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OFFICE OF
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Memorandum

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SUBJECT: Biological and Economic Analysis of Diazinon on Cole Crops

FROM: Colwell A. Cook, Entomologist
Herbicide and Insecticide Branch

T J Wyatt, Economist
Economic Analysis Branch
Biological and Economic Analysis Division (7503C)

THROUGH: David Brassard, Senior Entomologist
Arnet Jones Chief
Herbicide and Insecticide Branch

David Widawsky, Chief
Economic Analysis Branch

TO: John Hebert, Chemical Review Manager
Susan Lewis, Chief
Reregistration Branch 1
Special Review and Reregistration Division (7508C)

CC: Denise Keehner, Director
Biological and Economic Analysis Division

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SUMMARY

Based on available published information and personal communications with crop experts, BEAD believes that the impacts resulting from the cancellation of diazinon on cole crops – Brussels sprouts, broccoli, and cauliflower – will be moderate to major on acreage with pest problems currently treated with diazinon. The main cause of losses to producers will be due to reduced control of the cabbage root maggot, which is currently controlled with a combination of chlorpyrifos at transplanting and a followup application of diazinon. No effective alternative is currently available and yield losses are estimated at 10% for the affected acreage. Cabbage aphid, green peach aphid, flea beetles, and lepidopterous larvae are also controlled with diazinon applications during the growing season. There are many effective alternatives for these pests at some increase in production costs.

Total area affected could be around 27,400 acres out of 194,300 acres devoted to cole crops. BEAD estimates losses on impacted acres ranging from 14% of net revenues for cauliflower growers in Arizona, to over 90% losses to California growers of cauliflower. In absolute terms, losses are largest to broccoli, potentially $3.7 million annually out of $552 million in gross value, about 0.7%. In percentage terms, Brussels sprouts will be most affected since 80% of the acreage is treated with diazinon. Losses of around $1.3 million, representing almost 8% of gross value, might be seen. In total, losses for the three crops in the two states could be as much as $6.1 million or 0.8% of the gross value of production. Industry losses depend on the number of acres that are cropped more than once per year and that have chronic pest problems.

Scope and Limitations of the Assessment

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 cole crops. This mitigation scenario is in response to 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 cole crops production system. 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. The basis for these assumptions is knowledge acquired from reviewing available USDA crop profiles, state crop production guides, discussions with university extension and research entomologists knowledgeable in cole crop production, and other sources listed. Production of cole crops is a very complex system that can be affected by many 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. The economic analyses are based on crop budgets prepared by University Extension Specialists, which do not always include the exact combination of pesticides considered in BEAD's scenarios.

CROP PRODUCTION

Cole crops, such as Brussels sprouts, broccoli, and cauliflower, are cool season crops, belonging to the cabbage family, *Brassica*. Brassica plants thrive best in a cool humid climate, thus commercial production of these crops is concentrated in the "fog-belt" of California. Since the agricultural practices and the insect pests are similar for these crops, they will be grouped together and referred to as cole crops.

U.S. and Regional Production of Cole Crops

Together, cole crops gross almost $800 million dollars in revenues annually in the United States. Production has averaged almost 3 billion pounds over the past several years on about 194,000 acres nationwide. Table 1 provides summary statistics for acreage, production and value for total production and for individual crops.

Table 1. 1999-2001 Average Area, Production, and Value of Production, Cole Crops.

U.S./State	Harvested Acreage (Acres)	Production (million pounds)	Percent of U.S. Production	Value of Production ($1000)
United States	194,300	2,934.5	–	799,248
broccoli	144,400	2,100.0	–	552,040
cauliflower	47,200	785.5	–	229,908
brussels sprouts	2,700	48.0	–	17,300
California	175,200	2,546.6	86.9	689,227
broccoli	130,700	1,829.0	87.1	481,551
cauliflower	41,800	669.6	85.2	190,376
brussels sprouts	2,700	48.0	100	17,300
Arizona	17,600	367.8	12.5	103,839
broccoli	13,400	268.0	12.8	69,843
cauliflower	4,200	99.8	12.7	33,996
New York	900	12.8	0.4	4,915
Texas	500	4.1	0.1	1,124
Other[1]	100	2.2	0.1	143

[1] Michigan, Minnesota and Oregon.
Source: USDA/NASS Vegetable Summary 2002.

Total U.S. broccoli production was 2.1 billion pounds in 2001, and was valued at $504.2 million. California and Arizona comprise the major production region. Texas, Oregon, Michigan and Minnesota produce minor quantities. Over 90% of production goes to the fresh market and accounts for over 95% of value. However, over the past three years, production for the processed market has increased while fresh broccoli production has declined slightly. Farm gate prices range between $19.60/cwt for produce bound for processing to $26.72/cwt for that bound for the fresh market.

