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THE EFFECT OF TWO PESTICIDES ON SPIDERS IN SOUTH AFRICAN COTTON FIELDS*

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ABSTRACT

Key words: Alphamethrin, Araneae, cotton, endosulfan, spiders

During a four month period, 1 440 cotton plants were sampled with the whole plant bag sampling technique and 2 388 spiders representing 18 families, 61 genera and 76 species were collected. Numerically, Lycosidae was the dominant family, representing 41,9 % of all spiders collected and *Pardosa crassipalpis* Purcell the dominant species, representing 22,5 % of all spiders recorded. The application of alphamethrin reduced the number of spiders in treated plots by 75,7 % compared to 40,6 % in endosulfan-treated plots and 11,9 % in the untreated control plots. Initially, endosulfan markedly reduced spider numbers but the populations soon recovered. The four most common spider families Lycosidae, Clubionidae, Theridiidae and Linyphiidae, were all affected in different ways by the two pesticides.

Uittreksel

DIE EFFEK VAN TWEE PLAAGDODERS OP SPINNEKOPPE IN SUID-AFRIKAANSE KATOEN-LANDE

Gedurende 'n periode van vier maande is 1 440 heel katoenplante ondersoek en 2 388 spinnekoppe wat deur 18 families, 61 genera en 76 spesies verteenwoordig was, is versamel. Lycosidae was die numeries dominante familie en het 41,9 % van al die spinnekoppe verteenwoordig met Pardosa crassipalpis *Purcell die dominante spesie wat 22,5 % van alle spinnekoppe uitgemaak het. Die toediening van alfametrien het die aantal spinnekoppe in behandelde persele met 75,7 % verminder, vergeleke met 'n 40,6 % vermindering in die endosulfaanbehandelde persele en 11,9 % in die onbehandelde kontrolepersele. Aanvanklik het endosulfaan spinnekopgetalle merkbaar verminder, maar populasies het vinnig herstel. Die vier dominante spinnekopfamilies, Lycosidae, Clubionidae, Theridiidae en Linyphiidae, is almal op verskillende maniere deur die twee plaagdoders beïnvloed.*

INTRODUCTION

Cotton is one of South Africa's five major field crops and the annual production of cotton is still increasing (Cotton Board, 1988/89). Although cotton is attacked by many pests, these pests have a wide range of natural enemies of which spiders are one of the commonest. Much research has been done on controlling cotton pests by chemical means, but little attention has been paid to biological control and the effects of pesticides on the mortality and population density of the predator complex. Spiders are among the very first predators to colonise newly planted cotton fields and their numbers build up gradually as plant density and prey numbers increase (Dinkins *et al.*, 1970). Spiders may play an important role in integrated pest management programmes (Dippenaar-Schoeman, 1976), but more research is required to determine their specific role in cotton pest control.

In the USA, more than half of all pesticides applied for agricultural pest control, are applied to cotton (Johnson *et al.*, 1976) and in South Africa the same tendency is becoming apparent (N. C. J. Basson, Plant Protection Research Institute, Private Bag X134, Pretoria 0001, personal communication). The chemical control of spider mites on cotton is not only expensive but it may stimulate mite population increases and promote the development of resistance to acaricides. For these reasons greater interest is now being shown in integrated pest management in cotton which in turn has lead to increased interest in biological control.

In South Africa, the development and implementation of integrated control programmes on cotton began in the late 1970s (Botha, 1986). In studies of the natural predator complex of spider mites on cotton, predacious arthropods such as pirate bugs (Anthocoridae), predatory thrips (Thripidae), predacious mites (Phytoseiidae) and Dermaptera have received attention (Coates, 1974; Botha, 1986; Botha *et al.*, 1986). In contrast, information on spiders as natural enemies of cotton pests is limited. Furthermore, apart from a study by Dippenaar-Schoeman *et al.*, (1978) on dieldrin cover sprays, the effects of pesticide applications on spiders in South Africa have also not been investigated.

In this study the effects of alphamethrin and endosulfan on the spider community in a South African cotton field were investigated.

METHODS

Study area

The study took place at the Hartebeespoort Experimental Farm, a research station situated 5 km north of Brits in the south-eastern Transvaal (25° 36′ S, 27° 49′ E) at an altitude of 1 110 m above sea level. Laboratory work was carried out at the Plant Protection Research Institute in Pretoria, South Africa.

