STUDIES OF THE APPLICATION OF INSECTICIDES ON COTTON IN ZAMBIA

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APPROVAL

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ABSTRACT

The status of insect pest management on small farms in Zambia was investigated by interviewing the farmers. Field trials evaluated the timing of insecticide sprays, methods of spray application and the effect of different swath widths using the 'Electrodyn' sprayer.

Farmers were aware of the insect pests, their status and the losses they caused, so all of them applied insecticide on their cotton crops. They did not scout their crops for insect pests properly due to the lack of training and help from extension staff. The role of biological control and weed control in cotton insect pest management was unknown to most of the cotton farmers.

The majority of farmers had knapsack sprayers as these were more versatile and easily available. Some farmers reported problems due to water supply, diluting the insecticides, and the heavy weight of equipment.

Farmers who used 'Electrodyn' sprayers appreciated their effectiveness, light weight and the elimination of water. Farmers wanted 'Electrodyn' sprayers to be more versatile so that they could apply pesticides on other crops.

Many farmers were aware of the use of ULV spinning disc sprayers and the knapsack sprayers fitted with a tailboom but these were not available in their areas. They were generally not aware of fitting 2 nozzles on a lance, using an ox-drawn or tractor-mounted sprayer.

Twenty percent of the farmers had suffered from mild symptoms of insecticide poisoning. Protective clothing was not available in most areas and the important safety precautions during spraying were unknown to most of them. Only about half of the farmers had attended a training course or demonstrations, and at these there was very little emphasis on insect pest management of cotton.

The farmers expressed an urgent need for more training, particularly on insect pest scouting and the application of insecticides on cotton.

In field trials an economic threshold for Heliothis, a key pest of cotton in Zambia, was 0.50 eggs per plant, when 3 to 4 sprays gave yields similar to 5 routine sprays.

Heliothis infestation generally increased during the 10th week after germination coinciding with flowering of cotton so farmers could avoid the first or second spray in most seasons.

Similar yields of seed cotton were obtained when cypermethrin (30 g. a.i./ha) and lambda cyhalothrin (12 g. a.i./ha) were applied with an 'Electrodyn', knapsack and ULV sprayers. The yields were also similar when charged and partially discharged spray droplets were applied with 'Electrodyn' sprayers.

There is an urgent need to modify the currently recommended fixed schedule of 5 sprays of pyrethroids in Zambia and to emphasise the scouting of Heliothis eggs and other major pests to improve timing of sprays which should lead to the reduced application of insecticides using the improved application techniques appropriate to small scale cotton farmers.

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CHAPTER 1

GENERAL INTRODUCTION

COTTON IN ZAMBIA

In Zambia, there are about 600,000 small-scale farmers, of whom 38,400 grow cotton, with an average area of 1 to 2 hectares of cotton per farm. These growers are distributed in small villages throughout the cotton growing areas in Central, Southern, Eastern and Lusaka provinces, where more than 90% of the cotton is produced (Fig. 1). The cotton crop is produced as a family business, with all members of the family taking part in various production operations such as weeding and harvesting. Similarly, in many other African countries cotton is still produced mainly by small-scale growers.

In the 1984/85 cotton growing season, about 30,254 tonnes of seed cotton were produced, meeting the demands of the nationally important textile industries and also producing a surplus to provide a much needed source of foreign exchange for the country. In addition, seed cotton also provides an important source of oil and proteins.

Cotton provides an important source of cash for a large number of small-scale rural farmers, so its production has recently received more attention to realise its potential in Zambia. One of the priorities of the Zambian Government is to diversify the economic base so that the country is not overdependent on the export of copper as the major source of foreign exchange. The development of the rural sector has been the centre of this effort (Mweetwa et al.,1983).

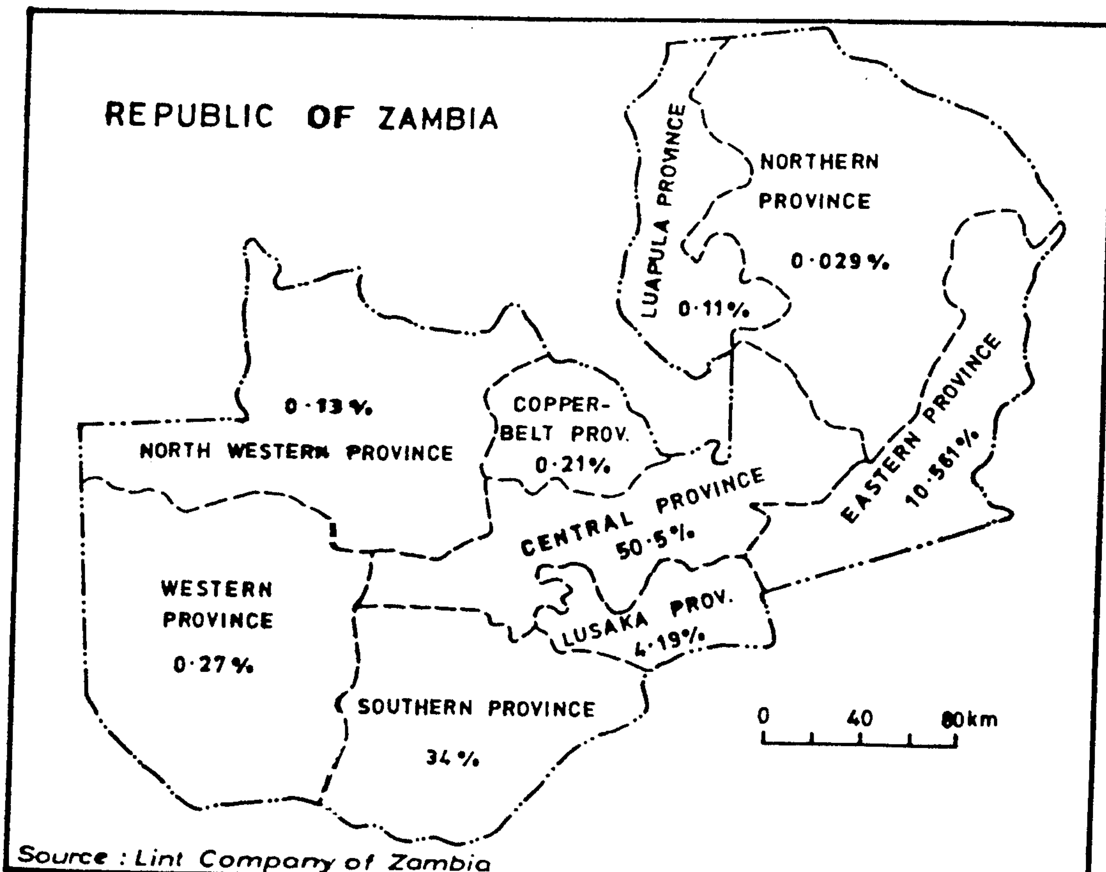

Fig.1: Cotton Production in different Provinces of Zambia, 1984-85.

In 1975, a cotton project under the National Agriculture Marketing Board (NAMBOARD) was established to increase the cotton production. It was decided that if this project became successful then a separate company will be formed to increase the cotton production in order to cut down the importation of lint (Anon, 1985a).

During 1977, His Excellency, President Kaunda announced the formation of the Lint Company of Zambia Ltd., which was subsequently incorporated in 1978, with the main objective of increasing cotton production in order to reach self sufficiency in lint requirements and also to create an export market (Anon, 1985a).

The increase in cotton production in Zambia can be attributed to the formation of the Lint Company of Zambia Ltd (LINTCO) in 1977/78 as the sole organization responsible for over-seeing production, marketing, and processing of the cotton. The production was further encouraged by the launching of the EEC (European Economic Commission) financed cotton project with LINTCO in 1979/80 (Kruel, 1983).

The number of cotton growers and the area under production has significantly increased during the last 10 years since the formation of LINTCO, resulting in a dramatic increase in the production of cotton. (Fig.2a The local textile industries are now supplied with all their lint requirements and a surplus is exported.

The present position of cotton in Zambia, in relation to other major agricultural crops (Table 1) shows that cotton is now the third most important crop in terms of the cash value.

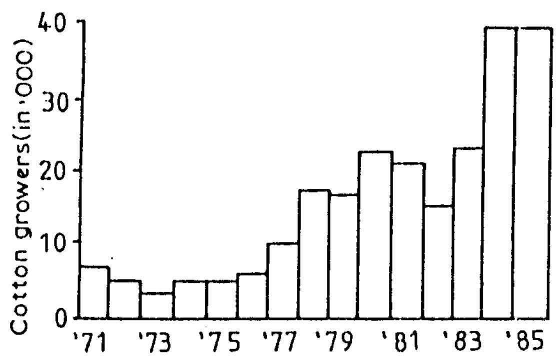

Fig. 2 (a). Number of Cotton Growers (1971–85).

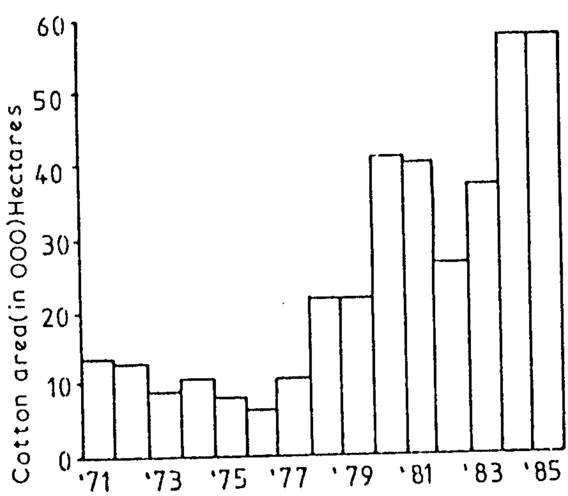

Fig 2 (b). Area under Cotton (1971–85)

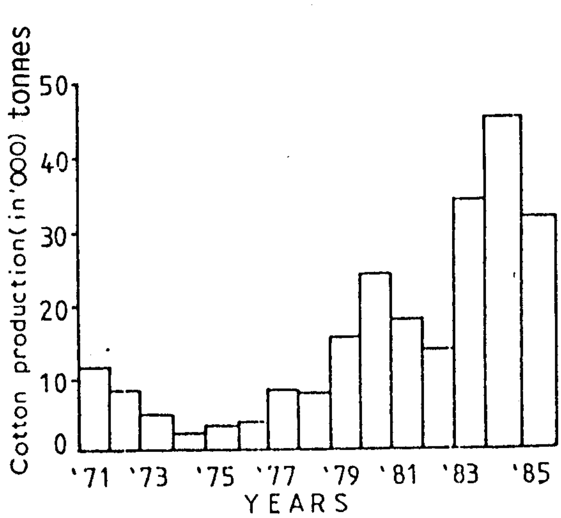

Fig. 2(c). Production of Cotton (1971–85).

Source: Lint Company of Zambia

Table 1 Table showing the position of cotton, in terms of value, in relation to the rest of major agricultural field crops in Zambia (1985).

Crops	Production in tonnes (1985)	Value (K,000)	% (of total crops value)
Maize	112,2372	200212	56.36
Sugarcane	143,182	93068.3	26.2
Cotton	30,254.069	20270	5.706
Sunflower	42,423.7	14217	4.002
Tobacco	2,619.55	8668	2.44
Soyabean	14,737.86	7174	2.019
Wheat	11,313.9	5343	1.504
Rice	11,232.88	3140	0.88
Groundnuts	14,517.44	2772	0.78
Sorghum	20,226.51	335	0.094
Millet	19,441.53	18	0.005
Total all crops		K355217.3	

Source: Central statistical office, Lusaka.

LINTCO has established about 500 depots in the rural areas, to provide technical and extension services to small-scale cotton farmers. All inputs, such as cotton seed, insecticides, spray machines, spare parts, and packing materials are supplied to the farmers in the form of seasonal loans, payment of which is made from the sale of produce to LINTCO. LINTCO, the sole buyer of seed cotton, pays the farmers within three weeks, and this system has attracted and encouraged many small-scale farmers to grow cotton in Zambia.

The main objective of LINTCO was to provide the extension services to small scale farmers in order to increase the cotton production. The extension officers are seconded to LINTCO under an agreement with the Ministry of Agriculture and Water Development (MAWD), LINTCO provides transport to extension officers including landrovers, motorcycles and bicycles at the appropriate levels. LINTCO also pays the travel and subsistance allowances to all extension agents seconded to it.

Through their constant contact with the farmers, LINTCO increased the production of seed cotton from 8,928,831 Kg in 1977/78 to 43,997,183 Kg in 1983/84 cotton growing season.

The seed cotton is graded at LINTCO depots on the basis of staining and trash contents. Most of the seed cotton (over 90%) is of grade A quality.

There are three types of lint qualities of cotton; (1) staple length of 1 and one sixteenth inches; (2) micronair 3.8 inches (at maturity stage); and (3) pressley strength 193.60 per square cm. (Anon, 1985 a).

In Zambia, there are five cotton ginneries; one located in Chipata in Eastern Province, two in Lusaka in Lusaka Province; a fourth in Gwembe valley in Southern province and the fifth is in Mumbwa.

The cotton seed is certified by Central Research Station at Mount Makulu. It is mostly acid delinted which is done at Lusaka ginnery.

COTTON PESTS

In Zambia, only a few insects are serious pests which attack cotton during the different stages of its development (Bruinsma, 1985).

The most important insect pest is the American bollworm (*Heliothis armigera*) which attacks buds, flowers and bolls of cotton. It has a wide range of host plants such as maize, tomato, sunflower, groundnuts and beans (Anon, 1968; Bohlen, 1982; Bruinsma 1985).

The red bollworm (*Diparopsis castanea*) exclusively feeds upon cotton and prior to 1969, this pest was confined to the Eastern province and the Gwembe valley area of Southern Province (Lyon, 1975a). It is now distributed in almost all cotton growing areas of Zambia and is regarded as the second most important pest.

The aphids (*Aphis gossypii*) cause direct damage by sucking plant sap, and also exude a sugary secretion from their bodies, that sticks to leaves and also on open bolls. The honeydew seriously hampers the growth of plants and a fungus known as sooty mould grows on it which discolours the lint of cotton at the end of the season.

The jassids (*Empoasca* spp.) suck the plant sap and inject toxic saliva which causes the discolouration of leaves from yellow to red. This symptom is usually called as hopperburn. The jassids are largely controlled by growing partially resistant varieties of cotton.

The stainers (*Dysdercus* spp.) are the late season pests. They pierce the bolls of cotton and suck the contents of seeds. They also cause damage by feeding on the open bolls. The attack of stainers is more devastating if their mouth parts are contaminated with the fungus (*Nematospora gossypii*). The fungus is transmitted into the cotton bolls during sucking and causes internal rot.

The whiteflies (*Bemisia tabaci*) are less serious on cotton in Zambia as compared to Sudan and some other cotton growing countries of the world.

The other insect pests are regarded as minor pests of cotton at present in Zambia and are normally controlled by spraying against the major pests. These are cotton semi looper (*Anomis flava*), loopers (*Trichoplusia* sp.), cotton leaf worm (*Spodoptera littoralis*), spiny bollworm (*Earias* sp.) cotton leaf minor (*Acrocercops bifasciata*), lygus bug (*Taylorilygus vosseleri*), and the elegant grasshopper (*Zonocerus elegans*).

The termites (*Microtermes* sp.) cause occasional damage during the dry spells. The red spider mites (*Tetranychus* sp.) are rarely important in this country.

There are no major diseases of cotton in Zambia. The bacterial blight of cotton has been recorded and remains as a potential threat. However, the cotton crop suffers from the boron deficiency in all parts of Zambia and five spray applications of 'solubor' are currently recommended.

The cotton is very much susceptible to weeds in Zambia particularly in the early stages of its development. Weeding by hand and using ox-drawn equipment are the most commonly practiced methods for weed control of cotton in all cotton growing areas of the country.

In Zambia, cotton production was tried many times in the past. Due to insect pests and the absence of effective control measures including the use of insecticides, it never became a really established crop (Anon, 1968). Prior to the 1960's, the cotton was no longer considered as an economical crop. However, the development of effective insecticides made the control measures possible. The increased yields were obtained by the application of insecticides and subsequently the area under cotton increased and the cotton reinstated as an important cash crop at many small-scale farms.

The insecticides used in the past were DDT, carbaryl, endosulfan and dimethoate (Anon, 1968). The application of these insecticides was considered essential for the control of insect pests. The carbaryl was applied mainly against *Diparopsis* and *Dysdercus*; and DDT for *Heliothis* control. The dimethoate was added against aphid control. However, the application of DDT and dimethoate on cotton has been abandoned in Zambia.

The currently recommended insecticides for use against cotton insect pests that are available to farmers, come in two types of small packages, collectively known as a "lima pack". They are especially packed for small-scale cotton farmers in Zambia. The 'conventional cotton packs' contain endosulfan and carbaryl in powder formulations and control a wide range of cotton pests. Endosulfan (50% wp) gives very good control of American bollworms as well as jassids; and carbaryl (85% wp) is very effective against red bollworms and stainers (Bruinsma, 1985). These two insecticides can also be used as a mixture. The current recommendations for the use of conventional cotton packs include a schedule of 10 spray applications at weekly intervals during the cotton growing season. The pyrethroid packs contain either cypermethrin or deltamethrin. Due to longer persistance effects of these insecticides, only five spray applications at an interval of two weeks are recommended. These insecticides provide good control of American bollworm, red bollworms, and stainers. The pyrethroid packs are replacing the conventional pack in Zambia and during 1986/87 about 97% of the cotton in Zambia was sprayed with pyrethroids (A. Mulala*, Personal communication). The spray applications with both types of insecticides must start seven weeks after germination (Bohlen, 1982), and the farmers pay the same price for both types of insecticide packs required to spray one hectare of cotton per growing season. Ideally, the insecticides must be applied according to the scouting of insect pests of cotton but due to the lack of effective training and adequate extension services, many farmers follow a fixed spray regime for both types of insecticide packs.

The application of insecticides by lever operated knapsack sprayers

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is still the most commonly practiced pesticide application technique on cotton in Zambia (Bruinsma, 1985).

The insect pest management practices at small cotton farms in Zambia were investigated by a survey of farmers. The application of insecticides on cotton was evaluated by field trials on the timing of spray applications, comparison of application techniques and the swath widths of 'Electrodyn' sprayers. The results of these studies are reported in this thesis.

SECTION A

CHAPTER 2

SURVEY OF FARMERS ON COTTON PEST MANAGEMENT

INTRODUCTION

The recommendations based upon the results from Mount Makulu and other research stations in Zambia were issued to the farmers on various aspects of insect pest management of cotton including the application of insecticides, but there was little feedback of information about how the individual farmers manage the cotton insect pests at their farms. So a survey was carried out in 1985 in different cotton growing areas of Zambia.

The results of the survey are presented in the next few chapters under various sections including background information, pest management, application techniques, safety precautions, extension services and the sources of advice; corresponding to the main sections of the questionnaire (appendix 1).

Each section of the questionnaire is described in a separate chapter along with the introduction, results, discussion and conclusions.

AIMS AND OPERATION OF THE SURVEY

This section describes the procedures and attempts which were aimed at studying what actually happens at the small-scale farm level regarding the insect pest management of cotton.

Some of the factors which were looked at using a personal interview of cotton farmers are presented in Table 2 .

The main objectives of the survey are summarised below:-

1. To study the currently adopted cotton pest management practices, application techniques, safety precautions, training and sources of advice available to small-scale farmers.

2. To understand and evaluate the problems faced by farmers for more meaningful research and extension programmes on cotton pest management in Zambia.

PROCEDURE

An intensive interview of the farmers was conducted and due care was taken to ensure that farmers interviewed understood the questionnaire and their responses were correctly interpreted. The interviews were conducted with the cotton farmers who were responsible for pest control decision making, and not with other members of their families.

The cotton development management of LINTCO had written to all the extension officers in the selected areas; 2-3 weeks in advance, informing them about the objectives of the survey and asked them to provide the maximum co-operation. Copies of such letters were also taken personally by the author because in some cases the letters had not reached the extension officers in rural areas. The extension officers helped a great deal, especially where language problems arose.

Table 2. Some factors included in the cotton pest management survey.

Background information	pests and pest management	Application of insecticides	Safety precautions	Sources of advice
Farm hectarage	Knowledge of pests	Types of sprayers used	Knowledge of	Training
Cotton hectarage	Status of pests	Effectiveness of sprayers	Protective clothing	Extension
Types of crops at farms	Loss estimates	Common problems	Knowledge of other safety precautions	Other sources of advice
Experience in cotton growing	Non-chemical control	Spare parts	Actual clothing during spraying	Visits by extension workers.
Reasons for cotton growing	Biological control	Improved techniques	Insecticide poisoning	Farmers suggestions for improvement.
Cotton yields	Rotation	Reasons for not using improved techniques	Actions in case of sickness	
production problems	Closed season	Farmers' suggestions for improvement		
Suggested solutions of production problems	Chemical control			
	Types and effectiveness of insecticides			
	Scouting for pests			

THE QUESTIONNAIRE

A standard questionnaire (appendix 1) was drawn up according to the main objectives. It was discussed with cotton entomologists, cotton agronomists, rural sociologists and various academicians in the field of rural economy. The questionnaire was divided into five sections.

Section A consisted of 12 questions which were related to the general description of the farms and production of cotton. Most of these questions were simple and straightforward to build the farmers confidence.

Section B (questions 13 to 35) was designed to obtain the maximum information from the farmers about major pests, their status, loss estimates, types and effectiveness of control measures and the timing to start and stop the insecticide spray applications.

Section C (questions 36 to 47) was concerned with the techniques of insecticide application and the farmer's attitudes towards the new and improved techniques with special reference to ULV and 'Electrodyn' sprayers.

Section D (questions 48 to 54) hoped to determine the farmer's knowledge and actual practices about the safety and other management practices of insecticides at small-scale farms.

Section E (questions 55 to 62) dealt with training and other sources of advice available to farmers in cotton pest management and also included the farmers suggestions/on how to improve on it.

PILOT SURVEY

A preliminary survey was carried out in January 1985, prior to the actual survey, to test and improve the questionnaire. Ten small-scale farmers were interviewed in the cotton growing areas in the vicinity of Lusaka including Chongwe and Chilanga areas. After compiling the information obtained from the pilot survey, the questionnaire was revised to increase its effectiveness. The revisions included modifications of a few questions so that farmers could understand them easily.

SELECTION OF TARGET AREAS.

Discussions were held with LINTCO officers regarding the selection of target areas. It was decided to select three areas including Magoye, Mukalaikwa and Keembe in Mazabuka, Mumbwa and Kabwe districts respectively. All selected areas had a very large number of small-scale cotton farmers and were also near to Lusaka so the visits were easier to arrange.

SELECTION OF TARGET FARMERS

Only small-scale farmers were included in the survey because they produce more than 90% cotton in Zambia. Due to limitations of time, transport and funds; a sample of 90 farmers; 30 from each selected area was considered to be adequate.

THE SAMPLE

Lists of cotton farmers were available from extension officers in most of the selected areas so these were used to select at random, samples of farmers for the interviews.

TIME OF SURVEY

The interviews were conducted from July to September 1985, during the dry season when farmers had the least field work. They had just completed their cotton harvests and could still remember the pest control operations.

THE INTERVIEWS

The farmers were very co-operative during the interviews and most of them continued informal discussions even at the end of the interviews. They appreciated the interest shown in their problems. Only 3 to 4 interviews were conducted on an average day.

ADDITIONAL INFORMATION

The general informations about cotton production, protection, training and extension activities were obtained through the records of LINTCO and detailed discussions held with their staff.

CHAPTER 3

BACKGROUND INFORMATION

INTRODUCTION

The small-scale cotton farmers in Zambia and in many other cotton growing countries in Africa are generally the poorest, most tradition bound, and have the least access to information. Tropical peasant farmers are the most neglected members of the human population (Haskell, 1977) and yet 60% of the world's cultivated land is being farmed by the subsistance and tropical farmer (Ruthenberg, 1976). However, the widespread food deficiency, recently being experienced in many developing countries, has compelled the national programmes and many international donors to place a high priority on improving the agricultural productivity of small-scale farmers (Matteson et al., 1984).

Many countries in Africa including Zambia, urgently need foreign exchange, and the export of cotton can provide this. The production of cotton on small farms also enhances the status of agriculture, and helps to prevent the migration of labour to towns.

The development of cotton production at small-scale farms is a top priority for the Government in Zambia. However, a small-scale cotton grower does not always have the same motivations as those of his Government (Morton, 1979); therefore it is fundamentally important to examine his incentives.

In the past very little attention has been directed towards the sociological aspects of cotton production by peasant farmers in Africa.

The previous programmes lacked the understanding and appreciation of ecological, and many socio-economic components (Morton, 1979).

Generally, many research programmes in the tropics have been patterned after those in developing countries. Most of these were also based upon the research stations, and they failed to consider many basic features of peasant agriculture. Such recommendations for small-scale farmers were agronomically, socio-economically and ecologically unacceptable to the target farmers (Matteson et al., 1984).

However, there is a need, more than ever, to look into the problems which surround the cotton growing at small farms in Zambia. In order to make the recommendations that farmers will use, one has to think in terms of the farmer's goals and the constraints in attaining these goals (Perrin et al.,1979). An increased understanding of the small farm situations that determines the conditions influencing the traditional cropping patterns demands a deep knowledge of the practical side of the small scale farms (Matteson et al., 1984).

This chapter deals with the generation of background information on the production of cotton on small -scale farms in Zambia. It is focussed on a better understanding of cotton production, identification of farmers' problems; their attitudes towards cotton production and their suggestions for recommendations that fit the farmers' goals and situation. Indeed, the research and extension can be more effective if it proceeds from the current circumstances of farmers, and hence there is a need to understand and identify these circumstances.

RESULTS

Farm size

The sample of farms included a range of different sizes. The smallest farm had an area of 1.6 hectares and the largest had about 80 hectares. The distribution of farms according to the classes of small, medium and large is shown in Figure 3. The small farms had the total cultivated area of up to 10 hectares, medium farms had 11-20 hectares, and the large farms had more than 21 hectares. The average cultivated land at the selected farms was about 15 hectares.

Cotton area

The area under cotton crop reported by farmers during the survey ranged from 0.8 to 8.8 hectares (Figure 4). The average area under cotton at selected farms was about 3.7 hectares.

Types of crops grown at farms.

In addition to cotton, the other crops grown by farmers were maize, sunflower, groundnuts and soyabean. Table 3a shows the crops grown by different farmers and the hectarage under various crops on an average farm.

Percentage area under crops.

The range of area (in percentages) under various crops such as maize, sunflower, groundnuts and soyabeans at the selected farms is shown in Figures 5, 6, 7 and 8. The mean percentage area under maize, sunflower, groundnuts and soyabeans at cotton farms was 43.20, 26.64, 10.35, and 6.65 percent respectively.

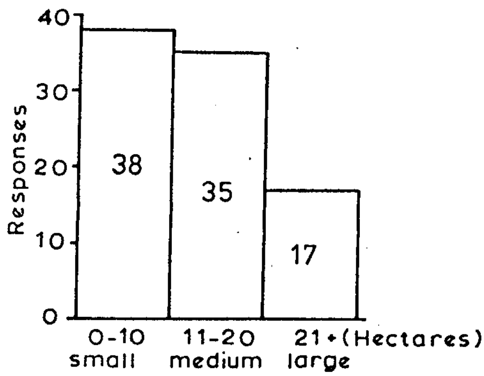

Figure 3. Farm size.

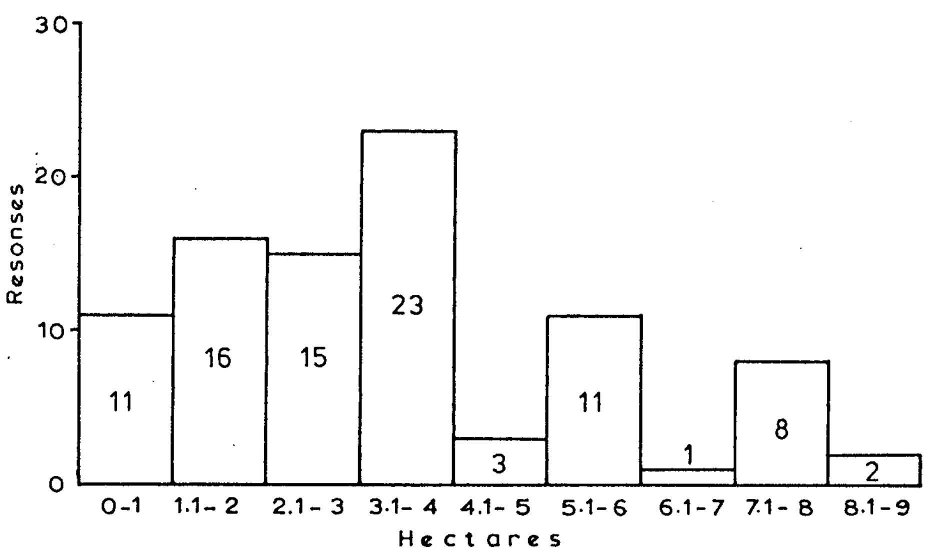

Figure 4. Area under cotton cultivation.

Table 3a. Types of crops grown by farmers in addition to cotton.

Crops	No. of farmers (out of 90)	Average hectarage per farm
Maize	89	6.51
Sunflower	68	3.30
Soyabean	17	1.08
Sorghum	6	0.73
Groundnuts	71	1.31
Vegetables	22	0.51

Types of fruit trees.

Many farmers had also grown several fruit trees such as mango, orange, banana, and guava. The types of fruits grown and the average number of fruit trees per farm are shown in Table 3b and Figure 9 .

Table 3b. Types of fruits grown at farms

Crops	No. of farmers (out of 90)	Average number of trees per farm
Mango	56	10.89
Orange	21	7.33
Banana	35	9.85
Guava	17	5.76

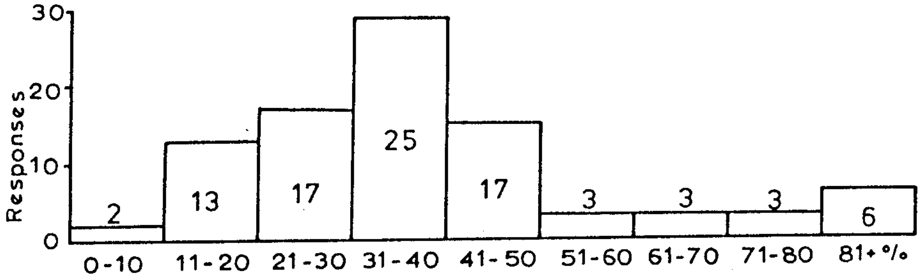

Figure 5. Maize, as percentage of total area of farms.

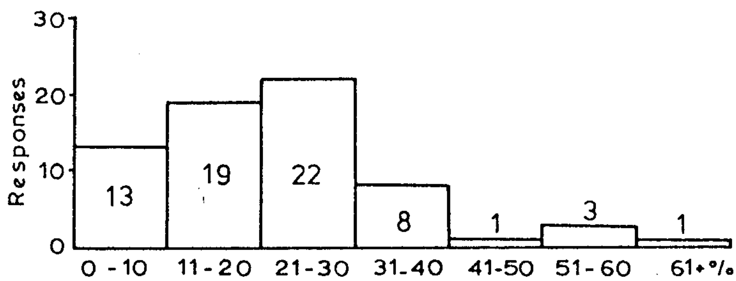

Figure 6. Sunflower, as percentage of total area of farms.

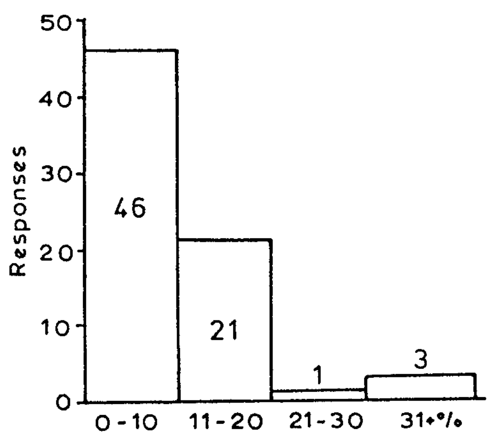

Figure 7. Groundnuts, as percentage of total area of farms.

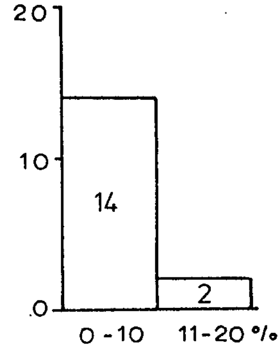

Fig. 8. Soya beans as ° of total area of farms.

Types of vegetables.

Vegetables were grown by only 24% of the farmers with an average area of 0.51 hectares per farm.

Livestock

Cattle were kept by 96% of the farmers with an average number of 33.6 cattle per farm. The range of the number of cattle at different farms is shown in Figure 10. In addition to cattle, about 23% of the farmers also kept goats with an average number of 12 goats per farm.

Cotton yield

The distribution of the yield of seed cotton reported by farmers is shown in Figure 11. The mean yield reported by farmers was 735 kg/ha. All farmers reported that the quality of cotton produced by them was of grade A.

Experience in cotton growing.

The experience of cotton growing reported by the farmers ranged from 1 to 35 years with an average of 12 years (Figure 12).

Reasons for cotton growing.

The farmers reported various reasons for growing cotton. Fifty two farmers reported cotton as a good cash crop, 24 no fertilizer requirement, 19 drought resistance, 12 credit facility to buy inputs from LINTCO, and 10 reported the advice from extension officers (Figure 13).

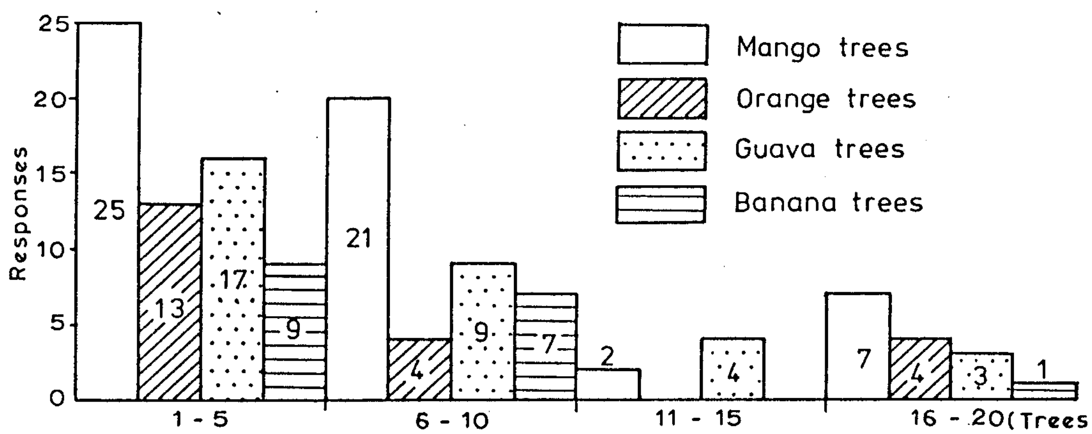

Figure 9. Range of fruit trees at the farms.

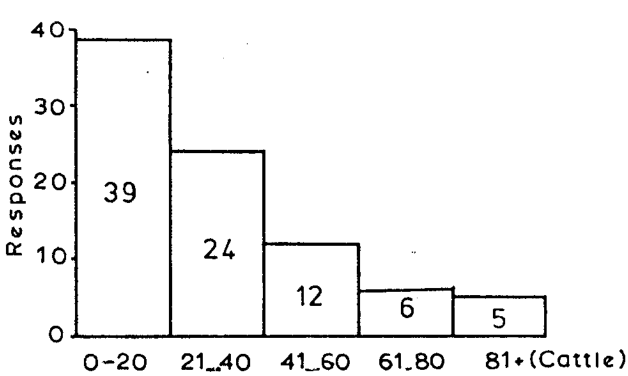

Figure 10. Numbers of cattle at the farms.

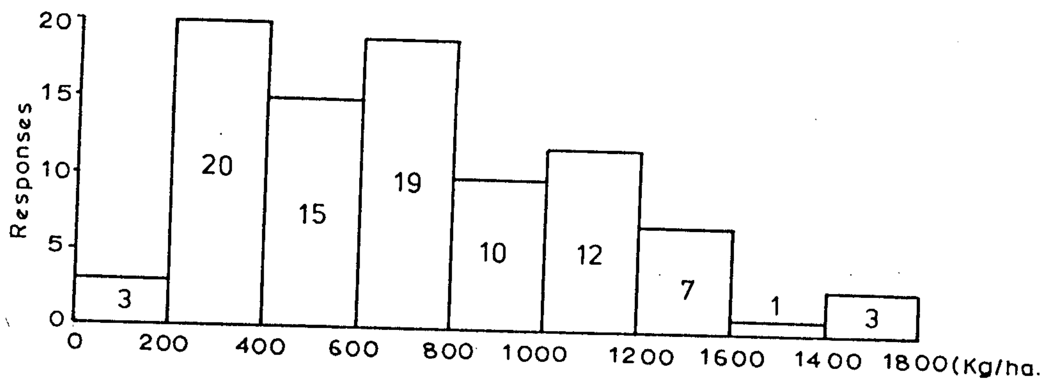

Figure 11. Yield of seed cotton in Kg/ha.

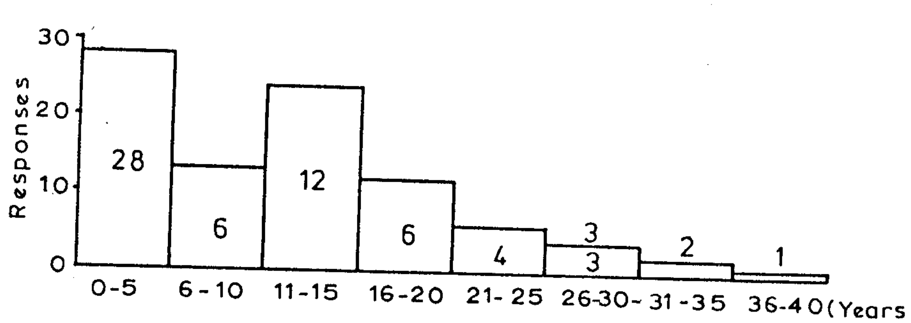

Figure 12. Experience of cotton growing in years.

Cotton production problems.

Sixty seven farmers reported weeds, 24 insect pests, 6 lack of training and 4 mentioned the harvesting of cotton as the major production problems of cotton. The other problems reported by few farmers (7) were; high cost of insecticides, application of insecticides, labour requirement, lack of credit facility from LINTCO to buy cotton herbicides and the unsuitable soil for cotton production (Figure 14).

Solutions of production problems.

The farmers also suggested various solutions for the cotton production problems at their farms. Thirty six farmers suggested the supply of herbicides for weed control in cotton, 17 better advice, 8 better weeding, 8 hiring more labour, 8 more loan facility from LINTCO, 6 better insecticide application methods, 4 better insecticides and the other three farmers suggested more training, demonstrations and field days (Figure 15).

Trends towards cotton production.

The farmers were asked whether they would like to increase or decrease the area under cotton at their farms during the next season. Seventy four farmers said they would increase, 8 would decrease and another 8 farmers reported to keep the same area under cotton during the next season (Figure 16).

Reasons for increase in cotton production.

Out of those farmers who reported to increase the area under cotton; 54 said it was a good cash crop, 14 mentioned no fertilizer

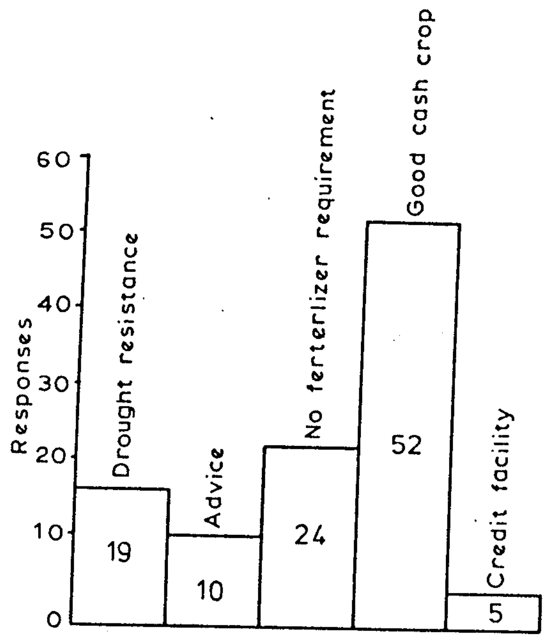

Figure 13. Reason for growing cotton.

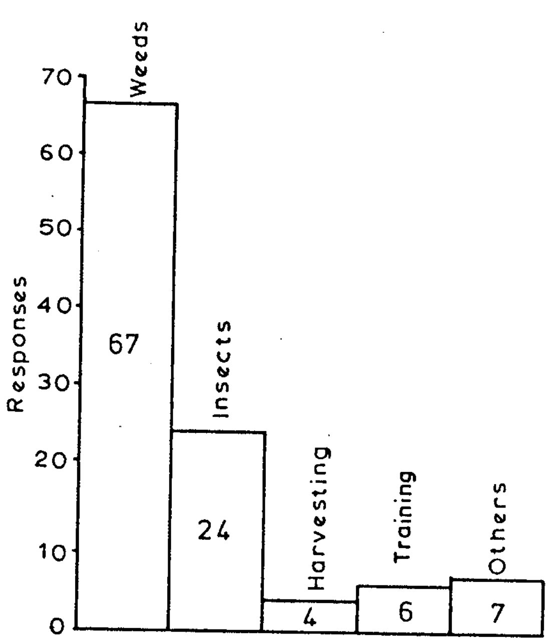

Figure 14.Cotton prodution problems.

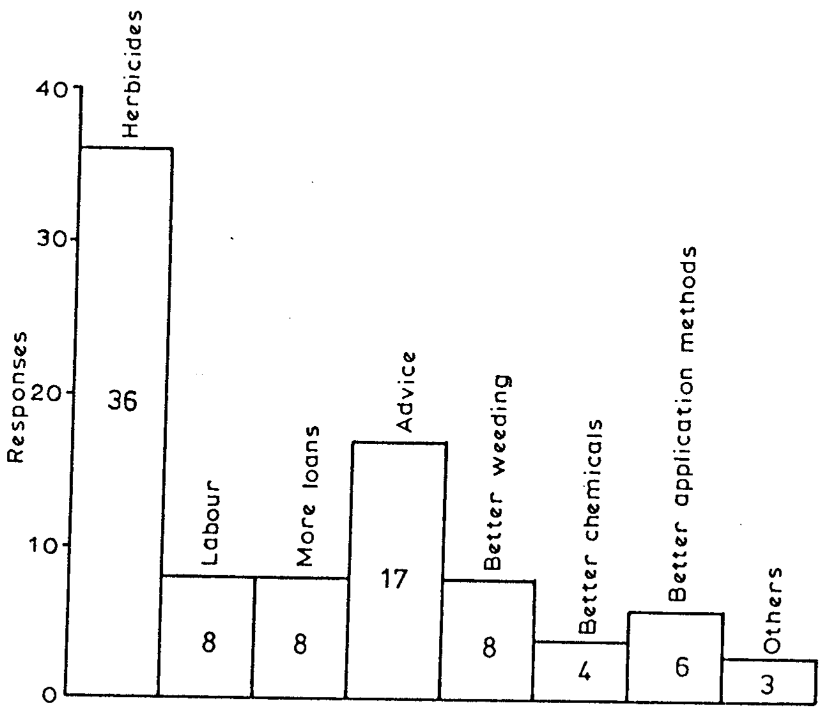

Figure 15. Suggested solutions of production problems.

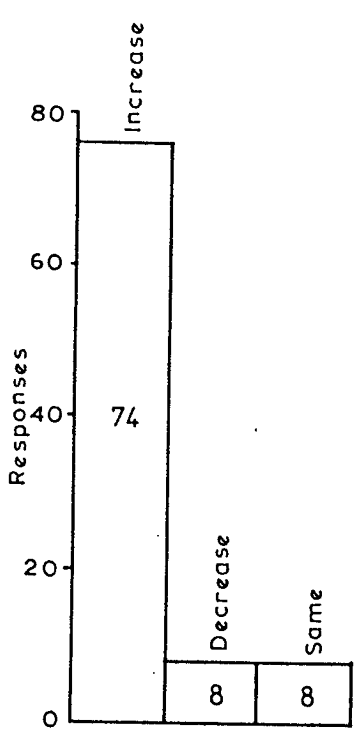

Fig. 16. Increase in cotton production.

requirement, 6 availability of family labour, 3 better prices, and 3 credit facilities from LINTCO (Figure 17). The other few farmers reported drought resistance and experience in cotton growing.

Decrease in cotton production.

Three farmers wanted to decrease the area under cotton due to weed problems, 2 said too much labour requirements, one farmer was too old to increase the area, another farmer had limited land at his farm, and one said that the chemicals were too expensive (Figure 18).

Same cotton area.

Out of 8 farmers, who reported to keep the same area under cotton during the next season, 4 reported weed problems, 3 had limited land at their farms and one had the labour problems (Figure 19).

DISCUSSION

Description of farms:- The small-scale farmers tend to specialize in 3 or 4 types of crops. The strain of management and the inputs is probably reduced. Maize being the staple food crop in Zambia, occupied the maximum cultivated area (43%) at the selected farms. However, it was surprising to note that only one fourth of the farmers had grown vegetables at their farms. The most common adaptations were rape, cabbage and beans. There is a need to encourage more farmers to grow vegetables, at least for their own consumption.

Cattle were the most important part of the farming system and the oxen were reported to be used for many farm operations. In addition to preparation of land, many farmers (70%) had used oxen for weeding in

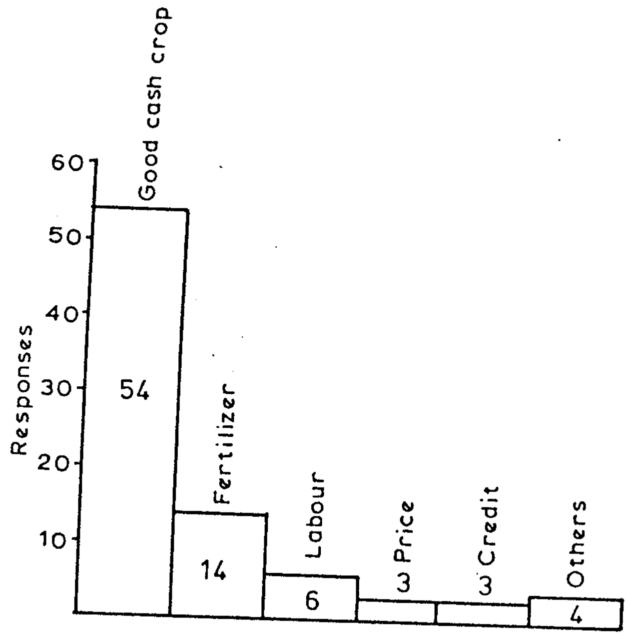

Figure 17. Reasons for increasing cotton production.

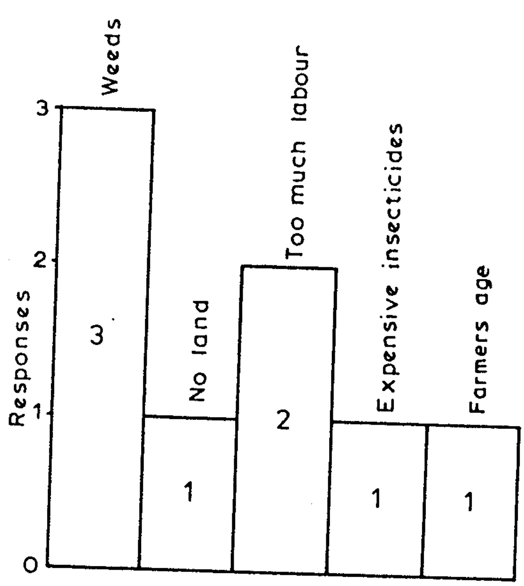

Figure 18. Reasons for decreasing cotton production.

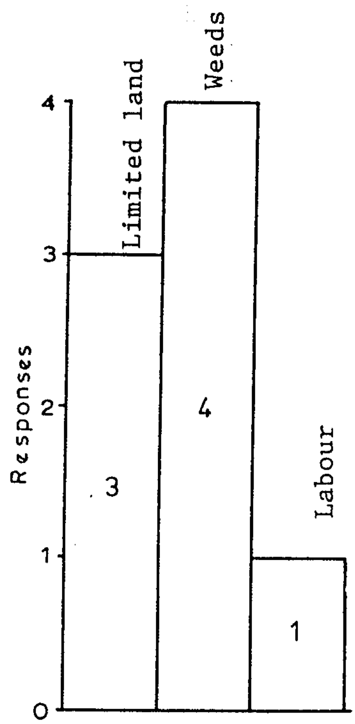

Fig. 19 Reasons for keeping same area under cotton.

their cotton crops. Cattle are also used for transporting the seed cotton from small villages to the LINTCO depots. They were also frequently seen grazing in cotton fields, after the cotton had been picked up.

Cotton at farms:- That only 30% of the cultivated area at an average farm was devoted to cotton is not surprising since cotton is a labour intensive crop and is technically more demanding as compared to other crops. The farmers also make some allowances for maize, sunflower and groundnuts (Mweetwa et al., 1983) which are commonly grown at such farms.

The yield of seed cotton,with an average of 735 kg/ha during the 1984/85 season, was mainly due to the unfavourable rainfall pattern which prevailed in the selected areas. The rains in most of the selected areas stopped too early which caused a lot of boll shedding resulting in the decrease of cotton yield. However, the average yields may be as high as 900 kg/ha in a good season, which compare favourably with rain-grown cotton anywhere in Africa. Individual yields may be much higher, and some small-scale farmers regularly obtain yields of 2000 to 2500 kg/ha as a result of good management of insect pests (Lyon, 1975a).

Cotton provides the most important source of cash which was considered very important by the majority of farmers (58%). A subsistance farmer likes cash with which he obtains the freedom to make his choice of purchase for himself and his family (Morton,1979).

Production problem:- The pests are a major problem reported by small-scale cotton farmers. As 70% of the farmers reported the problems of weeds, and they also suggested the supply of herbicides by LINTCO along with other inputs; the discussions were held with LINTCO officers and it was revealed that farmers are expected to make use of the family labour which is expected to be available at such farms for the manual weeding. But since the farmers are constrained with insufficient labour because many young men and women have left for towns in search of other types of jobs, and the provision of herbicides to cotton farmers on seasonal loans will indeed save a lot of labour which can possibly be utilized to increase the area under cotton or other crops grown.

Generally, the value of herbicides on the African peasant farm has not been assessed adequately. The herbicides are often regarded as too expensive especially with the apparent abundance of traditional labour (Morton, 1979). However, there is an increasing realization of the possibilities of herbicide use in some cotton growing countries such as Swaziland (Armitage and Brooks, 1976).

About one third of the farmers mentioned insect pest problems. They suggested that these problems could be solved using better pesticide application methods and by having more advice on pesticide use. These suggestions deserve more attention from the extension authorities.

Future cotton production:- Sixty percent of farmers started to grow cotton after the formation of LINTCO in 1977/78. This emphasises the importance of the incentives provided by LINTCO. The majority of the farmers (70%) indicated that they wanted to increase the area under cotton at their farms. It appears that cotton production on small-scale farms is very bright and that it might remain an important crop at such farms.

CONCLUSIONS

Cotton is a most important cash crop on small-scale farms. Most of the farmers started cotton growing after the formation of LINTCO, and many farmers have a tendency to increase the production of cotton at their farms. Since the cotton crop gives reasonably good yields, when planted after a well fertilized maize crop, without any additional fertilizer, it was also an important consideration for some farmers to grow cotton. Farmers need more advice on cotton production particularly on the management of pests.

CHAPTER 4

PEST MANAGEMENT PRACTICES ON COTTON

INTRODUCTION

A large number of insect pests have been recorded on cotton crops from south of the Sahara (Pearson and Darling, 1958). In Zambia, the major insect problems which deserve immediate attention and management include; the American bollworm, red bollworm, aphids, cotton stainers, jassids and red spider mites (Bruinsma, 1985). However, the status of these and other insect pests can always vary with changes in the environments, types of chemicals used, and cultural practices.

The insect damage can significantly reduce yields and the quality of seed cotton; up to 80% losses have been reported (Bruinsma, 1983). This is probably why over a third of insecticides used in agriculture in the world were reported to have been used on cotton in 1974 (Matthews, 1979).

However, reliance on insecticides not only fail to provide a permanent control of cotton pests but can increase problems in cotton agro-ecosystems such as the development of resistance and the emergence of the secondary outbreaks of insect pests (Eveleens 1983; Flint and van den Bosch, 1981).

In some cotton growing countries of Central America including Nicaragua, Guatemala, El-Salvador, and Honduras; the increased yields of cotton were obtained from 1949 to 1965 due to the use of insecticides. However, during the period of 1966 to 1970, pest resistance to insecticides developed, cotton yields declined drastically and due to other insecticide associated problems each country, suffered a severe economic crisis (Kumar, 1983). After these disasters, the integrated pest management programme of cotton has received particular attention in many cotton growing countries of the world.

The use of insecticides is still valuable for many small-scale cotton farmers in tropical countries, but there is a need for the judicious use of these chemicals and to integrate with other methods of control.

In Central Africa satisfactory results were obtained during field trials when the sprays were applied in relation to the data obtained by monitoring the insect pests of cotton (Matthews and Tunstall, 1968). In Zambia since the 1960's, there has been a great emphasis on scouting for insect pests of cotton to improve the timing of applications (Tunstall and Matthews 1961; Anon, 1968; Bohlen, 1982).

In this case fewer applications should be required when compared with a fixed number of spray applications. A reduction in the number of applications timed to coincide with pest intensity should reduce the selection pressure for pest resistance (Matthews, 1979).

However, in Zambia and many other cotton growing countries in Africa, the majority of small-scale cotton farmers still apply insecticides on their cotton crops on the prophylactic basis irrespective of the occurrence or level of an insect pest infestation.

This chapter describes the results obtained from a survey to investigate the actual practices and constraints of small-scale cotton farmers in the management of cotton insect pests in Zambia.

RESULTS

Insect Pests observed - The farmers were shown the photographs and specimens of common insect species of cotton and were asked which ones they had observed on their crops during the 1984/85 season. All farmers reported that their cotton crops suffered from various insect species. The number of farmers who reported to have observed each type of insect on their cotton is shown in Table 4. Most farmers had experienced the major key pests on their crops; 74 farmers reported stainers, 73 American bollworms, 61 red bollworms, 66 aphids and 58 Jassids.

The minor pests such as white flies and mites were reported by 29 and 17 farmers respectively. However, the elegant grasshopper and termites, generally regarded as minor pests, were reported by 65 and 67 farmers respectively.

Status of insect pests. - The farmers were then asked about the importance of cotton insects according to their own experience. The status of insect pests reported by the farmers as first, second and third pests is shown in Figure 20. The three key pests of cotton including the American bollworm, red bollworm, and aphids were reported to be the worst pests by the majority of farmers.

Table 4. Table showing the number of insect species reported by cotton farmers

Insect pests	Farmers responses
Mites (*Tetranchychus cinnabarinus*)	17
Whiteflies (*Bemisia tabaci*)	29
Spiny bollworm (*Earias* spp.)	45
Jassids (*Empoasca* spp.)	58
Red bollworm (*Diparopsis castanea*)	61
Grasshoppers (*Zonocerus elegans*)	65
Aphids (*Aphis gossypii*)	66
Termites (*Microtermes* spp.)	67
American bollworm (*Heliothis armigera*)	73
Cotton stainers (*Dysdercus* spp.)	74

Chemical Control. - All farmers interviewed had sprayed insecticides on their cotton crops in order to reduce the losses caused by insect pests and to improve the quality of cotton lint.

Yield loss estimates without insecticides. - The farmers estimates of yield losses caused by insect pests without the application of insecticides on cotton (Figure 21) show that the majority of them (65%) estimated 70-100% loss.

Quality loss estimates without insecticides. - Most farmers (62%) estimated that their seed cotton should have been of the lowest quality grade (grade C), while the others expected grade B if the application of insecticides was not carried out.

Insecticides used. - All but three farmers reported that they applied pyrethroid insecticides for the control of cotton pests. Cypermethrin and deltamethrin were the only two pyrethroids used in the selected areas. Most farmers had used the EC (emulsifiable concentrate) formulation of pyrethroids; of these 47 used 'Decis' (deltamethrin), 8 'Ripcord' and 5 'Cymbush (Figure 22). The 'Electrodyn' formulation of cypermethrin was also used by 37 farmers. However, a few farmers had also used both ED and EC formulations of cypermethrin.