Cauliflower is a $230 million dollar industry in the U.S., with the majority of production found in California and Arizona. Table 1 provides three-year averages for acreage, production and value for the U.S. and selected states. Almost 90% of production by weight goes to the fresh market, which accounts for almost 92% of the value. Since the mid-1990s, area devoted to cauliflower production has declined over 10%, from over 53,000 acres. However, yields have been increasing steadily leading to an overall increase in production of about 3%, from 762 million lbs to 786 million lbs. At the same time, farm gate prices have been falling throughout the U.S., from an average of $32.00 per hundredweight in 1994-96 to $30.10 in 1999-2001.

California is the major producer of cauliflower and area, yields and production have all been increasing over the past five years. In 2001, 42,500 acres of cauliflower were harvested for a total production of 701 million pounds. Arizona is the second largest producer; area and production are also expanding. Arizona boasts the highest yields in the nation, with almost 12 tons per acre compared to a national average of 8.3 tons/acre. Essentially all Arizona production is destined for the fresh market. Area and production are declining in New York and other states, although yields there are also increasing.

California is practically the sole producer of Brussels sprouts for commercial sales with about 2,700 acres harvested annually and an average production of 48 million pounds (USDA, 2001). The value of production is about $17.3 million dollars annually. Since the mid-1990s, production has declined by over 20%, driven by a decline in acres cultivated. Yields have risen slightly. Prices, however, have risen over the period by 35%, indicating that the demand for Brussels sprouts is inelastic. The average price between 1999 and 2001 is 36.1¢/lb.

U.S. broccoli exports in 2000 were over 180,000 metric tons (MT), about 17% of total U.S. production, while 73,000 MT of cauliflower were exported (FATUS, 2001). Canada and Japan were the largest consumers with 229,000 MT. Exports of broccoli were valued at over $126 million; those of cauliflower were almost $51 million. The U.S. imports both fresh and frozen broccoli, mostly from Mexico. Data do not separate broccoli and cauliflower, but in 2000, total imports were over 245,000 MT and were valued at $162 million.

Some U.S. Brussels sprouts are exported to Canada; the U.S. is, however, a net importer. Over 10 million pounds of frozen sprouts were imported in 1998 (Pfyffer Associates, 2001). About 40% came

from Belgium, whose capital provides the name of the tiny cabbages.

USAGE OF DIAZINON ON COLE CROPS

Previously, based on data from 1987-1997, BEAD estimated that about 12,000 lbs of diazinon by active ingredient (a.i.) were used annually on broccoli (BEAD, 2000). Area treated was estimated at approximately 11% of harvested area. More recent data are not very revealing. USDA (1999, 2001) reports 9% of broccoli acres were treated with diazinon in 1998 and 21% in 2000. Total lbs. a.i. applied is similarly variable with USDA reporting 8,200 lbs used in 1998 and 28,900 lbs in 2000. The California Environmental Protection Agency (2001) reports that between 8.8 and 11.1% of the broccoli area was treated in the past three years with an average of 14,900 lbs a.i. applied annually, about 16% less than USDA reports. USDA (1999, 2001) reports 800 to 1500 lbs of diazinon were used on broccoli in Arizona, with 13 to 17% of the acreage treated. For consistency, we use USDA figures, which are summarized in Table 2. The data indicate a recent upward trend in the use of diazinon on broccoli.

At the same time, BEAD (2000) reported approximately 16% of cauliflower acreage was treated with diazinon and total usage was about 5,000 lbs active ingredient (a.i.) annually. The two most recent USDA reports (1999, 2001) indicate a reduction in usage, from 13% of area treated in 1998 to 5% in 2000, with similar declines in usage from 3,900 lbs a.i. in 1998 to only 1,900 lbs a.i. in 2000. All usage is reported to be in California. However, EPA data indicate an average annual usage of 4,800 lbs a.i. in California for 1998-2000. The California Environmental Protection Agency, whose figures are based on applications from sprayers, indicate a fairly consistent rate of 3,500 lbs applied annually to 3,300 acres for the same period. This represents almost 8% of the harvested acreage (Table 3). USDA reports some use of diazinon in Arizona, but does not estimate amount used or acres treated.

According to the California Environmental Protection Agency (1999, 2000, 2001) about 2100 acres of Brussels sprouts are treated with diazinon every year (Table 3). This represents almost 80% of the acreage. Approximately 2,200 lbs active ingredient (a.i.) are applied for a rate slightly more than 1 lb per acre per year. The median number of applications is two per season with a rate of 0.5 lbs a.i. per acre.

Table 2. Diazinon Usage on Cole Crops, 1998-2000.

