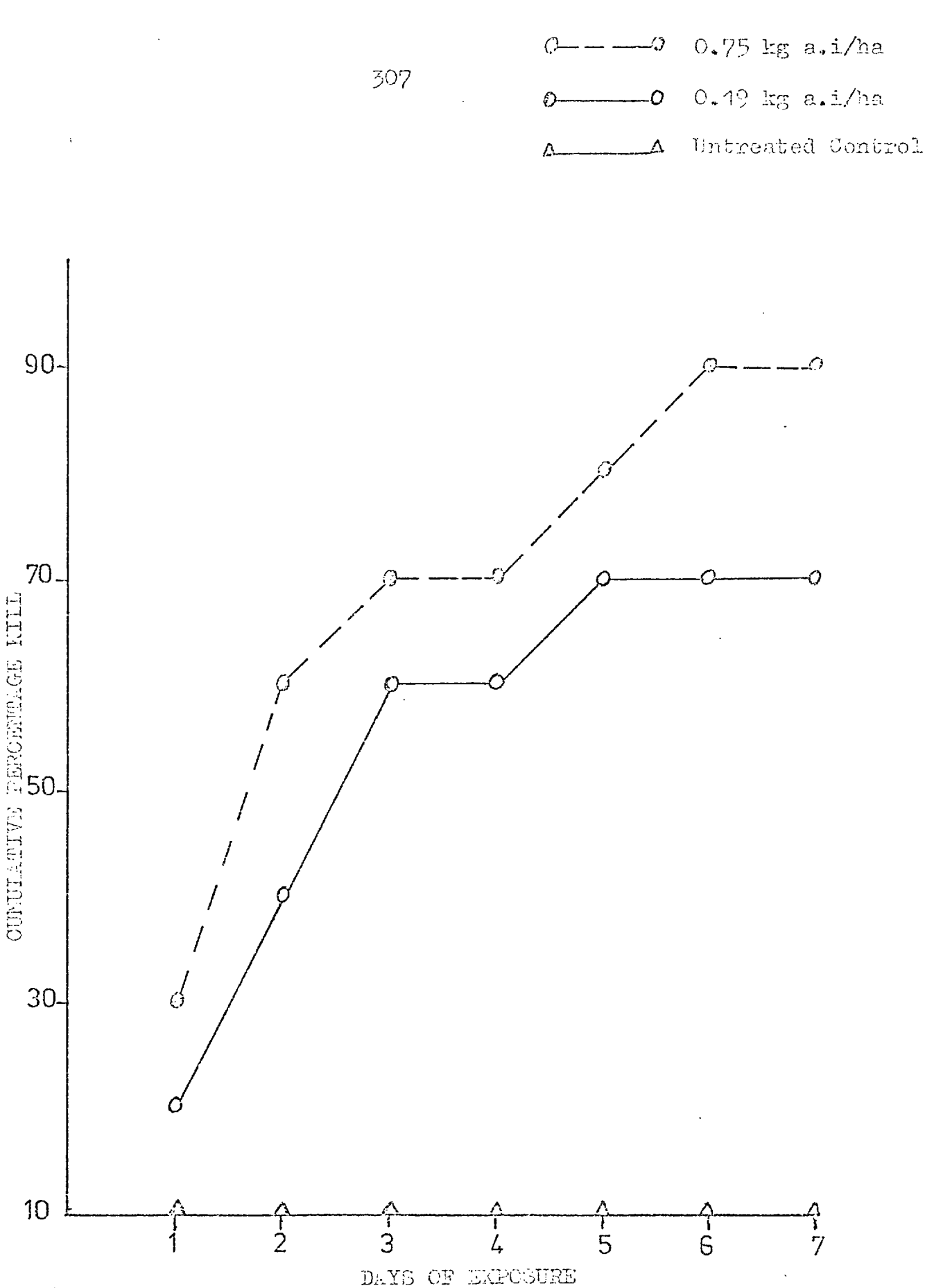


Fig. 50. KILLS OF Earias biplana ON ULV ENDOSULFAN TREATED BOLLS

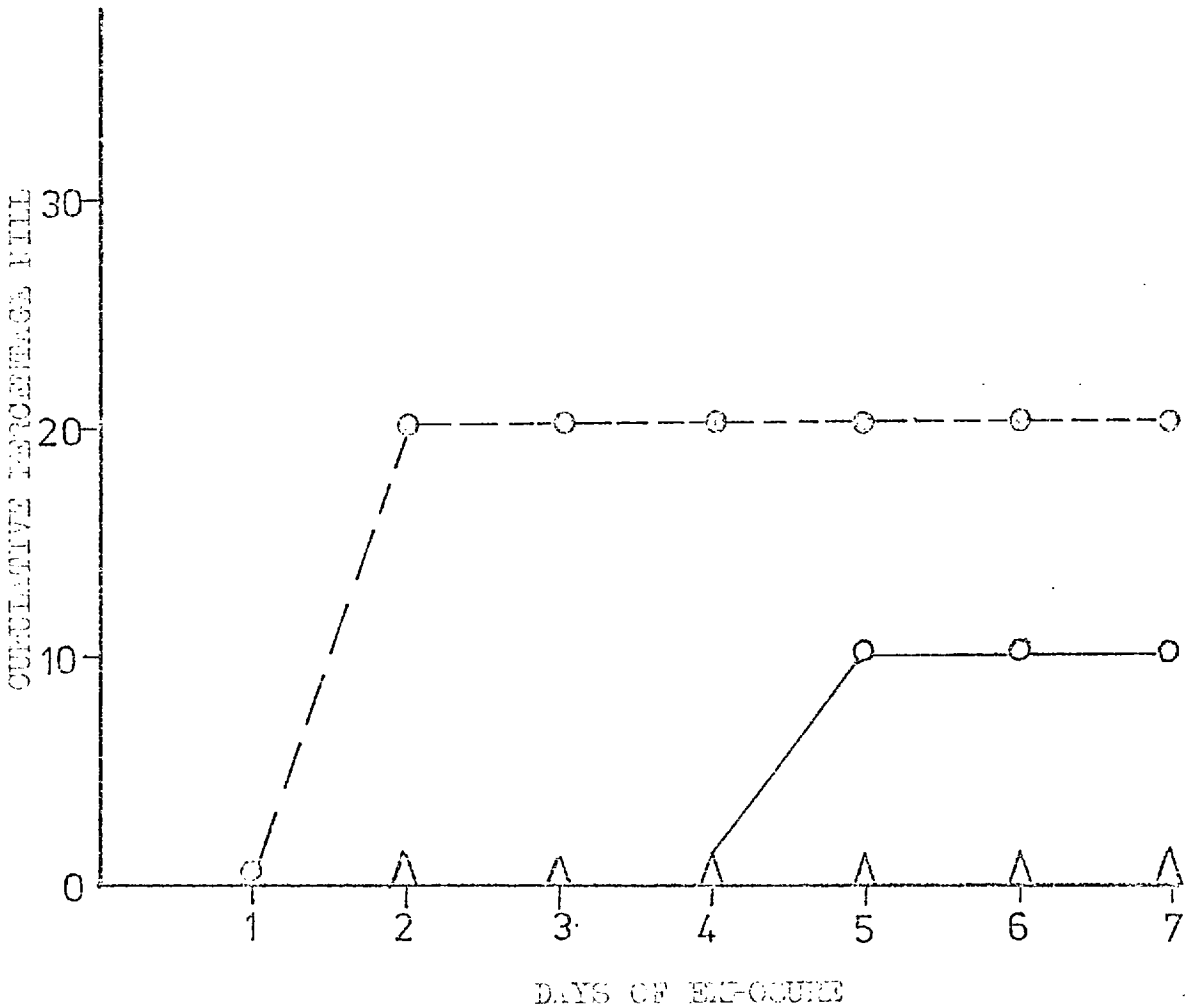


Fig.51. KILL OF *P. gossypiella* ON ULV ENDOSULF-N TREATED BOLLS

KEY

o - - - o 0.75 kg a.i/ha

o ——— o 0.19 kg a.i/ha

Δ ——— Δ Untreated Control

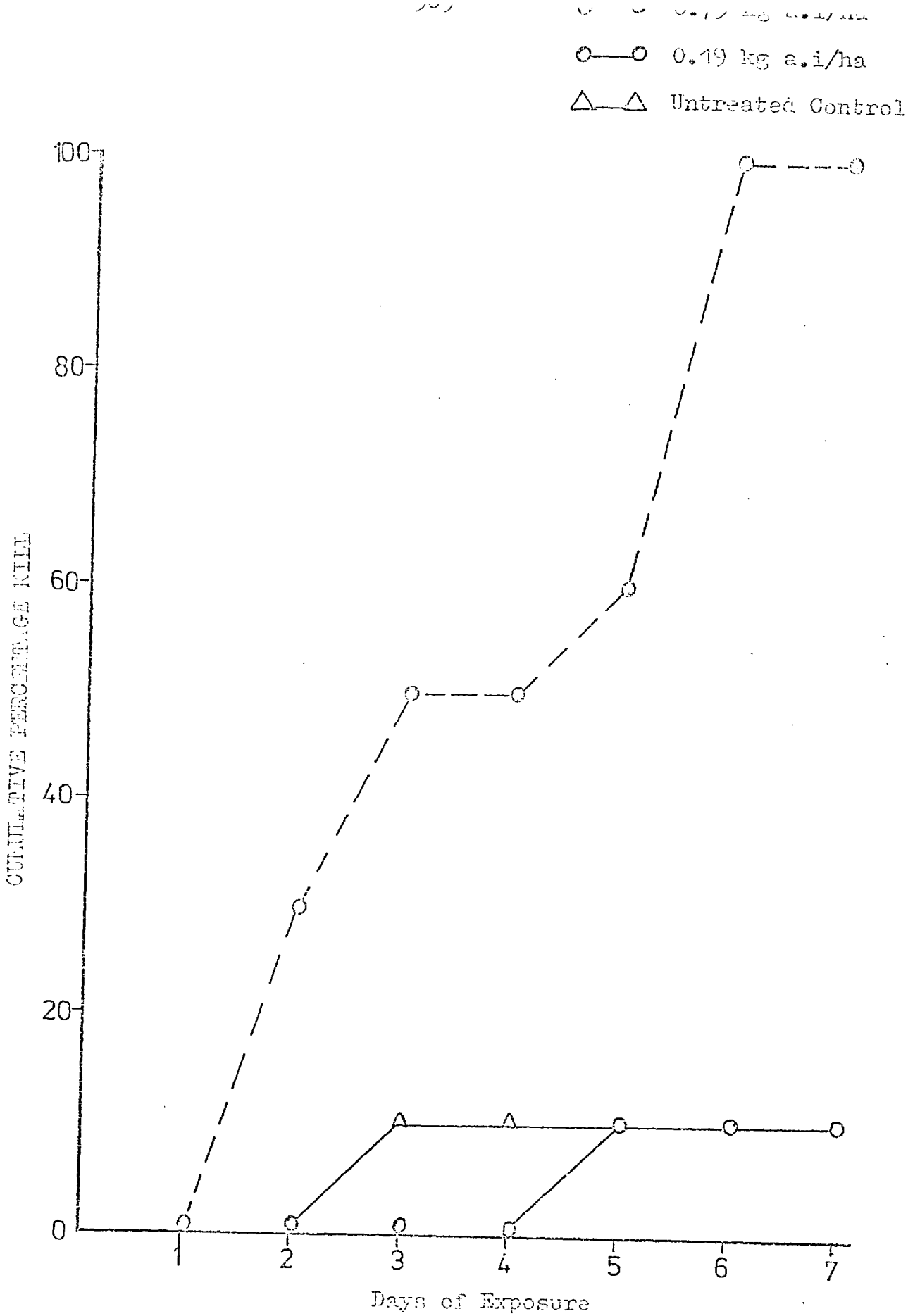


Fig. 52. KILLS OF H. armigera ON UIV ENDOSULFAN TREATED BOLLS.

Experiment II.

Effects of natural enemies on cotton aphids (Aphis gossypii)

1. INTRODUCTION

Methods cited (Beingolea, 1970; Falcon and Smith, 1973) for the evaluation of the efficiency of natural enemies of cotton pests include:-

1) Laboratory biological studies to determine the effectiveness of a predator or parasite by such criteria as the shortness of its life cycle in relation to that of its host or prey, and its reproductive and predation capacity;

2) Cage studies, comparing the fate of host or prey populations in the presence or absence of a predator or parasite;

3) Field and experimental studies involving reduction or exclusion of natural enemies through pesticide treatments (insecticide check);

4) Routine field observations which through the study of the collected data in pest infestations predator densities and parasitization level allow for some evaluation of the action of natural enemies involved;

5) The application of regression analysis to data collected through routine field

observation (e.g. within technical assistance programme on integrated control of cotton pests as practised in Peru and elsewhere);

6) Life tables or life budgets, prepared with field data collected according to a given scheme. The analysis of such tables or budgets will allow the identification of mortality factors and give insight into the impacts of various natural enemies.

In the present experiment an attempt has been made to compare the fate of measured cotton aphid population confined with known natural enemies.

2. MATERIALS AND METHODS

Plastic containers were used which were like those for the bioassay tests. Aphids, and the 4th instar larvae of the predators Chilomenes lunata and Platynaspis ferruginea were collected from untreated cotton plots.

Aphids and the predators were put on to a fresh cotton leaves placed in the plastic container by means of a carmel hair brush. Each plastic container, contained 20 medium sized aphids confined with one each of either predators. Fresh aphids and a fresh cotton leaf were supplied each 24 hours until the larva pupated. Each experiment was set up under the prevailing room temperature as per the bioassay tests; and treatments were replicated three times. The mean numbers of aphids

consumed per 24 hour period are represented in Table 93 .

3. RESULTS

When one Chilomenes lunata and one Platynaspis ferruginea were separately confined in small plastic containers containing a cotton leaf infested with A. gossypii, they induced notable reduction of the aphid population eating a daily average of 12 and 6 respectively.

The results indicated untreated C. lunata as a more efficient predator of aphids than P. ferruginea, since it consumed twice as many aphids as did P. ferruginea. Both C. lunata and P. ferruginea have the advantage for being able to feed an aphid during their larval and adult stages.

Both C. lunata and P. ferruginea are found in large numbers on food crops in the Mid-Western State of Nigeria; and, if properly supplemented through the use of desirable chemicals, could be nicely included in an integrated control programme.

More needs to be known about their feeding habits as adults and about their alternate sources of food besides aphids on cotton.

