INDIANA FARM-LEVEL IMPACTS OF POSSIBLE ENVIRONMENTAL PROTECTION AGENCY BANS ON SELECTED SOYBEAN INSECTICIDES

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In spite of the economic benefits of insecticides to farmers[1] and consumers, growing concern about the potential health and environmental hazards of some insecticides has resulted in the investigation of many insecticides by the Environmental Protection Agency (Boraiko). The use of several insecticides has already been banned.[2] Others are under review and their use may be banned or restricted in the future.[3]

The Environmental Protection Agency must evaluate, monitor, and regulate a wide range of chemical compounds. To do so requires the collection and analysis of information on the environmental, health, and economic impacts of the use of many diverse chemicals. Though regulatory action by the Environmental Protection Agency may reduce health and environmental risks, such action can also alter the profitability and performance of a farming operation.

More complete, detailed information on the farm-level impacts of restrictions on pesticide use is desired by many individuals who are involved in the production, sale, use, and regulation of pesticides. Improved technical and economic information should help these various decision makers develop a more nearly optimal pesticide use policy for American agriculture.

Soybeans have become a major U.S. crop and are especially important to Indiana agriculture. In recent years soybeans have occupied one of every three crop acres and have provided one fourth of gross farm income received by Indiana farmers (USDA).

Though soybean insect damage is not a major problem in Indiana, it can cause significant yield losses in some regions of the state. Insecticides are currently applied to about 3 percent of the soybean acres in Indiana (Office of the State Statistician). About 3 percent of all insecticides used in the U.S. are applied to soybeans (Eichers, Anderson, and Andrilenas).

The primary purpose of our study was to determine the economic impacts of a possible ban by the Environmental Protection Agency on selected soybean insecticides used by some farmers in Indiana who face periodic soybean yield losses due to insect damage. A 600-acre Indiana corn-soybean farm was analyzed by means of a linear programming model. The economic impacts of possible bans on soybean insecticides were measured in terms of changes in per-acre yields, production costs, farm income, per-acre profits, machinery and labor use, and timeliness of field operations. Yield and related information on alternative soybean insecticides was derived from test plot data.

SOYBEAN INSECTICIDE USE

Most of the insect damage to soybeans is the result of larvae feeding on the leaves or pods. The principal soybean insect pests in Indiana are the Mexican bean beetle and the green clover worm.

The most widely used soybean insecticide in the U.S. and Indiana is carbaryl (Sevin™). Carbaryl and toxaphene, also used on soybeans, are currently under review by the Environmental Protection Agency. Other soybean insecticides applied in Indiana include malathion (which is not currently recommended for use in Indiana), carbofuran, and methomyl (Lannate ™) (Table 1).

Soybeans are subject to sporadic or episodic pest infestations. Hence, soybean insecticide treatments are generally remedial to the specific pest problem. Airplane applications are usually made during the growing season when insect infestations occur. In contrast, for corn insecticide treatments are prophylactic and are usually applied at planting time to avoid potential pest problems such as cutworm, wireworm, or rootworm.

Three criteria were used to select the soybean insecticides analyzed in our study: (1) relative importance to Indiana farmers based

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[1]Research by Headley found a $4.00 marginal return for each dollar invested by farmers in the U.S. for pesticides in the 1960s.

[2]Insecticides that have been banned include DDT, dieldrin, and aldrin. Heptachlor and chlordane registration for all agricultural use will be cancelled by the close of the 1980 crop year.

[3]Important soybean insecticides currently under Rebuttal Presumption Against Registration (RPAR) review by the Environmental Protection Agency include carbaryl and toxaphene.