	Arizona	California	U.S.
Broccoli			
% area treated	13	15	15
area treated (acres)	1760	19400	21200
lbs a.i. applied	1150	17400	18600
Cauliflower			

	Arizona	California	U.S.
% area treated	1	10	9
area treated (acres)	60	3990	4050
lbs a.i. applied	50	2850	2900
Brussels sprouts % area treated		79	79
area treated (acres)		2140	2140
lbs a.i. applied		2220	2220

Source: USDA/NASS, California EPA (Brussels sprouts). Minor usage on acreage in other states is not reported.

Target Pests and Control

Target Pests

The primary insect pest for which diazinon is used in the California "fog belt" is the larval form of the cabbage root maggot, *Delia radicum*. Larvae form dense colonies on the feeder and taproots. In Arizona or the desert growing regions, diazinon is used for a variety of soil insects that eat either the seed or the emerging seedling. Secondary pests are a complex of aphids, flea beetles and lepidopteran larvae. The most troublesome species of aphids is the cabbage aphid, followed by the green peach aphid. The flea beetle complex include striped flea beetle, potato flea beetle, western black flea beetle, and western striped flea beetle. The lepidopteran larvae primarily include cabbage looper, imported cabbageworm, and beet armyworm. (For information concerning the biology of these insects, see Appendix A.)

The feeding of cabbage root maggots can cause plant stunting, yellowing, and wilting. Young seedlings are more susceptible to permanent damage than mature plants. Additionally, injury from root maggots provides an entry point for pathogens. Aphids damage plants by sucking phloem from the plants. If untreated, moderate levels of infestation will cause yellowing and stunted plant growth, reducing quality and yield, and damage from larger infestations can result in death of the plant . The presence of aphids on the commodity at harvest constitutes an adulterated, unmarketable product.

Flea beetles can be a problem for young seedlings. The larvae feed for up to one month on the foliage and roots, as well as mine the leaves or tunnel in the stems. The incidence of economic damage from larvae is unusual in cole crops. Flea beetles also chew on older leaves of cole crops, but this damage is less severe and is not of economic significance.

Lepidopteran larvae damage plants by chewing leaves and buds. Typically these larvae are most

threatening to young plants, and economic damage can result from stunted plant growth. Additionally, if larvae are on older plants their fecal matter and shed skins on the produce, renders the commodity adulterated and unmarketable. (See Appendix A for more information.)

State Recommended Control

The cabbage root maggot is a problem in the wet seasons (spring, fall) and in some locales that are wet year-round (such as northern Monterey Co.). The maggots feed on the roots of the plants and can destroy young seedlings.

It is recommended to the growers to apply chlorpyrifos as a pre-plant soil treatment or an at-transplant application in areas with cabbage root maggot. A few days later, they should follow up with a drench or directed application of diazinon. Both chemicals are necessary to obtain control of cabbage root maggot. It is estimated that chlorpyrifos alone would result in a 10% loss of yield in areas that have moist soil conditions (Sances, personal communication).

In desert regions a mix of methomyl and diazinon is recommended at planting, primarily the September and October plantings. One compound or the other is not sufficient to control the soil pests and crickets to get good stand establishment. It is estimated that with methomyl alone about 25% of the fields could have a 25-50% yield loss (Palumbo, personal communication), that is, the spray is used prophylactically and only about one-fourth of treated acreage would likely be infested. Assuming an average 40% yield loss on infested fields implies about a 10% yield loss on average for acres treated in the desert growing regions, similar to expected losses in the humid areas.

In addition, diazinon also controls aphids, flea beetles and a variety of lepidopterous larvae that may destroy the seedlings. The seedlings are very vulnerable and entire stands can be annihilated within 2 to 3 days. However, currently aphids can be controlled with an at transplant application of imidacloprid, or foliar applications of dimethoate or disulfoton. Flea beetles can be treated with permethrin or malathion. Lepidopteran larvae can be controlled with spinosad, methomyl, carbaryl, or synthetic pyrethroids. (For more information on alternatives see Appendix B.)

There are alternatives for the secondary pests on cole crops and BEAD believes that if diazinon were unavailable that the alternatives would be used. Although there would be no yield loss with these other compounds, production costs and environmental load would increase.

IMPACTS OF CANCELLATION OF DIAZINON

BEAD estimates a 10% loss of yield in areas that have moist soil conditions due to damage from cabbage root maggot if chlorpyrifos is used alone. In addition, BEAD believes that growers will select the other alternatives to control secondary insects on cole crops, increasing their production costs.

Economic Impacts

Broccoli

Per-acre impacts

A crop budget approach was used to determine the economic impact of diazinon cancellation on producers of cole crops. Sample production costs were obtained from the Agricultural Cooperative Extension programs of the University of California. 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.