TABLE 93. APHID-PREYING CAPACITY OF UNTREATED C. LUNATA AND P. FERRUGINEA IN A 24 HOUR PERIOD

Predators	Nos. of aphid fed to each predator per 24 hr.	No. of aphids eaten per predator
C. lunata	20	12
P. ferruginea	20	6

Experiment III.

Repellent effect of tomato on flea beetle (Podagrica spp.)

1. INTRODUCTION

Earlier results from 1972-74 mixed cropping trials demonstrated that cotton interplanted with tomato received the minimum infestation by Podagrica species. It was then decided to investigate in detail the possible repellent characteristic suspected to be responsible for the low Podagrica attack on cotton-tomato mixture.

2. MATERIALS AND METHODS

4.8 and 2.4 gms of tomato leaves collected from unsprayed plots were weighed out, squashed in a homogenizer and each made up to one litre in a distilled water. 4 potted cotton plants, were placed in a large wire netting cage (300 cm x 300 cm x 150 cm). Two of the potted plants were each sprayed with the two concentrations made from tomato leaves separately. 45 flea beetles were gently collected from unsprayed plots and released onto the four sprayed potted cotton; and readings of the number of the flea beetle retained on the sprayed plants and the numbers repelled were taken after 1 hour (Table 94). This cage trial was repeated twice. A further third trial was conducted directly on cotton plants in the field. Results are shown in Table 94 .

3. RESULTS

Results from the potted plants and field cotton demonstrated that squashed tomato leaves sprayed onto

cotton directly repelled Podagrica spp. from the crops. The higher concentration of tomato leaves repelled most flea beetle from cotton.

This repellent effect is probably due to olfactory response from the Podagrica species, and was thus responsible for the lower Podagrica population and hence lower flea beetle attack on cotton and tomato inter-cropped. This characteristic is worth investigating further for inclusion into an integrated control programme.

TABLE 94. PERCENTAGE FLEA BEETLES (PODAGRICA SPP.) REPELLED BY COTTON PLANTS SPRAYED WITH TOMATO LEAVES

Cage Test I.

Treatment	No. of flea beetle released	No. of flea beetle collected from sprayed plant	% repelled
4.8 gm Tomato leaf	90	7	92
2.4 gm " "	90	20	78

Cage Test II.

4.8 gm Tomato leaf	90	13	85
2.4 gm " "	90	24	73

Field Test

4.8 gm Tomato leaf	135	34	82
2.4 gm Tomato leaf	135	57	58

SECTION VII

GENERAL DISCUSSION

Chemical sprays and mixed cropping have been examined as a means of reducing the damage caused by insect pests of cotton. The implications of various attributes of these systems in terms of their possible effects on the abundance of pests, their natural enemies and yield of cotton crop are discussed to assess which system might be effective and practical for an integrated pest control programme.

1. Factors which affect the distribution of cotton insect pests during the growing season

Fluctuations of numbers of cotton pests observed during the trials, for example at the preliminary studies (Usenbo, 1974b) and in the main studies (Figure 29 , page 317a) are well known (Pearson, 1958).

Pearson (1958) indicated that such fluctuations are probably due to varying and interacting effects of weather conditions, host plants and natural enemies, and to effects of diapause and time and length of the cotton season.

Rainfall can have both indirect and direct effects on pests. When there is sufficient rainfall during the growing season, especially at boll formation, plant growth may be such that sufficient food is available for the available pests and perhaps even for the plants to produce good crops despite pest attack. Changes in humidity may

