States. Australian nurseries had higher labor costs (38.3% of sales) but lower direct material costs than in the United States. The lower material costs could have been due to Australian nurseries tending to propagate in-house plant material, whereas U.S. nurseries tend to outsource propagation material. The U.S. nurseries had a higher investment in capital. One of the reasons is the greater tendency by U.S. producers toward greenhouse production. The U.S. and Australian nurseries showed similar variability in employee and space productivity.

Future analysis of individual Australian nurseries and overall industry performance for Australian nurseries would benefit from consistent recording of nursery data. The industry would benefit from having standard expense classifications and a stated definition of nursery growing area.

Managers should consider reducing the number of different products, but still provide enough diversification to reduce risk while allowing for more automation to reduce costs.

The largest expense category for Australian nurseries was the cost of labor. Although the main concerns relating to labor were about recruitment and training, given the high cost of labor, the industry needs to continually address the issues of automation and other practical ideas for reducing labor input. The Australian Horticultural Research and Development Corporation report (Rakajewski and Gaydon, 1995) addresses this topic.

Literature cited

Australian Bureau of Statistics. 1995. Nursery cut flower and cultivated turf statistics, Australia 1993-4, ACT.

Brumfield, R.G. and P.F. McSweeney. 1996. Business profiles for Australian nurseries. Burnley College, Faculty of Agr., For. and Hort., Univ. of Melbourne.

Brumfield, R.G., L.E. Sim, P. Ford, C. Frumento, and D.J. Wolnick. 1993. The Pennsylvania greenhouse survey. Pennsylvania State Univ., College of Agr. Sci., Coop. Ext. Circ. 405.

Ferguson, B., F. Johnson, and W.Y.T. Tham. 1987. The Victorian cut flower industry: Issues and opportunities. Dept. of Agr. and Rural Affairs, Victoria.

Industry Commission. 1993. Horticulture. AGPS, Canberra.

Karingal Consultants. 1994. The Australian wildflower industry. Rural Ind. Res. and Dev. Corp., ACT.

Kloosterboer, W., E. Maddock, W. Green, and S. Craig. 1992. The New South Wales cut flower industry. New South Wales Agr., New South Wales.

Professional Plant Growers Association. 1994. 1994 Greenhouse operating performance report.

Rakajewski, V. and D. Gaydon. 1995. Practical ideas for increasing nursery efficiency. Hort. Res. and Dev. Corp. Proj. NY403, Dept. of Primary Industries, Queensland.

Sutton, J. 1978. A survey of the nursery industry in Victoria. Dept. of Agr., Victoria.

Victorian Agriculture and Horticulture Industries Training Board. 1983. Survey of the workforce in the recreational and environmental horticulture industry.

Crop Rotation Reduces the Cost of Colorado Potato Beetle Control in Potatoes

John Speese, III[1], and S.B. Sterrett[2]

Additional index words. integrated pest management, IPM, economics, *Leptinotarsa decemlineata*, *Solanum tuberosum*

Summary. The effect of crop rotation was investigated on the efficacy and the economics of various insecticide strategies for Colorado potato beetle (CPB) control in potatoes (*Solanum tuberosum* L.) in 1995–96. These included broad-spectrum insecticides and biorational (environmentally friendly, naturally occurring) combinations that targeted specific CPB life stages. CPB pressure was greater in the nonrotated than the rotated plots. Although all materials gave better CPB control than the check, significantly more spray applications were required to reduce CPB numbers below treatment thresholds in the nonrotated plots than the rotated plots in both years. Overall yields and economic returns were significantly greater in the rotated plots in 1995. Efficacy of insecticide strategies varied, with little defoliation and few CPB larvae found in the imidacloprid treatment in 1995 and 1996. All insecticide strategies except endosulfan resulted in significantly higher estimated returns to management than the untreated check;

Virginia Polytechnic and State University, Eastern Shore AREC, 33446 Research Drive, Painter, VA 23420.

[1]Senior research specialist.

[2]Associate professor.

We gratefully acknowledge the contribution of chemicals for this study by FMC (permethrin and endosulfan), Gowan Company (phosmet), Bayer Corp. (imidacloprid), Abbott Laboratories (Btt), and Elf Atochem North America, Inc. (cryolite). Assistance in the field plots by Helene Doughty, Christopher Willams, J. Thomas Custis, and the field staff is also greatly appreciated. This project was funded, in part, by the Virginia Irish Potato Board. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

the greatest returns occurred with permethrin and cryolite. No yields or returns could be obtained in 1996 due to excessive rainfall before harvest. These results indicate that yield and the cost of the insecticide strategy should be considered as well as insecticide efficacy in developing an effective integrated pest management program.