Climate

The study area has a hot summer, mild winter and a summer rainfall. During this study the average monthly maximum temperature was 28,6 °C and the average minimum 13,8 °C. The highest temperature was recorded in January (36,5 °C). The annual rainfall is usually low (600 mm) and the rate of evaporation high. During 1987/1988 the average monthly rainfall was 77,2 mm with the highest rainfall in November (166,2 mm). From December to March the average monthly rainfall was very constant, averaging 83,0 mm per month, but in April the rainfall declined sharply and no rain fell in May. Irrigation of the crop was most frequent during January. The average weekly relative humidity varied between 60 and 80 % during the season, with a slight increase from November to May. The highest relative humidity recorded was 90 % and the lowest 40 %.

Cotton cultivation

Acala 1517/70, the cultivar which constitutes 60 % of all cotton planted in South Africa, was used in this study. Normal fertilization, irrigation and other agricultural practices were followed. Irrigation was by

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means of a conventional overhead irrigation system. Cotton planted on 8 October 1987 was destroyed by hail and had to be replanted on 13 November 1987. The block of cotton, approximately 1,2 ha in extent was divided into 30 plots of 22 × 15,5 m with paths 1,5 and 2 m wide between each plot. Plants were 25 cm apart in rows 1 m apart. Around each plot a strip 2 m wide was left unscouted to eliminate border and adjacent effects. A large area around the cotton field was also left uncultivated so that the effect of spider mites and predacious arthropods from surrounding areas on the observations would be minimal.

The trial was laid out in a randomized block design with three treatments, each replicated 10 times. Because the blocks in each treatment were distributed at random it was accepted that any immigration of arthropods from outside the study area would also be reflected equally in all treatments.

Sampling techniques

Various methods have been used to sample arthropods on cotton and each has its advantages and disadvantages. During this study the whole plant bag sampling technique (WPBS) was used. Although labour intensive (González *et al.*, 1977), it is considered to give an absolute estimate of population density (Fleischer *et al.*, 1985).

Thirty plants per treatment (90 in total) were collected each week, for 16 weeks. Pre-treatment counts started six weeks after plant emergence. Plants were chosen at random by selecting a number between one and six for the row and then a random number of steps in each row for the plant. The procedure carried out at the first row was repeated seven and 14 rows further, giving a total of three plants sampled per plot.

Sleeves made from perlon (145 cm wide × 160 cm long) and open at both ends were pulled over each plant. The lower end of the sleeve was tied around the stem of the plant with string. The rest of the sleeve was pulled over the plant and left flat on the ground. After two days the open end of the sleeve was quickly pulled up over the plant, tied with string and numbered. The stem of the plant was cut off with pruning shears below the tied lower end of the sleeve and the whole plant removed.

In the laboratory, the plants inside their "bags" were placed in cold storage to immobilize any spiders and prevent cannibalism. The plants were thoroughly searched. All spiders were collected with aspirators or camel-hair brushes and placed in glass tubes with cotton wool stoppers. The species, sex and stage of development of each specimen were recorded. The juveniles of some species were reared to maturity for possible identification. All the adult spiders collected were deposited in the National Collection of Arachnida, Plant Protection Research Institute, Pretoria.

Pesticide application

Knapsack sprayers, specifically designed to simulate ground or aerial spraying of American bollworm, were used to apply two pesticides. Each sprayer had a capacity of 17 ℓ and a 1,0 m horizontal boom fitted with five evenly spaced D2-nozzles. The sprayers were calibrated to deliver 200 ℓ water/ha at a walking speed of 3 km/h.

The pesticides alphamethrin and endosulfan were chosen because both are commonly used for the control of insect pests on cotton in southern Africa. Alphamethrin is a non-systemic synthetic pyrethroid, which is known to stimulate the build-up of spider mite populations and be 'hard' on natural enemies. Endosulfan is an organochlorine pesticide, with translaminary activity; it is known to suppress spider mite populations and be 'soft' on predators. The three treatments evaluated were applied at the recommended dosage (Bot *et al.*, 1986), which were:

- alphamethrin 20 % EC at 200 mℓ formulation/ha.
- endosulfan 35 % EC at 1,5 ℓ formulation/ha and
- untreated control.

Spraying commenced 10 weeks after plant emergence when the larval population of American bollworm had just reached an economic threshold level (Basson, 1986). Both pesticides were applied five times at fortnightly intervals, except on one occasion when because of rain, spraying could only take place after three weeks. The spray dates were 29 January, 19 February, 26 February, 11 March and 25 March 1988.