TABLE 1. SOYBEAN ACRES TREATED WITH INSECTICIDES IN INDIANA, 1978

Type of Insecticide	Acres Treated	Treated as a Percent of Harvested[a]
	-Thousand Acres-	-%-
Organophosphate		
Malathion	1.4	0.03
Carbamate		
Carbofuran	5.1	0.12
Carbaryl[b]	85.9	2.10
Methomyl	2.0	0.05
Organochlorine		
Toxaphene[b]	1.4	0.03

[a]4.15 million acres of soybeans were harvested in 1978 in Indiana.
[b]Under review by the Environmental Protection Agency.
Source: Office of the State Statistician, *Pesticide Use on Field Crops in Indiana in 1978,* Purdue University Agr. Exp. Sta., 1979.

on current use, (2) whether included on the Environmental Protection Agency's Rebuttal Presumption Against Registration (RPAR) review list, and (3) availability of test plot data. On the basis of these criteria, three soybean insecticides were selected for analysis: (1) carbaryl, (2) malathion, and (3) methomyl. Carbaryl met all three criteria. Malathion and methomyl satisfied criteria one and three. Although toxaphene is on the RPAR review list and is used on soybeans in Indiana, no test plot data were available.

TEST PLOT DATA

Soybean insecticide test plots at several locations in southern Indiana provided the basic yield data used in the study. Yield data were available for the years 1975-77. Because of the sporadic and geographic aspects of soybean insect infestations in Indiana, the various insecticides were tested on several farms in five different counties in the state. The level of soybean insect infestation in these five counties in the period 1975-77 could be classified as light to moderate.[4]

To identify the change in soybean yields associated with a particular insecticide, we specified and estimated a regression equation. Binary variables were used to represent the particular insecticide applied, the specific county, and the year.

By use of binary variables, the yield impact of each insecticide, X_1 - X_4, can be separated from the yield impact of other factors. The location variables, X_5 - X_8, were included to reflect differences among test plots in such features as soil type, fertilizer applications, and weed control programs.[5] Though researchers attempted to use similar weed control and fertilizer programs on each test plot, there were some differences among test plots. Also, soil types vary among counties. The crop year variables, X_9 and X_{10}, primarily account for annual differences in weather conditions and in planting and harvest dates.

To avoid a singular matrix, we did not include variables for Lawrence County, the base location, and the year 1976 in the regression equation. Hence, the intercept represents the mean value of the untreated soybean yield for the test plots in Lawrence County, Indiana, for 1976. Lawrence County served as the location of the representative Indiana farm because the occurrence of soybean insect infestations has been more frequent in the southern part of the state where that county is located. Also, an ample amount of test plot data were available for that region.

The estimated regression equation is:[6]

$$\begin{aligned} Y = 23.53 &+ \underset{(1.69)}{2.46 X_1} + \underset{(1.81)}{2.84 X_2} + \underset{(1.77)}{3.35 X_3} + \\ &\underset{(0.70)}{1.11 X_4} - \underset{(-4.37)}{11.43 X_5} + \underset{(7.33)}{18.08 X_6} - \underset{(-4.30)}{5.54 X_7} \\ &- \underset{(-0.67)}{1.69 X_8} - \underset{(-1.97)}{3.39 X_9} + \underset{(9.41)}{26.10 X_{10}} \end{aligned}$$

$R^2 = 0.86$

where

Y = soybean yield in bushels per acre
X_1 = a carbaryl (Sevin™ 80S) treatment
X_2 = a methomyl (Lannate™) treatment
X_3 = a malathion treatment
X_4 = a carbaryl (Sevin™ 4 oil) treatment
X_5-X_8 = a 0-1 variable for each county except Lawrence
X_9 = a 0-1 variable for 1975
X_{10} = a 0-1 variable for 1977

Three of the four insecticide regression coefficients are statistically significant at the 0.10 level — carbaryl (Sevin™ 80S), malathion, and methomyl. The regression coefficient for carbaryl (Sevin™ 4 oil) is not statistically different from zero at normally acceptable levels. Hence, it was not analyzed further in the linear programming portion of the study.[7]

[4]The soybean insecticide test plot data were provided by Dr. C. Richard Edwards, Department of Entomology, Purdue University, West Lafayette, Indiana 47907. On the basis of sweet net counts taken before and after treatment, Dr. Edwards found that insect populations were at or approaching economic levels on most plots. He defined an economic level as 20 percent defoliation. The actual insect count data are available upon request from Dr. Edwards.

[5]The five Indiana counties are Lawrence, Dubois, Scott, Daviess, and Benton.

