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A REVIEW OF CABBAGE PEST MANAGEMENT IN NEW YORK: FROM THE PILOT PROJECTTO THE PRIVATE SECTOR, 1978—1982

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Field scout inspecting a cabbage field. IPM relies on accurate and efficient monitoring of pest populations.

Although a number of major pests attack cabbage in New York, insects are the most important. Two lepidopteran larval pests that begin to attack cabbage early in the season are the diamondback moth and the imported cabbageworm. The cabbage looper, a lepidopteran migrant from the south, arrives late in the season and usually becomes an additional threat. Cabbage maggot, flea beetle, cabbage aphids, and onion thrips are other insect pests that warrant control measures. Cabbage is also sporadically infected by diseases such as black rot, black leg, downy mildew, club root, and sugar beet cyst nematode, any of which can result in substantial crop loss.

Growers must protect their crop from these pests by any means available. Presently, pesticides are the most widely used and effective means of crop protection. However, total reliance upon pesticides, to the exclusion of other control tactics, can be inefficient. Strict adherence to pesticides and regular repetitive spraying may result in: increased pest resistance to pesticides; detrimental effects on non-target organisms; environmental pollution; potential hazard to the pesticide applicator, farm worker, and consumer; spiraling treatment costs; and uneconomical use of energy. Since processing cabbage (for sauerkraut) need not be cosmetically perfect, a certain amount of leaf damage by Lepidoptera or diseases is acceptable. This allows growers to treat sauerkraut cabbage less often than fresh market cabbage (approximately 4 vs 8 sprays/field/season, respectively). Since the return per acre of processed cabbage is considerably less than that of fresh market cabbage ($736 and $3,500, respectively), sauerkraut growers must be more economical in their crop protection practices.

The New York State Cabbage Pest Management Program was initiated in 1978 to assess the need for integrated pest management practices in New York cabbage production and to develop appropriate technology. In just 5 years, the project increased in scale from a research and demonstration project in 8 fields to a cooperative venture between the Cornell Integrated Pest Management Program and a crop consultant who provides the service aspects of the program on a contract basis with 28 growers covering 1,700 acres in 6 counties. This is the first inclusive report on the development of the program.

OBJECTIVES

The ultimate objective of the pest management program is the adoption by growers of sound crop protection practices that stress efficient and profitable production, but minimize human and environmental hazards. To accomplish this, an integrated pest management program was established with the following short term objectives:

1. To collate all available cabbage pest management information and techniques for integration into a demonstration pilot program.

2. To develop a biological monitoring system that allows for accurate and efficient assessment of pest populations and a feasible means of communicating this information to the grower and extension personnel.

3. To develop pest control strategies that aid growers in the optimal utilization of pest control measures.

4. To develop a pesticide usage and pest history record system that provides pest, crop, and spray data to the producer for analysis and future management decisions.

5. To provide education in crop protection principles based on Integrated Pest Management and to demonstrate the advantages of a pest surveillance program.

PROJECT ORGANIZATION

Steering and Commodity Advisory Committee

The initial impetus and overall direction of the cabbage IPM program was provided by the Cornell University IPM Steering Committee. Funding for the first 3 years of the program was acquired through this organization. To address the field related problems involved in program development and implementation, a working advisory committee was organized that was comprised of experienced vegetable extension, research, and agri-business personnel. This committee met weekly during the summers of 1979 and 1980 to review and discuss the scouting reports. Collectively, the group made treatment decisions on IPM test plots that helped develop interpretive charts and provided critical feedback that aided in the successful progress of the program. In 1981 and 1982, the advisory group met once a month to review current pest situations and respective control strategies. Annual fall and spring meetings were held to review the progress of the program and examine plans for the upcoming season.

Research personnel from the disciplines of entomology, plant pathology, vegetable crops, agricultural economics, and computer science collaborated in the program's planning since its inception. The researchers were integral in helping IPM personnel maintain commercial test plots in which short term applied research was conducted to develop sampling and reporting procedures, treatment thresholds, and control strategies. Cooperating researchers were also responsible for performing long term pest management research in biological control and various cropping systems.

