THE ECONOMICS OF INSECT CONTROL ON WHEAT, CORN, AND CANOLA IN CANADA, 1980-1985

A report prepared by the Insect Losses Committee, Part II, of the Entomological Society of Canada.

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EXECUTIVE SUMMARY

The Entomological Society of Canada has conducted this study, funded by Agriculture Canada, to document the costs and benefits of insect control on wheat, canola, and corn during 1980 to 1985.

Estimates of crop losses from insects on wheat, canola, and corn are not well documented in the scientific literature. This study used crop loss estimates obtained from researchers, extension personnel, agrichemical company representatives and distributors, and growers. This survey indicated a large variability in crop loss among years, crops, and regions.

The insects of greatest significance on wheat were grasshoppers, wireworms, wheat midge, and cutworms. The damage caused by grasshoppers and wireworms in Saskatchewan dominated crop losses on wheat. On canola, the insects of greatest significance were flea beetles, bertha armyworm, diamondback moth, and clover cutworm. The effects of flea beetles throughout the prairies dominates the crop losses on canola. The insects of greatest importance on field corn were corn rootworms, wireworms, seed corn maggot, and European corn borer. The effects of the western and northern corn rootworm in Ontario dominated crop losses on field corn.

To prevent these crop losses, growers primarily relied on the use of insecticides and to a less extent on crop rotation and the use of resistant varieties. It was not possible to calculate the economic return to the use of non-insecticide control techniques.

The average annual research and extension person years devoted to insect control on wheat were 4.3 and 1.1 person years at a cost of $704,000 and $85,700, respectively. The average annual research and extension person years devoted to insect control on canola were 9.1 and 0.6 person years at a cost of $1.48 million and $47,000, respectively. The average annual research and extension person years devoted to insect control on corn were 6.2 and 1.4 person years at a cost of $728,000 and $114,000, respectively.

The net benefits after accounting for insecticide and application costs, as well as research and extension costs averaged $45.7 million or $1.8% of total Canadian wheat value, $122.5 million or 15.3% of total Canadian canola value, and $49.8 million or 8.3% of total Canadian corn value, annually.

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INTRODUCTION

Few studies have addressed the economics of pest control in Canada. In response to this absence of information, the Entomological Society of Canada conducted a study, funded by Agriculture Canada, to determine the economics of insect control on onions, apples, and potatoes (Stemeroff and George, 1983). On the basis of the initial study, Agriculture Canada funded the study reported herein concerning the economics of insect control on wheat, canola, and corn. In 1985, these crops earned approximately $4 billion in cash receipts for farmers ($2.5 billion from wheat, $0.8 billion from canola, and $0.6 billion from corn), this being approximately 20% of total farm cash receipts in Canada.

The purpose of this study was to assess the cost of insect control methods in relation to the cost of destructive insects in wheat, canola, and corn in Canada. The specific objectives were to:

1. list and describe the insects of primary economic significance which infest wheat, corn, or canola in Canada;
2. quantify the loss in marketable yield in the study crops despite current insect control efforts;
3. quantify the changes in marketable yield in the study crops, if no insect controls were applied;
4. outline and describe the methods of insect control for the study crops;
5. quantify the costs of insect control measures by region, specifically to quantify the following cost categories:
   - — insecticide plus application costs,
   - — research,
   - — extension;
6. quantify the net benefits derived from insect control measures
   A) from the growers' perspective such that it can be determined if it was economical to treat the infested area; and
   B) from the societal perspective such that it can be determined if benefits from insect controls outweigh the cost of research and extension associated with these control methods;
7. provide a range of net benefit measures from insect controls on the study crops;
8. indicate the precision associated with the results presented in this report.

The above objectives were addressed for each crop and insect on a crop district, or provincial basis depending on the availability of data. This study did not address the losses of wheat, canola, and corn due to insects during storage.

This summary can only provide a cursory view of the findings and cannot include the crop loss data, the data on insecticide market share, or the detailed net benefit data. These data are contained in the original report. Thus, if the reader wishes further information, copies of the complete report are available from the following libraries of Agriculture Canada: Sir John Carling Building, Ottawa, 2. Research Station, Winnipeg, 3. Research Station, Saskatoon, and 4. Research Station, Lethbridge.

METHODS

Three equations were used to estimate the net benefits derived from insect controls, namely: 1) an equation that calculated net benefit to growers (revenues - costs) per treated hectare associated with the use of insect control measures (Equation 1); 2) an equation that calculated calculated total net benefit to all growers from the insect controls that were used (Equation 2); and 3) an equation that calculated the total net benefit after accounting for publicly funded research and extension costs (Equation 3). The sources, limitations, and assumptions associated with the independent variables required to compute the equations are discussed in detail in the full report.

EQUATION 1:

$$N = \left[\left(\frac{I}{100 + I}\right)(Q1)(P1)\right] - \left[(PC)(L)\left(\left(\frac{I}{100 + I}\right)(Q1)\right)\right]$$

EQUATION 2:

T = (N) × (Number of treated hectares)

EQUATION 3:

W = T - (R + E)

Independent Variables

- I = EFFICACY (% increase in marketable yield due to insect control);
- Q1 = YIELD (realized mean annual harvested yield, in kg/ha);
- P1 = CROP PRICE (5 year average price of the crop, in $/kg);
- PC = PEST CONTROL COSTS (current insecticide plus application costs per ha, per application, in $/ha/appl.);
- L = NUMBER OF APPLICATIONS PER GROWING SEASON;
- R = PUBLICLY FUNDED RESEARCH COSTS (in $);
- E = PUBLICLY FUNDED EXTENSION COSTS (in $);

Dependent Variables

- N = NET BENEFIT TO GROWERS (profit per treated hectare to growers derived from insect control, in $/ha);
- T = TOTAL NET BENEFIT TO ALL GROWERS (the total net benefit to all growers excluding research and extension costs, in $);
- W = TOTAL NET BENEFIT (net benefit after accounting for research and extension costs, in $);

A Monte Carlo cost/benefit program was used to calculate the net benefit to growers (N) using equation 1. The program calculated 100 values of (N) on the basis of an efficacy value (I) selected from the range of the mean crop loss ±25%. Since a uniform range was specified, the selection of efficacy values occurred with equal probability within this range. The program then calculated and reported the mean, minimum, and maximum net benefit to growers in $/ha for each set of data. The mean, maximum, and minimum estimates can all occur with equal probability. The mean net benefit to growers was reported and discussed in the text. The reader should refer to the appropriate table for the minimum and maximum values. This method compensates to a degree for the inherent variability and qualitative nature of the data used in these analyses.

All costs and benefits were expressed in constant 1985 dollars, thus eliminating the distorting influence of inflation. The procedure employed to express values in 1985 dollars was to inflate pre-1985 values with the relevant series of the farm input price indices (Statistics Canada, Cat. 62-004).

RESULTS

WHEAT

Insects of Economic Concern and Their Control Costs

Grasshoppers: While some 35 species of grasshopper attack wheat in western Canada, four species (*Melanoplus sanguinipes*, *M. bivittatus*, *M. packardii*, and *Camnula pellucida*) were significant pests. Grasshopper populations increased from low levels in 1980 to a major outbreak in the prairie provinces in 1984 and 1985. This outbreak was focussed in southern Saskatchewan and southern Alberta as well as south-west Manitoba.