The Colorado potato beetle (CPB) [*Leptinotarsa decemlineata* (Say)] (Coleoptera: Chrysomelidae) has become an increasingly difficult pest to control in commercial potato fields in Virginia. Due to the enormous reproductive potential of this insect, resistance to various classes of commercial insecticides has been documented to varying degrees in most potato producing regions in the United States (Boiteau and Ferro, 1993; Clark, 1986), including the Eastern Shore of Virginia (Hofmaster and Waterfield, 1965; Tisler and Zehnder, 1990). The use of multiple foliar insecticide applications of the same material or materials with similar modes of action to control CPB is costly and enhances resistance development. Crop rotation to a nonsolanaceous crop has long been recognized as a valuable cultural practice in managing CPB. Weisz et al. (1994) reported 50% reductions in insecticide requirements in rotated fields compared to a nonrotated field. Insecticide resistance and CPB populations are increased further when crop rotation is limited by availability of land suitable for potato production or by lack of access to irrigation. Weisz et al. (1994) demonstrated the efficacy of distances as short as 0.3 km between rotated and nonrotated fields in reducing CPB pressure.

The CPB overwinters in the soil as an adult beetle. These adults (known as the overwintering generation) emerge in the spring (as early as mid-April in eastern Virginia) and seek out solanaceous plants. Potatoes and eggplant are the preferred hosts. The CPB is prolific; an adult female will lay multiple egg masses over several weeks, each containing ≈30 eggs (Boiteau and LeBlanc, 1992). The larvae complete four instars in their development; the third and fourth instars consume the most foliage. The rate of development varies with different temperatures and the quality of the food source. Mature CPB larvae enter the ground to pupate, and the new (first generation) adults emerge 1 to 2 weeks later (Boiteau and LeBlanc, 1992), which is in late June in eastern Virginia. In northern potato production regions with full-season potato production and fall harvest, two complete generations develop on potatoes. In Virginia and other southern potato regions, the growing season for potatoes is shorter and warm temperatures after harvest result in the development of only one CPB generation on potatoes, although second generations may develop on other, less-preferred solanaceous hosts. Regardless of the number of generations produced, the CPB adults enter the soil when there is no longer sufficient food available and diapause until the following spring. In southern regions the CPB adults overwinter in the potato fields; in northern regions, where the soil freezes more deeply, the CPB adults migrate to protected overwintering sites such as nearby hedgerows or woods.

Zehnder and Speese (1987) demonstrated that CPB flight activity ceases below 22 °C. Since potatoes can grow at lower temperatures than those optimum for CPB activity, rotation away from the previous season's overwintering CPB populations allows the potatoes to make substantial early growth before they are colonized by either walking or flying CPB adults. Potatoes planted in nonrotated land, however, are colonized by emerging, overwintering adult beetles as soon as they sprout. At temperatures too cool for CPB flight, the beetles colonize the plants by walking. Even limited feeding on newly sprouted potato shoots results in severe defoliation. Zehnder and Evanylo (1989) demonstrated that severe early season defoliation significantly lowers the yields of 'Superior', an early maturing potato cultivar widely grown in Virginia. Foliar sprays are not effective early in the growing season due in part to the continuing emergence of adults daily and the lack of foliage surface area to spray. Growers can spend large sums of money in mostly futile attempts to protect their crop under such conditions.

The objectives of this study were to evaluate and compare the efficacy of various insecticide strategies to control CPB under eastern Virginia conditions and to examine the impact of crop rotation as part of the integrated pest management strategy for CPB. Economic analyses of insect management strategies were completed to determine the estimated return to management by incorporating crop yield, number of sprays required to reduce CPB populations below economic thresholds, and insecticide costs into the production budget for eastern Virginia (Sterrett et al., 1996).