Statistical analysis

All data were analysed on a Burroughs B7900 computer by the Directorate of Biometric and Datametric Services, Department of Agricultural Development, South Africa. The (LSTATS)P/RANBL program from the biometric programme library was used. Treatment means were compared using Scheffé's method (Miller, 1966) at the 0,05 level of probability.

RESULTS AND DISCUSSION

Species present

During the four month trapping period, 1 440 plants were sampled and 2 388 spiders collected representing 18 families (Tables 1–3), 61 genera and 76 species. This is a larger number of taxonomic groups than the 14 families, 28 genera and 33 species found in strawberry fields by Dippenaar-Schoeman (1979). It also compares well with surveys from other areas in South Africa where, for example, 23 families of spiders with 53 genera were collected in pine plantations (Van den Berg & Dippenaar-Schoeman, 1988) and 27 families and 82 genera collected in a nature reserve near Pretoria (Dippenaar-Schoeman *et al.* 1989). In other parts of Africa 22 spider families were collected with pitfall traps in Botswana (Russell-Smith, 1981) and 20 families from arid bushland in Kenya (Russell-Smith *et al.*, 1987). An average of 46 species occurred in the latter two habitats.

Whitcomb *et al.* (1963), Whitcomb & Bell (1964) and Lincoln *et al.* (1967) studied spiders as predators of bollworm in Arkansas cotton fields. Approximately 3 374 spiders were present per acre, representing 19 families and 160 species. In Australia, spiders form a large and conspicuous part of the total predatory fauna in cotton fields (Bishop, 1979); 10 families, 19 genera and 25 species were found (Bishop, 1980). In Texas, 97 species, 71 genera and 18 families of spiders occurred in cotton (Dean *et al.*, 1982), in China, 61 species from 13 families were recorded (Qu *et al.*, 1986). In Israel, Mansour (1987) found 18 families in an unsprayed field and 13 in sprayed cotton fields.

Russell-Smith (1981) suggested that sub-tropical faunas are likely to be richer in species than those of temperate regions and a comparison of the above results seems to substantiate this observation.

TABLE 1 The total number of spiders collected per week in the untreated control plots at Brits and tabulated according to family. The weeks in which spray applications were made to treated plots are indicated by #

			Pre-treatment period					Treatment period						Post-treatment period			
Family	6/1	13/1	20/1	27/1	#3/2	10/2	17/2	#24/2	#2/3	9/3	#16/3	23/3#	30/3	7/4	14/4	21/4	Total
Araneidae	2	3	5	6	3	1	3	4	1	0	2	3	3	3	7	10	56
Clubionidae	7	6	4	5	13	5	5	6	2	11	7	14	13	12	17	16	143
Dictynidae	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2	4
Gnaphosidae	2	0	0	2	1	0	0	0	0	1	1	0	0	1	0	0	8
Heteropodidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Linyphiidae	8	19	3	2	1	1	0	6	1	2	5	2	5	3	0	3	61
Lycosidae	41	28	30	49	24	22	27	28	27	41	31	31	16	10	13	14	432
Oxyopidae	1	1	3	0	0	2	0	0	0	0	0	0	0	0	0	0	7
Palpimanidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Philodromidae	3	6	3	5	3	4	6	3	4	7	4	6	7	2	7	6	76
Pholcidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Pisauridae	0	1	0	1	0	0	6	4	0	0	2	2	3	1	1	1	22
Salticidae	4	1	3	3	1	4	6	6	3	2	3	7	7	5	1	6	62
Tetragnathidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Theridiidae	3	3	2	4	2	3	5	5	5	5	5	11	8	6	7	6	80
Thomisidae	1	3	2	0	6	3	4	6	4	8	5	5	4	5	7	5	68
Uloboridae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Zodariidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	72	72	55	77	56	45	62	68	47	78	65	81	66	48	60	69	1 021
Mean			69						62,8						60,8		

TABLE 2 The total number of spiders collected per week in the alphamethrin-treated plots at Brits and tabulated according to family. The weeks in which spray applications were made are indicated by #