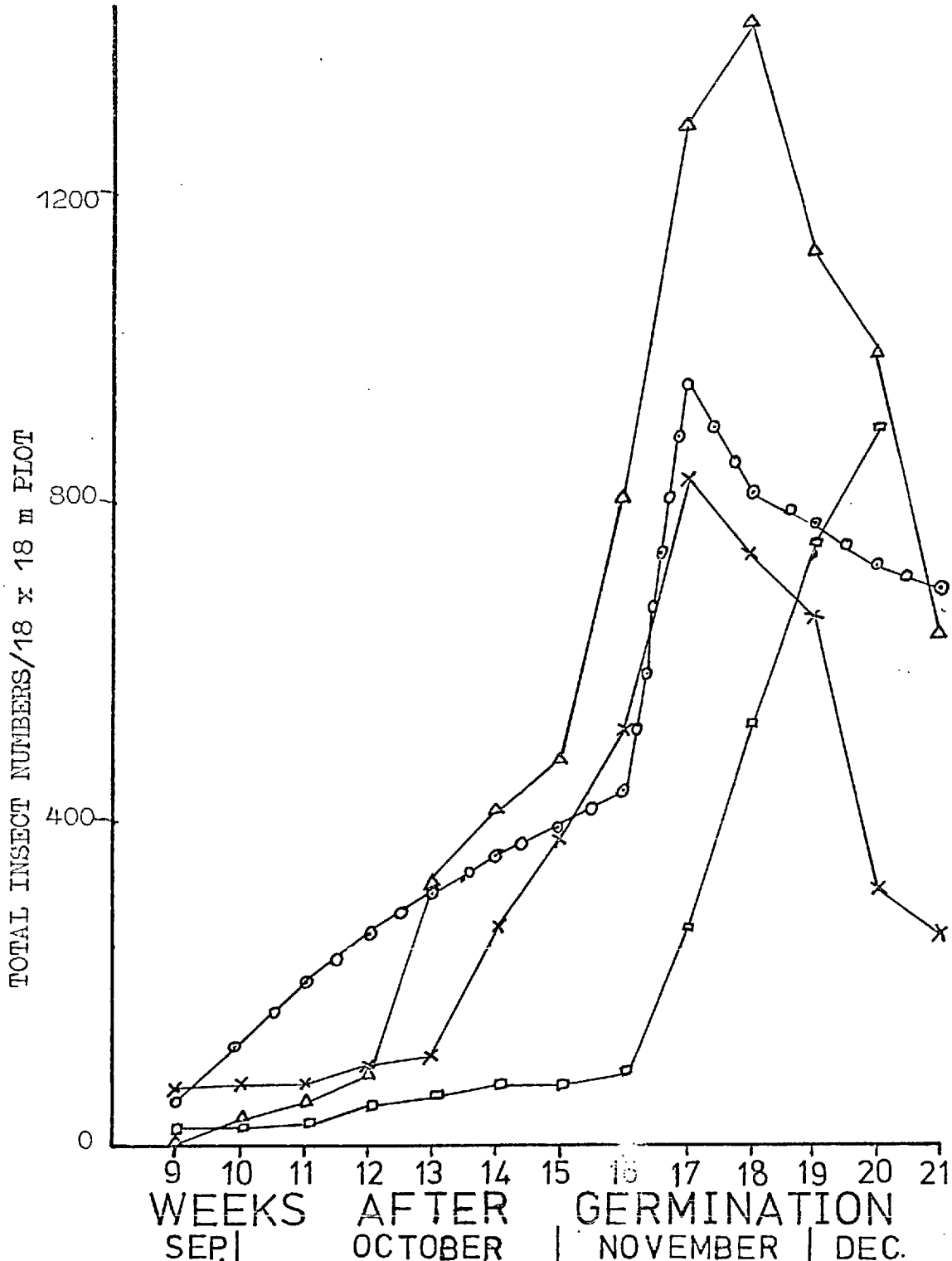


Figure. 29. Cotton pests in untreated plots during 1974–75 season in the ULV Endosulfan and Conventional Volume Carbaryl spray trial. Sites I & II.

KEY

- Mean no Pectinophora gossypiella
- Mean no Earias biplaga
- Mean no Dysdercus superstitiosus
- Mean no Aphis gossypi

affect the survival of pests. Thus early morning humidity allows first instar bollworms to find food before they desiccate. However, humidity could also enhance development of pathogenic fungi which may help reduce incidence of some pests.

The presence of other host plants may provide food on which the pests may 'carry over' between seasons and also provide food early in the cotton season before significant cotton is available.

Natural enemies can also exert a high degree of influence over cotton pests e.g. the adults and larvae of coccinellids (C. lunata) are important predators of A. gossypii, Bracon brevicornis is a predator of E. biplaga and the Reduviid Phonoctonus nigrofasciatus of D. superstitiosus (Pearson & Maxwell Darling, 1958). All these factors weather, host plants, and natural enemies no doubt contributed to the seasonal distribution of A. gossypii, E. biplaga, P. gossypiella and D. superstitiosus observed in the experimental cotton plots.

Superimposed on these, there are changes in population of pests in the treated plots associated with insecticide spraying.

2. Patterns of cotton insect control in Mid-Western State of Nigeria

The production of cotton in an agro-ecosystem can, according to Smith (1969), be characterised by five different stages, namely, the subsistence, exploitation,

crisis, disaster and integrated control stages.

Matthews (1974) has commented that in changing from subsistence agriculture to higher yielding 'exploitation stage', for example in Central America, new cotton varieties were introduced and sprayed heavily with insecticides. High dosages of a mixture of chemicals like toxaphene, DDT and Methyl Parathion were used against the pest complex; and resistance to insecticides developed. Subsequently into crisis stage; the cost of chemical sprays escalated so it was not profitable to grow cotton and this invariably led to the disaster stage. A similar situation was observed in Peru. 5% DDT, 3% BHC and mixtures of both with sulphur in a 3-5-40 formula, and 20% toxaphene were used in large amounts to control bollworms, aphids and other pests (Barducci, 1972). Consequently increases in yield were obtained. However after the first three years of chemical control, resistance problems set in, and heavy crop losses were sustained. As a result of this, the integrated control approach has been introduced in parts of Central America and in Canete Valley of Peru.

In Mid-Western Nigeria, farmers generally lack funds to buy chemicals to spray their farms; hence most of their crops remain at the subsistence stage. Although Government subsidizes the cost of buying sprayers, chemicals and seeds relatively few farmers take advantage of this. Loan schemes for fertilizer and the hire of tractors are also available, but not adequately utilized.

Farmers who cannot operate under the supervision of the government extension staff (i.e. follow recommended improved systems) cannot secure this loan for their farm operations. Thus with few chemicals used the "crisis stage" cannot yet be envisaged in Mid-Western Nigeria at present.

To avoid a "crisis stage" occurring in Nigeria, emphasis should be on integrating the use of chemicals with other suitable control measures. For example, the enforcement of "closed season" and the use of the high yielding cotton variety (Allen 26J) resistant to certain pests, notably jassids (Empoasca spp) and the disease bacterial blight (Xanthomonas malvecearum) (Pearson, 1958). These important control measures have been well established in the Mid-Western State.

(i) Choice of insecticides

A cheap and safe insecticide is required that is effective against the key pests reducing yields. Owing to the diversity of insect pests (i.e. bollworms, aphids and cotton stainers etc.) it is difficult to select a single chemical, so careful screening of a range of insecticides is needed to determine which approached most nearly the required specifications. Some chemicals tested (Section II) were locally available and are effective against cotton pests elsewhere. The basis of the insecticide spraying schedule was that used in Northern and Western Nigeria in which six sprays are applied at weekly intervals beginning nine weeks after sowing, although in

the first trial only four sprays were applied.

In the present trials in Mid-Western Nigeria, carbaryl formulated as a wettable powder proved very effective against bollworms, cotton stainers and aphids. This result confirmed studies by Hayward (1967) in which the amount of damaged cotton was reduced from more than 50% to 20% by carbaryl sprays. Carbaryl has been effective against cotton pests elsewhere in Nigeria (Hayward, 1967) and in Central Africa (Matthews, 1966) and in the U.S.A. (Presley, 1972). The rate of application is generally in the range of 1-2 kg a.i/ha although less has been used in Central Africa where the recommended rate varies from 0.25-1 kg/ha depending on the size of the plant.

(ii) Timing of spray application

Sprays in Central Africa were timed according to pest populations by scouting fields (Matthews and Tunstall, 1968) but in Nigeria they have been applied on a fixed schedule (Choyce et al, 1963; Choyce and Lyon, 1965; Lyon, 1971). Rather than attempt to train farmers or agricultural assistants on how to sample insect pests, the farmer is recommended to apply six sprays starting from the 9th week after sowing.

Lyon (1971) showed that yields of the order of 1000 kg seed cotton per hectare can be obtained in Northern Nigeria by spraying either early or late in the season but that the harvest is delayed the later the

sprays are applied. In the Western State, seven sprays were no more efficient than four late sprays applied to timely sown cotton (Hayward, 1967). So the main period of pest damage was probably in October. Spraying in September was seemingly unnecessary.

The importance of spraying in October was confirmed in Mid-Western Nigeria when cotton sown in the first half of July and sprayed four times with carbaryl from the first week of October, was well protected with yields of the order of 1000 kg seed cotton per hectare. This yield was comparable to that obtained in Northern Nigeria.

In Northern Nigeria Lyon (1971) regarded it unsafe to adopt a spray regime designed purely for late pest attack in October. In some years, even under the best crop management, weather conditions might prevent compensation for loss of early fruiting points; that is, there must be sufficient moisture in the soil late in the season to enable compensatory growth to occur. Where cotton is grown in fertile soil with good cultural methods for conserving water such as cross tied ridges, a satisfactory yield potential worth protecting with insecticide is achieved even in season when rainfall is poor and or late. Where soil conditions are less favourable for retaining moisture, protection of the early crop is of greater importance so in these circumstances this is advocated to control early pest attack and so permit early crop maturity.

(iii) Application of insecticides

Insect control and yield data on cotton obtained using ULV application of insecticides were not significantly different from that obtained with carbaryl conventional spraying applied at 225 litre sprays/ha, though insect attack was not heavy throughout the trials.

In Northern Nigeria (Beeden, 1974) and in Malawi (Matthews, 1973) ULV sprayed cotton produced yields comparable to a conventional LV sprayed crop. This is particularly important in those areas where there is great difficulty in obtaining sufficient water for spraying. ULV application is better at the end of the afternoon or early evening when inversion conditions tend to exist to achieve maximum deposition of insecticide on the cotton plants (Johnstone, 1970).