Materials and methods

Plots of 'Superior' potatoes were established on 17 Mar. 1995 and 6 Apr. 1996 on a Bojac sandy loam soil. Three row plots 7.6 m in length were used in 1995 and four row plots 6.1 m in length were used in 1996. Plots were contiguous in 1995 but separated by two unplanted rows in 1996 to facilitate foliar application of insecticides. A split-plot statistical design was used with rotation as the main plot and insecticide applications as the subplot treatments, including four replications. Standard cultural practices were used. In each year, potatoes preceded potatoes in the nonrotated plots for 1 year. Rotational crops before potatoes in the rotated treatments included cotton or fallow in 1995 (two replications in each) and wheat or wheat–soybean double crop in 1994 (two replications in each). None of these rotational crops serves as a host for CPB. Separation between rotated and nonrotated plots varied by replication but exceeded 150 m in all instances. Selected insecticides reflect the classes of chemistry currently used commercially (Tables 1–3). These include pyrethroid + synergist, organophosphate + synergist, organochloride (1995 only), chloronicotinyl, biological [*Bacillus thuringiensis tenebrionis*, (Btt)], and mineral (cryolite). Imidacloprid was applied in furrow at planting; all other materials were applied as foliar sprays. Foliar sprays were applied using a propane compressed-gas backpack sprayer at 40 lb/inch^2 using 8003 'T Jet' flat fan nozzles.

Decisions about foliar insecticide applications were based on recommended economic thresholds. The thresholds were reached with either 20% to 25% or greater defoliation before bloom (Zehnder and Evanylo, 1989), or 40 small (first and second instar) CPB larvae, 15 large (third and fourth instar) CPB larvae, or 5 CPB adults/10 main potato stems (Alexander et al., 1997). In the plots treated with biorational materials (Btt and cryolite) that are only effective on larvae, permethrin + piperonyl butoxide was used early season to maintain the adults below threshold. Treatments to control emerging overwintering adults began on 26 Apr. in nonrotated plots and 4 May in rotated plots in 1995; treatments began on 14 May in all plots in 1996. The 30% egg

Table 1. Insecticide treatment strategies and mean small larvae (SL), large larvae (LL), and adult (A) CPB per 10 random main stems per plot in 1995 averaged over rotated and nonrotated treatments.[z]

Class of chemistry/ common name	Rate (a.i.) (lb/acre)	Date (no. of days after planting) 16 May (60) SL	A[y]	30 May (74) SL	LL	A	5 June (79) SL	LL	A
Pyrethroid + sunergist									
Permethrin + PBO[x]	0.20 + 1.00	9.13 a[w]	11.00 a	67.75 a–c	10.00 bc	2.63 b	24.50 a–c	21.62 b–d	0.38 b
Organophospate + synergist									
Phosmet + PBO	1.00 + 0.50	11.12 a	9.25 a	88.13 a	34.75 ab	1.75 b	33.25 a–c	54.75 bc	2.13 ab
Organochloride									
Endosulfan	1.00	7.13 a	14.25 a	84.75 ab	37.37 ab	4.50 ab	61.12 a	59.50 b	0.75 b
Chloronicotinyl									
Imidacloprid	0.20	2.75 a	21.75 a	4.25 d	0.38 c	7.87 a	3.00 c	1.00 d	4.38 a
Biological									
Btt[v]	48.9–65.2[u]	9.50 a	8.00 a	38.62 cd	3.37 c	4.87 ab	24.38 a–c	13.62 d	2.12 ab
Mineral									
Cryolite	9.60	12.63 a	7.37 a	40.25 b–d	5.00 c	3.13 ab	10.63 c	2.37 d	1.50 ab
Untreated check		10.75 a	8.50 a	79.87 a–c	44.12 a	3.00 ab	49.63 ab	110.00 a	2.13 ab

[z]No significant rotation × insecticide treatment strategy at $P = 0.05$.
[y]Leptinotarsa units/ha.
[x]Piperonyl butoxide.
[w]Means in a column with a letter in common are not significantly different ($P \leq 0.05$, Ryan's Q test).
[v]*Bacillus thuringiensis tenebrionis.*
[u]Large larvae not present on this date.

hatch threshold for application of biorational materials established by Zehnder et al. (1992) was used for timing the first applications of the biorational materials (Tables 1 and 2). Biorational materials are most effective against neonate (newly hatched) CPB larvae. Dimethoate [active ingredient (a.i.)] at 0.25 lb/acre (0.03 $kg \cdot ha^{-1}$) or methamidophos (a.i.) at 1.00 lb/acre (1.12 $kg \cdot ha^{-1}$) was used when needed in the biorational and imidacloprid plots to control potato leafhopper (PLH) [*Empoasca fabae* (Harris), Homoptera: Cicadellidae] and European corn borer (ECB) [*Ostrinia nubilalis* (Huebner), Lepidoptera: Pyralidae]. A threshold of 1 PLH nymph/10 compound leaves and the occurrence of peak ECB moth flights (determined by catches in the black light trap operated at Painter) were used to time sprays for PLH and ECB, respectively. Imidacloprid does not control ECB; Btt and cryolite control neither ECB nor PLH. These materials were selected for their control of secondary pests without masking the treatment effect on the CPB. Weekly counts of CPB small larvae, large larvae, and adults were taken on 10 randomly selected main potato stems from the center row(s) of each plot to determine efficacy and treatment thresholds. Treatment thresholds were determined and spray decisions were made separately for each plot. The total cost of each CPB man-