Grasshopper populations were controlled through the use of foliar applied insecticides. The mean insecticide plus application costs for each hectare treated for the control of grasshoppers were between $18.68/ha/treatment and $18.98/ha/treatment from 1980 to 1985. This study does not address the costs of applying insecticides to ditches, as the hectarage of treated ditches adjacent to wheat fields could not be identified.

Wireworms: The second group of insects that have been consistently of significance on wheat in western Canada are wireworms. A number of species attack wheat, but the primary species is the prairie grain wireworm (*Ctenicera destructor*).

In fields where wireworms were consistently a problem, the seed was usually treated with a seed dressing containing an insecticide. The insecticide component of the seed dressing used on wheat to control wireworms was estimated to cost $3.78/ha in western Canada and $3.16/ha in Ontario and Quebec. There were no significant application costs associated with the use of seed dressings.

Wheat Midge: The wheat midge (*Sitodiplosis mosellana*) is found throughout the wheat growing regions of Canada, usually at very low populations. An outbreak, resulting in substantial losses during 1982 to 1985, was centered in northeastern Saskatchewan. Foliar applied insecticides were relied on to reduce wheat midge populations. Insecticide plus application costs for the control of the wheat midge totalled $19.70/ha.

Cutworms: Several species of cutworms have occurred sporadically in localized outbreaks in Canada. The most significant outbreak during 1980 to 1985 has involved the pale western cutworm (*Agrotis orthogonia*) in Alberta and Saskatchewan in 1984 and 1985. Foliar applications of insecticide were relied on to control cutworms. The insecticide plus application costs were $23.38/ha to $23.85/ha.

Wheat Stem Sawfly: The wheat stem sawfly is a significant pest in south-western Saskatchewan and southern Alberta. Control of this insect has relied entirely on the use of resistant, solid stem varieties of wheat. In the infested region, growers grow susceptible hollow stem varieties until population levels increase to significant levels. Susceptible varieties are preferred, because yields of these varieties usually are higher (approximately 0.330 tonnes/ha) than resistant varieties. When growers feel that populations are high, a resistant variety is planted, i.e. once every two to three years. Resistant varieties currently used include Canuck, Chester, and Leader. Resistant varieties do not cost more than susceptible varieties. Presently, 4.5% (358,000 ha) of wheat seeded in Saskatchewan and 3.4% (96,000 ha) of wheat seeded in Alberta are planted to resistant varieties annually.

Estimates of yields of resistant varities in relation to wheat stem sawfly populations are not available. In addition, if resistant varieties were never available, population levels of these insects may be higher than at present. As a result, it was not possible to accurately calculate the economic return to the use of varieties resistant to the wheat stem sawfly. However, to provide an indication as to what economic benefits may occur if a 1% net increase in yield resulted from the use of resistant varieties the following calculations are provided. On the basis of average annual yields of 1682 kg/ha and 1991 kg/ha in Saskatchewan and Alberta, respectively, and a wheat price of $0.20/kg, a net increase in yield of 1% would return $3.36/ha and $3.98/ha to growers using resistant varieties in Saskatchewan and Alberta, respectively. This would provide a total annual net benefit to growers of $1.6 million ($1.2 million in Saskatchewan and $0.4 million in Alberta). Approximately 0.7 person years annually were required to maintain and develop resistant varieties during 1980 to 1985. Based on a cost of

$163,000 per research person year, the total cost was $114,000 annually. Thus, assuming a net increase in yield of 1%, the total net benefit after accounting for research costs was $1.48 million annually. Because of the speculative nature of these data, they are not included in the analysis.

Armyworm: The armyworm is the primary insect pest attacking wheat in Ontario and Quebec. However, the number of hectares treated is very low in relation to that treated in western Canada for insect control. When necessary, foliar insecticide applications are used to reduce armyworm populations. Armyworm insecticide plus application costs were $34.33/ha.

Hessian Fly: The hessian fly can cause losses to winter wheat in Ontario, Quebec, and the Maritimes. In eastern Canada, the damage caused by this insect is avoided by growers planting winter wheat after the "fly-free date" (mid-September). This date refers to the time when almost all eggs have been laid and adults killed due to the onset of winter. This control technique has been used successfully for the past 35 years. In addition, germplasm conveying resistance is present in some varieties of winter wheat. However, the degree of resistance conferred, the effects of the resistance on yield, and the number of hectares that are planted with resistant varieties are not known. The presence of resistant germplasm is not considered a significant control technique, as growers do not base their selection of a variety on the presence or absence of resistance. As the potential losses due to the hessian fly are not known, it is not possible to calculate economic returns to the use of the "fly-free date" control method, or the use of resistant varieties. However, undoubtedly in the absence of these control strategies, the hessian fly would be an important pest based on crop losses in eastern Canada in the 1930's and 1940's.

Number of Treated Hectares and Net Benefits

BRITISH COLUMBIA
Wireworms: The annual number of hectares treated ranged from 6,880 ha in 1981 to 11,040 ha in 1985 (Table 1). The net benefit ranged from $7.89/ha in 1985 to $15.56/ha in 1981. The total annual net benefit from insect control in British Columbia ranged from $87,000 in 1985 to $149,000 in 1980. The total net benefit during 1980 to 1985 was $734,000.

ALBERTA
Grasshoppers: The net benefit was $55.69/ha in 1981 when 5,422 ha were treated, and $50.79/ha in 1983 when 18,690 ha were treated (Table 1). In 1984, the net benefit ranged from -$13.27/ha to $26.71/ha when 210,221 ha were treated. The vast majority of the treated area in 1984 was in south-west Alberta where the net benefit was between $20.56/ha and $26.71/ha. In 1985, the net benefits ranged from -$15.26/ha to $65.65/ha when 551, 649 ha were treated. The majority of treated hectares were in southern Alberta with mean net benefits of $29.13 to $65.65/ha. The total annual net benefit ranged from zero in 1980 and 1982 to $30.3 million in 1985. The total net benefit during 1980 to 1985 was $36.3 million.

Cutworms: The area treated to control cutworms increased from zero ha in 1981 to 93,465 ha in 1985 (Table 1). The net benefit ranged from $28.86/ha in 1985 to $58.99/ha in 1980. The total annual net benefit ranged from zero in 1981 to $2.7 million in 1985. The total net benefit during 1980 to 1985 was $3.8 million.

Wireworms: The number of hectares treated to control wireworms ranged from 388,640 ha in 1980 to 498,400 ha in 1983 (Table 1). The net benefit ranged from $7.89/ha in 1985 to $15.56/ha in 1981. The total annual net benefit ranged from $3.8 million in 1985 to $7.1 million in 1983. The total net benefit during 1980 to 1985 was $34.2 million.

Net Benefit From All Insect Control: Total annual net benefit from insect control in Alberta ranged from $5.6 million in 1980 to $36.8 million in 1985. The total net benefit during 1980 to 1985 was $74.3 million (Table 4A).

SASKATCHEWAN
Grasshoppers: The number of hectares treated annually ranged from 10,179 ha to 610,687 ha during 1980 to 1983. The net benefit during 1980 to 1983 ranged from $11.46/ha in 1980 to $41.14 in 1982. In 1984, when 622,183 ha were treated, the majority of the treated hectares occurred in districts with a net benefit of $20 to $52/ha. In 1985, when 2.1 million ha were

treated, the majority of the treated hectares occurred in districts with a net benefit of $30 to $135/ha. The total annual net benefit ranged from $184,000 in 1981 to $115 million in 1985. The total net benefit during 1980 to 1985 was $161 million.