3. Resistance problems

No resistance to carbaryl or endosulfan has been reported with either bollworms, aphids or cotton stainers in Nigeria as might be expected in view of very limited use. Development of resistance would be serious as no suitable alternative insecticide are available at present. Endosulfan either formulated as a wettable powder or ULV formulation presents some environmental risks due to its toxicity to fish if it contaminates local streams or rivers. In addition, the dermal toxicity of the ULV formulation necessitates more protective clothing than if the wettable powder is used. Adequate protective clothing makes application difficult in the tropics due to

discomfort to spray operators especially under hot and humid climatic condition.

Resistance of H. armigera may not be induced in present circumstances as part of the population is on other hosts which are not sprayed (though some like tomatoes are likely to be treated in future.

4. Cotton mixed cropping system in Mid-Western State of Nigeria

The present system of cropping by farmers in the Mid-West State is to plant yams in March-April. Some early maize is also sown in March and before these early crops are harvested, cowpeas, okra and tomatoes may be inter-planted. At present cotton is less commonly grown as a sole crop in the State. It is generally planted with yams sown in March-April, and with early maize planted in March late maize may be interplanted from August.

Yams are planted on large heaps spaced about 2 metres apart. Cotton is sown on the side of the same heaps, but if the yams are harvested late, the yields of cotton may be depressed. Early maize is generally well on to maturity by July when cotton is planted, so yield of cotton or maize is little affected. Tomatoes and okra planted at the same time as early maize do not affect yield of individual cotton plants. Ishan cotton (variety G. barbadense) seems well adapted to this method of mixed cropping, so is popular with the farmers.

No strict crop rotation is followed. Cotton is usually grown with other crops on new land or on land that has been left fallow for some years. No insecticides are used and as animal farming is not practiced, manure is not available. Cultivation is done by hand and this directly limits the total acreage that each farmer can own. During harvest, three pickings of seed cotton are done mainly by women and children at a time when there is little else to do on the farm. The first picking is done when about 50-70% of the bolls are open. Consequently an early heavy rainfall in January or February may increase the amount of dirty lint and thereby lower cotton quality. All these factors militate against good quality and high yields of seed cotton produced by local farmers. However, this situation can still be remedied by strictly adopting improved agricultural methods of farming. For example, maize planted early in March would be well on to maturity by July when cotton is planted, so that yield is not affected; but except planted in November, yams which are planted in March-April depress cotton yield by one-third (West, 1944). Similarly, crops like cowpea and sorghum which have long growth period like cotton, should not be incorporated into cotton crop mixture so as to minimize yield losses in cotton.

Yields of Allen cotton on peasant farms are low largely because the farmer cannot plant cotton early as food crops must be established first. Therefore a basic requirement for a high yield of Allen crop must be an

early planting so as to enable this variety to develop quickly and set many bolls in the sixteen weeks between planting in July and the onset of very low humidity with high temperatures in early November. Furthermore, early planted cotton stands the chance of evading pest infestation by late pests (bollworms) although it could suffer from cotton stainer attack.

There is also the need to apply fertilizer to the crop to compensate for soil nutrients which are heavily competed for by the cotton and other associated crops, since this would boost growth and increase crop yield. Finally, spraying cotton crops with insecticides would considerably reduce pest attack, improve plant growth and increase cotton yield.

5. Impact of mixed cropping system on yield

Mixed cropping is advantageous in many ways, particularly to the peasant farmer for whom conditions other than maximum yield are important; such as ensuring overall security of return, rather than the largest yields of any particular crop; also where labour restricts production capacity, output per unit of labour becomes important. In this respect peak labour periods are more widely spread out with mixed cropping than with systems that concentrate on monocultures of a few crops.

Maximum yield plot trials (i.e. all cultural practices including insecticides and fertilizer application) produce over 2000 kg seed cotton per hectare in

pure cotton stands in Northern Nigeria (Faulkner et al, 1974) and in Central Africa (Matthews, 1972; Matthews and Beeden, 1972). With such a high yield a farmer can easily cover all his input costs and still make a profit. In contrast, unsprayed sole cotton yielded 833 kg seed cotton per hectare in Mid-West State. Lower yields than this were obtained when cotton was sown interplanted with other crops in the ratios 1:1 to 1:6. Cotton interplanted with okra in ratio 1:1 had the least crop loss of 9% seed cotton. Similarly cotton sown into either tomato or maize suffered 44 and 64 percent crop loss respectively. The heaviest loss of 80% was sustained when cotton was sown in a ration 1:6 (i.e. through the other five associated crops, Section IV).

The main benefit in the mixed cropping systems investigated in Mid-West State, came from intercropping cotton with either okra, tomato or maize. Yield losses sustained from these 50:50 combinations were always less than 50 percent in two out of the three combinations; namely 9, 44 and 64% respectively, so in terms of area planted the cotton did better than on a monoculture system, and this could clearly benefit the farmer.

The success of cotton/okra, cotton/tomato and cotton/maize can be attributed partly to the fact that the effect of competition between crop combination was less if their peak demands on the environment occurred at different times. Cotton, okra, tomato and maize have different growth cycles, with okra, tomato and maize maturing

earlier and therefore harvested earlier than cotton. It also seems that cotton in some 50:50 combination, is less attractive to pests than when planted as pure stands; hence more of its potential yield is realised than in a monoculture. In the combinations, both crops compensated effectively for the drops in their population.

Where the population of cotton plants was reduced to $\frac{1}{6}$ of that in a pure stand, the yield of seed cotton was severely reduced. Interplanting with cowpeas or sorghum also resulted in lower cotton yield. The crop failure of cotton when it was intercropped with cowpea and sorghum seemed correlated with inter-specific competition in crop combinations. At certain period of crop development, especially during flowering and fruit formation, the demand for space, light, moisture and nutrients in the crop environment is at a maximum. For sorghum and cowpea this time comes in September and October and so also is cotton. Thus the two crops in the combinations of cotton/sorghum or cotton/cowpea are in competition for the vital requirement during this critical period. This stress was fascilitated by the fact that cotton, sorghum and cowpeas had similar growth cycles. Cowpeas and sorghum matured late at the time when cotton was making great demands on the soil.

When the crop values are pooled (i.e. cotton value plus associated crop yields) the ratios of the intercrops made great differences, especially where cotton was sown in ratio 1:6. The best crop value was obtained from

cotton sown into tomato followed, by cotton in ratio 1:6, cotton sown with okra and cotton sown with maize (Section IV). However, in terms of cash returns, the values obtained from cotton sown in ration 1:6 was far less than the returns from cotton sown either into okra, tomato or maize. The mixtures of cotton with cowpeas and cotton with sorghum were the poorest yielders as these combin-ations showed a decline in total crop value.

The low crop value can probably be attributed to low cotton plant population of 17% in the ratio 1:6 treatment compared to the treatment of ratio 50:50 e.g. as in cotton/tomato, cotton/okra or cotton/maize combination (Site I, Section IV). Sorghum and cowpea planted with cotton in ratio 50:50 and also in the six crops mixture, seemingly competed with the latter for nutrients to depress cotton value. But in the cotton/tomato, cotton/maize or cotton/okra combination, cotton had a longer growth period than any of the other associated crops (maize, tomato or okra) hence it was less in competition with either of the crops during the critical period. Also, cotton, tomato, maize and okra exhibited a strong capability for compensating for a drop in population. Cotton produces heavier bolls when they were reduced > 50% cotton stands per plot and after maize, tomato and okra have been harvested.

(i) Pest incidence and colonization in mixed cropping

A crop mixture may affect the visual and olfactory stimuli that attract insect pests into the crop.

This is important because with most arable crops, pest infestations come from outside the crop and so the amount of infestation depends on the pests ability to find the crop at the right time by visual and olfactory means (Southwood and Way, 1970). Thus a solid green background is more likely with intercropping to be less attractive to certain pests than one with a foliage/earth contrast (Smith, 1969; Raros, 1973; Dempster and Coaker, 1974).

In the Mid-Western State a preliminary investigation of insect pests of cotton and their natural enemies in a cotton growing community conducted in the 1971-72 and 1973-74 seasons, showed that tomato and cotton planted into tomato had much the least flea beetle attack. Experiments in the field as well as with potted plants demonstrated that flea beetles were seemingly repelled by tomato leaves as well as by plants treated with tomato leaf homogenate. This perhaps indicate that flea beetles were responding to olfactory stimuli as a result of the aromatic flavour emitted from tomato leaves.

On the one hand, pests may tend to colonize one particular crop in a mixture which thus serve as a diversionary host protecting other, perhaps more susceptible and economically valuable crops from attack. For instance, eports from I.I.T.A. (1974) indicated an egg-laying preference of the coreid bug Anoplocuemis curvipes for maize in a maize/cowpea intercrop. This bug causes severe damage to cowpea pods with no visible effect on

maize by young nymphs. On the contrary, the situation observed in Mid-West State during 1973-74 season was more of a pest attraction rather than diversion.

Flea beetle infestation was heaviest on okra compared to cotton and the other crops, indicating that okra was attracting flea beetles from cotton and the other crops. This beetle does severe damage to cotton especially at the early stages of cotton development, yet its attack on okra does not seem to cause visible effects on its yield. Similarly, higher infestations by H. armigera were found on tomato than on cotton or maize. Its period of attack coincided with flower formation in tomato.