Table 2. Insecticide treatment strategies and mean small larvae (SL), large larvae (LL), and adult (A) CPB per 10 random main stems per plot in 1996 averaged over rotated and nonrotated treatments.[z]

Class of chemistry/ common name	Rate (a.i.) ($kg \cdot ha^{-1}$)	Date (no. of days after planting) 28 May (52) SL	LL	4 June (59) SL	LL	A	11 June (66) SL	LL	A	18 June (73) SL	LL	A
Pyrethroid + sunergist												
Permethrin + PBO[y]	0.20 + 1.00	59.88 b[x]	1.63 b	38.63 bc	9.88 bc	0.38 b	4.50 a	23.75 a	0.13 a	5.25 a	10.38 b	1.50 b
Organophospate + synergist												
Phosmet + PBO	1.00 + 0.50	52.13 b	5.50 ab	41.00 b	21.88 b	0.38 b	1.75 a	24.38 b	0.00 a	3.50 a	5.88 bc	1.88 b
Chloronicotinyl												
Imidacloprid	0.20	0.13 c	0.00 b	0.25 c	0.00 c	3.13 a	0.00 a	0.00 b	0.13 a	0.00 a	0.38 c	0.13 b
Biological												
Btt[w]	48.9–65.2[v]	40.63 c	0.00 b	13.38 bc	0.75 c	0.75 b	7.63 a	16.13 b	0.38 a	6.25 a	20.63 a	0.00 b
Mineral												
Cryolite	9.60	36.88 c	0.13 b	9.75 bc	0.13 c	0.75 b	8.88 a	8.13 b	0.00 a	4.88 a	7.50 bc	0.25 b
Untreated check		95.88 a	10.25 a	108.63 a	62.50 a	0.50 b	3.13 a	59.00 a	0.25 a	1.25 a	11.38 b	11.88 a

[z]No significant rotation × insecticide treatment strategy at $P = 0.05$, except for SL at 52 d after planting and LL at 59 d after planting.
[y]Piperonyl butoxide.
[x]Means in a column with a letter in common are not significantly different ($P \leq 0.05$, Ryan's Q test).
[w]*Bacillus thuringiensis tenebrionis.*
[v]Million leptinotarsa units/ha.

Table 3. Yield of potato and estimated return to management as influenced by rotation or cost associated with insecticide treatment strategies in 1995.

	Rate (a.i.) ($kg\cdot ha^{-1}$)	Yield ($t\cdot ha^{-1}$)	Return $/ha
Factor			
Nonrotated		15.34 b[z]	552.50 b
Rotated		22.52 a	2,342.50 a
Significance		**	**
Class of chemistry/common name			
Pyrethroid + synergist			
Permethrin + PBO[y]	0.20 + 1.00	24.30 a	2,537.50 a
Organophospate + synergist			
Phosmet + PBO	1.00 + 0.50	19.34 ab	1,605.00 ab
Organochloride			
Endosulfan	1.00	15.29 bc	325.00 bc
Chloronicotinyl			
Imidacloprid	0.20	20.27 ab	1,870.00 ab
Biological			
Btt	48.9–65.2[x]	22.10 ab	2,007.50 ab
Mineral			
Cryolite	9.60	23.12 ab	2,312.50 a
Untreated check		8.54 c	–532.50 c
Significance		**	**

[z]Means within a column with a letter in common are not significantly different at $P \leq 0.05$ using Ryan's Q test.
[y]Piperoyl butoxide.
[x]Leptinotarsa units/ha.
[w]*Bacillus thuringiensis tenebrionis.*
**Significant at $P = 0.01$. Rotation × insecticide treatment strategy was not significant at $P = 0.05$.

agement strategy reflected the prices of all chemicals used in the strategy, the rates of application, and the number of applications needed to reduce the CPB below threshold and those needed to control secondary pests (ECB and PLH). Insecticide prices reflect the average of those quoted by three local distributors. On 6 July 1995 and 26 July 1996, the record rows of each plot were harvested and graded using commercial equipment to determine yields. Yields were adversely affected by excessive rainfall in 1996. The estimated return to management was determined in 1995 using yield estimates for each treatment, the projected fixed (labor, land, etc.) and variable (insecticide program, cost of hauling to market, etc.) costs, and the average 1995 market prices per hundred weight of grade A marketable yield. These calculations accounted for all production costs except those associated with management (salary of manager, taxes, etc.), and risk (weather-related losses or other uncertainties), hence the term estimated return to management. No meaningful return figures could be calculated for 1996 due to crop loss from excessive rainfall before harvest.

