EVALUATION OF INSECTICIDES FOR CONTROL OF BLACK MAIZE BEETLE (*Heteronychus licas*) IN SUGARCANE

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Abstract

With the development of resistance to dieldrin by the Black Maize Beetle (*Heteronychus licas* Klug), research has been intensified to screen alternative insecticides under both field and laboratory conditions in the search for chemicals for (a) applying at depth for control of larvae, and (b) spraying on the soil surface to control adults. The results obtained from preliminary trials are presented, indicating that suitable alternatives to dieldrin are available for use in sugarcane to control both the larval and adult stages of *H. licas*.

Introduction

The dynastid beetle (*Heteronychus licas* Klug), known commonly as the Black Maize Beetle but not to be confused with *H. arator* which shares the same common name, was first recorded in sugarcane in the Zimbabwe lowveld in 1966, but it was not until 1974, following the first of a series of wet seasons, that damage to cane started causing concern. By 1978 it had reached alarming proportions, but effective control with dieldrin over the next few years reduced populations in cultivated areas to levels which were of no economic consequence.

Reports of *H. licas* activity were again received in 1984 and 1985, after several years without evidence of serious crop damage, and over the next few years the situation deteriorated steadily in most sectors of the industry, until by 1990 the problem had increased to levels previously experienced in the late 1970s.

Infestation of sugarcane fields

H. licas is an endemic species, occurring wherever suitable conditions prevail for its reproduction and survival. In order to breed successfully, the beetles not only need an adequate food supply but the females must also have soft earth in which to burrow for oviposition. Areas of uncultivated bush are in a favourable condition for only limited periods, so that not all the eggs laid will hatch and many of the surviving larvae will succumb during the winter months when previously moist areas dry out. Under natural conditions, therefore, excessive multiplication of the species is seldom possible except in wet seasons when clay soils may remain moist enough throughout the dry season to support larval life.

Large tracts of irrigated sugarcane, on the other hand, offer the species optimum conditions throughout its life cycle, with the main factors limiting survival and reproduction in the bush eliminated. Thus *H. licas* has become established in sugarcane fields where conditions are well suited for mass reproduction and multiplication, and where it has become a pest of considerable economic importance.

Life cycle of Heteronychus licas

The life cycle of *H. licas* is completed in one year, with the first eggs being laid in November and all larvae pupating in the field from August to November of the following year. Table 1 reflects the probable life cycle in the lowveld, and is based on local observations and evidence, supported by the results of earlier work done in the Zimbabwe highveld (Symes, 1925), and in Swaziland (Sweeney, 1967). This life cycle pattern, and also the relative abundance of life cycle stages in different months, may vary slightly from year to year in accordance with variations in temperature and rainfall.

Damage to sugarcane

Damage to growing cane is caused by both adults and larvae of the species, which have different feeding habits.

Damage to shoots and tillers in young plant and ratoon cane is caused by adult beetles chewing into the sides of young tillers just below soil level, creating typical "deadheart" symptoms which are readily visible in young cane. In older cane they attack underground buds and burrow into developing stalks and crowns, causing damage without any visible effect. The result of adult damage in young cane is a reduction in millable stalk numbers, and in older cane a restriction in growth and development of the stalks.

Larvae damage cane roots, which can cause a serious growth check, and also underground shoots and setts. Whereas the main food of the first instar larvae is organic detritus in the soil, the second instar as it grows feeds to an increasing extent on live root tissue and the third instar larvae feed virtually exclusively on the roots, as well as on underground shoots and setts (Sweeney, 1967).

Damage to stand, when whole stools are killed off by the insects is common in heavily infested fields, and necessitates replanting in severe cases. Stand loss results from a combination of both adult and larval damage.

Poor crop uniformity and uneven maturity results from the loss of young tillers, as many of these are replaced by compensatory growth flushes 6-8 weeks after harvest, or even later. This has a direct effect on both yield and quality in the following ratoon.

Table 1

Life cycle of *Heteronychus licas*

Month:	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Eggs:					*	**	**	**	*	*		
Larvae:	**	*			*	**	**	**	**	**	**	**
Pre-pupae:	*	**	**	*								
Pupae:		*	**	**	*							
Adults:			*	*	**	**	**	**	*	*	*	

* small numbers ** abundance

Development of resistance to dieldrin by H. licas

Work conducted at the Zimbabwe Sugar Association Experiment Station since 1989 has shown that population increases of *H. licas* in recent years were due to a build-up of resistance by the pest to dieldrin, a possibility that had been suspected for some time but which needed confirmation. Not all individuals in the population are resistant to the chemical, and both dieldrin and aldrin are still achieving limited control of *H. licas* early in the season soon after the beetles have emerged. Later in the summer, when most susceptible individuals have succumbed to treatment and only resistant individuals remain, these chemicals are virtually ineffective. In many ways it is fortuitous that resistance has developed at a time when manufacture of these chemicals has been discontinued, but there remains an urgent need to find suitable replacements for them. Research on the problem has been intensified, and new candidate insecticides are being tested under both field and laboratory conditions.