6. The abundance of natural enemies in a sprayed and in mixed cropping system

Theoretically, the numbers of natural enemies might be higher in the more diverse situation created by mixed cropping. Raros (1973) observed more predatory spiders Lycosa spp in a corn-peanut mixed crop than in sole-cropped corn. Dempster (1967, 1968) recorded enhanced activity of ground-dwelling predators in the presence of weeds which reduced numbers of the small cabbage white (Pieris rapae L.) compared with a situation where the weeds were controlled. Similarly, Dempster and Coaker (1974) noticed greater effects of ground-dwelling predators when cruciferous crops were undersown with clover. Potts and Vickerman (1974) recorded similar effects from cereals undersown. In general, more natural enemies built up in the mixed crop trials investigated in Mid-West (1971-74)

than on plots treated with chemicals (Sections II - IV). In nearly all the trials where insecticides were sprayed, the numbers of natural enemies declined. Of the chemical insecticides sprayed both at the conventional low volume and ultra-low volume application, endosulfan applied either as a wettable or as a ULV formulation demonstrated more differential selectivity in favour of the natural enemies than carbaryl, although at the lower rates, endosulfan treatments did not compensate for the enhanced pest activities which tended to decrease yield especially at the post-spray period. However, the toxicity of the carbaryl sprays to the natural enemies was seemingly offset by the high level of protection given to the fruiting bodies and the security of high yields from crops treated with it.

For certain crop combination, favourable natural enemy species are likely to develop, thus during the mixed cropping trial, cotton/tomato and cotton/okra combinations harboured the largest populations of the natural enemies and hence seemed the most preferred hosts of these species.

7. Scouting and timing of spray

As in most African countries, cotton is grown in the Mid-West State of Nigeria in peasant farming conditions which lack capital for buying spraying equipment and insecticides. The spraying regime which has been adopted is based on the relatively expensive use of a single chemical applied six times at weekly intervals starting from nine weeks after germination. In Uganda the recommended

spray treatment is 1 lb DDT per acre at 10 day intervals using a single syringe pump (Bowden and Ingram, 1958), whereas in Tanzania ¾ DDT per acre in 10 gals of water at weekly intervals for two months is recommended (Valentine, 1960). Similar schedules have been used in Central Africa (Tunstall, Matthews and Rhodes, 1962; Matthews, 1967; Matthews and Tunstall, 1967). Matthews and Tunstall (1967) observed from field trials in Rhodesia that yield increases using fixed schedule were disappointing, because no account was taken of the variation in time and intensity of insect attack. With a fixed spraying schedule, chemicals may be applied to crops relatively free of insect pests and similarly no spray may be applied at a time of heavy insect attack. Thus efficient scouting for pest could help to overcome such a situation.

In Central Africa the timing of spray has been complicated by lack of a single chemical which would effectively control all the major pests at economic level (Matthews & Tunstall, 1967). However, this situation does not at the moment exist in Mid-Western State of Nigeria. H. armigera does not cause serious damage on sole crop cotton in the State, and as such, the need does not arise for the use of DDT as in Central Africa. Carbaryl at its prevailing recommendation is able to suppress E. biplaga and D. superstitiosus, the major cotton pests in the State and also reduces A. gossypii population when it is at a low infestation. D. watersi is fortunately not a pest.

In the future, scouting for insect pest as practised in Central Africa may be desirable. This would benefit the farmer by:-

i) Telling him when and the number of times to spray; this would invariably help to cut down on time and the cost of chemical sprays.

ii) Helping to avoid unnecessary spraying of the crops when the pests are not there and hence reduce the chances of phytotoxicity and induced resistance as well as keeping costs at a minimum.

8. Conclusion

This study of approaches to integrated control has demonstrated the potentialities of chemical pesticides and mixed cropping to control cotton pests and to increase cotton production. Mixed cropping has shown benefits in decreased pest attack and increased numbers of natural enemies which would help limit pest infestation.

The integration of cultural, biological and appropriately timed chemical control measures would seem particularly relevant and adaptable to the small-scale and capital-scarce farming system of the Mid-Western Nigeria; and as rightly stated by Way (1971), there is the need for a multi-disciplinary research approach to devise more effective pest management practices which would avoid the problems of depending entirely on toxic sprays and would also be compatible with the socio-economic conditions of

crop production in the State.

Therefore integrating ULV endosulfan sprayed cotton planted into either okra, tomato, or maize may be a feasible proposition in cotton development in Mid-Western State of Nigeria. With such combination it is possible to take advantage of chemical protection against cotton pests, exploit the full potentials of cotton yield with its associated crops in the mixture and at the same time enjoy the benefits of the natural enemies augumenting chemicals sprayed onto the crops.

It is hoped that with the realisation of the benefits of this integration, the cotton yield might be increased, but other arms which make for the full exploitation of this system must be examined as future strategies:-

a) determining the critical time of pest attack and hence when to apply chemical sprays,

b) evaluating the rates, concentrations and types of chemical spray to use (emphases being laid on types that are economical to the farmers);

c) determination of time of sowing to avoid the peak of pest infestation,

d) assessing different crop combination with a view to selecting or adopting types which can be a barrier to or repel pests or divert pests away from cotton when intercropped; and

e) with time, identify other possible alternatives to insecticides e.g. the use of pheromones and cotton varieties which are resistant to pests and diseases, higher yielding and early maturing.

SUMMARY

1. The work aimed to evaluate control measures for insect pests of cotton in the Mid-Western State of Nigeria, through some approaches to integrated control viz:- by conventional spray, Ultra-low Volume (ULV) sprays and mixed cropping systems.

2. Relevant literature on the following is reviewed:- cotton pest control by conventional sprays, control by ULV spray, role of mixed cropping, climate, vegetation and crops of the Mid-Western State, the major cotton pests in the Mid-West State together, and pest infestation in relation to cotton crop development.

3. As an approach to the development of an integrated control programme against cotton pests, a comparison of some insecticides (carbaryl 85 w.p., carbaryl 20 e.c., endosulfan e.c., endosulfan granule and monocrotophos) was made in the 1971-72 season with a view to identifying those with properties such as selective action which could be incorporated into an integrated control work.

4. The dorminant bollworms causing yield decreases were identified and the damage they cause were assessed during 1972-73 season.

5. Carbaryl w.p., monocrotophos and endosulfan gave increases in seed cotton yield and reduced the degree of damage and infestation by insect pests.

6. Carbaryl was most toxic to the predators, but was effective against P. gossypiella, E. biplaga and D. superstitiosus. Plots treated with it gave the highest yields of seed cotton per hectare and suffered the least damage to fruiting bodies.

7. Although endosulfan wettable powder applied at the different rates in 1973-74 trials was less toxic or harmful to the natural enemies than carbaryl w.p., its ability to control cotton pests was sometimes poorer than carbaryl. Populations of insect pests rose relatively in the crops treated with endosulfan w.p. during the post spray period.

8. As the provision of large quantities of water to spray cotton poses a big problem to cotton farmers in the State, an ultra-low volume spray application technique for insecticides was tested, using a suitable hand-carried battery operated spinning disc applicator. Three dosage rates (0.75, 0.38, 0.19 kg a.i/ha) of ULV endosulfan formulation applied during the main trial in 1974-75 season, were compared with carbaryl LV conventional spray; but in a preliminary trial, two rates namely, 2.5 kg and 0.625 kg a.i/ha were applied.

9. The highest yields of seed cotton were recorded from ULV application when sprays containing 2.5 kg and 0.75 kg a.i/ha were applied with the spray operator walking along each spray row. Yields were reduced

when the volume of spray was decreased. 2.5 kg a.i/ha sprayed during the preliminary trial significantly ($P < 0.05$) outyielded the lower rate of 0.625 kg a.i/ha and the untreated control. During the main trial all the insecticide treatments gave significantly higher ($P < 0.05$) increases in the yield of seed cotton than untreated control; thus treatment could be ranked according to yield: carbaryl > endosulfan 0.75 kg/ha > endosulfan 0.38 kg/ha > endosulfan 0.19 kg/ha > untreated control.

10. There was excellent correlation between pest numbers and yield in the post spray period. Linear regression analysis showed that higher pest numbers were associated with lower yields.

11. ULV endosulfan applied at the highest dosage rate 0.75 kg/ha and the LV carbaryl were very effective in reducing pest infestation. During spraying, significantly lower pest populations were recorded from plots treated with carbaryl and the highest ULV endosulfan rate.

12. At 0.75 kg a.i/ha ULV endosulfan showed marked evidence of differential selectivity in favour of the natural enemies over aphids compared to the ratios of these predators to aphids in carbaryl and the other treatments. Thus 0.75 kg/ha ULV endosulfan appeared to provide satisfactory level of pest control while at the same time conserving the

natural enemies to a higher degree than did the carbaryl.

13. In the ULV endosulfan trials a 6 metre swath width was adopted throughout the spraying period. This may have resulted in lower, though not significantly lower, yields compared to carbaryl treatment. A better control might have been secured if narrower (e.g. 1.8 meter) swath had been used especially, when at spraying cotton plants were 100 cm high.

14. The high dosages of ULV endosulfan (0.75, 0.38 and 0.19 kg a.i/ha) used in Mid-West State during the main trial were not reflected by the corresponding yield increases over control compared with elsewhere (e.g. Northern Nigeria, and Malawi). The lower yields obtained from Mid-West State compared to these other places may have been due to differences in swath width, and other factors including plant growth and density, variety and differing weather conditions.

15. Mixed cropping systems were used as possible component control measures against cotton pests. Higher P. gossypiella and E. biplaga numbers were found to develop on cotton interplanted with okra and on cotton in the four and six crop mixtures than on cotton intersown with tomato or maize. The H. armigera population was low during the trial, but numbers sampled from the crops showed that cotton interplanted with tomato recorded the highest numbers.

Similarly, the associated food crops, tomato, maize, sorghum also carried proportionate numbers of H. armigera. By far the greatest number of Podagrica spp. was recorded from okra and from cotton inter-planted with okra.

16. Higher predator numbers were sampled from cotton interplanted with tomato or maize than from the other crop combinations.