Results and discussion

In both years of this study, a significant rotation × treatment interaction was observed in the numbers of emerging, overwintering CPB adults ($P = 0.01$, 1995; $P = 0.02$, 1996) at 52 d after planting (Fig. 1). In 1995, all nonrotated plots had more emerging adults than in rotated plots. The nonrotated check plots were 100% defoliated (stemmed) at 52 d after planting; therefore, the adults tended to migrate to plots that had foliage. The adults that contacted the foliage in the imidacloprid plots soon became moribund, but did little, if any, feeding. It was observed that the adults in the plots with less-effective or slower-acting treatments tended to disperse, explaining the high number of adults in the imidacloprid plots (Fig. 1). In 1996, at 52 d after planting, overall overwintering adult pressure was low (<3 adults/10 plants). Although the emerging, overwintering adult pressure was evident in the nonrotated permethrin, cryolite, and check treatments, differences in number of emerging adults in the other treatments were opposite of what was expected (Fig. 1, bottom).

The 1995 season was more typical for eastern Virginia; a relatively mild winter and a hot, dry summer. The 1996 season was characterized by an unusually cool, wet winter and spring, with heavy rainfall in the summer. In contrast to 1995, when overwintering adults were the only CPB life stage present at 52 d after planting, there were substantial numbers of small and large larvae in the plots in 1996 at 52 d after planting (Table 2). Differences in small larva numbers and relative time of appearance for both years can be attributed, in part, to the weather. Due to the delayed planting date in 1996 as a result of adverse weather conditions, 52 d after planting occurred on 8 May 1995 and on 28 May 1996. From 180 to 200 degree-days (base 50 °F) are required from oviposition to CPB egg hatch, which usually occurs in middle May in this growing region (Zehnder et al., 1992). In 1995, there was one period of concentrated emergence of overwintering adults. Oviposition, egg hatch, and peak populations of small and large larvae occurred in distinct periods and were somewhat synchronized. In 1996, the cool weather resulted in a prolonged emergence period of overwintering adults. Adult counts remained below threshold until 14 May (the first spray date). The prolonged oviposition period resulted in a wide range of ages in the egg masses and subsequent overlapping life stages. High counts of small larvae can also reflect recent hatchlings that have not migrated from the egg masses and, therefore, have not come into contact with the applied insecticides. Heavy defoliation, particularly in the nonrotated plots in 1995, with observed cannibalization of egg masses, may also account for the differences in CPB larvae population dynamics in 1995 compared to 1996.

Feeding pressure resulted in 30% to 100% (average of 60%) defoliation in the 1995 nonrotated plots, even with more frequent spray applications (data not shown). Defoliation in all of the 1995 rotated plots at 52 d after planting was ≤5%. At 52 d after planting in 1996, however, defoliation levels were ≤5% regardless of treatment or rotation. Zehnder and Evanylo (1989) demonstrated that 'Superior' cannot compensate for early season defoliation and will suffer significant yield losses at defoliation levels of ≥25% before bloom, especially under dry conditions. However, 'Superior' can withstand 50% defoliation postbloom without significant yield losses. In most years in this growing region, 'Superior' begins blooming at ≈50 d after planting.

Differences in emerging adult populations in 1995 and 1996 also influenced the relative efficacy of the chemical management strategies. While the interaction between rotation and

