XA9743730

THE EFFECT OF LINDANE ON NON-TARGET FAUNA IN A MAIZE AGRO-ECOSYSTEM IN ZAMBIA

Y.D. DEEDAT, S. CHANDA, A M. CHIVUNDU, G. KALEMBE, C.D. MECHA
School of Agriculture, University of Zambia,
Lusaka, Zambia

Abstract

The effect of lindane on non-target fauna in a maize agro-ecosystem was studied in Zambia in 1992 and 1993. While lindane was effective against the stalk borers, a target pest, it also affected other non-target fauna. Ants, spiders and springtails were significantly reduced. However the effect was only transient and lasted for approximately two months. Lindane appeared to have no real effect on aerial non-target fauna or on soil inhabiting microorganisms

1. INTRODUCTION

Organochlorine pesticides such as DDT, endosulfan, lindane and toxophene have been widely used for the control of crop and animal pests in Zambia. These pesticides are highly persistent and may affect many of the non-target organisms. Acquiring quantitative information about the effects of pesticides on non-target fauna is fundamental in the determination of the role of insecticides in integrated pest management programmes.

In Zambia some studies have been made to determine the side effects from the use of organochlorine pesticides. However, these studies have been conducted solely in relation to tsetse fly eradification programmes [1,2]. There is no information on the effect of organochlorine pesticides within the agro-ecosystem. Thus this study was undertaken to determine the non-target effects of lindane in a maize agro-ecosystem.

2. MATERIALS AND METHODS

2.1 Experimental layout

This study was conducted at UNZA farm, 25km east of Lusaka during the 1991/92 and 1992/93 growing season. The field was cultivated by a tractor and planted with maize (Table I) at the rate of 25 kg ha^{-1} with a row to row spacing of 90 cm and a plant to plant distance of 20 cm. fertiliser, at the rate of 400 kg ha^{-1} was applied as basal dressing at planting. Urea was top dressed at the rate of 200 kg ha^{-1} when the crop was at knee height. Soil characteristics (Table I) as well as weather data (Table II) for the experimental site were recorded during each cropping season.

Two plots, each 100 m × 50 m, were marked out and separated by a distance of 100 m. About three weeks after plant emergence one plot was sprayed with Gammaxane 20 (Table I) at the rate of 1 kg AI ha^{-1} using a CP15 knapsack sprayer. The other plot was untreated and served as a control. Within each plot, four sub-plots (5 m × 5 m) were demarcated with an isolation distance of 5 m. These sub-plots were used for all sampling activities . All data were analyzed using F-test at P = 0.05 level of significance.

Table I. Crop, plot and soil characteristics of the experimental site at the University of Zambia farm for the 1992 and 1993 growing seasons.

Component	Characteristic	1992	1993
crop	variety	MM 602	MM 603
	seed	undressed	undressed
	planting date	25 November, 1991	30 December, 1992
	spraying date	7 January, 1992	20 January, 1993
	harvest date	6 May, 1992	5 June, 1993
Soil	sand	55.8 ± 1.3 %	65.6 ± 2.8 %
	silt	10.0 ± 0.4 %	14.3 ± 6.4 %
	clay	34.7 ± 1.4%	20.1 ± 3.6 %
	organic carbon	0.8 ± 0.1 %	0.3 ± 0.2 %
	organic matter	1.36 ± 0.1 %	0.5 ± 0.4 %
	pH (soil : water=1:2.5)	6.3 ± 0.1	9.7 ± 0.5
plot	cultivation	tractor	tractor
	weeding	by hand	by hand
	previous crop	fallow	maize (MM 602)
	neighbouring crop	maize	maize
	pesticide history	unknown	Gammaxane

Table II. Mean temperature and rainfall for the 1992 and 1993 growing seasons

Month	1992		1993	
	temperature, °C	rainfall, mm	temperature, °C	rainfall, mm
January	22.4	168	24.4	167.8
February	23.5	44.9	22.1	179.6
March	23.5	166.4	21.4	83.5
April	21.9	5.0	22.1	4.6
May	19.1	6.0	19.6	0.0
June	16.9	0	16.0	0.0

2.2. Sampling activities

Sampling for arthropods was done immediately pre-treatment and thereafter every two weeks for two months. Aerial fauna were swept using a standard net at two opposite diagonals across each sub-plot. Pitfall traps were used to assess fauna that inhabit the soil surface. Four pitfall traps (diameter, 50 mm; depth,100 mm) were randomly placed in each sub-plot. Each trap was filled with water to which a few drops of liquid detergent was added to reduce the surface tension. The traps were emptied after 48 hours.