			Pre-treatment period					Treatment period						Post-treatment period			
Family	6/1	13/1	20/1	27/1	#3/2	10/2	17/2	#24/2	#2/3	9/3#	16/3	23/3#	30/3	7/4	14/4	21/4	Total
Araneidae	8	8	9	5	2	3	0	1	0	1	2	1	0	1	2	0	43
Clubionidae	5	6	6	9	4	1	2	4	0	1	2	0	0	2	1	1	44
Dictynidae	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Gnaphosidae	0	2	0	1	0	1	0	0	0	0	1	0	0	0	0	2	5
Heteropodidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Linyphiidae	11	13	6	2	4	3	2	4	2	7	6	2	0	1	2	0	65
Lycosidae	31	21	29	33	13	16	31	21	18	23	27	6	5	1	3	2	280
Oxyopidae	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	3
Palpimanidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Philodromidae	3	9	2	2	4	3	0	4	1	1	3	3	1	1	1	0	38
Pholoidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pisauridae	0	0	1	1	0	0	4	3	0	2	0	1	2	2	0	0	16
Salticidae	7	6	4	3	3	5	3	7	3	3	4	3	4	5	3	2	65
Tetragnathidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Theridiidae	3	2	0	1	3	2	3	5	5	5	8	8	4	3	3	9	64
Thomisidae	1	2	4	4	2	0	3	1	1	1	0	1	0	0	2	1	23
Uloboridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zodariidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Total	70	71	61	61	36	34	49	51	32	44	53	26	16	16	17	15	652
Mean		65,8							40,6						16		

Effects of pesticides on spider numbers

During the present study, the application of alphamethrin and endosulfan had varying effects on spider numbers as seen in Fig. 1.

In the untreated plots (Table 1 and Fig. 1) an average of 69 spiders were collected per week in the pre-treatment period (6 to 27 January 1988). During the spray period (3 February to 23 March 1988) this figure dropped to 62,8 spiders per week and in the post-treatment period (30 March to 21 April 1988) an average of 60,8 spiders were collected per week. The decrease of 11,9 % between the pre- and post-treatment means is most likely due to natural fluctuations in the seasonal activity of the spider community as observed by Dippenaar-Schoeman *et al.* (1989) and Van den Berg & Dippenaar-Schoeman (1988). Russell-Smith (1981) found that 76 % of the species studied in two African savanna habitats reached their maximum population densities during summer (September to March) and declined in numbers towards and during the colder winter months.

In the alphamethrin-treated plots (Table 2 and Fig. 1) an average of 65,8 spiders were collected per week in the pre-treatment period compared to 62,8 in the endosulfan plots (Table 3 and Fig. 1). These figures are similar to that recorded from the untreated plots during the same period.

During the spraying period, the number of spiders in the alphamethrin treated plots dropped to an average of 40,6 per week, while in the endosulfan-treated plots the numbers fell to 39,4 per week. This represents a decrease of 38,4 % and 37,3 % from the pre-treatment period, respectively. In the untreated control a decrease of only 9 % was observed.

In the post-treatment period, a weekly average of only 16 spiders was collected in the alphamethrin-treated plots compared with 37,3 in the endosulfan-treated plots. A further decline in spider numbers after the five sprays was least in the endosulfan-treated plots (5,3 %) and greatest in the alphamethrin-treated plots (60,6 %).

TABLE 3 The total number of spiders collected per week in the endosulfan-treated plots at Brits and tabulated according to family. The weeks in which spray applications were made are indicated by #

	Pre-treatment period				Treatment period								Post-treatment period				
Family	6/1	13/1	20/1	27/1	#3/2	10/2	17/2	#24/2	#2/3	9/3	#16/3	23/3#	30/3	7/4	14/4	21/4	Total
Araneidae	1	5	8	2	1	4	1	2	1	1	5	3	3	5	1	4	47
Clubionidae	6	13	6	6	4	2	0	2	3	2	7	3	10	5	9	11	89
Dictynidae	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Gnaphosidae	0	1	2	0	0	0	0	1	0	0	1	0	0	1	1	2	9
Heteropodidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Linyphiidae	2	24	3	5	3	4	3	3	1	4	1	1	0	1	0	1	56
Lycosidae	27	25	37	34	20	18	12	18	19	17	19	11	16	10	3	3	289
Oxyopidae	1	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	5
Palpimanidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Philodromidae	3	0	2	2	6	1	3	4	2	0	1	6	5	5	2	5	47
Pholcidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pisauridae	0	0	1	0	1	0	1	2	1	3	3	1	2	1	2	0	18
Salticidae	3	6	2	0	2	0	7	2	1	1	2	0	1	3	5	4	39
Tetragnathidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Theridiidae	3	3	4	1	2	1	3	2	5	8	4	8	3	4	6	4	61
Thomisidae	2	4	3	3	4	8	2	3	6	0	1	4	5	2	3	0	50
Uloboridae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2
Zodariidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	48	82	68	53	45	39	33	40	39	36	46	37	45	37	32	35	715
Mean	62,8				39,4								37,3				