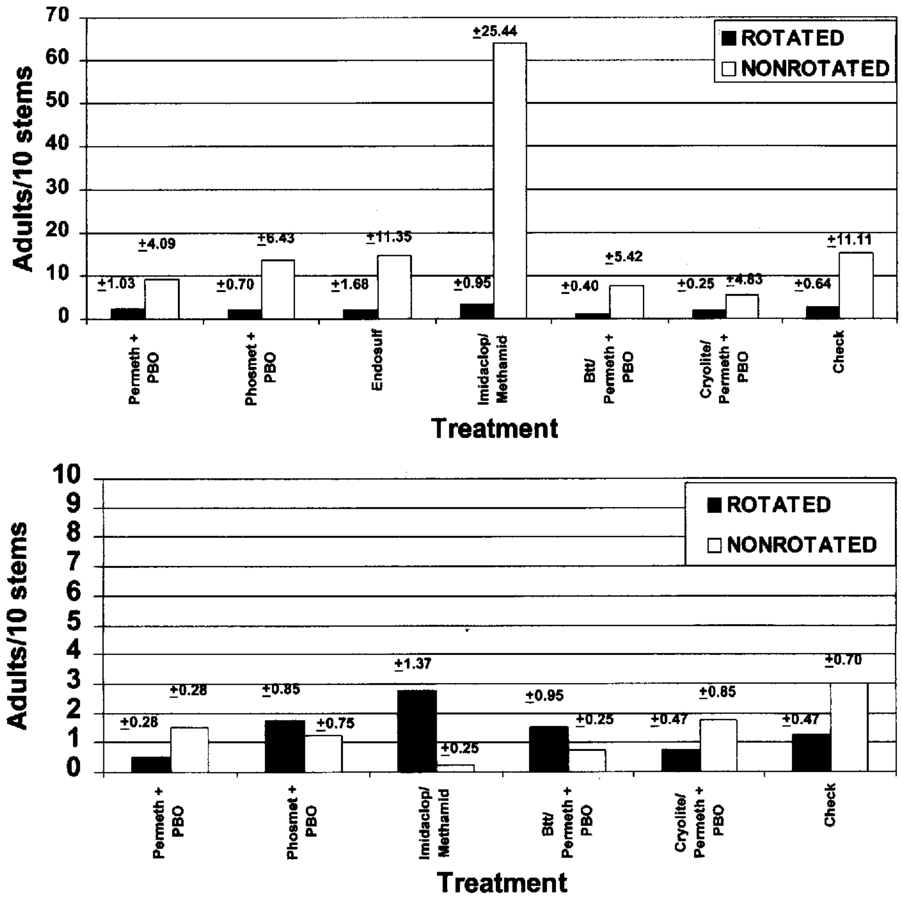

Fig. 1. Mean number of emerging, overwintering CPB adults per 10 stems in 1995 (top) and 1996 (bottom) at 52 d after planting in rotated and nonrotated plots. The mean of four replications and standard error of the mean are shown. Treatment × rotation interaction was significant in both years (P = 0.01, 1995; P = 0.02, 1996).

chemical management strategies was significant for emerging, overwintering adults (Figs. 1 and 2), subsequent CPB life stages were primarily affected by management strategies. There were no significant differences for either small or large larvae in either 1995 or 1996 due to rotation or the interaction of rotation × treatment except for small larvae at 52 d after planting and large larvae at 59 d after planting in 1996. In both years, imidacloprid provided season-long control of CPB larvae (Tables 1 and 2). The number of large larvae was significantly lower in the biorational treatments than in those with organophosphate or organ-ochloride at 74 and 79 d after planting in 1995. However, large larvae counts in the Btt treatment were significantly higher than either the control or the other strategies at 73 d after planting in 1996, reflecting the difficulty in maintaining adequate coverage of foliage during the wet, cold 1996 growing season. First-generation adults appeared at 73 d after planting in 1995 and 79 d after planting in 1996 (Tables 1 and 2, respectively). Because of severe defoliation in the check treatment and less effective organophosphate and organochloride treatments in 1995, adults tended to disperse to plants with more foliage. In 1996, control of first-generation adults at 73 d after planting was similar in all treatments but significantly greater than the check. Since treatments were applied at threshold in all plots, rotation had little significant influence on subsequent counts of CPB larvae and first-generation adults (data not shown).

A significant treatment × rotation interaction was observed (P = 0.01) each year in the mean numbers of applications required and the costs of each