Cutworms: The number of hectares treated to control cutworms was 20,200 ha in 1984 and 30,300 ha in 1985 (Table 1). The net benefit in 1984 was $37.84/ha and in 1985 was $28.86/ha. The total annual net benefit was $764,000 in 1984 and $874,000 in 1985. The total benefit during 1980 to 1985 was $1.6 million.

Wheat Midge: The number of hectares treated to control the wheat midge was 116,442 ha in 1984 and 40,267 ha in 1985 (Table 1). All treated hectares were in the north eastern region of Saskatchewan. The net benefit ranged from $10.59/ha to $64.11/ha in 1984 and from $20.53/ha to $96.92/ha in 1985. The majority of treated hectares were in districts with net benefits of $64.11/ha and $47.63/ha in 1984 and $96.92/ha and $23.87/ha in 1985. The total annual net benefit was $5.2 million in 1984 and $1.8 million in 1985. The total benefit during 1980 to 1985 was $7.0 million.

Wireworms: The number of hectares treated to control wireworms ranged from 640,980 ha in 1980 to 753,930 ha in 1983 and 1985 (Table 1). The net benefit ranged from $2.21/ha in 1984 to $5.16/ha in 1982. The total annual net benefit was from $1.6 million in 1984 to $3.7 million in 1982. The total net benefit from 1980 to 1985 was $14.9 million.

Net Benefit From All Insect Control: The total annual net benefit from insect control in Saskatchewan ranged from $2.4 million to $119.6 million. The total net benefit during 1980 to 1985 was $184.7 million (Table 4A).

MANITOBA

Grasshoppers: No control measures were used against grasshoppers during 1980 to 1982. In 1983, when 6,305 ha were treated to control grasshoppers, the net benefit ranged from -$15.09/ha to $10.24/ha (Table 1). The total benefit from the control of grasshoppers in 1983 was $4,000. In general, grasshopper control efforts on a provincial basis in 1983 just broke even, and in some crop districts the cost of controls were not recovered.

In contrast, grasshopper controls in 1984 and 1985 resulted in significantly higher net benefits than in 1983 (Table 1). Specifically, of the 21,804 ha treated in 1984, 89% of the hectares had positive net benefits to growers. The net benefit ranged from $15.18/ha to $63.01/ha on 89% of treated hectares in 1984. In 1985, almost all treated area (97,634 ha) had a positive net benefit (Table 1) and most treated hectares were in districts with a net benefit between $117.94/ha and $154.31/ha.

The total annual net benefit was $692,000 in 1984 and $10.0 million in 1985 (Table 1). The total net benefit during 1980 to 1985 was $10.7 million.

Wheat Midge: In 1984 and 1985, treatments to control the wheat midge were applied primarily in north-western Manitoba (Table 1). In this district, the net benefit was $26.00/ha in 1984 and $42.83/ha in 1985. The total net benefit was $714,000 in 1984 and $589,000 in 1985. The total net benefit during 1980 to 1985 was $1.3 million.

Wireworms: The number of hectares treated to control wireworms ranged from 66,800 ha in 1980 to 97,100 ha in 1985 (Table 1). The net benefit ranged from -$0.89/ha in 1980 to $1.26/ha in 1985. In all years, the minimum net benefit per hectare was negative. Therefore, there was an equal chance of incurring a loss as well as a gain in net benefit from applying seed treatments. This indicates that control measures for wireworms were near a break even position (i.e. the value of the gain in marketable yield with treatment is just offset by the cost of control). The total annual net benefit ranged from -$59,000 in 1980 to $122,000 in 1985. The total net benefit during 1980 to 1985 was $157,000.

Net Benefit From All Insect Control: The total annual net benefit from insect control in Manitoba ranged from -$59,000 in 1980 to $10.7 million in 1985. The total net benefit during 1980 to 1985 was $12.2 million (Table 4A).

ONTARIO

Wireworms: A small number of hectares (between 130 ha and 224 ha) were treated annually for wireworm control (Table 1). These treatments resulted in a loss of -$0.51/ha to -$1.39/ha.

The total annual net loss was between -$270 and -$110. The total loss during 1980 to 1985 was -$1,150.

Armyworm: The hectarage treated for the control of the armyworm ranged from 4,704 ha in 1985 to 8,105 ha in 1981 (Table 1). The net benefit ranged from $38.21/ha in 1982 to $84.45/ha in 1985. The total annual net benefit ranged from $204,000 in 1982 to $551,000 in 1984. The total net benefit during 1980 to 1985 was $2.3 million.

Net Benefit From All Insect Control: Since the loss from wireworm control was small, and since the armyworm was the only other insect for which treatments were applied, the total net benefit from insect control in Ontario was approximately equal to net benefit from armyworm control (Table 1 and 4A).

QUEBEC

Wireworms: The total area treated for wireworms was small (30 ha to 50 ha annually) (Table 1). The net loss ranged from -$0.38/ha in 1985 to -$1.04/ha in 1983. The total annual net loss ranged from -$20 in 1980 to -$40 in 1985. The total net loss during 1980 to 1985 was -$170.

Armyworm: The number of hectares treated for the control of the armyworm was small (90 ha to 1228 ha annually) (Table 1). The net benefit ranged from $33.77/ha in 1983 to $58.79/ha in 1985. The total annual net benefit ranged from $3,000 in 1983 to $49,000 in 1981. The total net benefit during 1980 to 1985 was $75,000.

Net Benefit From All Insect Control: Since the loss from wireworm control was small, the total net benefit from insect control in Quebec was the same as the net benefit from armyworm control (Table 1 and 4A).

CANOLA

Insects of Economic Concern and Their Control Costs

Flea Beetles: Five species of flea beetles are significant pests of canola with *Phyllotreta cruciferae* usually the most important species in Canada. In general, populations of flea beetles have been at relatively high levels throughout all of the canola growing regions of Canada, although populations have been the highest in Manitoba, intermediate in Saskatchewan, and lowest in Alberta, B.C., and Ontario. The only control measure used is the application of insecticides primarily as seed dressings or as infurrow granules. Seed dressings provide protection for about one week after emergence of the plant, and infurrow treatments for about 2 weeks. In areas where infestations are high, a combination of both infurrow granules and seed dressings are recommended. Foliar applications are only used under very dry conditions when the infurrow granules and seed dressings fail.

In Manitoba, insecticide plus application costs for flea beetles ranged from $10.38/ha to $14.06/ha. For Saskatchewan, insecticide plus application costs ranged from $7.53/ha to $9.11/ha. In Alberta and British Columbia, these costs ranged from $4.35/ha to $8.80/ha. Insecticide plus application costs were greatest in Manitoba, intermediate in Saskatchewan, and lowest in Alberta and British Columbia. This is due to the more extensive use of the more costly infurrow granular insecticides and foliar treatments in Manitoba, and to a lesser extent in Saskatchewan, than in Alberta and British Columbia. This is a result of the greater potential for losses in Manitoba and Saskatchewan than in Alberta and British Columbia.

Bertha Armyworm: The bertha armyworm (*Mamestra configurata*) has historically been a significant pest of canola in western Canada. However, during the study period the bertha armyworm caused sporadic damage with highest populations in 1980 in Saskatchwan. Foliar applied insecticides have been relied on to reduce populations of the bertha armyworm. The average insecticide plus application costs for this insect were $15.71/ha.