17. Cotton/tomato and cotton planted into the four or six mixtures gave the highest crop values per hectare, and the lowest pest infestation was recorded from the cotton/tomato mixture.

18. Laboratory experiments showed that higher cumulative % kill of E. biplaga, P. gossypiella and H. armigera was recorded from 0.75 kg a.i/ha of ULV endosulfan than the lower rate and the untreated controls used in a bioassay test.

19. C. lunata seemed a more efficient natural enemy for A. gossypii than P. ferruginea because it consumed an average of 60% of the total aphid numbers fed during 24 hours, and this was twice the consumption rate of P. ferruginea. A total of 20 A. gossypii were fed to each individual predator.

20. Squashed tomato leaves sprayed unto cotton crops seemingly repelled Podagrica spp from the crop. The higher the concentration of the squashed solution

sprayed, the higher the numbers of Podagrica repelled. It is thought that the repellent effect is due to olfactory response from Podagrica.

21. The high revenue derived from cotton/tomato, cotton/okra, cotton/maize indicates that more economic advantages could be gained by interplanting cotton with either tomato, maize or okra; but comparable crop values were also obtained from cotton planted as a sole crop and sprayed with carbaryl, though higher input values were inurred in raising one hectare of cotton.

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ANALYSIS OF VARIANCE

APPENDIX 1. WHOLE SEASON. PINK BOLLWORM - ILELE 1971/72. SITE I.

SOURCE OF VARIANCE	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	VARIANCE RATIO
ROWS	15.5342E-01	5	31.0684E-02	44.2277E-01
COLUMNS	19.5696E-01	5	39.1392E-02	55.7170E-01
TREATMENTS	90.8863E-01	5	18.1773E-01	25.8764E+00
RESIDUAL	14.0493E-01	20	70.2465E-03	
TOTAL	14.0039E+00	35		

$S\bar{x} \quad \sqrt{\frac{.0702465}{6}} = \underline{0.1082}$

Value of P =	2	3	4	5	6	7
Significant Studentised Range for 5% =	2.95	3.10	3.18	3.25	3.30	3.34
Least significant range =	.319	.335	.344	.352	.357	.361

	AZODRIN	SEVIN 85	ENDOSULFAN 35	SEVIN 20	ENDOSULFAN GRANULE	CONTROL
Ranking:-	0.872	0.875	0.931	1.019	1.678	1.753

1.753 - 0.872 = 0.881 > .361	significant	
1.753 - 0.875 = 0.878 > .357	✓	
1.753 - 0.931 = 0.822 > .352	✓	
1.753 - 1.019 = 0.734 > .344	✓	
1.753 - 1.678 = 0.075 < .335	N.S.	
1.678 - 0.872 = 0.806 > .357	significant	
1.678 - 0.875 = 0.803 > .352	✓	

1.678 - 0.931 = 0.747	.344	
1.678 - 1.019 = 0.659	.319	
1.019 - 0.872 = 0.147 <	.352	N.S.
1.019 - 0.875 = 0.144 <	.344	N.S.
1.019 - 0.931 = 0.088 <	.319	N.S.
0.931 - 0.872 = 0.059 <	.344	N.S.
0.931 - 0.875 = 0.056 <	.319	N.S.
0.875 - 0.872 = 0.003 <	.361	N.S.

N.S. (Not significant)

ANALYSIS OF VARIANCE

APPENDIX 2. INTER-SPRAY. PINK BOLLWORM - SITE 1. ILELE

SOURCE OF VARIANCE	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	VARIANCE RATIO
ROWS	36.3729E-03	5	72.7458E-04	66.3084E-01
COLUMNS	28.1146E-03	5	56.2292E-04	51.2533E-01
TREATMENTS	16.3790E-02	5	32.7579E-03	29.8591E+00**
RESIDUAL	21.9417E-03	20	10.9708E-04	
TOTAL	25.0219E	35		

$$Sx = \frac{\sqrt{.00109708}}{6} = \underline{.0135}$$

Value of P^6 =	2	3	4	5	6	7
SsR =	2.95	3.10	3.18	3.25	3.30	3.34
LsR =	.0398	.0419	.0429	.0439	.0446	.0451

	ENDOSULFAN E.C.	MONOCROTOPHOS	CARBARYL 85	CARBARYL 30	ENDOSULFAN GRANULE	CONTROL
Ranking:-	.151	.158	.163	.197	.298	.316

.316 - .151	=	.165 > .045	significant
.316 - .151	=	.165 > .044	>
.316 - .163	=	.153 > .043	>
.316 - .197	=	.119 > .042	significant
.316 - .298	=	.018 < .039	N.S.
.298 - .197	=	.101 > .035	significant
.197 - .151	=	.046 > .044	significant
.197 - .158	=	.039 < .043	N.S.
.197 - .163	=	.034 < .042	N.S.
.163 - .151	=	.012 < .042	N.S.

ANALYSIS OF VARIANCE

APPENDIX 3. PINK BOLLWORM. POSTSPRAY - SITE 1. ILELE

SOURCE OF VARIANCE	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	VARIANCE RATIO
ROWS	25.9315E-03	5	51.8629E-04	81.4975E-02
COLUMNS	70.5565E-03	5	14.1113E-03	22.1745E-01
TREATMENTS	15.3791E-02	5	30.7583E-03	48.3336E-01**
RESIDUAL	12.7275E-02	20	63.6374E-04	
TOTAL	37.7554E-02	35		

$S\bar{x} = \frac{\sqrt{.00636374}}{6} = \frac{.0326}{}$

Value of P	2	3	4	5	6	7
LsR =	.096	.101	.104	.106	.108	.109

	CARBARYL 85	MONOCROTOPHOS	CARBARYL 20	ENDOSULFAN E.C.	ENDOSULFAN GRANULE	CONTROL
Ranking:-	.148	.156	.159	.225	.296	.305

.305 - .148 = .157 >	.109	significant	
.305 - .156 = .149 >	.108	✓	
.305 - .159 = .146 >	.106	✓	
.305 - .225 = .08 <	.104	N.S.	
.305 - .296 = .009 <	.101	N.S.	

.296 - .148 = .148 >	.108	significant	
.296 - .156 = .140 >	.106		
.296 - .159 = .137 >	.104		
.296 - .225 = .071 <	.106	N.S.	
.225 - .148 = .077 >	.026		
.225 - .102 = .069 <	.104		
.225 - .159 = .066 <	.101	N.S.	
.159 - .148 = .011 <	.096	N.S.	

APPENDIX 4. YIELD Vs PESTS - POST-SPRAY PERIOD. ILELE SITE I.

LATIN SQUARE DESIGN - MULTIPLE LINEAR REGRESSION ANALYSIS

VAR OBS	1	2	3	4	5
1	155.300	6636.000	1911.000	3.080	0.980
2	125.800	20811.000	2737.560	4.270	2.240
3	108.900	38402.000	4818.310	43.190	49.420
4	115.400	26558.000	4220.790	28.630	28.420
5	162.200	6209.000	1976.100	3.220	0.910

SELECTION INDEP 2 3 4 DEP 1

CORRELATION X Y

VAR	
2	- 0.904398552
3	- 0.930593172
4	- 0.822991870

I VALUE 23.968799741

SELECTION INDEP 3 4 5 DEP 1

CORRELATION X Y

VAR		
3	- 0.930593172	(P. gossypiella)
4	- 0.822991870	
5	- 0.812775855	

F VALUE 18.900031071

APPENDIX 5. YIELD Vs PESTS - POST-SPRAY PERIOD. IRRUA SITE II

LATIN SQUARE DESIGN - MULTIPLE LINEAR REGRESSION ANALYSIS

VAR OBS	1	2	3	4	5
1	139.990	254.400	54.800	0.090	0.090
2	97.000	443.600	85.400	0.150	0.100
3	59.000	1524.400	113.000	1.460	2.000
4	88.020	657.800	88.000	0.550	1.520
5	150.850	160.800	42.400	0.080	0.090

SELECTION INDEP 2 3 4 DEP 1

CORRELATION X Y

VAR	
2	- 0.897789807
3	- 0.996915157
4	- 0.843813796

I VALUE 268.184010917

SELECTION INDEP 3 4 5 DEP 1

CORRELATION X Y

VAR		
3	- 0.990915157	(D. superstitiosus)
4	- 0.843813796	
5	- 0.841986084	

F VALUE 136.965690539

The Effects ULV Spray :: Pests of Cotton and Their Natural Enemies.

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SUMMARY

There was considerable fluctuation in field populations of cotton pests *Aphis gossypii* and *Dysdercus superstitiosus* and their predators, *Chilomines lunata* and spiders. Results of ULV spraying of 25% endosulfan showed that control of *A. gossypii* and *D. superstitiosus* was obtained at 2.5 kg ai/ha but not at 0.625 kg/ha. Numbers of these pests in plots were significantly different on post-spray records from controls. Abundance of the predator *C. lunata* was significantly reduced at 2.5 and 0.625 kg ha but to a lesser extent at the latter dosage rate and only the 2.5 kg/ha rate of application significantly decimated numbers of spiders. ULV sprays had no adverse effects on the relative abundance of the predators and their preys, but spraying at 2.5 kg/ha tended to selectively favour spiders over *A. gossypii* in treated plots. Key words: integrated control, aphids, cotton stainer.