Selection of insecticides. - Fifty farmers reported that the insecticides which they had used were the only ones available at LINTCO depots, 22 farmers reported the efficiency, 12 advice by extension officers, 4 experience, another 4 farmers mentioned the increased spray intervals between each spray application of pyrethroids, 2 reported

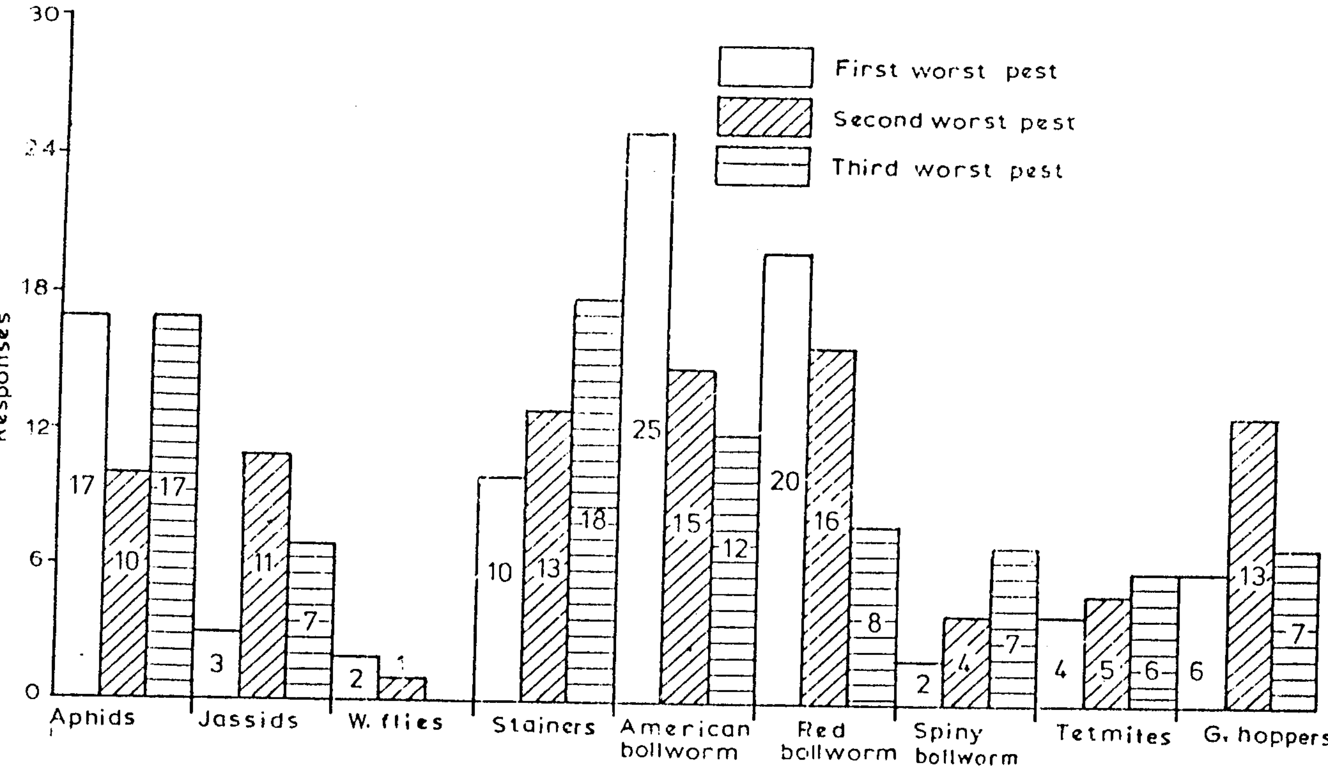

Figure 20. Status of Pests.

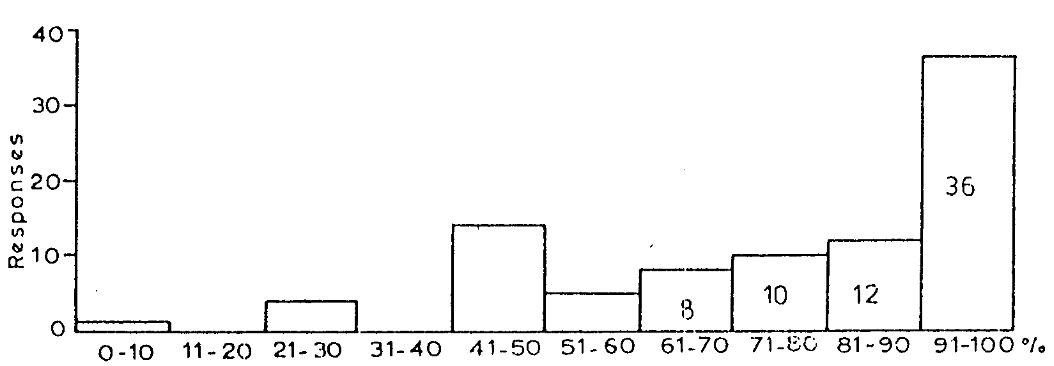

Figure 21. Loss estimates without insecticides.

cheaper prices and two farmers believed that the ED formulations stick better on the cotton foliage (Figure 23).

Estimated efficiency of insecticides - The farmers who used the 'Electrodyn' formulations of cypermethrin reported the average efficiency of 95% (Figure 24(a),(b)), on the other hand, those farmers who used the EC formulations of cypermethrin and deltamethrin estimated 75% effectiveness of the insecticides for the control of cotton pests.

Spray application frequency - A wide range of the number of spray applications of insecticides on cotton was reported by the farmers. Twenty five farmers reported 5 spray applications (according to recommendations), 25 less than 5 sprays, and 41 reported more than 5 spray applications (Figure 25).

Increase and decrease in spray applications - Fifty nine farmers reported to increase the number of spray applications, 12 to decrease, 15 to keep the same number of spray applications, and 4 to be based upon scouting during the next cototn season (Figure 26).

Reasons for increasing and decreasing spray applications - The farmers who wanted to increase the number of spray applications gave various reasons. Thirty three farmers reported to have better pest control, 10 better yields, 2 wanted to increase the area under cotton and they perceived that the increased area will require more spray applications; and 14 wanted to start early spraying (Figure 27). On the other hand, out of those farmers who wanted to decrease the number of spray applications; 5 reported that the insecticides were too expensive, 5 expected more rainfall probably to encourage the plant growth and vigour would require less spray applications, and 2 farmers expected a better

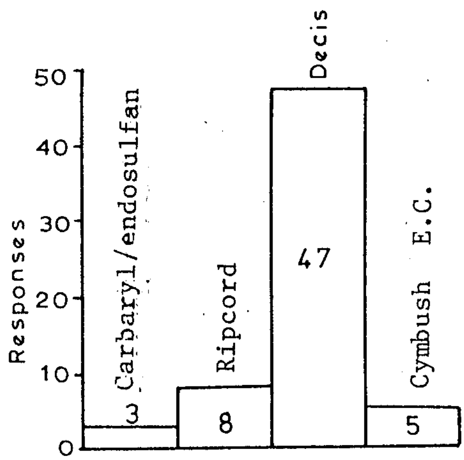

Figure 22. Types of insecticides used.

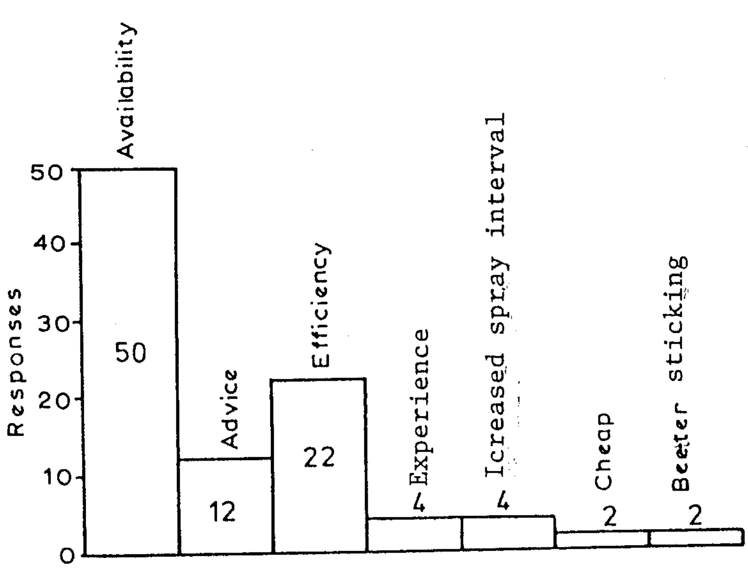

Figure 23, Selection of insecticides.

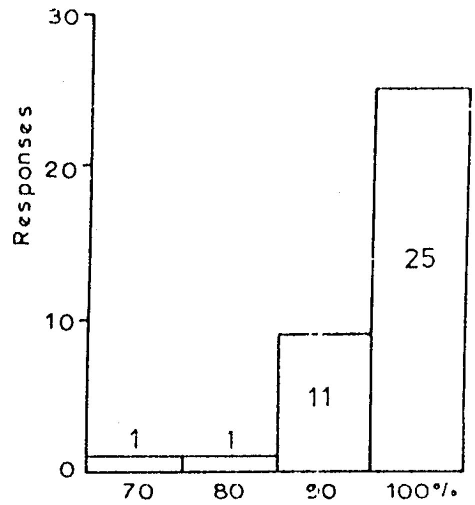

Figure 24a. Estimated efficiency of ED formulation.

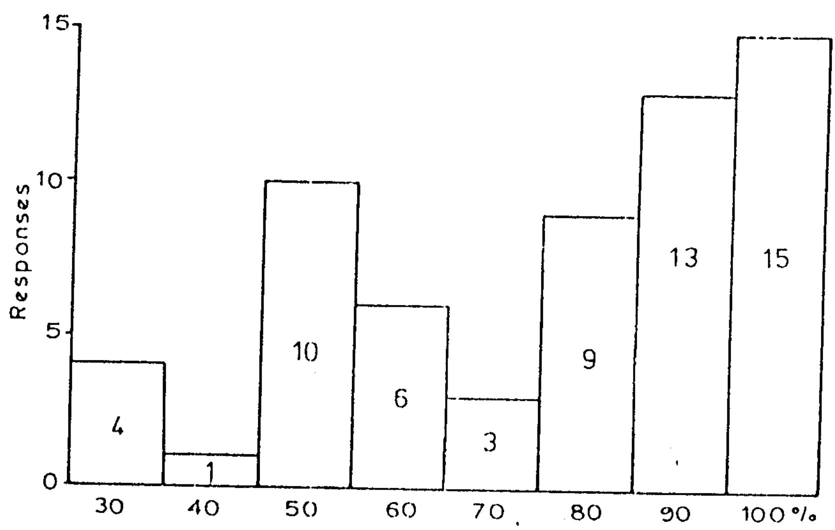

Figure 24b. Estimated efficiency of EC formulation.

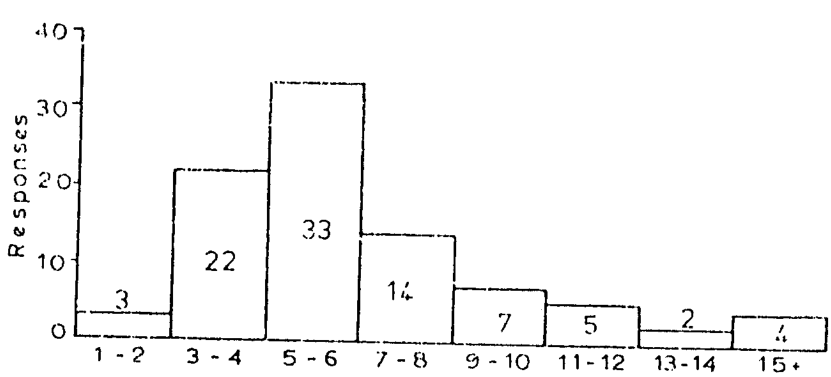

Figure 25. Number of insecticide spray applications during 1984-85 season.

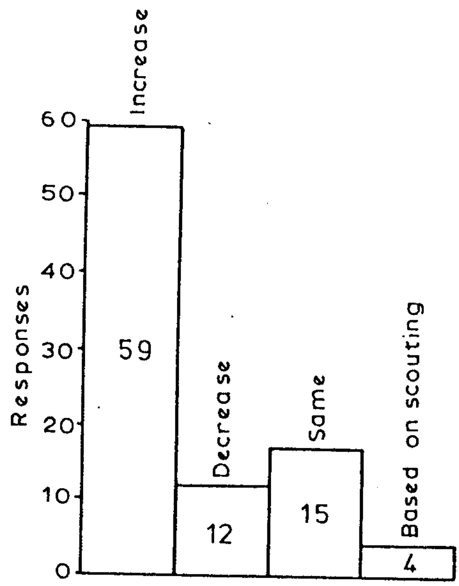

Figure 26., Trends in number of spray applications of insecticides.

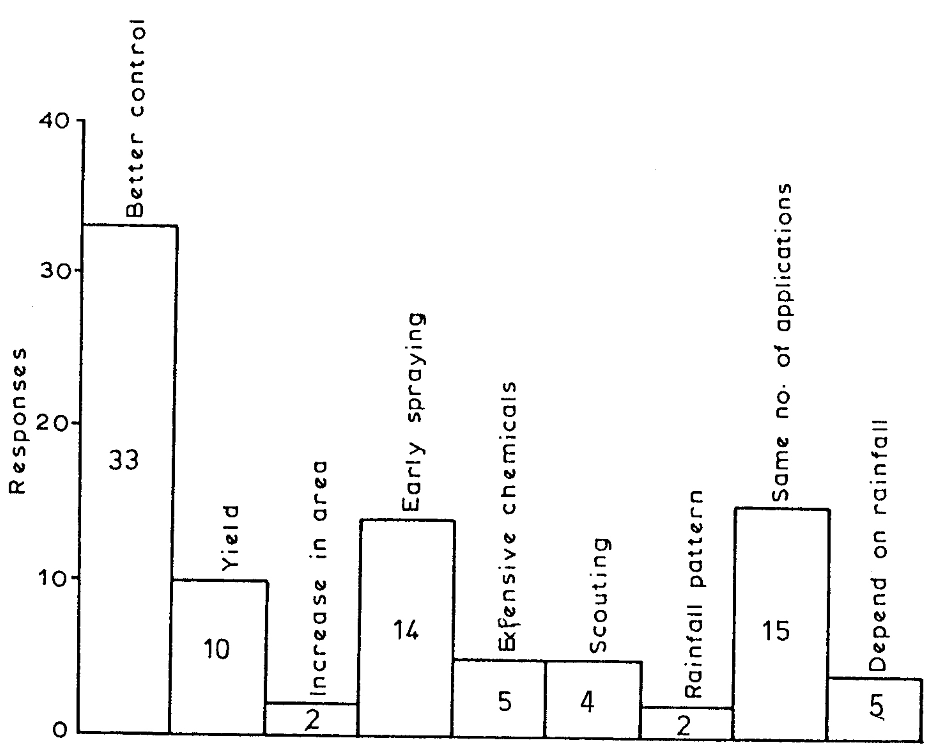

Figure 27. Reasons for increasing or decreasing spray applications.

pattern of rainfall resulting in a reduced number of spray applications. Fifteen farmers were satisfied with the same number of spray applications and wanted to repeat the same in the next season. Only four farmers reported to decide the spray applications according to the scouting of insect pests on cotton.

Pest scouting. - Seventy eight farmers (out of 90) reported that they look for insects (scout) in their cotton fields to decide the time of spray applications. The other 12 farmers reported to follow the fixed number of spray applications.

Scouting methods. - The farmers reported to use various methods for scouting insects in their cotton fields. Thirty two farmers used the diagonal method, 38 observed insects on various cotton rows, 6 used zigzag methods and 2 farmers observed few plants in their cotton fields (Figure 28).

Plants observed per diagonal for scouting. - There was a wide range of the number of plants reported to be observed per diagonal for scouting (Figure 29). Only one farmer reported he had observed 12 plants per diagonal according to the recommendations.

Row intervals for scouting. - The range of the intervals of cotton rows selected to scout insects is shown in Figure 30. The majority of farmers reported to observe insects at an interval of 1 to 6 rows.

The number of leaves per plant observed by 77 farmers for scouting insects are shown in Figure 31. Out of these, only 17 farmers reported

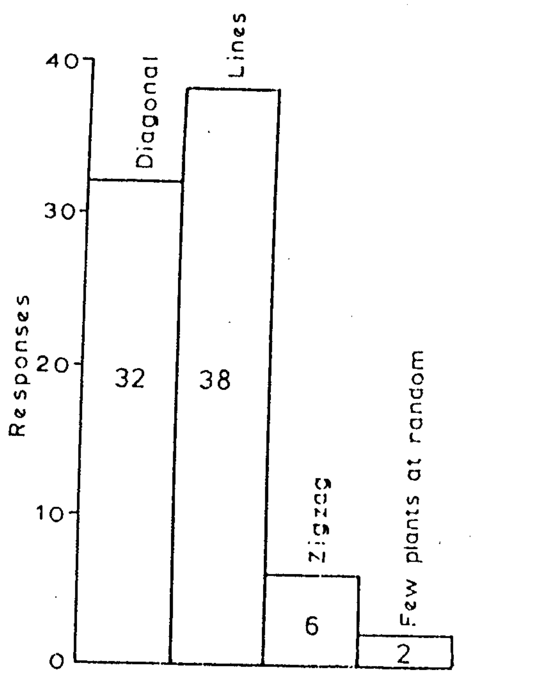

Figure 28. Scouting methods.

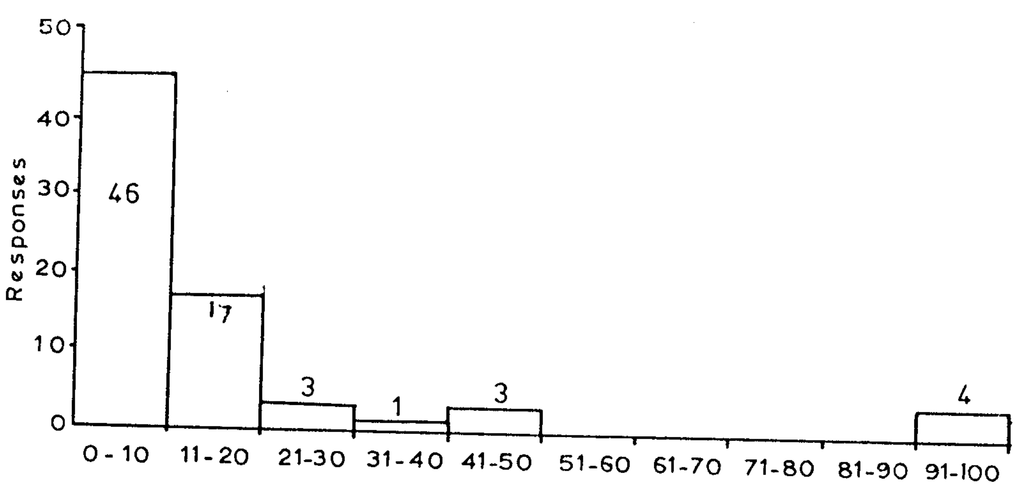

Figure 29. Number of plants per diagonal or per line for scouting insects.

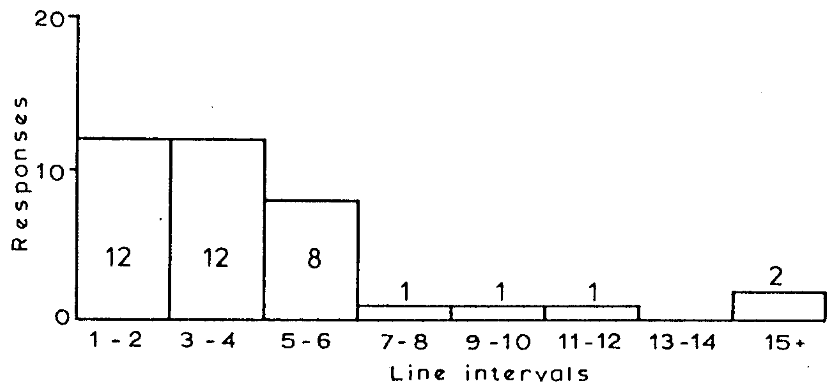

Figure 30. Line intervals for scouting.

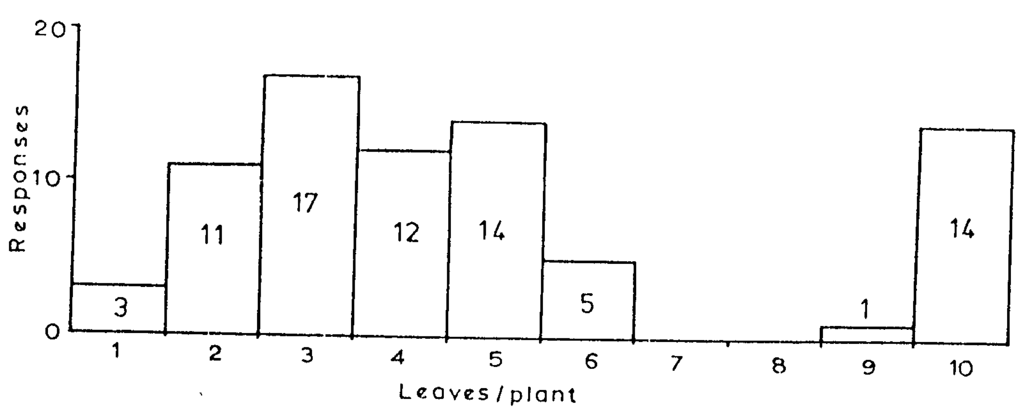

Figure 31. Number of leaves per plant.

to observe 3 leaves per plant (as recommended).

Scouting the eggs and larvae of bollworm. - Only 16 farmers (out of 90) reported that they were able to distinguish between the eggs and larvae of the American and red bollworms of cotton while the others replied in negative.

Suggestions for improving scouting. - The farmers gave various suggestions for improving the scouting of insects on their cotton plants. Sixty six farmers reported training, 22 more extension visits, 16 literature, 2 provision of hand lenses, 5 more help in the identification of insect pests (Fig. 32).

Decision to start spray applications. - Forty four farmers reported to decide spray application of insecticides according to various weeks after the germination of cotton plants, 33 decided according to the appearance of insects on cotton plants, and 13 farmers had followed the instructions on the insecticide packs (Figure 33).

Weeks after germination. - Those farmers (44) who based their decision to start spraying insecticides according to various weeks after germination reported a wide range of such periods in weeks (Figure 34). Only 11 of them reported to start insecticide applications at the 7th (recommended) week after the germination of cotton plants.

Decision to stop spray applications. - Seventy three farmers reported to decide to stop the spray applications according to the opening of balls, 9 according to completing the required number of spray

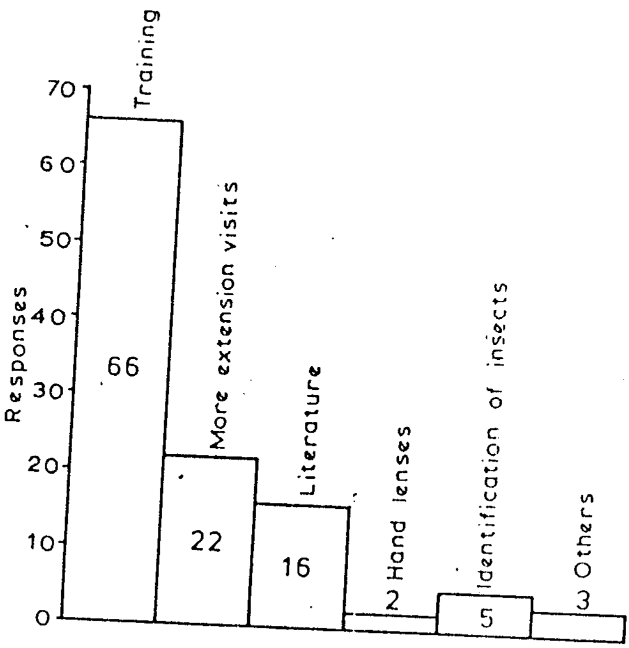

Figure 32. Suggestions for improving pest scouting.

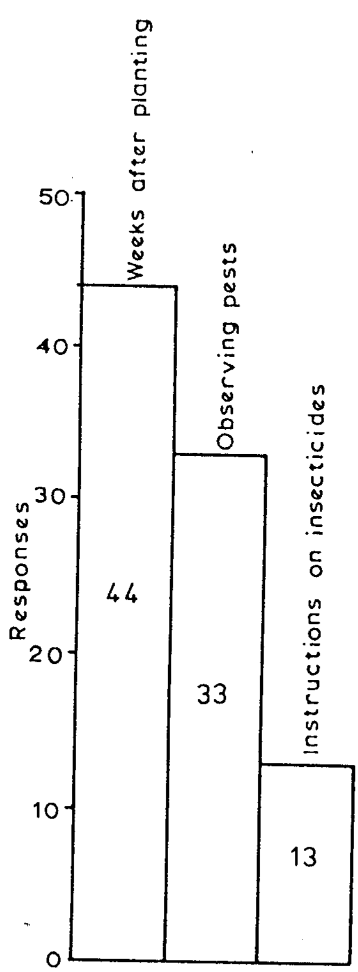

Figure 33. Decision to start spraying.

applications and observing the pests on cotton plants (Figure 35).

Non-chemical control. - Only 14 farmers (out of 90) apparently reported to have the knowledge of pest control methods on cotton other than insecticides, of these 12 reported weed control, 1 hand picking and another farmer mentioned crop rotation (Figure 36).

Biological control. - The farmers were asked about their knowledge regarding the useful insects. Thirty three farmers reported that some insects are also beneficial. Out of these farmers, 24 farmers believed that some insects eat others and 6 farmers mentioned the pollinating insects.

Crop rotation. - All farmers except one reported that they grow cotton in rotation with other crops (mostly maize).

Benefits of crop rotation. - The farmers reported various benefits of growing cotton in rotation with other crops. Sixty two farmers reported improvement in soil fertility, 12 insect pest control, 11 farmers mentioned both fertility and pest control, and 4 to obtain better yields of cotton (Figure 37).

Destruction of cotton plants after harvest. - All farmers interviewed reported to have destroyed cotton plants after harvest. Seventy nine farmers reported that the main reason for the destruction of cotton plants after harvest was insect control, 6 insect plus disease control, 2 improvement in soil fertility and 3 to keep their cotton fields clean (Figure 38).

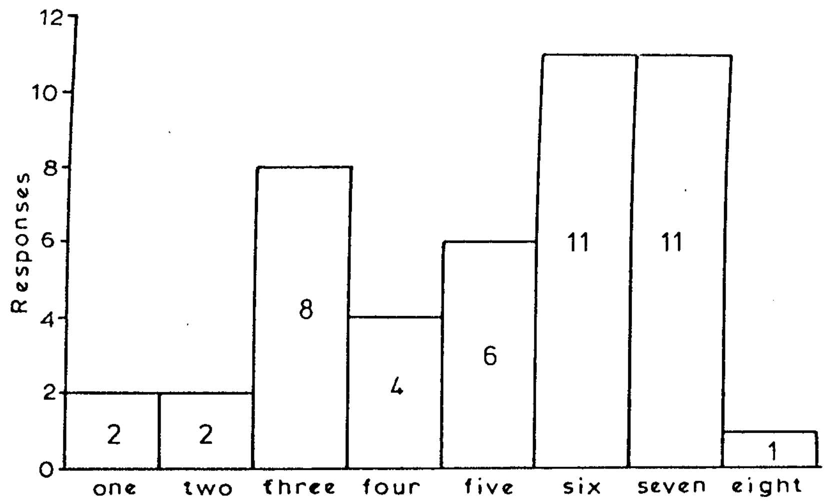

Figure 34. Number of weeks after planting to start spraying.

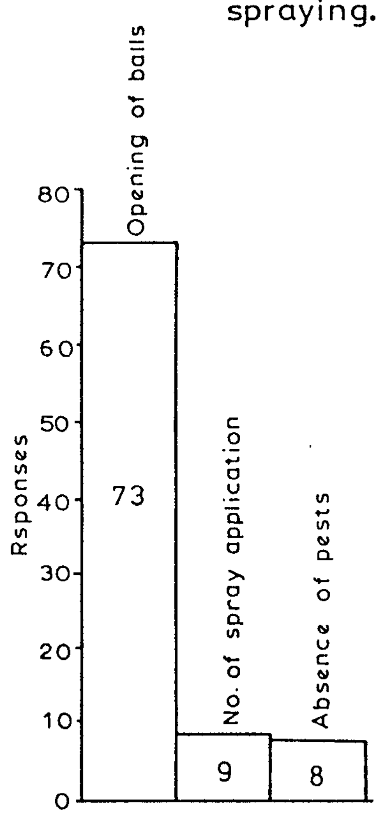

Figure 35 Decision to stop spraying insecticides.

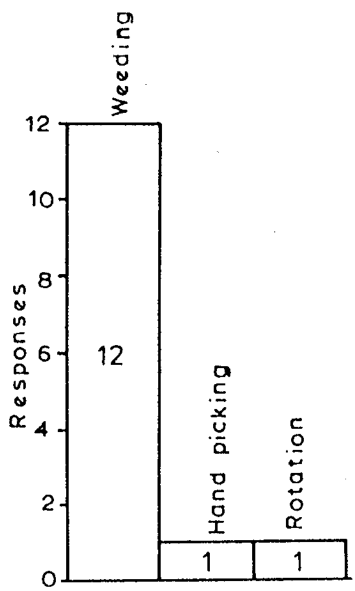

Fig. 36. Methods of cotton pest control other than insecticides.

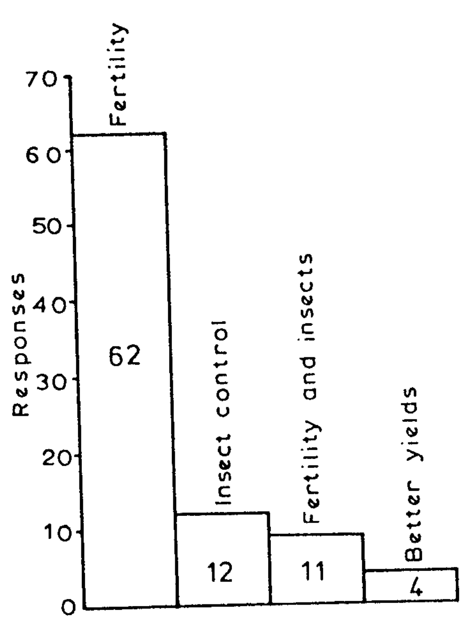

Figure 37. Benefits of rotation.

Methods of weed control. - All farmers interviewed reported to have controlled weeds in their cotton fields. Hand weeding and oxen weeding were the only methods used by farmers. However, 3 farmers had also applied herbicides in addition to weedings.

Number of weedings. - Thirty nine farmers reported to have practiced 3 hand weedings (as recommended), 30 less than 3 weedings, and 21 farmers practiced more than 3 weedings. Figure 39 shows the range of the number of hand weeding reported by various farmers.

Oxen weedings. - Seventy farmers also reported to practice oxen weeding using an equipment. Out of these 47 did 2 to 3 weedings. Figure 40 shows the range of the number of oxen weedings reported by farmers.

Total weedings. - The total number of weedings (hand weeding and oxen weeding) is shown in Figure 41. About half of the farmers had practiced 4 to 6 total weedings.

DISCUSSION

The farmers did not report any outbreak of new pests in the selected areas. However, the majority of farmers (about 70%) are well familiar with the major pests, since they are able to recognise the photographs and the names of these insect pests. In order to avoid damage caused by these pests, they followed various pest management practices at their farms.

Non-Chemical Methods. - That only 15% of the farmers had the apparent

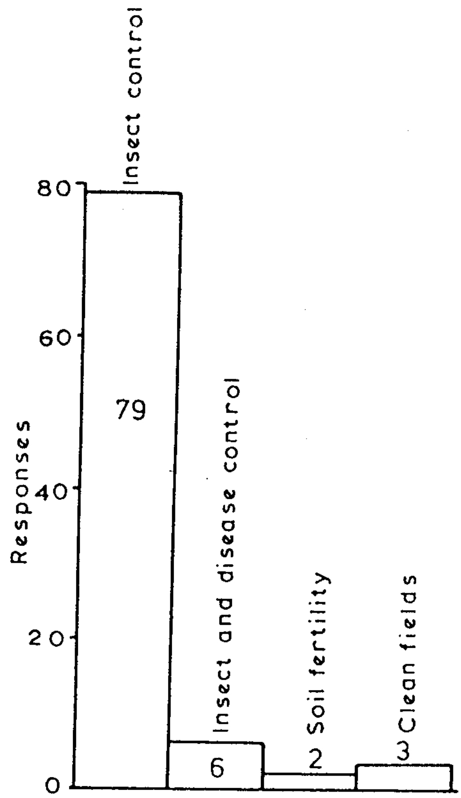

Fig.38. Reasons for destruction of cotton plants after harvest.

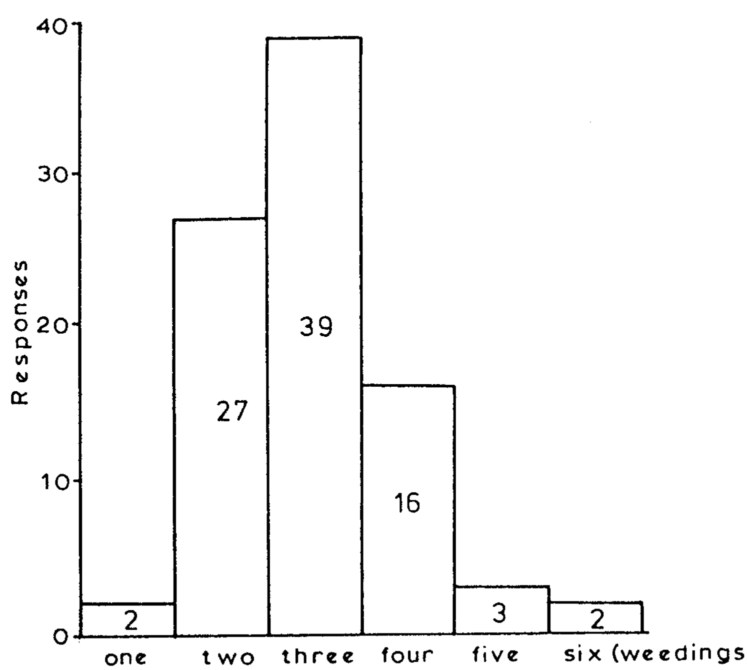

Figure 39. Number of hand weedings.

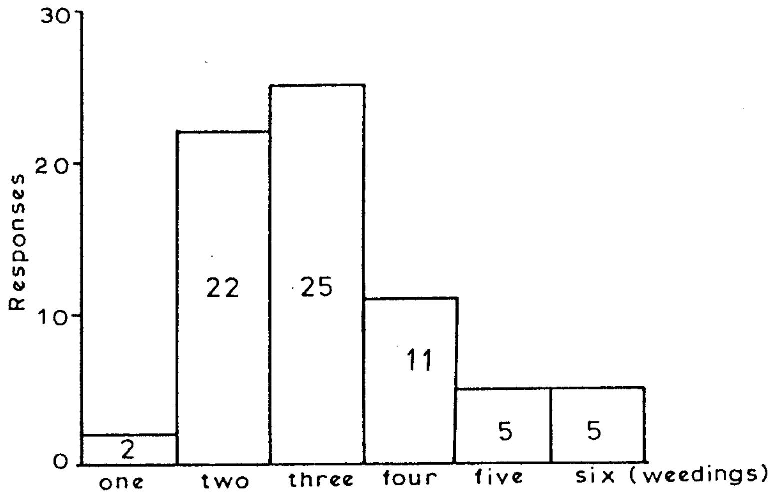

Figure 40·Number of ox weedings·

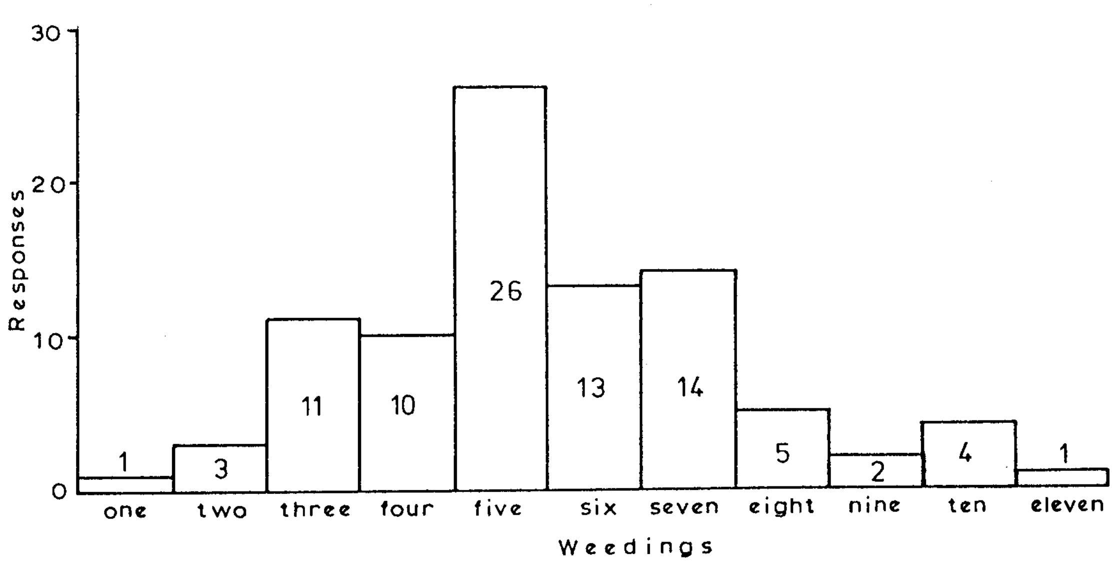

Figure 41· Total number of weedings.

knowledge of the insect pest control methods other than insecticides was surprising, but many farmers practiced the non-chemical components of pest management, mostly without recognising them.

The farmers, were asked directly about the reasons for destroying cotton plants after harvest, and it was encouraging that 94% of them indicated that the destruction of cotton plants after harvest was helpful in the control of insects and diseases. This practice which is particularly effective against the red bollworm (Diparopsis castanea), one of the key pest in many cotton growing areas of Zambia is well practiced by all farmers in the selected areas. The destruction of cotton plants by the first week of October is a law requirement in Zambia (Nelson, 1972).

Most of the farmers are not aware of the significance of weed control in the management of cotton pests, since only 13% of the farmers had reported weeding as a method of insect pest control. However, all farmers practice hand weeding and ox weeding mainly to avoid the competition for nutrients. The majority of farmers (80%) practiced more than 3 recommended weedings; apparently due to overestimation of the losses from weeds and the lack of information regarding the recommended timing and the number of weedings. Indeed, the weeds not only provide the alternative host plants for insect pests, but also act as a shelter for pests when the crop is being sprayed.

Only about one third of the farmers believe that cotton grown in rotation with maize helps in the control of insect pests and diseases. However, the main reason for planting cotton in rotation with maize is the lack of additional fertilizer requirement. Traditionally, cotton grown after well fertilized maize gives reasonable yields without the application of fertilizers.

The currently recommended varieties in Zambia are partly resistant to jassids. They are also resistant to bacterial blights (Xanthomonas malvacearum) which consequently is of minor importance. The control over the growing of recommended resistant varieties in different cotton growing areas of Zambia has been well regulated by LINTCO, which has got the rural depots throughout the country. In fact, the varietal resistance to jassids has enabled the cotton crop to be established in many parts of Africa (Parnell, 1925). Thus, the varietal resistance is an important component of cotton pest management that is being practiced against jassids by all cotton farmers in Zambia and probably in many other countries in Central Africa.

That most of the farmers (66%) are unaware of the role of the biological agents (predator and parasites) is mainly due to lack of appropriate training. It could be argued that there is a need to remedy this. Currently in Zimbabwe, the training courses in pest management of cotton do include the recognition, life histories, and the feeding habits of five commonly occurring predators of common insect pests. These courses also include the methods of assessing the field levels of these beneficial insects (Burgess, 1983). In Zambia, many surveyed farmers were surprised to hear about the natural enemies of insects and a few of them did not even believe it. The small-scale farmers in Zambia must be made aware of the common biological agents like the syrphid flies, lady bird beetles, and others, so that they keep these useful insects in view while applying insecticides on their cotton crops.

As most of the farmers had planted maize, groundnuts and sunflower crops at their farms, which are the alternative host plants of the American bollworm; a key pest of cotton, and since these are never sprayed with insecticides at present in Zambia, not all the generations of American bollworm are exposed to insecticides. This acts favourably against the rapid development of insect resistance. Thus, the vegetative diversity already existing in the traditional agro-ecosystem has some inherent advantages, which favour the insect pest management of cotton in Zambia.

The cotton grown in small fields in villages, isolated from each other, throughout the cotton growing areas in Zambia, seems to have the advantage of prohibiting the build-up of sudden, large pest populations as occurring in extensive monoculture systems.

Chemical methods. - Due to the wide dissemination of the importance of scouting, 86% of the farmers inspect their crops for insects to decide whether to spray.

However, the way in which they carry out these observations varies, most farmers observe pests while walking across diagonals of the field or along a zigzag course. The farmers seemed apparently confused by different methods, and must be advised to follow only one recommended method.

The information on economic thresholds is probably not well understood by many farmers. The current recommendations on economic thresholds for the American and red bollworm in cotton fields are based upon the number of eggs on 24 randomly selected plants in each field. However, only 17% of the farmers during the survey reported that they could identify the immature stages of these two key pests.

As the farmers observed 20 plants on an average, against the recommended 12 plants per diagonal, and 8 farmers examined whole plants and the rest had examined an average of 5 leaves per plant for foliar pests; there appears to be an urgent need to train farmers about the correct scouting procedures. Many farmers did not scout the insect pests according to the laid down recommendations.

Only 30% of the farmers reported making 5 insecticide applications, as recommended, but about half of the farmers had sprayed more than five times and they did not obtain an overall increase in the yield of seed cotton. That 65% of the farmers intended to increase the number of spray applications during the next season was probably due to the unawareness of avoiding the unnecessary and potentially damaging spray applications of insecticides which could be uneconomic, accelerate the build-up of resistance, and might affect the natural enemies. These are the important factors which deserve attention to improve the management of cotton pests in Zambia.

Some farmers revealed during the informal discussions at the end of the interviews that they were not informed about the five spray applications of the newly introduced pyrethroid insecticides in the selected areas. In fact, the farmers were used to making the 10 spray applications of 'conventional cotton packs' (endosulfan and carbaryl), and when these insecticides were replaced by pyrethroids, the farmers did not receive the advice from the extension services regarding the five spray applications. However, the previous observations on spray application in Zambia (Lyon, 1975a)indicate that the farmers actually made 6 applications instead of 10 recommended sprays of 'conventional insecticides'. Similarly a survey in Morogoro district of Tanzania reveals that farmers were aware of the recommended 8 applications but actually sprayed an average of 5.5 times and that the results match the local yields (Cox, 1982). In Malawi, Farrington (1977) also reported that fewer insecticide sprays were applied compared with the recommendations of up to 12 sprays but there were relatively dry seasons.

The farmers were asked about their suggestions on the long term solutions on the management of cotton pests. Indeed, the majority of the farmers emphasised the need for better training and extension services, particularly for the scouting of insect pests of cotton.

CONCLUSIONS

This study reveals that some components of pest management are already being practiced by small-scale cotton farmers in Zambia. The production of cotton in relatively small isolated fields (1 - 5ha) at different farms discourages the sudden outbreak of pests, as in monoculture systems. The cultivation of maize and sunflower, observed at most of the farms, provides alternative host plants for some generations of American bollworm which never receive insecticide treatment at present and thus the selection pressure for resistance is reduced.

Other practices, well practiced by almost all farmers included; destruction of plant debris after harvest for the control of red bollworm, planting of recommended varieties which are partially resistant to jassids, weed control which destroys alternative host plants for many pests, and crop rotation which is recommended for many insects with a limited host range such as red bollworm. However, farmers seemed unaware of the potential role of biological agents in pest management.

All farmers were familiar with common insects and their status on cotton, and had sprayed insecticides. Some farmers use more insecticide applications than is locally recommended probably because they overestimated potential losses. Many farmers felt that the insecticides they use (pyrethroids) are very effective against pests. In some cases, the ED formulation of cypermethrin was reported to be more effective than EC formulations. A major problem faced by the farmers was to decide on the best time to spray. Few studies exist which are aimed at determining economic thresholds for key pests of cotton in Africa; particularly in small-scale farming systems. Making thresholds appropriate to the circumstances of these farmers remains a major challenge (Matteson *et al.*,1984). One way is to develop locally accepted scouting devices such as the 'pegboard' method (Beeden, 1972), which does not require reading and writing by the farmer. It consists of a piece of wood with three rows of holes. A peg is moved along one row to record the number of plants sampled. The other rows are used to record egg counts for such key pests as the American and red bollworm. In addition many farmers felt that scouting of insects can be improved by more training, increased extension visits, and the provision of literature in local languages with pictures of different growth stages of insects.

CHAPTER 5

APPLICATION OF INSECTICIDES ON COTTON

INTRODUCTION

The effectiveness of insecticides for the proper control of insect pests of cotton is largely influenced by the proper use of appropriate equipment. However, the techniques involved in the pesticide application of crops throughout the world are seldom examined, despite the wide recognition that they are extremely inefficient (Matthews, 1977).

Many small-scale farmers in Africa and other developing countries apply insecticides to cotton with small, manually operated, metallic or plastic single nozzle, knapsack sprayers.

The single nozzle knapsack sprayers seldom provide complete coverage. The exposed surfaces receive too much liquid; the excess drips to the soil and may eventually reach the streams and rivers to cause more widespread environmental contamination (Matthews, 1977). Generally, the losses with these types of sprayers due to over spraying, drift, and deposition on non-target surfaces may exceed 60% of the product applied (Hislop, 1983).

To improve the control achieved with knapsack spraying, particularly against the red bollworm of cotton (*Diparopsis castanea*) in Central Africa (Zambia - Zimbabwe - Malawi), a tailboom modification was developed (Tunstall *et al.*,1961). It consists of four pairs of nozzles, which can be placed in various positions on the boom making it possible to vary spray output according to the growth of cotton plants. Thus the rate of application varies from 50 to 200 litres per hectare keeping the concentration of insecticide constant throughout the season (Tunstall <u>et al.</u>,1965).

However, there are two problems with the use of knapsack sprayers; they require large amounts of water for the application of insecticides to cotton and the production of spray droplets of the required sizes is not well controlled.

The development of ULV hand-held sprayers (Bals, 1970; Matthews, 1973a) not only provides controlled sized spray droplets to be produced but it can also eliminate the need for water.

In Central Africa, preliminary ULV field trials on cotton by Matthews from 1969 to 1971 appeared to be promising particularly in areas where a lack of water prevented the use of conventional spraying (Matthews 1973b). Since then, hand-held ULV sprayers have been extensively used by peasant farmers in various areas resulting in increased yields of cotton.

More recently, a hand-held 'Electrodyn' sprayer (Coffee,1979) has been developed with a number of potential benefits when applying insecticides to cotton and other crops, by small-scale farmers in the tropics (Coffee 1980; Coffee 1981; Coffee and Kohli, 1982; and Durand <u>et al.</u>,1984). The advantages claimed include low energy consumption, reduced drift, high recovery index of spray droplets, no water and mixing requirements, light weight and longer life of the machine.

Since the initial studies of 'Electrodyn' spray coverage on cotton and the control of Heliothis species in different countries (Morton 1981; 1982) the 'Electrodyn' is now commercially available (Durand *et al.*,1984) and some cotton farmers in Zambia in a few selected areas are using these sprayers. In some other countries such as Brazil and Kenya, the pest control and yields of cotton obtained by the application of pesticides with 'Electrodyn' have been rated by the farmers as equal or better than the conventional spraying (Smith, 1986; Mambiri, 1987). The studies in India also illustrate the considerable advantage in time and labour saving using the 'Electrodyn' in contrast to other spraying techniques (Matthews, 1985a).

Generally the application techniques used by most small-scale farmers in developing countries have not changed much despite the "improved" technology described above. There are various reasons for this lack of adoption including the type of farming systems involved, farmers' perceptions and experience, the relative costs of the new machines, the information available on them, and various other socio-economic factors. Unfortunately, these aspects have received very little attention in the past. This chapter describes the preliminary findings of a survey which was undertaken to study the reactions of small-scale cotton farmers towards various application techniques.

RESULTS

Types of sprayers used:- The cotton growers in selected areas used only two types of sprayers. Fifty-three farmers were reported to apply pesticides on cotton crop by knapsack sprayers, 24 used 'Electrodyn', and 13 had used both knapsack and 'Electrodyn' sprayers (Figure 42).

Knapsack sprayers:- The farmers used different types of knapsack sprayers, the capacities of which ranged from 10 to 20 litres (Figure 43).

Problems experienced with knapsacks:- Twenty farmers reported experiencing various problems with their machines; of these, 7 reported leakages, 7 had problems with pumps, 3 diaphragms, 2 nozzles, 2 pressure chambers and one farmer had a problem with the handle of his knapsack sprayer.

Time of purchase of knapsack sprayers:- Many farmers could remember the year when they had bought the knapsack sprayers. The period of purchase ranged from 1 to 11 years.

Spare parts:- Sixteen farmers (out of 53) reported that spare parts of knapsacks were not always available at LINTCO depots for the repair of applicators.

Water sources:- The farmers reported obtaining water from various sources for their knapsack sprayers. Fifty three farmers mentioned wells, 10 streams, 6 rain water nearest to the fields, 6 dams, 2 windmills and 3 boreholes (Figure 44).

Distance to collect water:- The distance that farmers often had to transport water for cotton spraying (Figure 45), was more than half a kilometre.

Efficiency* of knapsack spayers:- There was a wide range of the estimated efficiency of knapsack sprayers reported by farmers for the control of cotton insect pests (Figure 46). The average efficiency reported by farmers was 86% (weighted means).

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*Efficiency refers to the effectiveness of sprayers for the control of cotton pests.

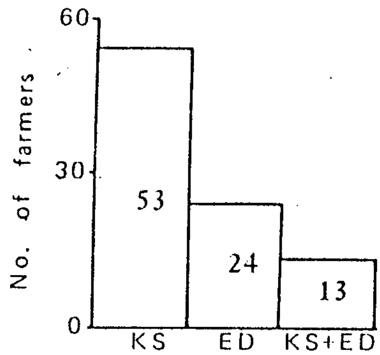

Figure42 Types of sprayers used.

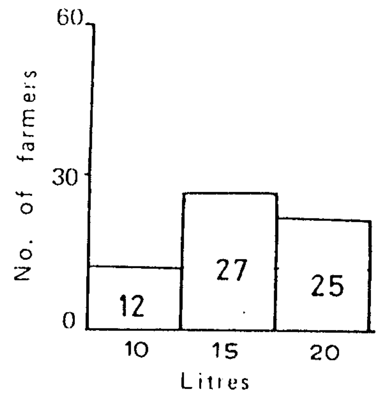

Figure43 Capacity of Knapsack sprayers.

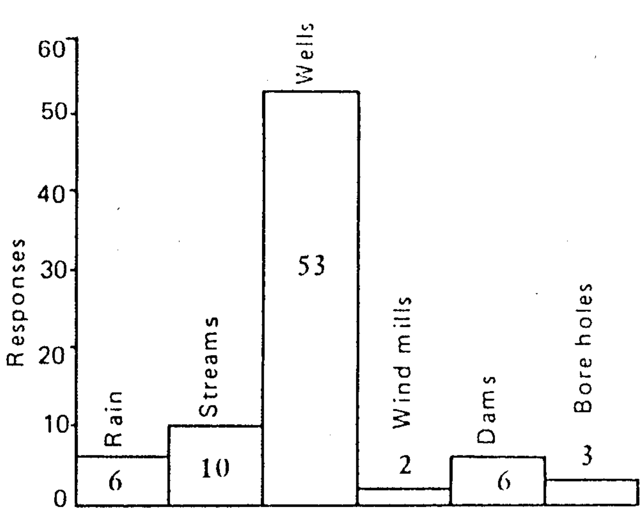

Figure 44 Sources of water for spraying insecticides.

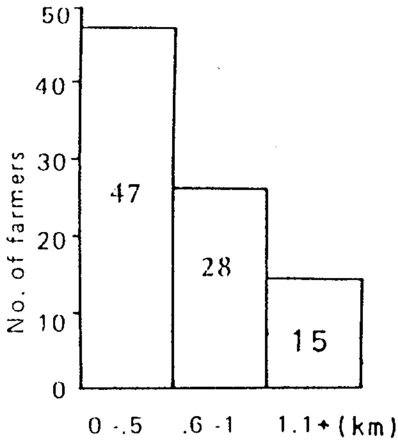

Figure 45. Transporting water from various distances for cotton spraying.

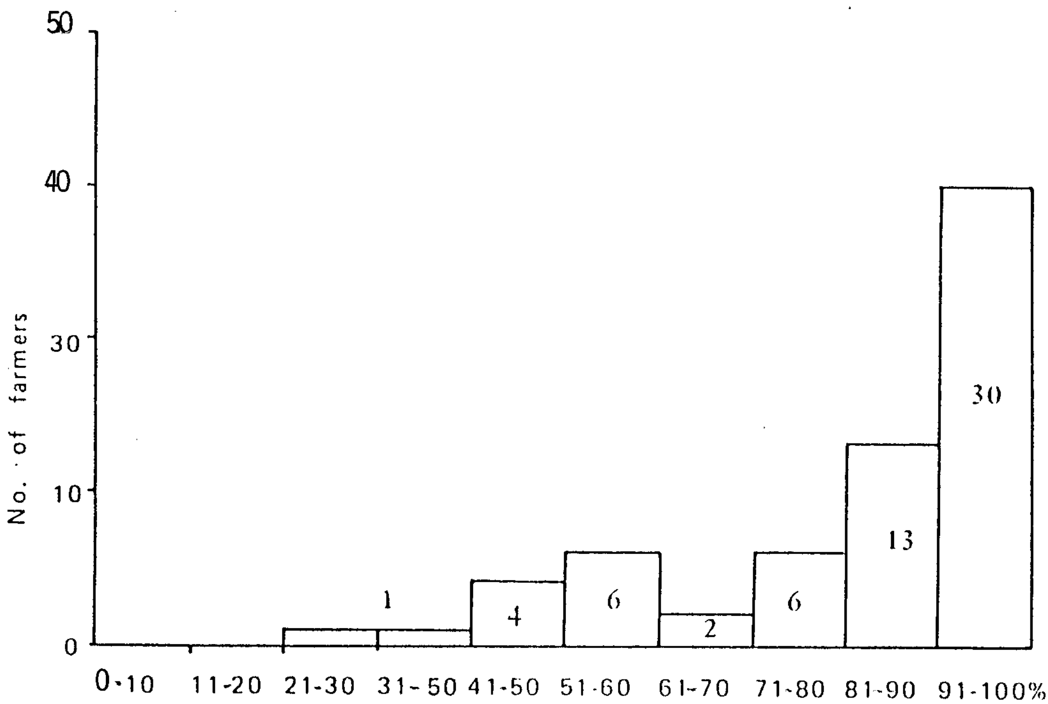

Figure 46. Estimated efficiency of Knapsack sprayers.

Additional uses:- The farmers reported to use knapsack sprayers for various other purposes in addition to cotton spraying. Sixteen farmers used the same applicators for applying pesticide on other crops (herbicides on maize crop), 30 on vegetables, 26 on cattle, 31 inside houses, and 3 on fruit trees (Figure 47).

Reasons for using knapsacks:- The farmers who had used knapsack sprayers reported various reasons to prefer these applicators. Twenty three farmers reported that these were the only sprayers available at the time of purchase, and 8 said that these were the only sprayers known to them, 7 reported the application of solubor (boron), 3 were able to see the spray droplets on cotton plants, 9 farmers reported to cover more than one row swath on small cotton plants, 5 availability of appropriate formulations and 3 reported less loss of pesticides. The other four reasons given by farmers were; no problems experienced in the past, cheap sprayer, no battery requirement and can afford only one sprayer (Figure 48).

Reasons for not using knapsacks:- The farmers who did not use knapsack sprayers gave various reasons. Out of these, 19 reported heavy weight of sprayers, 4 time consuming, 2 water problems, 4 unavailability of these applicators at LINTCO depots, 3 labour requirements, 2 mixing of proper doses of insecticides with water, and one farmer reported that it was not effective (Figure 49).

Knowledge of improved techniques:- The farmers were asked about other types of sprayers known to them for applying pesticides on cotton. Fifty eight farmers were aware of 'Electrodyn', 4 ULV, 43 knapsack

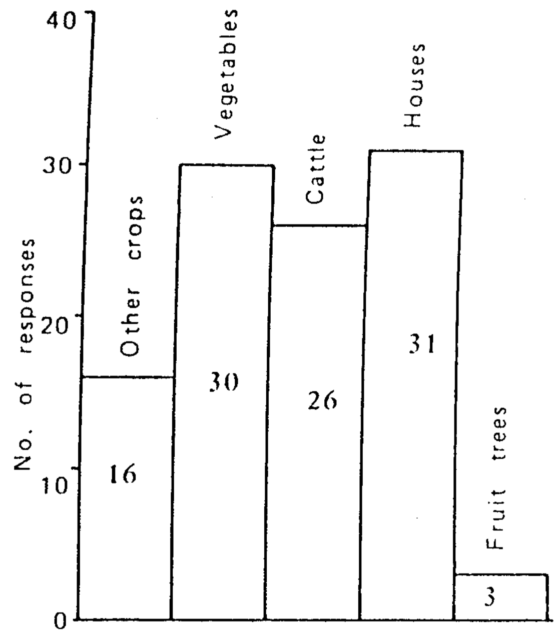

Figure 47 Uses of Knapsack sprayers.

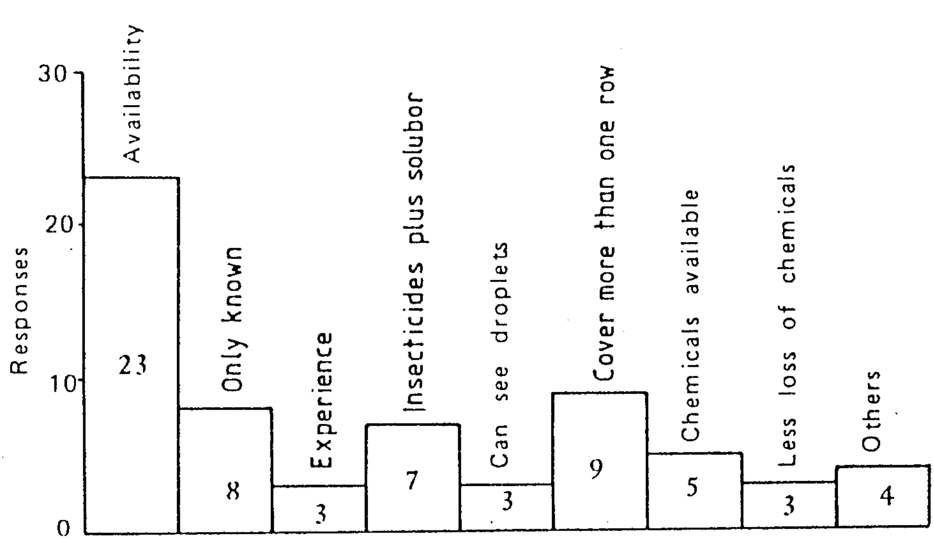

Figure 48 Reasons for using Knapsack sprayers

double nozzles, 67 tailbooms, 16 tractor mounted, and 7 oxen drawn sprayers (Figure 50).

