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OFFICE OF
PREVENTION, PESTICIDES
AND
TOXIC SUBSTANCES

Memorandum

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SUBJECT: Biological and Economic Analysis of Diazinon on Cabbage

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SUMMARY

Diazinon is widely used on cabbage for the control of the cabbage root maggot, a potentially devastating

pest, and it also targets diamondback moth and other lepidopterans. However, effective alternatives, chlorpyrifos for maggots and several chemicals for other pests, are available at only small increases in costs. BEAD believes that impacts from a cancellation of diazinon due to concerns over worker health risks would be small. Production costs per acre may rise $6-8.00/acre with chlorpyrifos and as much as $13.00/acre for *Bacillus thuringiensis*, but this represents only 0.5-2.6% losses in net revenues per acre. Total costs to the industry at the national level could range $54,000 to $80,000 per year, with Texas and the South incurring the greatest losses. This represents only 0.03% of the gross value of production.

LIMITATIONS AND SCOPE OF ANALYSIS

The scope of this analysis includes an examination of potential regional-level impacts associated with elimination (through a phase-out) of the use of diazinon in cabbage. This mitigation scenario reflects the high health risks to mixers, loaders and applicators as identified by the Health Effects Division of the Office of Pesticide Programs. This analysis does not attempt to address impacts associated with mitigation efforts targeted at workers reentering fields treated with diazinon, or potential mitigation for various environmental risks (i.e., risk mitigation for risks to terrestrial plants and organisms or water contamination).

There are limitations to this assessment. The impacts estimated by this analysis only represent potential short-term – 1 to 2 years – impacts on the cabbage production system and grower returns. National impacts are calculated by simply scaling up the estimated per-acre impacts. We ignore potential changes in price that may result from production changes and estimated grower impacts assume there will be no shift from cabbage to other crops.

Assumptions about yield and quality losses associated with the various scenarios are based on the best professional judgement of BEAD analysts when estimates were not available from other sources. Assumptions are based on a review of available USDA crop profiles, state crop production guides, discussions with university extension and research entomologists knowledgeable in cabbage production, and other sources listed. Cabbage production is a complex system that can be influenced by a variety of parameters (e. g., weather). BEAD's ability to quantitatively capture the wide array of events that could unfold given each hypothetical scenario listed above is very limited.

CROP PRODUCTION

Cabbage (*Brassica oleracea*, Family Brassicaceae) is a cool-season plant with a shallow and extensive root system that grows best at 60-65ºF. Cabbage is adaptable to a wide range of soil types, including heavy soils with poor drainage, and a pH of6.2-6.5. Cabbage requires high nutrient levels, especially nitrogen. Cabbage is hand-harvested.

Average U.S. production of fresh cabbage has been over 1.2 million tons in recent years (USDA/NASS, 2002). Table 1 provides average acreage, production and value figures for the nation and selected states. An additional 190,000 tons of cabbage are produced for the processed market. The combined gross value of production is nearly $320 million, with over $310 million coming from the fresh market. New York is

the leading producer of fresh cabbage with over 20% of production. Other mid-Atlantic states contribute an additional 12% of production. California produces 18% of total fresh production and Texas contributes just under 15%.

U.S. fresh cabbage exports totaled about 40,000 metric tons (MT) annually in 1999 and 2000, with about 35,000 MT bound for Canada (FATUS, 2001). This represents slightly more than 3% of production. Exports were valued at about $17 million each year. At the same time, the U.S. was importing almost the same quantity, 37,000 MT, mostly from Canada, but also from Mexico. Imports were valued at about $10 million each year.

Table 1. Cabbage acreage, production and value, 1998-2001 averages.