[6]The Student T-statistic is in parentheses below the corresponding regression coefficient. There were 51 degrees of freedom giving table t-values of 1.68, 2.01, 2.73, and 3.00 at the 0.10, 0.05, 0.01, and 0.005 levels, respectively.

[7]The per-acre application rates and treatment costs for the three insecticides analyzed in the linear programming model are shown in Table 2.

TABLE 2. SOYBEAN INSECTICIDE APPLICATION RATES AND COSTS

Insecticide	Application Rate[a] (lbs./acre)	Per Acre Cost[b]
Carbaryl (Sevin™ 80S)	.75	$ 5.50
Methomyl (1.8 EC)	.50	7.41
Malathion (57%)	1.25	10.60

[a]Pounds active ingredient per acre applied to test plots.
[b]Indiana Farm Bureau Cooperative, Tippecanoe County, Indiana, October 1979.

The fact that three of the four regression coefficients for the location variables (X_5, X_6, and X_7) are statistically significant at the .005 level suggests that locational factors did affect soybean yields among the test plots. However, the regression coefficient for Dubois County (X_8) is not statistically different from zero at the .10 level. Lawrence and Dubois are neighboring counties.

The regression coefficients for 1975 and 1977 are statistically different from zero at the .10 and .005 levels, respectively.[8] Hence, weather and related factors also affected test plot yields over the three-year period.

Each regression coefficient measures the change in yield associated with the corresponding variable. The estimated yield increases as a percentage of the untreated testplot yield in Lawrence County in 1976 for Carbaryl (Sevin™ 80S), methomyl, and malathion are 10.5, 12.1, and 14.2 percent, respectively. The estimated yields for those plots treated with carbaryl (Sevin™ 80S), methomyl, and malathion, *ceteris paribus*, are 26.0, 26.4, and 26.9 bushels per acre, respectively. If we assume an expected soybean yield in Lawrence County with no insecticide applications of 23.5 bushels per acre (the intercept),[9] the expected soybean yield gain for carbaryl (Sevin™ 80S), methomyl, and malathion would be 2.5, 2.9, and 3.4 bushels per acre, respectively.[10]

THE FARM-FIRM MODEL

A mathematical programming model was used to simulate the operation of a 600-acre Indiana corn-soybean farm.[11] This approach was selected because a change in the soybean insecticide used by a farmer simultaneously affects soybean yields and variable production costs. Consequently, resource use, production costs, farm income, the crop mix, and the timing of farming operations for corn and soybeans are all altered simultaneously. Furthermore, resource constraints may limit the performance of the farming operation under alternative pest control options.

The farm planning model was specified to maximize net income subject to constraints on the availability of land, labor, machinery, and field time.[12] The optimal model solution provides information on planting and harvesting dates, labor and machinery use, production costs, and farm income as well as shadow prices for the various factors of production.

The basic activities in the model include fall and spring land preparation, planting, postplanting, harvesting, crop processing, and marketing. The crop year was divided into 22 periods including 7 planting and 5 harvesting periods for soybeans and 6 planting and 4 harvesting periods for corn.[13] Each soybean insecticide represents a different soybean crop activity. The model can choose among three marketing alternatives for corn and soybeans: (1) sale at harvest, (2) sale in the fall after drying, and (3) sale after drying and storage.[14] Per-acre variable costs for seed, fertilizer, and interest were held constant throughout the study. Other per-acre variable costs depended on labor, machinery, and pesticide use.

Yield matrices were developed for corn and soybeans for the various combinations of planting and harvesting dates. These yield matrices reflect the difference between potential yield and the possible yield losses associated with planting and/or harvest delays. A soybean yield matrix was prepared for each of the three soybean insecticides on the basis of the potential yield gains attributed to the application of each insecticide as discussed in the preceding section. For each insecticide the yield coefficient in each of the cells in the untreated soybean matrix was increased by the estimated potential soybean yield gain. Average Indiana corn yield data for the period 1975-77 were used to calculate the corn yield matrix for the various corn planting and harvesting dates.[15]

In the analysis we assumed that if a soybean

[8]Indiana produced a record soybean crop in 1977, largely due to record yields (USDA).