Knapsack double nozzles:- Out of those farmers who did not use knapsack double nozzles, 35 reported unavailability, 5 extra water requirement, 4 extra costs, 2 mentioned heavy weight, and one farmer reported the blockage of nozzles(Figure 51).

Tailboom sprayers:- Many farmers did not use tailbooms due to various reasons. Twenty six farmers reported that these applicators were unavailable, 6 reported extra costs to buy tailbooms, 4 lack of training, 7 reported that nozzle got blocked during spraying, 11 farmers were unable to see behind while spraying, 12 reported that the weight of sprayers becomes too heavy, and one farmer said it requires too much water (Figure 52).

Oxen-drawn sprayers:- Only seven farmers were aware of the oxen-drawn sprayers and they did not use them due to unavailability of these applicators.

Tractor mounted sprayers:- The farmers did not use the tractor mounted sprayers because 7 of them said they had no tractors, another 7 farmers reported that these were too expensive and 2 said that they cannot use these sprayers during the rains (Figure 53).

ULV sprayers:- Many farmers were aware of ULV sprayers but they did not use them. Seventeen farmers reported that these sprayers were unavailable, 15 had battery problems, 17 spare part problems, 4 ULV

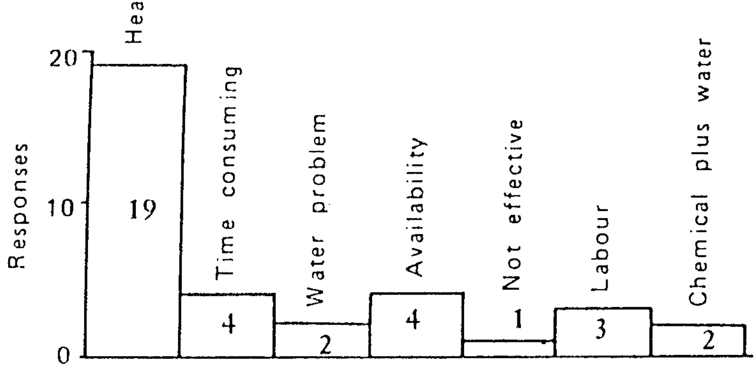

Figure 49 Reasons for not using Knapsack single nozzle sprayers.

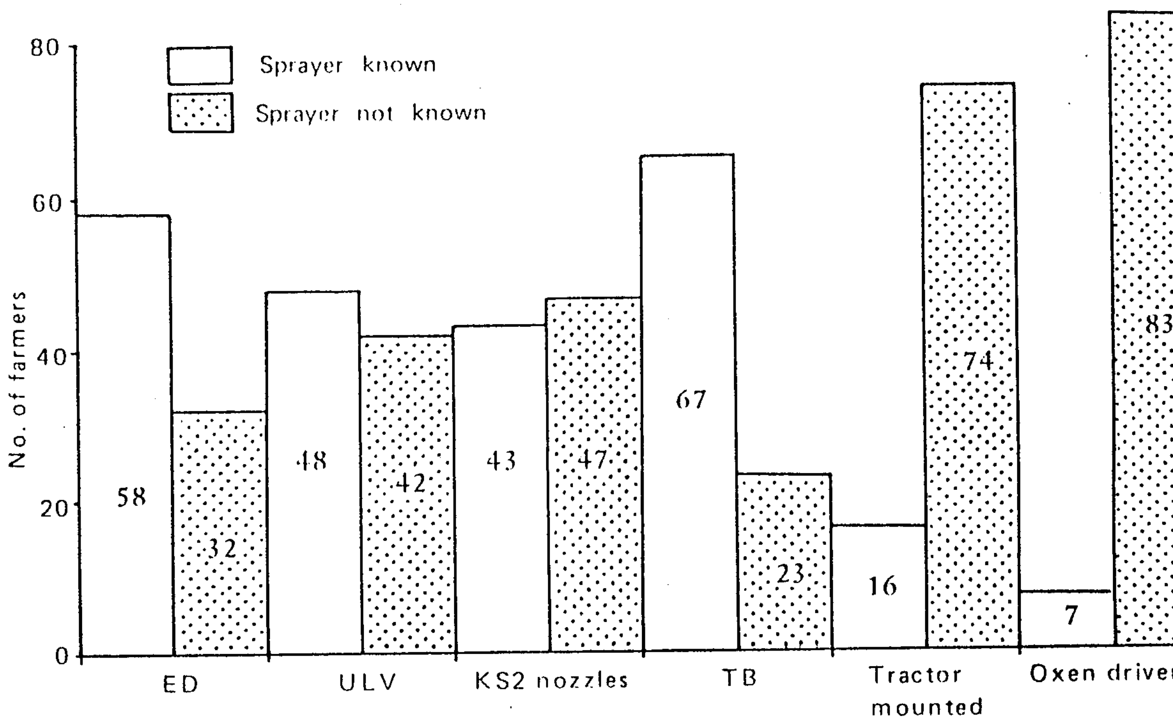

Figure50 Knowledge of sprayers

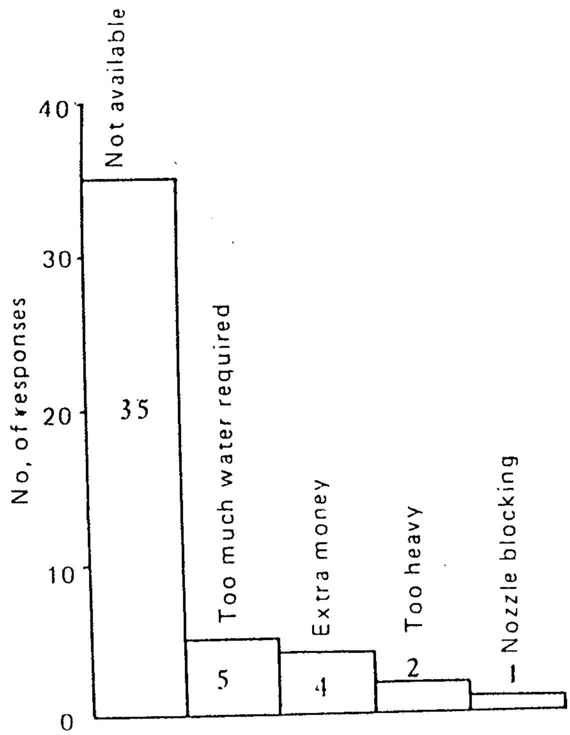

Figure 51. Reasons for not using Knapsack double nozzle sprayers.

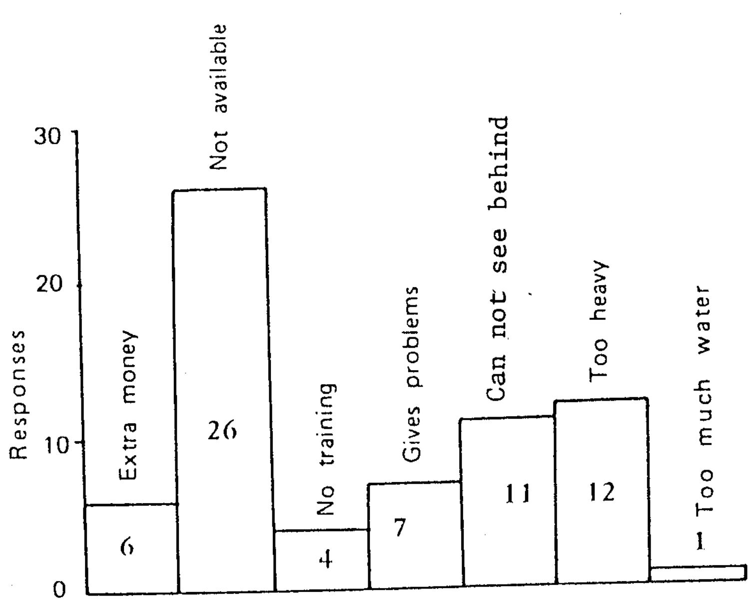

Figure 52. Reasons for not using Tailboom sprayers.

formulation, 2 toxicity of ULV formulations, one farmer said the droplets were too small, another reported that the machine was too expensive while another said that he was already having a knapsack sprayer and there was no need for an extra sprayer (Figure 54).

'Electrodyn' sprayer:- The farmers had bought the 'Electrodyn' sprayers during the previous one or two seasons only.

Problems experienced with 'Electrodyn':- Three farmers (out of 37) who had used 'Electrodyn' sprayers reported that the sprayers stopped working after one or two seasons. Another two farmers reported that the batteries for 'Electrodyn' sprayers were not always available.

Availability of spare parts:- Twenty farmers (out of 35) reported that the spare parts for 'Electrodyn' were not always available. If it stopped working they would not be able to repair it.

Efficiency of 'Electrodyn':- The estimated efficiency of 'Electrodyn' in percentages reported by farmers who used these sprayers is shown in Figure 55 . The average estimated efficiency was 95% (weighted means).

Reasons for using 'Electrodyn':- Twenty five farmers reported that it was very light in weight, 17 mentioned its efficiency in pest control, 8 lack of mixing requirements, 6 easy to operate, 2 lack of water requirements, another two said that it was the only sprayer available at LINTCO depots, one farmer said it does not require spare parts while another reported its cheap price (Figure 56).

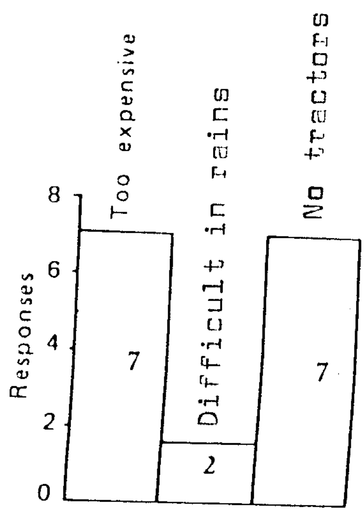

Figure 53. Reasons for not using tractor mounted sprayers.

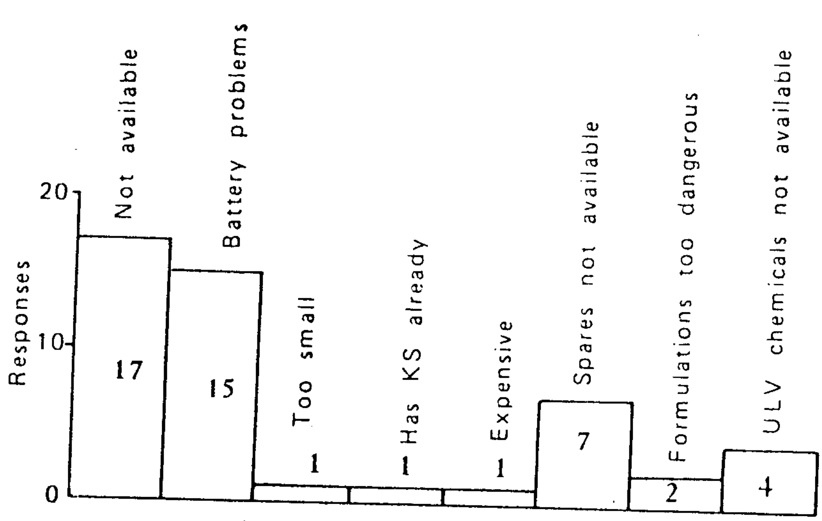

Figure 54. Reasons for not using ULV sprayers.

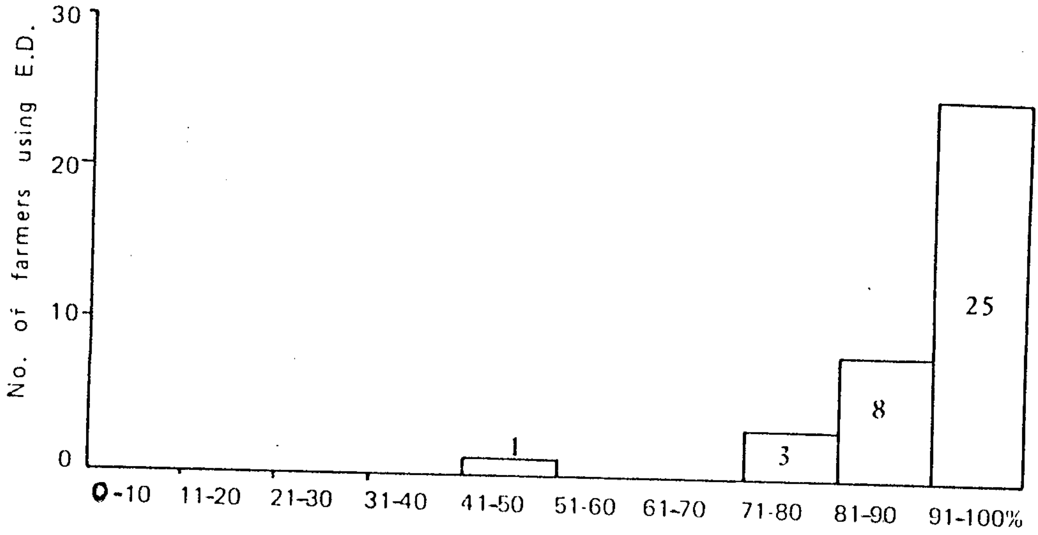

Figure 55. Estimated efficiency of 'Electrodyn' sprayer.

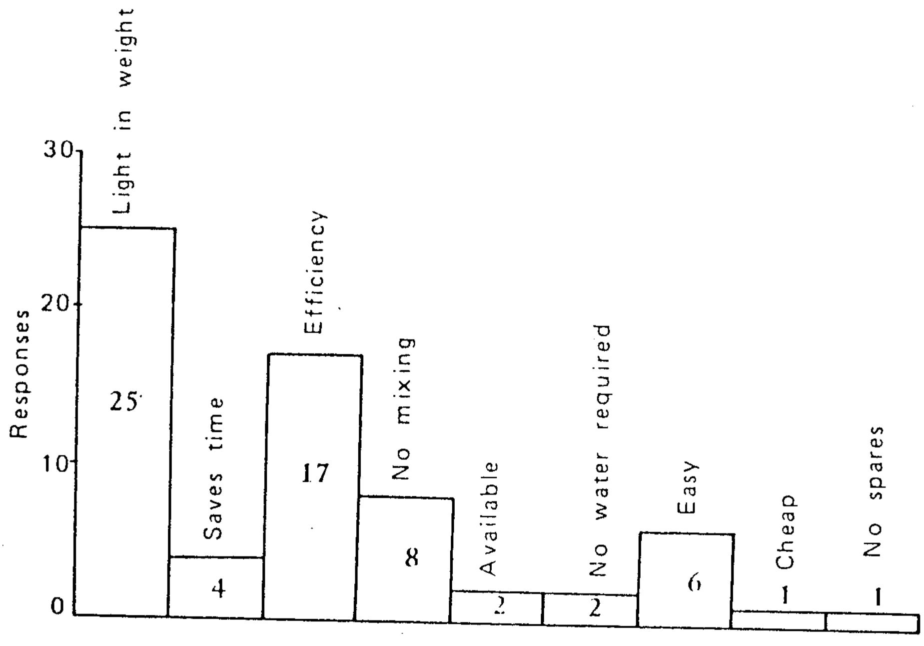

Figure 56. Reasons for using 'Electrodyn' Sprayer.

Reasons for not using 'Electrodyn':- Many farmers did not use 'Electrodyn' due to many reasons. Twenty nine farmers reported that the 'Electrodyn' was not known to them, 12 said that it covers only one row swath, 6 reported battery problems, 4 complained about the special requirements of ED formulations, 3 said it covers only the top canopy of cotton plants, 2 lacked training, another 2 mentioned the solubor (boron) appliction problem, 3 were unable to afford an extra sprayer because they were already using knapsacks, one farmer said it can only be used on cotton plants and another farmer reported that it was too expensive (Figure 57).

Persons who did actual spraying:- Sixty six farmers reported that they sprayed insecticides on cotton plants themselves, 9 mentioned their wives, 46 reported their sons, and 10 had hired workers (Figure 58).

Reasons for different persons spraying:- The farmers reported various reasons for different persons who sprayed insecticides on cotton. Twenty four farmers said they do not trust others, 13 had many sons, 12 had no funds for hiring labour, 11 were too old to spray themselves, another 3 farmers said that family members were supposed to help each other, and one farmer being an old lady was herself unable to spray (Figure 59).

Farmers' suggestions for more effective spraying:- Various suggestions were given by the farmers for improving the application of insecticides on cotton. Thirty three farmers reported training, 12 proper mixing of insecticide doses, another 12 reported to follow the proper walking speeds (calibration), 10 by following proper instructions, 10 suggested

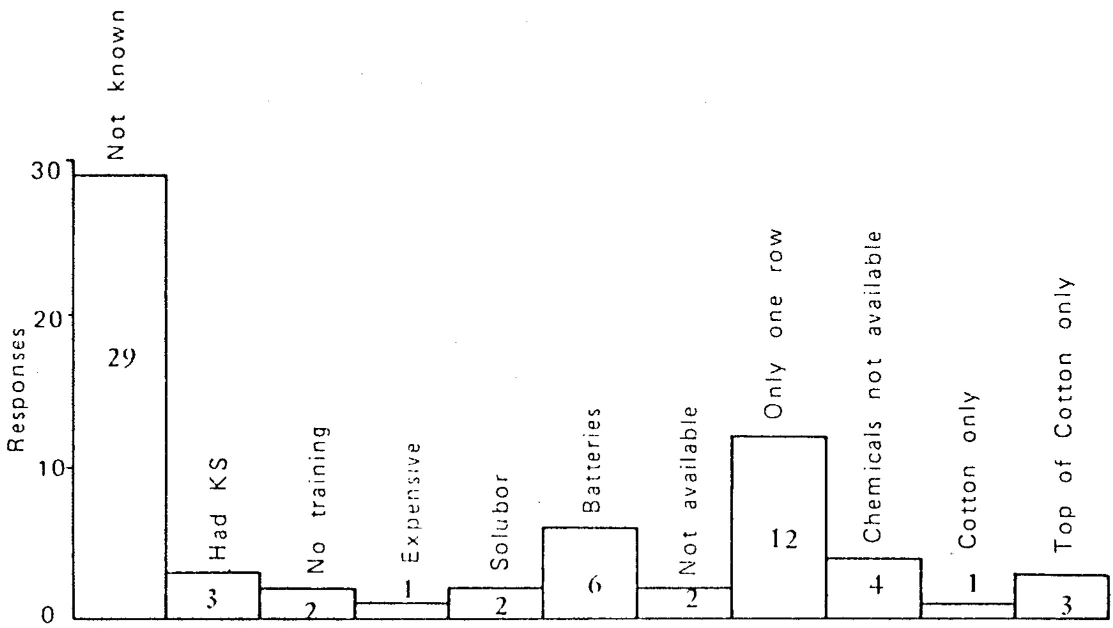

Figure 57• Reasons for not using 'Electrodyn' sprayer

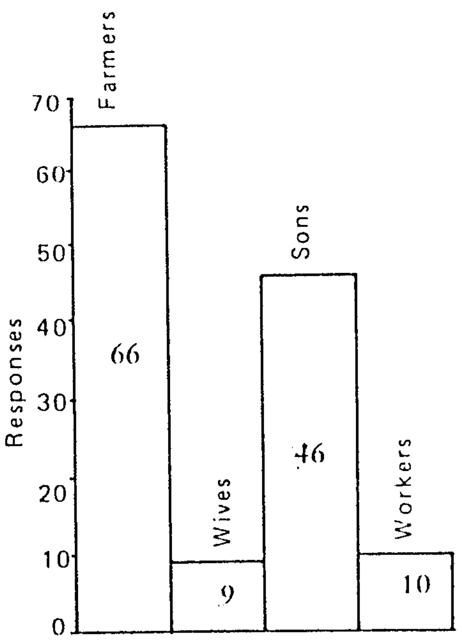

Figure 58• Different persons reported to spray cotton.

the increased number of spray applications, 6 said better sprayers, 6 reported better spray coverage, 3 said better insecticides, 2 suggested to increase the doses of insecticides, and one farmer said by employing more workers (Figure 60).

DISCUSSION

Knapsack Sprayers:- In Zambia most of the cotton crop is still sprayed with knapsack sprayers. The most common brands of knapsack sprayers used by the farmers interviewed were PTP - 15 (received under Norwegian aid) and Sikar 59 (received from India) but a wide range of machines have been available in various other cotton growing areas of Zambia.

The availability of different sprayers is probably because there are no testing and approval procedures for them. Difficulties in obtaining spare parts, reported by 30% of the farmers could probably be reduced by limiting the number of brands of sprayers as in Malawi. Generally, many small-scale farmers continued using defective sprayers in the absence of spare parts, increasing the risk of operator contamination. Spray coverage was also affected. The need for adequate supplies of spare parts cannot be over-emphasised, particularly in rural areas.

The most common problems experienced by the farmers were with the pumps and leakages.

Fifty four percent of farmers (who did not use knapsacks) complained about the heavy weight of these sprayers (particularly those

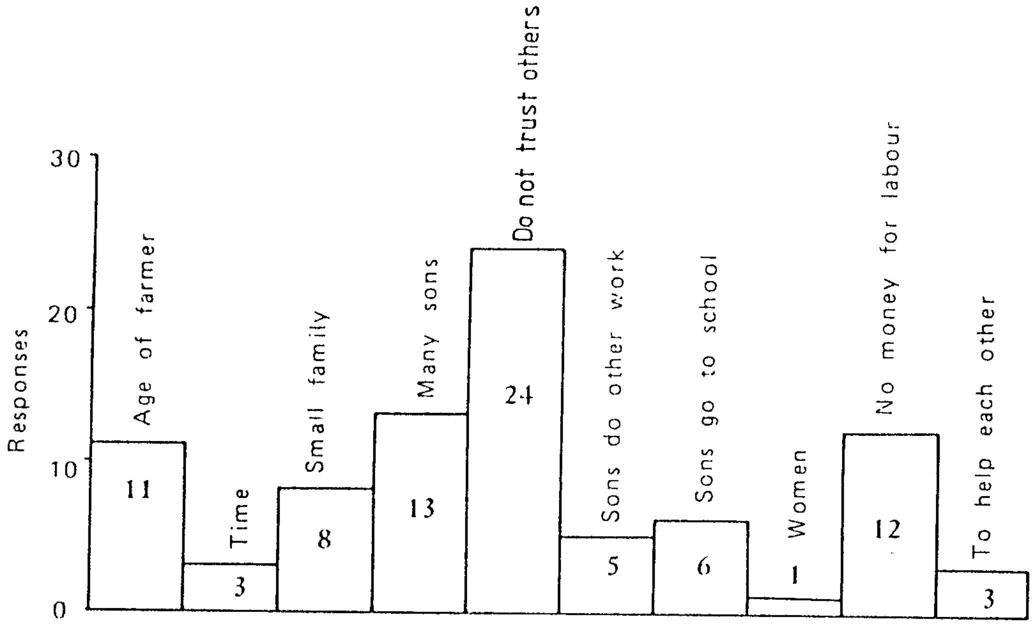

Figure 59. Reasons for different persons spraying cotton.

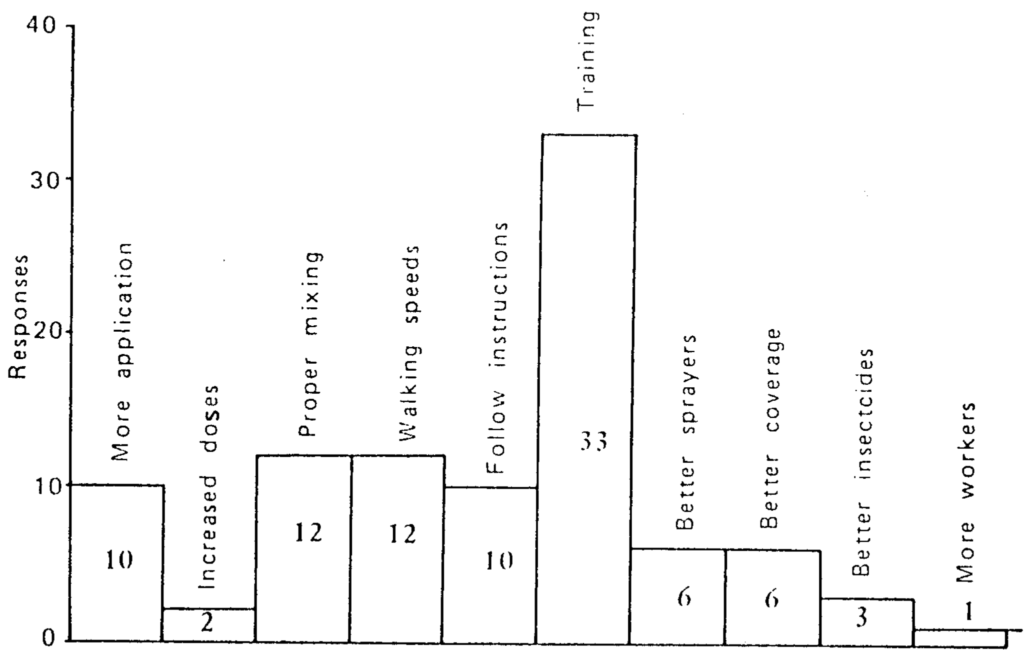

Figure 60. Suggestions for more effective spraying.

of metal). The plastic sprayers with 10 litre capacity might be more acceptable to small-scale farmers as most insecticide recommendations in Zambia are based on 10 litre capacity sprayers.

Transportation of water to cotton fields was another constraint, especially for about 48% of those who had to travel more than half a km. However, farmers must be discouraged from using dirty water for insecticide application such as dirty water collected from the nearest places to the cotton fields which might affect the nozzles and the effectiveness of chemicals due to the presence of clay and other materials. The sand particles in the water supply, particularly from dirty streams, generally block the nozzle (Matthews, 1982b).

About half of the farmers had bought sprayers during the last 3 years but 27% had experienced problems with sprayers which might be due to the repeated use of the same machine for applying pesticides on maize, vegetables, fruit crops, livestocks, and even against the household pests. The farmers expected more robust and durable machines at their farms.

In addition to spray pesticides all farmers interviewed had to use knapsack sprayers to make five foliar applications of solubor 20% WP, according to the current recommendations against the boron deficiency in all cotton growing areas of Zambia.

A one row swath is recommended when using knapsack sprayers but 17% of the farmers covered more than one row swath particularly when the cotton plants were still small in size. These farmers believed that the latest knapsack sprayers with good nozzles enabled them to increase the swath width. Some farmers perceived that the spray droplets produced by knapsack sprayers are easily visible on cotton plants and were more convincing to them.

However, the average yield of seed cotton obtained by farmers who used the knapsack sprayers was 745 kg/ha and the estimated efficiency of these machines was reported to be 86%.

Tailbooms:- This technique which is being used in Malawi and some other countries seems to have been abandoned in many cotton growing areas of Zambia due to unavailability and lack of extension regarding the potential benefits of these applications. In Zimbabwe, tailbooms are still the most effective means of delivering insecticides to all pests of cotton plants (Brettell, 1983).

Double nozzles:- Although 50% of the farmers were aware of the double nozzles, they were not available in the selected areas and the farmers were not practicing them. More advice on their use and their availability at LINTCO depots is needed.

Tractor mounted sprayers:- As small-scale cotton farmers do not have tractors, the majority of them (90%) were unaware about these sprayers. However, these could be used if and when the commercial farmers start cotton growing in Zambia.

Oxen-drawn sprayers:- Many farmers in the selected areas kept livestock and the majority of them used oxen for weed control in cotton. However, only 16% of the farmers were aware of the oxen-drawn sprayers which were not available to use. There is a need to exploit the potential of these applicators to save the labour and time of the farmers required for knapsack sprayers.

ULV Sprayers:- The ULV spraying on cotton was first recommended in Zambia during the 1973/74 season and introduced to small-scale farmers in the following season (Lyon, 1975b). However, the present survey indicated that only 50% of the farmers were aware of this application technique. The main reasons for not using ULV sprayers were the lack of suitable equipment and batteries. In consequence, efforts to encourage ULV spraying in Zambia have almost failed. Another reason was the alleged faulty formulations for ULV application (Mweetwa et al, 1983) as the quality of locally formulated products deteriorated after one year. This further discouraged the farmers.

The innovation of ULV spraying reduces labour inputs (Anon, 1985b) as well as water requirements and mixing of the insecticides so they have been adopted by cotton farmers in many countries particularly in French speaking West Africa. As indicated by Cauquil (1987), the cotton producing countries in French speaking Africa (Benin, Burkina Faso, Cameroon, Central African Republic, Ivory Coast, Mali, Niger, Senegel, Chad and Togo) adopted ULV spraying in 1975 and now virtually all 800,000 hectares of cotton are sprayed with ULV equipment. The introduction of ULV coupled with the use of pyrethroid insecticides has played an important role in the tremendous expansion of cotton pest control in these countries. It increased the yield of seed cotton and raised the total production in that region. In Tanzania, the Micron -

'ULVA' is being assembled with some local components while in Zimbabwe the 'Hispin' ULV sprayer is being manufactured.

The recent establishment of network of depots in the rural areas by LINTCO (Lint Company of Zambia Ltd.) might improve the regular supply of inputs such as ULV sprayers, spare parts, batteries and insecticides. Four percent of the farmers in the survey had ULV sprayers but were unable to use them due to lack of spare parts and appropriate pesticide formulations.

With the improvement of inputs and extension activities, the ULV sprayers still stand a good chance of success particularly in Mumbwa district and other areas where there is a shortage of water.

<u>'Electrodyn' sprayers</u>:- The farmers (30%) who used the 'Electrodyn' sprayers felt that they were light to carry as compared to knapsack sprayers and so easy to operate that their children could use them. Indeed, these are the main advantages of 'Electrodyn' sprayers as reported by the farmers. The supply of premixed insecticides, eliminate water problems and was considered very important for some farmers. The fact that the eletrodyn can be operated by children was perceived as an advantage by some farmers. But from the safety point of view, the appropriate authorities must advise farmers not to allow their children to apply pesticides with Electrodyn. The replacement of adults by children to apply ULV insecticides on cotton in French speaking countries is considered as a disadvantage and highly undesirable due to pesticide hazards (Cauquil, 1987).

The 'Electrodyn' is a new promising technique but various constraints as reported by many cotton farmers during the survey deserve attention.

Eight percent of the farmers who used an early version of the 'Electrodyn' sprayer explained that their machines stopped working after one or two seasons and they were unable to repair it and replace certain parts. The addresses of all these farmers were given to ICI and they promised to replace the applicators and to investigate the faults in machines. This is not surprising as out of two 'Electrodyn' sprayers bought by the author in 1984 for field trials, one stopped working as early as the first season; in spite of following all the necessary instruction on the use of 'Electrodyn' very carefully. The batteries were never left in the machines.

Little is known about the life span of 'Electrodyn' sprayers although they are expected to last for at least five years (Anon. 1985b); Coffee and Kohli, 1982). However, the small-scale farmers need a machine which is reliable and durable.

The small-scale farmers generally prefer a sprayer which can apply pesticides on all crops grown at their farms in addition to cotton. The 'Electrodyn' sprayer requires a special formulation, the range of which has been limited so far but is expected to increase (Durand et al., 1984; Matthews, 1984b). Cypermethrin was the only insecticide commercially available as an ED formulation in Zambia but cotton is attacked by many insect pest species which are difficult to control with a single type of insecticide. The continuous use of cypermethrin ED only is likely to result in secondary outbreaks of mites and other pests. However, cyhalothrin 'bozzles' are also expected to be available for cotton farmers in Zambia for the 1987-88 season. In Brazil, various products such as carbosulfan, malathion, Bromopropylate and cypermethrin are now available in ED formulations to suit the local pest complex of cotton (Smith, 1986).

Few farmers complained about the poor penetration of spray droplets into cotton canopy as they were able to see some insects on lower parts of the plants. Reduced penetration into the crop canopy with a charged sprayer is not unexpected especially when the canopy closes over the interrow.

All farmers were unable to spray solubor on cotton (for boron deficiency) with the 'Electrodyn' which at present implies an extra cost for knapsack sprayer. This was the most important economic consideration for many farmers.

As the 'Electrodyn' treats only a single row swath in contrast to up to six rows in each swath with the ULV sprayers, this was considered a further constraint by 22% of the farmers who did not use 'Electrodyn'.

In the initial introduction of a new type of equipment, farmers were not sure whether they would get the regular supplies of batteries and ED formulations of insecticides especially as many were aware that the failure of ULV spinning disc sprayers was due to the lack of regular supplies of those inputs.

The average yield of seed cotton obtained by farmers using 'Elect sprayers was 700 kg/ha. It is comparable to 745 kg/ha of seed cotton obtained by those farmers who used knapsack sprayers.

Generally, the farmers resist change. They certainly need more extension services and training on the improved application technology. Indeed, the majority of farmers suggested the need for training and calibration of sprayers for more effective spraying. The members of th farmers' families including sons and wives also participated in the application of insecticides and therefore the extension services should also be extended to them as the cotton production in Zambia is a family business.

CONCLUSIONS

The proper application of insecticides on cotton is an integral part of pest management and it must be given a top priority. The small-scale cotton farmers generally prefer equipment which is readily available, familiar to them, durable, easy to repair, and one which can be used flexibly on different crops. The knapsack sprayers, although the oldest application technique, was found to be commonly used by most of the farmers in Zambia.

It is evident from the results that knapsacks will probably continue to be used by many farmers in the near future. However, there is a desperate need to test and evaluate these applicators so that only approved and recommended brands are available to farmers.

The 'Electrodyn' sprayer is being used by many farmers in selected areas in Zambia on a trial basis but more research is needed to determine how this new technology can be introduced to benefit the farmers especially as foliar sprays of boron are needed.

Other improved application techniques such as ULV sprayers, tailbooms, double nozzles, tractor mounted, and ox-drawn sprayers are unavailable in all selected areas. But, the benefits of these techniques cannot be ignored. The regular supplies of suitable equipment and other inputs coupled with good extension services and effective training is needed.

CHAPTER 6

SAFETY PRECAUTIONS FOR INSECTICIDE APPLICATION ON COTTON

INTRODUCTION

The chemical control of cotton pests is always essential in Zambia to protect the crop from various insect pests. Inevitably, the farmers will have to apply insecticides on their cotton crops. The cotton in Zambia receives a maximum number of insecticide applications as compared to any other crop although the use of insecticides should be integrated with other non-chemical methods of control. However, if insecticides are needed, much has to be done to improve the way they are used (Matthews, 1987).

All insecticides are basically toxic substances. They are taken into the body by three routes; these are by mouth (oral), through lungs (inhalation) and through skin (dermal). The latter two routes are most common in cases of insecticide application on cotton by small-scale farmers in Zambia. Many cotton growers in Zambia and other developing countries are illiterate and the results of the present survey have shown that 50% of the cotton farmers in Zambia had never received training or attended any demonstrations on the control of cotton insect pests and the safe use of insecticides. Due to the lack of education and training, many small-scale farmers fail to understand the toxic nature of insecticides. They do not appreciate that insecticide contact may produce an adverse effect. A survey in the Philippines showed that no farmer was aware of the contact toxicity of insecticides and that individual cases of poisoning are seldom reported (Youdeowei and Service 1983). Many farmers in developing countries do not use protective clothing due to the lack of appreciation of hazards (Matthews, 1985a). The protective clothing must also be comfortable to wear if it is to be accepted by the operators and the adoption of authoritative standards would benefit both users and manufacturers (Lloyd, 1979).

The insecticide poisoning may result from a single dose of these chemicals (acute poisoning) or from the repeated intake of small quantities of an insecticide (chronic poisoning). The chronic poisoning is particularly important in the case of small-scale cotton farmers who repeatedly apply insecticides on their crops over a long period of time and are unaware of the chronic effects of insecticides. The major risk of farmers' contamination occurs when the concentration is measured out (Matthews, 1985a) and dermal contamination must be avoided (Matthews, 1976).

The toxicity of insecticides is usually expressed as acute oral and acute dermal LD 50s (lethal dose for 50% mortality of test animals). However, many small-scale cotton farmers are illiterate and are unaware of these figures. Much needs to be done on instructions easier to understand by the farmers. The farmers want simpler instructions for a particular product, the information may be given in the form of a pictogram (Matthews, 1987). However, instead of having a mass of information on the label, much of which is difficult to translate into local vernacular, some systems of symbols could be devised to clearly indicate the toxic nature and use of insecticides (Matthews, 1982b).

The cotton farmers in Zambia have a small acreage, they use knapsacks fitted with a lance and single nozzle. Unfortunately, the insecticide exposure is greatest for those using knapsack sprayers as compared to other techniques (Levy et al., 1980). In developing countries, spare parts are not always available, leakages from trigger valves hoses and spray tank increase operator contamination. The agricultural workers in developing countries are most exposed to pesticide contamination when measuring out concentrated formulations, and when mixing (Akesson et al., 1977). In the USA there are now regulations requiring the use of closed systems for the transfer of pesticides from containers to the sprayers to avoid the exposure of operations (Matthews, 1982b). However, for small-scale farmers in the tropics, it has been suggested that insecticides may be packed in small sachets, containing the quantities suitable for a knapsack load which may be safer and also reduce the risk of incorrect dosage being applied (Matthews, 1982b). The hot climates in the tropics restrict the choice of protective clothing. The users avoid these and therefore risk contamination (Matthews, 1985a).

According to WHO (World Health Organization), the data obtained on pesticide poisoning for 19 countries indicated that there were as many as 500,000 pesticide poisoning cases annually with a mortality rate of 1% in those countries where medical treatments and antidotes were available, and in other countries, where these facilities were less available, fatalities were presumably higher (Youdeowei and Service, 1983 ; Freed et al., 1983).

There is a lot of criticism regarding the use of pesticides by small-scale farmers causing incidents of poisoning but it is not always documented in official records (Bull, 1982). The insecticide poisoning is under reported in all parts of the world, particularly in developing countries (Davies, 1983), where problems of peasant farmers are generally not appreciated. There is a lot of ignorance and carelessness in the application of insecticides. Improper and careless use of insecticides can cause human exposure, destruction of beneficial organisms, and unwanted environmental contamination (Green et al., 1977; Matthews, 1979; Freed et al., 1983).

A reduction in pesticide exposure requires a knowledge of protective clothing, proper spray application, correct storage, and handling of insecticides as well as the action needed to be taken in the case of accidental poisoning; so farmers with small cotton farms in Zambia were surveyed to assess their knowledge on the safe use of pesticides and the results are reported in this chapter.

RESULTS

All the farmers interviewed had sprayed insecticides on cotton, but only 4% of the farmers reported using herbicides against weeds.

Protective clothing:- Seventy five farmers (out of 90) knew about protective clothing for the application of insecticides; of these; 30 knew about overalls, 14 gloves, 16 gumboots, 9 goggles and 2 farmers mentioned raincoats (Figure 61).

The farmers were then asked what protective clothing they had used themselves. Twenty used a separate set of old clothes, 29 had used the ordinary clothes that they wear often, 37 used overalls and dustcoats, 6 gumboots, 4 raincoats and 3 used goggles. Empty fertilizer bags were used by 5 farmers to protect their clothes, and 2 used a piece of ordinary cloth to cover their nose and mouth while spraying (Figure 62).

Safety precautions:- Additional safety precautions, farmers thought were necessary during the application of insecticides on cotton were, not spraying against the wind (30), not to smoke (30), not to eat anything (40), to wear gloves (3), to use empty fertilizer bags on their bodies (3). Five farmers reported other precautions such as to avoid touching leaves of treated plants, to wear hats, to eliminate leaks of sprayers, to wear an overall, and a raincoat (Figure 63).

When asked about safety precautions after they had finished spraying, 83 farmers (out of 90) reported they had a bath, 35 washed cloths, 13 washed their sprayers and 8 farmers reported washing hands only (Figure 64).

Insecticide doses:- All farmers reported that they were provided with a small measuring cup along with all insecticide packs and they had used the same cups to mix the proper amount of insecticide in water.

Storage of insecticides:- Seventy farmers (out of 90) reported that they stored insecticides and sprayers in separate rooms, 10 inside boxes, 5 in bedrooms, 3 in maize bins, 1 in toilets while another farmer reported that he kept it outside under a shed (Figure 65). Only 58 farmers reported that they locked the rooms where they had kept the insecticides.

Insecticide poisoning:- Eighteen farmers said that they had suffered from mild to moderate symptoms of insecticide poisoning. The farmers

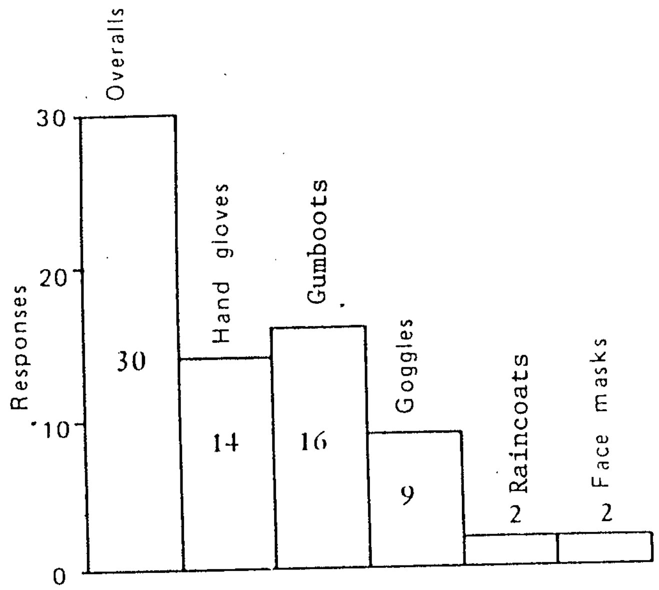

Figure 61. Type of protective clothing known to farmers..

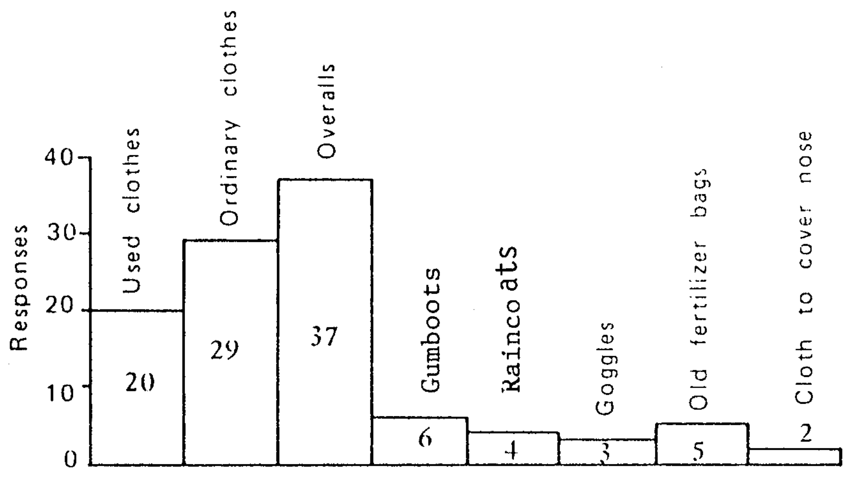

Figure 62. Actual clothing during spraying.

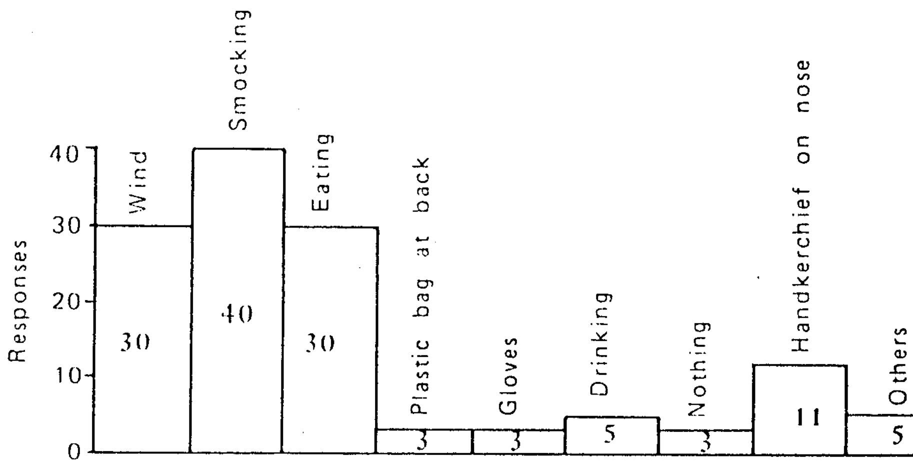

Figure 63. Safety precautions during spraying.

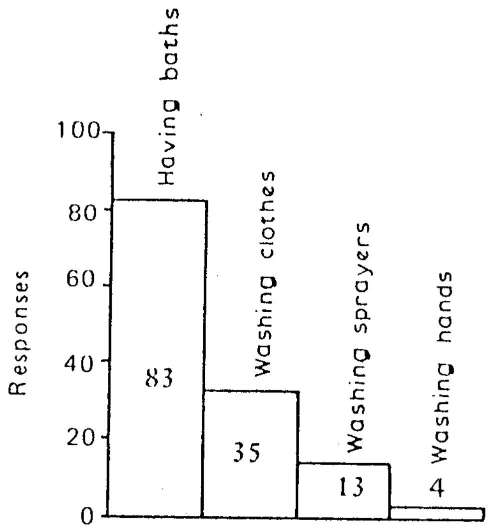

Figure 64. Safety precautions after spray.

were also asked about the circumstances under which the sicknesses had happened. Three farmers reported that it was due to the inhaling of insecticides, 4 spraying against the wind, 1 overflow or leakage while using the sprayer. The other farmers could not remember how the poisoning happened (Figure 66).

The farmers who had suffered from pesticides also mentioned various symptoms. Ten farmers reported itching and swelling on bodies particularly on their faces, 7 reported pain in the chest, and 4 sneezing (Figure 67).

Actions in case of sickness:- Various actions were thought to be necessary by the farmers in case of sickness due to insecticides. Sixty farmers said they would report to the nearest clinic, 47 would drink milk, 24 would induce vomiting, 3 would have a bath, 2 would eat uncooked eggs, and 1 would wash his mouth with clean water (Figure 68).

DISCUSSION

In Zambia the insecticides are supplied by three multinational companies but unfortunately none of these supply or market any sort of protective clothing. Neither LINTCO (Lint Company of Zambia), the sole organization for the supply of all inputs such as insecticides and sprayers to small-scale farmers. Although, the most toxic insecticides are not recommended on cotton in Zambia, but it would be better to reduce the unnecessary contamination by encouraging farmers to wear a maximum of appropriate protective clothing.

Overalls:- That only a third of the farmers knew about the use of overalls

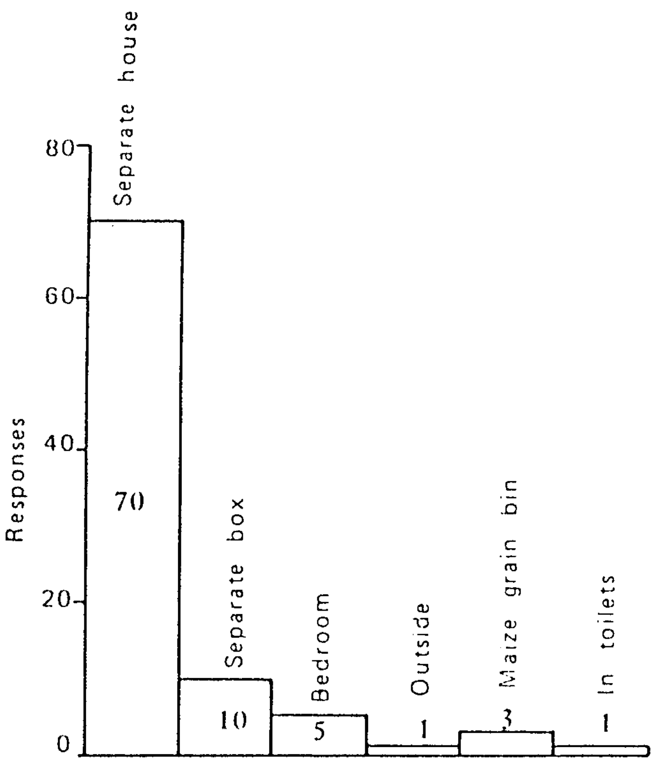

Figure 65.Storage of insecticides.

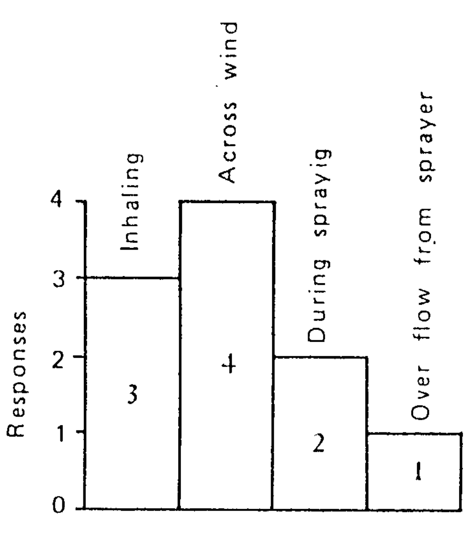

Figure 66 • Causes of illness •

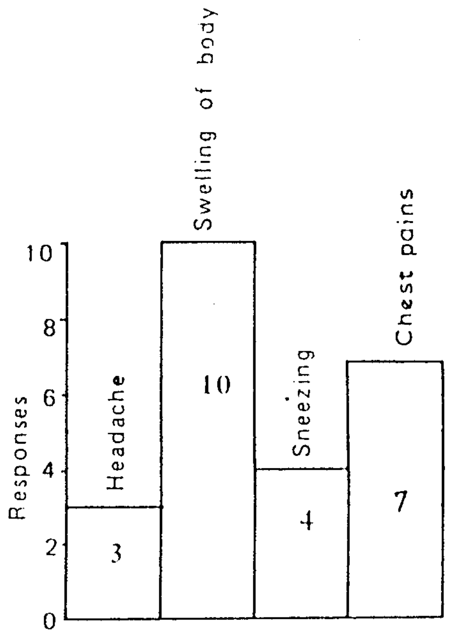

Figure 67. Symptoms of illness due to spraying.

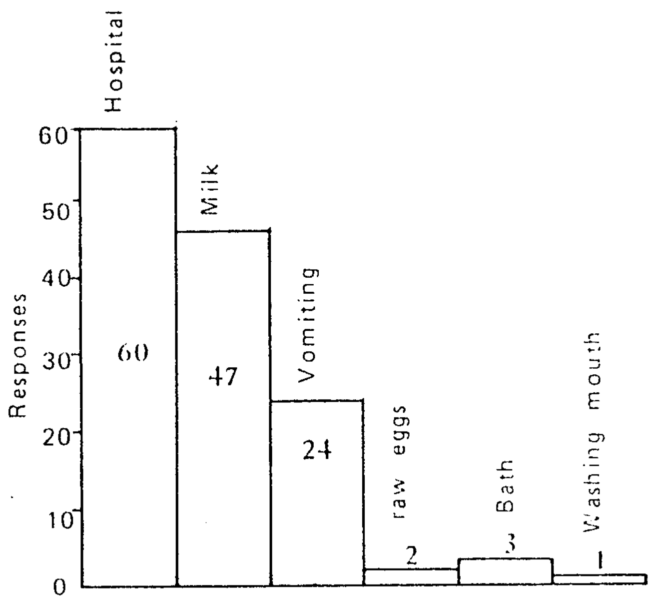

Figure 68. Actions in case of sickness.

disappointing, because ideally light cotton fabric overalls of a durable quality should be worn as they can provide 85% protection of the body. As the insecticide contamination is principally by absorption through the skin, the use of overalls on small-scale cotton farms should be encouraged (Matthews and Clayphon, 1973), especially in Zambia and many other developing countries the local textile industries can manufacture the appropriate overalls. The farmers should be advised to store the overalls away from insecticides and these should be washed with soap and detergent regularly.

The heavy clothing is generally uncomfortable to wear in tropical climates so there is a need to develop appropriate, comfortable, and economically acceptable protective clothing for small-scale tropical farmers. Future research is needed to see what type of material and design of garment would give the best protection.

Gloves:- The small number of farmers were aware of gloves which are needed principally during the mixing and handling of concentrated insecticides (Oudejans, 1982), is probably due to their not being available. The need for gloves depends very much on a particular insecticide which is being used. When the hazardous insecticides are used, gloves are essential during the dilution of concentrates and mixing chemicals. The gloves should be of neoprene and should be long enough to protect the wrists, but as some solvents can penetrate even this type of glove, any contamination should be washed off immediately. The importance and proper use of gloves must be encouraged and demonstrated to small-scale farmers. The gloves are particularly important during washing the sprayers as absorption of the insecticide is greater when the skin is wet (Matthews, 1979). However, the use of cotton and leather gloves which absorb the insecticides must be discouraged (Matthews and Clayphon, 1973).

Gumboots:- Most of the small-scale farmers spray insecticides either bare footed or they wear the old shoes. The gumboots are usually available at general stores in Zambia but cost too much. Sixteen percent of the farmers knew about the use of gumboots but only 6% actually used them during cotton spraying. The gumboots are particularly important when knapsacks are used with the nozzle in front of the operator as they walk through the treated foliage, and the lower leg and feet get contaminated more than the other parts of the body. Gumboots are also useful to protect farmers from snake bites. The use of shoes is often recommended (Matthews, 1979), but the farmers said that they were even more expensive than the gumboots and often get spoiled when the farmers apply insecticides after heavy rains as the soil is still wet.

Goggles:- The goggles are not always available on the market in Zambia but if there is any change to ULV spinning disc sprayers, the goggles would have to be provided to the farmers.

Hats:- As using a knapsack sprayer can take several hours, the farmers should wear a hat to protect them from the heat of the sun.

Raincoats:- In some countries a light weight plastic apron has been used while spraying to prevent the liquid soaking into the operator's clothes. These were not available in Zambia and only 5% of the farmers had used a raincoat. Instead, some farmers (6%) had used a plastic fertilizer bag as they had no extra raincoat. There is therefore, a need for more attention and the encouragement for farmers to use some sort of impermeable protection over their body.

Face masks:- These are quite expensive and generally not available, but a rag or a handkerchief tied around the nose and mouth will remove the contamination of skin in this area. Only 3% of the farmers were reported to use it.

However, in the absence of appropriate protective clothing the small-scale farmers must be encouraged to wear at least a separate long sleeved shirt, long trousers, that they do not wear every day. The old clothes can also be used provided they are not torn and full of holes.

Although insecticide users are advised not to smoke, eat and drink anything; only 30 to 40% of the farmers apparently knew about this.

As some farmers reported to have suffered from inhaling the spray mist, therefore, there is a need to discourage the farmers to spray during the strong winds which causes inhalation, contamination, and wets the clothes. It will also reduce the pesticide drift on non-targets.

The majority of farmers reported to have a bath after spraying insecticides but only 14% reported washing the sprayer which must also be encouraged as the same knapsack sprayer is used for the application of herbicides and for various additional purposes at small-scale farms.

Storage of insecticides:- When the farmers have only a small house, it is clearly difficult for them to keep the chemicals in a separate store room. Nevertheless most of them did use a separate room and it was encouraging that a third of them did lock the room in which the pesticides were kept. The supply of a cheap lock and small boxes to store insecticides is suggested. Ideally, all insecticides must be stored in original containers.

Insecticide poisoning:- That 20% of the farmers had suffered from mild to moderate symptoms of insecticide poisoning confirms that incidents occur more frequently in developing countries than indicated by official statistics, as many do not go to a clinic or a hospital.

The circumstances in these cases of poisoning such as spraying against the wind, contamination by insecticides, clearly indicates that the necessary precautions were obviously not followed by these farmers. More information on the symptoms of poisoning needs to be given to the farmers so that if they fall sick they will seek advice from the nearest clinic or a doctor as soon as possible.

The clinics were observed during the survey in all selected areas. However, all of these must have the appropriate antidotes along with the relevant information on the toxicity of commonly used cotton insecticides.

CONCLUSIONS

The insecticides recommended to small scale farmers for the management of cotton pests in Zambia have been the least toxic. Farmers must be encouraged to minimize their use and be advised and trained to apply them according to the scouting data rather than on a prophylactic basis.

None of those farmers who had suffered from insecticide poisoning had ever attended any training course or demonstration on pest control. Better and safer use of insecticides can only be achieved therefore if small-scale farmers receive more intensive training courses and demonstrations. They should be aware that insecticides are toxic and that they cannot be contaminated by different routes of entry into the body, and therefore wearing protective clothing is important to reduce the risk of poisoning. If the small-scale farmers understand the toxic effects of insecticides, they would be more likely to take the steps to avoid the exposure. More advice on the safe use of insecticides can be disseminated in illustrated booklets, leaflets and charts, along with more emphasis on radio programmes.

Many Governments in developing countries have limited funds, and infrastructure for effective training, so the multinational agrochemical companies should also accept the challenge to educate the small-scale farmers particularly in developing countries on the safe and proper use of their products. This is now beginning under the auspices of GIFAP and individual company product stewardship programmes. In Zambia, LINTCO should have the responsibility at its depots in the rural areas to supply all appropriate protective clothing with other inputs on seasonal loans. Each small packet of insecticide, supplied to a small-scale farmer must include a code of practice (Matthews and Clayphon, 1973), which gives the instructions for mixing, during application and after finishing the spray application of insecticides.

Improved application can also reduce the operator exposure, thus the recent developments in electrostatic spraying might provide comparatively better protection for small-scale farmers. All those who reported to have used 'Electrodyn' sprayers during the present survey, have not reported any insecticide poisoning symptoms.

The information on the toxicity of insecticides, appropriate protective clothing, other safety precautions, proper storage, personal hygiene, better application, safer application techniques will not only reduce the likelihood of exposures and pollution of environments, but will also ultimately improve the management of pests at small cotton farms.

CHAPTER 7

EXTENSION AND SOURCES OF ADVICE ON COTTON PEST MANAGEMENT

INTRODUCTION

The cotton farms in Zambia like many other parts of Africa are small and scattered and the educational background of the farmers is generally poor. The pest management strategies must relate to the needs of such farmers and their implementation depends on how effectively the ideas can be conveyed to the farmers in the field (Kumar, 1984). An efficient extension service guarantees the rapid transfer of pest management technologies from research to the field and conversely of the farmers' problems to the research scientists (Youdewi and Service, 1983). In virtually all countries, there is very little farmer training for those who actually use pesticides. For farmers in tropical countries, the situation is more complex due to the vast number of farmers and the remoteness of areas in which they live (Matthews, 1987).