Grower Cooperation

During the initial 3 years, the growers' patience and assistance were essential in establishing the program. Participants cooperated by altering their spray material or timing of application on commercial test plots upon the request of the advisory committee. Some growers cooperated in complex experiments that demanded their time and careful attention. Participating producers also provided confidential spray records and grading slips for analysis. In 1980, participating cabbage growers in Ontario and Yates counties contributed $3.50/acre to support scouting activities. In 1981, the service aspects were provided by an independent consultant. He established a scouting fee of $4.50-$6.50/acre depending on the number of fields enrolled by the grower. The consulting fee in 1982 was $6.50-$8.00/acre, which completely supported the scout, transportation, miscellaneous supplies, and technical information from the consultant.

Services Provided to the Growers

The necessity and feasibility of an IPM program on cabbage were carefully assessed in 1978. A scout was employed to monitor pests, collect spray records, and conduct a grower questionnaire among 12 processing and 6 fresh market cabbage producers. An analysis of crop protection practices in 1978 showed that a more efficient and economical crop protection program could be developed for the growers. We found that many growers were unable to distinguish between the three Lepidoptera, particularly during the early instars. This led to erroneous pesticide selection since the choice of insecticide should be based on the species, or species complex, present. Many growers were not adequately monitoring their own fields for insect or disease problems. Some growers' decisions to spray were based on damage rather than larval presence and numbers, and insect pests often went unnoticed until extensive damage occurred. However, other growers had adopted a protective spray schedule to avoid the risk of incurring this damage. The relationship between damage and crop quality was also poorly understood, which resulted in kraut growers practicing strict insect control that was not economically justified by improved cabbage grades (11).

Based on the experience gained in 1978, eight sauerkraut cabbage growers were asked to participate in a pilot pest management program in 1979. Growers received weekly scouting reports that summarized the current status of the pest and crop growth situations in each of their fields. To define action thresholds for Lepidoptera, growers were asked to treat half their fields only when it was deemed necessary by the Cabbage Advisory Committee. Treatment decisions were made independently by the grower on the other half of the field according to his normal practice.

After 1979, the pilot project expanded into a full-scale action program. In 1980, field monitoring services were offered on a limited basis, for a fee, and 11 growers participated by enrolling 400 acres. In addition to weekly field reports, charts were placed on the office or barn wall and updated weekly so growers could visualize the seasonal fluctuations in population density of the three primary lepidopteran pests. Moreover, interpretive guides were available to growers suggesting levels at which larval populations should be controlled, and the insecticides that most likely would be effective against a given pest. In 1981, scouting services were independently provided on a contract basis with growers by the individual who had scouted in 1980. The IPM Program provided report forms, wall charts, action thresholds, and technical support to the private scout and the growers, thus maintaining its role in the continued development of cabbage pest management in New York. Grower response to private IPM services was excellent as 10 growers enrolled over 450 acres of processing cabbage. Additionally, a pilot pest management project was initiated by the IPM Program in storage cabbage using and adapting similar techniques to those used in the processing cabbage program. In 1982, the same crop consultant provided services to processing, storage, and fresh market cabbage growers in Ontario, Yates, Genesee, Orleans, Monroe, and Niagara counties. He contracted with 3 scouts to cover 1,700 acres enrolled by 28 growers. Report charts and technical support were provided by the IPM Program. The consultant also provided the growers with a computer analysis of the pest situation. With the service aspects of the program being provided by a crop consultant, the Cornell IPM Program assumes the multiple roles of demonstrating technology, as in the test plots; teaching and training scouts, new county agents, and agribusiness field personnel; and refining IPM practices and techniques by assisting the research effort.

TOOLS, TECHNIQUES, AND COMPONENTS OF CABBAGE IPM

Data Collection

The most important information collected in the program is the weekly estimate of pest population density from each field. Experience has shown that no two cabbage fields are alike. Even within a field, different varieties, plant spacing, topography, and crop growth stages can occur, all affecting the pest population density; thus the grower must have estimates from each field. The population density of each pest also fluctuates over time. Until these fluctuations can be successfully forecast, monitoring must be performed each week. This information is vital to the grower in determining the proper timing and selection of control measures. However, the information can also be used extensively for research, as discussed below.