Chemical control measures

When the *H. licas* problem first arose in the late 1970s, chlorinated hydrocarbons such as dieldrin and aldrin were available on the market at relatively low cost, and because of their long residual life in the soil they were well suited for control of the pest. This was certainly shown by the early success with these chemicals (Cackett, 1980), and dieldrin in particular was extensively used and shown to be effective in controlling both adults and larvae with good residual activity for 2-3 years.

With most chlorinated hydrocarbons now either (a) banned for environmental reasons, (b) no longer produced, or (c) ineffective because of pest resistance, the availability of chemicals with long residual activity is very much more restricted than in the past. Whereas dieldrin provided adequate control of both adults and larvae it is unlikely that replacement chemicals will achieve the same success, and it is anticipated that future control strategies will have to be directed at targeting larvae and adults separately.

Control of larvae

For the control of larvae in the soil a product with long residual action is desirable, and at present the only candidate insecticide on the market is a controlled release formulation of chlorpyrifos manufactured in Australia by Incitec International and marketed under the trade name "suSCon Green", hereafter referred to as Suscon Green. This product is now used successfully in Australia to control a range of white grub species in sugarcane (Allsopp & Chandler, 1989), and it has also proved successful in other parts of the world in controlling soil-dwelling larvae of various beetle species (DeGroot & Valvasori, 1989, May & Hamilton, 1989, Saidi *et al.*, 1990). Other controlled release products, involving different active ingredients, are still in the developmental stages.

Control of adults

Chemicals of relatively short residual action can be considered for the control of adults, particularly as they tend to congregate after pupation in fields that have been harvested late in the season where the soil is moist and the cane is young. Ideally, what is needed is an effective sprayable formulation for application in a wide band over the cane rows soon after harvest to kill on contact with the beetles either when they emerge from the soil after pupation, or shortly thereafter when they re-enter the soil to feed underground. With early emergence of beetles starting in mid-September and with the main period of emergence extending from mid-October to mid-November, this means that a chemical with 8 to 10 weeks residual activity would be necessary to control adults during this period.

Methods

Bioassay trials

Standard bioassay techniques were used in the first of two bioassay trials, with beetles introduced into jars of soil mixed with insecticides at concentrations of 10 ppm. Twenty jars each of seven insecticides were compared with 40 untreated controls. After preparation, the soil in each bottle was moistened and a single beetle was introduced into each bottle with a small section of cane stalk as a food supply.

Bioassay methods bear no resemblance to field conditions, and are only of value in screening out chemicals which have no effect on the target pest. Insecticides that appear effective still need to be tested under field conditions to determine optimum rates and methods of application. In an attempt to simulate field conditions more closely, the second bioassay trial involved spraying nine chemicals onto the surface of soil in large pots at the concentrations recommended for field application. Insecticide treatments and controls were replicated five times, and twenty adult beetles were introduced into each pot the day after spraying. After 14 days, all pots were emptied and both dead and live beetles counted.

Field trials

Experiments conducted under field conditions aimed at using yield comparisons as a means of evaluating soil chemicals for control of *H. licas* have not been successful, mainly because of damage caused by adults during the early growth stages. Sites for insecticide trials are carefully selected in areas of commercial cane where considerable beetle damage is evident. Because of high beetle populations in surrounding areas, all plots in these trials are subjected to excessive damage, irrespective of insecticide treatment. Although many individuals must be affected by the chemicals and must ultimately die, this does not lessen the damage to the plots concerned which are immediately invaded by fresh populations. As a result it has proved impossible to measure the yield response to applied chemicals because all plots are equally devastated and produce uniformly low yields.

The value of such trials, however, has been in providing a means of measuring the effect of treatments on larval populations, and routine counts of larvae are made from sample pits in every plot in field trials. The results which follow were obtained in 1991 from four trials conducted on the estates by Experiment Station staff, and from two observation trials conducted by estate technical staff. In most of the trials larval counts were recorded from five soil samples per plot, each consisting of an area 0,5 x 0,5 m across the cane row excavated to a depth of 0,3 m. Because of the tedious nature of the work it was not possible to take larger numbers of samples, and thus sampling variation was predictably high. In the absence of *H. licas* adults and eggs in any of the samples, all small larvae present were assumed to be of a different species, and the larvae numbers quoted are the totals of *H. licas* second and third instars only.

