Pesticide Use in No-till Row-crop Fields Relative to Wildlife

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Introduction

Increased cover and food resources for wildlife result from the use of conservation tillage compared to conventional tillage practices (5, 10, 24, 25). A potential environmental drawback, however, is the possibility of increased exposure of wildlife to chemical pesticides and fertilizers. The primary purpose of this study was to determine how pesticide use differed between no-till and conventional planting practices in row-crop cultivation. Additionally, attempts were made to explore the impacts to wildlife of pesticide use under these tillage systems. Lastly, the relative merits of enhanced habitat conditions from no-till versus reduced pesticide use from conventional tillage were assessed.

Although a number of tillage practices qualify as conservation tillage, I was concerned with no-till or zero tillage, the most extreme form of reduced tillage practices. In no-till, herbicides substitute totally for mechanical practices in preparing a seedbed and controlling weeds. A contact herbicide kills all green vegetation at the time of planting and the crop is seeded directly into a narrow slot or drilled into the existing residue. Conventional tillage operations consist of mechanically preparing a seedbed by plowing, discing, and harrowing. Subsequent weed control depends on a combination of herbicides and mechanical treatment.

The deer mouse (*Peromyscus maniculatus*) was chosen as the subject for study of the impacts of pesticide use because this species was common under all field situations examined. Although birds may be more sensitive to the harmful effects of chemicals, nesting bird densities in row-crop fields are very low (5). Thus, it is difficult and time-consuming to find nests, and the residency status and amount of time that an encountered bird spends in a particular field are not known. Therefore, the extent of exposure to applied chemicals is unknown. Shrews (Soricidae) may be more appropriate mammals to study due to their higher trophic level. However, they were rarely encountered. Deer mice are acceptable subjects because they are year-round residents in row-crop fields, and their numbers are not greatly influenced by tillage practices and the habitat conditions that result (10). Because their diet is composed of a wide variety of invertebrates and plant seeds, deer mice may be exposed to agricultural chemicals through several pathways. Thus, the deer mouse may serve as a model of omnivores.

Methods

Pesticide Use

Information on pesticide use was obtained for 56 corn and soybean fields studied during 1983-1985 in Scott County, southeastern Indiana. All farms were privately operated and were selected on the basis of past and proposed planting and tillage conditions. The Scott County office of the Soil Conservation Service obtained pesticide application rates directly from farm operators. Toxicity levels of pesticides (Table 1) were obtained from published sources (8, 20).

Short-term Impacts of Planting

To explore the short-term impacts of chemical use and spring tillage practices, population densities and turnover rates of small mammals were measured using live trapping and marking methods. Deer mice were studied in 6 Lawrence County cornfields during 1984. All were private farms operated by local landowners and selected on the basis of

TABLE 1. Pesticides used on Scott County study fields.

Chemical name	Trade name	Reported acute oral toxicity, LD_{50} (mg/kg)
Herbicide		
Acifluorfen	Blazer	1,300
Alachlor	Lasso	1,800
Alachlor; glyphosate	Bronco	1,800; 4,300
Atrazine	AAtrex	3,080
Atrazine; metolachlor	Bicep	3,080; 2,780
Bentazon	Basagran	1,100
Butylate	Sutan +	4,659
2,4-D	2,4-D	300*-1,200
EPTC	Eradicane	1,630
Fluazifop-butyl	Fusilade	1,272
Glyphosate	Roundup	4,300
Linuron	Lorox	1,500
Metolachlor	Dual	2,780
Metribuzin	Lexone	1,930
Paraquat	Paraquat	150*
Trifluralin	Treflan	3,700
Insecticide		
Carbofuran	Furadan	11**
Isofenphos	Amaze	28**
Terbufos	Counter	4**

* Moderately toxic.
** Highly toxic.

current and proposed cultivation. Fields selected included one that had been planted to corn previously but was to be diverted from production and thus served as a control. A variety of annual and perennial forbs and grasses was present. One field was virtually a pure stand of sweet clover (*Meliotus* spp.) with a few patches of thistle (*Cirsium* spp.). This field was conventionally tilled and planted with corn. Four fields were planted to corn using no-till methods. Corn (field 3 in Table 2) and soybean (field 4) residue predominated in 2 no-till fields, while fields 5 and 6 had been idled the previous year and were dominated by sweet clover. A rodenticide (zinc phosphide) was intended for use on two of the no-till fields but delayed planting conditions and excessive vegetation growth precluded the use of this chemical. Planting information and pesticide use is detailed in Table 2.