There is a need for training individual farmers as well as extension staff, and marketing personnel, so that they know which chemical to use, when to apply it, and how to apply it safely (Matthews, 1985a; Matthews 1985b).

Cotton farmers in Zambia need extension services due to problems of pest control (Mweetwa, *et al*., 1983) and the challenge to develop better pest management programmes (Matteson, *et al*., 1984), because plant protection measures show a lower rate of adoption than other recommendations such as high yielding varieties and fertilizer (Pandya, 1981). The ultimate aim of research and extension in pest management is to achieve improvements in practice (Norton, 1982). Since information gaps can constrain some improvements, an important feature of research and extension should be the identification of major information gaps, why they exist, and how the allocation of research and extension effort can serve to overcome these gaps (Norton and Mumford, 1982).

The aim of the present study was to assess the status of training, extension service and other sources of advice and their effects on the insect pest management practices of small-scale cotton farmers. The major constraints are described, and suggestions for improvements in pest management are discussed.

RESULTS

Training:- Only 43 farmers out of 90 said they had received training on some aspects of insect pest management of cotton. Of these, 29 received training on cotton production including pest control, 12 on application of insecticides, 6 on scouting of insects, 3 on maize production and its related problems (e.g. control of *Heliothis* and rotation with cotton), 1 on the safety of pesticides while another farmer mentioned all aspects of cotton pest control because he had attended a two year course at Palabana Farm Training Institute (Figure 69).

The training courses on cotton pest control were mostly organised by Government Institutes. Nineteen farmers had attended these courses at Monze, 10 at Keembe and 5 at Mukulaikwa Farm Training Institutes. Only 4 farmers had received training from LINTCO and one farmer was a certificate holder from Palabana Farm Training Institute (Figure 70).

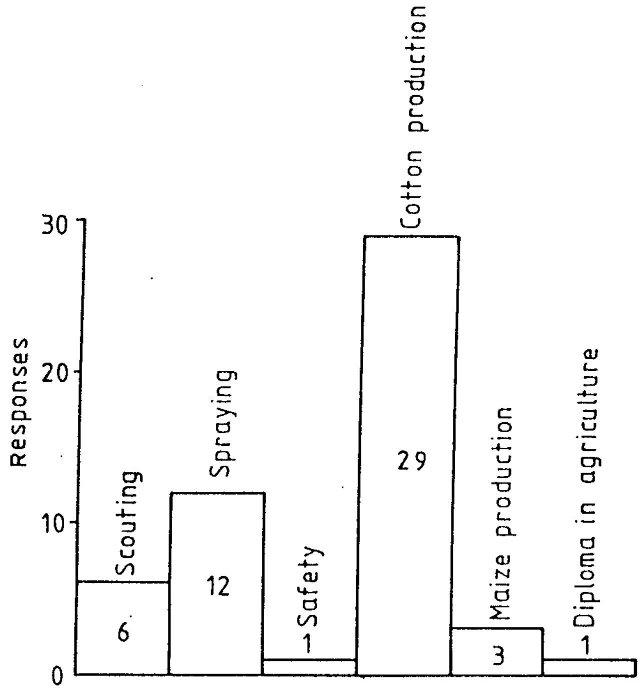

Figure 69. Aspects of Training.

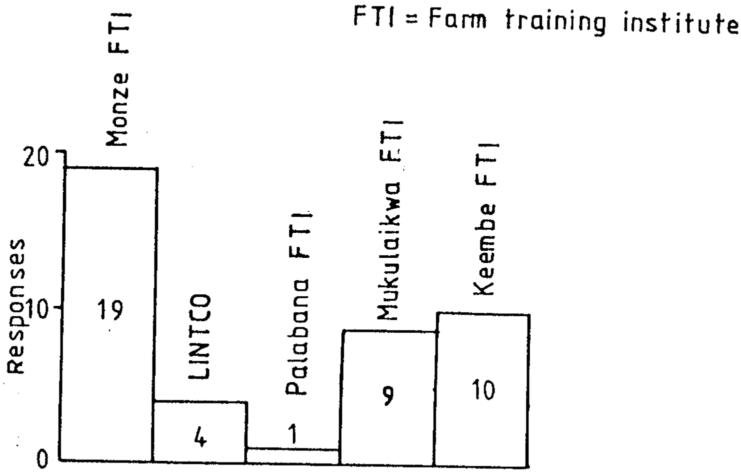

Figure 70. Training Institutions.

All but one farmer remembered the time when they received training. The time when the farmers had received training ranged from 1 to 25 years (Figure 71).

Extension service:- About 83 farmers (out of 90) reported that they were aware of the extension workers in their areas. The number of extension worker visits ranged from 1 to 15 (Figure 72) with weighted means of 4.8 visits per cotton growing season.

Two thirds of the farmers were visited by contact farmers 1 to 12 times per cotton growing season (Figure 73) (weighted means of 4 visits). Five farmers interviewed were contact farmers.

All 90 farmers interviewed reported the need for additional advice from extension workers and contact farmers on various aspects of insect pest management of cotton; 42 farmers expressed the need for more help on scouting of insect pests; 37 on application of insecticides, 23 on general aspects of cotton production including pest control; 17 on mixing of insecticides; 3 on safety of insecticides; 3 on the knowledge of new insecticides and 2 on the identification of insect pests of cotton (Figure 74).

Demonstrations:- Only 45 farmers said that they attended demonstrations on cotton pest control; 32 farmers attended the demonstration organised by ICI (Imperial Chemical Industries); 5 by Hoechest; 3 by Magoye Cotton Research Station; and 1 by Shell Chemicals (Figure 75). Most of these demonstrations had been in the 1st three years, (Figure 76).

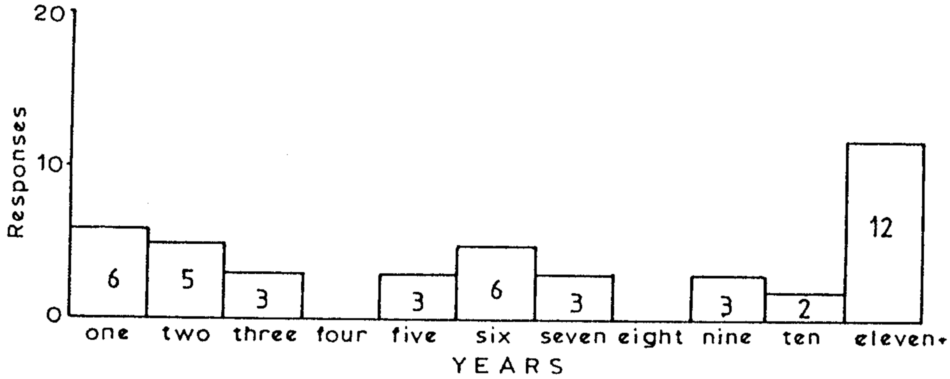

Figure 71. Time of receiving training.

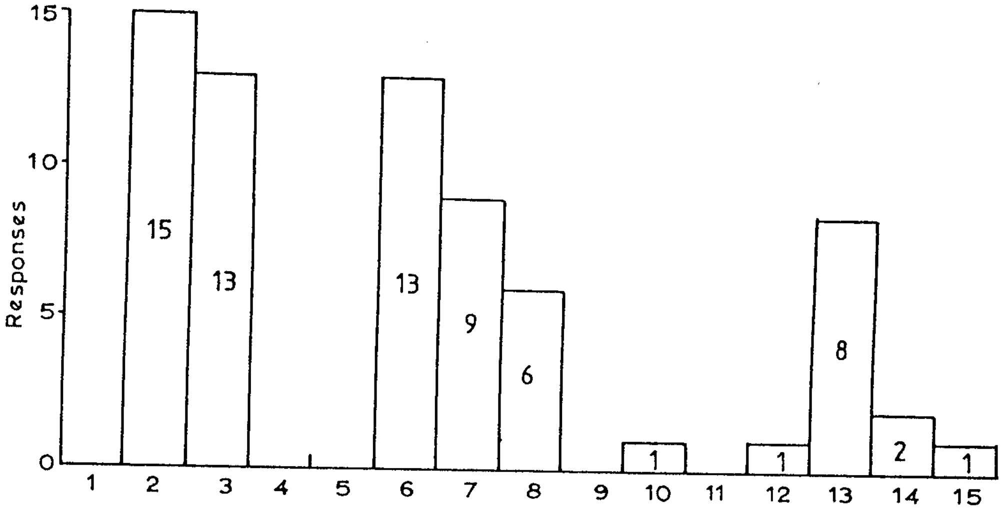

Figure 72. Extension workers' visits.

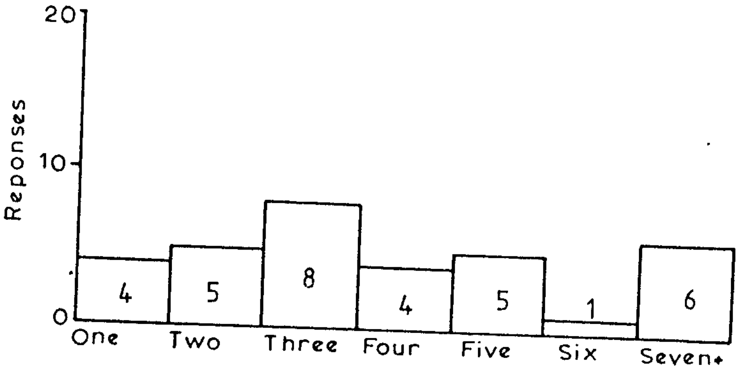

Figure 73. Number of visits by contact farmers.

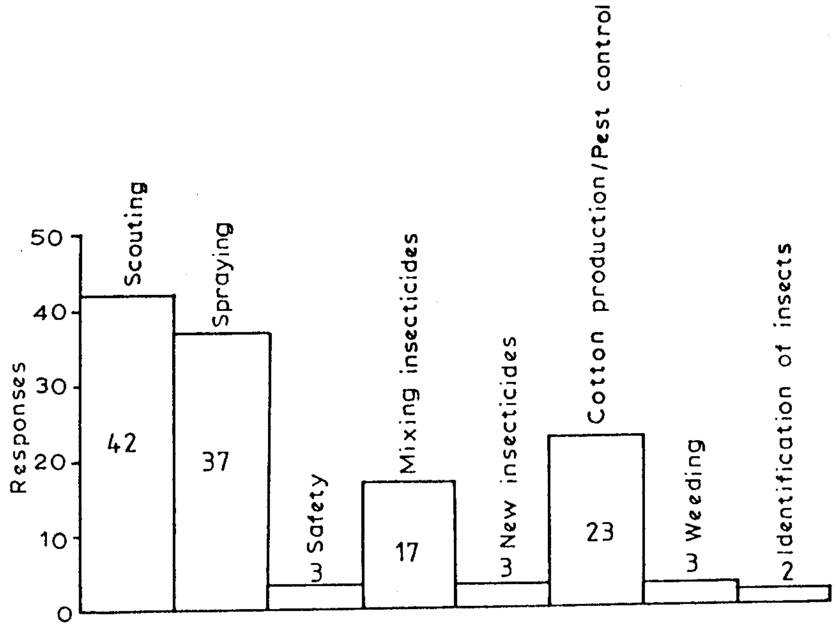

Figure 74. Advice needed by farmers.

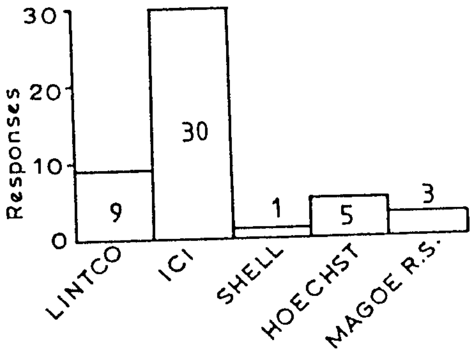

Figure 75 Demonstration Institutes.

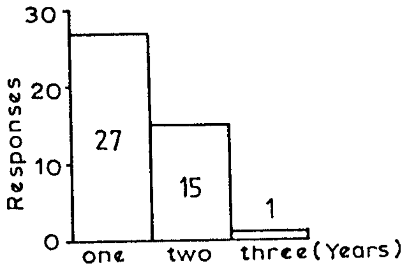

Figure 76. Time of demonstration.

Additional sources of advice:- Fifty farmers said they benefitted from information on the radio; 48 from leaflets; 45 from field days; 32 from fellow farmers; 2 from LINTCO, 1 from agricultural shows and another from private companies (Figure 77).

Improvement of Extension Services:- All farmers interviewed felt the need for improvement in the existing extension services and sources of advice used on insect pest management of cotton in Zambia; 45 farmers suggested additional training courses; 36 more frequent visits by extension officers; 17 provision of more literature; 13 demonstrations and informal meetings; 6 better insecticides; 3 safe use of insecticides and another 3 mentioned the provision of herbicides from LINTCO depots (Figure 78) on seasonal loans.

DISCUSSION

Training:- Prior to the formation of LINTCO in 1977/78, the Ministry of Agriculture and Water Development offered some occasional training courses to cotton farmers at Farmers Training Centres in different areas. Now the Lint Company of Zambia (LINTCO) provides some training courses and during the 1984/85 cotton growing season, 210 extension officers, 125 marketing staff (at LINTCO depots) and 350 contact farmers were trained on almost every aspect of cotton growing in Zambia. Special emphasis was on contact farmers to enable them to pass on their knowledge and skills to their fellow farmers (W. Kruel, personal communication).

Most districts have Farmers Training Centres which are suitable for conducting residential and day training courses. Although these centres

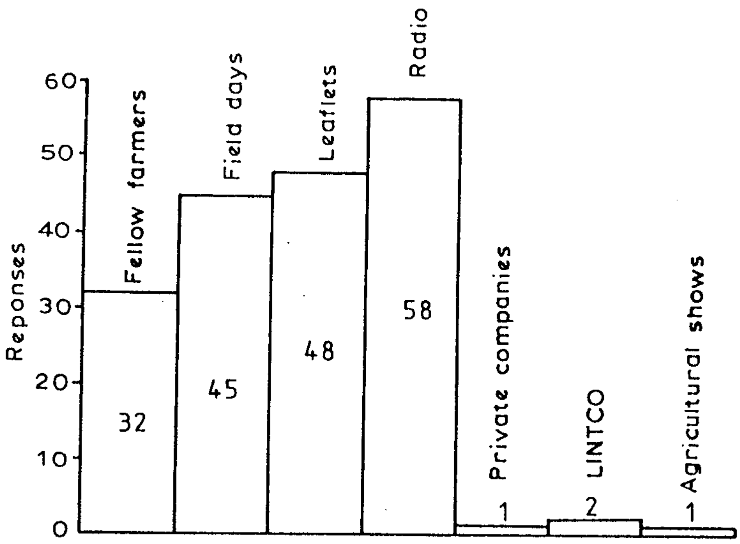

Figure 77. Other sources of advice.

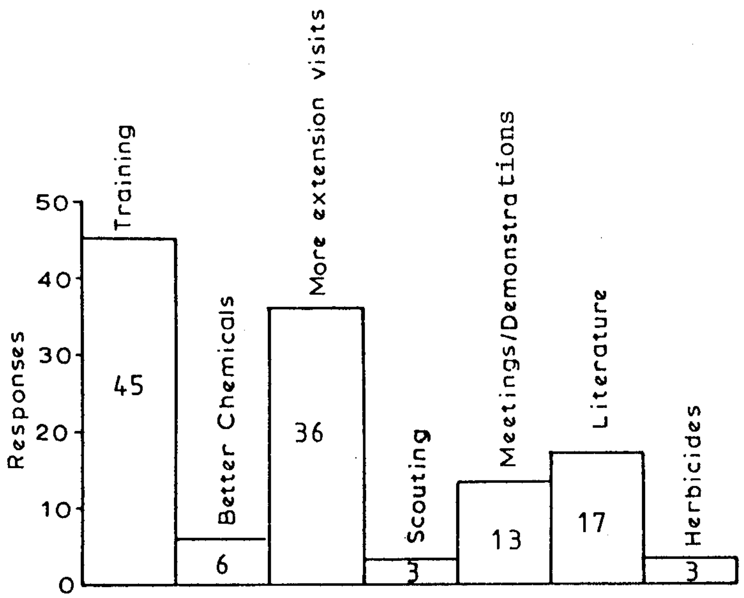

Figure 78. Farmer' suggestions.

are mainly established to train farmers, unfortunately the results have been poor and the funds are insufficient (Anon, 1984b). At the time of receiving training by the majority of farmers, 7 years ago, LINTCO had just been formed and therefore only 4 out of 43 trained farmers received training from LINTCO.

Previous recommendations for cotton pest control included carbaryl and endosulfan insecticides with up to 10 spray applications at weekly intervals. These insecticides have been replaced by pyrethroid insecticides in many parts of Zambia but these insecticides require only five sprays applied every two weeks. However, 40 farmers (out of 90) applied more than the 5 recommended applications of pyrethroids; because some farmers lacked the training and information on their use.

Clearly, the survey identified the desperate need for training of small-scale cotton farmers on the proper use of insecticides and other aspects of cotton insect pest management. Indeed, the identification of such information gaps in order to achieve improvements in practices is the ultimate aim of extension and research in pest management (Norton, 1982; Norton and Mumford, 1982).

If cotton production is to be increased in Zambia, adequate training of farmers with special emphasis on pest management is essential for judicious use of insecticides. This would reduce the need for foreign exchange expenditure on the import of insecticides, by avoiding unnecessary spray applications. Such cost saving measures are necessary as many Governments in developing countries cannot afford large expenditures on agricultural inputs including pesticides (Matteson al., 1984).

That only 6 farmers out of 43 who had attended courses had received some training on scouting of pests was surprising in view of the repeated emphasis in almost all pest control recommendations in Zambia (Anon, 1968, Lyon, 1975a, Bohlen, 1982). Little has been done practically to correct the situation, so that although 86% of the farmers interviewed were aware of the importance of scouting, they did not follow the correct scouting procedures due to the lack of adequate and effective training. Indeed, the need to train the farmers on proper scouting methods cannot be over-emphasised.

Small-scale cotton farmers in Zambia are mostly illiterate, so there is a need to develop and train them to use methods which are locally acceptable such as the 'pegboard' method developed in Malawi (Beeden, 1972).

Extension:- In Zambia, extension services are mainly provided by the Ministry of Agriculture and Water Development, with most in service training at 8 Provincial Farm Institutes, which provide residential short and long term courses. The main contact of farmers with the Ministry is through the extension workers stationed at agricultural camps in each district. A district is usually divided into 3 to 5 agricultural blocks and there are various agricultural camps (at village levels) in each block. Each camp has usually 5-6 extension workers depending upon the size of the village.

Now, LINTCO has been given the responsibility to provide all technical and extension services including pest control to cotton farmers. This arrangement is working effectively in all provinces of Zambia. The cotton extension strategy, developed and implemented through the co-operation between LINTCO and the Ministry of Agriculture and Water Development has been frequently cited as a model for the general agricultural extension services to small-scale farmers in Zambia (W. Kreul, personal communication).

The total number of extension workers, seconded to LINTCO was approximately 227 for 38,400 farmers during the 1984/85 cotton season; a very low ratio; as in many developing countries. Since 1983 these officers are also required to supervise farmers on soyabeans and coffee. In addition, LINTCO has recently started training "contact" farmers who are expected to pass on their knowledge to other farmers in their areas.

The extension officers are trained in general agriculture but they receive insufficient training on insect pest management of cotton and most are not familiar with various practical aspects of insect pest scouting. This factor is quickly recognised by farmers who need more help in pest scouting and application of insecticides.

LINTCO has had only one extension entomologist since 1977/78, while the number of cotton growers has increased from 15,107 to 38,400 in 1984/85. There is therefore an urgent need for more specialized inservice training of cotton extension staff on insect pest management of cotton and extension methods. Furthermore, the communication gap between research and extension workers need to be improved and by study of their attitudes and capabilities improved training (Matteson <u>et al</u>.,

1984) can benifit farmers.

A shortage of extension officers was generally observed in many areas during the present survey. Staff frequently resign because they are frustrated by the lack of accommodation and transport, and insufficient allowances (Mweetwa et al., 1983). Indeed, Governments in tropical countries do not seem to have established attractive career structures for extension service personnel, so young people are not attracted to this field (Youdeowi and Service, 1983). In Uganda, it was recognised that spraying according to scouting data was the most economic means of pesticide use, but such a programme was beyond the resources of already over-stretched extension services (Cox, 1982). Effective extension services are often the most neglected aspect of pest control programmes of developing countries (Kumar, 1984).

The most common type of extension officers contact is through the brief visits to individual farmers and less often by the attendance of meetings and the use of on-farm demonstrations. The number of extension worker visits is reported to be inadequate, while farmers did not get the useful information needed to carry out effective pest management programmes. Indeed, many farmers (40%) felt the need for more appropriate and frequent extension visits.

Demonstrations on cotton pest control, were also organised by private companies, (ICI, Hoechst, Shell) and attended by half of the farmers interviewed. The use of their products is emphasised, so farmers learn very little about insect pest management. Demonstrations by ICI were mostly on the use of 'Electrodyn' sprayers, which have been introduced recently in all the selected areas.

Other useful sources of information used by farmers such as radios, literature and fellow farmers receive little attention from the appropriate authorities and deserve more emphasis to improve the insect pest management of cotton. Indeed, the farmers perceptions about the effectiveness of advice must be taken into consideration.

The farmers felt the need for more training, literature availability, appropriate visits of extension officers for better insect pest management of cotton. If the new technology (whether for pests or crop management) is to be used for small-scale farmers, its development must start with them (Altieri, 1984).

A lack of proper training programmes and insufficient extension services were major constraints hindering effective insect pest management by small-scale cotton farmers in Zambia.

The uneven distribution of cotton farms throughout the country makes it difficult to organise adequate training for all farmers but clearly there are certain areas where intensive efforts could be more beneficial and knowledge gained can be spread to a wider audience by greater emphasis on the use of the radio, leaflets and other literature.

Proper training courses are essential and the experience in Zimbabwe has illustrated the importance of a cotton training institute at a national level to improve training of small-scale farmers on all aspects of cotton production but with particular emphasis on pest management. Residential three week training courses in Zimbabwe, followed by weekly extension visits during the four months of the cotton growing season have saved farmers up to four unnecessary spray applications and increased the yields up to 10% during a pilot scheme to assess a pest management programme for small-scale farmers (Burgess, 1983).

However, this involves the provision of additional extension staff with more specialised inservice training on cotton husbandry and pest management coupled with more incentives such as attractive allowances, suitable accommodation; and the allocation of adequate financial resources for an increased number of regular on-farm demonstrations and field days.

CONCLUSIONS

Training courses and demonstrations on pest control were attended by only about fifty percent of the farmers interviewed. The training, organised mostly by Government Farm Training Institutes, emphasised general aspects of cotton production. Whereas the demonstrations on chemical control were occasionally organised by multinational companies like ICI, Hoechst, and Shell Chemicals. Ninety two percent of the farmers were aware of the extension workers in their respective areas and were visited on an average of 4.8 times per growing season. The other sources of information on cotton pest management available to farmers were radios, field days, leaflets and informative discussions within the farming community. Farmers expressed the need for more advice on methods of insect scouting and application of insecticides on cotton. Farmers generally felt that cotton pest management can be improved by introducing frequent training courses, increased number of extension workers coupled with demonstrations in cotton fields.

CHAPTER 8

CONCLUSIONS ON THE SURVEY OF FARMERS

Insecticide usage, application and safety

All small scale farmers interviewed apply insecticides on cotton due to pest hazards and perceived crop yield losses. The synthetic pyrethroids are now well established for cotton pest control in Zambia a fact which has been confirmed by this study. The use of pyrethroids (cypermethrin and deltamethrin) on cotton has been very rapid and wide spread in Zambia. This has been the case despite their well known non selectivity against beneficial insects. The repeated application of broad spectrum insecticides like pyrethroids has often led to the upsurge of secondary insect pests through suppression of natural contr (predators and parasites) action. If a judicious plan for the use of pyrethroid is not worked out, these chemicals might soon or later show signs of reduced effectiveness against the major pests. In order to forestall the resistance to bollworms and to avoid the secondary outbreaks of minor pests, it is suggested that different types of insecticides (including endosulfan and carbaryl) must be rotated annually at provincial level. In Zimbabwe use of pyrethroids is only allowed during maximum flowering and boll formation periods. Before and after this period growers still use endosulfan and carbaryl as appropriate to a particular species of bollworms (Brettell, 1983).

Farmers have to decide on the strategy to follow when applying pyrethroids on cotton. Two main approaches can be identified. These include routine sprays and scouting based sprays. As described earlie routine spraying of cotton is the most established practice in Zambia. Control of cotton pests has relied heavily on this method which has changed very little during the last 50 years. But the survey showed that farmers did not carry out the routine spraying according to the laid down recommendations. A few farmers started spraying too early (before the 7th week after germination) because they observed early season pests on their crops. But the early season pests like Jassids, aphids, and whiteflies are generally regarded as minor pests in Zambia and might not cause a subsequent reduction on the yield of cotton. It would appear that farmers can not tolerate even the low populations of pests on their crops. So they start spraying early due to their perceptions of pest hazards rather than real damage and subsequent yield losses. In order to change the attitudes of farmers there is a need to educate them about the threshold levels of pests which unfortunately for Zambia, would be based on Zimbabwean recommendations (Bohlen, 1982) so that they could tolerate the low populations of insect pests on their crops. About half of the farmers interviewed applied excessive sprays (more than 5 routine applications). Those farmers seem to be unaware of the side effects of the overuse of pyrethroids on cotton including the effects on predators and parasites. Therefore there is a need to make farmers aware of the side effects of long term indiscriminate use of insecticides such as development of resistance problems and the out breaks of minor pests.

Scouting based sprays provide the most appropriate approach on cotton pest management. Inspite of the wide recognition of the benefits of such sprays, the practical implementation of this practice in Zambia has been very low. The introduction and adoption of scouting based sprays in developing countries has not been easy. Difficulties have been experienced in most of the countires when such recommendations were introduced at small scale farm level. BY talking to the farmers it appears that they are faced with various constraints in adopting the scouting based sprays. The currently recommended scouting procedures (Bohlen, 1982) are unknown to the farmers and therefore there is a desperate need for effective and appropriate training in the use of this methods to alleviate the constraints of the target group.

The effectiveness of pest control with insecticides is also determined by the efficiency of the spraying equipment used. Knapsack sprayers still remain the most commonly used applicators for spraying insecticides on cotton in Zambia. These applicators are very versatile, but are logistically regarded as inefficient as compared to other techniques. There is a need to reintroduce hand held ULV sprayers by LINTCO. Indeed, the smaller droplets produced by these applicators are more efficient at impaction and provide a better control of insect pests. The ULV sprayers have played a very important role in many cotton growing countries on the continent. The initial introduction of the Electrodyn has also been socio-economically acceptable at small scale cotton farms in Zambia and there is evidence for widespread adoption of the technology. But more research on the Electrodyn is suggested to make the sprayer more versiatile and therefore more readily acceptable.

The safe use of pesticides at small scale farms can not be ignored. The survey showed that cotton growers in Zambia like those in many other developing countries are unable to read instructions on insecticide packs and are not adequately trained. LINTCO must adopt a set of Pictograms which have been developed recently by International Agro-chemical Industry Association (GIFFAP), with the help of the Food and Agriculture Organisation (E. Bernet*, Personal communication). By using these symbols on pesticide containers it is expected to be easier to convey essential safety information to the farmers. The pictograms have been tested in various developing countries where they have proved successful. The government together with pesticide companies and LINTCO must work towards the introdution of pictograms in Zambia soon. There is also an urgent need for the government of Zambia to adopt the FAO code of conduct on the safe and effective use of pesticides (E. Bernet, Personal communication). The code is a useful instrument which would improve the safe use of insecticides at small scale farms in Zambia. It aims at reducing health and environmentalhazards due to improper handling of pesticides and describes the obligation with respect to labelling, storage, packing, disposal of empty containers and legislation of pesticides In conclusion there appears to be an urgent need for proper training of farmers on cotton pests management as suggested below.

Suggestions on farmer's training

Training of cotton growers on pest managment will help to increase the yield of cotton and keep cotton production stable. Consequently, this

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*Mr. E. Bernet is GIFFAP Director for Asia and Africa.

will eliminate insecticide associated problems such as those which have occurr in Sudan and in many other cotton growing countries. It is clear from the survey results that it is necessary for the government of Zambia and LINTCO to set aside sufficient funds for training of cotton growers. The farmers would be expected to pay a part of training costs, as is the case in Zimbabwe where training on scouting of cotton pests in supported by a crop levy (Burgess, 1983). In each cotton growing district, residential courses of 2 - 3 weeks are suggested for continuous training of different farmers on an annual basis. Farm training institutes in each cotton growing district have excellent facilities for such courses. The expertise gained from the training courses will enable farmers to scout their own cotton fields independently. For practical purposes farmers would have to be trained during the flowering periods of cotton to allow for assessing field levels of insect pests based on the scouting method. When scouting for bollworms eggs, 24 plants must be carefully examined in each field, 12 plants being examined along each diagonal (Bohlon, 1982). The training courses must emphasize detection of Heliothis and Diparopsis eggs, threshold levels, interpretation of data, effectiveness of insecticides for particular pests, side effects of insecticides, calibration and maintenance of knapsack sprayers, the potential of new application techniques and safe use of insecticides. It is also recommended that LINTCO should increase the number of extension entomologists and extension workers who should be provided with adequate transport in order to achieve frequent visits to cotton growers.

Need for further studies

This study shows that cotton growers in Zambia are faced with well known problems of insect pests on their crops. Timely and effective control measures are necessary if crop losses and hardships to the farmers are to be avoided. To all cotton growers in Zambia, one of the most effective methods for managing insect pests is the application of insecticides. There is therefore a need to investigate the efficient application of insecticides. It is beyond doubt that scouting based sprays provide the most appropriate approach on the timing of insecticide application. But the instructions on scouting based sprays which have been imposed on small scale cotton growers in Zambia are based upon the Zimbabwean recommendations (Bohlon, 1982) and might not fit under the insect pest levels of cotton in different cotton growing areas of Zambia. There is a need to develope the threshold levels of key pests (bollworms) in Zambia and to investigate the importance of early spraying on cotton. Studies should examine the reduction of dosage levels and the minimum number of spray applications which would continue to keep the insecticides effective for a longer time to avoid pests developing insecticide resistance. There is also a need for evaluation of different sprayers for their effectiveness and robustness. The development and evaluation of new and existing application equipment is urgently needed for efficient and safer pest control of cotton. The next section on field trials describes some of the work undertaken during the present studies to improve cotton pest management at small scale farms in Zambia.

SECTION B

CHAPTER 9

FIELD TRIALS

The cotton crop in Zambia is attacked by two types of bollworms which pose major problems for its successful production. The species involved are the American bollworm (*Heliothis armigera*) and the red bollworm (*Diparopsis castanea*).

The application of insecticides has been the most effective method for the control of bollworms. In the 1940s both species of bollworms ca heavy losses and cotton production in Central Africa (Zambia - Malawi - Zimbabwe) was very low due to absence of insecticides (Brettell, 1983). During the 1950s a large number of organochlorine insecticides became available. Of these, DDT was found to be very successful for *Heliothis* control. But none of the insecticides available at that time was effective against *Diparopsis*. However, in 1956 endrin was found to be effective against *Diparopsis*. But due to high toxicity of endrin it was not suitable for small scale cotton farmers. In the 1960s endosulfa was added to the range of insecticides for *Heliothis* control. It was an alternative to DDT and was also effective against mites. Carbaryl replaced endrin for *Heliothis* control because it was comparatively less toxic. In the 1970s pyrethroids were introduced because they were effective at lower dosage levels and had longer residual effects on cotton plants (Bruinsma, 1984). Out of these, cypermethrin and deltamethrin were recommended on cotton in Zambia in the late 1970s. The current recommendations include five routine spray applications of pyrethroids.

Attempts to control Heliothis and Diparopsis on cotton with host resistance, antifeedants, the use of bacteria and viruses have not been successful in Central Africa (Brettell, 1983). This means that for the foreseeable future, we will remain dependent upon insecticides for the management of key pests of cotton. But the effectiveness of insect pest management of cotton with insecticides is largely influenced by a judicious use of insecticides and the application equipment. So, the proper application of insecticides is important and deserves top priority, in the production of cotton.

In many cotton growing countries the research programmes on the management of cotton pests in the last two decades were aimed at developing the alternatives of routine spraying of insecticides. The mai advantages of such programmes have been to delay the development of insecticide resistance, to minimize environmental and health hazards, to reduce the cost of insecticide use and to sustain the agro-ecosystems. In Zambia, the research carried out on the management of cotton insect pests has not generated much information on alternatives of routine spraying. In fact, this aspect has been completely ignored at Magoye Cotton Research Station during the last decade. Also, the evaluation of improved application techniques has received very little attention in Zambia. So, a series of field trials were conducted in order to improve the application of insecticides for the management of cotton pests. The main objectives of the field trials were to:

1. Evaluate the timing of insecticide application on cotton.

2. Compare the existing and improved insecticide application techniques.

3. Evaluate the 'Electrodyn' swath widths.

The field trials are divided into three sections according to main objectives outlined above. Each section is presented in a separa chapter with its own introduction, results, discussion and conclusions There is a common chapter on methods and materials for the field trials.

CHAPTER 10

METHODS AND MATERIALS

General

The trials were located at the University of Zambia farm, 20 km east of Lusaka in the Lusaka Province of Zambia. Cotton followed soyabean in 1985-86 and wheat in 1986-87. Only one trial was repeated at NRDC (Natural Resource Development College), near Lusaka in 1985-86.

Cotton variety, sowing and spacing.

Chureza variety, a progeny of 'albar 637' was sown mechanically in 0.9 metre rows with plants subsequently thinned to 0.15 metres apart. Gaps were filled immediately after germination. In the 1985-86 cotton season all trials were sown on 13th December, 1985 but in 1986-87 it was done on 28th December, 1986. The plots were generally separated by one or two untreated rows of cotton.

Weed control

Before sowing, the herbicide trifluralin was sprayed and incorporated (mechanically) into the soil immediately after application but the trials were also weeded twice or three times depending on the weed population to control the broad leaved weeds in particular.

Application of fertilizers.

Small-scale farmers do not apply fertilizers to the cotton crop in Zambia, so the fertilizers were not applied in the trials. In both seasons, the previous crops had received fertilizers so some residual effect was expected. However, the foliar 'solubor' was applied to counteract boron deficiency according to local recommendations (Bohlen, 1982).

Harvesting

Only the central area of each plot was harvested by hand twice (Table 5 to 7). These areas were marked with tall bamboo sticks in both seasons.

Scouting of insects

Heliothis eggs and larvae

Each season, Heliothis eggs and larvae were counted on 10 plants selected at random along the two diagonals of each plot. Generally, the plants near plot borders were not selected to avoid the effects of spray drift. The whole of selected plants were examined carefully so that Diparopsis eggs and larvae could also be detected. However, in both seasons the eggs and larvae of Diparopsis were detected but the infestation was too low to be reported.

Scouting began at the 7th week after the germination and continued until the 17 or 18th week. But in 1985-86 trials the counting of Heliothis larvae was started at about the 10th or 11th week after germination.

Aphids, jassids and whiteflies

The number of nymphs and adult aphids and jassids was recorded, but in case of whiteflies only adults were recorded on only 2 leaves from the top, middle and bottom of the same 10 plants selected for bollworm counts as described earlier.

Bolls, buds and flowers.

In each trial, 10 plants were selected about 18 weeks after germination from each plot at random along two diagonals of each plot. The number of healthy and damaged bolls, buds and flowers was counted on each selected plant. The heights and the number of nodes of the same selected plants were also recorded.

The field trials were divided into 3 sets as described below and additional details are given in Tables 5 to 7.

A. Timing of spray applications

Threshold levels.

In scouting based treatments, where spray treatments were timed according to actual insect populations, the two threshold levels used were 0.25 and 0.50 eggs per plant. When these threshold levels were reached, sprays were applied on the same day using the 'Electrodyn' sprayer.

Reduced sprays

In some trials, the number of spray applications was reduced, thus the importance of early spraying was assessed by avoiding the first or second application and starting treatments at the 9th and 11th weeks after germination. This meant that only 4 or 3 sprays were applied. The number of sprays was also reduced by increasing the interval between applications to 3 weeks. In all trials, a control was included in which a routine 5 sprays were applied at 2 week intervals starting at the 7th week after germination. Untreated control plots were also included in all trials.

Trial No./ Objectives	Treatments: Timing of Application (wks after Germination)	Insecticide	Appl. rates (g.a.i./ha	Total No. of Sprays	Plot size	Yield Sample area
1. Scouting for *Heliothis* eggs Versus routine Sprays etc. 1986/87	i. 0.25 eggs/plant	CYP, ED	30	6	20 x 10m	6 x 6 m
	ii. 0.50 eggs/plant	CYP, ED	30	2		
	iii. 7,9,11,13,15,	CYP, ED	30	5		
	iv. 7,10,13,16	CYP.ED	30	4		
	v. Control	-	-	-		
2. Scouting for *Heliothis* eggs versus routine sprays etc. 1986/87	i. 0.25 eggs/plant	CYP, ED	30	6	16 x 10m	6 x 6 m
	ii. 0.50 eggs/plant	CYP, ED	30	2		
	iii. 7,10,13,16	CYP, ED	30	4		
	iv. 9,11,13,15	CYP, ED	30	4		
	v. 7,9,11,13,15	CYP, ED	30	5		
	vi. 11,13,15	CYP, ED	30	3		
	vii. control	-	-	-		
3. Routine versus reduced sprays of CYP and CYH etc. 1985/86	i. 9,11,13,15	CYP, ED	30	5	14 x 10 m	7 x 4 m
	ii. 7,9,11,13,15	CYP, ED	30	4		
	iii. 11,13,15	CYP, ED	30	3		
	iv. 9,11,13,15	CYH. ED	12	5		
	v. 7,9,11,13,15	CYH.ED	12	4		
	vi. 11,13,15	CYH.ED	12	3		
	vii. control	-	-	-		
4. Routine versus reduced sprays of CYP. 1986/87	i. 7,9,11,13,15	CYP.ED	30	5	10 x 9 m	6 x 6 m
	ii. 9,11,13,15	CYP, ED	30	4		
	iii. 11,13,15	CYP.ED	30	3		
	iv. control	-	-	-		

Note: ED - Electrodyn, CYP-cypermethrin, CYH- cyhalothrin, wks - weeks, appl-application.
Randomised complete Block Design with 4 replications per treatment used in all trials.

... Application and Insecticides.

Trial No./ objectives		Treatments: Timing of Application (wks after germination	Insecticides	Appl. rates g.a. i/ha	Total No. of sprays	Plot size	Yield Sample area
1. Comparison of ED, KS, ULV in scouting (Heliothis eggs) versus routine sprays	i.	7,9,11,13,15	CYP.EC	30	5	20 x 15 m	6 x 6 m
	ii.	7,9,11,13,15	CYP.ED	30	5		
	iii.	7,9,11,13,15	CYP.ULV	30	5		
	iv.	10,11,13	CYP.EC	30	3		
	v.	10,11,13	CYP.ED	30	3		
	vi.	10,13	CYP.ULV	30	2		
	vii.	Control	-	-	-		
2. Comparison of ED, KS, ULV using CYP versus CYH sprays at site 1 1985/86	i.	7,9,11,13,15	CYP.EC	30	5	20 x 15 m	6 x 6 m
	ii.	7,9,11,13,15	CYP.ED	30	5		
	iii.	7,9,11,13,15	CYP.ULV	30	5		
	iv.	7,9,11,13,15	CYH.EC	12	5		
	v.	7,9,11,13,15	CYH.ED	12	5		
	vi.	7,9,11,13,15	CYH.ULV	12	5		
	vii.	10,13	End.EC	250	2		
		Control	-	-	-		
3. Comparison of ED, KS, ULV in CYP versus CYH sprays at site 2 1985/86	i.	7,9,11,13,15	CYP.EC	30	5	30 x 11 m	8 x 8 m
	ii.	7,9,11,13,15	CYP.ED	30	5		
	iii.	7,9,11,13,15	CYP.ULV	30	5		
	iv.	7,9,11,13,15	CYH.EC	12	5		
	v.	7,9,11,13,15	CYH.ED	12	5		
	vi.	7,9,11,13,15	CYH.ULV	12	5		
	vii.	10,13	End.EC	250	2		
	viii.	Control	-	-	-		
4. Comparison of ED versus KS sprays 1986/87	i.	7,9,11,13,15	CYP.EC	30	5	10 x 7 m	6 x 6 m
	ii.	7,9,11,13,15	CYP.EC	60	5		
	iii.	7,9,11,13,15	CYP.ED	30	5		
	iv.	8,9	CYP.ED	30	2		
	v.	Control	-	-	-		

Note: ED - Electrodyn, KS - Knapsack, ULV - Utra low volume sprayers, CYP - cypermethrin, CYH - cyhalothrin, EC - Emulsifiable concentrates, Appl - application, wks - weeks. Randomised complete Block Design with 4 replications per treatment used in all trials.

Trial No/ objectives		Treatments: Timing of Application 1 wks after germination)	Swath widths ED ch/ED dis sprayer	Appl. rates of cypermethrin g.a.i. /ha	Total No. of sprays	Plot size	Yield sample area
1. Charged versus partially discharged ED in 1 to 4 row swath sprays 1985/86	i.	7,9,11,13,15	ED.ch 1R	30	5	21 x 10 m	8 x 6 m
	ii.	7,9,11,13,15	ED.ch 2R	30	5		
	iii.	7,9,11,13,15	ED. ch 3R	30	5		
	iv.	7,9,11,13,15	ED.ch 4R	30	5		
	v.	7,9,11,13,15	ED.dis 1R	30	5		
	vi.	7,9,11,13,15	ED.dis 2R	30	5		
	vii.	7,9,11,13,15	ED.dis 3R	30	5		
	viii.	7,9,11,13,15	ED.dis 4R	30	5		
	ix	Control	-	-	-		
2. Charged versus partially discharged ED in 1 & 2 row swaths. 1985/86	i.	7,9,11,13,15	ED.ch. 1R	30	5	10 x 10 m	6 x 4 m
	ii.	7,9,11,13,15	ED.ch. 2R	30	5		
	iii.	7,9,11,13,15	ED.dis. 1R	30	5		
	iv.	7,9,11,13,15	ED.dis 2R	30	5		
	v.	Control	-	-	-		
3. Scouting (<u>Heliothis</u> eggs) versus routine and reduced sprays in 1 and 2 row swaths 1985/86	i.	7,9,11,13,15	ED.ch 1R	30	5	14 x 10 m	6 x 4 m
	ii.	12,13,14	ED.ch 1R	30	3		
	iii.	7,9,11,13,15	ED.ch 2R	30	5		
	iv.	12,13,15	ED.ch 2R	30	3		
	v.	9,11,13,15	ED.ch 1R	30	4		
	vi.	9,11,13,15	ED.ch 2R	30	4		
	vii.	Control					
4. Comparison of ED 1 and 4 row swath using different dosage levels 1986/87	i.	7,9,11,13,15	ED.ch 1R	30	5	16 x 10 m	6 x 4 m
	ii.	7,9,11,13,15	ED.ch 4R	30	5		
	iii.	7,9,11,13,15	ED.ch 4R	7.5	5		
	iv.	7,9,11,13,15	ED.dis 1R	30	5		
	v.	7,9,11,13,15	ED.dis 4R	30	5		
	vi.	7,9,11,13,15	ED.dis 4R	7.5	5		
	vii.	Control	-	-	-		

Note: ED - Electrodyn, ch - charged, dis - discharged, appl - application, wks - weeks, R - swath rows. Randomised complete Block design with 4 replications per heatment used in all trials.

Insecticides

Cypermethrin was mostly applied at 30 g. a.i./ha using the ED formulation. In some trials, lambda cyhalothrin (12 g. a.i./ha) was also included, these two insecticides being available in an 'Electrodyn' formulation.

Spraying

Sprays were applied with a hand-held 'Electrodyn' sprayer using a single row swath, and a flow rate of 0.05 ml/sec(using the yellow nozzle). The nozzle was held between the rows at a height of about 0.50 to 0.75 metres above the cotton canopy. The operator walked at an average speed of 1 metre per second and at the end of each plot the nozzle was discharged by touching the cotton plant.

B. Comparison of application techniques

Three application techniques that are used by small-scale farmers were assessed during the trials.

Knapsack sprayer

A CP 15 mechanically operated diaphragm pump sprayer was fitted with a lance and a single cone nozzle. The amount of spray liquid was increased according to the plant height as locally recommended for small-scale cotton farmers (Bohlen, 1982). The lance was moved up and down to obtain complete coverage and the speed of operator was reduced during the latter applications.

ULV sprayer

ULV sprays were applied with a spinning disc sprayer (Micro-ULVA)

Swath widths were decreased 6-4-2 rows according to the Malawian recommendations (Matthews, 1971). The flow rate was nominally 0.5 ml per second with the disc held at 0.50 metres above the cotton canopy.

Time of sprays

In most trials, sprays were applied during early morning, when some wind was generally expected to distribute the ULV sprays. The sprays were applied as soon as the cotton foliage was dry from the dew.

Insecticides

Cypermethrin and lambda cyhalothrin were available in three formulations. The ED, EC and ULV formulations of both insecticides were sprayed with appropriate sprayers in various treatments. In two trials during 1985-86 (Table 6 , Trial 2 , and 3) the scouting based treatments of endosulfan (as control 1) were also included. These were based upon the threshold of Heliothis eggs (0.50 eggs per plant). The untreated controls (as control 2) were also included in all these trials. Due to ULV treatments, the plots were generally separated by 2-3 row untreated barriers to reduce the effects of drift.

C. 'Electrodyn' swaths

The 'Electrodyn' sprayer was assessed in the first trial by having swath widths extending to 4 rows to see if it could be used in a similar manner to ULV spinning disc sprayers. The four row treatment was also compared to the application of charged and partially discharged sprays, the latter being achieved by fixing a copper wire from the field adjusting electrodes with its ends free, pointing downwards. In the 1985-86 trials, cypermethrin at 30 g. a.i./ha was applied irrespective of the swath width or the level of charge of the spray. In the 1986-87 trial a quarter dose of cypermethrin (7.5 g.a.i./ha) was also compared a 4 row swath with both charged and partially discharged sprays. Two trials during 1985-86 using only one and two swaths (Table 7) were also carried out. In one trial, the scouting-based and reduced spray treatments (4 sprays) were also compared using 1 and 2 swath widths. In all these 4 trials, only cypermethrin sprays were applied (Table 7).

Statistical analysis

The data were analysed using the analysis of variance (ANOVA) and mean comparisons were done using Duncan's multiple range test, at $P \leq 0.05$ level. The ANOVA tables for yield, healthy bolls and aphids for the scouting trial of 1986/87 are shown in appendix 25 as an example. Data o other tables were analysed in the same way.

Soil type and climatic data

The experimental site (field B at the University of Zambia Farm) has a Chankukula sandy, clay loan soil type. During the previous two years, wheat and soyabeans had been planted in the field in sequence. The fertilizers applied to the wheat and soya beans included compound C (400 1 and compound D (300 kg/ha) respectively. The average annual rainfall duri the years of these trials was 1028 mm in 1985-86 and 736.6 mm in 1986-87 with a minimum and maximum temperature range of 13.3°C to 25.1°C in 1985-86 and 14.1°C to 23.1°C in 1986-87. Further informations on soil and climatic data are given in appendices 23 and 24.

CHAPTER 11

TIMING OF SPRAY APPLICATIONS

INTRODUCTION

Effective cotton pest control can be achieved by carefully monitoring the crop for early stages of pests and by effective application of low dosages of the most appropriate insecticides (Brettell, 1983). The effectiveness of minimum dosages will depend upon correct timing of sprays in relation to the status of bollworms and other insect pests (Matthews and Tunstall, 1968) and the most sensitive stage in the life cycle (Uk, 1987).

One of the major problems is how to get small-scale farmers to apply insecticides when needed (Matthews, 1987). In some cotton growing countries for example in some parts of USA (Arkansas) (Boyer *et al.*, 1962) and in Central Africa (Matthews, 1971), efforts have been made to establish the economic or 'action' thresholds at which farmers should apply insecticides. A good knowledge of the behaviour of an insect pest to be controlled is necessary for proper timing of spray applications. The stage in the life cycle of an insect that has to be sampled is also important if pesticides are to be employed to prevent the economic damage (Matthews, 1979).

In some parts of the USA, counting the number of damaged buds and bolls has been used to decide when to spray (Lincoln *et al.*, 1970). Similarly in Tanzania recommendations for scouting have also included counting flared squares (Nyambo, 1986). The counting of damaged squares, buds and bolls is considered to be easier than looking for the immature stages of insect pests, but much of the damage could already have been done by the time flaring is visible (Matthews, 1974). In Central Africa where different insecticides have been recommended for different bollworms, farmers need to scout to see which pest is present.

The scouting of bollworm larvae has also been recommended in some countries like Tanzania (Nyambo, 1986). But the first and second instar larvae of bollworms feed inside the buds, flowers and bolls and are, therefore, difficult to find. In the case of the red bollworm (Diparopsis castanea) which is a key pest of cotton in Central Africa, the time required for larvae from hatching to penetration into buds, or bolls can be less than 115 minutes (Tunstall, 1962). The early larval instars of bollworms are generally regarded as more vulnerable to insecticides but are often well protected inside buds and bolls. A larger dose of an insecticide is needed to kill the latter instars, otherwise, less control is achieved (Oudejans, 1982). However, the larger dose might contaminate the environment, and disturb the agro-ecosystems.

In Central Africa, most of the recommendations for scouting were based upon searching for bollworm eggs. The detection of bollworm eggs is most important to avoid delay in treatments (Matthews, 1979). Scouting the plants to detect the presence of insect pests including the eggs of bollworms remains the cornerstone of a successful programme of cotton pest control using minimum dosage rates in Zimbabwe (Brettell, 1983). A routine pest assessment of the level of pest infestation is required to avoid using fixed schedules.

Relatively simple techniques to monitor the insect pest populations are needed to allow farmers to decide themselves when their crops should be treated (Matthews, 1979). In Malawi a 'pegboard' was devised so that the individual farmers could scout bollworm eggs on their own crops (Beeden, 1972). The 'pegboard' is based upon sequential sampling which was used for sampling bollworms in Botswana (Ingram and Green, 1972). Scouting for cotton pests, mostly based upon bollworm eggs has also been strongly promoted in Swaziland (Morton, 1979).

In Sudan, where sprays are aerially applied, scouting is carried out under the supervision of group entomologists, each responsible for an area of about 15,000 hectares of cotton (Eveleens, 1983).

In contrast, in many cotton growing countries, insecticides have been applied on a prophylactic basis irrespective of the level of pest infestation (Matthews, 1979). These fixed schedules require no scouting as in Uganda, Zambia and some other countries (Morton, 1979), so a spray could be applied when no pests are present. Thus, the unnecessary spray applications might affect the natural enemies of insect pests and also have various other side effects.

A fixed spray schedule where an insecticide is applied regardless of the variation of pest attack is, therefore, unsatisfactory (Beeden, 1972), but skilled labour is needed for scouting and it can minimise the use of insecticides as compared to the fixed schedule of spraying.

Recently, in Zambia, the cost of cotton insecticides increased drastically and the foreign exchange needed to import them is scarce.

There are, therefore, economic reasons why the number of spray applications need to be minimised, so better timing of spray applications is even more crucial. There is no doubt that good scouting of insect pests can keep the number of spray applications to a minimum (Matthews,1974).

During the present studies, spray applications with an 'Electrodyn' sprayer were timed according to the different levels of Heliothis eggs as this is a major pest of cotton not only in Zambia but in many other countries where cotton is grown. The effect of delaying the start in using insecticides was also investigated, together with increasing the interval between each spray application. These treatments were compared with a fixed schedule of five applications at two week intervals starting at the 7th week after germination.

RESULTS

Yield of cotton

In the scouting trials where the number of sprays varied according to scouting data, yields were not significantly different within treatments irrespective of the number of spray applications (2 to 6) of cypermethrin (60 to 180g.a.i./ha/season) applied with 'Electrodyn' (Table 8).

The yields obtained by delaying to start the applications until the 9th and 11th weeks after germination (4 to 3 sprays per season) were also similar to routine spraying (Table 8).

There were no significant differences in the yields obtained by applying lambda cyhalothrin or cypermethrin insecticides (Table 8).

In these trials, increasing the interval to 3 weeks also provided yields similar to other treatments (Table 8). However, untreated plots gave significantly lower yields.

Effect on bolls, buds and flowers

In most of the trials, the number of healthy or damaged bolls, buds and flowers per plant were statistically similar irrespective of spray treatment, but untreated plots had significantly more damaged bolls, buds and flowers (Table 9). The heights and number of nodes per plant were similar in all treatments (Appendix 20).

Heliothis control

In scouting trials (Figs 79 to 80) there was a general increase in *Heliothis* infestation (number of eggs per plant) during the 10th week after germination. The maximum infestation in untreated plots (1.5 eggs per plant) was at the 15th week in 1985/86 and during the 14th week in 1986/87 trials (Fig. 79 , 80). A similar trend was recorded in reduced spray programme trials in both seasons (Fig. 81 , 82).

The weekly observations on the number of eggs in different treatments in most trials generally showed significant differences between untreated and treated plots during the 10th week after germination (Appendix 2). However, after the 10th week, the untreated plots had more eggs compared to the treated plots. The same general trend was found in *Heliothis* larvae (Appendix 3).

Table 8. Yield of seed cotton in Kg/ha in timing of spray application trials.

Insecticides	Treatments	Scouting trials							
		1985-86				1986-87			
		No. of sprays	a.i. g/ha	yield	SE	No. of sprays	a.i. g/ha	yield	SE
Cypermethrin	0.25 eggs	5	150	2535a	131.25	6	180	2141a	30.55
Cypermethrin	0.50 eggs	2	60	2831a	52.08	2	60	2030a	194.44
Cypermethrin	Routine sprays	5	150	2493a	110.40	5	150	2397a	291.80
Cypermethrin	3 weeks interval	4	120	2812a	304.16	4	120	2397a	166.66
Cypermethrin	9 weeks	-	-	-	-	4	120	2369a	152.77
Cypermethrin	11 weeks	-	-	-	-	3	90	2008a	125.00
Cyhalothrin	routine	-	-	-	-	-	-	-	-
Cyhalothrin	9 weeks	-	-	-	-	-	-	-	-
Cyhalothrin	11 weeks	-	-	-	-	-	-	-	-
Control	-	-	-	1662b	137.50	-	-	1388b	100.40

Continued

Insecticides	Treatments	Reduced number of spray trials							
		1985-86				1986-87			
		No. of sprays	a.i. g/ha	yield	SE	No. of sprays	a.i. g/ha	yield	SE
Cypermethrin	0.25	-	-	-	-	-	-	-	-
Cypermethrin	0.50	-	-	-	-	-	-	-	-
Cypermethrin	routine sprays	5	150	2578a	211.65	5	150	1766a	333.33
Cypermethrin	3 weeks interval	-	-	-	-	-	-	-	-
Cypermethrin	9 weeks	4	120	2324a	135.71	4	120	1822a	75.00
Cypermethrin	11 weeks	3	90	2525a	307.14	3	90	1513ab	135.11
Cyhalothrin	routine	5	60	2696a	189.28	-	-	-	-
Cyhalothrin	9 weeks	4	48	2453a	121.42	-	-	-	-
Cyhalothrin	11 weeks	3	36	2427a	200.00	-	-	-	-
Control	-	-	-	1489b	42.85	-	-	1008b	86.11

Note: 1. 0.25 and 0.50 eggs per plant are Heliothis thresholds.

2. Means per column with the same letter are not significantly different at P = .05 level according to Duncan's multiple range test. Columns with no letters have no significant differences. SE - standard error (+/-).

Table 9. Mean number of healthy and damaged bolls, buds and flowers per plant in timing of spray application trials.