To assess soil inhabiting fauna, four soil cores (diameter, 50 mm; depth, 150 mm) were randomly taken from each sub-plot prior to application of lindane and once after two months. The arthropods were extracted from the soil using Berelese funnels. Light bulbs serving as heat source were placed above the samples to obtain a temperature gradient. The soil samples were left in the funnels for 72 hours.

2.3. Determination of soil microbial activity

Prior to the application of lindane , four nylon bags (120 mm × 120 mm), each containing 50 leaf discs (25 mm in diameter) were randomly buried to a depth of 50 mm in each of the sub-plots. Three months later the bags were retrieved and the contents dried (at 60°C for 24 hours) and weighed.

2.4. Assessment of crop damage and yield

To assess damage due to stalk borers, all the plants in each sub-plot were searched and the proportion of infested plants recorded.

In each plot, maize yields were recorded from four sub-plots (2 m × 2 m) which were earmarked from the start of the experiment and left undisturbed until harvest. The cobs were dried, shelled and weighed at a moisture content of 13.8%.

3. RESULTS

3.1. Sweepnet

Due to low numbers of insects caught in the sweepnet, the data were grouped into two insect orders. In general there were no significant differences in the number of Coleoptera caught either before or after application of lindane (Table III). Prior to insecticide application, there was an apparently significantly higher number of Diptera in the "treated" plot in 1992 (Table III), for reasons unknown. After treatment, there were no significant differences between the treated and untreated plots. Overall there were no significant differences in the number of Diptera between the treated and untreated plots in 1993 (Table III).

Table III. Mean (±SE) number of insects caught using a sweepnet in the trials in 1992 and 1993.

Species	1992			1993		
	interval after spraying, days	untreated	treated	interval after spraying, days	untreated	treated
Coleoptera	pretreatment	0.8±0.3	0.6±0.3	pretreatment	0.5±0.4	0.3±0.3
	13	0.8±0.3	0.0±0.0*	15	0.5±0.4	0.5±0.5
	27	0.1±0.1	0.5±0.2	29	1.5±1.0	1.3±0.6
	41	1.3±0.3	0.6±0.1	43	1.8±0.4	3.3±1.6
	56	2.1±0.4	2.0±0.4	57	1.5±0.8	1.0±0.7
	69	1.6±0.6	0.6±0.3	71	2.0±0.7	1.5±0.5
Diptera	pretreatment	0.3±0.3	1.3±0.1*	pretreatment	0.8±0.4	0.5±0.4
	13	2.3±1.0	4.2±2.0	13	2.7±0.4	2.7±0.1
	27	3.1±0.9	0.8±0.3*	27	14.8±5.1	18.0±9.5
	41	1.6±1.0	2.1±0.6	41	2.3±1.2	5.8±1.1*
	56	1.8±0.6	2.3±1.0	56	3.0±1.1	7.5±5.1
	69	0.5±0.0	1.1±0.1*	69	2.8±1.9	1.5±1.0

* Means within rows significantly different at P = 0.05 level.

3.2. Pitfall

Overall the number of spiders caught in 1993 were higher than in 1992. Both in 1992 and 1993 the number of spiders were significantly reduced in the treated plots shortly after spraying (Table IV). Thereafter there were no significant differences between the treated and untreated plots.

In 1992 the number of ants, although not significantly different, was higher in the treated plots before the application of lindane. After spraying, the number of ants was significantly lower in the treated plots (Table IV). In 1993 the number of ants was significantly higher in the treated plots, before the application of lindane. After spraying there were no significant differences between the treated and untreated plots.

