Effects of FLUAZURON *and* IVERMECTIN TREATMENT OF CATTLE *on the structure of dung beetle communities*

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ABSTRACT

A long-term and large-scale field study was carried out to assess the ecotoxicological effect on the dung beetle fauna of cattle treatment with ivermectin (broad-spectrum endectocide) and fluazuron (acaricide) under normal extensive farming conditions in South Africa. One herd of 25 heifers was treated four times at an eight-week interval (starting late November 2001) with a standard injection of ivermectin (200 µg/kg) and a standard pour-on dosage of fluazuron (3 mg/kg) and another herd was left untreated as a control. This set-up was replicated on a second, separate farm and the four herds were kept in four separate paddocks of about 80 ha each. Dung beetle communities were monitored over an entire farming season, from early November 2001 until August 2002. This study was carried out in a very moist year with above average rainfall. The impact of the treatment on the dung beetle communities was examined using a variety of community measures as well as a wide range of univariate, graphical and multivariate analyses. There was no observable effect of the administered drugs on the dung beetle communities. Species richness and diversity seemed unaffected in the treated communities and the ecological similarity of the treated and control communities remained high through most of the trial. These results support the notion that the ecotoxicological impact of antiparasitic drugs depends on factors such as climatic conditions, spatial scale of treatment and proportion of animals treated.

Keywords: Dung beetle communities, ecotoxicology, fluazuron, ivermectin, long-term field trial

INTRODUCTION

The majority of South African commercial cattle farmers apply intensive parasite control using various antiparasitic drugs (Spickett and Fivaz, 1992). While the effective control of parasites seems socio-economically necessary to the farmer, unintended side effects of many pesiticides make them environmentally undesirable. Ecotoxicological effects on non-target organisms vary from product to product and scientific experiments aiming to identify products with the least detrimental effects are needed to provide farmers with the necessary information.

Macrocyclic lactones, especially ivermectin, are commonly used because of their broad spectrum against gastro-intestinal nematodes, lungworms, as endectocides with low vertebrate toxicity (Benz *et al.*, 1989; Pulliam and Preston, 1989; Strong and Wall, 1990; Wardhaugh and Beckmann, 1996/97).

After administration ivermectin is metabolized only to a limited extent and the parent compound and its metabolites subsequently enter the environment via the treated livestock's faeces (Halley *et al.*, 1989; Wardhaugh and Beckmann, 1996). Concern has been raised about potential adverse effects on dung beetles which contribute to soil fertility and sustainability of pastoral ecosystems (Wall and Strong, 1987; Strong, 1993; Wardhaugh and Beckmann, 1996/97; McKellar, 1997). Laboratory injections of avermectin/ivermectin to heifers negatively affected larval dung beetles including *Diastellopalpus quinquedens* and *Onthophagus gazella* (Sommer *et al.*, 1993; Sommer and Overgaard Nielsen, 1992), *O. binodis* (Roncalli, 1989), *O. ferox* (Ridsdill-Smith, 1993), *Euoniticellus intermedius* (Fincher, 1992) and *Onitis alexis* (Krüger and Scholtz, 1997). Field studies in South Africa detected reduced species diversity and increased species dominance in dung beetle communities after ivermectin treatment of cattle under drought, but not under high-rainfall conditions (Krüger and Scholtz, 1998a and 1998b).

Ivermectin is often used in combination with fluazuron (benzoylphenylurea), a very effective acaricide used to control the blue tick (Boophilus microplus) in South Africa. The compound is slowly metabolized and the major route of elimination is via the faeces of treated animals. Bioassays have shown that exposure to fluazuron had no detrimental effect on brood production or egg to adult development of *E. intermedius*, but lead to reduced brood production of *O. gazella*, and *O. taurus* (Fisara, 1994, 1995a, b, 1996).

The objective of this study was to determine the effect of a combined treatment with Acatak® (2.5% fluazuron pour-on) and Cevamec® (1% ivermectin injectable solution) during an entire grazing season on the structure of the dung beetle community under normal extensive farming conditions in South Africa.

MATERIAL AND METHODS

This study was conducted on two commercial cattle farms under the same management (Middlepunt and Abel, 26°54'S, 27°35'E). The farms were 1 km apart 14 km east of Parys (Free State Province, South Africa), at 1350 m a. s. l. on clay-loam soil. The sites were in the summer rainfall region and the grassland biome of South Africa (Rutherford and Westfall, 1986). Both farms were divided into two adjoining paddocks of 80 ha each with similar vegetation and rainfall patterns; one paddock on each farm being used for the treated cattle and one for the control group. Precipitation and temperature were recorded at the meteorological stations of the South African Weather Bureau at Parys and Vereeniging.