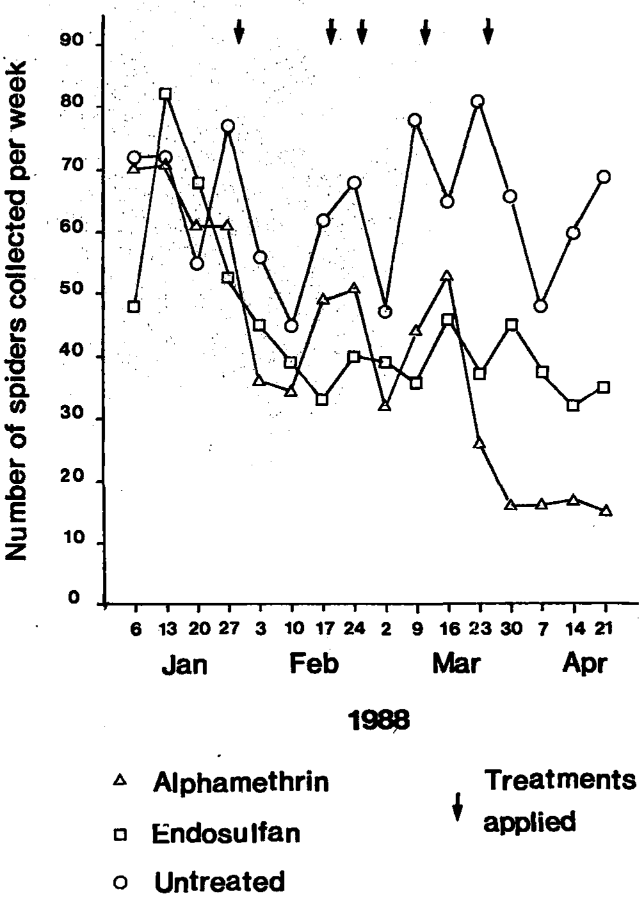

FIG. 1 The total number of spiders collected per week in alphamethrin-treated, endosulfan-treated and untreated cotton plots at Brits

There were no significant differences between the mean weekly numbers of spiders collected in the three treatments until the second pesticide application on 19 February 1988 (Table 4). At this time the untreated plots had significantly more spiders than the endosulfan-treated plots, but there were no significant differences between the alphamethrin and untreated control plots. In the tenth week (9 March 1988), the untreated control plots had significantly more spiders than the alphamethrin- and endosulfan-treated plots. From the twelfth week (23 March 1988), the untreated plots had significantly more spiders than the alphamethrin-treated plots.

These data indicate that alphamethrin significantly reduced the number of spiders in the test plots and this may be ascribed to the pesticides high toxicity, greater persistance and the well known repellent action of pyrethroids. Endosulfan, on the other hand, although having a greater initial effect on spider numbers (Fig. 1), allowed the population to recover and remain fairly constant during the rest of the season. Under laboratory conditions endosulfan caused high mortalities when the effects of agrochemical pesticides on four spider taxa were investigated (Mansour & Nentwig, 1988). Polesny (1987) reports that endosulfan is relatively harmless to spiders in vineyards, whereas organophosphates and pyrethroids have a strong negative effect.

In Israel, Mansour (1987) recorded an average of 9,1 spiders/m of row in unsprayed cotton and 5,1–5,6 spiders/m row in cotton sprayed with chlorinated hydrocarbons, organophosphates and pyrethroids. This compares well with the findings of this study where an average of 8,6 spiders/m row (= per four plants) were found in the unsprayed cotton plots compared with 5,9 in alphametrin-treated plots and 6,0 in endosulfan-treated plots.

Chant (1955) observed the short-term effect of some pesticides on spiders in orchards and found that spider populations reduced by spraying returned to normal within a few weeks after treatment. This was also reported by Dippenaar-Schoeman *et al.* (1978) who noted that tree-living spiders rapidly recovered from the effects of a dieldrin coverspray.