[9]Average actual yields in Lawrence County were 22, 24, and 27 bushels per acre for 1975, 1976, and 1977, respectively (USDA).

[10]Yield gains based on a simple comparison of the raw data for treated and untreated test plots for 1975-77 ranged from 0.5 to 4.0 bushels per acre.

[11]The basic linear programming farm planning model was developed at Purdue University for research and extension purposes. For more detail on the model structure and its use see McCarl and McCarl et al.

[12]The number of days available per week for field operations is assumed to equal the number in the 17th worst year out of 20 years. This assumption is based on several years of research and extension experience in working with Indiana farmers and observing their machinery investments and risk behavior.

[13]The various planting and harvesting periods reflect the substituting ability of the various resources during a given time period.

[14]The expected per-bushel prices for soybeans at harvest, after drying, and after drying and storage were $5.00, $5.50, and $6.00, respectively. The corresponding per-bushel expected prices for corn were $2.00, $2.25, and $2.50.

[15]Space limitations preclude a complete description of the model structure and data preparation. For further information on the yield matrices, input data, and structure of the linear programming model, see Cashman.

insect infestation occurred, all soybean acres on the farm were treated. Four different farm plans were analyzed. In the first farm plan no insecticides were applied. These results provide the optimal farm plan for the situation in which all soybean insecticides are banned. In each of the other three farm plans there were independent bans on carbaryl (Sevin™ 80S), malathion, and methomyl, respectively. Corn and soybean acreage, corn yields, machinery sets, and tillage practices were the same in each farm plan. However, field time and resource use could vary.

THE EMPIRICAL RESULTS

Comparison of the economic results of no treatment with those for each of the three insecticide treatments provides an indication of the economic impacts of possible soybean insecticide bans. Total farm income, cost of production, and returns to management and fixed resources provide an approximation of the economic conditions faced by the firm. Of particular importance to our investigation is not the absolute level of income and costs as each of the soybean insecticides is banned, but rather the relative changes in the results as each soybean insecticide is banned (Table 3).

TABLE 3. SUMMARY OF ECONOMIC RESULTS FOR AN INDIANA FARM UNDER VARIOUS SOYBEAN INSECTICIDE CONDITIONS[a]

	Untreated Soybeans	Carbaryl (Sevin™ 80S)	Malathion	Methomyl
		-dollars-		
Income				
Corn	77,297	77,271	77,271	77,271
Soybeans	40,306	44,774	46,828	45,297
Total Income	117,603	122,045	124,099	122,568
Insecticide Cost	2,100[b]	3,750	5,279	4,323
Total Variable Costs	57,949	59,621	61,160	60,197
Return to Management and Fixed Resources	59,654	62,424	62,939	62,371

[a]Assuming pest infestation levels of test plots in southern Indiana in 1975 to 1977.
[b]Represents only corn insecticide costs ($7.00/acre).

When carbaryl (Sevin™ 80S) was used average per-acre soybean yields increased 9 percent and sales increased 11 percent over the no-treatment levels (Table 4). The use of malathion resulted in the largest increase in soybean income, costs, and net returns per acre

TABLE 4. AVERAGE CORN AND SOYBEAN YIELDS, SALES, COSTS, AND NET RETURNS PER ACRE[a]

	Corn	Untreated Soybeans	Carbaryl (Sevin™ 80S)	Malathion	Methomyl
Yields (bu./acre)	104	23	25	27	25
Sales ($)	258	134	149	156	151
Costs ($)	119	67	73	78	74
Net Revenues ($)	139	67	76	78	77

[a]The per acre averages are rounded to the nearest bushel or dollar.

in relation to the no-treatment levels. Although malathion costs nearly twice as much as carbaryl (Sevin™ 80S), returns to management and fixed resources were still greater with malathion than they were with carbaryl.

Methomyl appears to provide economic results similar to those of carbaryl (Sevin™ 80S). Though soybean income did increase about 12 percent and yields increased about 9 percent in comparison with the no-treatment levels, the application cost is about $2.00 per acre more for methomyl than for carbaryl (Sevin™ 80S). Hence, the returns to management and fixed resources for methomyl are less than those for malathion and essentially the same as those for carbaryl (Sevin™ 80S).