Historical yield and price data were utilized to determine gross returns per acre. Yields in California have been reported as 7.0 tons/acre over the past several years while prices averaged $26.32/cwt, ranging from $23.80 to $30.80 (USDA, 2001). Table 3 presents gross returns, production costs and net cash returns to broccoli production in the coastal region of California (Smith, *et al.*, 2000). We assume an infestation of cabbage root maggots at emergence, treated with a combination of chlorpyrifos and diazinon, and that diazinon would normally be applied one time during the growing period for the control of aphids, flea beetle or lepidoptera larvae.

The cancellation of diazinon is expected to result in a yield loss of about 10% due to poor stand establishment. Further, alternative pesticides will have to be used for the control of growing season pests. EPA data provides an average cost for an application of diazinon at emergence of $12.39/acre and in season of $7.99/acre. No alternative is available for the emergence application. Alternatives for lepidoptera control range from a low of $5.86/acre for permethrin to $23.00/acre for spinosad. Since permethrin is already cheaper than diazinon, we assume that it is inappropriate for growers already using diazinon. Carbaryl, at $8.55/acre, is probably the cheapest possible alternative and will be used to establish the lower bound for grower impacts. Aphid control costs range from $3.59/acre for dimethoate to$25.78/acre for imidacloprid. The most likely option is disulfoton at $9.35/acre. However, we use imidacloprid to estimate the maximum grower losses.

Table 3. Gross returns, production costs and net returns to broccoli production, Monterey County, California, with cabbage root maggots at emergence and other growing-season pests.

	Base Scenario: two applications of diazinon	Alternative: none at emergence, carbaryl for lepidoptera	% Change	Alternative: none at emergence, imidacloprid for aphids	% Change

production (lbs/acre)	14,000	12,600	-10.0	12,600	-10.0
price ($/cwt)	26.32	26.32		26.32	
gross revenues ($/acre)	3684.80	3316.32	- 10.0	3316.32	- 10.0
insecticide costs ($/acre)					
emergence					
diazinon	12.39	0.00		0.00	
growing season					
diazinon	7.99				
carbaryl		8.55	7.0		
imidacloprid				25.78	222.7
other	91.62	91.62		91.62	
other pre-harvest costs ($/acre)	742.00	742.00		742.00	
harvest costs ($/acre)	2611.54	2350.38	- 10.0	2350.38	- 10.0
total operating costs ($/acre)	3465.57	3192.58	- 7.9	3209.81	- 7.4
net cash returns ($/acre)	219.23	123.74	- 43.6	106.51	- 51.4

Source: University of California Cooperative Extension, BEAD calculations.

The primary impact of a cancellation of diazinon would be the yield loss from reduced control of cabbage root maggots. Gross revenues would decline by over $350/acre. Depending on the pest complex during the growing season, growers could face additional insecticide costs, although they would save the cost of the diazinon application at emergence. Total insecticide costs could decline by over 10% if carbaryl were used for lepidoptera control or increase by more than 5% if imidacloprid were necessary to control aphids. Harvest costs, which are largely a function of yields, would decline, leading to an overall reduction in costs between $250 and $275/acre. Net revenues could decline by as much as $113/acre, with percentage losses between 44 and 51%. BEAD would characterize such losses as major. Growers frequently cultivate two crops of broccoli each year, implying lost income of around $200/acre, assuming chronic pest problems.

Maggots are mainly a problem in wetter environments, although the prevalence of irrigation may result in chronic problems. Without yield losses due to the maggots, cost increases are relatively minor. Losses of net revenues would range from 0.5% with carbaryl as the alternative to 15.9% if two applications of imidacloprid had to replace two diazinon applications for aphid control.

We assume that Arizona faces similar pest issues and estimate the same scenario using a crop budget from the University of Arizona Cooperative Extension (Teegerstrom and Umeda, 2001). According to the USDA (2001), yields in Arizona are 10 tons/acre and the average price over the past three years has been $26.43/cwt, implying gross returns of $5286/acre. Insecticide costs are approximately $117/acre, including two applications of diazinon. Other operating costs are slightly higher than in California, but harvest costs are slightly lower so that total variable costs are about $3320/acre and net revenues are about $420/acre. A ten percent loss in yield due to cabbage maggots would similarly reduce gross revenues. Diazinon applications during the growing season cost on average $7.85/acre. Probable alternatives range in cost from $8.05/acre for cypermethrin to $16.74/acre for spinosad, both of which control lepidoptera. Alternatives for aphid control are $10-11.00/acre for chlorpyrifos and imidacloprid. Losses in net revenues are largely driven by the yield losses and could range from $144/acre with cypermethrin as the alternative to $152/acre with spinosad. In percentage terms, this represents between 34 and 36% of net revenues, which BEAD characterizes as a major loss. As in California, broccoli acres are usually double cropped, implying annual income losses of $280-300/acre.