Diamondback Moth: The diamondback moth is found throughout the canola growing regions of Canada usually at relatively low levels. However, in 1985 a major outbreak of this pest occurred in Saskatchewan and to a lesser extent Alberta. Foliar applied insecticides were relied on to reduce populations of the diamondback moth. The insecticide plus application costs for the control of this insect were $25.33/ha.

Clover Cutworm: The clover cutworm is a relatively rare pest of canola. The only hectarage treated was in Alberta in 1982 and 1983. Foliar applied insecticides were relied on to reduce populations of the clover cutworm. Insecticide plus application costs for the control of this insect were $15.71/ha.

Number of Treated Hectares and Net Benefits

BRITISH COLUMBIA

Flea Beetles: The number of hectares treated for the control of flea beetles ranged from 22,440 ha in 1981 to 74,800 ha in 1984 (Table 2). The net benefit ranged from $22.79/ha in 1985 to $30.39/ha in 1980. The total net benefit ranged from $566,000 in 1981 to $1.9 million in 1983. The total net benefit from 1980 to 1985 was $8.5 million. As flea beetles were the only significant pest attacking canola in British Columbia, total benefits from insect control equal benefits from flea beetle control (Table 5A).

ALBERTA

Flea Beetles: The number of hectares treated to control flea beetles ranged from 553,548 ha in 1981 to 1,035,496 ha in 1984 (Table 2). The net benefit ranged from $14.89/ha in 1984 to $62.32/ha in 1984. The majority of net benefits were between $35/ha and $50/ha. The total annual net benefit ranged from $22.4 million in 1981 to $40.4 million in 1984. The total net benefit during 1980 to 1985 was $196.2 million.

Bertha Armyworm: Controls for the bertha armyworm were used on 6,232 ha in 1980, 2,934 ha in 1981, and 2,024 ha in 1983. The net benefit was $61.57/ha in 1980, $63.66/ha in 1981, and $50.20/ha in 1983. The total annual net benefit was $384,000 in 1980, $187,000 in 1981, and $102,000 in 1983. The total net benefit during 1980 to 1985 was $672,000.

Clover Cutworm: Controls for clover cutworm were applied on 10,000 ha in 1982 and 1,000 ha in 1983. The net benefit was $44.56/ha in 1982 and $56.20/ha in 1983. The total annual net benefit was $446,000 in 1982 and $56,000 in 1983. The total net benefit during 1980 to 1985 was $502,000.

Diamondback Moth: Controls for the diamondback moth were applied on 10,000 ha in 1985. The net benefit was $78.92/ha with a total net benefit of $789,000.

Net Benefit From All Insect Control: The total annual net benefit from controlling insects on canola in Alberta ranged from $22.6 million in 1981 to $40.4 million in 1984. The total net benefit during 1980 to 1985 was $198.1 million (Table 5A).

SASKATCHEWAN

Flea Beetles: The number of hectares treated annually to control flea beetles ranged from 459,089 ha to 1,050,315 ha (Table 2). The net benefit ranged from $27.27/ha in 1984 to $119.09/ha in 1985. The majority of net benefits were between $60/ha and $100/ha. The total annual net benefit ranged from $36.4 million in 1981 to $76.4 million in 1985. The total net benefit during 1980 to 1985 was $317.0 million.

Bertha Armyworm: With the exception of 1980 when 40,470 ha were treated to control the bertha armyworm, the number of treated hectares has been less than 4,000 annually (Table 2). The net benefit ranged from $37.92/ha to $52.42/ha. The total annual net benefit ranged from $57,000 in 1981 to $1.8 million in 1980. The total net benefit during 1980 to 1985 was $2.2 million.

Diamondback Moth: In 1983, 1,700 ha were treated for control of the diamondback moth while in 1985 457,860 ha received treatment (Table 2). The net benefit was $13.88/ha in 1983 and $85.99/ha in 1985. The total net benefit was $24,000 in 1983 and $39.4 million in 1985. The total net benefit during 1980 to 1985 was $39.4 million.

Net Benefit From All Insect Control: The total annual net benefit from controlling all insects on canola in Saskatchewan ranged from $36.5 million in 1981 to $116.0 million in 1985. The total net benefit during 1980 to 1985 was $358.6 million (Table 5A).

MANITOBA

Flea Beetles: The number of hectares treated annually to control flea beetles in Manitoba ranged from 218,036 ha in 1981 to 437,392 ha in 1984 (Table 2). The net benefit ranged from $36.74/ha in 1983 to $195.73/ha in 1985. The total annual net benefit ranged from $19.6 million in 1980 to $46.1 million in 1985. The total net benefit during 1980 to 1985 was $176.2 million.

Bertha Armyworm: Controls for bertha armyworm were applied in 1980 when 3,237 ha were treated and in 1981 when 6,556 ha received treatment. The net benefit was $27.00/ha in 1980 and $42.57/ha in 1981. The total annual net benefit was $87,000 in 1980 and $279,000 in 1981. The total net benefit during 1980 to 1985 was $366,000.

Net Benefit From All Insect Control: With the exception of 1980 and 1981, the total net benefit was equal to the total net benefit for flea beetle control. In 1980 and 1981, the total net benefit increased by a small amount due to bertha armyworm control. The total annual net benefit from controlling all insects ranged from $19.7 million in 1980 to $46.1 million in 1985. The total net benefit during 1980 to 1985 was $176.6 million (Table 5A).

ONTARIO

Flea Beetles: The number of hectares treated for the control of flea beetles increased from 5,865 ha in 1983 to 15,150 ha in 1985 (Table 2). The net benefit ranged from $65.22/ha in 1985 to $109.13/ha in 1983. The total annual net benefit ranged from $590,000 in 1984 to $1.1 million in 1985. The total net benefit during 1980 to 1985 was $2.3 million. As flea beetles were the only significant insect pest attacking canola, the total net benefit equals the total net benefit from flea beetle control (Table 5A).

CORN

Insects of Economic Concern and Their Control Costs

Rootworms: The western and northern corn rootworms (*Diabrotica barberi* and *Diabrotica virgifera virgifera*) are the primary insects attacking corn in Ontario and Quebec. Northern corn rootworms are found throughout Ontario and Quebec, while the western corn rootworm is found in significant populations west of Toronto. In general, populations of these two species are highest in south-western Ontario and decline through eastern Ontario and into Quebec.

Control methods that may be used for rootworms include crop rotation and the use of insecticides. As adult rootworms in Canada only oviposit in corn fields and early instar larvae are not dispersive, crop rotation is an effective control measure. However, atrazine is widely used as a relatively inexpensive means of weed control. Because atrazine residues carry over in the soil to the following year, they restrict the crops that can be grown and cause many growers to "continually crop" corn. Presently, all crops that could be used in rotation are susceptible to these atrazine residues. When growers do choose to rotate their corn fields, this production practice is rarely chosen solely for its ability to eliminate losses due to rootworms. Crop rotation has beneficial effects in regards to soil structure, fertility, and erosion control as well as the control of weeds and pathogens. Thus, the choice by growers to use crop rotation is a complex agronomic decision, only partially based on control of rootworms. There is no reliable estimate of the number of growers who do rotate their corn fields for insect control, or the weight given to this factor in making the decision to use crop rotation. In addition, yield increases due to control of rootworms resulting from crop rotation cannot be estimated. The absence of these estimates made economic returns to the use of crop rotation for rootworm control impossible to calculate.