Fresh	**Harvested Acres**	**Production (1000 tons)**	**Yield (ton/acre)**	**Value ($1000)**	**Average Price ($/ton)**
U.S.	77,400	1,224.1	15.8	308,926	252.40
New York	12,700	259.4	20.4	65,448	252.30
California	13,200	226.8	17.2	73,266	323.00
Texas	9,300	178.2	19.3	57,285	321.50
South[1]	24,300	305.0	12.6	59,622	195.50
Midwest[2]	8,600	105.1	12.2	20,551	195.50
Atlantic[3]	5,500	73.1	13.2	16,764	229.50
Other[4]	3,900	76.6	19.9	15,989	208.90
Processed	Harvested Acres	Production (1000 tons)	Yield (ton/acre)	Value ($1000)	Average Price ($/ton)
U.S.	6,900	183.3	26.5	8,466	46.20
Wisconsin	3,200	85.5	27.1	3,623	42.40
New York	2,700	69.9	25.9	3,512	50.30
Other[5]	1,100	27.9	26.1	1,328	47.50

Source: USDA, Vegetables 2001 Summary, January 2002.

[1] Florida, Georgia and North Carolina.

[2] Illinois, Michigan, Ohio, and Wisconsin.

[3] Maryland, New Jersey, Pennsylvania and Virginia.

[4] Arizona, Colorado and Hawaii.

[5] Michigan, Ohio, Oregon and Washington.

DIAZINON USAGE ON CABBAGE

Based on data from 1987 to 1997, BEAD (2000) estimated diazinon usage on cabbage to be about 14,000 lbs active ingredient (a.i.) annually, applied to approximately 9,000 acres or around 11% of the crop. The most recent reports by the USDA Agricultural Chemical Usage (1999 and 2001) appear to indicate a similar use patterns. Table 2 provides averages over the two years reported and the states surveyed, which represent about 88% of total cabbage acreage. The data indicate less than 7,500 acres were treated with slightly more than 8,000 lbs a.i. This represents almost 11% of the crop area in the states that were surveyed. Extrapolating from reporting states to others suggests that nationwide about 8,560 acres of fresh cabbage, on average, are treated yearly with about 8,870 lbs a.i. There was no reported use of diazinon on processed cabbage in 1998 and an unspecified amount in 2000 from the major producing states. Usage on processed cabbage appears to be minor.

Table 2. Reported diazinon usage on fresh cabbage, 1998 and 2000 averages.[1]

	Acres Planted	Acres Treated	Percent Crop Treated	lbs. a.i. Applied
U.S.	70,600	7,430	10.5	8,250
New York	13,000	180	1.4	180
California	13,850	1,660	12.0	1,650
Texas	9,850	2,920	29.6	4,450
South[2]	25,300	2,270	9.0	1,750
New Jersey[3]	1,850	330	17.6	150
Michigan[4]	1,950	80	1.2	80
West[5]		none reported		none reported

Source: USDA, Agricultural Chemical Usage, 1999 and 2001.

[1] Only selected states are sampled for chemical usage and not all chemicals are listed.

[2] Florida, Georgia and North Carolina.

[3] Only Atlantic state reporting.

[4] Michigan and Wisconsin reporting, but no diazinon reported in Wisconsin.

[5] Arizona and Colorado did not report.

Texas is the largest single user of diazinon on cabbage, treating almost a third of the acreage at a rate of 1.5 lbs a.i./acre/year. The average rate is about 1 lb a.i./acre/year as in New York, California and the Midwest. The South applies diazinon at an average rate of a little more than 0.75 lb a.i./acre/year. If New

Jersey is representative, the Atlantic states apply only about 0.5 lb a.i./acre/year.

Target Insect Pests and Control

The primary insect pests controlled by diazinon on cabbage are the cabbage root maggot (*Delia radiculum*) and soil insects, such as wireworms, white grubs, and cutworms. Diazinon is less frequently used to control other insects, including the cabbage aphid (*Brevicoryne brassicae*), the cabbage looper (*Trichoplusia ni*), the imported cabbageworm (*Pieris rapae*), the diamondback moth (*Plutella xylostella*), flea beetles, crickets, and ants. In most cabbage producing states, such as California and New York, the cabbage root maggot is diazinon's main target pest. In California desert areas, diazinon is also used to control flea beetles, and in Florida, diazinon is applied mainly to control the diamondback moth.