Insecticides	Treatments	Scouting Trial								1985 - 86					
		No. of sprays	a.i. g/ha season	H bolls	SE	D bolls	SE	H buds	SE	D buds	SE	H flower	SE	D flower	SE
Cyp	0.25 eggs	5	150	19.12	0.27	.74a	0.03	16.1	0.21	.76a	0.01	.92	0.21	.70	0.00
Cyp	0.50 eggs	2	60	19.0	1.30	.74a	0.03	15.72	0.71	.74a	0.01	1.0	0.24	.70	0.00
Cyp	routine sprays	5	150	18.65	1.80	.74a	0.01	16.97	1.30	.79a	0.03	1.0	0.20	.70	0.00
Cyp	3 weeks interval	4	120	15.67	1.30	.74a	0.01	16.9	0.46	.77a	0.04	1.4	0.16	.70	0.00
Cyp	9 week after germ.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyp	11 weeks after germ.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyh	routine sprays	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyh	9 weeks after germ.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyh	11 weeks after germ.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Control (untreated)		-	-	16.50	1.00	1.18b	1.06	15.52	0.61	1.21b	0.87	.57	0.22	0.70	0.00

Continued

Table 9 continued

Insecticides	Treatments	Scouting Trial								1986 - 87					
		No. of sprays	a.i. g/ha season	H bolls	SE	D bolls	SE	H buds	SE	D buds	SE	H flower	SE	D flower	SE
Cyp	0.25 eggs	6	180	20.35ab	1.45	.97a	0.06	2.53	1.40	.90	0.12	.70	0.19	.90a	0.06
Cyp	0.50 eggs	2	60	13.32b	0.97	1.15a	0.18	2.0	0.18	.91	0.09	.97	0.25	.84a	0.05
Cyp	routine sprays	5	150	16.60b	.95	1.05a	0.03	2.15	0.91	.77	0.06	1.23	0.36	.95a	0.13
Cyp	3 weeks interval	4	120	16.58b	1.65	1.05a	0.05	1.98	0.70	.99	0.12	.58	0.27	.82a	0.71
Cyp	9 weeks after germ.	4	120	18.25b	0.46	1.05a	0.09	1.85	0.33	.82	0.06	.93	0.14	.93a	0.09
Cyp	11 weeks after germ.	3	90	16.95b	1.12	1.11a	0.12	2.42	0.76	1.23	0.15	1.10	0.28	.89a	0.03
Cyh	routine sprays	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyh	9 weeks after germ.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyh	11 weeks after germ.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Control (untreated)	-	-	-	9.53a	1.42	2.45b	0.22	3.18	0.87	1.94	0.44	1.13	0.37	1.39b	0.11

Continued

Table 9 continued

Insec- ticides	Treat- ments	Reduced number of spray trials 1985 - 86													
		No. of sprays	a.i.g/ha season	H bolls	SE	D bolls	SE	H buds	SE	D buds	SE	H flower	SE	D flower	SE
Cyp	0.25 eggs	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyp	0.50 eggs	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyp	routine sprays	5	150	22.48	1.40	.74a	0.00	16.55	2.78	.77	0.00	1.60	0.22	.74	0.02
Cyp	3 weeks interval	-	-	-	-	-	-	-	-	-	-	-	--	-	-
Cyp	9 weeks after germ.	4	120	19.85	0.65	.79a	0.04	15.0	2.08	.93	0.07	1.30	0.25	.71	0.07
Cyp	11 weeks after germ.	3	90	18.45	0.44	.71a	0.03	14.80	1.88	.81	0.02	1.20	0.20	.72	0.02
Cyh	routine sprays	5	60	23.70	1.33	.77a	0.02	19.25	0.97	.77	0.00	1.63	0.30	.77	0.00
Cyh	9 weeks after germ.	4	48	21.10	2.59	.77a	0.05	16.40	2.54	.77	0.00	1.67	0.21	.72	0.02
Cyh	11 weeks after germ.	3	36	19.55	2.77	.80a	0.05	14.08	3.48	.83	.03	1.38	0.14	.75	0.02
Control (untreated)		-	-	16.55	0.55	1.12b	0.09	10.98	0.78	1.29	.10	0.97	0.24	.80	0.02

Continued

Insecticides	Treatments	No. of sprays	a.i. g/ha season	H bolls	SE	D bolls	SE	H buds	SE	D buds	SE	H flower	SE	D flower	SE
		Reduced number of spray trials								1986 - 87					
Cyp	0.25 eggs	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyp	0.50 eggs	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyp	routine sprays	5	150	14.05	2.89	.79a	0.04	1.88	0.78	.96	0.13	.53	0.25	.86	0.05
Cyp	3 weeks interval	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyp	9 weeks after germ.	4	120	14.13	1.18	.64a	0.15	.66	0.27	.74	0.03	.40	0.12	.62	0.15
Cyp	11 weeks after germ.	3	90	13.58	1.81	.74a	0.03	1.78	1.31	.72	0.01	.78	0.35	.85	0.10
Cyh	routine sprays	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyh	9 weeks after germ.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyh	11 weeks after germ.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Control (untreated)		-	-	14.5	1.71	1.36b	0.13	.73	0.57	1.01	0.14	.63	0.27	.88	0.05

Note: 1. Cyp - cypermethrin, Cyh - lambda cyhalothrin. 2. 0.50 and 0.25 eggs per plant are *Heliothis* thresholds.
3. H and D for healthy and damaged fruiting structures. 4. For damaged bolls, buds and flowers data transformed into $\sqrt{y + \frac{1}{2}}$ 5. Means per column with the same letter are not significantly different at P = 0.5 level according to Duncan's multiple range test. Columns with no letters have no significant differences. SE - standard error (+/-).

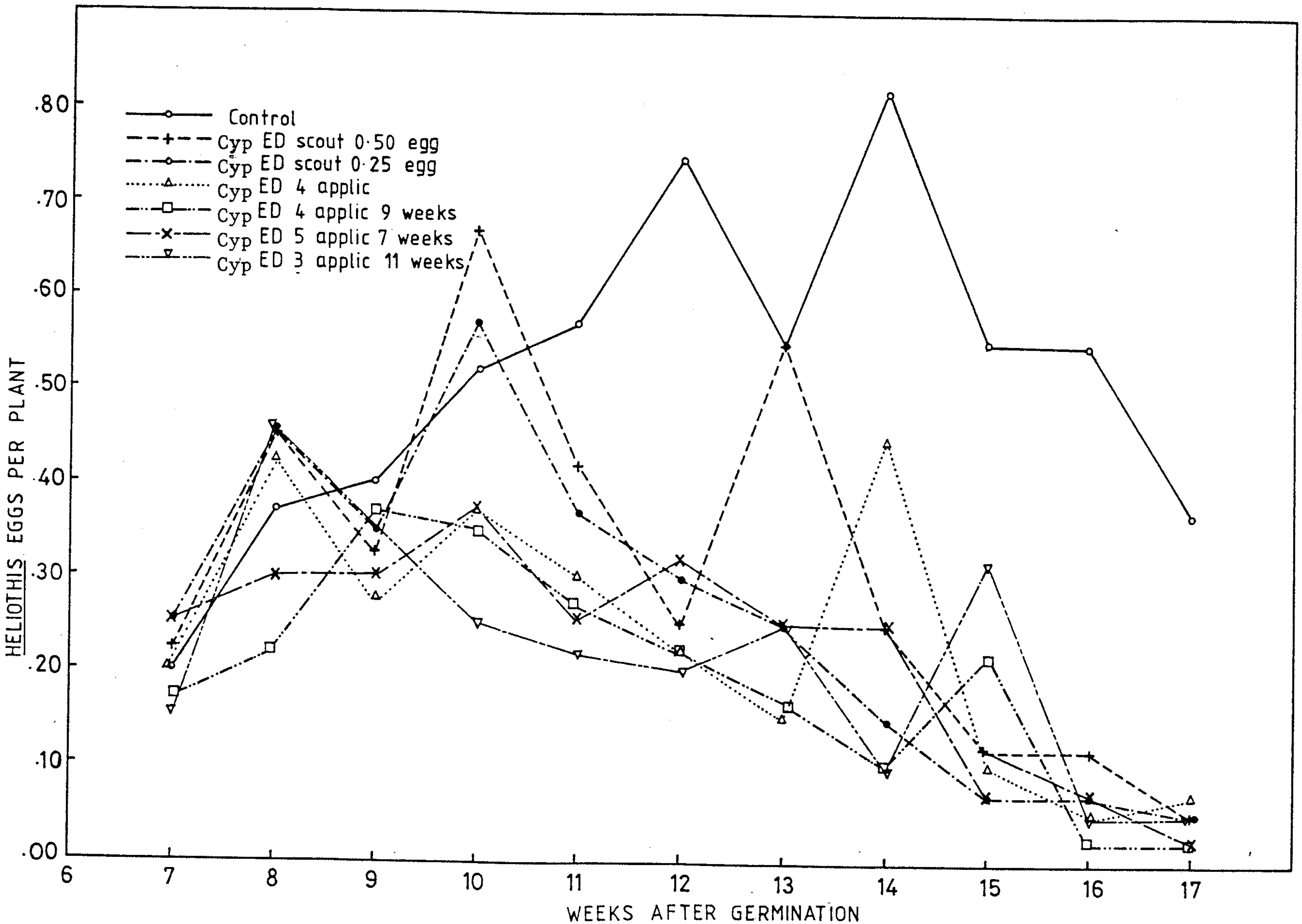

FIGURE 80. Heliothis eggs on treated and untreated plots sampled from 7th to 17th week after germination in scouting trial in 1986-87. Cyp = cypermethrin, ED = 'Electrodyn'

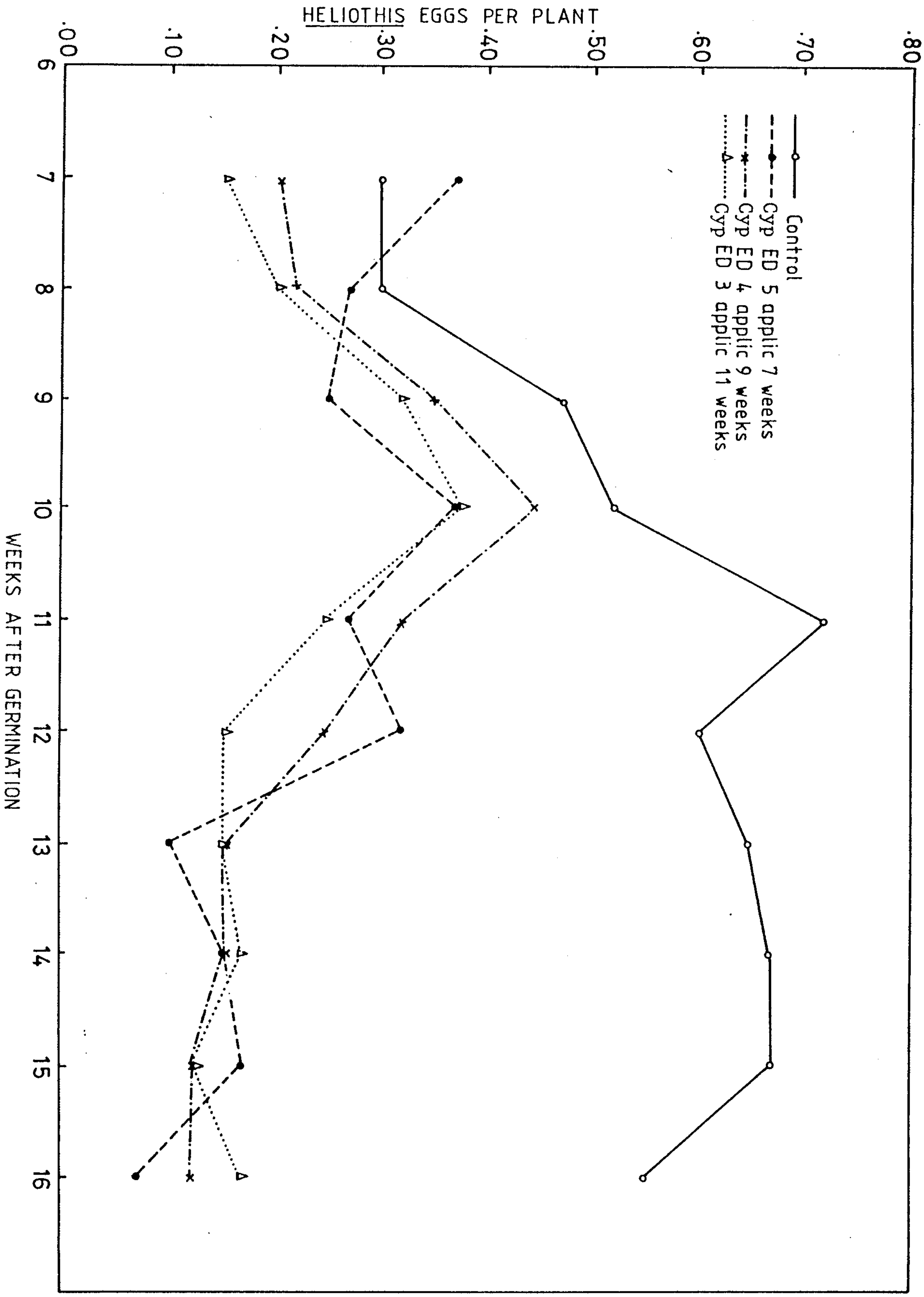

FIGURE 82. *Heliothis* eggs on treated and untreated plots sampled from 7 to 16th week after germination

Aphid control

In all 4 trials the untreated plots had more aphids, almost 50% higher than the treated plots (Table 10). In 1986/87 there were more aphids probably due to long dry periods. The statistical differences in various treatments during weekly observations of all trials are shown in Appendix 4.

Effect on mummified aphids*

The number of mummified aphids per plant in different treatments including the untreated plots was generally similar in most of the trials (Table 10). However, some differences were recorded during the weekly observations (Appendix 5) in which the untreated plots had more mummified aphids.

Jassid control

The untreated plots had slightly more jassids (Table 10) per plant, but there were no differences within other treatments which received a different number (2-6) of sprays. The statistical differences were recorded in only a few observations at weekly intervals (Appendix 6).

Whitefly control

A summary of observations in table 10, show little if any difference in the number of whiteflies in various treatments except the untreated plots (Table 10) although weekly observations showed very few statistical differences in various treatments (Appendix 7).

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*The purpose of counting mummified aphids was to find out parasitised aphids in different treatments.

Table 10. Mean number of aphids, mummified aphids, jassids and whiteflies per plant in timing of spray application trial.

Insecticides	Treatments	Scouting Trial					1985 - 86				
		No. of sprays	a.i. g/ha season	Aphids	SE	Mumm. aphids	SE	Jassids	SE	White flies	SE
Cyp	0.25 eggs	5	150	4.27	0.45	1.08	0.22	1.18	0.15	.92a	0.04
Cyp	0.50 eggs	2	60	3.90	0.78	1.14	0.09	1.21	0.15	.92a	0.02
Cyp	routine sprays	5	150	3.56	.74	1.03	0.09	1.14	0.13	.95a	0.12
Cyp	3 weeks interval	4	120	3.23	0.59	1.03	0.08	1.08	0.15	.91a	0.04
Cyp	9 weeks after germ.	-	-	-	-	-	-	-	-	-	-
Cyp	11 weeks after germ.	-	-	-	-	-	-	-	-	-	-
Cyh	routine sprays	-	- -	-	-	-	-	-	-	-	-
Cyh	9 weeks after germ.	-	-	-	-	-	-	-	-	-	-
Cyh	11 weeks after germ.	-	-	-	-	-	-	-	-	-	-
Control		-	-	6.15	0.65	1.10	0.12	1.53	0.11	1.0b	0.05

Continued

Table 10. continued

Insec-ticides	Treat-ments	Scouting Trial						1986 - 87			
		No. of sprays	a.i. g/ha season	Aphids	SE	Mumm. aphids	Se	Jassids	SE	White flies	SE
Cyp	0.25 eggs	5	150	13.35a	1.91	2.44	0.17	1.25	0.11	1.39	0.08
Cyp	o.50 eggs	2	60	14.06a	1.95	2.42	0.17	1.48	0.31	1.40	0.08
Cyp	routine sprays	5	150	13,5a	2.20	2.52	0.15	1.23	0.11	1.40	0.09
Cyp	3 weeks interval	4	120	14.11a	0.01	2.38	1.96	1.15	0.09	1.37a	0.10
Cyp	9 weeks after germ.	4	120	13.26a	2.05	2.53	0.17	1.25	0.11	1.45a	0.08
Cyp	11 weeks after germ.	3	90	14.20a	1.95	2.56	0.17	1.27	0.12	1.40a	0.07
Cyh	routine sprays	-	-	-	-	-	-	-	-	-	-
Cyh	9 weeks after germ.	-	-	-	-	-	-	-	-	-	-
Cyh	11 weeks after germ.	-	-	-	-	-	-	-	-	-	-
Control		-	-	25.11b	1.29	2.81	0.23	1.61	0.68	1.85b	0.13

Continued

Table 10 (Continued)

Insecticides	Treatments	Reduced number of Spray Trials							1985 - 86		
		No. of sprays	a.i. g/ha season	Aphids	SE	Mumm. aphids	SE	Jassids	SE	White flies	SE
Cyp	0.25 eggs	-	-	-	-	-	-	-	-	-	-
Cyp	0.50 eggs	-	-	-	-	-	-	-	-	-	-
Cyp	routine sprays	5	150	3.38	0.83	1.02	0.08	1.03	0.13	.89a	0.50
Cyp	3 weeks interval	-	-	-	-	-	-	-	-	-	-
Cyp	9 weeks after germ.	4	120	3.18	0.71	1.06	0.09	1.00	0.14	.99a	0.04
Cyp	11 weeks after germ.	3	90	3.74	0.92	1.04	0.11	1.12	0.18	.91a	0.04
Cyh	routine sprays	5	60	3.41	0.78	0.93	0.06	1.06	0.15	.93a	0.05
Cyh	9 weeks after germ.	4	48	3.10	0.65	0.99	0.08	1.05	0.15	.94a	0.03
Cyh	11 weeks after germ.	3	36	3.72	1.04	1.01	0.08	1.05	0.16	.92a	0.05
Control		-	-	6.15	1.18	1.11	0.07	1.29	0.12	1.10b	0.08

Continued

Table 10 (Continued)

Insec-ticides	Treat-ments	Reduced number of Trials							1986 - 87		
		No. of sprays	a.i. g/ha season	Aphids	SE	Mumm. aphids	SE	Jassids	SE	White flies	SE
Cyp	0.25 eggs	-	-	-	-	-	-	-	-	-	-
Cyp	o.50 eggs	-	-	-	-	-	-	-	-	-	-
Cyp	routine sprays	5	150	11.69a	1.85	2.15	0.15	1.23a	0.09	1.36a	0.05
Cyp	3 weeks interval	-	-	-	-	-	-	-	-	-	-
Cyp	9 weeks after germ.	4	120	12.49a	1.80	2.20	0.16	1.16a	0.08	1.46a	0.07
Cyp	11 weeks after germ.	3	90	13.50a	2.08	2.15	0.15	1.23a	0.11	1.36a	.04
Cyh	routine sprays	-	-	-	-	-	-	-	-	-	-
Cyh	9 weeks after germ.	-	-	-	-	-	-	-	-	-	-
Cyh	11 weeks after germ.	-	-	-	-	-	-	-	-	-	-
Control		-	-	24.70b	2.50	2.54	0.26	1.67b	0.11	1.88b	0.16

Note: 0.25 and 0.50 eggs per plant are Heliothis thresholds. These are summaries of weekly observations which are shown in detail in appendix 4 to 7. Means per column with the same letters are not significantly different at P =.05 level according to Duncan's multiple range test. Columns with no letters have no significant differences. Cyp - cypermethrin, Cyh - lambda cyhalothrin. SE - standard error (+/-).

DISCUSSION

In Zambia, cotton spraying is recommended on a routine schedule which does not take into consideration the difference in the infestation of insect pests at various times during the cotton growing season. During the 1986/87 cotton season about 97% cotton in Zambia received pyrethroid sprays (A.Mulala, personal communication). Five spray applications of pyrethroids are recommended and dosage levels are generally considered to be on the high side. The farmers are advised to apply about 57 grams of active ingredient of cypermethrin per spray with knapsack sprayers (Bruinsma, 1984). The unnecessary spraying at higher dosages might encourage the selection for resistance and secondary outbreaks of minor pests.

However, in order to avoid the calendar sprays with heavy doses of pyrethroids, there is an urgent need to improve and modify the timing of spray application on cotton in Zambia.

Time of *Heliothis* infestation

The maximum infestation of *Heliothis* (number of eggs per plant) on cotton during the present trials (1 to 4) in untreated plots was during the 10th to 15th week after germination, coinciding with the Zambian flowering period of the crop namely from the 9th to the 13th week after germination (Matthews, 1974).

However, the infestation of the crop by *Heliothis* might vary seasonally, so a system of scouting must be used to determine when an insecticide should be sprayed (Matthews, 1974). According to Gledhill (1981), the timing of infestation might vary in each province in different seasons which makes the timing of control measures even more dependent on crop scouting to ascertain the actual level of the target insect pest. Indeed, the economic control of *Heliothis* will depend on success in predicting the likely infestation and defining the economic thresholds and the proper timing of appropriate control measures (Way and Cammell,1977).

Heliothis thresholds

In the case of *Heliothis* it was decided to scout the pest in its egg stage. The eggs were generally found to be easier to detect as compared to the larvae which were well hidden inside bolls, buds and flowers. The damage thresholds have various disadvantages and might prove more complicated for small-scale cotton farmers (Matthews, 1974). In some countries like Chad Republic, the sprays have been applied after a certain number of fruiting bodies were found on the ground following an attack by bollworm (Brader and Atger, 1972). During the 1984-85 cotton season, the rains stopped too early in some cotton growing areas of Zambia resulting in heavy boll shedding. The cotton farmers during the survey perceived that this boll shedding was due to the inefficiency of deltamethrin which was supplied to the farmers in some areas for the first time. Indeed, shedding also needs careful examination as it can occur without insect damage, for example from water stress (Matthews, 1974).

However, during the present studies, thresholds were based upon different levels of *Heliothis* eggs per plant.

Threshold 1: 0.25 eggs per plant

This threshold (1 egg on 4 plants) proved to be too low to initiate insecticide sprays. It required 6 spray applications of cypermethrin which were even more than the routine 5 sprays. This level of threshold needed excessive sprays and an increase in the spray applications did not justify an overall increase in the yields of cotton in both seasons. This lower threshold (0.25 eggs per plant) has been recommended in Malawi to minimize the sampling errors and for any increase during the delay between scouting and spraying (Matthews, 1974). The delay is also caused if the water has to be collected and transported, but in Zambia, the farmers who use the 'Electrodyn' sprayer can get their fields sprayed very quickly. The cotton farmers also do not live far away from their cotton fields and if a threshold level is reached, they could be advised to spray on the same day or during the following day.

Threshold 2: 0.50 eggs per plant

In both seasons, using a threshold based upon 0.50 eggs per plant, saved about 50% of the insecticide compared with the 5 routine sprays. At this threshold (0.50 eggs/plant) level the start of spray applications was generally delayed and the yields of seed cotton obtained by 2 to 3 sprays compared favourably with routine spraying. Thus, the timely sprays will provide maximum benefits with a minimum number of sprays and might have less effect on the natural enemies.

The minimum spray applications also reduce the chances of contamination of farmers with insecticides. According to Brettell (1983), the pyrethroids have an irritant effect on some individuals. It was also confirmed during the present survey (Chapter 6) that some farmers had suffered from skin itching due to pyrethroid sprays.

Reduced number of sprays

There is an indication that early sprays during the 7th and 9th week could be avoided at least in some seasons as the control of Heliothis might not be necessary while cotton growth can compensate for early loss of buds. The results of the survey (Chapter 4) also indicate that some farmers made 3 to 4 sprays and obtained more or less the similar yields to those who reported 5 routine spray applications. The results of the trials conducted at Magoye (Anon, 1987) also confirm that the yields similar to 5 routine sprays were achieved by avoiding the first or second spray.

Minor pests

The pyrethroids are generally not considered appropriate for the control of aphids, jassids and white flies (Bohlen, 1982). Although there was a general decrease in aphids during present trials but the widespread use of pyrethroids may increase whitefly population as it happened in Thailand and Sudan (Brettell, 1983).

CONCLUSIONS

The early spraying for Heliothis control may not be entirely needed in all seasons and in all cotton growing areas of Zambia. The most economical threshold for Heliothis was found to be 0.50 eggs per plant provided the sprays were applied with the 'Electrodyn' on the same day. In all 4 trials the routine 5 sprays never provided significantly higher yields than scouting-based trials. The optimum cotton yields were obtained by applying 30 grams of active ingredients of cypermethrin with an 'Electrodyn' sprayer as compared to 57 grams of active ingredients of the same insecticide recommended for conventional spraying in Zambia. A new insecticide lambda cyhalothrin ED (12 g. a.i./ha) which was included in one of the experiments gave similar results to cypermethrin when applied with the 'Electrodyn' sprayer.

As the application of insecticides in relation to economic threshold levels provides more permanent chemical control (Matthews, 1985a), the small-scale cotton farmers in Zambia must initiate scouting for insect pests at their individual fields. The farmers need to be convinced that scouting results in a considerable saving in the cost of using insecticides, and they might accept it more readily now as the prices of insecticides have increased. Some farmers recently started to grow cotton with an average of about 5 hectares and are apparently more keen to learn scouting (Chapter 3). If the farmers in neighbouring countries like Malawi, Zimbabwe, Botswana and Swaziland can scout their own cotton fields, there seems to be no reason why the cotton farmers in Zambia should not be able to do the same. However, more emphasis on scouting in Zambia is urgently needed. The scouting of cotton fields at twice weekly intervals starting from the 8th or 9th week up to the splitting of bolls is suggested. Although more _Heliothis_ eggs are found in the top canopy of plants (Mabbett _et al._, 1980), farmers must be advised to inspect all parts of the selected plants which might be easier for them to understand than asking them to inspect the top canopies of plants.

However, more work is needed on the thresholds for _Diparopsis_ which is also a major pest of cotton in many cotton growing areas of Zambia particularly in Eastern Province and Gwembe Valley.

CHAPTER 12

COMPARISON OF APPLICATION TECHNIQUES

INTRODUCTION

Three application techniques used in the tropics by small-scale farmers to spray cotton crops were studied in a series of trials.

1. Conventional hydraulic spraying with a knapsack sprayer.
2. Ultra-low volume application using a hand carried spinning disc sprayer.
3. Electrostatic charging of a ULV spray using the 'Electrodyn' sprayer.

1. Conventional hydraulic spraying

Knapsack sprayers were developed before 1896 (Lodeman, 1896) and similar designs are still used to apply insecticides on cotton in tropical countries, although nowadays, many components are made of polypropylene and other plastics instead of metal. However, knapsack spraying suffers from several operational difficulties, deficiencies and weaknesses which reduce the efficiency of insecticide application (Matthews, 1981).

A major problem is that the applicators are entirely dependent on water which may not be readily available when the sprays are urgently needed. Even when water is available, the source might be at a considerable distance from the farmers' fields. Collection, storage and transport to the field mostly by head loads in many tropical countries takes time and labour which could be used most effectively on other work (Matthews, 1981; 1982b; 1985a).

Farmers have to measure, mix, and dilute insecticides in the correct amounts of water but they seldom receive sufficient instructions on how they should do it. Consequently, there is often a risk of incorrect dosages being applied (Matthews, 1985a). The farmers are exposed to contamination particularly while measuring and mixing the concentrated insecticides but also during spraying. They generally keep the nozzle in front of them, and so walk into the sprayed area and get contaminated on their legs. Sprayers break down frequently and spare parts are seldom available, so leakages from valves further increase contamination (Matthews, 1985a).

The heavy weight (15 to 20 litres) and arduous pumping discourages the farmers to apply the recommended amounts of water on their crops (Litsinger et al.,1978). This might result in poor distribution of insecticides on plants and ultimately inadequate control of pests. Indeed, a lot of labour is involved with knapsack sprayers (King, 1976). The farmers have to use these applicators over a considerable time and often get tired during spraying. It has been estimated that 4 man days are needed to treat one hectare when the water is far from the fields (Matthews,1987). Prolonged wet periods and strong winds can also limit timely spray applications (Matthews, 1982b).

Besides operational problems, there is a widely accepted view that the hydraulic sprayers are inefficient (Matthews, 1982b). The hydraulic nozzles produce sprays with a wide range of droplet sizes. Furthermore, with fluctuating pressures depending on the frequency of pumping, the dosage is not always kept very regular. According to Graham-Bryce (1977), rather less than 1% of the insecticide normally reaches insect pests within foliage (quoted in Matthews, 1982b).

2. Ultra-low volume application

To overcome the problems associated with hydraulic spraying, research into application methodology has been directed towards decreasing spray volume. ULV was introduced using a spinning disc designed to produce a uniform size of droplets; 70 µm droplets were produced initially for the spray coverage of cotton foliage. The spray volume was significantly reduced to 1 to 3 litres per hectare as compared to conventional spraying. In central Africa, research on ULV spraying from 1969 to 1972 led to a recommendation for hand-held battery-operated ULV sprayers on cotton (Matthews, 1973b). The ULV sprayers provide greater control of droplet size by changing the rotational speed and adjusting the flow rates (Matthews, 1979).

ULV spraying of cotton has been adopted in many countries including Nigeria, the Gambia, Tanzania, Mozambique, Zimbabwe, Swaziland and in many parts of West Africa (Matthews, 1981), where 97% of the cotton area was treated in French-speaking countries (Cauquil, 1987).

ULV spraying has various advantages particularly for small-scale cotton farmers in the tropics. The applicators are light in weight, easily operated, provide an increased work rate, require very low volume of insecticides and are not dependent on water. Nevertheless, there are limitations which include the dependence of droplet dispersal on wind and gravity so some pesticide is deposited on non-target surfaces. The small droplets can be carried upwards if there is strong convection at the time of application and deposition is essentially on windward surfaces unless there is sufficient turbulence (Matthews, 1982a). Battery consumption on these machines is relatively high, special oil-based formulations are required, there is a need for spare parts and often frequent maintenance (Matthews, 1981).

A need for lower power consumption but particularly the need to reduce spray drift and for various other reasons, further research has led to the development of Electrostatic spraying.

3. <u>The 'Electrodyn' sprayers</u>

Efforts to improve pesticide application using eletrical forces were started about 50 years ago. In the 1940's, Hampe (Coffee, 1981) demonstrated the idea of an electrostatic crop duster but it was not sufficiently reliable. In the 1960's Felici used the rotary cylinder electrostatic, but this proved too bulky, too costly and complicated to be used by farmers.

Attention was then directed towards the investigation of various means of charging and atomization of liquids using the spinning disc sprayers. Electrostatically charged droplets can be produced from a spinning disc (Arnold and Pye, 1980). One important development was the hand-held Electrodynamic nozzle (Coffee, 1979) which enables the spray to be atomised into even spray droplets using electrostatic forces.

The 'Electrodyn' has generated a considerable interest in many developing countries because it has more potential for adoption by small-scale farmers (Nyirenda, 1986) and is being tested world-wide. The 'Electrodyn' sprayer can be an ideal tool for the management of cotton insect pests for small-scale farmers (Smith, 1986).

However, the advantages and disadvantages of the 'Electrodyn' knapsack and ULV sprayers in the Zambian context with special reference to small-scale cotton farmers are given in Table 11.

Comparison of the three application techniques

Similar yields of cotton have been obtained both on research stations and farmers' fields in Malawi by spraying insecticides (carbaryl, DDT and dimethoate) with a spinning disc and tailboom sprayers (Matthews, 1973a and b). More recently Nyirenda (1986) also confirmed this. Similarly in Zambia, the yields of cotton and the level of pest control from the ULV techniques compared well with those obtained from the knapsack tailboom sprayers (Lyon, 1975a). Similar results have been reported from elsewhere particularly in French-speaking countries where the same doses of active ingredients provided equivalent protection with both ULV and conventional sprayers without any significant difference in the yield of seed cotton (Cauquil, 1987).

The 'Electrodyn' is a recent innovation,so few studies on cotton have been reported. Initial trials on cotton in Australia gave no significant difference in yield between 'Electrodyn' and knapsack sprayers despite better control of *Heliothis* and other pests (Morton, 1981). Similarly in Paraguay, the control of *Heliothis* and other pests was superior to conventional methods and the 'Electrodyn' gave better yields.

The 'Electrodyn' has proved more efficient for the control of Bollweevil in Brazil as compared to conventional methods (Smith, 1986). The charged sprays with cypermethrin gave similar insect control and

Table 11 Comparison of insecticide application techniques on cotton in Zambian cotext

Application techniques	Advantages	Disadvantages	Current status in Zambia
"Electrodyn' (Hand-held version)	No water requirements, pre-calibrated pre-mixed insecticides, light in weight, easy and timely applications, Production of electrically charged uniform droplets, less drift and wastage of insecticides. Regarded as efficient by farmers who used it.	Not known to many farmers, unavailable in most of the areas, less versatile, coverage of only single row swaths, limited product range, uncertainty for regular supplies of batteries and bozzles. Durability not known.	Being used by cotton farmers at a limited scale in few selected areas. Likely to expand in more areas. Cypermethrin and cyhalothrin bozzles available. More extension and technical support needed, possibilit for implementation by small-scale cotton farmers in the near future.
Knapsacks (fitted with single nozzle on lance)	Only known technique to many farmers, more versatile, specially suitable for foliar application of solubor on cotton, more robust, considered as more durable, farmers experienced to use it, more product range available	Problem of collection, storage and transportation of water, mixing and calibration required, protective clothing unavailable, farmers untrained on its proper use, leakages are common, maintenance problems, spare parts have to be imported, not always available, problems with nozzles. Too heavy, logistically considered as inefficient.	Most commonly used and available throughout the country. Will continue to be used on cotton in near future. Various brands, capacities, imported from different countries, no standard testing procedures. Application of solubor on cotton main advantage. Also used to spray pesticides on animals.
ULV (Ultra low volume sprayers)	No water and mixing requirement, more swath rows coverage, increased work rate, light in weight, more product range available for application on cotton, production of small controlled sized droplets.	Deposition of droplets depend on wind, oil based formulations considered more concentrated and toxic by the farmers, they cannot see very small droplets, regular supplies of spare parts are needed, ULV formulation slightly expensive, more power	Introduced (Turbair) in 1970's. Almost abandoned at present, lack of extension support, unavailable in almost all areas. In past, proble in the supplies of batteries, ULV formulations, spare parts. No complaints from the farmers regarding its efficiency who used it.

yields when the same insecticides were applied with knapsack and spinning disc sprayers in Malawi (Nyirenda, 1986). In Kenya, the 'Electrodyn' gave better or similar yields of cotton in most of the trials when compared with ULV and knapsack sprayers (Mambiri, 1987).

The permethrin applied against cotton pests with vehicle-mounted 'Electrodyn' sprayer at 0.056 Kg a.i./ha gave better control of Heliothis than conventional spraying at 0.24 Kg. a.i./ha in USA (Sherman and Sullivan, 1983).

The present studies were aimed at comparing the 'Electrodyn' with the knapsack and ULV sprayers against the cotton pest complex in Zambia.

RESULTS

Effect on yield

All spray treatments gave a significant increase in the yield of seed cotton over the untreated control but yields were similar irrespective of three methods of application. Applying fewer sprays did not decrease the yield in these trials and there was no difference due to the pyrethroid lambda cyhalothrin or cypermethrin, used (Table 12).

Effect on bolls, buds and flowers

The untreated plots in most of the trials had significantly more damaged bolls, buds and flowers (Table 13). The number of healthy bolls, buds, flowers, nodes and heights, per plant were in general not statistically different irrespective of the application techniques, types of insecticides and the number of spray applications (Table 13), Appendix 21).

Table 12. Yield of seed cotton in Kg/ha in different trials for the comparison of application techniques

Treatment	Chems	Trial 1 1986-87				Trial 2 1985 - 86			
		No. of sprays	a.i. g/ha season	yield	SE	No. of sprays	a.i. g/ha season	yield	SE
ED routine sprays	Cyp	5	150	2738b	141.66	5	150	3064c	192.12
KS routine sprays	Cyp	5	150	2500b	113.88	5	150	2821bc	125.00
ULV routine sprays	Cyp	5	150	2600b	327.77	5	150	2907bc	152.42
ED scouting	Cyp	3	90	2441b	258.33	-	-	-	-
KS scouting dose B	Cyp	3	90	2327b	316.66	-	-	-	-
ULV Scouting	Cyp	2	60	2158b	197.22	-	-	-	-
ED Routine sprays	Cyh	-	-	-	-	5	60	2768bc	94.90
KS Routine sprays	Cyh	-	-	-	-	5	60	2729bc	203.70
ULV routine sprays	Cyh	-	-	-	-	5	60	2976bc	113.95
ED scouting	Cyh	-	-	-	-	-	-	-	-
KS scouting	Cyh	-	-		-	-	-	-	-
Control 1	End	-	-	-	-	2	500	2608b	131.94
Control 2		-	-	1327a	113.88	-	-	1462a	113.42

Continued

Table 12 (Continued)

Treatment	Chems	Trial 3 1985 - 86				Trial 4 1986 - 87			
		No. of sprays	a.i. g/ha season	yield	SE	No. of sprays	a.i.g/ha season	yield	SE
ED routine sprays	Cyp	5	150	1080 b	129.16	5	150	1305b	63.88
KS routine sprays	Cyp	5	150	948b	89.58	5	150	1250 b	80 .55
ULV routine sprays	Cyp	5	150	920 b	100 .00	-	-	-	-
ED scouting	Cyp	-	-	-	-	2	6	1466b	105.55
KS scouting dose B	Cyp	-	-	-	-	5	300	1152b	136.11
ULV scouting	Cyp	-	-	-	-	-	-	-	-
ED routine sprays	Cyh	5	60	1062b	139.58	-	-	-	-
KS routine sprays	Cyh	5	60	941b	147.09	-	-	-	-
ULV routine sprays	Cyh	5	60	953b	85.41	-	-	-	-
ED scouting	Cyh	-	-	-	-	-	-	-	-
KS scouting	Cyh	-	-	-	-	-	-	-	-
Control 1	End	2	500	906b	139.58	-	-	-	-
Control 2		-	-	350 a	150 .00	-	-	516a	86.11

Note: (1) ED - 'Electrodyn', KS - Knapsack, ULV - Ultra low volume sprayer (2) Cyp - Cypermethrin, Cyh - lambda cyhalothrin End - endosulfan. (3) Means per column with the same letter are not significantly different at P =0.05 level according to Duncan's multiple range test. Columns with no letters have no significant differences. Se - Standard error (+/-)

Table 13. Mean number of healthy (H) and damaged (D) bolls, buds and flowers per plant in different trials for the comparison of application techniques.

Treatment	Chems	Trial 1							1986 - 87					
		No. of sprays	H bolls	SE	D bolls	SE	H buds	SE	D buds	SE	H flower	SE	D flower	SE
ED routine sprays	Cyp	5	18.42	2.40	1.05a	0.10	2.48	0.16	0.81a	0.06	1.60	0.42	0.77a	0.00
KS routine sprays	Cyp	5	29.35	1.53	0.96a	0.07	5.93	2.00	0.80a	0.04	1.40	0.16	0.84a	0.07
ULV routine sprays	Cyp	5	22.65	2.90	0.91a	0.08	4.93	1.64	0.82a	0.04	1.48	0.28	0.82a	0.05
ED scouting	Cyp	3	19.93	1.06	0.80a	0.03	5.47	0.58	0.95a	0.13	2.38	0.19	0.88a	0.06
KS scouting dose B	Cyp	3	18.93	2.40	1.07a	0.04	5.45	1.94	0.98a	0.15	1.77	0.48	0.95a	0.09
ULV scouting	Cyp	2	17.25	0.53	0.95a	0.10	4.48	0.99	0.82a	0.06	1.85	0.23	0.85a	0.06
ED routine sprays	Cyh	-	-	-	-	-	-	-	-	-	-	-	-	-
KS routine sprays	Cyh	-	-	-	-	-	-	-	-	-	-	-	-	-
ULV routine sprays	Cyh	-	-	-	-	-	-	-	-	-	-	-	-	-
ED scouting	Cyh	-	-	-	-	-	-	-	-	-	-	-	-	-
KS scouting	Cyh	-	-	-	-	-	-	-	-	-	-	-	-	-
Control 1	End	-	-	-	-	-	-	-	-	-	-	-	-	--
Control 2		-	19.47	0.72	2.77b	0.25	4.97	1.19	2.26b	0.27	2.07	0.13	1.42b	0.15

Continued

Table 13. (Continued)

Treatment	Chems	Trial 2							1985 - 86					
		No. of sprays	H bolls	SE	D bolls	SE	H buds	SE	D buds	SE	H flower	SE	D flower	SE
ED routine sprays	Cyp	5	19.05	2.52	0.90	0.07	12.23	1.38	0.81a	0.04	1.70	0.22	.71	0.01
KS routine sprays	Cyp	5	17.65	0.51	0.85	0.07	12.35	0.47	0.85a	0.06	1.30	0.07	.71	0.02
ULV routine sprays	Cyp	5	17.23	0.38	0.90	0.04	11.38	0.16	0.84a	0.01	1.68	0.18	.71	0.01
ED scouting	Cyp	-	-	-	-	-	-	-	-	-	-	-	-	-
KS scouting dose B	Cyp	-	-	-	-	-	-	-	-	-	-	-	-	-
ULV scouting	Cyp	-	-	-	-	-	-	-	-	-	-	-	-	-
ED routine sprays	Cyh	5	18.78	0.99	0.84	0.05	12.18	0.14	0.89a	0.07	1.50	0.16	.71	0.02
KS routine sprays	Cyh	5	18.62	0.88	0.96	0.04	11.72	1.05	0.81a	0.02	1.73	0.11	.71	0.01
ULV routine sprays	Cyh	5	16.85	0.83	0.84	0.05	11.27	1.17	0.76a	0.03	1.45	1.11	.70	0.00
ED scouting	Cyh	-	-	-	-	-	-	-	-	-	-	-	-	-
KS scouting	Cyh	-	-	-	-	-	-	-	-	-	-	-	-	-
Control 1	End	2	17.08	0.52	0.91	0.01	11.65	0.41	0.82a	0.04	1.52	0.11	.70	0.00
Control 2		-	13.88	1.08	1.23	0.07	9.22	1.37	1.17b	0.06	1.05	0.15	.89	0.05

Continued

Table 13 (Continued)

Treatment	Chem	Trial 3							1985 - 86					
		No. of sprays	H bolls	SE	D bolls	SE	H buds	SE	D buds	SE	H flower	SE	D flower	SE
ED routine sprays	Cyp	5	12.5	0.33	.74a	0.02	6.13	0.47	.72a	0.02	0.93	0.24	.7	0.00
KS routine sprays	Cyp	5	9.77	0.99	.76a	0.04	4.43	0.83	.71a	0.00	0.28	0.11	.71	0.00
ULV routine sprays	Cyp	5	9.88	1.65	.86a	0.06	4.15	0.29	.71a	0.00	0.53	0.23	.71	0.00
ED scouting	Cyp	-	-	-	-	-	-	-	-	-	-	-	-	-
KS scouting dose B	Cyp	-	-	-	-	-	-	-	-	-	-	-	-	-
ULV scouting	Cyp	-	-	-	-	-	-	-	-	-	-	-	-	-
ED routine sprays	Cyh	5	10.22	1.53	.74a	0.02	3.70	1.32	.79a	0.04	0.33	0.16	.71	0.00
KS routine sprays	Cyh	5	12.03	0.64	.74a	0.02	6.85	1.15	.74a	0.00	0.80	0.27	.71	0.00
ULV routine sprays	Cyh	5	10.10	0.30	.76a	0.05	3.73	0.79	.78a	0.09	0.23	0.13	.71	0.00
ED scouting	Cyh	-	-	-	-	-	-	-	-	-	-	-	-	-
KS scouting	Vyh	-	-	-	-	-	-	-	-	-	-	-	-	-
Control 1	End	2	12.68	1.81	.74a	0.02	7.30	2.52	.80a	0.11	0.63	0.62	.72	.02
Control 2		-	9.93	0.51	1.09ab	0.09	4.85	1.25	1.06b	0.22	0.38	0.22	.71	0.00

Continued

Table 13 (Continued)

Treatment	Chem	Trial 4									1986 - 87			
sprays		No. of sprays	H bolls	SE	D bolls	SE	H buds	SE	D buds	SE	H flower	SE	D flower	SE
ED routine sprays	Cyp	5	16.18	2.20	0.84	0.01	1.30	0.09	0.71	0.00	0.67	0.14	.72	0.03
KS routine sprays	Cyp	5	14.78	2.20	0.79	0.01	.43	0.09	.71	0.00	.45	0.14	.74	0.03
ULV routine sprays	Cyp	-	-	-	-p	-	-	-	-	-	-	-	-	-
ED scouting	Cyp	2	16.18	1.67	0.84	0.03	1.30	1.20	0.71	0.02	0.67	0.14	0.72	0.00
KS scouting dose B	Cyp	5	14.55	1.11	0.81	0.06	0.53	0.30	0.71	0.00	.30	0.14	.71	0.00
ULV scouting	Cyh	-	-	-	-	-	-	-	-	-	-	-	-	-
ED routine sprays	Cyh	-	-	-	-	-	-	-	-	-	-	-	-	-
KS routine sprays	Cyh	-	-	-	-	-	-	-	-	-	-	-	-	-
ULV routine sprays	Cyh	-	-	-	-	-	-	-	-	-	-	-	-	-
ED scouting	Cyh	-	-	-	-	-	-	-	-	-	-	-	-	-
KS scouting	Cyh	-	-	-	-	-	-	-	-	-	-	-	-	-
Control 1	End	-	-	-	-	--	-	-	-	-	-	-	-	-
Control 2		-	8.08	1.30	1.29	0.07	3.55	1.45	1.22	0.15	1.20	0.46	.74	0.01

Note: (1) ED - 'Electrodyn', KS - Knapsack, ULV - Ultra low volume sprayer (2) Cyp - Cypermethrin, Cyh - lambda cyhalothrin End - endosulfan. (3) H - Healthy fruiting organs, D - damaged fruiting organs. (4) Means per column with the same letters are not significantly different at P = .05 level according to Duncan's multiple range test. Columns with no letters have no significant differences. SE - standard error (+/-).

Heliothis control

In most of the observations the untreated plots had significantly more eggs and larvae than the treated plots. The *Heliothis* infestation in various treatments in all trials is shown in Figs 83 to 86 and the statistical differences in the numbers of eggs and larvae at weekly intervals are given in appendix 8 and 9.

Aphid control

Overall, the number of aphids in untreated plots was higher when compared with treated plots (Table 14). Some statistical differences in the individual weekly observations are given in appendix 10.

Mummified aphids

Only few observations revealed statistical differences in the number of mummified aphids recorded at weekly intervals in different treatments (appendix 11). In general, the overall number of mummified aphids in different trials was almost similar in various treatments (Table 14).

Jassid control

Apart from untreated plots, there were not many statistical differences during weekly observations in most of the trials (appendix 12 , Table 14).

Whitefly control

The weekly observations on whiteflies showed some statistical differences between the treated and untreated control plots (appendix 13). In general, the population of whiteflies remained low (Table 14).

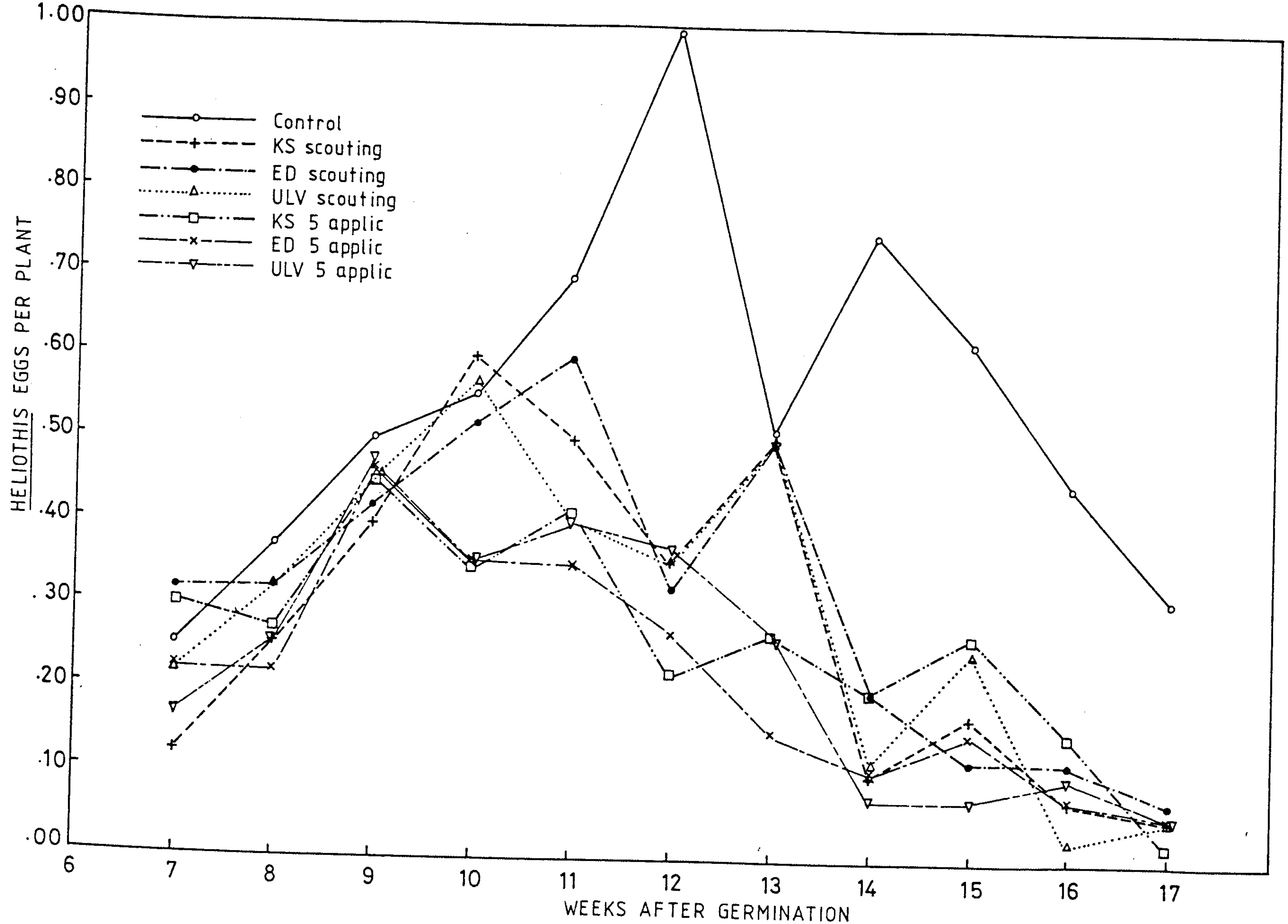

FIGURE 83. Heliothis eggs on treated and untreated plots sampled from 7 to 16th week afte

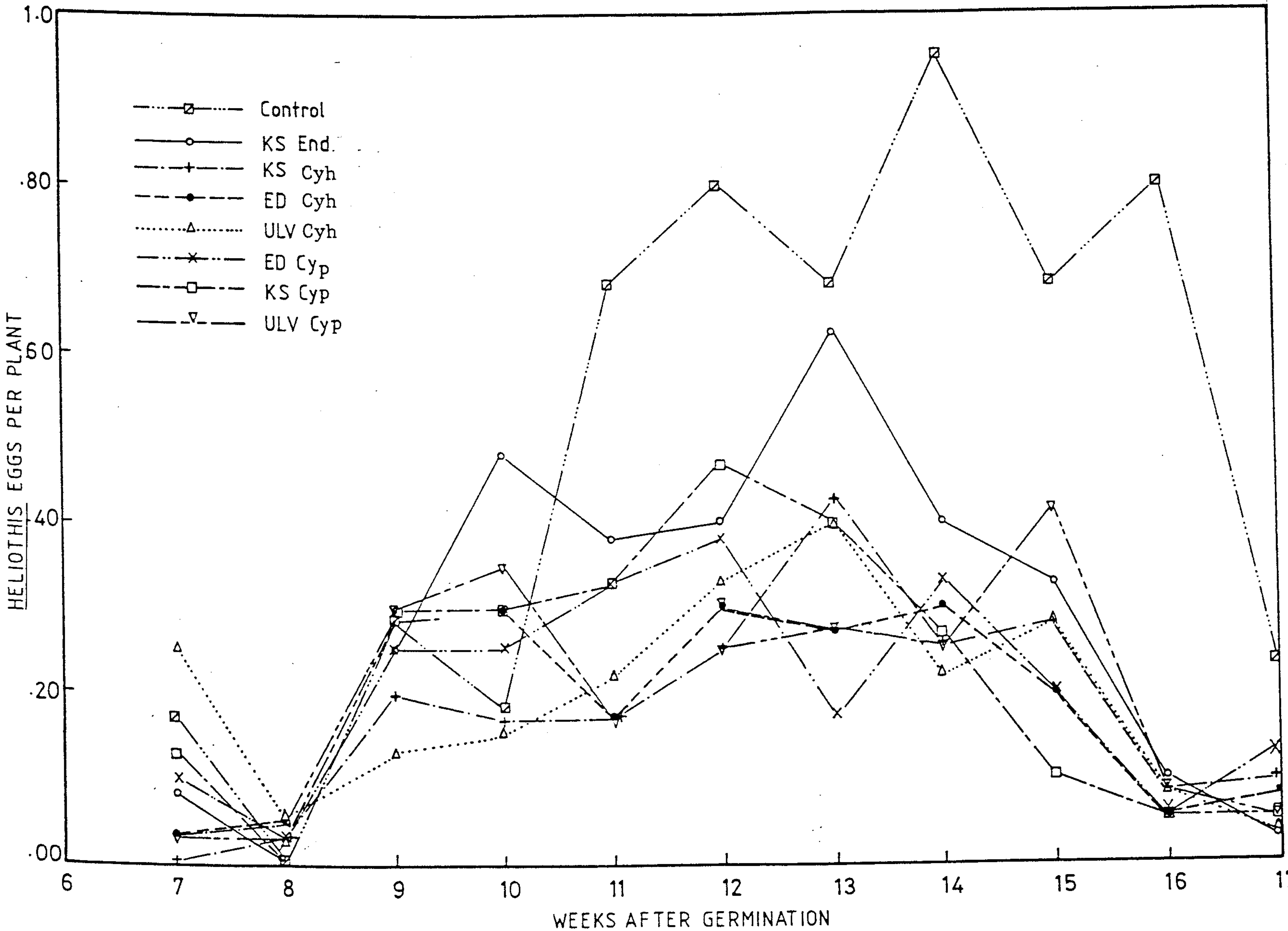

FIGURE 84. _Heliothis_ eggs on treated and untreated plots sampled from 7 to 17th week after germination in trial 2 for the comparison of application techniques in 1985-86. at site 1. KS - Knapsack, ED -

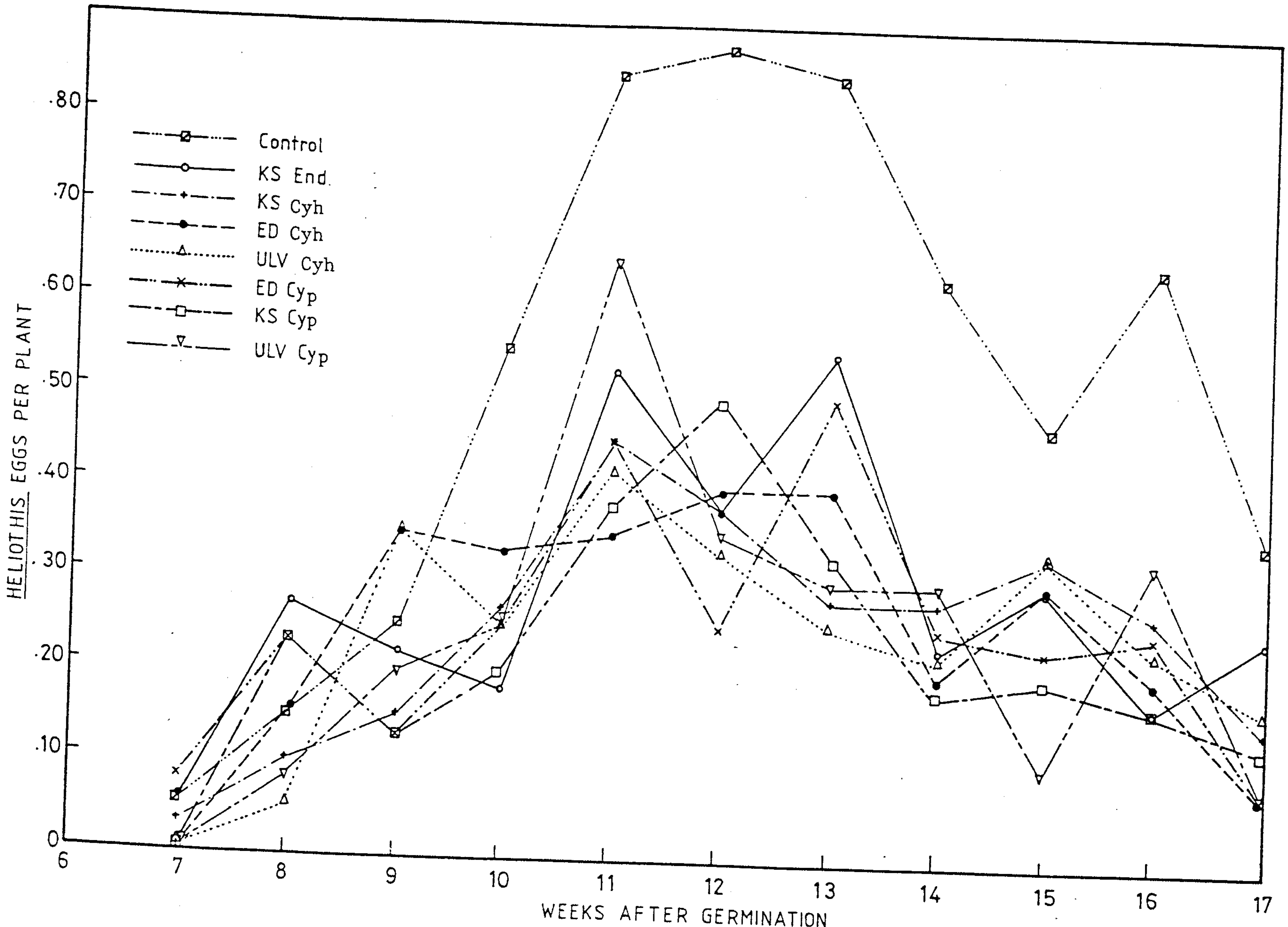

FIGURE 85. Heliothis eggs on treated and untreated plots sampled from 7 to 17th week after germination in trial 3 for the comparison of application techniques in 1985-86 at Site 2. **KS - Knapsack, ED -**

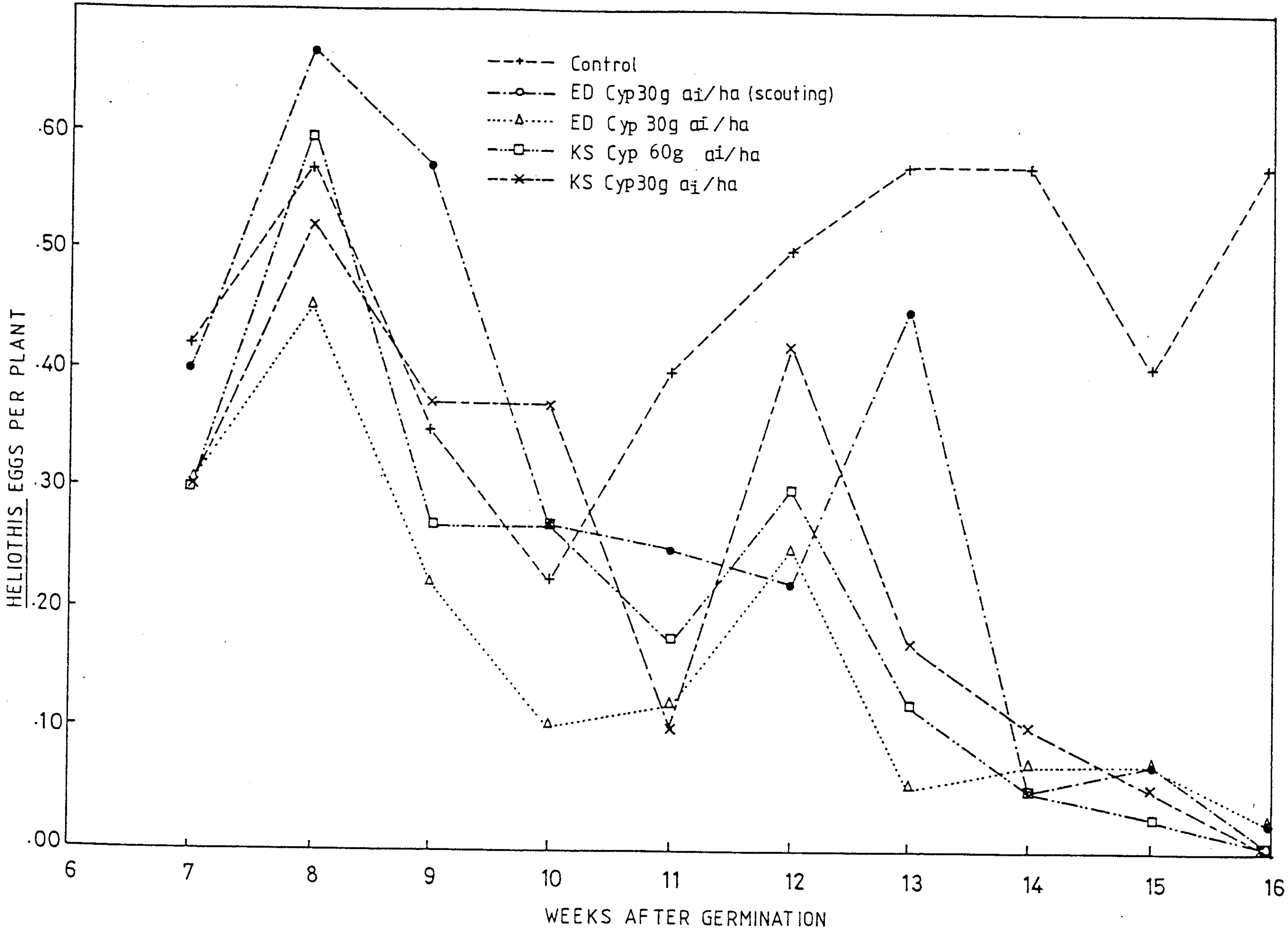

FIGURE 86. <u>Heliothis</u> eggs on treated and untreated plots sampled from 7 to 18th week after germination in trial 4 for the comparison of application techniques in 1986-87. ED - 'Electrodyn', KS - Knapsack, Cyp

Table 14. Mean number of aphids, mummified aphids, jassids, and whiteflies per plant (6 leaves) in different trials for the comparison of application techniques.