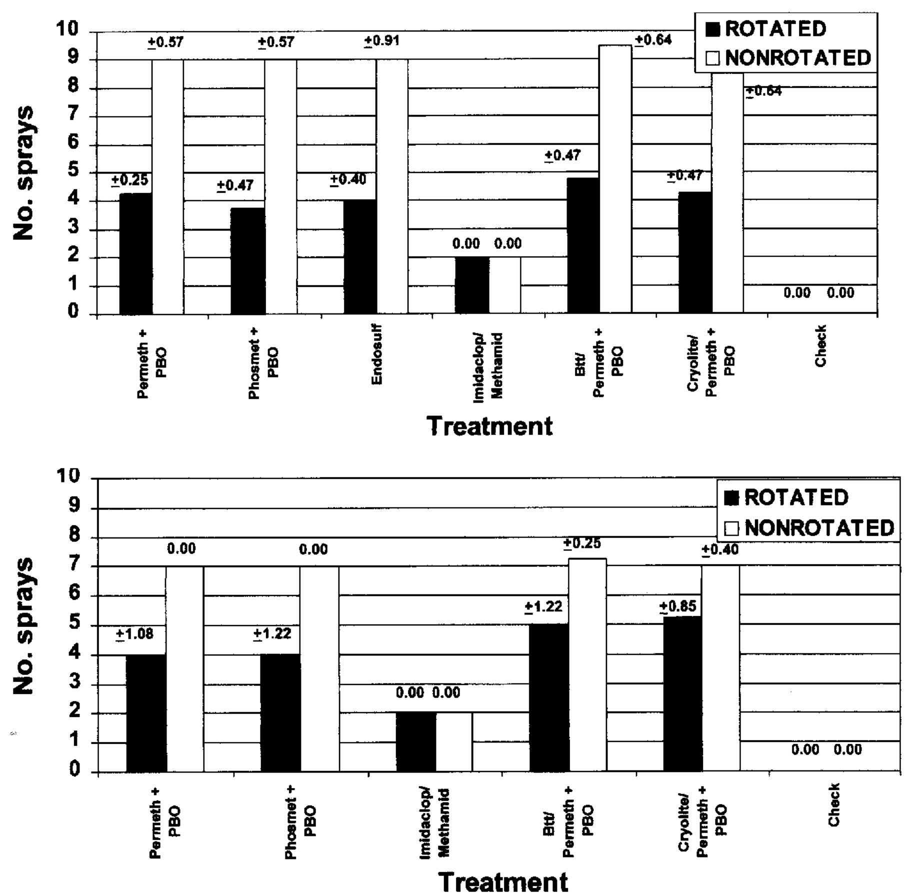

Fig. 2. Mean number of insecticide sprays required in 1995 (top) and 1996 (bottom) to control CPB and secondary insect pests in rotated and nonrotated plots. The mean of four replications and standard error of the mean are shown. Treatment × rotation interaction was significant in both years (P = 0.01).

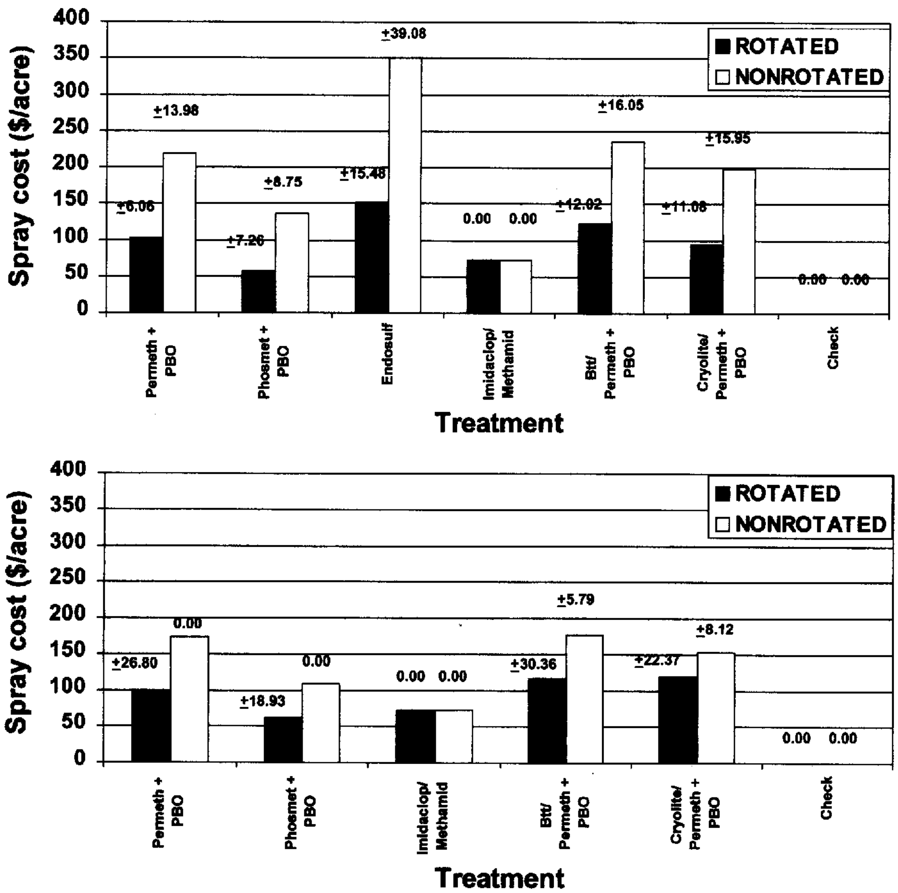

Fig. 3. Cost of the sprays for the 1995 (top) and 1996 (bottom) seasons for insect control in rotated and nonrotated plots. The mean of four replications and standard error of the mean are shown. Treatment × rotation interaction was significant in both years (P = 0.01).

treatment to maintain CPB control (Figs. 2 and 3). The number of spray applications needed for CPB control was greater in the nonrotated plots in both years for all treatments except for the furrow-applied imidacloprid treatment. This treatment provided season-long CPB control regardless of rotation. Our data were consistent with that of Wright (1984) and Weisz et al (1994), in which about twice the number of applications were required in nonrotated compared to rotated potato fields to reduce CPB populations below threshold.