3.3. Soil core

In both years, neither springtails nor mites were recorded from the soil core samples. However, that springtails were present in the field, was confirmed by the numbers caught in pitfall traps. The number of springtails recorded in 1993 was much lower than in 1992. Spraying of lindane did significantly reduce the number of springtails in both years. The effect lasted for almost two months (Table V).

3.4. Organic matter breakdown

The losses in weight of the leaf litter bags owing to soil microbial activity were moderate with around 50% losses during the period of burial. In 1992 the organic matter breakdown was significantly higher in the treated plots (0.74 $\pm$ 0.33 g) than in the untreated

Table IV. Mean ($\pm$SE) number of arthropods caught using pitfall traps in the trials in 1992 and 1993.

Species	1992			1993		
	Interval after spraying., days	untreated	treated	interval after spraying, days	untreated	treated
Araneida	pretreated	0.8$\pm$0.2	0.5$\pm$0.2	pretreated	35.7$\pm$30.5	4.5$\pm$1.9
	14	1.6$\pm$0.4	0.2$\pm$0.2*	15	3.5$\pm$1.2	1.0$\pm$1.0*
	28	0.5$\pm$0.1	0.4$\pm$0.1	29	8.5$\pm$4.6	3.3$\pm$1.4
	42	0.4$\pm$0.2	1.4$\pm$1.2	43	4.8$\pm$1.4	3.3$\pm$1.4
	57	0.9$\pm$0.4	0.6$\pm$0.2	57	2.5$\pm$1.4	3.8$\pm$1.4
	70	0.6$\pm$0.1	0.2$\pm$0.1	71	4.3$\pm$1.4	7.0$\pm$4.3
Formicidae	pretreated	4.6$\pm$3.3	14.3$\pm$7.6	pretreated	10.3$\pm$10.2	113.5$\pm$31.1*
	14	23.7$\pm$3.3	9.8$\pm$0.6*	15	7.8$\pm$ 3.8	15.3$\pm$ 4.7
	28	9.0$\pm$2.7	6.2$\pm$2.4	29	7.5$\pm$ 7.0	11.0$\pm$ 2.8
	42	13.8$\pm$3.2	5.3$\pm$2.7	43	17.5$\pm$17.5	21.3$\pm$ 8.9
	57	7.9$\pm$1.2	4.1$\pm$1.0*	57	42.8$\pm$25.5	34.3$\pm$12.1
	70	16.4$\pm$2.0	8.1$\pm$2.6*	71	38.5$\pm$ 5.4	33.3$\pm$25.9

* Means within rows significantly different at P = 0.05 level.

Table V. Mean (+SE) number of Collembola caught in pitfall traps in the trials in 1992 and 1993.

1992			1993		
interval after spraying, days	untreated	treated	interval after spraying, days	untreated	treated
pretreatment	38.6+14.2	216.0+68.6*	pretreatment	18.0+4.7	5.8+3.8
14	75.3+17.1	0.3+0.2*	15	9.8+2.2	1.8+2.1*
28	18.4+ 1.7	3.1+1.3*	29	5.8+1.5	0.3+0.4*
42	14.4+ 9.1	1.5+0.7	43	9.5+5.6	3.3+1.9*
57	46.5+19.1	10.3+2.4	57	7.5+2.2	2.3+0.8*
70	31.2+10.6	22.7+1.5	71	17.8+2.4	10.8+4.2

* Means within rows significantly different at P < 0.05 level.

plots (0.89 + 0.03). In 1993, this situation was reversed with a greater recovery of leaf material from the bags buried in the treated plots (0.89 +0.19 g) than in the untreated plots (0.67 + 0.38 g) though with the higher experimental variation in this, the difference was not statistically significant.

3.5. Plant damage

In both years a single application of lindane significantly reduced damage due to stalk borers. However, significantly higher yield of maize was only obtained in 1993 (Table VI). The results showed that about 10-12% damage could be tolerated without significantly loosing yield in 1992. Whereas, in 1993 about 8-10% damage due to stalk borers could not be tolerated without significantly affecting the yield.