Tests of non-additivity were made on larval counts in all experiments, but they were only significant ($P = 0,05$) in two out of seven cases. Square root transformations eliminated these significant effects and improved coefficients of variation, but they did not alter the significance of treatment differences nor the interpretation of results.

Results

Bioassay Trial 1 (1989/90)

The insecticides tested and resultant beetle mortality are presented in Table 2. Mortality was very rapid in all but the dieldrin treatment, with all beetles killed by the 8th day after exposure. At that stage dieldrin had accounted for only 45% mortality, but this figure increased to 55% by the 12th day and thereafter remained unchanged until the trial was terminated after 20 days. Results of this trial provided the first experimental evidence of resistance to dieldrin, and also showed that there were several alternative chemicals capable of controlling beetles.

Table 2

Percentage mortality: Bioassay Trial 1

Insecticide		Formulation	% mortality
Mocap	(ethoprop)	10 G	100
Mocap	(ethoprop)	72 EC	100
Counter	(terbufos)	5 G	100
Dursban	(chlorpyrifos)	10 G	100
Miral	(isazofos)	10 G	100
Oftanol	(isofenphos)	50 EC	100
Dieldrin		50 WP	55
Control		—	2

Bioassay Trial 2 (1991)

Results shown in Table 3 indicated good control from three of the insecticides, which all gave over 90% beetle mortality. It is significant that all three of the successful insecticides were also shown to be effective in Bioassay Trial 1, when they each recorded 100% beetle mortality.

Table 3

Percentage mortality: Bioassay Trial 2

Insecticide		Formulation	Rate prod/ha	% mortality
Oftanol	(isofenphos)	50 EC	1,00 ℓ	92,8
Mocap	(ethoprop)	70 EC	3,00 ℓ	91,7
Dursban	(chlorpyrifos)	50 EC	1,00 ℓ	90,6
Heptachlor		40 WP	4,00 kg	11,2
Force	(tefluthrin)	20 CS	0,75 ℓ	6,1
Confidor	(imidacloprid)	20 SL	0,83 ℓ	5,2
Steladone	(chlorfenvinphos)	30 EC	1,00 ℓ	4,1
Nuvacron	(monocrotophos)	40 EC	1,50 ℓ	2,9
Dieldrin		50 WP	4,00 kg	1,9
Control		—	—	3,0

Soil Insecticide Trial 1 (plant cane)

In this trial six granular soil insecticides were compared with standard dieldrin treatment and an untreated control, with all chemicals applied in the base of the furrow at the time of planting. The trial was planted in September 1989 in a randomised block design with four replications. No larval counts were made in the plant crop, but counts were made in the first ratoon on two occasions in June and August, 1991.

Soil Insecticide Trial 2 (ratoon cane)

The same treatments were compared in this trial, the only difference being that the insecticides were applied to a stand of third ratoon cane in September 1989 about one month after the cane had been harvested. The granular formulations were applied in a shallow furrow on each side of the cane rows and covered, about 5 cm deep, whereas dieldrin was applied by knapsack in about a 30 cm band on each side of the cane rows and covered over lightly. Larval counts were made on a single occasion during the second crop cycle after treatment.

The insecticide treatments and the results of the two soil insecticide trials are presented in Table 4, with larval counts meaned for the two sampling dates in the case of Trial 1. Yields were poor in both seasons as a result of *H. licas* damage, with neither trial showing any significant treatment effects in either year.

Larval counts revealed clear evidence of treatment responses in Trial 1, and the Suscon Green treatment caused significant reductions in larvae populations during the second year of activity of the chemical. Mocap also had some effect, which was surprising in a chemical with such limited persistence, but it did not reduce larval numbers significantly. There was also evidence of a response to Suscon parathion and to Miral in the June but not in the August sampling, and these effects are attributed to random variability.

Larval numbers per sample were high in Trial 2, but none of the treatment differences was significant. Results indicated that applying insecticides in narrow bands on the sides of the cane rows did not provide measurable control of larvae. This was not surprising in view of the small contact area involved and the fact that placement of the insecticides was too shallow and too far from the main zone of larval activity, which is below the cane stool and not to the side of it.