The cabbage root maggot feeds on the roots and lower stems of cabbage and other cruciferous crops, causing young plants to wilt and die. Several hundred larvae can infest a single plant, seriously damaging or destroying its root system, resulting in plant stunting, yellowing, and wilting. Tunneling by larvae predisposes the plant to secondary infections, such as blackleg and soft rot. In New York, up to 75% of the cabbage acreage is affected each year, with yield losses reaching a maximum of 50% in severely infested fields. It is not uncommon for entire loads of cabbage to be rejected for having maggots in the cores (USDA Crop Profile for Cabbage in New York), while in Michigan yield losses may be 10-20% (USDA Crop Profile for Cabbage in Michigan). Soil-inhabiting insects, such as a wireworms, feed on the plant's root system, killing seedlings and young plants when infestations are severe. Aphids suck the plant's phloem, causing yellowing and curling of leaves. Seedlings and young plants may be stunted or die when infestations are severe. Flea beetles chew small holes on cabbage leaves and, when abundant, may stunt or even kill seedlings and young plants. The cabbage looper feeds on leaves and buds, and may bore into the developing head. Feeding damage and contamination with droppings may render cabbage unmarketable. The larvae of other lepidopteran pests, such as the diamond back moth and the imported cabbage worm, feed on the cabbage leaves and the developing head.

ALTERNATIVE CONTROL METHODS

Chlorpyrifos is the only effective alternative insecticide registered for control of the cabbage root maggot and soil insects, and in California it is reported to be more effective than diazinon for this use (USDA Crop Profile for Cabbage in California). There are several alternative insecticides for use against all other diazinon target insect pests, including organophosphates, carbamates, and pyrethroids. In addition, imidacloprid, a neonicotinoid, is also available for aphid control, while spinosad and B.t. are available for control of lepidopteran larvae.

Since maggots survive in crop remains and related organic matter in soil between crops, fallowing fields can reduce their populations significantly. Other useful cultural pest control practices include crop rotation, destruction and burying of crop residues, and the use of spunbound row covers.

IMPACTS OF CANCELLATION OF DIAZINON ON CABBAGE

Biological Impacts

Diazinon is used on cabbage primarily for control of the cabbage root maggot, soil insects, and flea beetles. Other insect pests controlled include the cabbage aphid and several lepidopterans. In New York, yield losses caused by the cabbage root maggot may reach a maximum of 50% in severely infested fields, while in Michigan yield losses are estimated at 10-20% (USDA Crop Profiles for Cabbage in New York and Michigan). Since there is one effective alternative insecticide for control of the cabbage root maggot, and several alternatives for all other diazinon uses on cabbage, cancellation of diazinon should not significantly affect cabbage producers. Without diazinon, cabbage producers will have to use chlorpyrifos to control the cabbage root maggot, the principal pest in California and Texas. For control of diamond back moth and other lepidopterans alternatives include Bt, methomyl and spinosad.

Economic Impacts

Per-acre Impacts

Sample production costs were obtained from several states with high diazinon use and are used to calculate expected impacts of a cancellation of diazinon on cabbage. These budgets are reflective of the likely incurred costs, but are not based on cost of production surveys. This analysis assumes that farm gate prices are not affected by any changes at the grower level and that growers do not drastically alter their production practices. We focus solely on operating costs, ignoring overhead and other opportunity costs, as these are difficult to measure. Thus net cash returns overstate actual profits to the grower.