Mammals were captured in aluminum live traps (8 × 9 × 23 cm) arranged in a 6 × 8 grid with 15-m spacing. Sunflower seeds were used for bait and traps checked once daily over a 2-week period prior to the planned planting date and for 3-5 weeks after planting. Trapping intensity for individual fields is given in Table 2.

Trapping began 19 April and pre-planting trapping was completed by 2 May (Table 2). One field was planted earlier than expected so trapping was terminated prematurely. Intervals between trapping periods varied among fields due to differences in planting dates.

Captured mammals were individually marked by clipping toes and immediately released. The CAPTURE program (26) was used to calculate estimates of population density. The open model (M_0) was used in estimation although other models were selected as more appropriate in some cases. The open model was used throughout because this model was most appropriate in a majority of cases, a consistently used model was desirable for comparisons between fields and treatments, and some of the models selected did not provide population estimates. Animal densities were calculated from the population

TABLE 2. Planting information and trapping results for 6 Lawrence County cornfields studied during 1984. Data from pre- and post-planting trapping periods are separated by a slash.

	Field					
	1	2	3	4	5	6
Tillage type[a]	ID	CT	NT	NT	NT	NT
Date						
Tillage	—	19 MAY	—	—	—	—
Pesticide application	—	31 MAY	2 JUN	2 MAY	25 MAY	6 JUN
Planting	—	31 MAY	1 JUN	1 MAY	24 MAY	6 JUN
Application rates of pesticides (kg/ha)						
Paraquat	—	—	0.6	0.4	0.3	0.3
Atrazine	—	1.8	1.8	2.7	1.8	1.8
Metolachlor	—	—	1.1	1.1	2.2	2.2
EPTC	—	9.0	—	—	—	—
Carbofuran	—	1.7	1.5	1.3	1.7	1.7
Nights trapped	11/15	11/14	11/14	5/23	11/14	11/14
Days between trapping periods	20	34	34	7	34	41
Captures						
Deer mouse	25/29	17/23	6/5	10/50	16/19	26/19
Prairie vole	1/3	57/0	0/0	0/0	0/15	5/2
White-footed mouse	0/0	1/0	0/0	0/0	0/3	0/8
Population density (no./ha)						
Deer mouse	27/29	17/27[b]	16/4	22/54[b]	15/21[b]	29/6[b]
Prairie vole	–[c]/–[c]	96/0[b]	0/0	0/0	0/31[b]	–[c]/–[c]
White-footed mouse	0/0	–[c]/0	0/0	0/0	0/–[c]	0/17
Recapture rates of deer mice (%)	42	6	67	38	25	26

[a] Idled (ID), conventionally tilled (CT), no-till (NT).
[b] Pre- and post-planting densities significantly ($P < 0.05$) different.
[c] Too few individuals captured to estimate density.

estimates by dividing by 1.08 ha, the assumed effective trapped area of each 6 × 8 grid with 15 m spacing of traps.

The assumption of closure may have been violated by using a grid size smaller than recommended and by trapping for extended periods of time. Thus, estimates of population densities may be inflated. However, estimating densities was secondary to capturing and marking individuals to determine relative recovery rates between capture periods. Both numbers of individuals captured and density estimates are presented in Table 2, although density estimates allow better comparisons between trapping periods because they take into account trapping effort and the extent of animal movements.

Results

Pesticide Use

Fourteen herbicides (16 commercial formulations) and 3 insecticides were used on the Scott County corn and soybean fields during this 3-year study (Tables 1, 3). Her-

TABLE 3. Application rates (kg/ha of active ingredient) and frequency of use (in parentheses) of pesticides used on 56 corn and soybean fields in Scott County, Indiana, 1983-1985.

