Diazinon and Carbaryl: Effects on the Vegetation of a Soybean Ecosystem[1]

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Abstract. *Two non-persistent insecticides, diazinon and carbaryl, were selected to assess their effect upon the vegetation component of a simplified agroecosystem located on the Piedmont Plateau of New Jersey. Vegetational analysis to determine the effect of the insecticide on the biomass of six species, including a miscellaneous grouping of small cover species, revealed the stimulation of three species* (Raphanus raphanistrum, Agropyron repens, *and* Ambrosia artemisiifolia) *and the inhibition of* Convolvulus sepium.

Vegetational differences between the insecticide treatments are attributed to diazinon's modifying effect of competition to the stimulated species. The changes attributed to diazinon treatment are viewed as neither beneficial or detrimental to the simplified ecosystem, but must be viewed as having potential to alter community structure, food web relationships, and mineral cycling within the experimental area.

INTRODUCTION

The secondary effects resulting from the introduction of pesticides and other toxic substances to ecosystems, whether intentional or accidental, are becoming an important concern of man. Nowhere are these introductions more evident than from technologies supporting food production and disease prevention. Pesticides have been shown to act as stresses to numerous living systems, causing changes in ecosystem structure and stability (Woodwell, 1970, Barrett *et al.*, 1967, Bulan *et al.*, 1971, Odum, 1969). Generally many of these stresses or perturbations have been associated with persistent pesticides. Accordingly, expert recommendations (U.S.D.H.E.W., 1967; Wurster, 1969; State of New Jersey, 1970; Anonymous, 1971) have affected restrictions to the use of certain pesticides, bringing many non-persistent pesticides into common usage.

A study was designed to assess the effects of two non-persistent insecticides on the structure of the vegetation component of a simplified ecosystem, soybean monoculture, since such ecosystems are noted for their sensitivity to perturbation (Barrett, 1968). Plant biomass was used to define the direct effect of insecticide stress on the vegetational community of the ecosystem defined by this study.

Two insecticides, diazinon and carbaryl, were selected for study. An organophosphate insecticide, diazinon is closely related to parathion and pyrazinon. The chemical fate of diazinon has been documented widely (Ralls and Cortes, 1966; Ralls *et al.*, 1966; Getzin, 1967; Kearney and Helling, 1969). Carbaryl is a carbamate insecticide used in control of insects and terrestrial molluscs (Bowen and Lloyd, 1971). Riva and Carisano (1969), Tilden and Middelem 1970), Hughes (1971) and Knaak (1971) have described the structure and degradation products of carbaryl. Both insecticides are used extensively in agriculture; and the mode of insecticidal action is cholinesterase inhibition (Fukuto, 1969; Jewess and McFarlane, 1969; Saito, 1969; Quistad *et al.*, 1970).

MATERIALS AND METHODS

During the summer of 1970, field research plots were established adjacent to Hutcheson Memorial Forest in East Millstone, New Jersey. Located on the Piedmont Plateau of New Jersey, the soil of the experimental area is derived from a parent material of Triassic red shale of the Brunswick Formation (Kummel, 1940; Ugolini, 1964). Previous ecological studies have depicted the states of biotic succession following abandonment of these fields (Bard, 1962; Pearson, 1959; Root and Pearson, 1964; Shure, 1971; Kricher, 1971; Shure, 1971, 1973).

Two fallow, replicate hectares delimited the study area. Each hectare was subdivided into three insecticide treatment plots, each 80 x 20 meters in size. Treatment plots were positioned to minimize site variability, since the study area displayed irregular elevation and drainage patterns. Treatment plots were separated from one another and from the site perimeter by a 10 meter buffer zone to prevent the translocation of insecticides and to minimize edge effects. The 2-hectare area was plowed and disked to a depth of 15 centimeters during mid-May of 1970 to remove the native vegetation.

On June 10, 1970, diazinon was sprayed on one 80 x 20 meter treatment plot in each hectare. Diazinon was applied in the form of a wettable powder (Diazinon 50 W; Geigy Agricultural Chemicals) at a rate of 4 pounds of active ingredient per acre. The entire area was disked to a depth of 15 centimeters and the entire 2-hectare area was drilled in soybean (*Glycine max* Merr.) variety Adelphia. Forty days later, when the soybeans were approximately 30 centimeters in height, carbaryl was applied to one 80 x 20 meter plot in each hectare. Carbaryl was supplied as a foliar spray to the vegetation in the form of a wettable powder (Sevin 50-W; Union Carbide Corporation) at the rate of 1 pound of active ingredient per acre. One 80 x 20 meter plot in each hectare was left unsprayed and represented a control insecticide treatment. The application rates of both insecticides were derived from recommendations set by the College of Agriculture and Environmental Science, Rutgers University (1970).