The only other means of control used is the application of granular insecticides into the soil at seeding. The insecticide and application costs to control of rootworms in Ontario and Quebec ranged from $38.09/ha to $47.22/ha.

Wireworms and Seed Corn Maggot: Other soil insects that attack grain corn include wireworms and the seed corn maggot (*Hylemya platura*). Of these, wireworms are the most significant problem. Control measures rely on the use of infurrow insecticide applications, or, to a lesser extent, seed dressings and the granular insecticides applied for the control of rootworms. The cost of the insecticide component of the seed dressing used to control wireworms and seed corn maggots was $1.00/ha.

European Corn Borer: The insects that attack corn above the ground are relatively minor in comparison to the effects of soil insects, but can cause significant losses in isolated fields. The European corn borer (*Ostrinia nubilalis*) is found throughout all corn growing regions of Canada.

The control of the European corn borer has relied on the use of resistant varieties and foliar applied insecticides. The use of resistant/tolerant varieties has been successful for preventing significant damage from the European corn borer in most instances. All corn varieties grown in Canada have some degree of resistance to this insect. Without the presence of resistance or the use of an alternative control measure, corn yield would be substantially reduced. This statement is based on the observation that when the European corn borer spread into Ontario during the 1930's, substantial losses occurred due to this insect. At that time, no resistance to European corn borer was present in the varieties grown. As a result of the damage caused by this insect, the European Corn Borer Act was passed in Ontario. This act required corn growers to plow down or burn all stubble on fields to reduce overwintering populations of this insect. The cost of such control measures in terms of labor, energy, and damage to the soil would probably negate the use of these measures today. Rather, insecticides would probably be used as a control measure, resulting in increased production costs.

The resistant corn varieties that have been developed may be resistant to damage as a result of improved stalk quality and/or the presence of antibiosis. As different corn varieties have varying degrees and types of resistance, and differences in yield of these varities is dependent on many factors not simply ability to withstand corn borer attack, the yield benefit specifically associated with this resistance cannot be identified. In addition, the population levels that would be present if resistant varieties had not been developed cannot be estimated. However, the magnitude of the impact of resistant varieties should not be under estimated. Despite the use of resistant varieties, a significant percentage of the corn crop in Manitoba received insecticide treatment during 1983 to 1985. Total insecticide and application costs for the control of the European corn borer were $36.98/ha.

Number of Treated Hectares and Net Benefits

MANITOBA

European Corn Borer: Total number of treated hectares ranged from 0 ha in 1980 to 1982 to 54,750 in 1984. The net benefit ranged from -$1.56/ha in 1985 to $20.77/ha in 1984 (Table 3). The total annual net benefit ranged from -$42,000 in 1985 to $1.1 million in 1984. The total net benefit during 1980 to 1985 was $1.1 million.

Wireworms and Seed Corn Maggot: The number of hectares treated for the control of wireworms and the seed corn maggot ranged from 26,700 ha in 1985 to 54,660 ha in 1981 (Table 3). The net benefit ranged from $0.46/ha in 1983 to $1.33/ha in 1981. The total annual net benefit ranged from $19,000 in 1985 to $73,000 in 1981. The total net benefit during 1980 to 1985 was $196,000.

Cutworms: Less than 500 ha annually received treatment for the control of cutworms (Table 3). The net benefits were consistently negative. The minimum net benefit was -$14.56/ha in 1983 and maximum -$1.13/ha in 1980. From these data it is apparent that in most situations it did not pay to control cutworms. The total net loss for 1980 to 1985 was -$20,000.

Net Benefit From All Insect Control: The total annual net benefit from all insect control on corn in Manitoba ranged from -$25,000 to $1.2 million. The total net benefit during 1980 to 1985 was $1.3 million (Table 6A).

ONTARIO

Rootworms: The number of hectares treated annually to control rootworms was relatively constant (351,527 ha to 387,429 ha) (Table 3). In the regions of Ontario where approximately 80% of corn production occurs, the net benefit ranged from $98.16/ha to $167.81/ha. The net benefit/ha was greatest in south-western Ontario and lowest in eastern Ontario. The total annual net benefit ranged from $40.2 million in 1980 to $49.9 million in 1985. The total net benefit during 1980 to 1985 was $265.7 million.

Wireworms and Seed Corn Maggot: The number of hectares treated to control wireworms and the seed corn maggot ranged from 526,092 ha in 1980 to 586,300 ha in 1985 (Table 3). The

net benefit ranged from $10.38/ha in 1980 to $11.24/ha in 1982. The total annual net benefit ranged from $5.5 million in 1983 to $6.5 million in 1985. The total net benefit during 1980 to 1985 was $36.0 million.

Net Benefit From All Insect Control: The total annual net benefit from all insect control on corn in Ontario ranged from $45.6 million to $56.4 million. The total net benefit during 1980 to 1985 was $301.7 million (Table 6A).

QUEBEC

Rootworms: The number of treated hectares increased from negligible in 1980 to 36,750 ha in 1985 (Table 3). The net benefits from rootworm control, although low, were usually positive. They increased during 1980 to 1985 such that in 1985 the net benefit was $8.56/ha. The total annual net benefit ranged from -$7,000 in 1982 to $315,000 in 1985. The total net benefit during 1980 to 1985 was $515,000.

Wireworms and Seed Corn Maggot: The number of hectares treated for the control of these insects during 1980 to 1985 ranged from 93,000 ha in 1980 to 151,900 ha in 1985 (Table 3). The net benefits ranged from $2.41/ha in 1980 to $2.88/ha in 1985. The total annual net benefit ranged from $224,000 in 1980 to $437,000 in 1985. The total net benefit during 1980 to 1985 was $1.9 million.

Net Benefit From All Insect Control: The total annual net benefit to corn growers in Quebec from insect control ranged from $224,000 in 1980 to $752,000 in 1985. The total net benefit during 1980 to 1985 Was $2.4 million (Table 6A).

TOTAL NET BENEFITS PRIOR TO AND AFTER ACCOUNTING FOR RESEARCH AND EXTENSION COSTS

To evaluate the net benefits derived from insect controls on wheat, canola, and corn for Canada, the total net benefits were summed across each province by crop and year (Tables 4A, 5A, and 6A). To determine the true net benefits to Canada, research and extension costs were subtracted from the total net benefit. Research and development costs incurred by the agrichemical industry were accounted for in the price of insecticides. Interviews with extension and agrichemical dealers indicated that a large proportion of the wheat, corn, and canola growers received extension advice from agrichemical dealers and technical representatives of agrichemical companies. The cost of this private extension support also was accounted for in the cost of insecticides.

Wheat

The results of the Inventory of Canadian Agricultural Research surveys and consultations with research personnel indicated that the total person years devoted to insect control research on wheat in Canada were 4.47 during 1980 and 1981, 2.90 during 1982 and 1983, and 5.58 during 1984 and 1985 (Table 7). The majority of research occurred on the Prairies. The cost of this research was $729,000/year in 1980 and 1981, $473,000/year in 1982 and 1983, and $910,000 in 1984 and 1985.

The total person years devoted to extension in Canada for insect control on wheat was approximately one person year, with a cost of $78,400 to $90,400 annually during 1980 to 1985 (Table 7).

