Effects of Six Insecticides and a Fungicide on the Numbers and Biomass of Earthworms in Pasture[1]

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The importance of earthworms in maintaining soil structure and fertility has been reviewed by HOPP and SLATER (1949), SATCHELL (1967) and EDWARDS and LOFTY (1972). Previous studies of the effects of insecticides on earthworm populations have been extensively reviewed by THOMPSON (1971) and EDWARDS and THOMPSON (1973).

STENERSON et al. (1973) found that cholinesterase depression was less severe, and recovery faster for carbofuran treated worms (Lumbricus terrestris L.) than for worms treated with paraoxon or fensulfothion, although the latter were less toxic. Carbofuran treatments were also found to cause segmental swellings.

KENNEL (1972) found that earthworms confined in boxes of soil were killed by benomyl drenches, and, in regularly mown orchards treated with benomyl, there was an accumulation of mulched grass which he suggested was due to the effects of benomyl on earthworm activity. Benomyl has been reported to have a depressing effect on populations of aphids and spider mites (PARR and BINNS, 1969) and an ovicidal effect (CRANHAM 1970). STRINGER and WRIGHT (1973) and WRIGHT and STRINGER (1973) found greatly reduced earthworm populations in orchards sprayed with benomyl. Benomyl drenches at 7.75 kg AI/ha and 1.55 kg AI/ha killed 100% and 60% of worms respectively 14 days after treatment.

THOMPSON and SANS (1973) found residues of insecticides in worms from insecticide treated plots (3 weeks after treatment) ranging from 125 ppm total DDT residues, 22.5 ppm fensulfothion sulphone, 9.7 ppm chlorpyrifos, and 26.3 ppm Bayer 37289 (O-ethyl O-2,4,5-trichlorophenylethylphosphonothioate), to negligible residues for worms retrieved from plots

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treated with Bux (R) [m-(1-ethylpropyl)phenyl methylcarbamate mixture (1-4) with m-(1-methylbutyl)phenyl methylcarbamate], endrin and carbaryl. A year after treatment only DDT and its metabolites were detected in appreciable amounts.

EDWARDS and THOMPSON (1973) concluded that little is known of effects of pesticides on populations of earthworms. This paper reports the initial effect of 6 insecticides and a fungicide on earthworm populations in trefoil pasture under similar conditions to those described by THOMPSON (1971) and THOMPSON and SANS (1973).

EXPERIMENTAL

The experiment was carried out in London, Ontario on trefoil pasture. Prior to staking out the plots random soil samples had been taken from the pasture field to determine some of the insecticide residues of the soil. The pesticide treatments included 6 insecticides and a fungicide; formulations and rates of application of the compounds are given in Table 1. Each plot of the randomized block design was 3 m square; each of the 12 blocks contained the 6 treatment insecticide plots plus 2 control plots (total of 96 plots). Walkways 1.8 m wide were left between plots. In addition 4 replicate plots each of benomyl and carbofuran (granular formulation) were treated but not included in the overall design (total of 8 plots; grand total 104 plots). A pre-spray earthworm sample was taken 3 days before treatment on 33 of the 104 plots to estimate population levels and biomass. Sampling was accomplished by the method described by THOMPSON (1971), mowing a strip 0.8 m wide across each plot close to the soil surface upon which the two 0.6 m square wooden sampling quadrats were placed. Two consecutive treatments of 4.6 L of dilute formation solution (25 ml of 40% formaldehyde in 4.6 L of water) were poured onto each of the 2 quadrats with a sprinkling can. Worms brought to the surface were counted, weighed and immediately frozen for subsequent chemical analysis in the case of leptophos and methomyl treated plots.

The insecticides were applied, but not incorporated into the soil on the evening of June 11, 1973 after the sward had been cut to 5 - 7.5 cm and the cuttings removed. The temperature during the treatments ranged from 24-26°C with an RH from 70-80%.

The pesticides used in the experiment were: AC 92100 [O,O-diethyl-S (tertbutylthio)methyl phosphorodithioate], benomyl [methyl N-[1-(butylcarbamoyl-2-benzimidazole] carbamate], and WL 24073 [O-(2-chloro-1-(2,5-dichlorophenyl)vinyl) O-methyl ethylphosphonothioate], carbofuran, methomyl, leptophos, and phorate.

The plots were sampled as above 21 days after pesticide treatment.

RESULTS AND DISCUSSION

The species order of abundance was *Allolobophora caliginosa* (Savigny)>>*Lumbricus terrestris* (Linnaeus)>*Allolobophora chlorotica* (Savigny). In the pre-spray earthworm samples, the means for counts and biomass were 149.7 and 78.8 gm respectively. The corresponding standard deviations were 22.7 and 24.7 gm.