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On August 14, 1970 plant biomass (soybean and native vegetation) present within the treatment plots were estimated using the harvest method. Fifteen sample points in each 80 x 20 meter plot were selected at random. At each sample point, the vegetation within a 0.25 $meter^2$ frame was clipped to ground level, bagged, and returned to the laboratory. The vegetation was then separated into species, dried at 90 °C for 48 hours, and weighed.

Data collected for field study followed a factorial design of the analysis of variance. Factorial designs allow the observation of the effects of several different factors simultaneously and the treatments are composed of the various combinations that the factors may take (Cohran and Cox, 1950). Factors considered were: Hectare (H), the source of replication, with two levels, and Insecticide (I) with three levels. Sources considered in the analysis of variance were:

Source of Variation	*df*
Hectare	1
Insecticide	2
I x H	2
Samples (I x H)	84
Total	89

RESULTS

The response measured was dry weight biomass of plant species within the insecticide treatment plots. Soybean (*Glycine max* Merr.) displayed the greatest biomass while hedge bindweed (*Convolvulus sepium*) and quack grass (*Agropyron repens*) also exhibited high biomass (Table 1). Analysis of variance results for plant species, considering Hectare, Insecticide, and Hectare x Insecticide effects are compiled in Table 2. The statistical analysis demonstrated an insecticide effect for four of the plant species: wild radish (*Raphanus raphanistrum*), quack grass (*Agropyron repens*), ragweed (*Ambrosia artemisiifolia*), and hedge bindweed (*Convolvulus sepium*).

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Table 1. Biomass (g/.25 m^2) of plant species collected from experimental area

D is diazinon treatment, S is carbaryl treatment, C is control

Means (N = 15) are presented.

Species/Treatment	Hectare 1	Hectare 2
Glycine max		
D	40.75	36.33
S	40.28	41.08
C	49.90	38.62
Raphanus raphanistrum		
D	3.49*	3.81*
S	0.40	0.79
C	0.21	0.42
Agropyron repens		
D	5.09*	8.43*
S	3.35	5.91
C	1.65	5.67
Solanum carolinense		
D	0.85	2.15
S	1.27	1.28
C	1.06	0.83
Ambrosia artemisiifolia		
D	1.32*	0.60*
S	0.39	0.15
C	0.13	0.07
Convolvulus sepium		
D	4.03	2.91
S	6.75	3.41
C	6.68**	6.42**
Miscellaneous		
D	0.89	0.85
S	0.81	0.60
C	0.82	0.75

*Denotes biomass of diazinon treatment significantly greater ($P \leq .05$) than control treatment.

**Denotes biomass of control treatment significantly greater ($P \leq .05$) than diazinon treatment.

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Table 2. Analysis of variance summary table depicting the significance of the main effects (Hectare and Insecticides) upon the plant species collected

No significant effects were noted for the interaction of the main effects (H X I)

ns denotes nonsignificant F-tests.

Species	Hectare	Insecticide
Glycine max	ns	ns
Raphanus raphanistrum	ns	$P \leq .005$
Agropyron repens	$P \leq .005$	$P \leq .05$
Solanum carolinense	ns	ns
Ambrosia artemisiifolia	$P \leq .05$	$P \leq .005$
Convolvulus sepium	ns	$P \leq .05$
Miscellaneous	ns	ns

Two plant species exhibited significant differences in biomass between hectares. Differential propagation of rhizomes, despite uniform plowing and disking of the experimental area, was the probable cause of greater quack grass biomass in Hectare 2. Significantly greater ragweed biomass was noted for Hectare 1; the small, but significant, difference from ragweed biomass in Hectare 2 was considered inconsequential. The two hectares were considered replicates in the analysis of data.

Diazinon-treated plots exhibited significantly larger biomass than control plots for wild radish, quack grass, and ragweed. Carbaryl-treated plots, although not significantly different from control plots with respect to biomass of these species, demonstrated biomasses intermediate to control and diazinon plots (Fig. 1).