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ULTRA low volume (ULV) spray has been defined as the minimum amount of liquid per unit area compatible with economic requirements of achieving control (1). In this report the application rate was below five litres per hectare. Although this is a new approach to chemical control of cotton pests in Nigeria (2) first attempt was made at Samaru and Kadawa (Hayward and Beeden, in press), a great number of pests have been successfully controlled elsewhere using ULV concepts on a wide range of crops (9). Earlier works on ULV spraying of cotton include those of Joyce (6, 7, 8). who applied DDT concentrate at about 4 l/ha to control the cotton Jassid, *Empoasca lybica* (DeBerg) in the Sudan Gezira. In Malawi, Matthews (10) sprayed ULV formulations of carbaryl and DDT and obtained optimum control of bollworms *Diparopsis castanea* Hmps. and *Heliothis armigera* (Hbn) with 10% spray at 5 l/ha. This paper discusses the results of a preliminary study of the effects of ULV spray on cotton pests viz: *Aphis gossypii* Glover (Aphididae) and *Dysdercus superstitiosus* (F) (Pyrrhocoridae) and their natural enemies: *Chilomines lunata* (F) (Coleoptera: Coccinellidae) and spiders. The experiment was conducted at Irrua farm centre (Mid-Western State of Nigeria) with a view to exploiting 2.5 or 0.625 kg/ha active ingredient endosulfan ULV spray in an integrated control programme of pests on cotton.

MATERIALS AND METHODS

The experimental design was a randomized complete block with four replications. The three treatments were 2.5 kg/ha ai endosulfan, 0.625 kg/ha ai endosulfan and an untreated control. The plot size was 16.5m² (= 0.03 ha) made up of 18 ridges. Each plot was surrounded with 0.9 m path and blocks were 1.8 m apart. The Agrosan treated cotton seeds, Allen 26J, were sown at a rate of 22.5 kg/ha on 4 August, 1973. The seeds were drilled 2.5 cm deep in the row with 45 cm between the ridges. Calcium ammonium nitrate was applied as a fertilizer at the rate of 251 kg/ha.

A small battery-driven spinning disc (Micron ULVA) sprayer (Turbair and Micron Sprayers, U.K.) designed by Bals (2) was used to apply the endosulfan in-

secticide. This sprayer has two stacked plastic atomizer discs. The spray fluid was atomized into a medium fine spray with a volume median diameter (VMD) of (70-120 microns); powered by two sets of 8-1.5 volt batteries. A 6-m spraying swath was adopted for this preliminary study.

The insecticide used was endosulfan 25% ULV formulation, flowing at the rate of 1.12 ml/sec through a 1.5 mm orifice using the red stem of the sprayer. Two concentration rates of the insecticide, 2.5 kg/ha ai applied by walking four times along each spray row and 0.625 kg/ha ai applied by walking once along the spray row, were tested (11).

To obviate edge effects, sampling for insect populations was confined to the 16 inner ridges. Adults and nymphs of *D. superstitiosus* were counted on 128 randomly selected plants per plot, once before spraying and once two days after spraying. *A. gossypii* was sampled after the method of Banks (3). Predators, mainly the larvae and adults of *C. lunata* and spiders were sampled as for *D. superstitiosus*.

RESULTS

Effects of ULV spray on Cotton Pests

Changes in numbers of *A. gossypii* and *D. superstitiosus* following application of ULV sprays are shown in Figs. 1 and 2. Vertical arrows indicate the dates on which plots were sprayed. After the first and second sprayings, aphid populations declined in control and treated plots. Numbers of aphids declined after each 2.5kg/ha endosulfan application. In the plots treated with 0.625 kg/ha of endosulfan and the control plots, aphid numbers increased after the last and penultimate sprayings (Fig. 1).

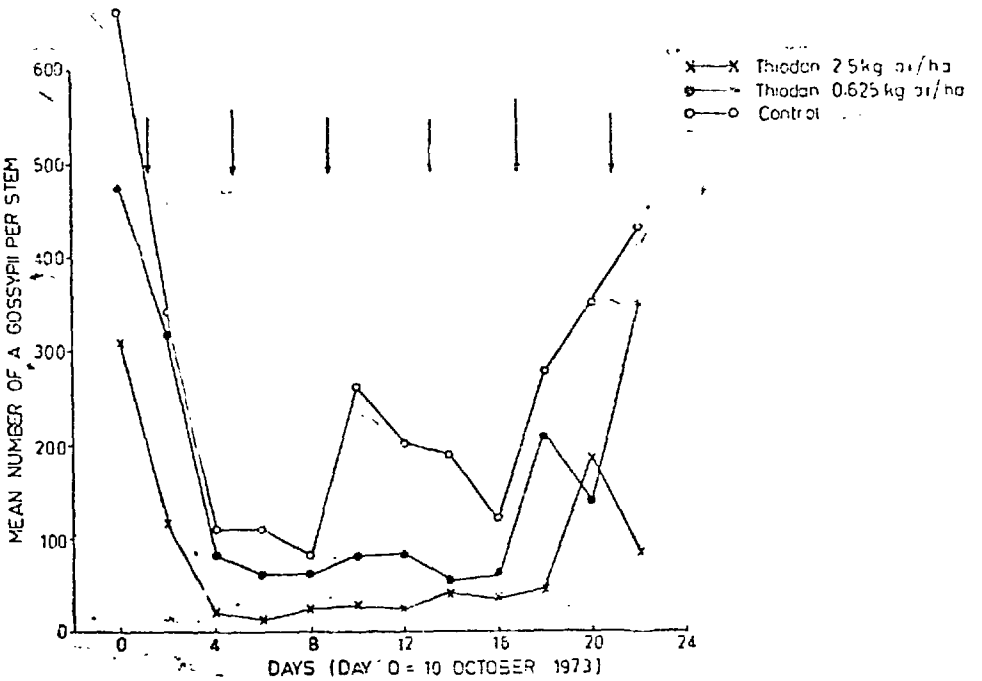


Fig. 1 Effect of ulv spray on populations of Aphis gossypii.

The numbers of aphids on plots treated with 2.5 kg/ha endosulfan were significantly less (P=0.05) than those treated with 0.625 kg/ha and untreated control. The numbers of aphids counted on each of six occasions immediately following spraying varied with treatments and sampling dates.

Numbers of *D. superstitiosus* in sprayed and unsprayed plots tended to increase from the start of the experiment until a little after the penultimate application and then decreased afterwards (Fig. 2). No control of cotton stainers was obtained with 0.625 kg/ha but the numbers in plots treated with 2.5 kg/ha were significantly less (P=0.01) than those in unsprayed plots.

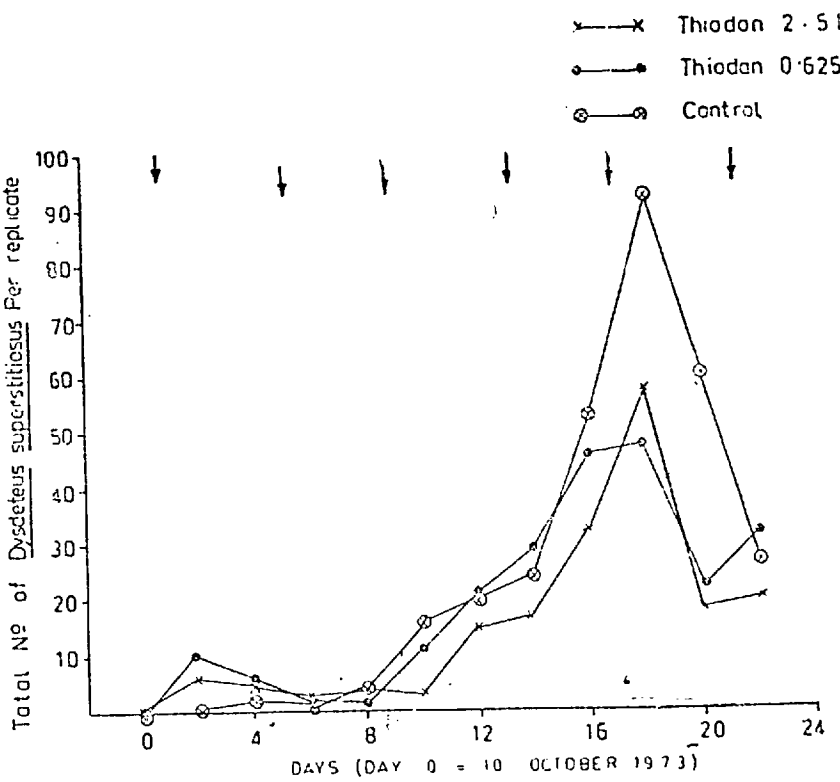


Fig 2 Effect of ULV spray on populations of cotton stainer, D. superstitiosus.

Effects of ULV spray on Predators

Fluctuations in numbers of *C. lunata* and spiders in sprayed and unsprayed plots are shown in Figs. 3 and 4 respectively. Numbers of *C. lunata* in plots treated with either 2.5 kg/ha or 0.625 kg/ha were less than those in unsprayed plots. There was no significant difference between treatments in total number of spiders.

ULV sprays had no adverse effects on the relative abundance of *A. gossypii* and the predators, *C. lunata* (Table 1). At the higher concentration, 2.5 kg/ha, there was some evidence of differential selectivity in favour of spiders over aphids as compared with the ratio of spiders to aphids in unsprayed plots (Table 1).

Table 1. Ratio of predators *Chilmines lunata* and spiders to *Aphis gossypii* in sprayed and unsprayed cotton plots.