Effects of pesticides on numerically dominant families

Different spider taxa respond in different ways when exposed to pesticide residues (Mansour & Nentwig, 1988). During this study Lycosidae, Clubionidae, Theridiidae and Linyphiidae were the four most common families (Table 5). Lycosidae was the numerically dominant family in all three treatments, representing an average of 41,9 % of all the spiders collected. The second most common family, Clubionidae, represented an average of 11 % of all spiders

TABLE 4 Statistical comparison of the mean number of spiders on three plants collected weekly in each treatment at Brits. Treatment means followed by the same letter do not differ significantly at the 0,05 test level

Date	Alphamethrin	Endosulfan	Untreated
6/1	7,1 a	5,0 a	7,2 a
13/1	7,0 a	8,2 a	7,4 a
20/1	6,3 a	6,7 a	5,5 a
27/1	6,2 a	5,4 a	7,7 a
3/2	3,7 a	4,5 a	5,5 a
10/2	3,4 a	4,1 a	4,7 a
17/2	4,9 a	3,4 a	6,3 a
24/2	5,3 ab	3,9 b	7,0 a
2/3	7,1 a	5,0 a	7,2 a
9/3	4,5 a	3,8 a	7,8 b
16/3	5,3 a	4,7 a	6,6 a
23/3	2,6 a	3,9 ab	8,2 b
30/3	1,6 a	4,4 ab	6,8 b
7/4	1,7 a	3,7 ab	4,9 b
14/4	1,8 a	3,1 a	6,1 b
21/4	0,9 a	1,3 ab	1,7 b
Mean ± SD	4,3 ± 2,1	4,4 ± 1,5	6,3 ± 1,6

TABLE 5 The relative percentage abundance of spider families collected in Alphamethrin (n = 652), Endosulfan (n = 715) and untreated control plots (n = 1021) at Brits

Family	A[a]	E	U	Family	A[a]	E	U
Lycosidae	42,9	40,4	42,3	Gnaphosidae	0,8	1,3	0,8
Clubionidae	6,7	12,4	14,0	Oxyopidae	0,5	0,7	0,7
Theridiidae	9,8	8,5	7,8	Dictynidae	0,3	0,6	0,4
Linyphiidae	10,0	7,8	6,0	Uloboridae	0	0,6	0,1
Salticidae	10,0	5,5	6,1	Tetragnathidae	0,2	0,1	0
Philodromidae	5,8	6,6	7,4	Heteropodidae	0,2	0	0
Araneidae	6,6	6,6	5,5	Palpimanidae	0,2	0	0
Thomisidae	3,5	7,0	6,6	Pholcidae	0	0	0,1
Pisauridae	2,4	2,5	2,2	Zodariidae	0,2	0	0

[a]A = Alphamethrin E = Endosulfan U = Untreated

collected. The effects of alphamethrin and endosulfan on each of the four most common families are discussed below.

Lycosidae: Before spraying commenced, an average of 37 lycosids were collected per week in the untreated control plots (Table 1), 29 in the alphamethrin-treated plots (Table 2) and 31 in the endosulfan-treated plots (Table 3). During treatment these figures decreased to 29 in the untreated plots, 19 in alphamethrin plots and 17 in endosulfan plots.

The largest differences in lycosid numbers between the untreated control and pesticide-treated plots became apparent in the post-treatment period. In the control plots an average of 13 spiders were collected weekly, eight in the endosulfan plots and only three in the alphamethrin plots. This is a reduction in lycosid numbers of 65 % in the control plots compared to 89,6 % in alphamethrin and 74 % in endosulfan-treated plots.

It was concluded that alphamethrin has a greater toxicity towards lycosids than endosulfan. However, as there was a general decline in lycosid numbers in untreated control plots over the same period, this decrease cannot be ascribed to the effects of pesticides alone. Dippenaar-Schoeman (1977) indicated that the seasonal activity of *Pardosa crassipalpis* is usually at its maximum between September and March and declines thereafter. This could explain the decrease in the untreated plots. Apart from the natural population decline, the application of pesticides did not seem to have a major effect on these wandering spiders.

Of the family Lycosidae, *Pardosa crassipalpis* Purcell was collected in the greatest numbers.