Industry Impacts

USDA/NASS data (2001) indicate that 19,400 acres of broccoli in California and 1,760 acres in Arizona are treated with diazinon (see Table 2). Given BEAD's estimated losses in net revenues for two crops of broccoli, California could face losses of as much as $3.9 million dollars out of gross revenues of $482 million. Losses in Arizona could range from $490,000 to $530,000 from a total value of production of $70 million. Additional losses might also be expected on a small number of acres in other producing states. These losses are likely the maximum that the industry could face, since they are based on chronic pest problems over two crops in a single year.

Cauliflower

A similar analysis was conducted for cauliflower. California yields have averaged 8 tons/acre, ranging from 7.8 to 8.3 tons/acre, and prices $28.43/cwt (USDA, 2001). Gross revenues are thus approximately $4,550/acre. Table 4 compares net revenues between the scenarios of interest. The base case assumes two applications with diazinon, one at emergence for control of cabbage root maggots and one during the growing season for control of aphids, beetles or lepidoptera larvae. EPA data indicate that diazinon costs are $8.72/acre and $4.11/acre, respectively. Without diazinon, yield and gross revenue losses from cabbage root maggots are expected to be around 10%. Alternatives for control of other pests range from $5.64/acre for permethrin for lepidoptera control to $33.30/acre for aphid control using imidacloprid. Total operating costs will decline due to less produce available to harvest, but net revenues could decline by $150 to $175/acre, 90% or more of net revenues, on acres with pest problems that are currently treated with diazinon.

Table 4. Gross returns, production costs and net returns to cauliflower production, Monterey County, California, with cabbage root maggots at emergence and other growing-season pests.

	Base Scenario: two applications of diazinon	Alternative: none at emergence, permethrin for lepidoptera	% Change	Alternative: none at emergence, imidacloprid for aphids	% Change
production (lbs/acre)	16,000	14,400	-10.0	14,400	-10.0
price ($/cwt)	28.43	28.43		28.43	
gross revenues ($/acre)	$4548.80	4093.92	- 10.0	4093.92	- 10.0
insecticide costs ($/acre)					
emergence					
diazinon	8.72	0.00		0.00	
growing season					
diazinon	4.11				
carbaryl		5.64	0.4		
imidacloprid				33.30	710.0
other	62.14	62.14		62.14	
other pre-harvest costs ($/acre)	1290.00	1290.00		1290.00	
harvest costs ($/acre)	3009.20	2708.28	- 10.0	2708.28	- 10.0
total operating costs ($/acre)	4386.20	4078.09	- 7.0	4105.75	- 6.4
net cash returns ($/acre)	164.62	17.65	- 89.3	- 10.01	- 106.1

Source: University of California Cooperative Extension, BEAD calculations.

BEAD characterizes the impacts of a diazinon cancellation on cauliflower as major to disastrous, depending on the alternative required. Losses of over 100% of net revenues are unlikely, since less expensive alternatives to imidacloprid are available for aphid control. However, the main driver of these losses are reductions in yields due to cabbage root maggots. Growers may cultivate one or two crops of cauliflower per year, but those experiencing pest problems are unlikely to continue cultivation given these losses.

Production of cauliflower is much more remunerative in Arizona. Yields are 11.9 tons/acre and prices $64.06/cwt (USDA, 2001). Gross revenues are over $8,100/acre. Production costs in western Arizona total $5,720/acre for net cash returns of $2,790/acre (Teegerstrom, *et al.*, 2001). Production

costs include $317.60/acre in insecticides, including two applications of diazinon at $24.40/acre. The high cost of diazinon may explain the relatively small amount of cauliflower acres treated in Arizona. Only imidacloprid as a control for aphids is more expensive; most growers probably use one of the other alternatives already. Without diazinon, cabbage root maggots could cause yield losses of 10%, reducing gross revenues by over $800/acre. At $59.57/acre, use of imidacloprid during the growing season would increase total insecticide costs by almost $11/acre, even accounting for the monetary saving if diazinon were not used at emergence. Harvest costs would also decline, resulting in total variable costs of approximately $4,900/acre. Net revenues could fall by almost $400/acre, or 14.1%. BEAD characterizes this loss as moderate.

Industry Impacts

USDA/NASS data (2001) indicate that 3,990 acres of cauliflower in California and only 60 acres in Arizona are treated with diazinon (see Table 2). With per acre losses in California of around $150-175/acre for each crop, total losses to the state's cauliflower industry could range from $1.2 to $1.4 million. This represents about 0.6% of total gross revenues of $190 million. Under the worst case scenario of two crops in Arizona, annual losses from a cancellation of diazinon come to $47,000, 0.1% of $34 million in gross revenues. Other producing states face similar impacts from cancellation.