On each farm one herd of 25 cows (with calves) was treated simultaneously with the two products according to the manufacturer's specifications and another herd was left untreated as control group. Acatak® (fluazuron 2.5%) was applied as pour-on at 3 mg fluazuron/kg body mass, Cevamec® (ivermectin 1%) as subcutaneous injections at 200µg iveremctin/kg body mass. The treatments were applied in late November 2001, January, March, and May 2002.

Dung beetle populations were sampled on nine occasions in each of the four paddocks along five randomly selected transects with five pitfall traps each. The first sampling occurred just before the first treatment in November 2001, and was repeated at monthly interval until May 2002, once in July and once in August 2002. The trapped beetles were sorted, counted and identified.

Statistical Analyses

The overall diversity between treatment and control paddocks was compared using species richness and Shannon index (Magurran, 1988). The evenness of species abundance was calculated with Pielou's J' (J'=H'/lnS; Pielou, 1975). These indices were computed with the software ESTIMATES (Colwell, 1997).

The distributional properties of each dung beetle community were presented as k-dominance curves (Lambshead *et al.*, 1983; Magurran, 1988) using the program PRIMER (Plymouth Routines In: Multivariate Ecological Research; Clarke, 1993).

Non-metric multidimensional scaling (MDS) was performed on the fourth-root transformed, mean abundances of species in the communities using the Bray-Curtis coefficient (Bray and Curtis, 1957; Faith *et al.*, 1987) in SAS® (SAS Institute Inc.).

Differences between sampling sites and dates were analyzed for similarity via ANOSIM, a component of PRIMER (Clarke, 1993; Clarke and Gorley, 2001).

The 'similarity percentages' procedure (SIMPER, a component of PRIMER) described by Clarke (1993) and Clarke and Warwick (1994), was used to identify similarity/dissimilarity according to contributions of each species (µi) and ranking them in order of importance.

Table 1 - Measures of overall dung beetle diversity in four South African paddocks (species richness, S, Shannon's diversity index, H', and species evenness, J'), global t-tests showed no significant differences between control and treatment paddocks.

Month	Farm	Regime	S	H'	J'
November-01	Middelpunt	Control	38	2.65	0.728505
	Middelpunt	**Cevamec/Acatak**	**34**	**2.67**	**0.757155**
	Abel	Control	23	2.63	0.838783
	Abel	**Cevamec/Acatak**	**39**	**2.25**	**0.614156**
December-01	Middelpunt	Control	32	2.24	0.646327
	Middelpunt	**Cevamec/Acatak**	**33**	**2.67**	**0.763619**
	Abel	Control	25	2.48	0.770455
	Abel	**Cevamec/Acatak**	**36**	**2.71**	**0.75624**
January-02	Middelpunt	Control	27	2.33	0.706952
	Middelpunt	**Cevamec/Acatak**	**31**	**2.05**	**0.596974**
	Abel	Control	35	2.33	0.655351
	Abel	**Cevamec/Acatak**	**35**	**2.77**	**0.779108**
February-02	Middelpunt	Control	35	2.73	0.767857
	Middelpunt	**Cevamec/Acatak**	**31**	**2.51**	**0.730929**
	Abel	Control	44	2.75	0.726708
	Abel	**Cevamec/Acatak**	**43**	**2.76**	**0.733808**
March-02	Middelpunt	Control	31	2.87	0.835763
	Middelpunt	**Cevamec/Acatak**	**35**	**2.8**	**0.787546**
	Abel	Control	38	2.7	0.74225
	Abel	**Cevamec/Acatak**	**36**	**2.28**	**0.636246**
April-02	Middelpunt	Control	27	2.03	0.615929
	Middelpunt	**Cevamec/Acatak**	**28**	**1.94**	**0.582197**
	Abel	Control	30	2.51	0.737975
	Abel	**Cevamec/Acatak**	**29**	**2.25**	**0.668192**
May-02	Middelpunt	Control	24	2.51	0.789792
	Middelpunt	**Cevamec/Acatak**	**21**	**2.57**	**0.844139**
	Abel	Control	23	2.63	0.838783
	Abel	**Cevamec/Acatak**	**27**	**2.03**	**0.615929**
July-02	Middelpunt	Control	8	1.89	0.908898
	Middelpunt	**Cevamec/Acatak**	**10**	**1.63**	**0.7079**
	Abel	Control	7	1.1	0.565288
	Abel	**Cevamec/Acatak**	**7**	**1.13**	**0.580705**
August-02	Middelpunt	Control	14	2.34	0.88668
	Middelpunt	**Cevamec/Acatak**	**19**	**2.44**	**0.828681**
	Abel	Control	15	1.89	0.697919
	Abel	**Cevamec/Acatak**	**15**	**1.71**	**0.631451**