On the basis of the empirical results of our study, if carbaryl (Sevin™ 80S) — which is currently on the RPAR review list — were banned, both malathion and methomyl could serve as technically and economically acceptable substitutes. Malathion would be likely to result in slightly higher yields and returns to management and fixed resources. However, yields and net income for methomyl are still greater than those for untreated soybeans.

Because the insecticide cost was the only variable cost which changed substantially among the different soybean insecticide farm plans, a simple benefit-cost analysis can be performed. Insecticide cost increments relative to the no-treatment case can be compared with the increase in revenues resulting from higher yields. Because this procedure compares changes in income and cost between two linear programming solutions — treatment versus no treatment — the benefit-cost ratios are closer to an average than to a marginal return for each dollar of insecticide expenditure.

The benefit-cost ratio for each of the three soybean insecticides was greater than two (Table 5). Carbaryl (Sevin™ 80S) gave the

TABLE 5. SOYBEAN INCOME PER DOLLAR OF INSECTICIDE[a]

Insecticide	Income Per Dollar of Insecticide[b]
Malathion (57%)	2.0
Methomyl (1.8 EC)	2.2
Carbaryl (Sevin™ 80S)	2.7

[a]Since the ratios are based on a comparison of a no insecticide linear programming solution to alternative insecticide solutions, the returns per dollar of insecticide expenditures are closer to an average than a marginal return concept.

[b]Since changes in yield could alter drying costs, incremental soybean drying costs were added to the insecticide cost. However, few soybeans were dried and incremental drying costs were quite small.

highest and malathion the lowest return per dollar of soybean insecticide expenditure. It is important to bear in mind that these calculations were based on 1979 price and cost relationships and estimates of potential yield gains if insect infestations similar to those found in southern Indiana in the period 1975-77 were controlled with the respective insecticides.

It should also be noted that these are private and not social benefit-cost ratios. Possible external costs from insecticide drift, human health damage, or damage to nontarget species are not included. Benefits other than yield increases, e.g., improved soybean quality due to less insect damage, that add to the farm firm's income are not considered either.

No major changes in resource use occurred in corn or soybean production for any of the different soybean insecticide scenarios. Shadow prices for corn land remained at $91 per acre. With corn and soybean acreage held constant, the shadow prices for soybeans ranged from $85 to $91 per acre as the soybean insecticide applied was varied.

POLICY IMPLICATIONS

Soybean insecticides are not currently widely used in Indiana. However, the empirical results of our study suggest that when insect defoliation levels approach 20 percent, timely spraying can be profitable. Improved insect control was found to increase soybean yields 10 to 14 percent per acre. Benefit-cost ratios greater than two suggest that Indiana farmers could find the use of soybean insecticides profitable under insect conditions similar to those in southern Indiana in the period 1975-77.

One of the insecticides analyzed, carbaryl (Sevin™ 80S), is currently under review by the Environmental Protection Agency. Though it is the least expensive and provided the largest benefit-cost ratio of the three insecticides analyzed, malathion and methomyl appear to offer similar yield increases, comparable returns to management and fixed resources, and acceptable benefit-cost ratios. Hence, though a ban on carbaryl could affect some farming operations, the overall impacts of such an action by the Environmental Protection Agency on soybean operations in Indiana would be minimal. Concurrent bans on all three soybean insecticides would have significantly greater economic impacts on those farming operations in Indiana where soybean insect damage is frequent.

Any careful analysis of the possible economic impacts of bans on insecticide use requires an interdisciplinary effort. The approach followed in our study integrates test plot results generated by entomologists into a farm planning model. Such an optimization technique provides useful information on the economic benefits and costs as well as resource allocation implications of restrictions on pesticide use. Additional analyses of this type should be conducted for various geographic regions, farming systems, and pest management systems. Analysts should design the experiment carefully in order to separate insecticide treatment effects from other factors which can affect yields. The empirical results provided by such careful interdisciplinary studies are essential if decision makers are to select more nearly optimal pest management practices.

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