Post-spray occasions	*Treatments and ratios* x 10^3					
	2.5 kg/ha Endosulfan		*0.625 kg/ha Endosulfan*		*Control*	
	C. lunata	*Spiders*	*C. lunata*	*Spiders*	*C. lunata*	*Spiders*
1	3	13	2	4	3	2
2	100	33	21	25	42	20
3	22	36	19	6	9	6
4	25	41	31	41	10	18
5	4	36	6	7	5	8
6	3	11	2	8	0.3	5

The ratio of numbers of the predators, *C. lunata* and spiders to *D. superstitiosus* in sprayed and unsprayed plots varied enourmously between sampling occasions. (Table 2). The relative abundance of predator and prey remained virtually undamaged in plots sprayed with endosulfan at either 2.5kg/ha or 0.625 kg/ha.

Table 2. Ratio of predators, *Chilmines lunata* and spiders to prey, *Dysdercus superstitiosus* in sprayed and unsprayed cotton plots.

Post-spray occasions	*Treatments and ratios*					
	2.5 kg/ha endosulfan		*0.625 kg/ha endosulfan*		*Control*	
	C. lunata	*Spiders*	*C. lunata*	*Spiders*	*C. lunata*	*Spiders*
1	0.33	1.38	0.55	0.84	14.2	0.87
2	4.7	1.63	13.3	16.6	33.3	1.66
3	1.9	3.15	1.9	0.64	1.9	1.25
4	0.77	1.23	0.77	1.03	0.97	1.83
5	0.03	0.33	0.34	0.04	0.2	0.34
6	0.17	0.63	0.25	1.11	0.56	1.07

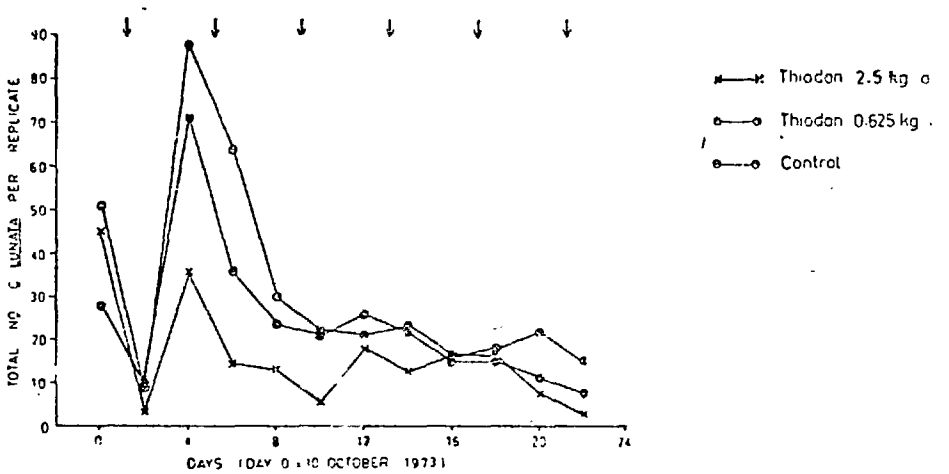


Fig 3 Effect of ULV spray on numbers of Chilomines lunata.

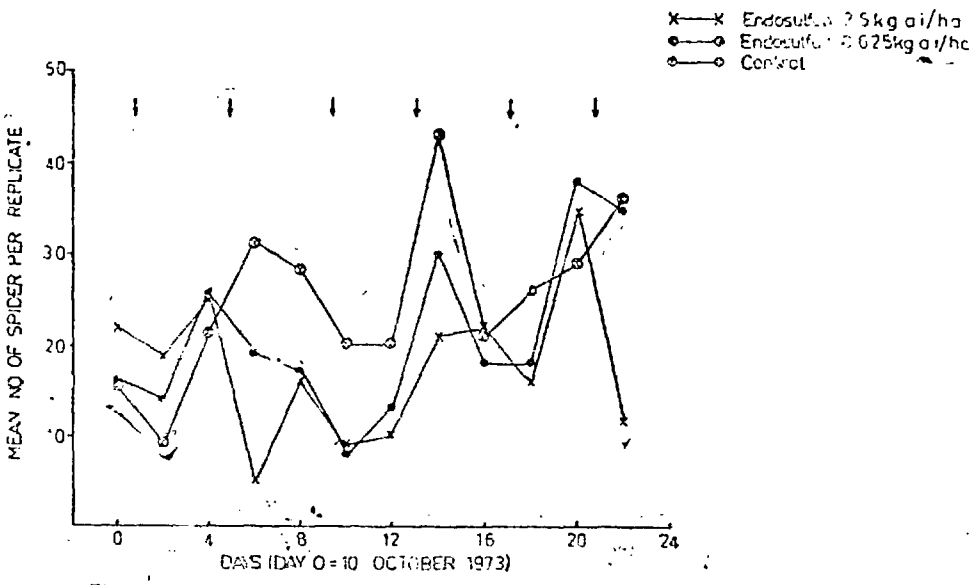


Fig.4. Effect of ulv spray on numbers of spiders on cotton.

DISCUSSION

The patterns of fluctuation of cotton pests in unsprayed plots (Figs. 1 and 2) are in accordance with the seasonal abundance of *A. gossypii* (4) and *D. superstitiosus* (12) on cotton. Changes in populations of pests in treated plots are associated with spraying. The present studies have shown that significant control of aphids and cotton stainers was obtained at 2.5 kg/ha but not at 0.625 kg/ha endosulfan.

Control of *D. superstitiosus* and *A. gossypii* was not achieved at 0.625 kg/ha and spraying endosulfan at the rate of 0.625 kg/ha had no significant depression on abundance of predatory spiders (Fig. 4) and caused less mortality of *C. lunata* than at 2.5 kg/ha. The spider-aphid ratio in the plots treated with 2.5 kg/ha tended to be higher than in plots sprayed with 0.625 kg/ha (Table 1). The decimation of *C. lunata* in this study was not necessarily associated with unfavourable predator/prey influences as the combined effects of ULV spray at 2.5 kg/ha and the action of predatory spiders accounted for the marked control of *A. gossypii* in the present experiment. On the other hand, that ULV spraying had no adverse effects on the relative abundance of predators and their prey (Tables 1 and 2) could have significance in biological or integrated control of cotton pests. For example, it is possible that a "clean up" of aphids and stainers could be envisaged after spraying ULV at 0.625 kg/ha since this

dosage was less disruptive than 2.5 kg/ha to the action of *C. lunata* with no significant effect on abundance of spiders. Thus, although, populations of spiders in plant foliage are known to fluctuate widely (5) the fall and rise in their numbers (Fig. 4) could be associated with the corresponding rise and fall in population of *D. superstitiosus* (Fig. 2). The present trial has shown that appropriate dosages of ULV formulation of endosulfan could control pests of cotton as well as conserve populations of their predators. Further trials are required to ascertain optimum swath width, droplet size and dosage rate of ULV sprays for use in integrated pest control on cotton.

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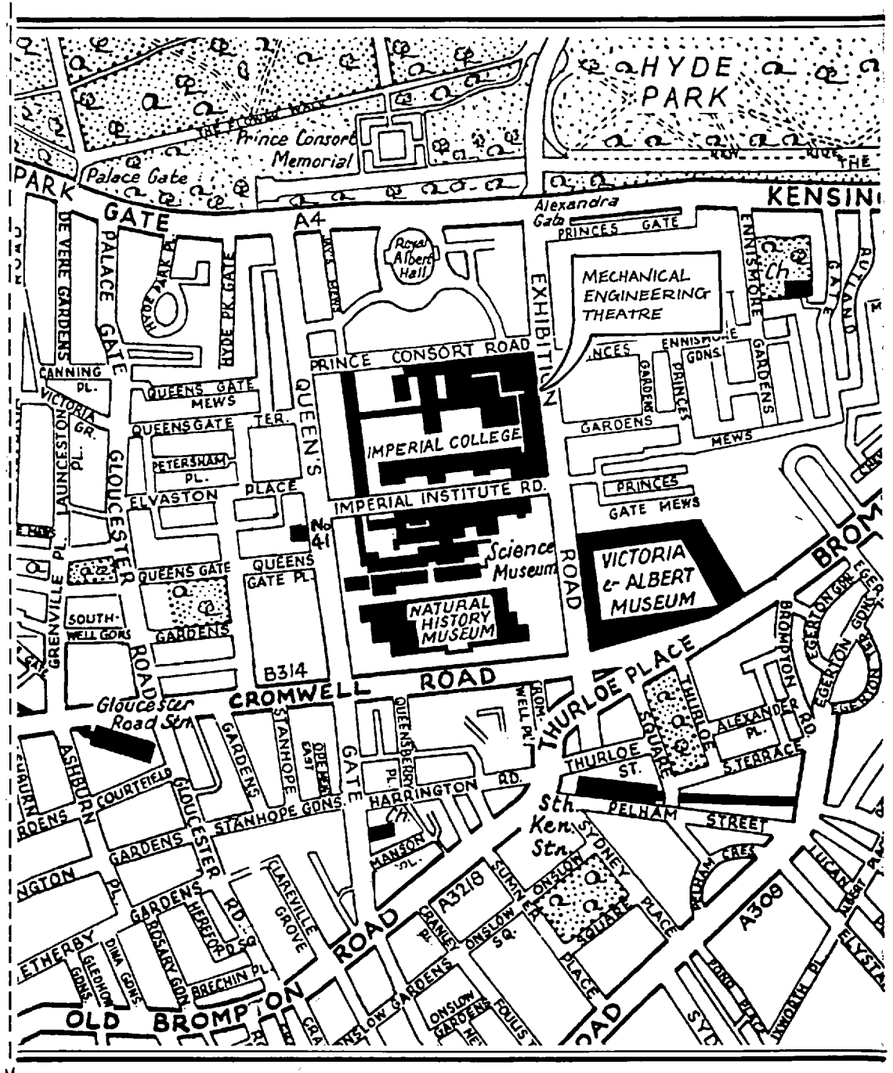
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