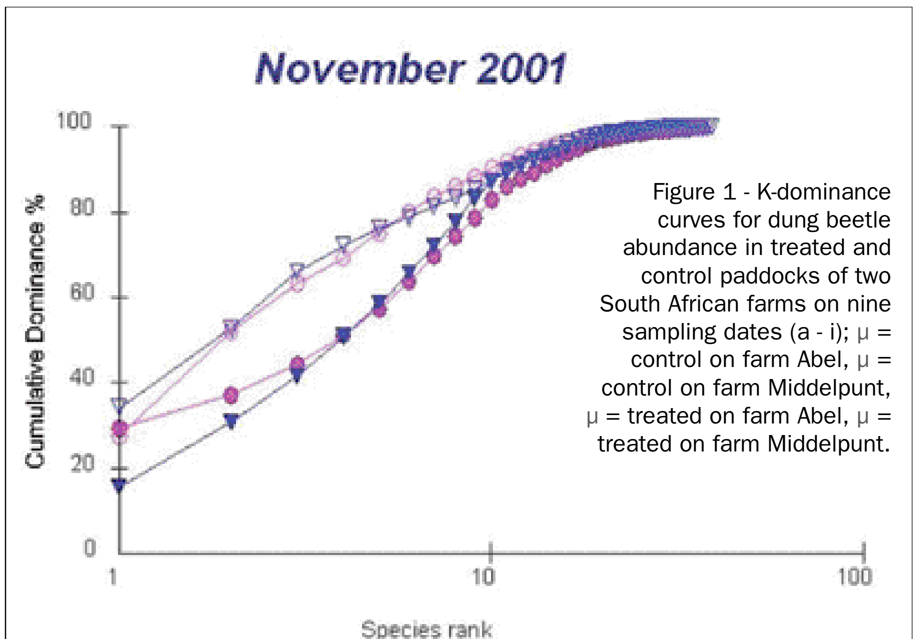


Figure 1 - K-dominance curves for dung beetle abundance in treated and control paddocks of two South African farms on nine sampling dates (a - i); μ = control on farm Abel, μ = control on farm Middelpunt, μ = treated on farm Abel, μ = treated on farm Middelpunt.