Brussels Sprouts

Detailed crop budgets are not available for Brussels sprouts. Average yields in California are 8.9 tons/acre and prices are about $36/cwt (USDA, 2001). Expected gross returns are thus around $6,415/acre. Production costs are assumed to be similar to those of broccoli and cauliflower, that is, ranging from $3,560 to $4,390/acre, respectively. Net revenues would be between $2,030 and $2,860/acre. Yield losses of 10% due to cabbage root maggots may result from a cancellation of diazinon, which would reduce gross returns to around $5,774/acre. While harvest costs would decline, insecticide costs may increase as growers switch to more costly alternatives to control pests during the growing season. If operating costs, including harvest costs, are similar to broccoli and growers switch to carbaryl or imidacloprid, (see Table 3), net revenues could decline from $2,860 to around $2,500 or by 12.6 to 13.2%. If costs and alternatives are similar to cauliflower production (see Table 4), net revenues might decline by 16.5 to 17.8% with permethrin or imidacloprid, from $2,030 to under $1,700/acre. These losses would be characterized as moderate.

In California, BEAD estimates about 80% of the Brussels sprouts acreage is treated with diazinon, or 2,140 acres (see Table 2). Assuming losses of around $350/acre and two crops per year implies losses of almost $1.5 million annually out of $17.3 million in gross revenues or losses in excess of 8.5% of total value. However, the percentage of fields with pest problems that are double cropped is probably less than 100.

CONCLUSION

Given the data available for analysis, BEAD believes that the impacts of cancelling diazinon for use on cole crops will be moderate to major with some growers facing a disastrous situation. The main cause is reduced control of the cabbage root maggot during the crucial emergence period of the crop that may result in a 10% loss in yields. Table 5 summarizes our findings. Impacts to California growers are consistently greater than to those in Arizona, where better yields and higher prices provide growers with greater net revenues. As an industry, Brussels sprouts are significantly impacted because 80% of the acreage is currently treated with diazinon. By contrast, few acres of cauliflower are treated in Arizona and industry losses are small. The values in the table are point estimates of acreage and losses and are subject to some uncertainty. Actual values will also vary from year to year according to pest population dynamics. Cost/acre/year is a weighted per acre loss, taking into account the range of potential losses and the number of crops cultivated on an acre during the year that experiences pest problems. We take the mid-point in the range of per acre losses from the analyses above. We assume that 80% of the acreage in Arizona produces two crops per year; that is, the per acre loss is multiplied by 1.8 to arrive at the cost/acre/year value. In California, where broccoli and cauliflower provide lower returns and are often grown in rotation with other vegetables, we assume 60% of the acreage will be cultivated in a second crop. We use a factor of 1.8 for Brussels sprouts.

Table 6. Summary of potential impacts to cole crop production of cancellation of diazinon.

	Broccoli	Cauliflower	Brussels sprouts	Total
Arizona				
acres impacted	1,760	60		1820
cost/acre/year[1]	266	707		
% net revenue	35.2	14.1		
characterization	major	moderate		
total cost	468,900	42,400		513,300
% gross value	0.7	0.1		0.5
California				
acres impacted	19,400	3,990	2,140	25,530
cost/acre/year[1]	166	258	630	
% net revenue	47.5	98.2	14.3	
characterization	major	major-disaster	moderate	
total cost	3,228,200	1,027,800	1,348,200	5,604,200
% gross value	0.7	0.5	7.8	0.8

Total[2] acres impacted	21,160	4,050	2,140	27,350
costs	3,697,000	1,070,300	1,348,200	6,115,500
% gross value	0.7	0.5	7.8	0.8

[1] Assumes most acres are cultivated twice per year.
[2] Ignores potential impacts in other producing states.
Source: BEAD calculations

To understand the level of uncertainty, we determine the total losses under alternative assumptions. If only 50% of the treated acres in both states are double cropped and must be treated again, total costs to the production of cole crops from the cancellation would be $5.5 million dollars, instead of $6.1 million, about 0.7% of the gross value of production. If we take the minimum estimated per acre loss and our original double-cropping assumptions, BEAD calculates total losses to cole crops of $5.7 million, again, about 0.7% of gross value.

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Appendix A: Target Insect Pests – Biology and Damage

Cabbage Root Maggot, *Delia radicum*

The primary insect pest for which diazinon is used is the larval form of the cabbage root maggot, *Delia radicum*. Larvae form dense colonies on the feeder and taproot of Brussels sprouts. Several hundred larvae can be found on one plant. They feed for 3 weeks, then pupate in the soil or on the roots of the host plant for 2 to 3 weeks before emerging as adults. Most years there are 2 to 3 generations, but under favorable weather conditions there can be more generations per season.

Cabbage root maggots can cause plant stunting, yellowing, and wilting. Young seedlings are more susceptible to permanent damage than mature plants. Additionally, injury from root maggots provides an entry point for pathogens.