Table 4

Mean larvae per sample: Soil Insecticide Trials 1 and 2

Treatment		Formulation & rate a.i./ha		Larvae per sample		Percent of control	
				Trial 1	Trial 2	Trial 1	Trial 2
Control				8,58	10,45	100,0	100,0
Suscon	(parathion)	15 CR	4,0 kg	7,55	8,45	88,0	80,9
Counter	(terbufos)	5 G	1,0 kg	8,63	8,90	100,6	85,2
Mocap	(ethoprop)	10 G	2,0 kg	6,48	11,10	75,5	106,2
Suscon	(chlorpyrifos)	10 CR	4,0 kg	4,33	9,75	50,4	93,3
Miral	(isazofos)	10 G	2,0 kg	6,80	8,50	79,3	81,3
Dursban	(chlorpyrifos)	10 G	2,0 kg	10,28	9,65	119,8	92,3
Dieldrin		50 WP	2,0 kg	10,65	9,45	124,2	90,4
L.S.D. P = 0,05				3,47	NS		
P = 0,01				NS	NS		
Trial mean				7,91	9,53		
S.E. Plot ±				2,37	2,68		
S.E. Mean ±				1,18	1,34		
C.V. %				29,87	28,16		

Suscon Green trials

These two trials were designed to evaluate Suscon Green (10% chlorpyrifos) for control of *H. licas* larvae, and they included three rates of application (20, 30, and 40 kg/ha of product), compared with the standard dieldrin treatment (2 kg/ha a.i.) and an untreated control. The Suscon Green was banded across the base of the furrow immediately before planting and covered to a depth of 8 to 10 cm, with the dieldrin applied in the furrow by knapsack before covering in the same way. The results of the two trials are presented in Table 5.

Table 5

Mean larvae per sample: Suscon Green Trials 1 and 2

Treatment	Larvae per sample		Percent of control	
	Trial 1	Trial 2	Trial 1	Trial 2
Control	3,88	1,70	100,0	100,0
Dieldrin 50WP @ 4 kg/ha	1,90	2,75	49,0	161,8
Suscon Green @ 20 kg/ha	0,63	1,00	16,1	58,8
Suscon Green @ 30 kg/ha	1,03	0,65	26,5	38,2
Suscon Green @ 40 kg/ha	0,73	0,70	18,7	41,2
L.S.D. P = 0,05	0,59	1,48		
P = 0,01	0,82	NS		
Trial mean	1,63	1,36		
S.E. Plot ±	0,38	0,96		
S.E. Mean ±	0,19	0,48		
C.V. %	23,23	70,57		

Suscon Green Trial 1 (Triangle)

The trial was planted to N14 in September 1990, with treatments on large plots of 0,4 ha each replicated four times. High yields were recorded at this trial site, where the crop was not extensively damaged by adult beetles during the early growth stages, and although differences in cane yields between treatments were not great they nevertheless attained significance, with the mean of the Suscon Green treatments outyielding the control (P = 0,05). Larval counts made from pit samples on two occasions in May and July showed that populations were relatively low, particularly at the second sampling, but there were still adequate numbers present to reveal highly significant treatment responses (P = 0,01). Larval counts in Table 5 are the means of the two sampling dates. In the three Suscon Green treatments larval numbers did not differ significantly, but the average count of these treatments was significantly lower than in the control and in the dieldrin treatment.

Suscon Green Trial 2 (Hippo Valley Estates)

This was a repeat of Trial 1 (Triangle), with four replications on different sites where relatively uniform soil conditions could be found. Cane yields were erratic and variable as a result of game damage, and no significant treatment effects were recorded. Larval counts were made on a single occasion in June, with results showing a significant response to Suscon Green (P = 0,05), although reductions in larval numbers were not as great as in the Triangle trial.

Observational Trial (Triangle)

This trial was designed to compare a range of soil insecticides in plant cane, and was laid out in plots of about 0,23 ha, with four replications of treatments. Because of poor stand establishment and lack of water for irrigation, the trial was destined to failure from an early stage, and it was maintained only for the purpose of conducting larval counts. Despite poor and erratic stands it was possible to sample in growing cane in all plots, but the surface horizon was very dry when sampled in May 1991, and larval numbers were relatively low.