Pesticide	Conventional				No-till			
	Corn (N=14)		Soybeans (N=14)		Corn (N=14)		Soybeans (N=14)	
Herbicide								
Alachlor[a]	2.66	(8)	2.39	(9)	2.80	(13)	2.61	(9)
Atrazine[b]	1.70	(14)	—	(0)	1.78	(14)	—	(0)
Paraquat	—	(0)	—	(0)	0.48	(14)	0.40	(10)
Linuron	—	(0)	0.65	(6)	—	(0)	0.65	(13)
Metolachlor[b]	2.10	(2)	—	(0)	2.10	(1)	2.24	(4)
Metribuzin	—	(0)	0.35	(3)	—	(0)	0.19	(3)
Trifluralin	—	(0)	1.06	(5)	—	(0)	—	(0)
Glyphosate[a]	—	(0)	—	(0)	—	(0)	1.54	(4)
Butylate	7.47	(3)	—	(0)	—	(0)	—	(0)
Fluazifop-butyl	—	(0)	0.28	(1)	—	(0)	0.28	(1)
EPTC	6.16	(1)	—	(0)	—	(0)	—	(0)
Bentazon	—	(0)	0.56	(1)	—	(0)	—	(0)
Acifluorfen	—	(0)	0.56	(1)	—	(0)	—	(0)
2,4-D	—	(0)	—	(0)	—	(0)	0.63	(1)
Insecticide								
Carbofuran	2.02	(2)	—	(0)	2.13	(6)	—	(0)
Terbufos	1.12	(3)	—	(0)	—	(0)	—	(0)
Isofenphos	1.57	(1)	—	(0)	—	(0)	—	(0)

[a] Sometimes applied as Bronco.
[b] Sometimes applied as Bicep.

bicides were used on all 56 fields while insecticides were applied to only 12 (21%) fields (Table 3). Insecticides were not applied to any soybean fields, while 12 (43%) cornfields ($X^2 = 15.3$, df $= 1$, $P < 0.001$) were treated with insecticides, primarily for corn rootworms. An equal number of no-till and conventionally tilled cornfields were treated with insecticides.

The number of different herbicides used in each field was consistently 2.0 for conventional cornfields and 3.0 for no-till cornfields. The difference is totally due to the addition of a contact herbicide (paraquat) used with no-till. For soybean fields, a mean of 1.9 herbicides was used on conventionally tilled fields compared to 3.2 for no-till fields. Again the difference is primarily due to the use of a contact herbicide (paraquat, glyphosate) in the no-till fields.

Acute oral toxicities of pesticides were used as a general guide to determine the potential impacts of chemical use on wildlife frequenting row-crop fields. All 3 insecticides are classified as highly toxic to rodents, while herbicides are rated less toxic (Table 1). Reported oral toxicities are low for all herbicides except paraquat and some formulations of 2,4-D.

Of the chemicals considered, only paraquat and glyphosate are unique to no-till situations. Therefore, comparisons of tillage systems should focus primarily on these herbicides. However, the frequency and application rates of other chemicals may be influenced by the choice of tillage system and should also be examined. Application rates of alachlor were 9% greater in no-till soybean fields than conventionally tilled soybeans, but rates of linuron were similar (Table 3). Application rates of atrazine and alachlor were 5% greater in no-till cornfields compared to conventional cornfields.

Short-term Impacts of Planting

Deer mouse population densities during the pre-planting period averaged 21.0

animals/ha with a range of 15-29/ha (Table 2). Densities during the post-planting period averaged 23.5 animals/ha and ranged from 4-54 mice/ha. The idled field showed similar densities during both trapping periods, while the tilled field indicated a significant increase. The increase was most likely an artifact of increased movements of individuals caused by the disruption of home ranges attributable to disturbances from tillage operations. Deer mouse densities in no-till fields declined in 2 fields (although only 1 difference was statistically significant) and increased significantly in 2 fields. Due to the ambiguity of these results, it appears that tillage and spraying treatments or the absence of them have little discernible, direct impacts on deer mouse densities on a short-term basis. If chemical applications and tillage operations were immediately detrimental to deer mice, population densities and recapture rates should have been drastically and consistently lower during the post-planting period.

Although deer mice predominated in most fields studied, other species were important in several fields. A large prairie vole (*Microtus ochrogaster*) population existed in a dense stand of sweet clover, but was decimated when this habitat was converted to bare ground prior to planting. This species colonized one of the no-till fields between trapping periods. A population of white-footed mice (*Peromyscus leucopus*) was also found in moderate densities in a no-till field during the post-planting trapping period.

Recapture rates (proportion of rodents marked during the first trapping period and subsequently recaptured during the second period) were low for all fields including the control field (Table 2). Mean recapture rates were highest for the control field (42%) and lowest for the conventionaly tilled field (6%). No-till fields generally had intermediate values (25-68%) and the overall recapture rate of 31% for no-till fields was not appreciably lower than the control field, considering the differences in the time intervals between trapping periods. Again, recapture rates lend support to the conclusion that tillage is more disruptive than no-till planting over the short term.