4. DISCUSSION AND CONCLUSIONS

In general, the activity of insects was low probably due to the drought conditions that prevailed during the experimental period. Data from soil core samples and organic matter breakdown also indicated low faunal activity. This was not surprising considering the highly alkaline soils having poor organic matter.

Table VI. Proportion of plants damaged by stalk borers and maize yields in the trials in 1992 and 1993.

Observation	1992			1993		
	interval after spraying, days	untreated	treated	interval after spraying, days	untreated	treated
% damage	pretreat	13.6+ 1.0	10.4+ 0.6	pretreat	8.0+ 2.2	7.1+2.4
	13	8.4+0.9	2.8+0.6*	15	13.3+3.7	2.0+0.6*
	27	15.5+2.5	2.0+0.4*	29	13.5+1.9	1.3+0.5*
	41	12.2+2.1	2.5+0.3*	43	7.5+2.2	1.3+0.4*
	-	-	-	57	2.9+1.0	0.9+0.3
yield, $kgha^{-1}$		5988+1037	8041+1016		5799+782	7395+1504*

* Means within rows significantly different at P < 0.05 level..

Application of lindane appeared to have no real effect on aerial fauna. Although lindane is known to be toxic to Coleoptera and Diptera [3], the lack of significance may have been due to the low activity of these insects as well as emigration and immigration. Furthermore, the effectiveness of lindane is reduced under low rainfall conditions [4] which were experienced during the present studies. In addition, because of its relative high vapour pressure, the action of lindane under tropical conditions is not as persistent when compared to lower temperatures under temperate conditions [5].

Lindane significantly reduced the number of ants, springtails and spiders, recovered from pitfall traps. These findings are in agreement with those of other reports [6]. However in the present study the impact of lindane on these arthropods lasted for about two months. These findings agree well with other concurrent studies which have shown that lindane dissipates rapidly from the soil under Zambian field conditions. About 75% of the initial concentration of lindane is lost during the first 60 days after treatment [7].

Organochlorine insecticides are known to reduce microorganisms in the soil [8] and in turn affect the breakdown of leaf litter (organic matter). Contrary to the expected findings the present study showed that lindane did not significantly affect these microorganisms and our data are difficult to harmonize with those of other studies. Probably greater breakdown of organic matter would have occurred in the untreated plots had the litter bags been left in the soil for a longer period.

In both years lindane was highly effective against the target pest (stalk borers) as indicated by a reduction in the proportion of plants damaged. The yields were relatively higher in the treated plots when compared with the untreated plots although a clear relationship between damage and yield could not be established by the results in this study.

ACKNOWLEDGEMENTS

Financial support provided by the joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture is gratefully acknowledged. We are also appreciative of the technical assistance provided by Alfred Phiri.

REFERENCES

[1] GRAHAM, P., Destruction of birds and other wildlife, by dieldrin spraying against tsetse fly in Bechuanaland.Arnoldia **10** 1-4 (1964).

[2] WILSON, V.J., Observation on the effect of dieldrin on wildlife during tsetse fly *Glossina morsitans* control operations in Eastern Zambia, Arnoldia **5** 16-20 (1972).

[3] ZINCHENKO, V.A., KALININ, V.A., ISLOVTSOV, R., Chemical Protection of Plants. R. Islovtsov (Ed.). Mir Publishers, Russia (1988).

[4] SHEETS, T.J., Pesticides; Contemporary Ideas in Agriculture Health and Environment, T.J.Sheets, D. Pimentall (Eds), Clifton, New Jersey (1979).

[5] KUMAR, R.,(Ed.), Insect Pest Control with Special Reference to African Agriculture, Edward Arnold, London (1984).

[6] BROWN, A.W.A. (Ed.), Ecology of Pesticides, John Wiley and Sons, New York (1978).

[7] MWANGALA, et al., this TECDOC.

[8] PERFECT, T.J., Environmental impact of DDT in a tropical agro-ecosystem, Ambio **9** 16-21 (1980).