Marketable yield and the economic estimated return to management were significantly greater in the rotated than in the nonrotated plots (Table 3). Lack of a chemical management strategy (untreated check) resulted in significantly lower yield and return than any of the chemical strategies tested except the expensive but ineffective endosulfan. Superior control of CPB was obtained with imidacloprid but yield was not significantly improved over other chemical management strategies, suggesting that growers in this region have several viable options for integrated pest management.

The continuous use every year of the same material would not be in the growers' best interests in terms of resistance management. Zehnder (1986) demonstrated the efficacy of using different classes of chemistry on different life stages for CPB control, and this approach was used in the biorational treatments (pyrethroid for adults; biorational material for larvae). This approach is also in accordance with current resistance management recommendations (Alexander et al., 1997).

The results of this study suggest that growers have several options for effectively managing CPB damage without sacrificing marketable yield or economic returns. Practicing crop rotation as part of the CPB control program significantly increased yield and estimated return to management. Over the long term, any cultural practice, such as rotation, that enables growers to reduce the number of insecticide applications and still maintain acceptable CPB control should be of value in managing resistance development.

Literature cited

Alexander, S.A., H.E. Hohlt, C.R. O'Dell, J. Speese, III, S.B. Sterrett, and H.P. Wilson. 1997. Commercial vegetable production recommendations. Va. Coop. Ext. Serv. Publ. p. 456–420.

Boiteau, G. and D.N. Ferro. 1993. Management of insect pests. In: R.C. Rowe (ed.). Potato health management. APS Press, St. Paul, Minn.

Boiteau, G. and J.R. LeBlanc. 1992. Colorado potato beetle life stages. Agr. Can. Publ. 1878/E.

Clark, J.M. 1986. Insecticide resistance. In: C.S. Hollingsworth, D.N. Ferro, and W.M. Coli (eds.). Potato production in the northeast. A guide to integrated pest management. Mass. Coop. Ext. Serv., Amherst.

Hofmaster, R.N. and R.L. Waterfield. 1965. The Colorado potato beetle in Virginia and the present status of control measures. Trans. Peninsula Hort. Soc. 1965:20–26.

Sterrett, S.B., S.D. Thornsbury, C.W. Coale, D.B. Taylor, S.G. Sturt, and J.W. Mapp. 1996. The process for evaluating agricultural alternatives: An Eastern Shore Virginia example. Va. Coop. Ext. Serv. Publ. 448-220/REAP RO22.

Tisler, A.M. and G.W. Zehnder. 1990. Insecticide resistance in the Colorado potato beetle on the Eastern Shore of Virginia. J. Econ. Entomol. 88:666–671.

Weisz, R., Z. Smilowitz, and B. Christ. 1994. Distance, rotation, and border crops affect Colorado potato beetle (Coleoptera: Chrysomelidae) colonization and population density and early blight (*Alternaria solani*) severity in rotated potato fields. J. Econ. Entomol. 87:723–729.

Wright, R.J. 1984. Evaluation of crop rotation for control of Colorado potato beetles in commercial potato fields on Long Island. J. Econ. Entomol. 77:1254–1259.

Zehnder, G.W. 1986. Timing of insecticides for control of Colorado potato beetle in eastern Virginia based on differential susceptibility of life stages. J. Econ. Entomol. 79:851–856.

Zehnder, G.W. and G.K. Evanylo. 1989. Influence of extent and timing of Colorado potato beetle defoliation on potato tuber production in eastern Virginia. J. Econ. Entomol. 82:948–953.

Zehnder, G.W., G.M. Ghidiu, and J. Speese, III. 1992. Use of the occurrence of peak Colorado potato beetle egg hatch for timing of *Bacillus thuringiensis* spray applications in potatoes. J. Econ. Entomol. 85:281–288.

Zehnder, G.W. and J. Speese III. 1987. Assessment of color response and flight activity of *Leptinotarsa decemlineata* using window flight traps. Environ. Entomol. 16:1199–1202.