Growth of hedge bindweed was inhibited within diazinon treatment plots. The control plots displayed significantly greater biomass than diazinon-treated plots, for this species; while, biomass of hedge bindweed in carbaryl-treated plots proved to be not significantly different from that of the controls (Fig. 1).

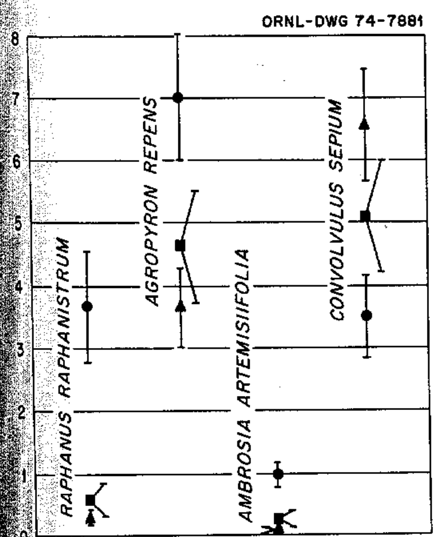
DISCUSSION

The plant biomass data indicated that the insecticides diazinon and carbaryl had no effect on soybeans, but the growth of four associated plant species was affected. The cause of the stimulatory effect of diazinon on three of the species, wild radish, quack grass, and ragweed are as yet unclear. Proposed explanations for this stimulatory effect include: (1) a direct fertilizer effect by diazinon; (2) an indirect fertilizer effect by diazinon with the insecticide acting as a microbial substrate affecting mineral cycling; (3) removal of phytophagous insects through the insecticidal action of diazinon, with subsequent retention of biomass usually lost to insect grazing; and, (4) a phytotoxic effect by diazinon to competitors of the stimulated species. In addition, soil treatment with organophosphate insecticides has been shown to promote plant growth in greenhouse studies (Kabir and Kahn, 1972), in monoculture ecosystems (Tarjan, 1964; Winchester and Burt, 1964; Streu and Vasvary, 1966, 1967), and old field ecosystems (Malone, 1968; Shure, 1971).

Evidence for microbial degradation of diazinon, one explanation of the stimulatory effect, has been presented by Getzin (1967). A major pathway for degradation of the diazinon molecule in soils is hydrolysis at the heterocyclic phosphate bond. Hydrolysis gives rise to two organic moieties, one a pyrimidine capable of microbial degradation, the other diethyl phosphate that may be an available source of phosphate to vegetation (personal communication: D. D. Kaufman).

Diazinon application exercised an inhibitory effect upon hedge bindweed. A similar inhibition of hedge bindweed was observed by Shure (1971), who used a high e of the insecticide in an old field ecosystem adjacent the site of the present study. As yet, the mechanism diazinon inhibition of hedge bindweed growth is a tter of conjecture. Bowling and Hudgins (1966) and ling (1967) noted that certain plant species exhibit d and seedling mortality when exposed to organophos- te insecticides. Evidence from this study and that of re (1971) suggests that the propagules (seeds and omes) of this early growing season competitor of the inon-stimulated species were inhibited by diazinon atment.

The information presented strongly suggests a multi- ted mechanism wherein a substance utilized solely for cticidal purposes elicits responses indicative of changes species selection, nutrient availability (Malone 1969; re 1971), and vegetation growth. Whether it is the ct diazinon molecule or one of its hydrolysis products t limits growth of hedge bindweed is not known. How- r, with limitation of this important competitor, the e stimulated species could well be expected to flourish. rient limitations also could have been eased by at st two of the degradation products of diazinon; one ing as a potential phosphate source to plants, and other as a microbial substrate instrumental in en- ncing turnover of elements within the treated plots. this experiment, diazinon is seen as mediating the oval of natural environmental stresses to the stimu- d species. By decreasing the impact of hedge bind- d competition, nutrient immobilization, and insect hivores, diazinon provided conditions conducive to the mulation of wild radish, quack grass, and ragweed hin the ecosystem defined by this study.



1. The Insecticide Effect Upon the Biomass of *Raphanus Raphanistrum*, *Agropyron Repens*, *Ambrosia Artemisiifolia*, and *Convolvulus Sepium* on August 14, 1970. Means (N=15)±1 Standard Error are Presented. ● Denotes Diazinon Treatment, ■ Carbaryl Treatment and ▲ Control.

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