Figure 1a

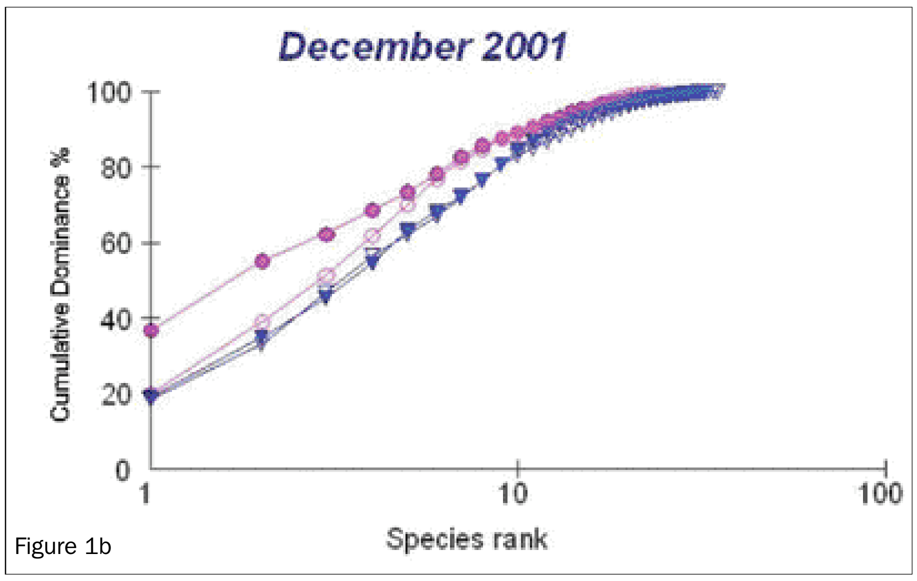


Figure 1b

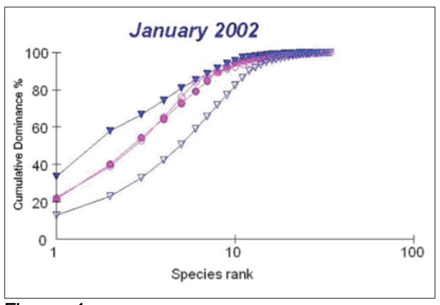
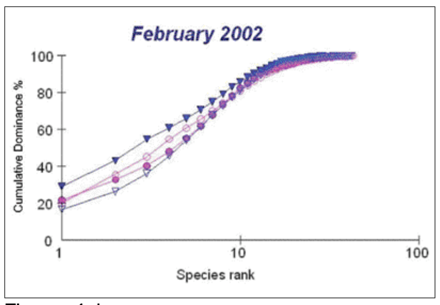


Figure 1c



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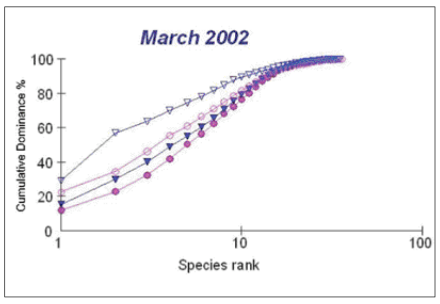

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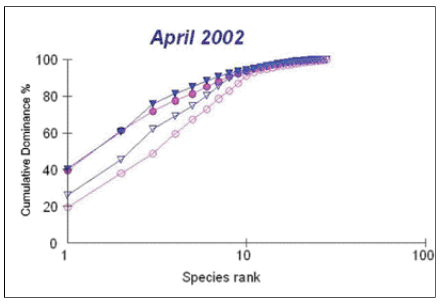

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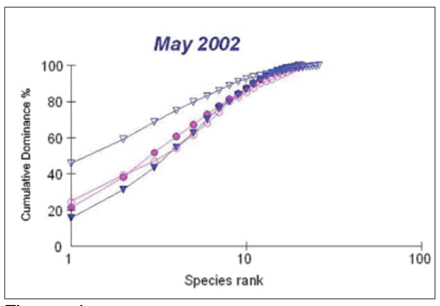


Figure 1g

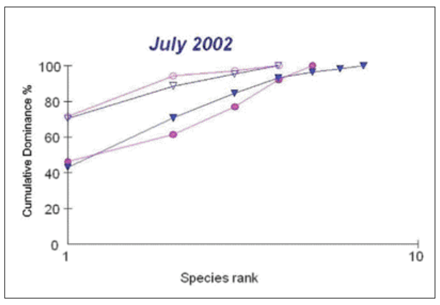
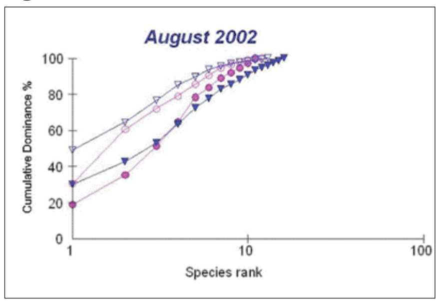


Figure 1h

Figure 1i



RESULTS

A total of 33,388 dung beetle specimens representing 72 species were processed.

During the rain season (October 2001 to April 2002), rainfall reached a total of 865.9 mm, clearly above the mean (1904-1994) of 520.5 mm for this period.

The values for the overall diversity of dung beetles shown in Table 1 revealed a relatively stable and comparable dung beetle community in both farms. Pre- and post-treatment values for all diversity measures were very homogenous and there was no difference in the dung beetle communities of the control compared to the treatment paddocks. The drop in diversity in May-August 2002 was due to a halt in dung beetle activity during the winter months.

The k-dominance curves were sigmoid for both paddocks on farm Middelpunt in November 2001 (Fig. 1a), indicative of undisturbed communities with high species diversity. In December 2001 this situation was similar on farm Abel, with the control paddock showing a lower diversity than the treatment paddock (Fig. 1b). This pattern stayed stable for both farms until May 2002 (Figs. 1c-g), suggesting that the dung beetle communities experienced no negative side effects from the treatment of cattle with Acatak®/Cevamec®.

The similarity of the dung beetle communities in both treated and control paddocks in terms of relative species abundance was very high throughout most of the season (Fig.2). The same level of relative similarity between treatment and control communities as in the pre-treatment sample was found from December 2001 until May 2002, and the communities in the control paddocks were more similar to those of the corresponding treatment than to each other (Fig. 2).