Treatment		Trial 1									1986 - 87
		No. of sprays	a.i. g/ha season	Aphid	SE	Mumm. aphid	SE	Jassid	SE	White flies	SE
ED routine sprays	Cyp	5	150	12.90a	1.90	2.30	0.17	1.29a	0.13	1.39a	0.11
KS routine sprays	Cyp	5	150	13.04a	2.00	2.46	0.14	1.20a	0.11	1.41a	0.08
ULV routine sprays	Cyp	5	150	12.79a	2.10	2.36	0.17	1.26a	0.12	1.41a	0.08
ED scouting	Cyp	3	90	13.57a	2.00	2.30	0.15	1.30a	0.12	1.49a	0.09
KS scouting dose B	Cyp	3	90	13.65a	2.00	2.36	0.22	1.29a	0.12	1.42a	0.09
ULV scouting	Cyp	2	60	13.53a	2.00	2.28	0.15	1.31a	0.13	1.51a	0.08
ED routine sprays	Cyh	-	-	-	-	-	-	-	-	-	-
KS routine sprays	Cyh	-	-	-	-	-	-	-	-	-	-
ULV routine sprays	Cyh	-	-	-	-	-	-	-	-	-	-
ED scouting	Cyh	-	-	-	-	-	-	-	-	-	-
KS scouting	Cyh	-	-	-	-	-	-	-	-	-	-
Control 1	End	-	-	-	-	-	-	-	-	-	-
Control 2		-	-	24.73b	1.60	2.77	0.25	1.66b	0.11	2.0b	0.13

Continued

Table 14 (Continued)

Treatment				Trial 2				1985 - 86			
		No. of sprays	a.i. g/ha season	Aphid	SE	Mumm. aphid	SE	Jassid	SE	White flies	SE
ED routine sprays	Cyp	5	150	4.34	0.94	1.11	0.09	1.07	0.14	0.96	0.03
KS routine sprays	Cyp	5	150	4.39	0.99	1.10	0.10	1.19	0.16	1.00	0.04
ULV routine sprays	Cyp	5	150	4.87	1.23	1.15	0.11	1.14	0.15	0.89	0.05
ED scouting	Cyp	-	-	-	-	-	-	-	-	-	-
KS scouting dose B	Cyp	-	-	-	-	-	-	-	-	-	-
ULV scouting	Cyp	-	-	-	-	-	-	-	-	-	-
ED routine sprays	Cyh	5	60	4.05	0.86	1.10	0.11	1.13	0.15	0.99	0.04
KS routine sprays	Cyh	5	60	4.02	0.81	1.09	0.11	1.16	0.18	0.93	0.03
ULV routine sprays	Cyh	5	60	4.21		1.15	0.11	1.07	0.15	0.96	0.03
ED scouting	Cyh	-	-	-	-	-	-	-	-	-	-
KS scouting	Cyh	-	-	-	-	-	-	-	-	-	-
Control 1	End	2	500	4.88	0.83	1.13	0.56	1.21	0.16	1.00	0.03
Control 2		-	-	8.17	0.99	1.29	0.14	1.58	0.08	1.09	0.05

Continued

Table 14 (Continued)

Treatment		Trial 3					1985 - 86				
		No. of sprays	a.i. g/ha season	Aphid	SE	Mumm. aphid	SE	Jassid	SE	White flies	SE
ED routine sprays	Cyp	5	150	4.04	1.10	1.19a	0.05	1.02	0.13	1.09	0.06
KS routine sprays	Cyp	5	150	5.37	1.50	1.28a	0.08	0.93	0.12	1.01	0.04
ED scouting	Cyp	-	-	-	-	-	-	-	-	-	-
KS scouting dose B	Cyp	-	-	-	-	-	-	-	-	-	-
ULV scouting	Cyp	-	-	-	-	-	-	-	-	-	-
ED routine sprays	Cyh	5	60	4.1	0.85	1.20a	0.05	0.96	0.11	1.04	0.05
KS routine sprays	Cyh	5	60	4.86	1.42	1.25a	0.06	0.96	0.11	1.00	0.04
ULV routine sprays	Cyh	5	60	4.38	1.14	1.21a	0.06	0.95	0.10	1.08	0.05
ED scouting	Cyh	-	-	-	-	-	-	-	-	-	-
Control 1	End	2	500	5.08	1.40	1.24a	0.07	0.97	0.10	1.04	0.05
Control 2		-	-	7.85	1.30	1.39b	0.05	1.36	0.18	1.15	0.08

Continued

sprays											
KS routine sprays	Cyp	5	150	13.62a	2.50	2.53	0.21	1.18a	0.11	1.41a	0.13
ULV routine sprays	Cyp	-	-	-	-	-	-	-	-	-	-
ED scouting	Cyp	2	60	13.58a	2.20	2.37	0.18	1.14a	0.11	1.39a	0.09
KS scouting dose B	Cyp	5	300	12.86a	2.40	2.39	0.17	1.18a	0.10	1.41a	0.10
ULV scouting	Cyp	-	-	-	-	-	-	-	-	-	-
ED routine sprays	Cyh	-	-	-	-	-	-	-	-	-	-
KS routine sprays	Cyh	-	-	-	-	-	-	-	-	-	-
ULV routine sprays	Cyh	-	-	-	-	-	-	-	-	-	-
ED scouting	Cyh	-	-	-	-	-	-	-	-	-	-
KS scouting	Cyh	-	-	-	-	-	-	-	-	-	-
Control 1	End	-	-	-	-	-	-	-	-	-	-
Control 2		-	-	25.09b	1.40	2.87	0.20	1.59b	0.08	1.95b	0.15

Note: (1) ED - 'Electrodyn', KS - Knapsack, ULV - Ultra low volume sprayer (2) Cyp - Cypermethrin, Cyh - lambda cyhalothrin End - endosulfan. (3) Mumm aphid - mummified aphids. (4) Means per column with the same letter are not significantly different at P = .05 level according to Duncan's multiple range test. Columns with no letters have no significant differences. Se - standard error ((+/-).

DISCUSSION

The average heightsof cotton plants in most trials were similar to those observed on farmers' fields as no fertilizer was applied at any site. The common pests such as Heliothis, aphids, jassids and whiteflies were all recorded during the trials. Diparopsis infestation was extremely low, but Heliothis eggs and larvae were more easily found on most trials. In Zambia, Heliothis is a key pest and is widely distributed in all areas where cotton is a rainfed crop.

Comparable yields of seed cotton were obtained in both seasons, including a trial at the second site during the 1985-86 season. This suggests that the 'Electrodyn' and ULV sprayers might provide similar yields in other areas, as noted at Magoye and other research centres (Anon, 1984a). The survey of farmers (Chapter 4) also confirmed that in the few cotton growing areas of Zambia where the 'Electrodyn' sprayer has been introduced on a limited scale, similar yields of seed cotton were obtained by farmers using the 'Electrodyn' and knapsack sprayers.

Clearly, the 'Electrodyn' can give similar yields with much less cypermethrin compared with the dosage applied with a knapsack sprayer. However, the knapsack sprayers are being used extensively in Zambia and the results of the present survey (Chapter 5) confirmed that some farmers have to transport water over a considerable distance (particularly in Mumbwa district) to apply insecticides by these sprayers. An early end of rainy season in Zambia discourages the farmers from continuing spraying if the water has to be transported from a long way (Lyon, 1975a). Similarly, in the Gambia, many farmers failed to apply the full quota of sprays on cotton with conventional spraying because of the difficulty of obtaining water (King, 1976).

Unfortunately, the extension services in Zambia have not promoted *alternative application techniques which are not dependent on water.*

All cotton in Zambia is virtually produced by small-scale farmers (93%) and the insect pests are one of the major production problems faced by these farmers (Chapter 3). The farmers are mostly illiterate and do not receive sufficient training on the dilution of insecticides and the calibration of knapsack sprayers (Chapter 7). However, under these circumstances, the premixed insecticides and precalibrated applicators can play an important role in the management of insect pests of cotton and can also minimize the contamination of small-scale farmers.

Cotton is an important crop in the economy of Zambia. Its export could earn foreign exchange for the country and it provides an important source of cash to small-scale farmers and hence efficient, safe, economical and easy methods of insecticide application are needed.

Although the product range has been limited in the case of the 'Electrodyn', other products have been or are under development. Of these, the new pyrethroid lambda cyhalothrin gave comparable results to cypermethrin during the current trials. In the 1987-88 cotton season, cyhalothrin ('Karate') 'bozzles' are expected to be supplied to cotton farmers in some of the cotton growing areas of Zambia. The range of ED formulations is likely to be increased in the future as has been the case in Brazil where formulations such as cypermethrin ED, bromopryphylate ED, carbosulfan ED, and malathion ED are in use (Smith, 1986).

The new application techniques can play an important role in the management of Heliothis and other insect pests of cotton in Zambia.

CONCLUSIONS

The time spent on collection, storage and transportation of water has been a major deterrent to farmers producing and protecting their cotton crops. Too often the farmers cannot respond quickly if a pest infestation occurs and the mixing of pesticides is often incorrect so the control achieved may be too late and inadequate. Unfortunately, the application of insecticides on cotton in Zambia has not changed during the past 50 years as compared to other cotton producing countries on the continent. In order to make the cotton pest control easy and effective, there is a need to exploit the potential of new application techniques particularly those which have been developed for small-scale cotton producers in the tropics. The government and private companies (LINTCO, ICI, Shell etc) must work together to provide information, appropriate training and extension services coupled with the package of all items needed for improved application techniques for a better management of cotton insect pests and safer use of insecticides in Zambia.

CHAPTER 13

ELECTRODYN SWATH ROWS

INTRODUCTION

In general a single or two row swaths with the current version of hand held 'Electrodyn' have been recommended for the small-scale cotton farmers in the developing countries. But in areas where the spinning disc sprayers have been used to treat cotton, particularly in some African countries, the farmers have been accustomed to using wider swaths. Little work seems to have been done to investigate the effects of swath widths. In Malawi, by increasing swath widths by 1 to 7 metres and at the same time by reducing the dosage, the charged sprays gave less control and lower yield of cotton; the decrease in yield being proportional to the dosage (Nyirenda, 1986). According to Morton (1981) the 'Electrodyn' sprays were more effective when used to do one row swath than 2 row swaths on cotton in Australia.

However, the following approaches have been suggested to the problem.

1. Deflectrode

Coffee (1980) developed a version of the 'Electrodyn' fitted with a deflectrode to affect the projecting of the charged droplets and to increase the swath width for the control of insect pests of cotton. The deflectrode has two rod like projectors at the same voltage as the 'Bozzle' which can be placed along the length of the handle when not in use. Thus by opening the deflectrode a swath of 2.7 metres has been recorded. But little has been published on the field evaluation of this version of equipment on cotton crops.

2. Less charge

In order to achieve a wider swath it is possible to reduce the charge so that the spray cloud is more affected by air movements in the same way as the spinning disc device. The partial discharge has also been suggested for downward movement of droplets into the canopy (Coffee, 1980) because with the current version of the hand-held 'Electrodyn' the penetration of charged droplets into the canopies of various crops is restricted as the charged droplets impact on the nearest earthed surface (Matthews, 1982a).

3. Reduced dosage

Another approach to achieving a wider swath is to see the effects of the required dosage levels applied with hand-held 'Electrodyn' sprayers.

The present studies endeavoured to investigate the effect of various swath rows using the 'Electrodyn' sprayer. The swaths used were 1, 2, 3 and 4 rows using the charged and partially discharged 'Electrodyn' in most of the trials.

RESULTS

Yield of Cotton

In the first trial (1985-86), the same dose of cypermethrin (30 g. a.i./ha), applied with a charged and partially discharged 'Electrodyn' gave similar yields irrespective of the swath widths (1, 2, 3 and 4). Similar results were obtained in two more trials in that season, in which only 1 and 2 row swaths were compared (Table 15). In the third trial, treatments based on scouting (3 sprays) and reduced spray applications (4 sprays at 3 week intervals), using 1 and 2 row swaths also provided similar yields.

In a fourth trial, during 1986-87, the same amount of cypermethrin (30 g. a.i./ha) with charged 1 row swath gave significantly higher yields than charged 4 row swath (Table 15). But statistically similar yields were recorded in charged 1 row, discharged 1 row and discharged 4 row treatments (Table 15). However, the treatments in which a quarter dose of cypermethrin (7.5 g. a.i./ha) was applied at a 4 row swath with charged and partially discharged 'Electrodyn' gave significantly lower yields (Table 15).

Effect on bolls, buds and flowers

In general the damaged bolls, buds and flowers were significantly higher in untreated plots as compared to the treated ones. However, there were fewer statistical differences in the number of healthy bolls, buds and flowers in various trials irrespective of the swath widths and the use of charged and partially discharged 'Electrodyn' (Table 16). The heights and number of nodes per plant were generally similar in all treatments (appendix 22).

Heliothis control

The *Heliothis* infestation (number of eggs per plant) remained generally higher in untreated control plots (Figs 87 to 90) reaching at its peak around 13 and 14 weeks after the germination of cotton plants. The statistical differences during the weekly observations on the number of *Heliothis* eggs and larvae generally showed significantly higher infestation in untreated plots with little differences within treated

	rows	season						
ED charg (1 row)	1 ch.	150	2104a	59.74	1 ch.	150	2025a	116.66
ED charg (1 row) scouting)	-	-	-	-	-	-	-	-
ED charg (1 row reduced sprays)	-	-	-	-	-	- -	-	-
ED charg (2 rows)	2 ch.	150	2150 a	185.88	2 ch.	150	2062a	283.33
ED charg (2 rows scouting)	-	-	-	-	-	-	-	-
ED charg (2 rows reduced sprays)	-	-	-	-	-	-	-	-
ED charg (3 rows)	2 ch.	150	2252a	168.17	-	-	-	-
ED charg (4 rows)	4 ch.	150	2135a	143.83	-	-	-	-
ED charg (4 rows ¼ dose)	4 ch.	-	-	-	-	-	-	-
ED disch. (1 row)	1 dis.	150	2195a	104.00	1 dis	150	2020 a	145.83
ED disch. (2 rows)	2 dis.	150	2270 a	64.17	1 dis	150	2108a	262.50
ED disch. (3 rows)	3 dis.	150	2004a	123.92	-	-	-	-
ED disch. (4 rows)	4 dis.	150	1964a	148.26	-	-	-	-
ED disch. (4 rows ¼ dose)	4 dis.	-	-	-	-	-	-	-
Control	-	-	1189b	210.22	-	-	1058b	62.50

Continued

	Trial 3 1985 - 86				Trial 4 1986 - 87			
	Swath rows	a.i. g/ha season	yield	SE	Swath rows	a.i. g/ha season	Yield	SE
ED charg (1 row)	1 ch.	150	2312a	196.87	1 ch.	150	2572bc	172.22
ED charg. (1 row scouting)	1 ch.	90	2064a	75.00	-	-	-	-
ED charg (1 row reduced sprays)	1 ch.	120	2450a	300.00	-	-	-	-
ED charg (2 rows)	2 ch.	150	2243a	209.37	-	-	-	-
ED charg (2 rows scouting)	2 ch.	90	2127a	121.87	-	-	-	-
ED charg (2 rows reduced sprays)	2 ch.	120	2062a	196.87	-	-	-	-
ED charg (3 rows)	-	-	-	-	4 ch.	150	2111b	116.66
ED charg (4 rows ¼ dose)	-	-	-	-	4 ch.	37.5	1666a	77.77
ED disch.(1 row)	-	-	-	-	1 dis.	150	2391bc	175.00
ED disch. (2 rows)	-	-	-	-	-	-	-	-
ED disch. (3 rows)	-	-	-	-	-	-	-	-
ED disch (4 rows)	-	-	-	-	4 dis.	150	2319bc	144.44
ED disch. (4 rows ¼ dose)	-	-	-	-	4 dis.	37.5	1538a	55.55
Control	-	-	1338b	146.87	-	-	1372a	152.77

Note: ED charg and ED disch. - Electrodyn charged and discharged sprayer. Five sprays in all trials except in trial 3 in which scouting based treatments required 3 sprays and in reduced spray treatments 4 applications were made. Means per column with the same letter are not significantly different at P = 0.5 level according to Duncan's multiple range test. Columns with no letters have no significant difference. SE - standard error (+/-).

Table 16. Mean number of healthy and damaged bolls, buds and flowers per plant in 'Electrodyn' swath row trials.

Treatment	Trial 1									1985 - 86				
	Swath	a.i. g/ha season	H bolls	SE	D bolls	SE	H buds	SE	D buds	SE	H flower	SE	D flower	SE
ED charg (1 row)	1	150	16.60	1.31	0.81	.04	11.80ab	1.22	0.81a	0.04	0.90	0.17	0.71	0.00
ED charg (1 row scouting)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (1 row reduced sprays)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (2 rows)	2	150	16.98	0.77	0.80	.03	16.60a	0.48	0.90a	0.09	1.40	0.04	0.71	0.00
ED charg (2 rows scouting)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (2 rows reduced sprays)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (3 rows)	3	150	15.50	0.43	0.84	.05	10.55a	0.54	0.95a	0.12	1.10	0.12	0.74	0.00
ED charg (4 rows)	4	150	11.90	0.92	0.88	.03	11.90ab	0.96	0.81a	0.02	1.18	0.30	0.71	0.00
ED charg (4 rows ¼ dose)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED disch. (1 row)	1	150	17.62	1.52	0.75	0.01	17.50c	0.61	0.76	0.06	1.30	0.29	.71	0.00
ED disch. (2 rows)	2	150	16.03	1.29	0.85	0.03	14.40b	0.88	0.71a	0.01	0.90	0.29	.72	0.00
ED disch. (3 rows)	3	150	16.93	0.83	0.78	0.04	13.55ab	0.59	0.91a	0.06	1.23	0.14	.74	.01
ED disch. (4 rows)	4	150	16.23	0.67	0.85	0.03	14.05b	0.27	0.83a	0.07	1.18	0.18	.74	0.00
ED disch. (4 rows ¼ dose)	4	-	-	-	-	-	-	-	-	-	-	-	-	-
Control	-	-	13.85	1.25	1.20	0.16	11.97ab	1.68	1.56b	0.06	0.98	0.23	0.74	0.00

Continued

Table 16 (continued)

Treatment	Trial 2							1985 - 86						
	Swath	a.i. g/ha season	H bolls	SE	D bolls	SE	H buds	SE	D buds	SE	H flowers	SE	D flower	SE
ED charg (1 row)	1	150	18.95	1.71	0.74a	0.02	12.75	0.78	0.82a	0.01	1.15	0.25	0.72	0.00
ED charg (1 row scouting)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (1 row reduced sprays)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (2 rows)	2	150	15.35	0.72	0.85a	0.05	8.83	0.53	0.81a	0.11	1.07	0.23	0.74	0.02
ED charg (2 rows scouting)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (2 rows reduced sprays)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (3 rows)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (4 rows)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (4 rows ¼ dose)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED disch. (1 row)		150	17.93	2.59	0.85a	0.05	10.75	0.82	0.76a	0.01	1.21	0.12	.71	0.01
ED disch. (2 rows)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED disch. (3 rows)	3	150	16.35a	1.50	0.79a	0.04	8.88	1.60	0.72a	0.01	1.10	0.13	.72	0.01
ED disch. (4 rows)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED disch. (4 rows ¼ dose)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Control	-	-	12.33	1.33	1.37b	0.05	9.30	0.67	1.35b	0.70	0.75	0.11	0.92	0.08

Continued

Table 16 (continued)

Treatment	Swath	a.i. g/ha season	H bolls	SE	D bolls	SE	H buds	SE	D buds	SE	H flower	SE	D flower	SE
	Trial 3						1985 - 86							
ED charg (1 row)	1	150	22.48c	2.20	0.85	0.05	7.38	0.89	0.82a	0.12	1.78	0.19	0.72	0.03
ED charg (1 row scouting)	-	90	20.05bc	0.67	1.02a	0.03	9.13	1.90	0.81a	0.06	1.30ab	0.15	0.71	0.00
ED charg (1 row reduced sprays)	1	120	17.25ab	0.91	0.80a	0.04	10.35	1.29	0.76a	0.03	1.58b	0.17	0.71	0.00
ED charg (2 rows)	2	150	21.05bc	0.58	0.92a	0.07	9.32	1.32	1.02b	0.05	1.83b	0.34	0.72	0.02
ED charg (2 rows scouting)	2	90	20.63bc	1.10	0.84a	0.07	8.20	0.96	0.30a	0.03	1.25ab	0.19	0.72	0.02
ED charg (2 rows reduced sprays)	2	120	17.05ab	1.17	0.82a	0.06	7.95	1.29	0.74a	0.02	1.58b	0.28	.71	0.00
ED charg (3 rows)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (4 rows)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED char (4 rows)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (4 rows ¼ dose)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED disch. (1 row)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED disch. (2 rows)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED disch. (3 rows)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED disch. (4 rows)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED disch. (4 rows ¼ dose)	-	- -	-	-	-	-	-	-	-	-	-	-	-	-
Control	-	-	13.35a	0.53	1.44b	0.09	1.43	0.66	1.37cb	0.13	0.55a	0.11	0.83	0.04

Continued

Table 16 (Continued)

Treatment	Trial 4						1986 - 87							
	Swath	a.i. g/ha season	H bolls	SE	D bolls	SE	H buds	SE	D buds	SE	H flower	SE	D flower	SE
ED charg (1 row)	1	150	16.80b	0.96	0.88a	0.04	2.50ab	0.84	0.60a	0.14	1.45abc	0.32	0.92ab	0.07
ED charg (1 row) scouting)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (1 row reduced sprays)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (2 rows)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (2 rows scouting)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (2 rows reduced sprays)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ed charg (3 rows)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED charg (4 rows)	4	150	16.90b	2.28	0.99ab	0.10	3.30b	0.77	0.74a	0.21	1.35abc	0.36	0.86a	0.05
ED charg (4 rows ¼ dose)	4	37.5	14.00b	3.76	0.90ab	0.13	1.13a	0.52	0.83a	0.10	0.87a	0.30	0.79a	0.11
ED disch. (1 row)	1	150	17.07b	1.22	0.87a	0.07	1.80ab	0.40	0.85a	0.08	0.43a	0.21	0.72a	0.02
ED disch. (2 rows)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED disch. 93 rows)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED disch. (4 rows)	4	150	16.30b	3.23	1.14b	0.07	2.20ab	0.56	0.97a	0.09	0.98b	0.23	0.05ab	0.13
ED disch. (4 rows ¼ dose)	4	37.5	13.53ab	0.39	0.95ab	0.05	3.65b	0.75	0.69a	0.20	1.88bc	0.08	1.01b	0.13
Control	-	-	8.83a	0.62	1.59c	0.05	3.20b	0.32	1.54b	0.13	2.30c	0.58	1.24b	0.18

Note: ED charg and ED disch. - Electrodyn charged and discharged sprayer. Five sprays in all trials except in trial 3 in which scouting based treatments required 3 sprays and in reduced spray treatments 4 applications were made. Means per column with the same letter are not significantly different at P = 0.5 level according to Duncan's multiple range test. Columns with no letters have no significant difference. H and D are healthy and damaged fruiting organs. SE - standard error (+/-).

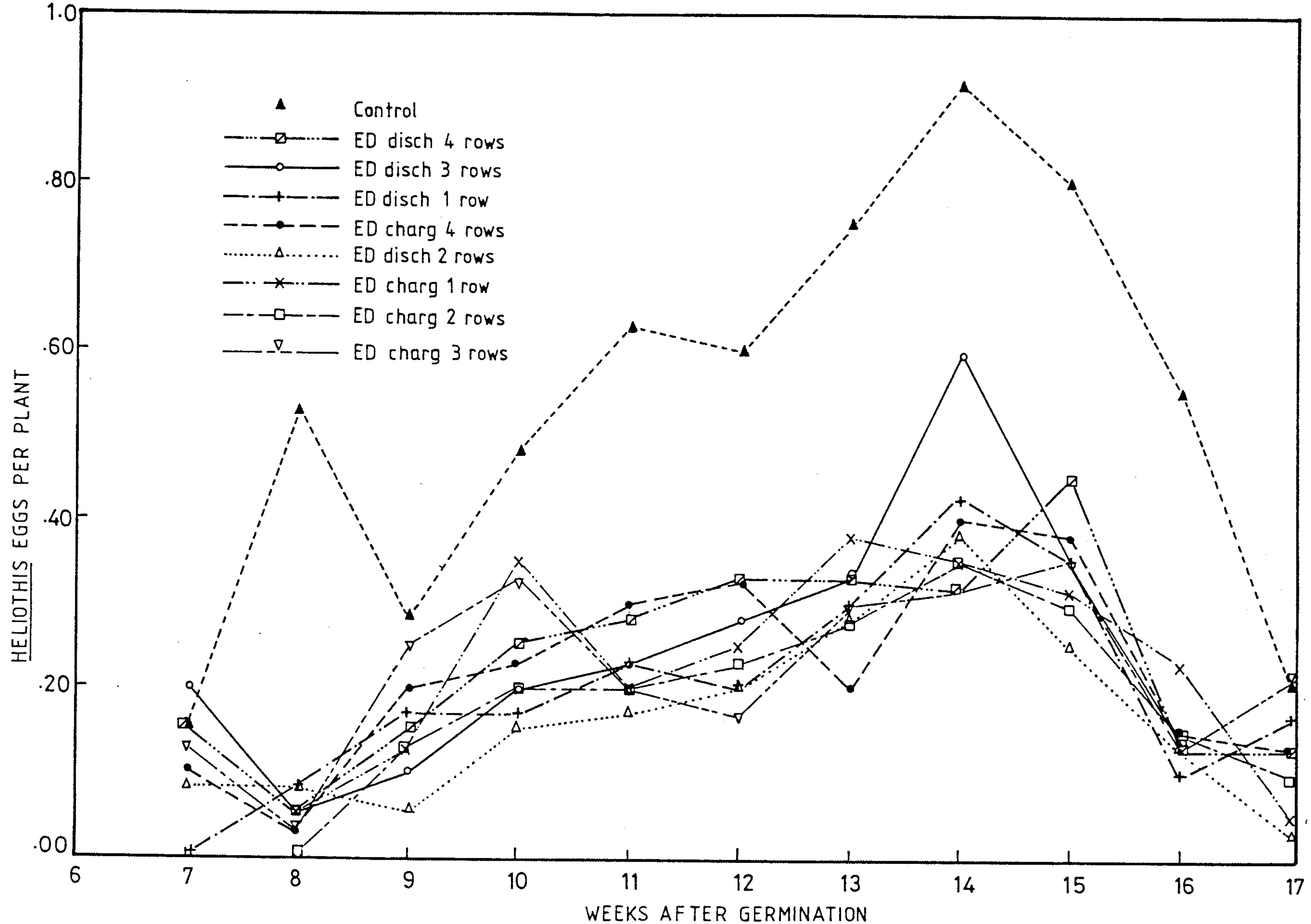

FIGURE 87. *Heliothis* eggs on treated and untreated plots sampled from 7th to 17th week after germination in trial 1 for comparison of swath width (1 to 4 rows) with charged and partially di[illegible]

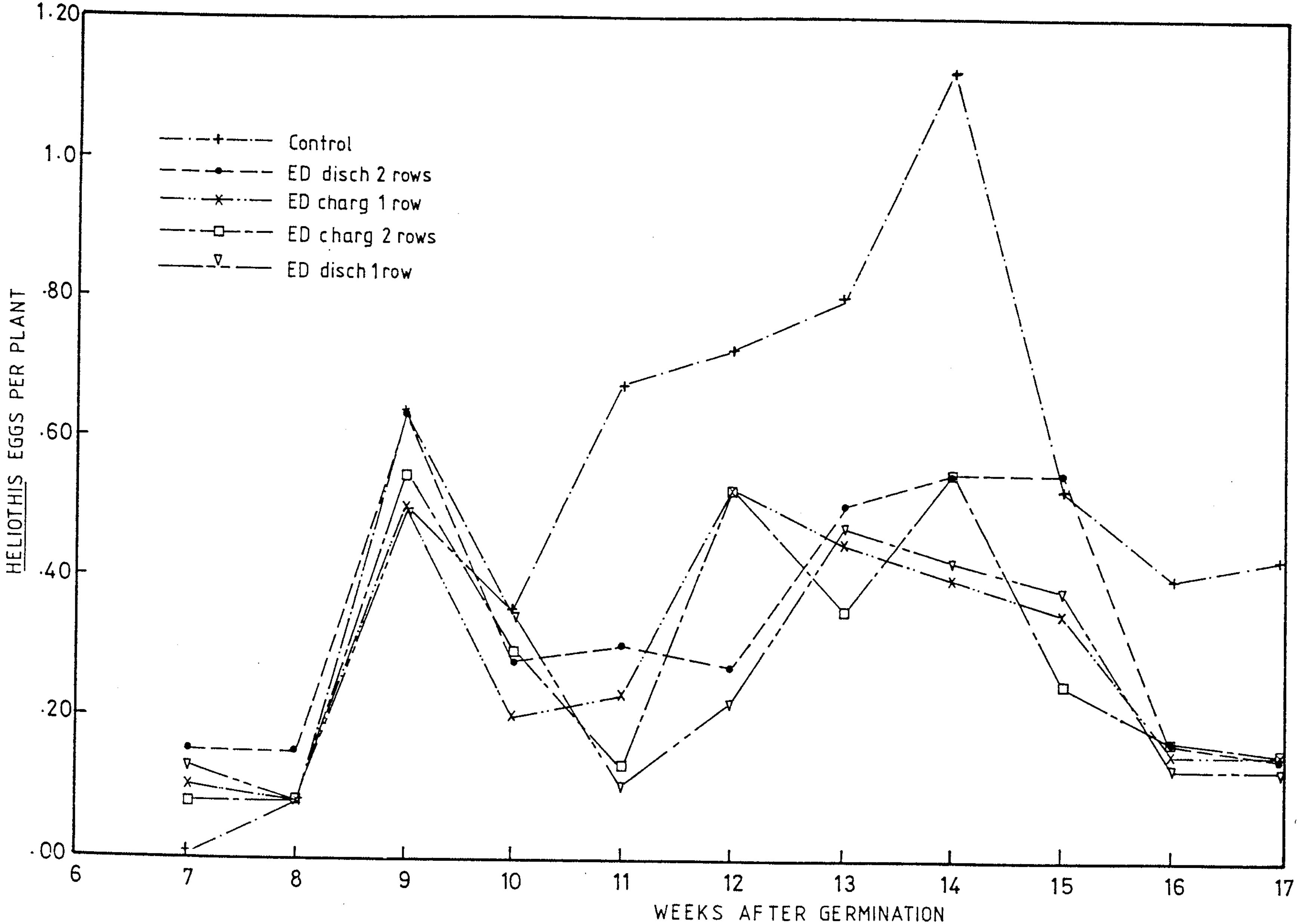

FIGURE 88. Heliothis eggs on treated and untreated plots sampled from 7th to 17th week after germination in trial 2 in comparison of swath widths (1 to 2 rows) with 'Electrodyn'. ED - Electrodyn,

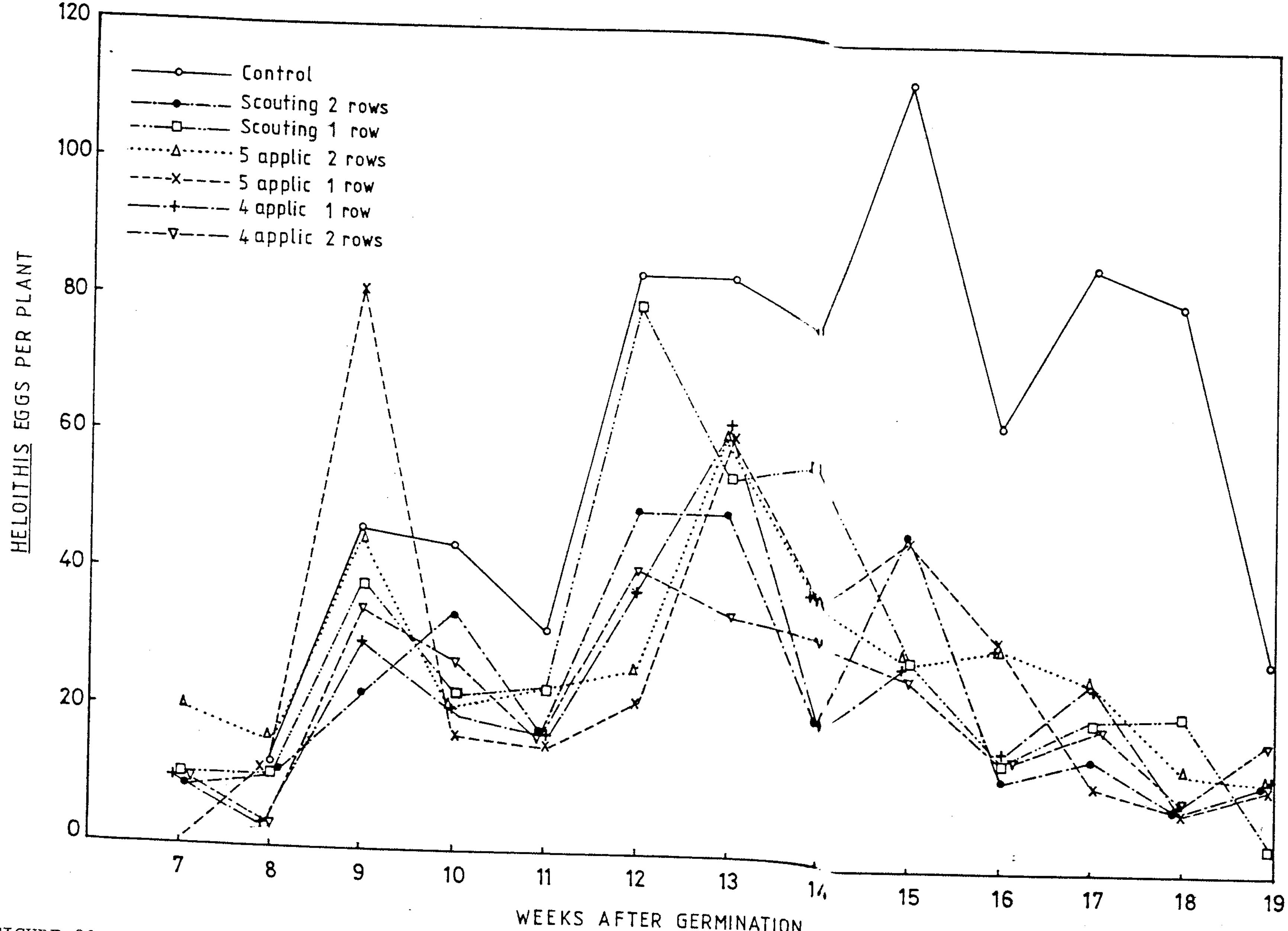

FIGURE 89. *Heliotis* eggs on treated and untreated plots sampled from 7th to 19th week after germination in trial 3 for comparison of swath widths (1 to 2 rows) with 'Electrodyn' in routine, scouting

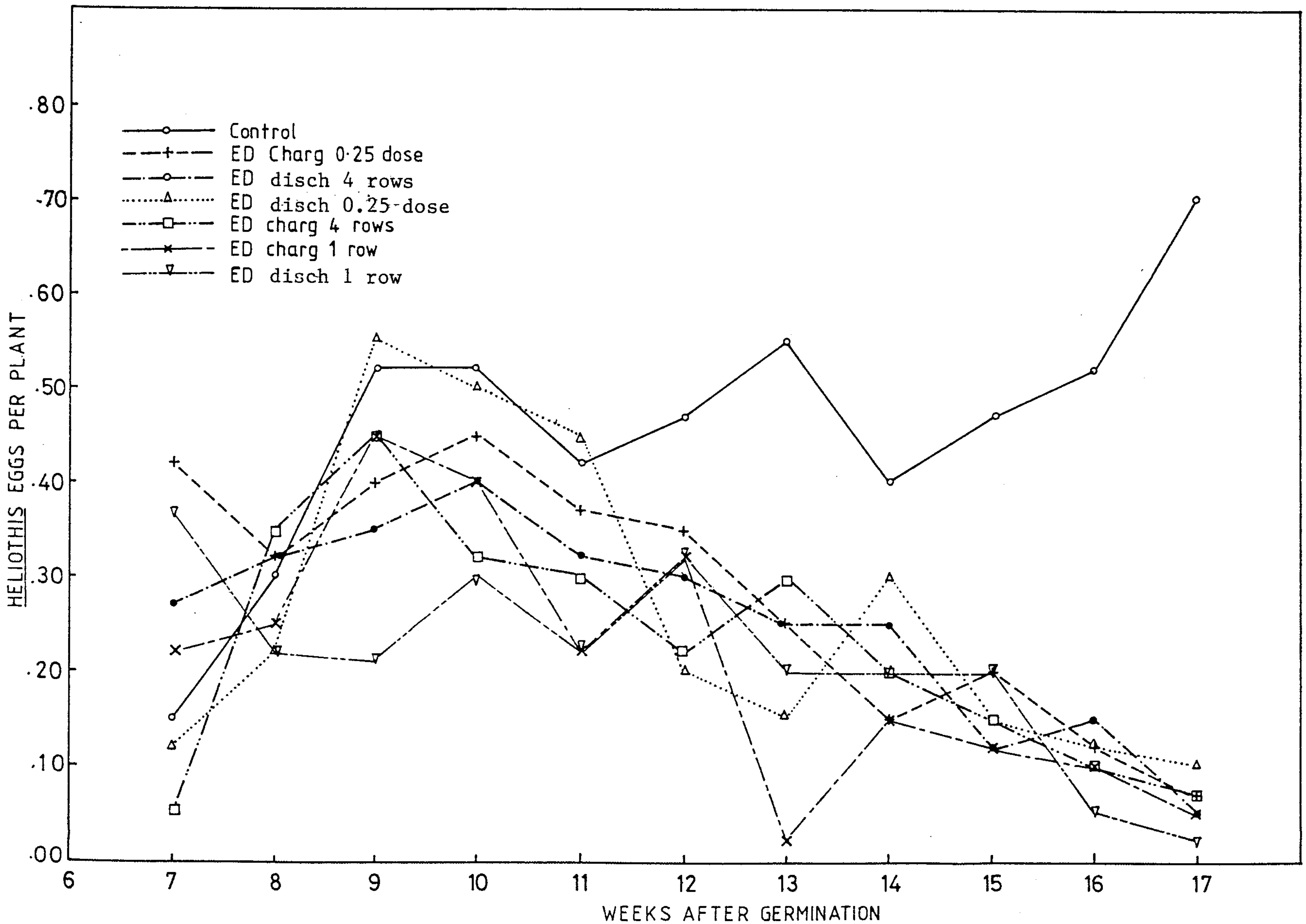

FIGURE 90. <u>Heliothis</u> eggs on treated and untreated plots sampled from 7th to 17th week after germination

plots (Appendix 14 and 15).

Aphid control

The number of aphids in untreated control was much higher as compared to treated plots but in general there were very few differences between swath widths (Table 17). However, the statistical differences during weekly observations in various treatments in the trials are shown in Appendix 16.

Mummified aphids

The significant differences during the weekly observations on mummified aphids in a series of trials are shown in Appendix 17. In general, very few differences in the number of mummified aphids between the treatments were detected (Table 17).

Jassid control

Compared with untreated control plots, sprayed plots had fewer jassids and in general the number of jassids declined towards the end of season (Table 17, Appendix 18).

Whitefly control

Few significant differences were recorded in the number of white-flies in various treatments during weekly observations in various trials (Appendix 19). Generally, the population of whiteflies was very low as summarised in Table 19.

Table 17. Number of aphids, mummified aphids, jassids and whiteflies per plant in 'Electrodyn' swath row trials

Treatment	Trial 1						1985 - 86			
	Swath	a.i. g/ha season	Aphid	SE	Mumm. aphid	SE	Jassid	SE	White flies	SE
ED charg (1 row)	1	150	4.12a	0.80	1.19	0.11	1.00	0.11	1.02	0.05
ED charg (1 row scouting)	-	-	-	-	-	-	-	-	-	-
ED charg (1 row reduced sprays)	-	-	-	-	-	-	-	-	-	-
ED charg (2 rows)	2	150	5.03a	1.11	1.26	0.12	0.97	0.12	0.98	0.03
ED charg (2 rows scouting)	-	-	-	-	-	-	-	-	-	-
ED charg (2 rows reduced sprays)	-	-	-	-	-	-	-	-	-	-
ED charg (3 rows)	3	150	4.92a	0.96	1.14	0.11	0.97	0.11	1.0	0.04
ED charg (4 rows)	4	150	4.88a	1.14	1.30	0.10	1.01	0.12	0.92	0.03
ED charg (4 rows ¼ dose)	-	-	-	-	-	-	-	-	-	-
ED disch. (1 row)	1	150	4.36a	1.01	1.21	0.09	1.01	0.12	0.98	0.03
ED disch. (2 rows)	2	150	4.63a	0.90	1.22	0.09	1.04	0.14	1.01	0.02
ED disch. (3 rows)	3	150	5.24a	1.14	1.27	0.10	0.94	0.10	1.04	0.04
ED disch. (4 rows)	4	150	4.71a	0.91	1.26	0.10	1.06	0.15	0.98	0.04
ED disch. (4 rows ¼ dose)	4	-	-	-	-	-	-	-	-	-
Control	-	-	8.91b	1.50	1.58	0.19	1.25	0.12	1.08	0.04

Continued

Table 17 (Continued

Treatment	Trial 2					1985 - 86				
	Swath	a.i. g/ha season	Aphid	SE	Mumm. aphid	SE	Jassid	SE	White flies	SE
ED charg (1 row)	1	150	3.44	0.59	1.15	0.11	1.11	0.14	0.95	0.04
ED charg (1 row scouting)	-	-	-	-	-	-	-	-	-	-
ED charg (1 row reduced sprays)	-	-	-	-	-	-	-	-	-	-
ED charg (2 rows)	2	150	4.37	0.69	1.19	0.03	1.02	0.12	0.93	0.04
ED charg (2 rows scouting)	-	-	-	-	-	-	-	-	-	-
ED charg (2 rows reduced sprays)	-	-	-	-	-	-	-	-	-	-
ED charg (3 rows)	-	-	-	-	-	-	-	-	-	-
ED charg (4 rows)	-	-	-	-	-	-	-	-	-	-
ED charg (4 rows ¼ dose)	-	-	-	-	-	-	-	-	-	-
ED disch. (1 row)	1	150	3.92	0.61	1.15	0.08	1.06	0.13	0.91	0.03
ED disch. (2 rows)	1	150	4.05	0.67	1.19	0.10	1.04	0.14	0.95	0.04
ED disch. (3 rows)	-	-	-	-	-	-	-	-	-	-
ED disch. (4 rows)	-	-	-	-	-	-	-	-	-	-
ED disch. (4 rows ¼ dose)	-	-	-	-	-	-	-	-	-	-
Control	-	-	6.43	1.14	1.20	0.09	1.55	0.08	1.10	0.06

Continued

Table 17 (Continued)

Treatment	Trial 3					1985 - 86				
	Swath	a.i. g/ha season	Aphid	SE	Mumm. aphid	SE	Jassid	SE	White flies	SE
ED charg (1 row)	1	150	3.50a	0.66	1.16	0.07	1.01	0.13	0.94a	0.03
ED charg (1 row scouting)	1	90	4.25a	0.67	1.14	0.09	1.05	0.13	1.01a	0.03
ED charg (1 row reduced sprays)	1	120	3.96a	0.47	1.09	0.08	1.14	0.16	0.95a	0.03
ED charg (2 rows)	2	150	3.95a	0.68	1.19	0.46	0.99	1.30	0.95a	0.03
ED charg (2 rows scouting)	2	90	4.48a	0.89	1.13	0.07	1.04	0.12	0.97a	0.04
ED charg (2 rows reduced sprays	2	120	3.85a	0.59	1.12	0.07	1.02	0.11	0.92a	0.03
ED charg (3 rows)	-	-	-	-	-	-	-	-	-	-
ED charg (4 rows)	-	-	-	-	-	-	-	-	-	-
ED charg (4 rows ¼ dose)	-	-	-	-	-	-	-	-	-	-
ED disch. (1 row)	-	-	-	-	-	-	-	-	-	-
ED disch. (2 rows)	-	-	-	-	-	-	-	-	-	-
ED disch. (3 rows)	-	-	-	-	-	-	-	-	-	-
ED disch. (4 rows)	-	-	-	-	-	-	-	-	-	-
ED disch. (4 rows) ¼ dose)	-	-	-	-	-	-	-	-	-	-
Control	-	-	7.44b	1.11	1.20	0.11	1.42	0.09	1.18b	0.05

Continued

Table 17 (Continued)

Treatment	Trial 4									1986 - 87
	Swath	a.i. g/ha season	Aphid	SE	Mumm. aphid	SE	Jassid	SE	White flies	SE
ED charg (1 row)	1	150	13.04a	1.66	2.29	0.16	0.93	0.11	1.38	0.09
ED charg (1 row scouting)	-	-	-	-	-	-	-	-	-	-
ED charg (1 row reduced sprays)	-	-	-	-	-	-	-	-	-	-
ED charg (2 rows)	-	-	-	-	-	-	-	-	-	-
ED charg (2 rows scouting)	-	-	-	-	-	-	-	-	-	-
ED charg (2 rows reduced sprays)	-	-	-	-	-	-	-	-	-	-
ED charg (3 rows)	-	-	-	-	-	-	-	-	-	-
ED charg (4 rows)	4	150	14.29a	1.91	5.52	0.19	1.28	0.12	1.57	0.08
ED charg (4 rows ¼ dose)	-	37.5	14.60a	1.92	2.39		1.22		1.45	0.07
ED disch. (1 row)	1	150	12.94a	1.92	2.41	0.21	1.27	0.11	1.43	0.07
ED disch. (2 rows)	-	-	-	-	-	-	-	-	-	-
ED disch. (3 rows)	-	-	-	-	-	-	-	-	-	-
ED disch. (4 rows)	4	150	14.82a	1.91	2.31	0.11	1.32	0.15	1.40	0.08
ED disch. (4 rows ¼ dose)	4	37.5	15.57a	1.99	2.36	0.14	1.37	0.13	1.45	0.07
Control	-	-	24.85b	1.71	2.71	0.23	1.64	0.14	1.88	0.14

Note: ED charg and ED disch. - 'Electrodyn' charged and discharged sprayer. For aphids, mummified aphids, jassids and whiteflies ten plants observed per plot (two leaves from top, middle and bottom of each plant). Means column with the same letter are not significantly different at P = 0.5 level according to Duncan's multiple range test. Columns with no letters have no significant difference. SE - (standard error +/-).

DISCUSSION

Charged and partially discharged 'Electrodyn'

As the deflectrode version of the hand-held 'Electrodyn' was not available, an ordinary copper wire was used to partially discharge the 'Electrodyn' during the current trials. However, similar yields and pest control were obtained in most of the trials, irrespective of whether charged or partially discharged sprays were applied suggest that probably the severity of insect pest attack may not have been sufificiently high to show the differences in spray distribution. Similar results were obtained in various field trials in Malawi with charged and partially discharged 'Electrodyn'. However, the heavy infestations of *Dysdercus* were not adequately controlled by charged sprays resulting in the lower yield of seed cotton (Nyirenda, 1986).

Swath widths

That the same amount of cypermethrin (30 g. a.i./ha) applied with the 'Electrodyn' at various swath rows provided similar yields, could be due to the low infestations of *Diparopsis* and *Dysdercus*. But the *Heliothis* infestation, a key pest of cotton in almost all cotton growing areas of Zambia, was recorded in all trials. The insect pests frequently recorded during current trials including *Heliothis*, aphids, jassids and white fly adults generally feed in the upper canopy of cotton plants. However, the results of the trial suggest that under a similar pest pressure, a wider swath of up to 2 or even more rows is possible with the current version of hand-held 'Electrodyn' without any significant effect on the yield of seed cotton. In Malawi, Nyirenda (1986) suggested that swath widths could be changed from 3-2-1 rows as the cotton grew.

Reduced dosages

Clearly, a well distributed minimum dosage is needed to control Heliothis, so when 1/4 of the recommended dose of cypermethrin (7.5 g. a.i./ha) was applied at a 4 row swath significantly lower yields of seed cotton was obtained. Similarly, in Malawi, the increased swaths with reduced dosages generally gave lower yields (Nyirenda, 1986). Herzog et al (1983) also obtained lower yields and lower pest control when the quarter doses were applied electrostatically.

CONCLUSIONS

A disadvantage of discharging a spray is when, small-scale farmers with other crops in close proximity is the risk of drift so there is a need to confine swath widths with good deposition on the treated rows. More research on wider swaths probably by using other techniques to partially discharge the 'Electrodyn' and the effects on Diparopsis and Dysdercus is needed. The increased swaths of 'Electrodyn' coupled with sprays based upon scouting or reduced number of spray applications might result in a considerable saving in insecticides and the time spent on spraying.

CHAPTER 14

SUMMARY

1. The Lint Company (LINTCO) has an important role in the increase of cotton production in Zambia. The farmers reported a general trend to increase their cotton area, as cotton provides an important source of cash and grows well without fertilizers.
2. Farmers knew the common insect pests of cotton and singled out the American bollworm, red bollworm, and aphids as being the worst pests.
3. Farmers generally over-estimated potential losses caused by insect pests and consequently some of them applied more insecticide sprays than is locally recommended.
4. The commonly used non-chemical components of cotton insect pest management reported by the farmers were: growing cotton in rotation with other crops and the destruction of cotton plants after harvest.
5. Only a few farmers were aware of the role of biological control and the significance of weeding in cotton insect pest management.
6. Many farmers inspected their cotton crops to decide the timing of spray applications, but they did not follow the recommended scouting methods.
7. The majority of farmers were unable to identify the eggs of American and red bollworms of cotton to enable them to scout for the pests effectively.
8. The farmers had either used knapsack (single nozzle) or 'Electrodyn' sprayers while a few indicated that they had used both types of sprayers.

9. The average yields of seed cotton obtained by farmers who used knapsack, 'Electrodyn' and both types of sprayers were 745, 709 and 711 Kg/ha respectively.
10. Farmers were experienced in the use of knapsack sprayers which were more readily available in all areas of the survey.
11. Farmers recognised the versatility of knapsack sprayers, because in addition to cotton they could be used to treat other crops and livestock.
12. Farmers who did not use knapsack sprayers considered that they were too heavy and required too much water to operate.
13. The farmers who used the 'Electrodyn' sprayers reported that the light weight, the use of pre-packed insecticides and the efficiency of the equipment were some of the advantages of the 'Electrodyn' sprayers.
14. In the opinion of farmers, the disadvantages of the 'Electrodyn' sprayers were its limitation on swath row coverage because the 'Electrodyn' covers only one row swath as compared to the ULV sprayers which can cover up to six rows; and that the 'Electrodyn' sprayer could not be used to apply solubor (boron) which is recommended as a foliar nutrient spray on cotton in Zambia.
15. Farmers estimated efficiency of knapsack sprayers was 86% but was increased to 95% for the 'Electrodyn' sprayers.
16. The majority of cotton farmers were unaware of fitting more than 1 nozzle on knapsack sprayers and did not know the use of oxen driven or tractor mounted sprayers.
17. Among other application techniques, some farmers were aware of the knapsack tailbooms used in Malawi and ULV spinning disc sprayers, but they were unable to use them because these applicators were generally not available in their areas.

18. Twenty percent of the farmers interviewed reported that they had suffered from illnesses due to insecticide spraying on cotton. The symptoms of poisoning included chest pain, headache, swelling and itching on bodies.
19. The symptoms of poisoning were reported to have occurred more often while spraying insecticides against the wind and by inhalation of spray mist.
20. Sixteen percent of the farmers were unaware of the need of protective clothing. The others had limited knowledge about the use of overalls, hand gloves and goggles.
21. The safety precautions while spraying insecticides such as not to eat and smoke nor spray against the wind, were known to about 30% of the farmers.
22. After finishing spraying insecticides on cotton, the farmers reported washing of their clothes and taking a bath as some of the safety measures known to the majority of them.
23. Six percent of the farmers stored insecticides inside their bedrooms, and the rest of them kept them in other rooms within the houses. About 30% of the farmers never locked up the insecticides at their farms.
24. Only 50% of the farmers interviewed attended the training courses and demonstrations on insect pest control of cotton.
25. The training courses mostly organised by farm training institutes emphasised general aspects of cotton production. The demonstrations on chemical control were occasionally organised by multinational companies such as ICI, Hoechest and Shell Chemicals.
26. The majority of farmers knew the extension staff in their areas. The average visits of extension staff were 4.8 during the cotton growing season.

27. The additional sources of information available to farmers on cotton pest management were radios, field days, leaflets and informal discussions within the farming community.
28. Farmers expressed the need for more advice on methods of insect scouting and application of insecticides on cotton.
29. The majority of farmers felt that cotton pest management can be improved by introducing additional training courses, increased number of extension staff, coupled with demonstrations in cotton fields.
30. The application of insecticides on cotton in Zambia at present is based upon routine spraying, irrespective of the difference in pest population.
31. Heliothis is a key pest of cotton in Zambia, therefore insecticide treatments should be based upon the number of eggs present per plant. A threshold of 0.25 eggs (1 Heliothis egg on 4 plants) was too low as unnecessary sprays were applied without any significant increase in the yield of seed cotton.
32. The most economical and optimum threshold to initiate spraying for the control of Heliothis was found to be 0.50 eggs per plant (1 egg on 2 plants) in most of the trials. Spraying according to this threshold can limit the number of applications to 3 or 4 per season.
33. Routine spraying had a tendency for excessive use of insecticides which cotton yields could not justify. The routine sprays (5 applications at 2 week intervals) never provided significantly higher yields than the scouting based treatments (0.50 eggs of Heliothis per plant).

34. When spraying was delayed and only 4 or 3 spray applciations were made starting from the 9th and 11th weeks respectively after germination (predetermined dates), the cotton yields were similar to 5 routine spray applications starting at the 7th week after germination.

35. Heliothis infestation (eggs per plant) were higher during the 10th to 15th week after the germination which co-incided with the cotton flowering period.

36. The 'Electrodyn' knapsack and ULV sprayers gave similar yields with cypermethrin at 30 g. a.i./ha.

37. Lambda cyhalothrin at 12 g.a.i./ha gave similar yields as cypermethrin (30 g. a.i./ha) irrespective of the spraying techniques ('Electrodyn', knapsack and ULV).

38. Similar yields were obtained with both charged and partially discharged spray droplets from the 'Electrodyn' sprayer.

39. An increase in swath width up to 4 rows using the 'Electrodyn' did not significantly affect the yields if the same dosage was maintained and the infestation was light. However, a charged spray over a 4 row swath gave a significantly lower yield in one season. A reduction in dose of cypermethrin from 30 to 7.5 g. a.i./ha applied with charged and partially discharged 'Electrodyn' at a 4 row swath gave significantly lower yields.

40. The use of 'Electrodyn' sprayers is considered to be appropriate for small-scale cotton farmers in Zambia who have difficulty in collecting, storing and transporting water to their fields (they have to dilute the insecticides without protective clothing and proper training).

4 1 The time spent in the transportation of water could be used for insect scouting followed by a quick spray application by improved techniques.