Recent yield and price data (see Table 1) were used to calculate gross revenues. Yields of fresh cabbage in California average about 17.2 tons/acre and bring a price of about $323.00/ton for gross revenues of $5,555.60/acre. Table 3 presents this information and selected categories of production costs to calculate net revenues per acre. Production cost data are from Mayberry (2000). The base scenario represents the application of diazinon for control of cabbage root maggot, while the alternative is to use chlorpyrifos. EPA data provides an average price of diazinon for this purpose of $8.00/acre while cholpyrifos would cost $14.00/acre. This is a 75% increase in control costs and represents an increase of about 2% in total insecticide costs and of about 0.1% in total operating costs, including harvest costs. Net cash returns, estimated at about $1330/acre would fall to around $1325/acre, a decrease of about 0.5%. BEAD characterizes such losses in net revenues as negligible.

Table 3. Gross returns, production costs and net returns to cabbage production, Imperial County, California, with cabbage root maggots at emergence.

	Base Scenario: application of diazinon	Alternative: application of chlorpyrifos	% Change
production (tons/acre)	17.2	17.2	
price ($/cwt)	323.00	323.00	
gross revenues ($/acre)	5555.60	5555.60	0.0
insecticide costs ($/acre)	291.00	297.00	2.1
diazinon chlorpyrifos	8.00	14.00	75.0
other	283.00	283.00	
other pre-harvest costs ($/acre)	1353.30	1353.30	
harvest costs ($/acre)	2580.00	2580.00	
total operating costs ($/acre)	4224.30	4230.30	0.1
net cash returns ($/acre)	1331.30	1325.30	-0.5

Source: University of California Cooperative Extension, BEAD calculations.

A similar analysis was conducted to determine likely impacts in Texas. Average yields of 19.3 tons/acre and prices of $321.50/ton imply gross revenues of over $6200/acre. Production costs obtained from Texas A&M University Extension Program and are based on 1999 projections for District 12, South Texas. These data are presented in Table 4. EPA data provides average costs of applying diazinon and chlorpyrifos as $7.57/acre and $11.50/acre, respectively. This represents an increase of 51.9% and increases total insecticide costs by 6.4%. Total operating costs, or which harvest costs are the major share, would increase by 0.1%. Net revenues, of around $2,840/acre, would decline by almost $4.00/acre, or a loss of 0.1%. BEAD characterizes this loss as negligible.

Table 4. Gross returns, production costs and net returns to cabbage production, District 12, South Texas, with cabbage root maggots at emergence.

	Base Scenario: application of diazinon	Alternative: application of chlorpyrifos	% Change
production (tons/acre)	19.3	19.3	
price ($/cwt)	321.50	321.50	
gross revenues ($/acre)	6204.95	6204.95	0.0
insecticide costs ($/acre)	61.57	65.50	6.4
diazinon chlorpyrifos	7.57	11.50	51.9
other	54.00	54.00	
other pre-harvest costs ($/acre)	640.50	640.50	
harvest costs ($/acre)	2663.80	2663.80	
total operating costs ($/acre)	3365.87	3365.87	0.1
net cash returns ($/acre)	2839.08	2835.15	-0.1

Source: Texas A&M University Agricultural Extension, BEAD calculations.

These figures appear to be representative of the impacts associated with control of the cabbage root maggot, the primary target pest. However, in Florida, and perhaps other areas of the South, the diamond back moth and other lepidopterans are the main pests controlled by diazinon. Alternatives to diazinon include Bt., methomyl and spinsosad. According to USDA/NASS (2002), Florida cabbage yields average about 13.3 tons/acre and prices are around $226.50/ton, somewhat higher than the southern states as a whole. This implies gross revenues of around $3,012/acre. EPA price data indicates that diazinon, applied at 0.75 lbs a.i./acre would cost about $5.10/acre and that costs for alternatives to control this pest complex range from $12.00/acre for methomyl to $18.20/acre for Bt. Spinosad costs about $13.00/acre. Production costs (University of Florida, 2002) are shown in Table 5, comparing the base scenario using diazinon to the additional costs of methomyl and Bt. These are relatively large increases in control costs and result in an increase in total insecticide costs of between 4.6 and 8.8%. Overall, production costs would increase 0.3-0.5% and net revenues would decline by 1.4 to 2.6%. While more than increases associated with control of the cabbage root maggot, BEAD would still characterize these losses as negligible.