Aphids: Cabbage Aphid, *Brevicoryne brassicae*; Green Peach Aphid, *Myzus persicae*

The most troublesome species of aphids is the cabbage aphid, followed by the green peach aphid. Adult cabbage aphid females asexually produce live offspring, and populations can increase to damaging levels very rapidly. As many as 21 generations per year can occur in warmer climates, such as areas in California where Brussels sprouts are grown. When population levels are high, winged forms of the aphids are produced, which then disperse and infest new plants.

The cabbage aphid is a sap-sucking insect that feeds by inserting a stylet into the plant's vascular system

and sucking cell sap, causing the leaves to become curled and crinkled. If untreated, moderate levels of infestation will cause yellowing and stunted plant growth, reducing quality and yield . The presence of aphids on the commodity at harvest constitutes adulterated, unmarketable product, and damage from larger infestations can result in death of the plant. Infestations of cabbage aphid threaten marketable yield losses of 100% if not treated.

Flea Beetles: Striped Flea Beetle, *Phyllotreta striolata*; Potato Flea Beetle, *Epitrix cucumeris*; Western Black Flea Beetle, *Phyllotreta pusilla*; Western Striped Flea Beetle, *Phyllotreta ramosa*

Several types of flea beetles are commonly found in California and can be a problem for young seedlings. Flea beetles are found regularly in the Desert areas starting in early September. Large populations of migrating adults from adjacent fields can completely destroy young Brassica stands in 24 to 48 hours if left unchecked.

Adults hibernate over winter months and emerge in mid-spring, feeding on any available foliage. Crop injury occurs by adults chewing small irregular shaped holes from the underside of the leaves, producing a shot hole effect. Beetles can cause stunting at low populations and death of small plants if the apical meristem is fed upon. Eggs are laid in the soil and larvae emerge after about 10 days. The larvae feed for up to one month on the foliage and roots, as well as mine the leaves or tunnel in the stems. Feeding terminates prior to pupation when late instar larvae drop from plants and pupate in the soil. The incidence of economic damage from larvae is unusual in cole crops. Flea beetles also chew on older leaves of cole crops, but this damage is less severe and is not of economic significance.

Lepidopterous Larvae

Other minor pests for which diazinon is used are lepidopteran larvae. These primarily include cabbage looper, imported cabbageworm, and beet armyworm. Cabbage looper feeds on the leaves, occasionally damaging seedlings, but they inflict the most economic damage directly to the sprout heads. Aside from the damage caused to the sprouts from chewing, cabbage loopers deposit fecal matter and their exuviae remains on the sprouts, rendering the commodity adulterated and unmarketable. Larvae of the imported cabbageworm feed for two to three weeks on the leaves and bore into the sprout heads. As with the cabbage looper, economic damage from imported cabbageworm is the result of direct feeding or contamination of the heads. The coastal areas are subject to infestations of armyworm from June through October. Beet armyworm is most threatening to young foliage and buds, and economic damage results primarily from stunted plant growth as a result of feeding damage.

Appendix B. ALTERNATIVE PEST CONTROL METHODS:

Cabbage Root Maggot

- Chlorpyrifos is the most efficacious insecticide for the control of cabbage root maggot in Brussels sprouts.

- Diazinon is registered for use against cabbage maggot, but it is not as efficacious as chlorpyrifos.
- Fonofos can be used as a preplant insecticide. However, the manufacturer has discontinued the product because of low profitability. Existing supplies can be used until December 31, 2001, at which time registration will expire and the manufacturer will buy back remaining product.

Aphids

It is important to prevent the establishment of cabbage aphid in Brussels sprouts during the early stages of plant growth. This aphid is a difficult pest to control once the canopy has developed and the sprouts have formed. These are the chemicals recommended by the state and in the crop profiles.

- Chlorpyrifos is the standard for controlling aphids in Brussels sprouts. It has been called the "linchpin" of commercial Brussels sprouts production, because pest control programs for this vegetable revolve around it. It is faster acting than oxydemeton-methyl, dimethoate, and imidacloprid.
- Dimethoate is a systemic insecticide usually mixed with chlorpyrifos and applied two times per season. This helps to prevent pest resistance to chlorpyrifos, and increases aphicidal efficacy during periods of high infestation. Dimethoate is also effective against green peach aphid.
- Oxydemeton-methyl was the third most commonly used material in the late 1990s, but the label prohibits ground spray applications of this product within 100 feet of an occupied building, or within 150 feet for aerial applications. Because of this restriction, imidacloprid is usually substituted for oxydemeton-methyl for aphid control in these areas.
- Diazinon is usually applied when diamondback moths are also present in the field. With the registration of spinosad for diamondback moth, usage of diazinon appears to be declining.
- Imidacloprid is a systemic, chloronicotinyl insecticide with foliar and soil uses. Previous low use of this chemical may be explained by high product cost, coupled with poor efficacy as a foliar application. Label states "Provado 1.6 Flowable will not knock down heavy aphid or whitefly populations." The soil treatment is efficacious for approximately 80 days after application. This is adequate control for early maturing varieties, but most other varieties require a foliar application mid- to late- season.
- Disulfoton is being replaced to some extent by imidacloprid for control of cabbage aphid and green peach aphid.
- Endosulfan is a rotational material with spinosad for diamondback moth control, although it is applied to control aphids.
- Malathion is not very effective in aphid control.