The total net benefit from insect controls after subtracting research and extension costs on wheat (Table 4B) ranged from $7.7 million in 1980 to $166.6 million in 1985. The average total annual net benefit from 1980 to 1985 was $45.7 million or 1.8% of the total farm gate value of wheat in Canada.

Canola

The total number of research person years for insect control decreased from 9.66 person years during 1980 and 1981 to 8.7 during 1984 and 1985 (Table 7). The annual research costs ranged from $1.4 to $1.6 million. The majority of this research effort occurred in Manitoba.

Total extension person years for insect control in canola were 0.53 to 0.65 person years annually at an annual cost of $42,000 to $52,000 (Table 7).

The total net benefit from insect controls after subtracting research and extension costs ranged from $79.5 million in 1981 to $200.8 million in 1985 (Table 5B). The average total annual net benefit from 1980 to 1985 was $122.5 million or 15.3% of the total farm gate value of canola in Canada.

Corn

The total research person years for insect control ranged from 5.17 during 1980 and 1981 to 7.87 during 1984 and 1985 (Table 7). The research cost increased from $843,000 in 1980 to $1.3 million in 1985. Most of this research was in Ontario and Quebec.

The total extension person years ranged from 1.3 to 1.7 person years (Table 7). The annual extension costs ranged from $102,000 to $134,000.

The total net benefit from insect controls after subtracting research and extension costs ranged from $45.0 million in 1980 to $55.8 million in 1985 (Table 6B). The average total annual net benefit from 1980 to 1985 was $49.8 million or 8.3% of the total farm gate value of field corn in Canada.

GENERAL DISCUSSION

MEASUREMENT OF ECONOMIC BENEFITS

The economic benefits of pesticide use are many and varied, and accrue to different groups within society. The basic benefits are as follows:

1. Pesticides prevent crop loss. The use of pesticides may result in lower costs of production per unit of output and an increase in revenue to the farmer due to added marketable yield. In addition, the uncertainty of crop loss (i.e. inter-year variability) from pests may be reduced.
2. Farm input suppliers (i.e. machinery, fertilizer, chemical, seed companies, etc.) may benefit from increased sales, when farmers receive increased yields.
3. Consumers may benefit (both household and processors/retailers) through price decreases of raw food, improved quality of food products, or a combination of the two.
4. Society as a whole (which includes farmers, suppliers, and consumers) may benefit from a wide range of consequences, including increased employment in agriculture and input supply industries, expanded exports of food products, and increased foreign exchange earnings.

All of these "benefits" from pesticide use may contribute to the well-being (economic welfare) of society. In turn, society attempts to place monetary values on these increases in economic welfare and positive impacts in order to compare benefits from pesticides to other innovations or policy-decisions. The majority of economic studies have focused on the benefits at the farm-gate level: Headley, (1968); Fischer (1970); Langham *et al.* (1972); Miranowski (1975); Fox *et al.* (1968); Pimental *et al.* (1977, 1978, 1979); Campbell (1976); Lamb and Turnock (1982); Paul (1940); Gage and Mukerji (1978); and Stemeroff and George (1983). With few exceptions, the studies cited above indicated that the economic benefits of pesticide use (either insecticides, fungicides, herbicides, or all three together) were greater than the costs of the controls. In addition, there was considerable variability in net benefits within and among crops and regions. Therefore, it would be misleading to conclude from one or two studies a "general" benefit derived from pesticides or pest control itself. Rather, analysis of benefits from pesticides should proceed on an individual crop, region, or time period basis, after which comparisons to other crops, regions, and time periods might proceed.

In most instances, growers earned very large benefits from the use of insecticides. In all cases, the net benefits were highly variable among crops, regions, and years. The results of Lamb and Turnock (1982) in regards to the economics of flea beetle control on canola and those derived herein for this crop and these insects were similar. Specifically, Lamb and Turnock (1982) estimated that total net benefit to flea beetle control ranged from $31.5 million to $140.8 million in 1979 depending on the method of analysis used. Based on 1985 dollars, this would range from $49.8 million to $222.4 million. This study estimates that in 1980, total net benefits amounted to $103.3 million (Table 5B).

In instances where benefits were low or negative, the question should be asked why do growers invest in controls for a negligible or negative return. Either the benefits calculated in this study are in error and are lower than the true return, or growers apply the insecticides to reduce the risk of losses. The net benefits calculated herein do not incorporate growers' risk perceptions regarding expected crop loss from soil insects. For example, many growers apply insect controls for wireworms as a form of insurance against the possibility of significant infestations. This "insurance" is a benefit of indeterminate value at a very low cost ($1 to

$3.78/ha). The insurance aspect of wireworm controls does not, in general, cost the participating producers much money.

DISTRIBUTION OF ECONOMIC BENEFITS

Roberts *et al.* (1985) argue that the impact of price changes to growers resulting from pest control must be considered in studies of this nature in order to assess accurately the true benefits of crop protection. However, upon investigation of the markets for wheat, canola, and corn in Canada, it was evident that changes in domestic production of these crops had virtually no effects on prices received by growers. This is because the prices of these crops are largely determined in the international market which is to a great extent influenced by U.S. production. Canada's production of wheat, canola, and corn is a relatively minor component of the total world supply of cereals and oilseed crops. The ultimate consequence of this situation is that crop losses from insects on wheat, canola, and corn in Canada will not result in any significant price increases due to reduced supply unless world supplies of cereals and oilseed crops are equally affected. Alternatively, the net benefits acquired from insect control will not result in price reductions.

Table 1. Total Net Benefit to Wheat Growers from Insect Control, 1980-1985

		1980	1981	1982	1983	1984	1985	1980-85
BRITISH COLUMBIA								
Total Ha Planted (,000)		65	43	61	65	65	69	
WIREWORMS								
Number TRT Ha		10400	6880	9760	10400	10400	11040	
Total Net Benefit	Mean	149	107	140	147	103	87	734
($,000)	Min	109	75	96	106	72	59	518
	Max	191	133	175	187	135	114	953
ALBERTA								
Total Ha Planted (,000)		2429	2711	2752	3115	2934	3015	
GRASSHOPPERS								
Number TRT Ha		0	5422	0	18690	210221	551649	
Total Net Benefit	Mean	0	302	0	949	4782	30302	36336
($,000)	Min	0	210	0	734	2835	23758	27537
	Max	0	365	0	1213	6120	38100	45798
CUTWORMS								
Number TRT Ha		490	0	550	5000	20510	93465	
Total Net Benefit	Mean	29	0	32	291	776	2697	3825
($,000)	Min	21	0	22	206	531	1810	2591
	Max	36	0	39	356	1018	3693	5141
WIREWORMS								
Number TRT Ha		388640	433760	440320	498400	468800	482400	
Total Net Benefit	Mean	5585	6749	6305	7057	4665	3806	34167
($,000)	Min	4081	4724	4337	5069	3528	2590	24059
	Max	7151	8380	7899	8951	6090	4964	43435
SASKATCHEWAN								
Total Ha Planted (,000)		7122	7830	7931	8377	8115	8377	
GRASSHOPPERS								
Number TRT Ha		49854	10179	610687	175917	622183	2098362	
Total Net Benefit	Mean	571	184	25124	3068	17075	115166	161188
($,000)	Min	289	105	17820	1585	11586	91157	122541
	Max	909	252	31860	4196	22471	136252	195939
WHEAT MIDGE								
Number TRT Ha		0	0	0	0	116442	40267	
Total Net Benefit	Mean	0	0	0	0	5168	1838	7006
($,000)	Min	0	0	0	0	3181	1353	4534
	Max	0	0	0	0	6936	2363	9299
CUTWORMS								
Number TRT Ha		0	0	0	0	20200	30300	
Total Net Benefit	Mean	0	0	0	0	764	874	1638
($,000)	Min	0	0	0	0	522	587	1109
	Max	0	0	0	0	1002	1197	2199
WIREWORMS								
Number TRT Ha		640980	704700	713790	753930	730350	753930	
Total Net Benefit	Mean	1801	2939	3683	3114	1614	1742	14892
($,000)	Min	814	1529	2377	1636	665	769	7790
	Max	2807	3996	5125	4418	2702	2857	21906
MANITOBA								
Total Ha Planted (,000)		1336	1578	1619	1862	1801	1942	
GRASSHOPPERS								
Number TRT Ha		0	0	0	6305	21804	97634	
Total Net Benefit	Mean	0	0	0	4	692	10027	10722
($,000)	Min	0	0	0	-20	454	8036	8469
	Max	0	0	0	31	890	12086	13008