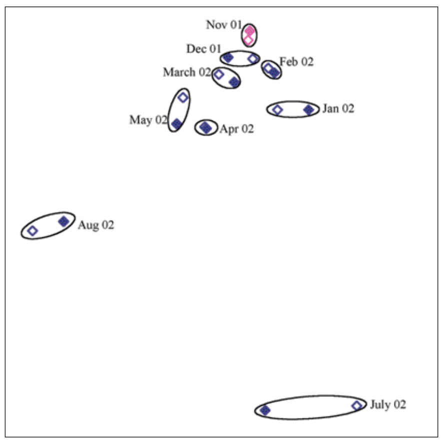


Figure 2 - Two-dimensional, non-metric scaling ordination of the relative, fourth-root transformed species abundance data of pooled samples collected on nine different dates; Åû = control paddocks, Åü = treated paddocks.

There was a highly significant change in community within each paddock among the various dates. Sampling transects in each paddock were indistinguishable and consequently pooled for further analyses (Table 2). However, in both farms the dung beetle communities before and after treatment were not significantly different from each other, indicative of no negative ecotoxicological effect.

Pooling the data on farm level showed slight indications of differences in the

Table 2 - ANOSIM results of testing for differences in dung beetle communities between treatment and control data from two South African farms pooled; bold = significant differences between communities.

	1-way R-value	**2-way (Regime/Farm) R-value**	**2-way (Regime/Date) R-value**
global	-0.001	-0.005 / 0.039	0.059 / 0.66
Nov	0.187	0.268 / 0.37	
Dec	0.136	0.194 / 0.188	
Jan	-0.032	0.06 / 0.496	
Feb	0.024	0.144 / 0.496	
Mar	-0.02	0.012 / 0.126	
Apr	-0.041	-0.04 / 0.342	
May	0.112	0.13 / 0.278	
Jul	0.173	0.146 / 0.08	
Aug	-0.006	-0.003 / 0.276	

beetle communities between the two farms, six values barely allowing separation, two R-values approaching the critical 0.5 limit for clear difference (Table 2). The data were therefore analyzed separately for each farm (values not shown). The differences in terms of dung beetle communities consistently retrieved significant and high values among sampling dates but control and treatment paddocks remained indistinguishable.

The SIMPER analyses showed that on both farms the number of discriminating species remained within the same range throughout the experiment and did not increase after the treatment. Furthermore, absolute and percentage numbers of typical species were comparable in the control and treated paddocks and remained at the same level in the latter throughout most of the trial. Exceptions to this trend were only found in the winter months on both farms and in March on farm Abel and coincided with the dry period.

DISCUSSION

The data collected over nine month field study spanning an entire farming season showed that the treatment of cattle with ivermectin and fluazuron had no adverse effect on the dung beetle fauna. Observed disparities between treatment and control were insignificant and probably due to the respective paddocks and their microclimate.

In the present study *O. gazella* did not contribute to differences between treatment and control paddocks, and *E. intermedius* was one of the more common species across all paddocks on both farms. Moreover, *E. intermedius* was abundant in the treated paddocks suggesting that the influence of the pesticides was not marked.

Instead of using the normal application on young animals only, in the present study drugs were administered to all adult animals in the treated herds. As a consequence, the entire dung beetle fauna was exposed synchronously to faecal residues. The absence of any difference in the dung beetle communities between treated and control paddocks strongly suggests that the treatment did not affect the monitored species.

Krüger and Scholtz (1998a; b) found that ivermectin led to changes in dung insect communities under drought conditions, but not under high-rainfall conditions. The rainfall registered during September 2001 to May 2002 in the present trial was 345.4 mm above average for the rain season. This emphasizes the influence of climatic conditions on the impact of antiparasitic drugs (McKellar, 1997).

The spatial scale of treatment is known to have an important influence on the impact of pesticides on invertebrate populations (Duffield and Aebischer, 1994; Jepson and Thacker, 1990). Plots in this trial were 80 ha, with the two treated plots spatially well separated but each treated plot adjacent to a control plot. Immigration of dung beetles from the control into the treatment paddocks may have moderated any non-lethal effect of the pesticides, but no difference was observed among treated transects.

This study demonstrated that cattle treatment with ivermectin and fluazuron under extensive farming conditions on the South African Highveld can be considered safe with regards to the dung beetle communities under high-rainfall condition.

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