Alternative Chemical Controls:

- Naled– although registered for aphid on Brussels sprouts, the label rate indicates its use is appropriate for looper control which may not be sufficient to control aphids.
- Soap– due to the attractiveness of Brussels sprouts to aphid and the morphology of the plant, cabbage aphid is difficult to control with soaps. Numerous applications, at weekly intervals in some cases, are necessary to reduce aphid populations. Even with this usage regime, control of cabbage aphid on Brussels sprouts with insecticidal soap is extremely difficult.

Biological Controls:

- *Diaertiella rapae*, a parasite, can help aid in the control of aphid, but cannot control large infestations. Aphids are also preyed upon by lady beetles, green lacewing and syrphid larvae. However, once the aphid gets inside the sprout, predators have difficulty reaching them, and their effectiveness as biological control agents is minimized.

Cultural Control Practices:

- Brussels sprouts and other cole crops are often surrounded by non-crop areas that are not managed and provide alternate hosts for cabbage aphid, especially wild mustards that are genetically similar to cole crops. Cabbage aphid can infest Brussels sprouts and wild mustard concurrently, and therefore adjacent weedy areas must be kept clean of this source of aphid colonization. Tillage and herbicides can be used in an effective field sanitation program to minimize aphid pressures. However, this conflicts with no-till and low-till situations in some watershed areas.

Flea Beetles

Flea beetles may be controlled with permethrin, diazinon, malathion, disulfoton, dimethoate, carbaryl, and endosulfan, the latter four are seldom applied specifically for these pests.

- Permethrin–Of the chemicals used for flea beetle control, permethrin is the primary material used in the Desert. It is applied at the maximum label rate of 0.10 lb ai/ac. The first plantings usually require 3 applications during stand establishment, consisting of two rounds of chemigation followed by one spray application, or one chemigation followed by two sprays.

- Diazinon--One application at preplant or during seedling stage. It is soil incorporated at 0.8 lb to 1.0 lb ai/ac, or as foliar spray at 0.5 lb ai/ac. The presence of flea beetle in the Desert accounts for the higher Usage Intensity for diazinon. UI indices: Central Coast, 5; South Coast, 1; SJ Valley 3; Desert, 25.

- Malathion--Two to three applications are made early season (September) during stand establishment. The average application rate is 1.63 lb ai/acre (low end of label range of rates). However, most malathion use on California cauliflower is targeted at aphid control in the SJ Valley and Coastal growing regions.

Biological Controls:

- There are no acceptable biological controls for flea beetles.

Cultural Control Practices:

- Most commercial growers normally follow sound cultural practice for flea beetle control. This includes keeping field margins and ditches clean of alternate weed hosts.

Lepidoptera Larvae

- The Lepidoptera larvae may be controlled by permethrin, methomyl, naled, spinosad, carbaryl, cypermethrin, and lambda-cyhalothrin. Some of these chemicals only work on the early instars of beet armyworm.

Biological Controls:

- There are no known effective biological controls for cabbage maggot. There are several predators and parasitoids that target the Lepidoptera larvae.

Cultural Control Practices:

- Since maggots require crop residue and high organic matter in soil to persist between crops, fallowing fields for even short periods can reduce maggot incidence significantly. This is particularly true if soil is allowed to dry between plantings. Deep plowing and cultivation to bury organic matter deep underground can also reduce maggot pressure. Any other method of cultivation or crop management directed at avoidance of organic matter in the seed row, can reduce maggot incidence and damage to the young crop.
- There are no known cultural practices for control of the various lepidopteran larvae.

Current Insecticide Use

Table 1. Leading Insecticides used in California to control aphids or cabbage root maggots in Brussels Sprouts.

Brussel Sprout Insecticides in Order if Importance (Based on Percent of California Crop Treated in 1999)	% Crop Treated
Chlorpyrifos	94%
Diazinon	77%
Oxydemeton-Methyl	66%
Imidacloprid	60%
Dimethoate	55%
Azinphos-Methyl	29%
Endosulfan	8%

Disulfoton	7%
Malathion	5%
Acephate	< 1%
Pyrethrins	< 1%

(Source: California Department of Pesticide Regulation Pesticide Use Data from 1999.