Table 1. Total Net Benefit to Wheat Growers from Insect Control, 1980-1985 — *Continued*

WHEAT MIDGE								
Number TRT Ha		0	0	0	0	28767	16938	
Total Net Benefit	Mean	0	0	0	0	714	589	1303
($,000)	Min	0	0	0	0	468	413	881
	Max	0	0	0	0	977	798	1775
WIREWORMS								
Number TRT Ha		66800	78900	80950	93100	90050	97100	
Total Net Benefit	Mean	-59	28	57	-14	23	122	157
($,000)	Min	-109	-44	-28	-98	-55	-8	-341
	Max	-25	109	148	61	116	213	621
ONTARIO								
Total Ha Planted (,000)		202	213	130	240	217	224	
WIREWORMS								
Number TRT Ha		202	213	130	240	217	224	
Total Net Benefit	Mean	-0.19	-0.24	-0.18	-0.27	-0.16	-0.11	-1.15
($,000)	Min	-0.28	-0.33	-0.24	-0.40	-0.30	-0.27	-1.82
	Max	-0.07	-0.11	-0.13	-0.16	-0.06	-0.02	-0.54
ARMYWORM								
Number TRT Ha		5884	8105	5326	6008	8011	4704	
Total Net Benefit	Mean	386	480	204	320	551	397	2339
($,000)	Min	228	301	116	202	375	286	1509
	Max	497	649	306	459	758	535	3205
QUEBEC								
Total Ha Planted (,000)		43	41	32	30	37	50	
WIREWORMS								
Number TRT Ha		43	41	32	30	37	50	
Total Net Benefit	Mean	-0.04	-0.03	-0.03	-0.03	-0.02	-0.02	-0.17
($,000)	Min	-0.06	-0.06	-0.04	-0.04	-0.04	-0.05	-0.30
	Max	-0.01	-0.01	-0.01	-0.01	.00	0.01	-0.04
ARMYWORM								
Number TRT Ha		128	1228	96	90	111	150	
Total Net Benefit	Mean	5	49	4	3	5	9	75
($,000)	Min	3	24	2	2	3	5	38
	Max	7	68	5	5	8	11	104

Table 2. Total Net Benefit to Canola Growers from Insect Control, 1980-1985

		1980	1981	1982	1983	1984	1985	1980-85
BRITISH COLUMBIA								
Total Ha Planted (,000)		57	26	57	81	85	71	
FLEA BEETLES								
Number TRT Ha		49896	22440	49896	71280	74800	62480	
Total Net Benefit	Mean	1516	566	1262	1905	1860	1424	8534
($,000)	Min	1095	429	932	1481	1376	1062	6375
	Max	1877	697	1549	2353	2212	1800	10488
ALBERTA								
Total Ha Planted (,000)		890	587	769	1012	1214	1133	
FLEA BEETLES								
Number TRT Ha		788140	553548	685212	900646	1035496	998788	
Total Net Benefit	Mean	32065	22381	29911	34576	40387	36845	196164
($,000)	Min	23989	16970	22462	26675	31464	28167	149727
	Max	39358	27123	36207	42006	49410	45332	239435
BERTHA ARMYWORM								
Number TRT Ha		6232	2934	0	2024	0	0	
Total Net Benefit	Mean	384	187	0	102	0	0	672
($,000)	Min	289	141	0	75	0	0	505
	Max	483	226	0	126	0	0	836
CLOVER CUTWORM								
Number TRT Ha		0	0	10000	1000	0	0	
Total Net Benefit	Mean	0	0	446	56	0	0	502
($,000)	Min	0	0	313	44	0	0	357
	Max	0	0	558	61	0	0	619
DIAMONDBACK MOTH								
Number TRT Ha		0	0	0	0	0	10000	
Total Net Benefit	Mean	0	0	0	0	0	789	789
($,000)	Min	0	0	0	0	0	564	564
	Max	0	0	0	0	0	920	920
SASKATCHEWAN								
Total Ha Planted (,000)		809	546	607	850	1295	1174	
FLEA BEETLES								
Number TRT Ha		685833	459089	511975	720311	1050315	999192	
Total Net Benefit	Mean	49420	36439	38574	53733	62418	76430	317016
($,000)	Min	38241	28410	29897	42149	48824	60632	248153
	Max	58979	43854	46203	119920	76271	93520	438747
BERTHA ARMYWORM								
Number TRT Ha		40470	1093	0	0	3885	3522	
Total Net Benefit	Mean	1818	57	0	0	147	151	2174
($,000)	Min	1388	43	0	0	109	114	1654
	Max	2179	67	0	0	179	182	2607
DIAMONDBACK MOTH								
Number TRT Ha		0	0	0	1700	0	457860	
Total Net Benefit	Mean	0	0	0	24	0	39371	39395
($,000)	Min	0	0	0	11	0	30384	30395
	Max	0	0	0	36	0	48538	48574
MANITOBA								
Total Ha Planted (,000)		324	243	344	384	486	405	
FLEA BEETLES								
Number TRT Ha		289655	218036	310504	344801	437392	359247	
Total Net Benefit	Mean	19630	21194	28037	25477	35740	46131	176209
($,000)	Min	15041	16432	21477	19266	27739	36409	136364
	Max	23612	25227	33668	30948	43343	54805	211603

Table 2. Total Net Benefit to Canola Growers from Insect Control, 1980-1985 — *Continued*

BERTHA ARMYWORM								
Number TRT Ha		3237	6556	0	0	0	0	
Total Net Benefit	Mean	87	279	0	0	0	0	366
($,000)	Min	57	198	0	0	0	0	255
	Max	111	364	0	0	0	0	475
ONTARIO								
Total Ha Planted (,000)		N.A.	N.A.	N.A.	7	11	20	
FLEA BEETLES								
Number TRT Ha		0	0	0	5865	9040	15150	
Total Net Benefit	Mean	0	0	0	640	590	1087	2317
($,000)	Min	0	0	213	399	848	1460	
	Max	0	0	0	1070	695	1407	3173