Clubionidae: In the untreated control plots (Table 1) an average of 5,5 clubionids were collected per week during the pre-treatment period, compared to 6,5 in the alphamethrin- (Table 2) and 7,8 in the endosulfan-treated plots (Table 3). During the spraying period, in the control plots this increased to 7,8 per week but decreased to 1,8 in the alphamethrin and to 2,9 in the endosulfan-treated plots. This initial decrease in clubionid numbers of 63 % in the endosulfan-treated plots during spraying corresponds with the findings of Mansour *et al.* (1981) who showed that endosulfan rapidly and severely affected *Chiracanthium* sp. killing all spiders within two days. However, the present study indicates that the clubionid population recovered rapidly once spraying ceased. The nocturnal behaviour of clubionids could help to minimise the effect of pesticide applications on them.

In the post-treatment period, the average number of clubionid spiders increased to 14,5 per week in the untreated plots and 8,8 in the endosulfan-treated plots, but in the alphamethrin-treated plots numbers decreased to 1,0. The 11 % increase in the endosulfan plots may be ascribed to a natural increase in Clubionidae during the trapping period as indicated by the 62 % increase in the untreated control plots. In the alphamethrin-treated plots the Clubionidae were severely affected, decreasing by 84 %, and the population did not recover.

The dominant clubionid species during this study was *Chiracanthium lawrencei* Roewer. In Israel, *C. mildei* L. Koch was found to be a dominant species, comprising 35,8 % of all spiders collected in unsprayed cotton (Mansour, 1987). The susceptibility of *C. mildei* to 17 pesticides at field recommended concentrations has been investigated in laboratory tests (Mansour, 1987).

Theridiidae: In the untreated control plots (Table 1) an average of three theridiids were recorded per week before spraying started. This increased by 55 % to 6,8 in the post-treatment period. In the alphamethrin-treated plots (Table 2) an average of 1,5 theridiids recorded in the pre-treatment period, increased by 68 % to 4,8 per week in the post-treatment period. In the endosulfan-treated plots (Table 3) numbers increased from 2,8 in the pre-treatment period to 4,3 after spraying, an increase of 38 %.

Theridiid spiders were not adversely affected by alphamethrin or endosulfan sprays. The Theridiidae are web-builders and make their webs near flowers and bracts, under dry leaves and between leaves where they are protected from pesticide sprays.

The fourth most abundant species collected during this study was *Enoplognatha* sp.

Linyphiidae: In the pre-treatment period an average of eight linyphiids were collected per week in all three treatments. This number decreased by 65 % to an average of 2,8 linyphiids in the untreated control plots in the post-treatment period (Table 1), compared to a 90 % decrease in the alphamethrin-treated plots (Table 2) and 93 % in endosulfan-treated plots (Table 3).

Unlike the theridiidae, alphamethrin and endosulfan had a severe effect on the Linyphiidae population. The Linyphiidae were observed in webs on the upper surfaces of leaves, a niche that would expose them to direct contact with the pesticide sprays. In laboratory tests endosulfan caused 100 % mortality in *Linyphia triangularis* when the susceptibility of spiders to 30 pesticides was determind (Mansour & Nentwig, 1988).

CONCLUSIONS

During this study 1 440 cotton plants were sampled and 2 388 spiders representing 18 families, 61 genera and 76 species collected. It was found that the application of alphamethrin and endosulfan reduced the number of spiders.

Alphamethrin reduced spider numbers to a significantly lower level than that in the untreated plots. Although the initial effect of endosulfan drastically reduced spider numbers the final populations were not significantly lower than those in the untreated plots.

Lycosidae was the numerically dominant family with 42,3 % of spiders collected in untreated control plots, 42,9 % in the alphamethrin-treated plots and 40,4 % in endosulfan-treated plots belonging to this group. *Pardosa crassipalpis* was the most dominant species representing 53,6 % of the Lycosidae and 22,5 % of the total number of spiders collected. Other families found in significant but lesser numbers were the Clubionidae, Theridiidae and Linyphiidae.

The four most common spider families were all affected in different ways by the two pesticides. As wandering spiders, Lycosidae were the least affected by the pesticides. Clubionidae were severely reduced by alphamethrin and initial applications of endosulfan, but the population recovered rapidly in endosulfan-treated plots when spraying ceased. Theridiidae were not adversely affected by the pesticides as their webs are situated in areas where they are protected from direct spray contact. Linyphiidae were severely reduced by the application of both pesticides as their webs on the upper surfaces of leaves are exposed to the spray. This indicates that the behaviour and habitat of each spider family play an important role in determining the effect of pesticides on them.

If spiders are to be protected in the cotton field, highly toxic pesticides such as alphamethrin should be avoided and less toxic materials such as endosulfan applied.

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