GENERAL CONCLUSION

The cotton farmers in Zambia are faced with well known problems of insect pests on their crops. The routine sprays of pyrethroids with knapsack sprayers currently recommended, are costly, generally encourage resistance, secondary out breaks of insect pests and might not be necessary in all seasons in different cotton growing areas of Zambia. Therefore, the appropriate authorities must emphasise the training of farmers in the new techniques coupled with improved extension services to scout for insect pests as some of the neighbouring countries of Zambia do. The field trials confirmed that sprays based on 0.50 eggs of *Heliothis* reduced the number of sprays and the yields were similar to routine sprays. The 'Electrodyn' and ULV sprayers compared well with knapsacks and have more potential for cotton farmers in Zambia. However, more research on the application of solubor with 'Electrodyn' and to increase its swath width is suggested.

ACKNOWLEDGEMENTS

I am grateful to my supervisors Dr. G.A. Matthews (Imperial College, University of London) and Dr. J.N. Zulu (Department of Biology, University of Zambia) for their interest, advice, encouragement and invaluable help throughout the study.

Sincere thanks are due to the Research and Higher Degrees Committee of the University of Zambia for approving this project. I would like to thank Professor A. A. Siwela, Dean, School of Natural Sciences for his help and encouragement.

Thanks are also due to Dr. G.A. Norton, Dr. J.D. Mumford and Professor J. Ziche for useful discussions and their assistance in the preparation of the questionnaire for the survey of farmers. The help and co-operation of LINTCO staff and all farmers who participated in the interviews is also acknowledged with thanks.

I am also grateful to the management of the University of Zambia farm for the excellent co-operation in carrying out the field trials.

I wish to thank private companies including ICI, Shell Chemicals, Micron Sprayers Ltd.,(U.K.) and National Agricultural Marketing Board (NAMBOARD) for supplying the pesticides and sprayers for field trials. In particular, I thank ICI for providing some funds which enabled me to complete my thesis at Silwood Park. Finally, thanks to my wife, relatives and friends for their invaluable moral support.

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APPENDIX I

COTTON PEST MANAGEMENT

SURVEY QUESTIONNAIRE

Date________________

Location_____________

Farm No._____________

SECTION A - BACKGROUND INFORMATION

1. What was the total cultivated area of your farm this year (hectares)?
2. What crops do you grow at your farm and how much is the area under each crop (hectares)?

Crops	Area	Crops	Area
Cotton		Soyabean	
Maize		Vegetables	
Sunflower		Fruits	
Groundnuts		Others	

3. Do you keep livestock at your farm (yes or no)? If yes, can you give the number of the following:

   Cattle Goats Pigs

4. How much yield of cotton did you get this year?
5. What proportion (%) of your cotton was grade A - B - C?
6. When did you start cotton growing?
7. Why did you start cotton growing (drought resistance - advice - no fertilizer - good cash crop)?

8. Do you know the nearest cotton grower in your area? If yes how far is he from you (in km)?
9. What do you think is the most important cotton production problem in this area (weeds - insects - harvesting - training)?
10. How do you plan to solve this production problem next year?
11. Would you like to increase or decrease your cotton area next year?
12. What do you think is the main reason for increasing or decreasing your cotton area?

SECTION B - PEST CONTROL

13. Here are some specimens and photographs of insects which are often found on cotton crops. Which ones did you have at your farm and how worst do you think they were (1st worst - 2nd worst - 3rd worst)?

Pests	Presence	Importance	Pests	Presence	Importance
Aphids			American bollworm		
Jassids			Red bollworms		
Whiteflies			Spiny bollworms		
Stainers			Termites		
Mites			Grasshoppers		

14. Did you spray your cotton crop with insecticides this year (Yes or No)?
15. If yes what percentage of your cotton yield do you think you would have lost if it was not sprayed?
16. What grade do you think you would have got if cotton crop was not sprayed (A - B - C)?

17. What types of insecticides (cotton packs) did you use to control insects this year (conventional pack - ripcord - decis - others)?
18. Why did you use these particular types of insecticides (availability - advice - effectiveness - experience)?
19. How efficient (%) do you think these insecticides are for the control of cotton insects (100% - 90%....)?
20. How many times did you spray your cotton crop this year?
21. Do you want to increase or decrease the number of spray applications next year?
22. What do you think is the reason for increasing or decreasing the number of spray applications next year?
23. Do you scout (observe) insects on cotton crop to decide about timing of spray applications (Yes or No)?
24. If yes, how do you normally scout?
25. Can you distinguish between eggs and larvae of the following insects on cotton?

    American bollworm

    Red bollworm

    Spiny bollworm
26. Can you suggest how the scouting of insects for spraying cotton can be improved?
27. How do you decide when to start spraying for your cotton crop (weeks after planting - observing pests - instructions on insecticide packs)?
28. How do you decide when to stop spraying cotton at your farm (opening of bolls - number of spray applications - others)?
29. What methods can you use other than insecticides to control cotton insects?

30. Do you think some insects can be good on your crop? If yes, how?
31. Do you include cotton in rotation with other crops (Yes or No)?
32. If yes, what is the main benefit of rotation?
33. What do you think is the main reason for destroying cotton plants after harvest?
34. How do you control weeds of cotton (hand weeding - oxen - herbicides)?
35. How many weedings did you do this year (if hand weeded)?

SECTION C - APPLICATION OF PESTICIDES

36. What type of sprayer did you use for spraying your cotton crop this year (type - brand - capacity)?
37. How efficient (%) do you think this sprayer is (which you used) for the control of cotton insects (100%, 90%.....)?
38. When did you buy this machine?
39. Has it given you any problem since you bought it (Yes or No)? If yes, what was the major problem?
40. Can you always get its spare parts?
41. Do you use your sprayer for the control of insects on other crops vegetables - cattle - your house?
42. From where do you get water for spraying your cotton crop (rain water - drinking water - streams - other sources)?
43. How far is the above water source from your field (Km)?
44. Do you know about the following sprayers? Knapsacks (single nozzle - double nozzle - tailboom)

    ULV (battery operated)

    'Electrodyn'

    Oxen driven

Tractor mounted

45. If yes, why did you prefer the particular machine (which you used) and not the alternatives?

ULV

'Electrodyn'

Tailboom

Oxen driven

Others

46. Who does the spraying on your cotton crop (yourself - wife - sons - hired workers)? Any reason for it.

47. How do you think you can make your spraying more effective?

SECTION D - SAFETY PRECAUTIONS

48. Do you know about protective clothing for spraying (overalls - gloves - others)?

49. What do you (or others) normally wear when spraying cotton at your farm (used clothes - ordinary clothes)?

50. What other safety precautions do you think are necessary during spraying (avoid inhalation - others)?

51. Where do you store your insecticides and spray machines when not in use?

52. Can you tell us - how do you measure insecticides before you put them in sprayer?

53. Do you think you have ever suffered from illness due to spraying (Yes or No). If yes, under what circumstances did it happen?

54. What action do you think you should take if you ever feel sick due to spraying insecticides?

SECTION E - ADVICE

55. Did you ever receive any training on the control of cotton insects (Yes or No)?

56. If yes, what was it about (scouting - spraying - safety - precautions)?

57. Do you know the extension worker of your area (Yes or No). If yes, how many times did you see him during this cotton season?

58. Do you know the contact farmer of this area? (Yes or No). If yes, how many times did you see him during this cotton season?

59. What additional advice would you like from extension worker - contact farmer (scouting - spraying - others)?

60. Do you remember any demonstration on insect control by Shell Chemicals, ICI or any other organizations (Yes or No). If yes, how useful was it?

61. What are your other sources of advice on cotton pest control (other farmers, field days, leaflets, mass media, private companies)?

62. Can you suggest as how the present extension service on cotton pest control can be improved?

APPENDIX 2

Table 1. Mean number of American bollworm eggs per plant in scouting trial (1985-86).

Timing of (1) application	Chems.(2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)											
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18
Scouting 0.25 eggs	Cyp/ED	30	.57	.74	.72	.95	.91a	.85ab	.88a	.91a	.97a	.81a	.84a	.82ab
Scouting 0.50 eggs	Cyp/ED	30	.63	.74	.74	1.06	.91a	.80a	.91a	.85a	1.05a	.88a	.77a	.75a
Five appl.	Cyp/ED	30	.58	.74	.76	.93	.89a	.89abc	.87a	.87a	1.20a	.85a	.79a	.80ab
Four appl. (3 weeks int.)	Cyp/ED	30	.57	.82	.74	1.03	.93a	1.01c	.89a	.86a	.94a	.86a	.80a	.79a
Control	-	-	.91	.74	.72	.92	1.08b	.99bc	1.0b	1.14b	1.24b	1.13b	1.13b	.93b

1. Scouting based upon eggs of American bollworm. In case of four applications, the sprays were applied at 3 week intervals starting from 7th week after the germination of cotton.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W18 are weekly scouting occasions during the spraying period.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 2 (Continued)

Table 2. Mean number of American bollworm eggs per plant in scouting trial (1986-87).

Timing of application (1)	No. of spray	Chems./ sprayer (2)	a.i. g/ha/	Scouting Occasions (weeks after germination) (3)										
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
7 Weeks	5	Cyp/ED	30	.86	.89ab	.98	.93abc	.86a	.90a	.86	.85ab	.76	.76a	.73a
9 Weeks	4	Cyp/ED	30	.82	.85a	.94	.92ab	.88a	.85a	.82	.77a	.85	.73a	.74a
11 Weeks	3	Cyp/ED	30	.80	.97b	1.17	.87a	.85a	.84a	.86	.82ab	.92	.74a	.74a
Scouting 0.25 eggs	6	Cyp/ED	30	.86	.96b	.92	1.04cd	.94ab	.90a	.87	.80ab	.76	.76a	.74a
Scouting 0.50 eggs	2	Cyp/ED	30	.85	.98b	.91	1.06d	.96ab	.87a	1.01	.86ab	.79	.79a	.74a
Four applic. (3 weeks int.)	4	Cyp/ED	30	.84	.94ab	.89	.95abc	.89a	.84a	.80	.90b	.77	.74a	.76a
Control	-	-	-	.86	.94ab	1.10	.99bcd	1.03b	1.11b	.93	1.15c	1.05	1.02b	.94b

1. Weeks after germination. 0.25 and 0.50 eggs per plant are <u>Heliothis</u> thresholds.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 2 (continued)

Table 3. Mean number of American bollworm eggs per plant in reduced number of sprays trial (1985-86).

Timing of (1) application	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
7 Weeks	Cyp/ED	30	.75	.74	.89	.79ab	.86	.79a	.88a	.88a	.85a	.84ab
9 Weeks	Cyp/ED	30	.75	.72	.85	.89b	.86	.88a	.83a	.89a	.82a	.79a
11 Weeks	Cyp/ED	30	.72	.74	.88	.82ab	.88	.82a	.96a	.89a	.83a	.74a
7 Weeks	Cyh/ED	12	.74	.74	.88	.84ab	.89	.86a	.87a	.89a	.79a	.76a
9 Weeks	Cyh/ED	12	.82	.76	.91	.88b	.89	.82a	.86a	.89a	.82a	.82ab
11 Weeks	Cyh/ED	12	.79	.79	.88	.76a	.88	.89a	.82a	.88a	.77a	.77a
Control	-	-	.72	.77	.89	.85ab	.96	1.07b	1.06b	1.30b	1.16b	.93b

1. Weeks after germination.
2. Cyp - cypermethrin, Cyh - lambda cyhalothrin
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 2 (continued)

Table 4. Mean number of American bollworm eggs per plant in reduced number of sprays trial (1986-87).

Timing of (1) application	No. of Spray Applic.	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
7 Weeks	5	Cyp/ED	30	.89	.88	.87	.93	.87a	.92ab	.77	.80a	.82a	.76a
9 Weeks	4	Cyp/ED	30	.84	.85	.92	.97	.91a	.86a	.80	.81a	.79a	.79a
11 Weeks	3	Cyp/ED	30	.80	.83	.91	.93	.87a	.81a	.80	.82a	.79a	.82a
Control	-	-	-	.89	.89	.98	.99	1.11b	1.04b	.81	1.09b	1.08b	1.03b

1. Weeks after germination.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 3

Table 1. Mean number of American bollworm larvae per plant in scouting trial (1985-86).

Timing of (1) application	Chems.	a.i. (2) g/ha/ spray	Scouting Occasions (weeks after germination) (3)						
			W12	W13	W14	W15	W16	W17	W18
Scouting 0.25 eggs	Cyp/ED	30	.79	.79	.84a	.70	.70	.71a	.72a
Scouting 0.50 eggs	Cyp/ED	30	.77	.81	.76a	.70	.70	.72a	.80a
Five appl.	Cyp/ED	30	.79	.74	.74a	.70	.70	.71a	.77a
Four appl. (3 weeks int.)	Cyp/ED	30	.77	.77	.74a	.70	.70	.74a	.72a
Control	-	-	.82	.91	1.06b	.97	.97	1.14b	1.08b

1. Scouting based upon eggs of American bollworm. In case of four applications, the sprays were applied at 3 week intervals starting from 7th week after the germination of cotton.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W12 to W18 are weekly American bollworm during the spraying period.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 3 (continued)

Table 2. Mean number of American bollworm larvae per plant in scouting trial (1986-87).

Timing of (1) application	No. of spray	Chems./(2) sprayer	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
7 Weeks	5	Cyp/ED	30	.83a	.80	.83	.87	.82ab	.80	.77	.82	.74	.73	.71
9 Weeks	4	Cyp/ED	30	.85ab	.85	.83	.88	.70a	.80	.79	.81	.74	.76	.74
11 Weeks	3	Cyp/ED	30	.97b	.79	.83	.85	.88b	.80	.79	.74	.78	.71	.72
Scouting 0.25 eggs	6	Cyp/ED	30	.86ab	.71	.79	.78	.83ab	.77	.72	.72	.74	.74	.74
Scouting 0.50 eggs	2	Cyp/ED	30	.82a	.79	.86	.90	.82ab	.84	.82	.71	.71	.74	.74
Four applic. (3 weeks int.)	4	Cyp/ED	30	.88ab	.89	.83	.88	.87b	.80	.74	.79	.72	.81	.77
Control	-	-	-	.78a	.85	.92	.96	1.12c	1.39	1.10	.96	1.25	1.11	1.12

1. Weeks after germination. 0.25 and 0.50 eggs per plant are Heliothis thresholds.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 3 (continued)

Table 3. Mean number of American bollworm larvae per plant in reduced number of sprays trial (1985-86).

Timing of application (1)	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)				
			W12	W13	W14	W15	W16
7 Weeks	Cyp/ED	30	.71	.72a	.77a	.71a	.77
9 Weeks	Cyp/ED	30	.72	.71a	.71a	.71a	.71
11 Weeks	Cyp/ED	30	.71	.74a	.74a	.74a	.74
7 Weeks	Cyh/ED	12	.71	.72a	.74a	.77a	.74
9 Weeks	Cyh/ED	12	.72	.72a	.74a	.74a	.72
11. Weeks	Cyh/ED	12	.72	.82a	.76a	.74a	.76
Control	-	-	.71	1.21b	1.26b	1.30b	.96

1. Weeks after germination.
2. Cyp - cypermethrin, Cyh - lambda cyhalothrin
3. W12 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 3 (continued)

Table 4. Mean number of American bollworm larvae per plant in reduced number of sprays trial (1986-87).

Timing of (1) application	No. of Spray Applic.	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
7 Weeks	5	Cyp/ED	30	.65	.77ab	.80	.77a	.84	.76a	.79a	.71a	.72	.74
9 Weeks	4	Cyp/ED	30	.76	.72a	.76	.76a	.79	.74a	.79a	.71	.71	.73
11 Weeks	3	Cyp/ED	30	.87	.81bc	.85	.97b	.95	.78a	.72a	.74	.71	.71
Control	-	-	-	.86	.87c	.86	1.06b	1.01	1.01b	1.18b	1.05	1.20	1.06

1. Weeks after germination.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 4

Table 1. Mean number of aphids per plant in scouting trial (1985-86).

Timing of (1) application	Chems.(2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)											
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18
Scouting 0.25 eggs	Cyp/ED	30	4.50	2.19b	6.13	5.90	8.20b	6.54	2.60ab	3.58b	2.78ab	.95a	1.73a	1.75a
Scouting 0.50 eggs	Cyp/ED	30	3.03	3.78c	5.35	7.63	9.63b	7.58	2.45ab	3.88b	3.85b	.95a	1.68a	1.45a
Five appl.	Cyp/ED	30	4.48	.55a	4.27	5.40	8.78b	7.13	2.15a	3.88b	2.15a	1.13a	1.38a	1.43a
Four appl. (3 weeks int.)	Cyp/ED	30	3.95	.43a	3.83	5.35	5.0a	7.43	2.85ab	2.05a	3.85b	1.43a	1.08a	1.55a
Control	-	-	3.23	2.88bc	6.15	9.07	8.43b	9.03	4.15b	6.28c	7.52c	4.35b	4.43b	3.88b

1. Scouting based upon eggs of American bollworm. In case of four applications, the sprays were applied at 3 week intervals starting from 7th week after the germination of cotton.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W18 are weekly scouting occasions during the spraying period. Ten plants observed per plot (2 leaves from top, middle and bottom of each plant).
4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 4 (continued)

Table 2. Mean number of aphids per plant in scouting trial (1986-87).

Timing of (1) application	No. of Spray	Chems./ (2) sprayer	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
7 Weeks	5	Cyp/ED	30	16.35bc	18.93	19.15	19.40	20.48	22.90a	11.43a	6.73a	5.65a	4.53a	2.95ab
9 Weeks	4	Cyp/ED	30	12.85a	18.32	19.33	16.82	21.00	21.88a	12.70a	9.65b	6.63ab	4.10a	2.63a
11 Weeks	3	Cyp/ED	30	17.07bc	20.13	18.55	20.15	20.70	20.05a	12.68a	11.18bc	8.08b	4.55a	4.00b
Scouting 0.25 eggs	6	Cyp/ED	30	15.42b	17.47	17.73	19.53	18.95	21.55a	9.00a	11.77bc	6.63ab	5.40a	3.45ab
Scouting 0.50 eggs	2	Cyp/ED	30	17.35bc	18.62	19.10	19.58	19.03	21.75a	12.65a	10.70bc	6.60ab	6.13a	3.18ab
Four applic. (3 weeks int.)	4	Cyp/ED	30	17.98c	17.07	18.57	18.95	20.80	21.88a	12.00a	12.15c	7.43ab	4.95a	3.43ab
Control	-	-	-	17.95bc	19.93	21.28	23.40	22.68	27.67b	28.40b	29.03d	29.7c	28.48b	27.78c

1. Weeks after germination. 0.25 and 0.50 eggs per plant are Heliothis thresholds.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).

4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 4 (continued)

Table 3. Mean number of aphids per plant in reduced number of sprays trial (1985-86).

Timing of (1) application	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
7 Weeks	Cyp/ED	30	3.60	1.30a	6.38a	6.38a	7.88ab	3.53a	.50a	1.20a	1.63abc	1.43a
9 Weeks	Cyp/ED	30	3.28	2.10	5.35a	6.55a	6.40a	3.93a	.53a	1.23a	1.07a	1.40a
11 Weeks	Cyp/ED	30	3.83	2.05	8.78ab	6.98a	7.28ab	3.73a	.90a	1.35a	1.25ab	1.25a
7 Weeks	Cyh/ED	12	3.60	1.67	5.15a	7.63a	7.13ab	3.70a	1.30a	1.13a	1.45abc	1.43a
9 Weeks	Cyh/ED	12	3.67	1.93	6.13a	6.25a	4.92a	3.30a	.55a	1.28a	1.80bc	1.23a
11 Weeks	Cyh/ED	12	4.65	1.35	10.98b	7.70a	4.18a	2.88a	.68a	1.30a	2.08c	1.52a
Control	-	-	3.43	2.75	6.23a	14.28b	11.40b	6.03b	4.35b	4.53b	4.63d	3.90b

1. Weeks after germination.
2. Cyp - cypermethrin, Cyh - lambda cyhalothrin
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 4 (continued)

Table 4. Mean number of aphids per plant in reduced number of sprays trial (1986-87).

Timing of (1) application	No. of Spray Applic.	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
7 Weeks	5	Cyp/ED	30	8.60	15.45ab	17.31a	18.50a	17.20a	14.78	10.51a	8.83a	3.95a	1.83a
9 Weeks	4	Cyp/ED	30	9.10	14.13a	15.83a	18.05a	18.42ab	17.95b	14.43b	9.22a	5.98a	1.82a
11 Weeks	3	Cyp/ED	30	9.28	17.48b	19.10ab	19.43a	20.55bc	19.00b	13.45b	9.28a	5.00a	2.48a
Control	-	-	-	8.80	18.3b	22.08b	21.83b	21.23c	26.65c	30.65c	30.10b	31.75b	35.63b

1. Weeks after germination.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).

4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 5

Table 1. Mean number of mummified aphids per plant in scouting trial (1985-86).

Timing of (1) application	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)											
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18
Scouting 0.25 eggs	Cyp/ED	30	.70	.70	.80	.71	1.02a	1.78	1.45	1.63	1.44	1.02ab	1.28b	1.20b
Scouting 0.50 eggs	Cyp/ED	30	.70	.70	.77	.74	.98a	1.48	1.10	1.71	1.37	1.64ab	1.14ab	1.24b
Five appl.	Cyp/ED	30	.70	.72	.71	.72	.77a	1.38	1.22	1.55	1.38	1.08b	1.01a	1.20b
Four appl. 3 week int.	Cyp/ED	30	.72	.70	.71	.74	1.08a	1.33	1.51	1.39	1.35	.90a	.93a	1.02a
Control	-	-	.70	.70	.31	.71	1.40b	1.60	1.32	1.55	1.40	1.08b	1.28b	1.16b

1. Scouting based upon eggs of American bollworm. In case of four applications, the sprays were applied at 3 week intervals starting from 7th week after the germination of cotton.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W18 are weekly scouting occasions during the spraying period. Ten plants observed per plot (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 5 (continued)

Table 2. Mean number of mummified aphids per plant in scouting trial (1986-87).

Timing of (1) application	No. of spray	Chems./ (2) sprayer	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
7 Weeks	5	Cyp/ED	30	1.53ab	1.96	2.15	3.05	2.33	2.44a	2.47ab	2.75a	3.13bc	3.22	2.72a
9 Weeks	4	Cyp/ED	30	1.66ab	1.70	2.04	2.32	2.27	2.56a	2.71c	2.96a	3.29cd	3.24	3.02a
11 Weeks	3	Cyp/ED	30	1.74b	1.72	2.09	3.30	2.24	2.59a	2.34a	2.92a	2.99abc	3.38	2.90a
Scouting 0.25 eggs	6	Cyp/ED	30	1.51ab	1.66	2.01	2.26	2.38	2.51a	2.45abc	3.20ab	2.69a	3.17	3.05a
Scouting 0.50 eggs	2	Cyp/ED	30	1.77b	1.49	2.03	1.93	2.28	2.45a	2.68ac	3.14ab	2.74ab	3.21	2.91a
Four applic. (3 weeks int.)	4	Cyp/ED	30	1.40a	1.66	1.75	2.20	2.09	2.79ab	2.34ab	3.03a	2.92abc	3.27	2.82a
Control	-	-	-	1.54ab	1.79	2.24	2.46	2.46	3.01b	3.13d	3.56b	3.5d	3.39	3.90b

1. Weeks after germination. 0.25 and 0.50 eggs per plant are *Heliothis* thresholds.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 5 (continued)

Table 3. Mean number of mummified aphids per plant in reduced number of sprays trial (1985-86).

Timing of (1) application	Chems.(2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
7 Weeks	Cyp/ED	30	.71	.72	.93	1.08ab	1.61bc	1.07	1.01a	.82ab	1.04a	1.27
9 Weeks	Cyp/ED	30	.71	.74	.72	1.50b	1.41abc	1.30	1.02a	.89bc	1.11a	1.27
11 Weeks	Cyp/ED	30	.74	.74	.90	1.47ab	1.76c	1.18	0.86a	.72a	.94a	1.18
7 Weeks	Cyh/ED	12	.71	.74	.72	.99a	1.11a	1.10	0.98a	.77ab	1.02a	1.23
9 Weeks	Cyh/ED	12	.74	.72	.99	1.50b	1.15a	1.13	0.79a	.77ab	.98a	1.20
11 Weeks	Cyh/ED	12	.71	.75	.92	1.12ab	1.60bc	1.11	.99a	.90bc	.93a	1.11
Control	-	-	.72	.72	1.03	1.20ab	1.24ab	1.19	1.33b	1.02c	1.41b	1.25

1. Weeks after germination.
2. Cyp - cypermethrin, Cyh - lambda cyhalothrin
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 5 (continued)

Table 4. Mean number of mummified aphids per plant in reduced number of sprays trial (1986-87).

Timing of (1) application	No. of Spray Applic.	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
7 Weeks	5	Cyp/ED	30	1.35	1.64	1.97	2.04	2.33	2.29a	1.91a	2.32a	2.65a	3.03a
9 Weeks	4	Cyp/ED	30	1.52	1.64	1.77	1.92	2.22	2.49ab	2.26b	2.22a	2.86a	3.10a
11 Weeks	3	Cyp/ED	30	1.46	1.60	1.75	1.93	2.32	2.30a	2.19ab	2.24a	2.59a	3.12a
Control	-	-	-	1.36	1.41	1.94	2.23	2.37	2.78b	2.73c	3.40b	3.49b	3.75b

1. Weeks after germination.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 6

Table 1. Mean number of jassids per plant in scouting trial (1985-86).

Timing of (1) application	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
Scouting 0.25 eggs	Cyp/ED	30	1.96ab	1.57bc	2.09b	1.70a	1.44b	.72	.76a	.76	.89a	.72a	.71
Scouting 0.50 eggs	Cyp/ED	30	2.04ab	1.32b	2.09b	1.66	1.36ab	.71	.82a	.71	.77a	.79a	.74
Five appl.	Cyp/ED	30	1.75a	1.30b	1.92b	1.65	1.45b	.74	.72a	.74	.82a	.74a	.79
Four appl. (3 weeks int.)	Cyp/ED	30	2.46b	.84a	1.57a	1.44	1.10a	.71	.85a	.77	.79a	.72a	.71
Control	-	-	1.54a	1.70c	2.17b	1.86	2.02c	1.18	1.37b	1.41	1.56b	.92b	1.10

1. Scouting based upon eggs of American bollworm. In case of four applications, the sprays were applied at 3 week intervals starting from 7th week after the germination of cotton.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants observed per plot (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 6 (continued)

Table 2. Mean number of jassids per plant in scouting trial (1986-87).

Timing of (1) application	No. of spray	Chems./ (2) sprayer	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
7 Weeks	5	Cyp/ED	30	1.53	1.45ab	1.78	1.41a	1.55	1.50a	1.22	.85a	.77a	.71	.77
9 Weeks	4	Cyp/ED	30	1.25	1.37a	1.84	1.47a	1.41	1.51a	1.47	1.22a	.78a	.80	.71
11 Weeks	3	Cyp/ED	30	1.43	1.78c	1.89	1.50ab	1.41	1.58a	1.24	1.02a	.76a	.72	.71
Scouting 0.25 eggs	6	Cyp/ED	30	1.26	1.44ab	1.76	1.30a	1.48	1.62a	1.28	1.24a	.74a	.74	.73
Scouting 0.50 eggs	2	Cyp/ED	30	4.39	1.54abc	1.82	1.44a	1.28	1.41a	1.31	.89a	.74a	.74	.74
Four applic. (3 weeks int.)	4	Cyp/ED	30	1.34	1.2a	1.46	1.29a	1.42	1.54a	1.31	.94a	.78a	.73	.74
Control	-	-	-	1.47	1.69bc	1.95	1.84b	1.55	1.98b	1.60	1.91b	1.37b	1.10	1.26

1. Weeks after germination. 0.25 and 0.50 eggs per plant are Heliothis thresholds.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 6 (continued)

Table 3. Mean number of jassids per plant in reduced number of sprays trial (1985-86).

Timing of (1) application	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
7 Weeks	Cyp/ED	30	1.77	1.51a	1.54	.89	.76	.79	.72	.72a	.77	.75
9 Weeks	Cyp/ED	30	2.05	1.32a	1.44	.86	.71	.77	.71	.76a	.76	.71
11 Weeks	Cyp/ED	30	2.41	1.66a	1.68	.80	.72	.92	.71	.76a	.77	.74
7 Weeks	Cyh/ED	12	2.12	1.60a	1.47	.86	.82	.72	.71	.76a	.77	.71
9 Weeks	Cyh/ED	12	2.01	1.68ab	1.45	1.03	.74	.77	.71	.79a	.74	.72
11 Weeks	Cyh/ED	12	2.12	1.60a	1.59	.85	.71	.71	.71	.76a	.79	.71
Control	-	-	1.86	2.01b	1.51	1.14	1.37	1.09	.99	.91b	.91	1.20

1. Weeks after germination.
2. Cyp - cypermethrin, Cyh - lambda cyhalothrin
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 6 (continued)

Table 4 . Mean number of jassids per plant in reduced number of sprays trial (1986-87).

Timing of (1) application	No. of Spray Applic.	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
7 Weeks	5	Cyp/ED	30	1.22	1.26	1.35ab	1.71a	1.38a	1.48ab	1.17a	1.22a	.84a	.73a
9 Weeks	4	Cyp/ED	30	1.31	1.15	1.02a	1.73a	1.24a	1.32a	1.17a	1.00a	.95a	.73a
11 Weeks	3	Cyp/ED	30	1.16	1.42	1.67b	1.81	.96a	1.32a	1.17a	1.28a	.84a	.74a
Control	-	-	-	1.29	1.38	1.77b	2.11b	1.95b	2.06b	1.80b	1.84b	1.38b	1.18b

1. Weeks after germination.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 7

Table 1. Mean number of whiteflies per plant in scouting trial (1985-86).

Timing of (1) application	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)											
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18
Scouting 0.25 eggs	Cyp/ED	30	.85	.60	1.02	.95	.95	.88a	.80ab	1.09	1.21ab	.79a	.96	1.02a
Scouting 0.50 eggs	Cyp/ED	30	.83	.93	1.03	.95	.93	.78a	.79ab	1.0	1.02a	.86ab	.93	1.00a
Five appl.	Cyp/ED	30	.89	.98	1.03	1.0	1.04	.91a	.72a	1.11	1.06a	.88ab	.93	.93a
Four appl. (3 weeks int.)	Cyp/ED	30	.79	.65	.98	.97	1.0	1.10b	.85b	1.03	1.05a	.84ab	.80	.91a
Control	-	-	.84	.90	1.02	1.11	1.0	.84a	1.08c	1.45	1.38b	1.03ab	1.14	1.22b

1. Scouting based upon eggs of American bollworm. In case of four applications, the sprays were applied at 3 week intervals starting from 7th week after the germination of cotton.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W18 are weekly scouting occasions during the spraying period. Ten plants observed per plot (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 7 (continued)

Table 2. Mean number of whiteflies per plant in scouting trial (1986-87).

Timing of (1) application	No. of spray	Chems./(2) sprayer	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
7 Weeks	5	Cyp/ED	30	1.25	1.42	1.65	1.77	1.67	1.34a	1.39a	1.78a	1.61a	.83a	.87a
9 Weeks	4	Cyp/ED	30	1.30	1.47	1.69	1.71	1.74	1.38a	1.53a	1.64a	1.65a	1.03a	.91a
11 Weeks	3	Cyp/ED	30	1.33	1.36	1.64	1.66	1.46	1.41a	1.50	1.60a	1.50a	1.00a	.97a
Scouting 0.25 eggs	6	Cyp/ED	30	1.19	1.23	1.68	1.69	1.57	1.34a	1.54a	1.65a	1.54a	.90a	1.04a
Scouting 0.50 eggs	2	Cyp/ED	30	1.45	1.41	1.63	1.63	1.48	1.33a	1.76a	1.47a	1.49a	.98a	.84a
Four applic. (3 weeks int.)	4	Cyp/ED	30	1.22	1.12	1.72	1.73	1.48	1.23a	1.54a	1.85a	1.42a	.96a	.81a
Control	-	-	-	1.31	1.14	1.72	1.63	1.63	1.83b	2.16b	2.5b	2.43b	1.73b	2.31b

1. Weeks after germination. 0.25 and 0.50 eggs per plant are Heliothis thresholds.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 7 (continued)

Table 3. Mean number of whiteflies per plant in reduced number of sprays trial (1985-86).

Timing of (1) application	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
7 Weeks	Cyp/ED	30	.72	1.19	.98	.90a	.82a	.65	.71	1.02bc	1.05a	.86a
9 Weeks	Cyp/ED	30	.90	1.11	1.04	.98ab	.86a	1.28	.76	.93abc	1.07ab	.97a
11 Weeks	Cyp/ED	30	.72	1.15	1.02	.97ab	.82a	.90	.74	.90ab	.97a	.93a
7 Weeks	Cyh/ED	12	.80	1.11	1.0	1.18b	.82a	.73	.78	.83a	1.09ab	1.01a
9 Weeks	Cyh/ED	12	.80	1.0	1.10	1.12ab	.85a	.73	.92	.92a	1.01a	.98a
11 Weeks	Cyh/ED	12	.80	1.19	1.02	1.01ab	.80a	.73	.72	1.03bc	1.03a	.89a
Control	-	-	.83	1.04	.93	1.17ab	1.22b	1.93	1.34	1.10c	1.24b	1.22b

1. Weeks after germination.
2. Cyp - cypermethrin, Cyh - lambda cyhalothrin
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 7 (continued)

Table 4. Mean number of whiteflies per plant in reduced number of sprays trial (1986-87).

Timing of (1) application	No. of Spray Applic.	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
7 Weeks	5	Cyp/ED	30	1.19	1.45	1.34	1.24	1.63ab	1.53a	1.41	1.23a	1.40a	1.21a
9 Weeks	4	Cyp/ED	30	1.13	1.33	1.28	1.62	1.73a	1.65ab	2.20	1.19a	1.39a	1.14a
11 Weeks	3	Cyp/ED	30	1.19	1.31	1.27	1.61	1.51ab	1.54a	1.38	1.35a	1.32a	1.20a
Control	-	-	-	1.35	1.28	1.36	1.61	1.71b	1.86b	1.90	2.11b	2.86b	2.33b

1. Weeks after germination.
2. Cyp - cypermethrin, ED - 'Electrodyn'
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 8

Table 1. Mean number of American bollworm eggs per plant in trial 1 for the comparison of application techniques (1986-87).

Sprayers (1)	No. of Spray	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
'Electrodyn' (5 appl.)	5	Cyp	30	.85	.85	.97	.92	.90	.87	.81a	.78a	.80a	.40	.74a
Knapsack (5 appl.)	5	Cyp	30	.89	.88	.97	.92	.95	.85	.88a	.80a	.87a	.80	.72a
ULV (5 appl.)	5	Cyp	30	.82	.86	.98	.92	.95	.93	.88a	.76a	.68a	.77	.74a
'Electrodyn' (Scouting)	3	Cyp	30	.91	.91	.96	1.01	1.05	.91	1.0b	.84a	.66a	.79	.76a
Knapsack (Scouting)	3	Cyp	30	.79	.86	.95	1.05	1.00	.92	1.0b	.78a	.82a	.76	.74a
ULV (Scouting)	2	Cyp	30	.85	.91	.98	1.04	.95	.92	1.0b	.79a	.86a	.72	.74a
Control	-	-	-	.86	.94	1.00	1.02	1.08	1.00	1.0b	1.07b	1.11b	.97	.90b

1. Scouting based upon the eggs of American bollworm (0.50 eggs per plant).
2. Cyp - cypermethrin.
3. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 8 (continued)

Table 2. Mean number of American bollworm eggs per plant in trial 2 for the comparison of application techniques (1985-86 Site 1).

Sprayers	Chems.(1)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (2)										
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
'Electrodyn'	Cyp	30	.77	.72	.85	.72	.91ab	.91ab	.82a	.91a	.84ab	.74a	.79ab
Knapsack	Cyp	30	.78	.71	.88	.71	.91ab	.98b	.94ab	.88a	.77a	.74a	.74a
ULV	Cyp	30	.72	.74	.89	.74	.82a	.25a	.88a	.86a	.96c	.76a	.77ab
'Electrodyn'	Cyh	12	.72	.72	.88	.72	.82a	.89ab	.88a	.89a	.83ab	.74a	.76a
Knapsack	Cyh	12	.71	.03	.83	.72	.82a	.86a	.96ab	.86a	.88abc	.76a	.74a
ULV	Cyh	12	.80	.74	.87	.74	.85ab	.91ab	.94ab	.85a	.88abc	.76a	.72a
Control I	End	250	.71	.71	.86	.71	.94b	.95ab	1.06b	.95a	.91bc	.77a	.72a
Control 2	-	-	.71	.71	.88	.71	1.08c	1.14c	1.08b	1.20b	1.08d	1.13b	.85b

1. Cyp - cypermethrin, Cyh - lambda cyhalothrin, End- Endosulfan.
2. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot.
3. The data transformed into $\sqrt{y + \frac{1}{2}}$
4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 8 (continued)

Table 3. Mean number of American bollworm eggs per plant in trial 3 for the comparison of application techniques (1986-87 Site 2).

Sprayers	Chems.(1)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (2)											
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18
'Electrodyn'	Cyp	30	.75	.85bc	.79	.85	.97a	.86a	1.0a	.86a	.84a	.87a	.76a	.77
Knapsack	Cyp	30	.71	.84abc	.79	.84	.93a	1.0a	.91a	.82a	.83a	.82a	.79ab	.76
ULV	Cyp	30	.71	.76ab	.83	.86	1.07ab	.92a	.89a	.89a	.77a	.91a	.76a	.74
'Electrodyn'	Cyh	12	.71	.81abc	.92	.90	.92a	.95a	.94a	.84a	.89ab	.83a	.83a	.77
Knapsack	Cyh	12	.72	.82abc	.80	.88	.97a	.13a	.88a	.88a	.91ab	.88a	.88ab	.83
ULV	Cyh	12	.71	.74a	.92	.86	.96a	.91a	.86a	.85a	.91ab	.85a	.82ab	.77
Control I	End	250	.74	.88c	.85	.82	1.01a	.94a	1.01ab	.85a	.89ab	.82a	.86bc	.77
Control 2	-	-	.74	.81abc	.86	1.02	1.16b	1.17b	1.15b	1.06b	.99b	1.06b	.92c	.81

1. Cyp - cypermethrin, Cyh - lambda cyhalothrin, End- Endosulfan.
2. W7 is a prespray observation, and W8 to W18 are weekly scouting occasions during the spraying period. Ten plants were observed per plot.
3. The data transformed into $\sqrt{y + \frac{1}{2}}$
4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 8 (continued)

Table 4. Mean number of American bollworm eggs per plant in trial 4 for the comparison of application techniques (1986-87).

Sprayers (1)	No. of Spray	Chems.	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
Knapsack (5 appl.)	5	Cyp	30	.89	1.01	.94a	.94c	.77a	.96	.82a	.77a	.74a	.71
Knapsack (5 appl.)	5	Cyp	60	.88	1.04	.88a	.88bc	.82a	.89	.79a	.74a	.73a	.71
'Electrodyn' (5 appl.)	5	Cyp	30	.90	.98	.86a	.77a	.79a	.86	.74a	.76a	.76a	.71
'Electrodyn' (scouting)	2	Cyp	30	1.01	1.08	1.04b	.88bc	.86ab	.84	.98b	.74a	.76a	.73
Control	-	-	-	.96	1.04	.90a	.85b	.94b	1.03	1.04b	1.04b	.93b	1.04

1. Scouting based upon the eggs of Heliothis (0.50 eggs per plant).
2. Cyp - cypermethrin.
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 9

Table 1. Mean number of American bollworm larvae per plant in trial 1 for the comparison of application techniques (1986-87).

Sprayers (1)	No. of Sprays	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
'Electrodyn' (5 appl.)	5	Cyp	30	.82	.77	.79	.79a	.88ab	.85	.79a	.76a	.73	.74a	.72
Knapsack (5 appl.)	5	Cyp	30	.83	.79	.76	.82ab	.77a	.84	.76a	.72a	.71	.74a	.72
ULV (5 appl.)	5	Cyp	30	.93	.82	.76	.82ab	.91b	.85	.74a	.76a	.71	.72a	.77
'Electrodyn' (Scouting)	3	Cyp	30	.79	.85	.79	.85ab	.82ab	.84	.78a	.72a	.72	.74a	.71
Knapsack (Scouting)	3	Cyp	30	.79	.91	.79	.89bc	.82ab	.79	.77a	.76a	.73	.72a	.72
ULV (Scouting)	2	Cyp	30	.79	.88	.77	.85ab	.92b	.86	.79a	.74a	.77	.72a	.74
Control	-	-	-	.79	.69	.85	.96c	1.16c	1.14	1.17b	1.26	1.20	1.18b	1.20

1. Scouting based upon the eggs of American bollworm (0.50 eggs per plant).
2. Cyp - cypermethrin.
3. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 9 (continued)

Table 2. Mean number of American bollworm larvae per plant in trial 2 for the comparison of application techniques (1985-86 Site 1).

Sprayers	Chems.(1)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (2)					
			W12	W13	W14	W15	W16	W17
'Electrodyn'	Cyp	30	.71a	.71	.76a	.72	.74a	.74a
Knapsack	Cyp	30	.72a	.71	.72a	.80	.74a	.74a
ULV	Cyp	30	.71a	.71	.77a	.72	.71a	.74a
'Electrodyn'	Cyh	12	.76a	.72	.76a	.72	.71a	.80a
Knapsack	Cyh	12	.76a	.76	.71a	.74	.74a	.82a
ULV	Cyh	12	.71a	.72	.71a	.77	.74a	.82a
Control I	End	250	.79a	.77	.76a	.72	.72a	.74a
Control 2	-	-	.89	.80	.94b	.81	1.02b	1.04b

1. Cyp - cypermethrin, Cyh - lambda cyhalothrin, End- Endosulfan.
2. W12 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot.
3. The data transformed into $\sqrt{y + \frac{1}{2}}$
4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 9 (continued)

Table 3. Mean number of American bollworm larvae per plant in trial 3 for the comparison of application techniques (1986-87 Site 2).

Sprayers	Chems.(1)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (2)							
			W11	W12	W13	W14	W15	W16	W17	W18
'Electrodyn'	Cyp	32	.74	.71	.71	.79a	.71	.74	.79a	.72
Knapsack	Cyp	32	.74	.74	.79	.74a	.71	.76	.76a	.77
ULV	Cyp	32	.77	.72	.79	.76a	.71	.71	.76a	.74
'Electrodyn'	Cyh	12	.74	.71	.71	.77a	.71	.82	.81a	.79
Knapsack	Cyh	12	.72	.71	.72	.76a	.72	.74	.74a	.76
ULV	Cyh	12	.77	.71	.76	.79a	.71	.74	.72a	.77
Control I	End	250	.72	.71	.76	.76a	.74	.85	.80a	.80
Control 2	-	-	.77	.77	.79	.93b	.92	1.09	1.14b	1.20

1. Cyp - cypermethrin, Cyh - lambda cyhalothrin, End- Endosulfan.
2. W11 to W18 are weekly scouting occasions during the spraying period. Ten plants were observed per plot.
3. The data transformed into $\sqrt{y + \frac{1}{2}}$
4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 9 (continued)

Table 4. Mean number of American bollworm larvae per plant in trial 4 for the comparison of application techniques (1986-87).

Sprayers (1)	No. of Spray	Chems.	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
Knapsack (5 appl.)	5	Cyp	30	.85	.83	.82ab	.74a	.77a	.78	.76a	.74	.76ab	.74
Knapsack (5 appl.)	5	Cyp	60	.79	.76	.82ab	.73a	.76a	.74	.74a	.76	.77ab	.71
'Electrodyn' (5 appl.)	5	Cyp	30	.83	.77	.78a	.78a	.74a	.74	.77a	.79	.73a	.73
'Electrodyn' (scouting)	2	Cyp	30	.86	.79	.82ab	.76a	.79a	.77	.72a	.71	.83b	.78
Control	-	-	-	.88	.92	.91b	.99b	1.16b	1.22	1.18b	1.09	1.26c	.98

1. Scouting based upon the eggs of Heliothis (0.50 eggs per plant).
2. Cyp - cypermethrin.
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 10

Table 1. Mean number of aphids per plant in trial 1 for the comparison of application techniques (1986-87).

Sprayers (1)	No. of Spray	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
'Electrodyn' (5 appl.)	5	Cyp	30	11.53	16.35	18.52a	17.87a	19.75a	21.73a	13.48a	8.63a	6.98a	3.97ab	3.18a
Knapsack (5 appl.)	5	Cyp	30	11.70	17.62	17.75a	19.90a	20.48a	21.45a	13.78a	8.63a	5.90a	3.35a	2.95a
ULV (5 appl.)	5	Cyp	30	10.00	18.28	19.65ab	18.42a	21.65ab	20.55a	12.98a	6.76a	6.68a	3.18a	2.55a
'Electrodyn' (Scouting)	3	Cyp	30	11.28	18.83	17.87a	18.20a	19.77a	22.10a	16.2a	10.98a	6.35	5.08b	2.70a
Knapsack (Scouting)	3	Cyp	30	10.85	17.68	18.50a	20.03a	20.87ab	21.82a	16.15a	9.50a	7.72a	4.17ab	2.95a
ULV (Scouting)	2	Cyp	30	10.83	17.23	18.03a	19.25a	20.90ab	21.65a	16.70a	9.10a	7.55a	4.05ab	3.68a
Control	-	-	-	11.68	21.43	20.95b	23.10b	23.10b	28.12b	30.73b	25.38b	30.17b	28.55c	28.83b

1. Scouting based upon the eggs of American bollworm (0.50 eggs per plant).
2. Cyp - cypermethrin.
3. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 10 (continued)

Table 2. Mean number of aphids per plant in trial 2 for the comparison of application techniques (1985-86 Site 1).

Sprayers	Chems.(1)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (2)										
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
'Electrodyn'	Cyp	32	3.18	4.97	9.4ab	8.3a	8.53bc	3.78a	3.0ab	3.68ab	1.03a	1.07a	.8a
Knapsack	Cyp	32	3.2	7.3	10.68ab	8.5a	6.197abc	3.02a	2.78ab	4.03ab	1.07a	.73a	.85a
ULV	Cyp	32	2.8	5.5	13.55b	9.78a	8.15abc	3.38a	2.3a	4.95b	1.3a	.95a	.92a
'Electrodyn'	Cyh	12	2.93	4.8	7.03a	10.2a	5.17ab	3.3a	3.53bc	4.75ab	1.42a	.63a	.85a
Knapsack	Cyh	12	2.95	5.95	9.38ab	7.33a	4.43a	2.85a	3.88bcd	4.1ab	1.43a	1.07a	.9a
ULV	Cyh	12	4.0	3.53	8.35a	9.15a	6.78abc	3.02a	4.3cd	3.45a	1.5a	1.18a	1.13a
Control I	End	250	2.7	7.25	9.45ab	7.7a	10.03c	3.80a	4.7d	4.5ab	1.35a	1.2a	1.03a
Control 2	-	-	3.05	7.63	13.7b	15.68b	14.6d	7.35b	6.85e	8.15c	4.1b	4.25b	4.58b

1. Cyp - cypermethrin, Cyh - lambda cyhalothrin, End- Endosulfan. Endosulfan applied according to scouting of American bollworm.
2. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
3. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 10 (continued)

Table 3. Mean number of aphids per plant in trial 3 for the comparison of application techniques (1986-87 Site 2).

Sprayers	Chems.(1)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (2)											
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18
'Electrodyn'	Cyp	30	14.55abc	6.18a	6.55a	5.63a	2.15a	2.18a	3.47	2.30ab	1.53a	1.0a	1.43a	1.60
Knapsack	Cyp	30	17.45c	11.5bc	9.70a	8.40ab	3.18ab	3.20a	2.90	2.80bc	1.5a	.95a	1.73a	1.15
ULV	Cyp	30	13.43abc	10.5abc	9.45a	10.78b	2.10a	2.05a	4.08	2.28ab	1.18a	1.15a	1.90a	1.73
'Electrodyn'	Cyh	12	10.18a	6.25a	6.05a	8.28ab	2.82a	3.28a	3.85	2.83bc	1.28a	1.38a	1.30a	1.70
Knapsack	Cyh	12	17.60c	10.55abc	6.88a	6.33a	2.15a	2.90a	3.48	2.65abc	1.58a	1.30a	1.45	1.50
ULV	Cyh	12	13.80abc	7.38ab	6.05a	8.57ab	2.45a	2.23a	4.80	2.40a	1.25a	.85a	1.56a	1.30
Control I	End	250	15.18bc	12.93c	6.63a	8.13ab	4.30b	1.80a	3.55	2.95c	1.63a	1.15a	1.82a	.85
Control 2	-	-	12.0ab	10.85abc	16.85b	15.35c	6.95c	5.45b	4.25	5.70d	4.68b	4.33b	4.50a	3.30

1. Cyp - cypermethrin, Cyh - lambda cyhalothrin, End- Endosulfan. Five applications of pyrethroids at two week intervals, starting seven weeks after germination. Endosulfan applied according to scouting based upon the eggs of American bollworms.
2. W7 is a prespray observation, and W8 to W18 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
3. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 10

Table 4. Mean number of aphids per plant in trial 4 for the comparison of application techniques (1986-87).

Sprayers (1)	No. of Spray	Chems.	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)								
				W7	W8	W9	W10	W11	W12	W13	W14	W15
Knapsack (5 appl.)	5	Cyp	30	21.20	17.98a	20.07	20.50a	18.85a	8.73a	6.38a	4.85a	4.02a
Knapsack (5 appl.)	5	Cyp	60	18.70	17.70a	18.45	19.20a	18.60a	8.73ab	6.35a	4.53a	3.48a
'Electrodyn' (5 appl.)	5	Cyp	30	18.83	17.43a	18.30	20.13a	19.70a	7.28a	7.76a	5.70a	3.18a
'Electrodyn' (scouting)	2	Cyp	30	19.38	17.07a	19.55	20.30a	19.88a	9.30b	8.00a	5.05a	3.76a
Control	-	-	-	18.90	20.73b	19.33	22.73b	31.13b	30.63c	28.93b	26.93b	26.52b

1. Scouting based upon the eggs of Heliothis (0.50 eggs per plant).
2. Cyp - cypermethrin.
3. W7 is a prespray observation, and W8 to W15 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 11

Table 1. Mean number of mummified aphids per plant in trial 1 for the comparison of application techniques (1986-87).

Sprayers (1)	No. of Spray	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
'Electrodyn' (5 appl.)	5	Cyp	30	1.55	1.75	2.05	2.31	1.98	2.13	2.45ab	2.71ab	2.76a	3.04a	2.62
Knapsack (5 appl.)	5	Cyp	30	1.73	1.79	2.05	2.04	2.54	2.89	2.70b	2.75ab	2.93a	2.89a	2.79
ULV (5 appl.)	5	Cyp	30	1.40	1.73	2.14	2.30	2.30	2.02	2.54ab	2.52a	3.06a	3.33a	2.72
'Electrodyn' (Scouting)	3	Cyp	30	1.37	1.71	2.14	2.12	2.08	2.56	2.49ab	2.41a	2.71a	3.17a	2.63
Knapsack (Scouting)	3	Cyp	30	1.23	1.70	1.92	2.28	2.32	2.66	2.26a	2.93ab	3.11a	3.02a	2.63
ULV (Scouting)	2	Cyp	30	1.31	1.75	2.17	2.43	2.29	2.06	2.39ab	2.33a	2.76a	2.97a	2.67
Control	-	-	-	1.38	1.73	2.35	2.33	2.39	2.64	3.22c	3.17b	3.78b	3.87b	3.63

1. Scouting based upon the eggs of American bollworm (0.50 eggs per plant).
2. Cyp - cypermethrin.
3. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 11 (continued)

Table 2. Mean number of mummified aphids per plant in trial 2 for the comparison of application techniques (1985-86 Site 1).

Sprayers	Chems.(1)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (2)										
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
'Electrodyn'	Cyp	30	.77	.71	.97a	.71	1.45	1.45	1.57	1.40	1.07	1.08ab	1.07a
Knapsack	Cyp	30	.71	.71	1.18a	.71	1.66	1.36	1.55	1.35	.90	.91a	1.09a
ULV	Cyp	30	.71	.71	1.22a	.71	1.72	1.41	1.53	1.44	1.06	.97ab	1.17a
'Electrodyn'	Cyh	12	.71	.72	.92a	.72	1.66	1.42	1.54	1.52	.97	.95ab	1.09a
Knapsack	Cyh	12	.71	.72	1.01a	.72	1.73	1.49	1.46	1.45	.94	.95ab	1.14a
ULV	Cyh	12	.72	.72	1.19a	.72	1.88	1.43	1.48	1.45	1.03	.89a	1.14a
Control I	End	250	.71	.71	1.36ab	.72	1.76	1.17	1.40	1.60	.98	.98ab	1.08a
Control 2	-	-	.71	.71	1.83b	.72	2.10	1.50	1.54	1.42	1.13	1.20b	1.38b

1. Cyp - cypermethrin, Cyh - lambda cyhalothrin, End- Endosulfan.
2. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
3. The data transformed into $\sqrt{y + \frac{1}{2}}$
4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 11 (continued)

Table 3. Mean number of mummified aphids per plant in trial 3 for the comparison of application techniques (1986-87 Site 2).

Sprayers	Chems.(1)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (2)											
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18
'Electrodyn'	Cyp	32	1.19	1.29	1.33	1.51	1.12ab	1.21abc	1.39	1.22	1.05	.94	.98abc	1.11a
Knapsack	Cyp	32	1.34	1.38	1.51	2.06	1.33bcd	1.10ab	1.25	1.29	1.10	1.06	.91a	1.14ab
ULV	Cyp	32	1.09	1.24	1.61	2.0	1.22bc	1.41	1.45	1.21	1.14	1.01	1.08bc	1.05a
'Electrodyn'	Cyh	12	1.16	1.26	1.36	1.67	1.18abc	1.05a	1.27	1.16	1.17	1.09	1.11c	1.03a
Knapsack	Cyh	12	1.44	1.25	1.37	1.69	.94a	1.44c	1.33	1.26	1.27	1.00	.95ab	1.13a
ULV	Cyh	12	1.16	1.01	1.36	1.61	1.31bcd	1.22abc	1.48	1.24	1.23	1.02	.90a	1.09a
Control I	End	250	1.21	1.39	1.38	1.71	1.52a	1.06a	1.44	1.32	1.05	.95	.90a	1.0a
Control 2	-	-	1.39	1.29	1.73	2.04	1.45cd	1.39abc	1.35	1.35	1.34	1.10	.88a	1.40b

1. Cyp - cypermethrin, Cyh - lambda cyhalothrin, End- Endosulfan.
2. W7 is a prespray observation, and W8 to W18 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
3. The data transformed into $\sqrt{y + \frac{1}{2}}$
4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 11 (continued)

Table 4. Mean number of mummified aphids per plant in trial 4 for the comparison of application techniques (1986-87).

Sprayers (1)	No. of Spray	Chems.	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
Knapsack (5 appl.)	5	Cyp	30	2.06	1.86	2.69	3.39	1.77a	2.55ab	2.55	1.88ab	3.20a	3.38
Knapsack (5 appl.)	5	Cyp	60	1.87	1.82	2.52	2.37	2.50ab	2.56ab	2.62	1.44a	2.98a	3.26a
'Electrodyn' (5 appl.)	5	Cyp	30	1.69	1.92	2.45	2.36	2.44ab	2.54ab	2.81	1.30a	3.05a	3.42a
'Electrodyn' (scouting)	3	Cyp	30	1.67	1.89	2.46	2.35	2.59b	2.30a	2.80	1.49a	3.19a	3.06a
Control	-	-	-	2.22	2.30	2.40	2.37	2.96b	2.99b	3.40	2.40b	3.78b	3.89b

1. Scouting based upon the eggs of Heliothis (0.50 eggs per plant).
2. Cyp - cypermethrin.
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 12

Table 1. Mean number of jassids per plant in trial 1 for the comparison of application techniques (1986-87).

Sprayers (1)	No. of Spray	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
'Electrodyn' (5 appl.)	5	Cyp	30	1.34	1.57	1.88	1.85	1.33	1.77a	1.17	1.09a	.87a	.77	.71
Knapsack (5 appl.)	5	Cyp	30	1.17	1.43	1.76	1.43	1.47	1.57a	1.24	.88a	.82a	.71	.72
ULV (5 appl.)	5	Cyp	30	1.38	1.44	1.77	1.70	1.55	1.53a	1.29	1.05a	.74a	.76	.71
'Electrodyn' (Scouting)	3	Cyp	30	1.44	1.58	1.86	1.71	1.42	1.61a	1.38	1.09a	.84a	.72	.71
Knapsack (Scouting)	3	Cyp	30	1.22	1.51	1.85	1.59	1.80	1.54a	1.42	1.07a	.79a	.72	.78
ULV (Scouting)	2	Cyp	30	1.24	1.45	1.95	1.76	1.51	1.72a	1.50	1.10a	.78a	.76	.71
Control	-	-	-	1.10	1.69	2.06	1.92	1.66	2.21b	1.989	1.81b	1.43b	1.17	1.26

1. Scouting based upon the eggs of American bollworm (0.50 eggs per plant).
2. Cyp - cypermethrin.
3. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 12 (continued)

Table 2. Mean number of jassids per plant in trial 2 for the comparison of application techniques (1985-86 Site 1).