Table 3. Total Net Benefit to Corn Growers from Insect Control, 1980-1985

		1980	1981	1982	1983	1984	1985	1980-85
MANITOBA								
Total Ha Planted (,000)		57	91	81	77	73	45	
EUROPEAN CORN BORER								
Number TRT Ha		0	0	0	385	54750	26700	
Total Net Benefit	Mean	0	0	0	5	1137	-42	1100
($,000)	Min	0	0	0	1	417	-236	182
	Max	0	0	0	9	1680	158	1855
WIREWORMS/SEED CORN MAGGOT								
Number TRT Ha		34020	54660	48540	46200	43800	26700	
Total Net Benefit	Mean	25	73	28	21	30	19	196
($,000)	Min	14	49	11	5	12	9	100
	Max	40	112	46	36	45	28	308
CUTWORMS								
Number TRT Ha		284	456	405	385	365	223	
Total Net Benefit	Mean	-0.3	-1.9	-5.1	-5.6	-4.4	-2.5	-20
($,000)	Min	-0.4	-4.8	-6.7	-6.7	-5.9	-3.4	-28
	Max	-0.2	0.1	-3.9	-4.4	-3.2	-1.9	-13
ONTARIO								
Total Ha Planted (,000)		809	879	842	809	890	902	
CORN ROOTWORMS								
Number TRT Ha		357587	379593	361343	351527	384612	387429	
Total Net Benefit	Mean	40187	43869	44219	40396	47095	49915	265681
($,000)	Min	29978	33664	32940	30250	34933	37498	199219
	Max	50314	55981	54684	49667	57841	60986	329473
WIREWORMS/SEED CORN MAGGOT								
Number TRT Ha		526092	571277	547136	526092	578701	586300	
Total Net Benefit	Mean	5461	6038	6150	5513	6400	6484	36047
($,000)	Min	3988	4422	4290	3846	4659	4673	25876
	Max	6755	7564	7550	6702	7940	8138	37854
QUEBEC								
Total Ha Planted (,000)		150	165	179	182	220	245	
CORN ROOTWORMS								
Number TRT Ha		0	4950	8980	9100	22000	36750	
Total Net Benefit	Mean	0	2	-7	25	180	315	515
($,000)	Min	0	-25	-5	-30	30	83	53
	Max	0	23	34	75	314	550	996
WIREWORMS/SEED CORN MAGGOT								
Number TRT Ha		93000	102300	110980	112840	136400	151900	
Total Net Benefit	Mean	224	282	307	287	393	437	1931
($,000)	Min	159	199	202	187	284	307	1338
	Max	312	381	400	369	535	583	2580

Table 4A. Total Net Benefits to Growers Resulting from Insect Control on Wheat in Canada, 1980 to 1985 ($,000)

		1980	*1981*	*1982*	*1983*	*1984*	*1985*	*Total*
B.C.	Mean	149	107	140	147	103	87	733
	Min	109	75	96	106	72	59	517
	Max	191	133	175	187	135	114	935
ALB.	Mean	5614	7051	6337	8297	10223	36806	74328
	Min	4102	4934	4359	6009	6623	28159	54186
	Max	7187	8745	7939	10520	13227	46757	94375
SASK.	Mean	2372	3123	28807	6182	24621	119620	184725
	Min	1103	1634	20197	3221	15954	93866	135975
	Max	3716	4247	36985	8614	33112	142669	229343
MAN.	Mean	-59	28	57	-10	1429	10738	12183
	Min	-109	-44	-28	-118	867	8441	9009
	Max	-25	109	148	92	1983	13097	15404
ONT.	Mean	386	480	203	319	551	397	2336
	Min	228	300	116	202	375	286	1507
	Max	497	649	306	459	758	535	3204
QUE.	Mean	5	49	4	3	5	9	75
	Min	2	24	2	2	3	5	38
	Max	7	68	5	5	5	11	101
Total	Mean	8467	10838	35548	14938	36932	167657	274380
	Max	5435	6923	24742	9422	23894	130816	201232
	Min	11573	13941	45558	19877	49220	203183	343362

Table 4B. Total Net Benefits Resulting from Insect Control in Wheat After Accounting for Research and Extension Costs ($,000)

	1980	*1981*	*1982*	*1983*	*1984*	*1985*	*Total*
Mean	7652	10023	34993	14387	35932	166645	269632
Min	4620	6108	24187	8871	22894	129804	196484
Max	10758	13136	45003	19326	48220	202171	338614

Table 5A. Total Net Benefits to Growers Resulting from Insect Control on Canola in Canada, 1980 to 1985 ($,000)

		1980	*1981*	*1982*	*1983*	*1984*	*1985*	*Total*
B.C.	Mean	1516	566	1262	1905	1860	1424	8533
	Min	1095	429	932	1481	1376	1062	6375
	Max	1877	697	1549	2353	2212	1800	10488
ALB.	Mean	32449	22568	30357	34734	40387	37634	198129
	Min	24279	17111	22776	26794	31464	28167	150591
	Max	39842	27348	36764	42193	49410	45332	240889
SASK.	Mean	51238	36497	38574	53757	62566	115953	358585
	Min	39629	28453	29897	42160	48933	91129	280201
	Max	61158	43921	46203	119957	76449	142241	489929
MAN.	Mean	19717	21473	28037	25477	35740	46131	176575
	Min	15098	16630	21477	19266	27739	36409	136619
	Max	23723	25591	33668	30948	43343	54805	212078
ONT.	Mean	0	0	0	640	590	1087	2317
	Min	0	0	0	213	399	848	1460
	Max	0	0	0	1070	695	1407	3172
Total	Mean	104920	81104	98230	116513	141143	20229	744139
	Max	80101	62623	75082	89914	109911	157615	575246
	Min	126600	97557	118184	196521	172109	245585	956556

Table 5B. Total Net Benefits Resulting from Insect Control in Canola After Accounting for Research and Extension Cost ($,000)

	1980	*1981*	*1982*	*1983*	*1984*	*1985*	*Total*
Mean	103297	79481	96725	115008	139683	200759	734953
Min	78478	61000	73577	88409	108451	156145	566060
Max	124977	95934	116679	195016	170649	244115	947370

Table 6A. Total Net Benefits to Growers Resulting from Insect Control on Corn in Canada, 1980 to 1985 ($,000)

		1980	*1981*	*1982*	*1983*	*1984*	*1985*	*Total*
MAN.	Mean	25	71	23	21	1163	-25	1278
	Min	13	44	4	-1	423	-230	253
	Max	40	112	42	41	1730	185	2150
ONT.	Mean	45648	49908	50369	45909	53495	56399	301728
	Min	33966	38086	37230	34051	39592	42171	225096
	Max	57069	63545	55439	56370	65780	69124	367327
QUE.	Mean	224	284	301	311	573	752	2445
	Min	159	174	197	158	313	390	1391
	Max	312	403	434	444	849	1133	3575
Total	Mean	45897	50263	50693	46241	55231	57126	305451
	Max	34138	38304	37431	34208	40328	42331	226740
	Min	57421	64060	55915	56855	68359	70442	373052

Table 6B. Total Net Benefits Resulting from Insect Control in Corn After Accounting for Research and Extension Costs ($,000)

	1980	*1981*	*1982*	*1983*	*1984*	*1985*	*Total*
Mean	44952	49318	49676	45218	53836	55709	298709
Min.	33193	37359	36414	33185	38933	40914	219998
Max.	56476	63115	54898	55832	66964	69025	366310

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