Table 5. Gross returns, production costs and net returns to cabbage production, Hastings area, Florida, with control of diamond back moths.

	Base Scenario: application of diazinon	Alternative: application of methomyl	% Change	Alternative: application of Bt	% Change
production (tons/acre)	13.3	13.3		13.3	
price ($/cwt)	226.50	226.50		226.50	
gross revenues ($/acre)	3012.45	3012.45	0.0	3012.45	0.0
insecticide costs ($/acre)	149.50	156.40	4.6	162.60	8.8
diazinon methomyl Bt	5.10	12.00	135.3	18.20	256.9
other	144.40	144.40		144.40	
other pre-harvest costs	1007.25	1007.25		1007.25	
harvest costs	1356.60	1356.60		1356.60	
total operating costs	2513.35	2520.25	0.3	2526.46	0.5
net cash returns ($/acre)	499.10	492.20	-1.4	485.99	-2.6

Source: University of Florida Center for Agribusiness, BEAD calculations.

Industry Level Impacts

In the usage section above, BEAD estimated that about 8,560 acres of cabbage were treated annually with diazinon. Of these, about 2,300 acres are likely in the South where diamond back moths and other lepidopterans are the primary pests. We assume that costs per acre of $6-8.00/acre are associated with more expensive control of the cabbage root maggot and that costs range from $6.90 to $13.10/acre for control of other pests due to a cancellation of diazinon. Simple multiplication of the per acre costs by the number of impacted acres provides an estimate of total costs to the state and national cabbage industry, shown in Table 6. Impacts would be largest in the South, where per-acre costs are somewhat higher, and in Texas, where relatively more diazinon is used. Overall, however, costs are a very small proportion of the gross value of production. Total costs at the national level could range from $53,660 to almost $80,000 out of total gross revenues of $308,926,000.

Table 6. Industry costs associated with a cancellation of diazinon.

State/Region	Impacted Acres[1]	Cost per Acre	Total Cost	Gross Value of Production[2] ($1000)	Total Cost as % of Gross Value
New York	180	6-8.00	1,080-1,440	65,448	< 0.01
California	1,660	6-8.00	9,960-13,280	73,266	0.01-0.02
Texas	2,920	6-8.00	17,520-23,360	57,285	0.03-0.04
South[3]	2,300	7-13.00	16,100-29,900	59,622	0.03-0.05
Midwest[4]	370	6-8.00	2,220-2,960	20,551	0.01
Atlantic[5]	1,130	6-8.00	6,780-9,040	16,764	0.04-0.05
Other[6]	0	6-8.00	0	15,989	0
U.S.	8,560		53,660-79,980	308,926	0.02-0.03

[1] See Table 2 and associated text.
[2] See Table 1.
[3] Florida, Georgia and North Carolina.
[4] Illinois, Michigan, Ohio, and Wisconsin.
[5] Maryland, New Jersey, Pennsylvania and Virginia.
[6] Arizona, Colorado and Hawaii.

CONCLUSION

BEAD believes that any impacts associated with the cancellation of diazinon for use on cabbage will be small. Diazinon is mostly used to control the cabbage root maggot, a potentially devastating pest. However, chlorpyrifos offers an effective alternative at only slightly higher costs. For control of lepidopterans, which is important in Florida, effective alternatives are also available, but at an increase in costs. These increases will likely be negligible on impacted areas, ranging from net revenue losses of 0.5% for maggot control to 2.6% for control of lepidopterans. Costs to the industry at the state and national levels will be small. In total, costs may range from $54,000 to $80,000 compared to a gross value of production of almost $310 million.

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