Sprayers	Chems.(1)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (2)										
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
'Electrodyn'	Cyp	30	1.99	1.59a	1.22a	1.59a	.74	.77a	.77a	.76	.76	.90a	.70
Knapsack	Cyp	30	2.06	1.90abc	1.35ab	1.90abc	.77	.78a	.97ab	.79	.74	.76a	1.07
ULV	Cyp	30	2.05	1.77bc	1.35ab	1.97bc	.77	.82a	.77a	.80	.70	.85a	.70
'Electrodyn'	Cyh	12	2.13	1.69ab	1.48ab	1.69ab	.83	.75a	.85a	.74	.79	.80a	.70
Knapsack	Cyh	12	2.21	1.85abc	1.67b	1.85abc	.72	.72a	.80a	.72	.70	.85a	.70
ULV	Cyh	12	1.77	1.82abc	1.32ab	1.82abc	.71	.75a	.74a	.70	.74	.80a	.70
Control I	End	250	1.84	2.05c	1.48ab	2.05c	1.04	.91a	.97ab	.90	.70	.74a	.70
Control 2	-	-	2.02	1.89bc	1.61b	1.98bc	1.29	1.42b	1.21b	1.53	1.64	1.57b	1.30

1. Cyp - cypermethrin, Cyh - lambda cyhalothrin, End- Endosulfan.
2. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
3. The data transformed into $\sqrt{y + \frac{1}{2}}$
4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 12 (continued)

Table 3. Mean number of jassids per plant in trial 3 for the comparison of application techniques (1986-87 Site 2).

Sprayers	Chems.(1)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (2)											
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18
'Electrodyn'	Cyp	32	2.43	1.40	1.11	.88	.80a	.72	.86a	.79	.76a	.79	.99a	.83
Knapsack	Cyp	32	2.07	1.57	1.15	.80	.72a	.71	.82a	.86	.76a	.82	.92a	.77
ULV	Cyp	32	2.36	1.44	.98	.71	.72a	.71	.79a	.80	.74a	.76	.92a	.77
'Electrodyn'	Cyh	12	2.06	1.35	.95	.85	.77a	.72	.80a	.82	.74a	.79	.91a	.82
Knapsack	Cyh	12	2.06	1.21	.95	.80	.72a	.72	.84a	.89	.76a	.85	.92a	.89
ULV	Cyh	12	1.93	1.34	.95	.83	.72a	.72	.76a	.84	,74a	.74	.97a	.96
Control I	End	250	2.06	1.13	1.04	.77	.79a	.74	.80a	.86	.74a	.77	1.04a	.95
Control 2	-	-	1.86	1.46	1.16	1.90	1.09b	1.23	1.39b	1.15	1.40	.91	1.48b	1.35

1. Cyp - cypermethrin, Cyh - lambda cyhalothrin, End- Endosulfan.
2. W7 is a prespray observation, and W8 to W18 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
3. The data transformed into $\sqrt{y + \frac{1}{2}}$
4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 12 (continued)

Table 4. Mean number of jassids per plant in trial 4 for the comparison of application techniques (1986-87).

Sprayers (1)	No. of Spray	Chems.	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
Knapsack (5 appl.)	5	Cyp	30	1.57	1.66	1.53	1.53ab	1.45	1.07a	1.0a	1.26ab	.73a	.73
Knapsack (5 appl.)	5	Cyp	60	1.48	1.50	1.51	1.40a	1.46	1.00a	1.01a	1.02ab	.74a	.71
'Electrodyn' (5 appl.)	5	Cyp	30	1.64	1.63	1.35	1.41a	1.36	1.05a	.97a	.86ab	.73a	.73
'Electrodyn' (scouting)	2	Cyp	30	1.69	1.51	1.41	1.33a	1.29	1.03a	.91a	.80a	.74a	.73
Control	-	-	-	1.73	1.83	1.70	1.77b	1.77	1.75b	1.66b	1.32b	1.05b	1.34

1. Scouting based upon the eggs of *Heliothis* (0.50 eggs per plant).
2. Cyp - cypermethrin.
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 13

Table 1. Mean number of whiteflies per plant in trial 1 for the comparison of application techniques (1986-87).

Sprayers (1)	No. of Spray	Chems. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
'Electrodyn' (5 appl.)	5	Cyp	30	1.12	1.46	1.66a	1.72	1.50ab	1.81ab	1.18a	1.34a	1.80a	.97a	.83a
Knapsack (5 appl.)	5	Cyp	30	1.21	1.46	1.63a	1.41	1.49ab	1.78ab	1.48a	1.45a	1.71a	.93a	.98a
ULV (5 appl.)	5	Cyp	30	1.21	1.49	1.52a	1.58	1.45ab	1.61a	1.58a	1.41a	1.69a	.98a	.95a
'Electrodyn' (Scouting)	3	Cyp	30	1.08	1.52	1.66a	1.57	1.74b	1.69a	1.61a	1.66a	1.94a	1.12ab	.85a
Knapsack (Scouting)	3	Cyp	30	1.12	1.43	1.69ab	1.68	1.38a	1.77ab	1.54a	1.50a	1.71a	.94a	.87a
ULV (Scouting)	2	Cyp	30	1.16	1.59	1.64a	1.71	1.71b	1.79ab	1.59a	1.57a	1.77a	1.30b	.86a
Control	-	-	-	1.11	1.55	1.90b	1.67	1.76b	2.09b	2.22b	2.40b	2.69b	2.30c	2.35b

1. Scouting based upon the eggs of American bollworm (0.50 eggs per plant).
2. Cyp - cypermethrin.
3. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 13 (continued)

Table 2. Mean number of whiteflies per plant in trial 2 for the comparison of application techniques (1985-86 Site 1).

Sprayers	Chems.(1)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (2)										
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
'Electrodyn'	Cyp	30	1.08abc	.97	1.00	.97	1.13	.88	1.05	.95	.87a	.84	.91a
Knapsack	Cyp	30	1.24c	.98	.87	.98	1.11	.87	1.19	1.09	.98a	.85	.92ab
ULV	Cyp	30	.44ab	.88	.94	.88	.85	.83	1.11	1.04	.98a	.96	.89a
'Electrodyn'	Cyh	12	1.11bc	1.14	.89	1.14	1.15	.85	.95	1.01	.83a	.95	.90a
Knapsack	Cyh	12	.80a	1.10	.79	1.10	.80	.84	.96	.99	.88a	1.00	.97ab
ULV	Cyh	12	1.13bc	.97	.90	.97	.79	.96	.99	1.07	.93a	.98	.88a
Control I	End	250	1.05abc	.99	1.17	.99	1.07	.94	1.09	1.15	.82a	.93	.86a
Control 2	-	-	.93ab	.98	1.06	.98	1.45	.85	1.22	1.14	1.20b	1.10	1.08b

1. Cyp - cypermethrin, Cyh - lambda cyhalothrin, End- Endosulfan.
2. W7 is a prespray observation, and W8 to W17 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
3. The data transformed into $\sqrt{y + \frac{1}{2}}$
4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 13 (continued)

Table 3. Mean number of whiteflies per plant in trial 3 for the comparison of application techniques (1986-87 Site 2).

Sprayers	Chems.(1)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (2)											
			W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18
'Electrodyn'	Cyp	32	1.04	1.03	1.18ab	1.27	.79	1.45	1.11	1.32	.86	.93ab	1.08a	1.03a
Knapsack	Cyp	32	.96	1.14	1.07ab	.98	.76	.83	1.20	1.24	.92	.95ab	1.13a	.96a
ULV	Cyp	32	.99	1.16	1.06ab	1.16	.72	.94	1.06	1.20	.96	.89a	1.04a	1.05a
'Electrodyn'	Cyh	12	.89	1.04	1.33b	1.06	.84	.80	.99	1.30	.97	1.01ab	1.14a	1.15a
Knapsack	Cyh	12	1.02	1.07	.91a	1.07	.86	.83	1.02	1.28	.92	.96ab	1.16a	1.0a
ULV	Cyh	12	1.04	1.10	1.33b	1.21	.89	.82	1.10	1.28	.85	1.08b	1.27a	1.05
Control I	End	250	.96	1.16	1.28b	1.20	.80	.81	1.02	1.16	.93	.86a	1.29a	1.04a
Control 2	-	-	.89	.99	1.13ab	1.22	.77	.82	1.15	1.53	1.10	1.25c	1.65b	1.38b

1. Cyp - cypermethrin, Cyh - lambda cyhalothrin, End- Endosulfan.
2. W7 is a prespray observation, and W8 to W18 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
3. The data transformed into $\sqrt{y + \frac{1}{2}}$
4. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 13 (continued)

Table 4. Mean number of whiteflies per plant in trial 4 for the comparison of application techniques (1986-87).

Sprayers (1)	No. of Spray	Chems.	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)									
				W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
Knapsack (5 appl.)	5	Cyp	30	1.40	1.53a	.67ab	1.75	1.75	1.57a	1.46a	1.88ab	.73a	1.03a
Knapsack (5 appl.)	5	Cyp	60	1.44	1.62a	1.76ab	1.57	1.54	1.43a	1.65a	1.44a	.74a	.91a
'Electrodyn' (5 appl.)	5	Cyp	30	1.44	1.49a	1.51a	1.59	1.60	1.54a	1.33a	1.30a	.73a	1.11a
'Electrodyn' (scouting)	2	Cyp	30	1.55	1.57a	1.74ab	1.52	1.54	1.49a	1.32a	1.49a	.74a	1.02a
Control	-	-	-	1.25	2.09b	1.85b	1.80	1.79	2.42b	2.55b	2.40b	1.05b	2.31b

1. Scouting based upon the eggs of Heliothis (0.50 eggs per plant).
2. Cyp - cypermethrin.
3. W7 is a prespray observation, and W8 to W16 are weekly scouting occasions during the spraying period. Ten plants were observed per plot. (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letter are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letter have no significant differences.

APPENDIX 14

Table 1. Mean number of American bollworm eggs per plant in 'Electrodyn' swath rows - Trial 1 1985-86.

Sprayer (1)	Swath rows	Flow rate	Chem. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
					W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	.80	.75	.79abc	.92ab	.84a	.86	.93a	.92ab	.91ab	.85a	.74
ED Charged	2 Rows	.1	Cyp	30	.71	.71	.79abc	.83a	.84a	.85	.88a	.92ab	.89ab	.81a	.77
ED Charged	3 Rows	.1	Cyp	30	.79	.72	.86cd	.91ab	.84a	.82	.89a	.90a	.92ab	.79a	.82
ED Charged	4 Rows	.1	Cyp	30	.77	.72	.83bcd	.85a	.89a	.91	.84a	.95ab	.93ab	.79a	.79
ED Discharged	1 Row	.05	Cyp	30	.71	.76	.82abcd	.82a	.85a	.84	.89a	.96ab	.92ab	.77a	.82
ED Discharged	2 Rows	.1	Cyp	30	.76	.76	.74a	.80a	.82a	.83	.88a	.93ab	.87a	.79a	.72
ED Discharged	3 Rows	.1	Cyp	30	.83	.74	.77ab	.84a	.85a	.88	.91a	1.05b	.72ab	.81a	.79
ED Discharged	4 Rows	.1	Cyp	30	.81	.74	.81abcd	.86a	.88a	.90	.91a	.90a	.97b	.79a	.79
Control	-	-	-	-	.77	.77	.88d	.98b	1.06b	1.04	1.12b	1.19c	1.14c	1.02b	.83

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 14 (continued)

Table 2. Mean number of American bollworm eggs per plant in 'Electrodyn' swath rows - Trial 2 1985-86.

Sprayer (1)	Swath rows	Flow rate	Chem.(2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
					W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	.77	.76	.99	.83	.85a	1.01bc	.97a	.95a	.92ab	.80a	.80a
ED Charged	2 Rows	.1	Cyp	30	.76	.76	1.02	.89	.79a	1.01bc	.92a	1.02a	.86a	.82a	.80a
ED Discharged	1 Row	.05	Cyp	30	.79	.76	1.00	.92	.77a	.85a	.98a	.96a	.93ab	.79a	.79a
ED Discharged	2 Rows	.1	Cyp	30	.81	.80	1.05	.87	.89a	.88ab	.99a	1.02a	1.02b	.80a	.80b
Control	-	-	-	-	.71	.76	1.06	.92	1.08b	1.10c	1.14b	1.27b	1.01b	.95b	.96b

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 14 (continued)

Table 3. Mean number of American bollworm eggs per plant in 'Electrodyn' swath rows - Trial 3 1985-86.

ED Swath rows	Appli (1) timings	Flow rate	Chem. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3) W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19
2 Rows	Scouting (3 applic)	.1	Cyp	30	.76	.77	.85	.92ab	.82	.96a	.95	.83a	.75a	.79a	.82a	.76a	.80
1 Row	Scouting (3 applic)	.05	Cyp	30	.77	.77	.94	.85a	.81	1.14a	1.02	.82a	.90a	.82a	.85a	.85	.74
2 Rows	5 applic (2 week)	.1	Cyp	30	.83	.80	.97	.84a	.86	.88a	1.06	.93a	.89a	.91a	.88a	.81a	.79
1 Row	5 applic (2 week)	.05	Cyp	30	.71	.79	1.12	.81a	.81	.85a	1.06	.93a	.98a	.90a	.79a	.76a	.79
1 Row	4 applic	.05	Cyp	30	.74	.74	.89	.84a	.82	.94a	1.06	.83a	.89a	.82a	.88a	.77a	.79
2 Rows	4 applic	.1	Cyp	30	.77	.72	.92	.88ab	.81	.96a	.92	.91a	.88a	.80a	.85a	.77a	.84
Control	-	-	-	-	.77	.79	.98	.97b	.91	1.15	1.16	1.13b	1.28	1.07	1.17	1.05	.89

1. Scouting based upon 0.50 egg of Heliothis per plant.
2. Cyp - Cypermethrin applied
3. W7 is a prespray observation, W8 to W19 are weekly scouting occasions during the spraying period. Ten plants per plot
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 14 (continued)

Table 4. Mean number of American bollworm eggs per plant in 'Electrodyn' swath rows - Trial 4 1986-87.

Sprayer (1)	Swath rows	Flow rate	Chem. (2)	a.i. g/ha/ spray	No. of sprays	Scouting Occasions (weeks after germination) (3)										
						W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	5	.85ab	.87	.96ab	.95	.85	.89	.72	.81	.79a	.77	.74a
ED Charged	4 Rows	.1	Cyp	30	5	.74a	.92	.97ab	.91	.89	.86	.89	.83	.80a	.77	.74a
ED Discharged	1 Row	.05	Cyp	30	5	.94b	.84	.87a	.89	.85	.91	.83	.83	.83ab	.74	.72a
ED Discharged	4 Rows	.1	Cyp	30	5	.86ab	.91	.92ab	.80	.91	.89	.87	.86	.77a	.80	.74a
ED Charged	4 Rows	.1	Cyp	7.5	5	.93ab	.91	.95ab	.96	.93	.92	.86	.81	.83ab	.79	.76a
ED Discharged	4 Rows	.1	Cyp	7.5	5	.79a	.85	1.03b	1.00	.97	.84	.82	.89	.77a	.79	.77a
Control	-	-	-	-	-	.89ab	.98	1.01b	1.01	.96	.97	1.02	.94	.98b	1.01	1.09b

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period. (Ten plants per plot)
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 15

Table 1. Mean number of American bollworm larvae per plant in 'Electrodyn' swath rows - Trial 1 1985-86.

Sprayer (1)	Swath rows	Flow rate	Chem.(2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)				
					W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	.70	.70a	.78a	.77a	.74a
ED Charged	2 Rows	.1	Cyp	30	.74	.77a	.77a	.78a	.74a
ED Charged	3 Rows	.1	Cyp	30	.70	.74a	.82a	.77a	.76a
ED Charged	4 Rows	.1	Cyp	30	.70	.74a	.80a	.82a	.71a
ED Discharged	1 Row	.05	Cyp	30	.76	.72a	.81a	.83a	.71a
ED Discharged	2 Rows	.1	Cyp	30	.70	.74a	.84a	.82a	.79a
ED Discharged	3 Rows	.1	Cyp	30	.80	.76a	.84a	.77a	.73a
ED Discharged	4 Rows	.1	Cyp	30	.79	.74a	.88a	.81a	.79a
Control	-	-	-	-	.76	1.03b	1.10b	1.19b	1.06b

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 15 (continued)

Table 2. Mean number of American bollworm larvae per plant in 'Electrodyn' swath rows - Trial 2 1985-86.

Sprayer (1)	Swath rows	Flow rate	Chem. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)					
					W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	.71	.77	.70a	.76a	.79a	.76
ED Charged	2 Rows	.1	Cyp	30	.72	.77	.73a	.76a	.72a	.77
ED Discharged	1 Row	.05	Cyp	30	.71	.71	.70a	.72a	.74a	.71
ED Discharged	2 Rows	.1	Cyp	30	.72	.77	.79a	.76a	.74a	.75
Control	-	-	-	-	.78	.85	.95b	1.00b	1.16b	.86

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 15 (continued)

Table 3. Mean number of American bollworm larvae per plant in 'Electrodyn' swath rows - Trial 3 1985-86.

ED Swath rows	Appli (1) timings	Flow rate	Chem. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)							
					W12	W13	W14	W15	W16	W17	W18	W19
2 Rows	Scouting (3 applic)	.1	Cyp	30	.74	.74	.82	.71	.79a	.71	.74	.72
1 Row	Scouting (3 applic)	.05	Cyp	30	.72	.76	.71	.71	.72a	.74	.74	.74
2 Rows	5 applic (2 week)	.1	Cyp	30	.71	.73	.72	.76	.74a	.74	.72	.71
1 Row	5 applic (2 week)	.05	Cyp	30	.71	.71	.74	.71	.74a	.72	.71	.71
1 Row	4 applic	.05	Cyp	30	.71	.73	.74	.74	.76a	.72	.77	.71
2 Rows	4 applic	.1	Cyp	30	.72	.71	.74	.82	.72a	.72	.72	.74
Control	-	-	-	-	.80	.72	.85	.98	1.12b	1.10	1.15	.42

1. Scouting based upon 0.50 egg of Heliothis per plant.
2. Cyp - Cypermethrin applied
3. W12 to W19 are weekly scouting occasions during the spraying period. Ten plants per plot
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 15 (continued)

Table 4. Mean number of American bollworm larvae per plant in 'Electrodyn' swath rows - Trial 4 1986-87.

Sprayer (1)	Swath rows	Flow rate	Chem. (2)	a.i. g/ha/ spray	No. of sprays	Scouting Occasions (weeks after germination) (3)										
						W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	5	.82	.83	.79	.80	.82	.83a	.78a	.74a	.76a	.71	.71
ED Charged	4 Rows	.1	Cyp	30	5	.79	.89	.76	.88	.85	1.15c	.98b	.85ab	.82ab	.74	.77
ED Discharged	1 Row	.05	Cyp	30	5	.76	.83	.82	.84	.83	.84a	.92ab	.79ab	.74a	.71	.73
ED Discharged	4 Rows	.1	Cyp	30	5	.78	.88	.98	.86	.88	1.13c	.93ab	.85ab	.79ab	.74	.76
ED Charged	4 Rows	.1	Cyp	7.5	5	.83	.81	.84	.82	.86	1.13c	.99b	.77ab	.85b	.71	.77
ED Discharged	4 Rows	.1	Cyp	7.5	5	.80	.85	.80	.94	1.03	.95ab	.87ab	.91b	.74a	.71	.76
Control	-	-	-	-	-	.82	.92	.92	.97	1.27	1.02bc	1.24c	1.26c	1.26c	1.22	1.14

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period. Ten plants per plot.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 1.6

Table 1. Mean number of aphids per plant in 'Electrodyn' swath rows - Trial 1 1985-86.

Sprayer (1)	Swath rows	Flow rate	Chem. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
					W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	1.35	4.55ab	6.53a	8.70a	7.68a	4.15ab	4.52a	3.88a	1.88a	1.52a	.65a
ED Charged	2 Rows	.1	Cyp	30	1.55	8.1c	10.43abc	11.18a	7.83a	3.20ab	4.35a	3.88a	1.78a	2.08ab	1.05a
ED Charged	3 Rows	.1	Cyp	30	1.7	5.9abc	11.58bc	8.73a	7.75a	4.68b	4.23a	4.13a	2.35a	2.13ab	.96a
ED Charged	4 Rows	.1	Cyp	30	1.58	5.65abc	12.2bc	10.68a	8.53a	3.60ab	4.08a	4.10a	2.03a	2.23ab	1.10a
ED Discharged	1 Row	.05	Cyp	30	1.55	3.0a	8.1ab	10.65a	9.18a	2.55ab	3.80a	4.20a	1.58a	2.08ab	1.28a
ED Discharged	2 Rows	.1	Cyp	30	2.15	6.23bc	8.65ab	10.10a	6.90a	3.83ab	4.33a	4.08a	1.63a	1.85ab	1.20a
ED Discharged	3 Rows	.1	Cyp	30	2.03	8.33c	11.98bc	11.88a	4.97a	4.43ab	4.35a	3.58a	2.10a	2.53b	1.48a
ED Discharged	4 Rows	.1	Cyp	30	2.42	5.8abc	9.98abc	9.98a	6.32a	2.33a	4.38a	4.48a	1.95a	2.53b	1.73a
Control	-	-	-	-	2.05	6.3bc	13.83c	17.93b	15.90b	10.4c	7.35b	7.15b	5.73b	5.23c	6.15b

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period. Ten plants per plot, 2 leaves from top, middle and bottom of each plant.
4. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 16 (continued)

Table 2. Mean number of aphids per plant in 'Electrodyn' swath rows - Trial 2 1985-86.

Sprayer (1)	Swath rows	Flow rate	Chem.(2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
					W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	1.55	4.20	5.37	4.22a	7.13a	4.43a	4.02	3.30	1.88a	1.23a	.60a
ED Charged	2 Rows	.1	Cyp	30	3.13	5.78	5.53	8.55b	7.35a	3.98a	4.90	3.57	1.95a	1.55a	1.85ab
ED Discharged	1 Row	.05	Cyp	30	1.80	4.70	6.33	5.93ab	7.13a	3.72a	4.40	4.27	1.68a	1.43a	1.80ab
ED Discharged	2 Rows	.1	Cyp	30	1.70	4.17	6.50	7.13ab	7.35a	4.13a	4.58	4.08	1.78a	1.30a	1.88ab
Control	-	-	-	-	2.07	5.88	7.25	14.53c	11.7b	8.20b	4.55	4.80	3.73b	4.97	3.05b

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period. (Ten plants per plot, 2 leaves from top, middle and bottom of each plant).
4. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 16 (continued)

Table 3. Mean number of aphids per plant in 'Electrodyn' swath rows - Trial 3 1985-86.

ED Swath rows	Appli (1) timings	Flow rate	Chem. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)												
					W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19
2 Rows	Scouting (3 applic)	.1	Cyp	30	2.83	3.58ab	7.80	8.25b	11.42bc	7.60a	4.23b	2.85a	3.28a	1.80a	1.68a	1.48a	1.55a
1 Row	Scouting (3 applic)	.05	Cyp	30	3.93	5.37b	7.60	8.82b	4.73b	7.10a	4.63b	3.33a	3.0a	1.95a	1.50a	2.00a	1.23a
2 Rows	5 applic (2 week)	.1	Cyp	30	3.80	2.13a	6.28	8.07b	7.63abc	7.0a	4.15b	3.50a	2.42a	1.55a	1.52a	1.78a	1.53a
1 Row	5 applic (2 week)	.05	Cyp	30	3.08	1.95a	5.30	7.55b	7.50abc	6.63a	2.60a	2.98a	1.65a	1.68a	1.07a	1.43a	2.17a
1 Row	4 applic	.05	Cyp	30	2.80	2.55ab	5.35	4.33a	5.85a	5.73a	4.45b	2.68a	1.95a	1.08a	1.68a	1.33a	1.65a
2 Rows	4 applic	.1	Cyp	30	3.43	2.35a	7.03	5.40a	6.47ab	7.60a	4.43b	3.33a	2.95a	2.08a	1.80a	1.70	1.55a
Control	-	-	-	-	2.58	3.43ab	8.04	15.47c	12.05c	13.23b	7.55c	6.63b	8.43b	3.95b	5.70	4.65b	4.75b

1. Scouting based upon 0.50 egg of <u>Heliothis</u> per plant.
2. Cyp - Cypermethrin applied
3. W7 is a prespray observation, W8 to W19 are weekly scouting occasions during the spraying period. Ten plants per plot (2 leaves from top, middle and bottom of each plant).

4. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 16 (continued)

Table 4. Mean number of Aphids per plant in 'Electrodyn' swath rows - Trial 4 1986-87.

Sprayer (1)	Swath rows	Flow rate	Chem. (2)	a.i. g/ha/ spray	No. of sprays	Scouting Occasions (weeks after germination) (3)										
						W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	5	13.13	17.62	19.88	18.5a	18.12a	17.33a	10.03a	8.05a	6.60a	4.23ab	2.95a
ED Charged	4 Rows	.1	Cyp	30	5	12.65	18.10	21.30	20.70abc	19.88a	17.78a	18.28b	9.65ab	9.22b	6.68b	2.98a
ED Discharged	1 Row	.05	Cyp	30	5	12.00	17.77	19.66	18.27a	19.90a	17.77a	14.80ab	8.65a	7.18a	3.58a	2.80a
ED Discharged	4 Rows	.1	Cyp	30	5	12.37	21.23	19.85	19.55ab	18.33a	19.88a	16.10b	10.90b	11.05c	4.85ab	3.00a
ED Charged	4 Rows	.1	Cyp	7.5	5	13.48	18.93	20.93	19.90abc	19.95a	20.05a	18.23b	9.60ab	9.68bc	6.32b	3.6a
ED Discharged	4 Rows	.1	Cyp	7.5	5	14.10	18.78	20.20	23.23c	20.93ab	20.67ab	19.40b	14.25c	9.18b	6.72b	3.19a
Control	-	-	-	-	-	13.68	18.80	19.70	22.83bc	24.04b	24.55b	31.10c	30.35d	30.35d	29.48c	27.08b

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period. Ten plants per plot (2 from top, middle and bottom of each plant)

4. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 17

Table 1. Mean number of mummified aphids per plant in 'Electrodyn' swath rows - Trial 1 1985-86.

Sprayer (1)	Swath rows	Flow rate	Chem. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
					W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	.71	.71	.88a	1.29	1.73a	1.36a	1.62	1.59	1.03a	1.16	1.07a
ED Charged	2 Rows	.1	Cyp	30	.71	.71	1.01a	1.64	1.92a	1.24a	1.70	1.57	1.17a	1.15	1.12ab
ED Charged	3 Rows	.1	Cyp	30	.74	.71	1.34ab	1.60	1.87a	1.44a	1.54	1.44	1.03a	1.29	1.21ab
ED Charged	4 Rows	.1	Cyp	30	.71	.72	1.55b	1.47	1.84a	1.31a	1.59	1.53	1.15a	1.30	1.21abc
ED Discharged	1 Row	.05	Cyp	30	.71	.72	.92a	1.38	1.58a	1.32a	1.63	1.49	1.14a	1.23	1.24abc
ED Discharged	2 Rows	.1	Cyp	30	.72	.71	1.07a	1.39	1.47a	1.16a	1.66	1.58	1.14a	1.31	1.29bc
ED Discharged	3 Rows	.1	Cyp	30	.71	.71	1.23ab	1.59	1.64a	1.34a	1.78	1.61	1.09a	1.20	1.16ab
ED Discharged	4 Rows	.1	Cyp	30	.91	.72	1.15ab	1.55	1.82a	1.14a	1.71	1.49	1.08a	1.30	1.08a
Control	-	-	-	-	.71	.71	1.27ab	1.79	2.74b	2.78b	1.50	1.71	1.57b	1.24	1.36c

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period. (Ten plants per plot, 2 leaves from top, middle and bottom of each plant)
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 17 (continued)

Table 2. Mean number of mummified aphids per plant in 'Electrodyn' swath rows - Trial 2 1985-86.

Sprayer (1)	Swath rows	Flow rate	Chem. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
					W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	.82	.71	.72	1.16a	1.48	1.80	1.38	1.66a	1.0	1.09	.89a
ED Charged	2 Rows	.1	Cyp	30	.74	.77	.72	1.37ab	1.57	1.48	1.51	1.51	1.07	1.21	1.16a
ED Discharged	1 Row	.05	Cyp	30	.86	.72	.76	1.16a	1.33	1.54	1.40	1.45	1.11	1.23	1.12a
ED Discharged	2 Rows	.1	Cyp	30	.72	.71	.84	1.38ab	1.27	1.77	1.52	1.47	1.20	1.13	1.14a
Control	-	-	-	-	.74	.71	.80	1.61b	1.37	1.54	1.31	1.37	1.22	1.13	1.45b

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period. (Ten plants per plot, 2 leaves from top, middle, and bottom of each plant)
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 17 (continued)

Table 3. Mean number of mummified aphids per plant in 'Electrodyn' swath rows - Trial 3 1985-86.

ED Swath rows	Appli (1) timings	Flow rate	Chem. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)												
					W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19
2 Rows	Scouting (3 applic)	.1	Cyp	30	-	.72	.82	1.30ab	1.14ab	1.52	1.33	1.32	1.20	.95	1.08	1.15	1.11ab
1 Row	Scouting (3 applic)	.05	Cyp	30	-	.72	.71	1.66bc	.95a	1.43a	1.46	1.49	1.15	1.09	1.09	1.03	1.01a
2 Rows	5 applic (2 week)	.1	Cyp	30	-	.76	.80	1.86c	1.46bc	1.72a	1.25	1.37	1.18	1.00	1.10	.95	.89a
1 Row	5 applic (2 week)	.05	Cyp	30	-	.82	.72	1.14a	1.11a	1.63a	1.56	1.24	1.25	1.2	1.09	.99	1.26ab
1 Row	4 applic	.05	Cyp	30	-	.72	.71	1.30ab	1.00a	1.48a	1.68	1.35	1.14	.98	1.06	.94	1.08a
2 Rows	4 applic	.1	Cyp	30	-	.75	.78	1.23ab	1.11a	1.52a	1.48	1.20	1.11	1.03	1.06	1.05	1.16ab
Control	-	-	-	-	-	.71	.76	.98b	1.58c	2.12b	1.26	1.27	1.06	1.13	1.11	1.10	1.43b

1. Scouting based upon 0.50 egg of <u>Heliothis</u> per plant.
2. Cyp - Cypermethrin applied
3. W7 is a prespray observation, W8 to W19 are weekly scouting occasions during the spraying period. Ten plants per plot (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 17 (continued)

Table 4. Mean number of mummified aphids per plant in 'Electrodyn' swath rows - Trial 4 1986-87.

Sprayer (1)	Swath rows	Flow rate	Chem. (2)	a.i. g/ha/ spray	No. of sprays	Scouting Occasions (weeks after germination) (3)										
						W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	5	1.58	1.54	1.74ab	2.19ab	2.38	2.45	1.97	2.92	2.88a	2.99ab	2.60a
ED Charged	4 Rows	.1	Cyp	30	5	1.32	1.63	1.70a	2.42cd	2.45	2.26	1.96	3.18	2.90a	3.34bc	2.77a
ED Discharged	1 Row	.05	Cyp	30	5	1.55	1.73	1.66a	2.13a	2.23	2.84	2.47	2.97	2.97a	3.14ab	2.92a
ED Discharged	4 Rows	.1	Cyp	30	5	1.54	1.96	2.07b	2.34abcd	2.45	2.13	2.00	2.72	2.64a	3.02ab	2.59a
ED Charged	4 Rows	.1	Cyp	7.5	5	1.63	1.83	1.97ab	2.22abc	2.27	2.19	2.48	3.06	2.66a	3.12ab	2.90a
ED Discharged	4 Rows	.1	Cyp	7.5	5	1.60	1.89	2.01ab	2.45d	2.28	2.03	2.37	2.89	3.05a	2.74a	2.67a
Control	-	-	-	-	-	1.68	1.74	2.0ab	2.39bcd	2.61	2.36	2.57	3.24	3.70b	3.73c	3.80b

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period. Ten plants per plot (2 leaves from top, middle and bottom of each plant)
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 18

Table 1. Mean number of jassids per plant in 'Electrodyn' swath rows - Trial 1 1985-86.

Sprayer (1)	Swath rows	Flow rate	Chem. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
					W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	1.60	1.72ab	1.39a	1.03a	.73	.78	.72	.82a	.80a	.74a	.71
ED Charged	2 Rows	.1	Cyp	30	1.62	1.77ab	1.43ab	.72a	.74	.72	.72	.74a	.74	.77a	.71
ED Charged	3 Rows	.1	Cyp	30	1.60	1.69ab	1.25a	.80a	.71	.77	.76	.80a	.77	.86a	.71
ED Charged	4 Rows	.1	Cyp	30	1.44	1.95b	1.42ab	.84a	.71	.77	.77	.91a	.81	.83a	.71
ED Discharged	1 Row	.05	Cyp	30	1.62	1.79b	1.55ab	.95a	.71	.71	.78	.82a	.76	.76a	.71
ED Discharged	2 Rows	.1	Cyp	30	1.85	1.90ab	1.54ab	.87a	.71	.71	.72	.85a	.76	.86a	.75
ED Discharged	3 Rows	.1	Cyp	30	1.69	1.51a	1.24a	.81a	.71	.74	.72	.76a	.71	.76a	.71
ED Discharged	4 Rows	.1	Cyp	30	1.60	2.04b	1.85bc	.91a	.71	.71	.71	.83a	.86	.77a	.71
Control	-	-	-	-	1.08	1.74ab	2.04c	1.77b	.98	1.26	.87	1.05b	.89	1.02b	1.11

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 1 8 (continued)

Table 2. Mean number of jassids per plant in 'Electrodyn' swath rows - Trial 2 1985-86.

Sprayer (1)	Swath rows	Flow rate	Chem. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
					W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	1.81	1.94b	1.48	1.44ab	.83a	.71	.93a	.89a	.74	.80a	.71
ED Charged	2 Rows	.1	Cyp	30	1.80	1.60ab	1.64	.76a	.80a	.71	.83a	.95a	.74	.74a	.72
ED Discharged	1 Row	.05	Cyp	30	1.73	1.88b	1.69	.82a	.76a	.85	.82a	.92a	.71	.80a	.71
ED Discharged	2 Rows	.1	Cyp	30	2.10	1.46a	1.52	.87a	.74a	.72	.87a	.87a	.71	.94a	.72
Control	-	-	-	-	1.99	1.77ab	1.63	1.96b	1.62b	1.34	1.47b	1.25b	1.09	1.52b	1.55

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period. (Ten plants per plot, 2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 18 (continued)

Table 3. Mean number of jassids per plant in 'Electrodyn' swath rows - Trial 3 1985-86.

ED Swath rows	Appli(1) timings	Flow rate	Chem. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)												
					W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19
2 Rows	Scouting (3 applic)	.1	Cyp	30	1.63	1.79	1.65	1.27	1.24a	.28	.99a	.95	.82a	.28a	.71	.72	.71
1 Row	Scouting (3 applic)	.05	Cyp	30	1.86	1.72	2.08	.86	.92a	.74	.83a	.84	.82a	.76a	.82	.77	.71
2 Rows	5 applic (2 week)	.1	Cyp	30	1.61	1.63	1.80	.85	.85a	.71	.82a	.83	.77a	.74a	.74	.83	.71
1 Row	5 applic (2 week)	.05	Cyp	30	1.66	1.66	1.95	.88	.75a	.76	.89a	.86	.79a	.72a	.76	.86	.71
1 Row	4 applic	.05	Cyp	30	1.91	1.59	1.87	1.02	2.35b	.76	.83a	.77	.81a	.75a	.77	.72	.72
2 Rows	4 applic	.1	Cyp	30	1.79	1.56	1.82	.77	1.03a	.78	.86a	.80	.77a	.74a	.83	.82	.71
Control	-	-	-	-	1.89	1.67	1.91	1.93	1.62ab	1.14	1.42b	1.30	1.21b	1.02b	.99	1.40	1.07

1. Scouting based upon 0.50 egg of <u>Heliothis</u> per plant.
2. Cyp - Cypermethrin applied
3. W7 is a prespray observation, W8 to W19 are weekly scouting occasions during the spraying period. Ten plants per plot (2 leaves from top, middle and bottom of each plant)
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 18 (continued)

Table 4. Mean number of jassids per plant in 'Electrodyn' swath rows - Trial 4 1986-87.

Sprayer (1)	Swath rows	Flow rate	Chem. (2)	a.i. g/ha/ spray	No. of sprays	Scouting Occasions (weeks after germination) (3)										
						W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	5	1.22	1.64	1.70a	1.30a	1.18ab	1.72	1.18a	.93a	.71	.82a	.71
ED Charged	4 Rows	.1	Cyp	30	5	1.30	1.55	1.80a	1.24a	1.65ab	1.78	1.52a	1.09a	.74	.73a	.74
ED Discharged	1 Row	.05	Cyp	30	5	1.35	1.56	1.52a	1.56abc	1.48ab	1.73	1.43a	1.10a	.79	.73a	.73
ED Discharged	4 Rows	.1	Cyp	30	5	1.29	1.69	2.25b	1.52ab	1.56ab	1.75	1.32a	.95a	.81	.72a	.74
ED Charged	4 Rows	.1	Cyp	7.5	5	1.29	1.64	1.61a	1.28a	1.35a	1.63	1.55a	1.01a	.80	.72a	.71
ED Discharged	4 Rows	.1	Cyp	7.5	5	1.44	1.47	1.71a	1.91bc	1.69bc	1.64	1.4a	.95a	.77	.78a	.74
Control	-	-	-	-	-	1.21	1.46	1.89a	1.97c	1.97c	2.55b	1.97b	.99b	1.66	1.22b	1.22

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period. Ten plants per plot (2 leaves from top, middle and bottom of each plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 19

Table 1. Mean number of whiteflies per plant in 'Electrodyn' swath rows - Trial 1 1985-86.

Sprayer (1)	Swath rows	Flow rate	Chem. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
					W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	1.5	1.08	1.08	.98a	.79	.91	1.01a	1.00	1.04a	1.00	.89
ED Charged	2 Rows	.1	Cyp	30	.97	1.01	1.22	1.08ab	.84	.82	.97a	.97	1.07a	.97	.94
ED Charged	3 Rows	.1	Cyp	30	1.08	.87	1.12	1.20ab	.84	.71	1.07ab	1.07	.94a	1.09	1.02
ED Charged	4 Rows	.1	Cyp	30	.86	.99	1.07	1.02a	.85	.90	1.16ab	1.12	1.05a	1.15	1.09
ED Discharged	1 Row	.05	Cyp	30	.97	.97	1.07	1.11ab	.85	.77	1.06ab	1.04	1.03a	1.00	.93
ED Discharged	2 Rows	.1	Cyp	30	1.11	1.06	1.18	1.03a	.79	.95	1.05ab	1.04	.96a	.94	1.00
ED Discharged	3 Rows	.1	Cyp	30	1.19	.94	1.18	1.13ab	1.12	.72	1.05ab	1.13	1.0a	1.06	.96
ED Discharged	4 Rows	.1	Cyp	30	1.02	1.02	1.22	1.07b	.76	.77	1.03ab	1.03	1.01a	.94	.99
Control	-	-	-	-	1.12	.95	1.09	1.32b	.95	.84	1.23b	1.01	1.24b	1.07	1.16

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period.
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 19 (continued)

Table 2. Mean number of whiteflies per plant in 'Electrodyn' swath rows - Trial 2 1985-86.

Sprayer (1)	Swath rows	Flow rate	Chem. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)										
					W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	1.15	1.05	1.05	1.06	.96	.80	.91	1.06	.77	.92a	.74
ED Charged	2 Rows	.1	Cyp	30	1.00	1.04	.92	1.10	.82	.76	.96	1.17	.91	.87a	.77
ED Discharged	1 Row	.05	Cyp	30	1.02	.97	.82a	1.01	.92	.82	.94	1.09	.85	.94a	.71
ED Discharged	2 Rows	.1	Cyp	30	1.08	.93	.93	1.02	.97	.81	1.10	1.12	.82	1.02a	.71
Control	-	-	-	-	1.20	1.09	.98	1.29	1.14	.88	.96	1.14	.94	1.57b	1.10

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period. (Ten plants per plot, 2 leaves from top, middle and bottom of plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 19 (continued)

Table 3. Mean number of whiteflies per plant in 'Electrodyn' swath rows - Trial 3 1985-86.

ED Swath rows	Appli (1) timings	Flow rate	Chem. (2)	a.i. g/ha/ spray	Scouting Occasions (weeks after germination) (3)												
					W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19
2 Rows	Scouting (3 applic)	.1	Cyp	30	.80	.91	.94	1.14	1.17a	.81	1.12abc	1.21	.85	.93	.99ab	1.00a	.83a
1 Row	Scouting (3 applic)	.05	Cyp	30	.89	1.13	.91	1.03	1.02a	.88	1.22bc	1.03	.98	1.01	1.15bc	.98a	.92a
2 Rows	5 applic (2 week)	.1	Cyp	30	1.01	1.16	1.09	.98	.99	.77	.93ab	1.08	.86	.90	.86a	.97a	.76a
1 Row	5 applic (2 week)	.05	Cyp	30	.93	1.06	.91	.93	1.02	.80	.86a	1.12	.93	.99	.88a	1.01a	.88a
1 Row	4 applic	.05	Cyp	30	.84	1.07	1.11	.90	1.08a	.97	.97a	1.12	.94	.82	.88a	1.01a	.74a
2 Rows	4 applic	.1	Cyp	30	.80	1.15	.87	1.03	1.01a	.81	1.13abc	.97	.89	.80	.82a	1.01a	.79a
Control	-	-	-	-	.93	1.08	.97	1.15	1.41b	1.05	1.35c	1.13	1.09	1.05	1.31c	1.43c	1.48b

1. Scouting based upon 0.50 egg of *Heliothis* per plant.
2. Cyp - Cypermethrin applied
3. W7 is a prespray observation, W8 to W19 are weekly scouting occasions during the spraying period. Ten plants per plot (2 leaves from top, middle and bottom of plant).
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 19 (continued)

Table 4. Mean number of whiteflies per plant in 'Electrodyn' swath rows - Trial 4 1986-87.

Sprayer (1)	Swath rows	Flow rate	Chem. (2)	a.i. g/ha/ spray	No. of sprays	Scouting Occasions (weeks after germination) (3)										
						W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
ED Charged	1 Row	.05	Cyp	30	5	1.26	1.52	1.10	1.55	1.76	1.87	1.45a	1.25a	1.58a	1.10a	.80a
ED Charged	4 Rows	.1	Cyp	30	5	1.48	1.44	1.39	1.61	1.70	1.73	1.78ab	1.67a	1.67a	1.30a	.89a
ED Discharged	1 Row	.05	Cyp	30	5	1.32	1.57	1.51	1.49	1.79	1.76	1.41a	1.39a	1.46a	1.17a	.94a
ED Discharged	4 Rows	.1	Cyp	30	5	1.14	1.45	1.60	1.43	1.63	1.74	1.53a	1.41a	1.54a	1.07a	.88a
ED Charged	4 Rows	.1	Cyp	7.5	5	1.18	1.57	1.54	1.54	1.76	1.53	1.63ab	1.46a	1.62a	1.21a	.96a
ED Discharged	4 Rows	.1	Cyp	7.5	5	1.17	1.45	1.45	1.81	1.65	1.69	1.50a	1.52a	1.56a	1.28a	.95a
Control	-	-	-	-	-	1.22	1.57	1.46	1.77	1.71	1.65	2.05b	2.28b	2.4b	2.40b	2.20b

1. ED - 'Electrodyn'
2. Cyp - Cypermethrin
3. W7 is a prespray observation, W8 to W17 are weekly scouting occasions during the spraying period. Ten plants per plot (2 leaves from top, middle and bottom of each plant)
4. The data transformed into $\sqrt{y + \frac{1}{2}}$
5. Means per column with the same letters are not significantly different at P = .05 level according to Duncans multiple range test. Columns with no letters have no significant differences.

APPENDIX 20

Table 1. Mean heights and number of nodes per plant in various timing of spray application trials.

		Scouting trials 1985-86				Scouting trials 1986-87			
Insecticides	Treatment	No. of sprays	a.i. g/ha season	heights cm	nodes/ plant	No. of sprays	a.i. g/ha season	heights cm	nodes/ plant
Cypermethrin	0.50 eggs	2	60	137.12	94.54	2	60	103.90	85.83
Cypermethrin	0.25 eggs	5	150	138.32	94.54	6	180	104.48	88.68
Cypermethrin	routine sprays	5	150	135.62	94.1	5	150	106.55	89.60
Cypermethrin	3 weeks inter.	4	120	136.97	91.45	4	120	108.53	91.88
Cypermethrin	9 weeks	-	-	-	-	4	120	106.78	93.08
Cypermethrin	11 weeks	-	-	-	-	3	90	108.73	95.25
Cyhalothrin	routine sprays	-	-	-	-	-	-	-	-
Cyhalothrin	9 weeks	-	-	-	-	-	-	-	-
Cyhalothrin	11 weeks	-	-	-	-	-	-	-	-
Control	-	-	-	136.52	89.3	-	-	111.48	94.22

continued......

Table 1. (Continued)

Insecticides	Treatment	Reduced spray trials 1985-86				Reduced spray trials 1986-87			
		No. of sprays	a.i. g/ha season	heights cm	nodes/ plant	No. of sprays	a.i. g/ha season	heights cm	nodes/ plant
Cypermethrin	0.50 eggs	-	-	-	-	-	-	-	-
Cypermethrin	0.25 eggs	-	-	-	-	-	-	-	-
Cypermethrin	routine sprays	5	150	147.18	109.48	5	150	104.35	77.98
Cypermethrin	3 weeks inter.	-	-	-	-	-	-	-	-
Cypermethrin	9 weeks	4	120	140.47	103.28	4	120	107.28	77.95
Cypermethrin	11 weeks	3	90	144.98	104.15	3	90	109.50	80.73
Cyhalothrin	routine sprays	5	60	144.0	106.55	-	-	-	-
Cyhalothrin	9 weeks	4	48	146.65	105.60	-	-	-	-
Cyhalothrin	11 weeks	3	36	150.40	107.55	-	-	-	-
Control	-	-	-	140.20	101.40	-	-	-	84.78

Note: 0.50 and 0.25 eggs per plant are *Heliothis* thresholds. Ten plants observed in each plot.

APPENDIX 21

Table 1. Mean heights and number of nodes per plant in various trials for the comparison of application techniques (ten plants per plot).

Treatments	Chems	Trial 1 1986-87				Trial 2 1985-86 (Site I)			
		No. of sprays	a.i. g/ha season	heights cm	nodes/ plant	No. of sprays	a.i. g/ha season	heights cm	nodes/ plant
ED Routine sprays	Cyp	5	150	111.75	82.20	5	150	145.99	103.05
KS Routine sprays	Cyp	5	150	105.23	83.65	5	150	150.35	104.28
ULV Routine sprays	Cyp	5	150	112.30	94.43	5	150	143.20	108.15
ED Scouting	Cyp	3	90	112.80	98.00	-	-	-	-
KS Scouting/ dose B	Cyp	3	90	117.95	95.33	-	-	-	-
ULV Scouting	Cyp	2	60	120.60	102.05	-	-	-	-
ED Routine sprays	Cyh	-	-	-	-	5	60	151.75	110.38
KS Routine sprays	Cyh	-	-	-	-	5	60	153.40	107.87
ULV Routine sprays	Cyh	-	-	-	-	5	60	145.83	104.80
Control 1	End	-	-	-	-	2	500	147.28	107.00
Control 2	-	-	-	121.25	109.30	-	-	147.00	104.90

continued....

Table 1. (Continued)

Treatments	Chems	Trial 3 1985-86 (Site 2)				Trial 4 1985-86			
		No. of sprays	a.i. g/ha season	heights cm	nodes/ plant	No. of sprays	a.i. g/ha season	heights cm	nodes/ plant
ED Routine sprays	Cyp	5	150	101.15	66.90	5	150	107.85	83.72b
KS Routine sprays	Cyp	5	150	74.65	59.00	5	150	101.60	66.45a
ULV Routine sprays	Cyp	5	150	87.33	59.63	-	-	-	-
ED Scouting	Cyp	-	-	-	-	3	90	108.13	73.05ab
KS Scouting/ dose B	Cyp	-	-	-	-	5	300	102.82	63.88a
ULV Scouting	Cyp	-	-	-	-	-	-	-	-
ED Routine sprays	Cyh	5	60	93.68	62.73	-	-	-	-
KS Routine sprays	Cyh	5	60	102.55	72.75	-	-	-	-
ULV Routine sprays	Cyh	5	60	84.30	70.32	-	-	-	-
Control 1	End	2	500	114.40	78.90	-	-	-	-
Control 2	-	-	-	98.20	68.30	-	-	170.55	79.90ab

Note: ED - 'Electrodyn', KS - Knapsack, ULV - Ultra low volume sprayers (2) Cyp - cypermethrin cyh - lambda cyhalothrin, End - endosulfan (3) Means per column with the same letter are not significantly different at P = .05 level according to Duncan's multiple range test. Columns with no letters have no significant differences.

APPENDIX 22

Table 1. Mean heights and number of nodes per plant in various 'Electrodyn' swath row trials.

Treatments	Trial 1 (1985-86)				Trial 2 (1985-86)			
	Swath rows	a.i. g/ha season	heights cm	nodes/ plant	Swath rows	a.i. g/ha season	heights cm	nodes/ plant
ED char 1 row	1 ch	150	154.23	100.68	1 ch	150	132.00	85.15
ED char 1 row (scouting)	-	-	-	-	-	-	-	-
ED char 1 row reduced sprays	-	-	-	-	-	-	-	-
ED char 2 rows	2 ch	150	152.13	99.30	2 ch	150	122.65	78.70
ED char 2 rows (scouting)	-	-	-	-	-	-	-	-
ED char 2 rows reduced sprays	-	-	-	-	-	-	-	-
ED char 3 rows	3 ch	150	151.25	103.20	-	-	-	-
ED char 4 rows	4 ch	150	151.13	96.78	-	-	-	-
ED char 4 rows ¼ dose	4 ch	-	-	-	-	-	-	-
ED disch 1 row	1 disch	150	149.82	98.75	1 disch	150	126.45	83.85
ED disch 2 rows	2 disch	150	150	95.03	2 disch	150	129.35	99.97
ED disch 3 rows	3 disch	150	148.35	97.45	-	-	-	-
ED disch 4 rows	4 disch	150	136.98	94.52	-	-	-	-
ED disch 4 rows	4 disch	-	-	-	-	-	-	-

Table 1. (Continued)

Treatments	Trial 3 (1985-86) Swath rows	a.i. g/ha season	heights cm	nodes / plant	Trial 4 (1986-87) Swath rows	a.i. g/ha season	heights cm	nodes / plant
ED char 1 row	1 ch	150	129.28	98.08	1 ch	150	99.95	86.53
ED char 1 row (scouting)	1 ch	90	131.25	95.60	-	-	-	-
ED char 1 row reduced sprays	1 ch	120	137.22	105.90	-	-	-	-
ED char 2 rows	2 ch	150	130.75	96.23	-	-	-	-
ED char 2 rows (scouting)	2 ch	90	131.98	94.80	-	-	-	-
ED char 2 rows reduced sprays	2 ch	120	121.80	92.45	-	-	-	-
ED char 3 rows	-	-	-	-	-	-	-	-
ED char 4 rows	-	-	-	-	4 ch	150	104.70	84.98
ED char 4 rows ¼ dose	-	-	-	-	4 ch	37.5	107.65	86.50
ED disch 1 row	-	-	-	-	1 disch	150	101.75	80.03
ED disch 2 rows	-	-	-	-	-	-	-	-
ED disch 3 rows	-	-	-	-	-	-	-	-
ED disch 4 rows	-	-	-	-	4 disch	150	102.93	83.95
ED disch 4 rows ¼ dose	-	-	-	-	4 disch	37.5	97.53	78.45
Control	-	-	125.57	96.35	-	-	103.72	87.65

Note: ED char and ED disch - charged and discharged 'Electrodyn'. Ten plants observed in each plot.

APPENDIX 23

Table 1 : Mean monthly climatic data of the University Farm (1985-86)

15°23'S   28°28E   1140 m MSL

	J	A	S	O	N	D	J	F	M	A	M	J	Annual
Rainfall (mm)	0	0	0	34.1	83.1	221.5	352.2	207.8	135.0	74.1	0	0	1029
Penevaporation (mm)	136.4	175.1	198.9	263.8	172.7	112.3	118.3	109.0	122.5	123.5	134.7	122.4	1790
Penman P.E.T. (mm)	105.1	131.7	159.4	180.2	143.3	102.2	104.2	96.1	107.5	87.9	76.2	93.1	1337
Mean max. T, °C	22.7	25.3	27.6	27.8	23.4	25.3	25.7	25.7	26.5	24.7	23.9	22.2	25.1
Mean min. T, °C	7.5	8.1	12.5	15.6	15.8	17.5	17.6	17.3	16.8	14.7	9.2	7.2	13.3
Mean soil T at 50 cm, °C	16.7	19.1	23.4	27.4	26.4	24.9	24.0	23.6	24.2	23.3	21.6	19.2	23.5
Rel. humidity %	40.8	36.9	32.1	33.7	47.7	73.7	73.6	73.1	69.8	52.9	49.6	45.2	52.4
Wind speed (m/s)	2.0	2.1	2.2	2.5	2.3	1.5	1.1	1.1	1.1	1.3	1.5	2.0	1.7
Sunshine	9.5	9.8	9.3	9.6	8.2	3.7	4.7	4.8	6.2	6.8	8.5	8.9	7.4

(Continued)

Table 2 : Mean monthly climatic data of the University Farm (1986-87)

15°23'S 28°28E 1140 m MSL

	J	A	S	O	N	D	J	F	M	A	M	J	Annual
Rainfall (mm)	0.0	0.0	0.0	47.6	127.9	211.8	220.0	90.2	39.0	0.0	1.1	0.0	737.6
Pan evaporation (mm)	132.4	169.6	190.8	197.6	186.3	100.8	114.5	159.2	170.3	166.1	148.5	128.1	1866.5
Penman P.E.T. (mm)	103.7	128.2	156.6	154.0	137.7	75.7	122.0	123.1	136.3	129.1	115.5	101.7	1483.6
Mean max. T,°C	22.7	26.5	28.5	30.1	28.5	27.7	27.7	27.2	29.3	28.5	26.7	23.4	27.4
Mean min. T,°C	7.5	8.8	12.4	17.1	17.3	17.2	18.2	18.1	17.5	14.5	12.6	7.5	14.1
Mean soil T at 50 cm, °C	18.0	19.2	21.7	24.1	24.9	24.3	25.3	25.9	26.1	24.9	22.7	19.4	23.1
Rel. humidity %	40.8	40.2	31.7	42.6	52.6	62.7	63.7	61.1	54.4	44.6	40.2	36.6	47.6
Wind speed (m/s)	1.9	1.9	2.2	1.8	1.9	1.5	1.4	1.4	1.5	1.7	1.9	2.0	1.8
Sunshine	9.8	10.4	9.3	7.6	7.8	12.8	6.4	8.7	8.9	10.5	9.8	9.4	9.2

Source = Soil Science Department, School of Agricultural Sciences, University of Zambia, P.O. Box 32379, Lusaka, Zambia.

APPENDIX 24

Soil Analysis

Depth (cm)	Horizon	Texture	Clay % <2 m	Silt % 2-50 m	Sand % >50 m
0-24	AP1	SL	21.70	17.60	60.70
24-38	AP2	SL	28.50	16.80	54.70
38-66	Bt1	SCL	34.90	15.30	49.80
66-109	Bt2	C	41.90	13.80	44.30
109-157	Bt3	C	44.50	13.90	41.60
157-195	Bt4	C	42.00	15.90	42.10

Depth (cm)	Horizon	Exch. cations (meq/100 g soil) K	Na	Ca	Mg	Al+ H	Avail. P (ppm)	BD g/cm3
0-24	AP1	0.20	0.10	4.00	1.20	1.80	4.50	1.76
24-38	AP2	0.20	TR	3.30	1.10	2.30		1.92
38-66	Bt1	0.20	TR	2.10	1.10	3.90		1.68
66-109	Bt2	0.20	TR	1.80	1.10	4.60		1.61
109-157	Bt3	0.10	TR	1.80	1.20	3.80		1.49
157-195	Bt4	0.10	TR	1.70	1.30	2.70		1.54

Depth (cm)	Horizon	CEC meq/100g soil	CEC meq/100g clay	Base sat. %	Al+H sat. %
0-24	AP1	7.30	33.00	75.00	25.00
24-38	AP2	6.90	24.00	67.00	33.00
38-66	Bt1	7.30	21.00	47.00	53.00
66-109	Bt2	7.70	18.00	40.00	60.00
109-157	Bt3	6.90	16.00	45.00	55.00
157-195	Bt4	5.80	14.00	53.00	47.00

Depth (cm)	Horizon	pH H20	pH CaCl2	Total N %	Org. C %	Fe203 % DCB extract
0-24	AP1	6.70	6.30	0.048	0.63	2
24-38	AP2	6.80	6.20	0.042	0.55	3
38-66	Bt1	6.00	5.50	0.039	0.49	3
66-109	Bt2	5.60	5.00	-	0.39	4
109-157	Bt3	5.80	5.50	-	0.24	4
157-195	Bt4	6.20	5.90	-	0.18	4

Source = Soil Science Department, School of Agricultural Sciences, University of Zambia, P.O. Box 32379, Lusaka, Zambia.

APPENDIX 25

Details of the analysis of variance for scouting trial in 1986-87

Table 1. Analysis of variance for yield of Seed cotton

Source of variation	df	Sum of squares	Mean squares	F ratio
Treatments	6	3074807.43	512467.90	4.46**
Error	21	2413756.00	114940.76	
Totals	27	5488563.43		

Table 2. Analysis of variance for healthy bolls

Source of variation	df	Sum of squares	Mean squares	F ratio
Treatments	6	270.40	45.07	3.65**
Error	21	259.23	12.34	
Totals	27	529.65		

(Continued)

APPENDIX 25 (Continued)

Table 3. Analysis of variance for aphids

Source of variation	df	Sum of squares	Mean squares	F ratio
Treatments	6	1209.08	201.50	4.93 **
Error	70	2861.93	40.88	
Totals	76	4071.01		

Duncan's Test

Error Mean square	=	40.88
Degrees of freedom	=	70.00
Alpha level	=	.05

Multiple comparison

Level	Mean	Separation
2	13.26	a
4	13.35	a
1	13.50	a
5	14.06	a
6	14.11	a
3	14.29	a
7	25.04	b

** Indicate significance at 1% propability level.

Note: All other analysis of variance followed the same procedure as outlined in the above example.