Table 6

Mean larvae per sample: Observation Trial (Triangle)

Treatment	Formulation and rate of product per ha		Larvae per sample	Percent of control
Control			1,83	100,0
Dieldrin	50 WP	4,00 kg	2,25	123,0
Suscon Green	10 CR	30,00 kg	0,46	25,0
Confidor (imidacloprid)	20 EC	0,83 ℓ	0,42	22,8
Dursban (chlorpyrifos)	48 EC	6,25 ℓ	0,30	15,9
Nuvacron (monocrotophos)	40 EC	3,00 ℓ	1,75	95,6
Oftanol (isofenphos)	50 EC	3,30 ℓ	0,00	0,0
L.S.D. P = 0,05			1,07	
P = 0,01			1,47	
S.E. Plot ±			0,73	
S.E. Mean ±			0,36	
Trial mean			1,00	
C.V.%			72,86	

The chemicals tested and the results of larval counts are given in Table 6. In spite of relatively low numbers and high sampling variability, results showed dieldrin and Nuvacron to have been ineffective, with Suscon Green giving a significant reduction in larvae numbers (P = 0,05). Only Suscon Green and dieldrin were applied at seedcane depth, and the other treatments were sprayed in a band over the cane rows after germination. The effects of Oftanol, Dursban and Confidor in reducing larval numbers when applied as surface sprays was an indirect effect associated with control of adult beetles and interference with oviposition on treated plots.

Observational Trial (Hippo Valley Estates)

An area of ratoon cane exhibiting excessive damage by adult beetles was selected to investigate the merit of applying insecticide over the cane rows and splitting back by machine to cover it effectively, thus converting the irrigation layout from an in-row to an inter-row system. Treatments were applied to large unreplicated plots as follows:

Control – no insecticide. Rows split back as for treated plots.

Suscon Green (chlorpyrifos) 10 CR. Applied in a band over the cane row before covering back.

Confidor (imidacloprid) 20 EC. Sprayed in a wide band over the cane rows before splitting back.

Table 7
Mean larvae per sample: Observation Trial (Hippo Valley)

Treatment	Larvae per sample	Percent of control
Control	4,9	100,1
Suscon Green	1,4	28,6
Confidor	2,7	55,1

The plots were not yielded, but mean larvae counts recorded in July from 10 pit samples per plot are shown in Table 7. Results indicated that both insecticides were effective in controlling larvae, with Suscon Green and Confidor reducing larval populations by 71% and 45% respectively.

Discussion

With the object of finding alternatives to dieldrin for control of *H. licas*, and of using control strategies based on targeting the larvae and the adults separately, the results obtained from these preliminary trials have indicated that suitable alternatives are available for control of both the larval and adult stages of *H. licas.*

When applied to the soil surface as sprayable formulations for the control of adults, Dursban (chlorpyrifos), Oftanol (isofenphos) and Mocap (ethoprop) have given good results, and other chemicals such as Miral (isazophos) and Confidor (imidacloprid) have shown promise and deserve further trial.

Suscon Green has proved consistently successful in controlling larvae, particularly during its first year of activity. Work in Australia (Hitchcock *et al.*, 1984) has shown that Suscon chlorpyrifos will provide up to three years' control of white grubs, but the duration of its residual activity under local soil and climatic conditions has still to be determined.

The main limitation of chlorpyrifos is that it degrades rapidly in sunlight, and to optimise its residual activity it must be covered with soil. Thus the effectiveness of Dursban EC applied to the soil surface for control of adults is dependent on its being adequately covered. For the same reason Suscon Green is unsuitable for ratoon applications because of the problem of applying it at depth, and its use is likely to be restricted to new plantings where it can be banded at seedcane depth.

It would be of considerable benefit to have more than one effective insecticide available for use at any one time, as this would enable different chemicals to be used in rotation in different areas, or in different years, as a means of delaying the build-up of resistance to any one of them. For this reason it would be inadvisable to use chemicals with the same active ingredient for control of both larvae and adult, e.g. Suscon Green for larval control and Dursban EC for adult control, both containing chlorpyrifos as the active component. However, as most of the insecticides being tested for the control of *H. licas* are organo-phosphates, it can be expected that cross-resistance will ultimately develop in spite of efforts to rotate their usage.

Conclusions

Experience has shown that it is not possible to rely exclusively upon any single method for a permanent solution to insect pest problems. They can seldom be eliminated completely and must be dealt with continually, and the more varied the approach the more likely the success, even in the short term.

Many lessons can be learnt from the past, particularly in the development of resistance to pesticides, and the use of dieldrin in the sugar industry over the past 12 years has exemplified how insecticides should not be used if pest resistance is to be avoided or delayed. Williams (1985) emphasised that the first step in an integrated pest management programme was to determine infestation levels by regular monitoring to assess the numbers and distribution of the pest. Future control strategies must be based on this, and on other procedures which minimise the use of expensive and hazardous chemicals, not only to make them more cost effective, but to ensure that a more rational and pragmatic approach to pest control is adopted and that fields are not treated routinely and unnecessarily. Only in this way can *H. licas* control policies be sustained to provide a long term solution to the pest problem.

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