Discussion

The ultimate impact of pesticides to farmland wildlife depends upon a complex combination of factors, including type of pesticides, formulation of chemicals, acute and chronic toxicity of chemicals, toxicity of surfactants and carriers, interactions among different pesticides, interactions of chemicals with soil and vegetation, persistence of chemicals, application rate, mode of application, timing of application, and species of wildlife and their behavior. Chemicals can be applied in many different ways: sprayed on foliage, incorporated into the soil, banded below the soil surface, or broadcast on the soil surface. Modes of application pose differing risks to wildlife depending on food habits and feeding behavior of a species.

Rough comparisons of relative toxicities among pesticides may be made by considering reported acute toxicities and application rates used in this study. With this analysis, carbofuran is potentially 60× more toxic than paraquat in corn plantings. Similar comparisons of paraquat with atrazine and alachlor in corn, show paraquat being potentially more toxic by a fctor of 6× and 2×, respectively. In soybean fields, paraquat may be 7-8× more toxic than glyphosate. Thus, insecticide use, which was similar in no-till and conventional tillage situations, should be the primary focus of environmental concern. Insecticides, however, were not frequently employed in this study, especially in soybean fields.

Carbofuran, the most commonly used insecticide in this study, has been the subject of numerous studies (12). Detrimental effects in wildlife have been documented in laboratory trials (4, 22, G. Linder, Cornell Univ., unpubl. data) and carbofuran has been shown to be a source of mortality under actual field conditions (2, 3, 14, 15). Because it is commonly used in granular form, carbofuran is readily ingested as grit or mistaken for food by birds and small mammals.

Deer mice collected from some of the fields included in this study were analyzed for herbicide residues and the results have been reported previously (7). Of 4 herbicides included, residues of atrazine, linuron, and alachlor were not detected or the levels found were minor. Liver damage was not noted in deer mice from fields in which these chemicals were used. All 3 pooled samples of deer mice (15 mice from 2 fields) tested for paraquat revealed metabolites presumed to be degradation products of this herbicide. Two of 3 mice from paraquat-treated fields had damaged livers consistent with paraquat effects (24).

Literature on the effects of paraquat in the laboratory is numerous (see 7), but difficult to interpret from a wildlife standpoint at normal field application levels. Bauer (6) found minimal negative impacts of paraquat on northern bobwhite (*Colinus virginianus*) survival, growth, and reproduction at field application rates. Bunck et al. (9) could find no differences in discrimination learning abilities of northern bobwhite fed paraquat. Paraquat, however, has been shown to negatively affect survival and reproduction in prairie voles (G. Linder, unpubl. data), and the growth and survival of young American kestrels (*Falco sparverius*) (19). Paraquat exhibited a high degree of embryotoxic and teratogenic effects on mallard (*Anas platyrhynchos*) eggs (17, 18).

Because most laboratory studies indicate detrimental effects of paraquat, further research at the field level is warranted, and the use of glyphosate as a preferred alternative should be encouraged. Glyphosate has been found to pose little environmental hazard at field application rates (1, 13, 16).

Although this study addresses pesticide use exclusively in the terrestrial environment, off-site aquatic contamination should be considered. Many agricultural chemicals are more toxic to fish and other aquatic life than they are to terrestrial organisms (21). Compared to conventional planting methods, substantially greater amounts of vegetative residues are present after minimum tillage, resulting in reduced movement of soil particles into waterways. This difference would appear to offset any negative impacts of greater application rates of some pesticides used in no-till (11).

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Summary

Application rates of pesticides were compiled for 56 no-till and conventional corn and soybean fields in Scott County, southeastern Indiana, 1983-1985. The most common of 14 herbicides used were alachlor, atrazine (cornfields), paraquat (no-till fields), and linuron (soybean fields). Three insecticides, primarily carbofuran, were used on 21% of the fields, all cornfields. Reported acute oral toxicities of these chemicals were generally rated low, except for the insecticides, which were classified as highly toxic, and paraquat and some formulations of 2,4-D, which were classified as moderately toxic. Application rates of alachlor were 9% greater in no-till soybean fields than conventionally tilled soybeans, but rates of linuron were similar. Application rates of atrazine and alachlor were 5% greater in no-till cornfields compared to conventional cornfields. Small mammal populations studied by capture trapping methods in Lawrence County indicated that conventional tillage is more disruptive than the short-term effects of no-till planting methods.

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