The pre-spray sample shows the enormous drop in earthworm populations between June 8 and July 2 from 150 worms/.36 m to 30/.36 m. This was probably due to the normal seasonal activity of earthworms induced by higher temperatures, lower soil conditons at the later date, and perhaps mowing of the sward prior to insecticide treatment.

The pre-treatment residue analysis of the soil revealed that only DDT and its analogues were present in measurable amounts using gas chromatography. The soil burden of DDT was as follows in parts per million: p,p'-DDT, 0.12; o,p'-, 0.03; p,p'-DDE, 0.04 and p,p'-DDD, < 0.01 ppm.

For the randomized block design experiment, in order to establish the within plot variances, the data for both counts and biomass were transformed by $\log_{10} [X + 1]$, where X is measured response per quadrat (for either counts or biomass). This is a standard transformation to use when the standard deviation is related to the mean as was the case with these data. Statistical analysis revealed that the treatments were a highly significant source of variation($P < .001$). The treatment means are shown in Table 1 (transformed and untransformed)along with the per cent reduction of the population and biomass compared to control. For transformed counts: the standard error (SE) of treatment means was 0.0534 and for the control mean was 0.0378 while the SE of the difference between a treatment mean and the control mean was 0.0654. For transformed biomass: the SE of treatment mean was 0.0573 and for the control mean was 0.0405, while the SE of the difference between a treatment mean and a control mean was 0.0701. The SE of control means is lower than the SE of the treatment means because more observations were taken for the control (4/block for control and 2/block for treatments).

Single treatments except leptophos were significantly lower than control for counts and all treatments, except methomyl, were significantly lower than control for biomass.

The means of counts and biomass for the two additional treatments (carbofuran 10 G at 5.6 kg AI/ha and benomyl(Benlate(R) 50 WP at 7.8 kg AI/ha) are shown in Table 2. The SE's of these means are 0.0775 for counts, and 0.0784 for biomass. The difference between these means and the control means of the main experiment is so large, relative to their respective standard errors, that a real treatment effect can be safely assumed even though a statistical test of significance is not strictly valid.

TABLE 1

Treatments, population means, biomass and reductions (as % of control) following application of the pesticides.

Treatment	Formulation *	Application	Counts			Biomass		
		Rate	Transformed	Untransformed	% Reduction	Transformed	Untransformed (gm)	% Reduction
Control	-	-	1.492	30.01	-	1.341	20.95	-
leptophos	2.7 EC	3.4 kg AI/ha	1.450	27.16	9.5	1.092	11.35	45.8 *
methomyl	90 SP	"	1.350	21.36	28.5 *	1.279	18.00	14.1
WL 24073	10 EC	"	1.282	18.16	39.5 *	0.981	8.57	59.1 *
carbofuran	4.8 F	"	1.261	17.22	42.6 *	1.182	14.21	32.2 *
phorate	10 G	"	0.537	2.45	91.8 *	0.441	1.76	91.6 *
AC 92100	15 G	"	0.494	2.12	92.9 *	0.266	0.85	95.9 *

* - Significantly different from control (P< .05).

TABLE 2

Population means, biomass and reductions (as % of control) following application of carbofuran and benomyl

Treatment	Counts			Biomass		
	Trans formed	Untrans- formed	% Reduction	Trans- formed	Untrans- formed	% Reduction
carbofuran	0.244	1.75	94.2	0.126	1.34	93.6
benomyl	0.208	1.62	94.6	0.261	1.83	91.3

Population reductions due to pesticide treatment varied from a low of 9.5% for leptophos to a high of 94.6% for benomyl; reduction of the earthworm biomass ranged from a low of 14.1% for methomyl to a high of 95.9% for AC 92100. The toxicity of the treatments is in ascending order (for counts) down Table 1. It also appears that population reduction is generally correlated to biomass reduction. We also observed that although relatively few _L. terrestris_ were collected from each sample (in the control samples from 3-7), they made up a very substantial proportion of the biomass of that sample because of their proportionately much greater mass than _A. caliginosa_. This experiment did not attempt to detect different treatment effects on the different species, although these effects may exist.

Based on the data of Table 1 an approximate order of toxicity obtained by summing biomass and count % reductions would be as follows: AC 92100 = phorate > WL 24073 > carbofuran F > leptophos > methomyl. It is obvious too that benomyl and carbofuran G are highly toxic to earthworms at the treatment rates used in this experiment.

The earthworm's ability to break down leaf litter, aerate the soil and distribute nutrients makes it an important component in soil fertility, especially non-cultivated soils. Where alternative materials are available the use of carbofuran (in granular formulations), phorate, AC 92100 and benomyl should be carefully considered for situations where earthworms are important in agriculture practices; such situations would include orchards, pastures, and vineyards.

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