Monitoring pest populations during the early years of the program involved inspecting a fixed sample of 50 (1978) or 40 (1979, 1980) cabbage plants distributed among 10 sample sites along a V-shaped transect through the field. All the leaves on each plant were scrutinized for any insect pest, and their numbers were recorded on a field inspection form. A visual survey was conducted for disease symptoms, weeds, or localized insect feeding problem areas while walking along the transect. As acreage increased, we found the fixed sample size to be inefficient. At very high or very low pest population densities, more plants were being inspected than was necessary to make an acceptable estimate of the pest population density.

To acquire greater efficiency, the use of a sequential sampling procedure was considered (7, 8). When following a sequential sampling procedure, a decision is made after each observation to continue or terminate sampling, depending upon the estimate of population density (typically of one given insect pest e.g., cabbage looper) obtained from all previous observations. If the population density of cabbage loopers can be classified as either above or below a given density (i.e. the treatment threshold) with a predefined level of precision, the decision to treat or not is indicated and sampling is terminated. If the population density cannot be so classified, then sampling is continued until it can be. Sequential sampling, however, is not an acceptable alternative for our program because we must monitor and manage a pest complex. An important objective in cabbage pest management is the early detection of other less common, but potentially serious insect, disease, and weed pests, some of which can only be found by inspecting plants. This requires an extensive survey of the entire field and inspection of plants throughout the field. This cannot be done if sampling is terminated quickly based on a sequential sampling decision for any one pest. Our treatment thresholds in processing cabbage varied considerably based on factors such as crop growth stage, temperature, and previous stress. A need existed for an efficient sampling plan for any pest that might require control measures, but one that focused on information for treatment decisions for the most important cabbage pests, cabbage looper and imported cabbageworm (5).

A variable intensity sampling scheme (9) was developed to address the needs of the program. The field is walked along a V-shaped transect, which is mentally mapped and divided into 10 equal sections. Each of these sections is sampled, but the intensity of sampling is varied, depending on estimates of pest population density from previous sections. If the estimate from previous sections indicates that the population density of cabbage loopers and imported cabbageworms could be within a range where treatment may be necessary, depending on other variables like weather conditions, sampling along the next section will be intensive; if the estimate indicates that the density is very high or very low, and the treatment decision is therefore obvious, sampling along the next section will be less intensive. Variable intensity sampling is more efficient than procedures utilizing a fixed sample size. It is more useful than a sequential sampling plan because it requires that the field be covered by a visual survey and that plants be inspected throughout the field, minimizing the chances of missing an isolated pocket of pest infestation.

Communication

Data collected from cabbage fields were reported to growers in written form. Over the years, a grower report form has been developed that includes a graphic and numerical display of the lepidopteran larval population densities for each field (Fig. 1). Crop stage was described by leaf number, head diameter, or by characteristics displayed by the forming cabbage head e.g., precupping, cupping, early head formation, head fill, and mature head. These specific growth stages have been described with an appropriate definition and picture for each stage by Andaloro et al (2). Other insect pests were reported in terms of per cent plants infested. When necessary, maps of problem areas were drawn. The scout also communicated information verbally to the grower whenever possible.

IPM information was always available to the county extension agent in whose county the program was implemented. A duplicate carbonless copy of the grower report form for each field was sent weekly to the agent until 1982, when data from all fields were provided each week on a separate county agents' report. Weekly reports were also sent to research and extension personnel statewide via a computer-based information delivery system called SCAMP. County extension offices can access SCAMP through their own computer terminals and obtain field reports and pest summaries from the different regions covered by all scouts. In addition to the scout's reports, interpretations of current pest situations by extension specialists and daily weather forecasts are available through SCAMP.

The review of problems during the season, plans for the upcoming season, and concepts and techniques of IPM are communicated to growers, agents, and agribusiness through grower meetings, agent newsletters, winter workshops, and field days.

To ensure proper identification of pests and knowledge of the cabbage pest's biology, picture fact sheets on specific cabbage pests have been prepared. These one sheet descriptions review the identification, biology, control, and monitoring procedures of cabbage looper (3), imported cabbageworm (10), diamondback moth (1), and onion thrips (4).

Management Strategies

The Cabbage IPM program has attempted to help the grower make optimal control decisions by providing pest control guidelines and interpretations of the biological events occurring in the field. In 1978, no specific thresholds were recommended. In

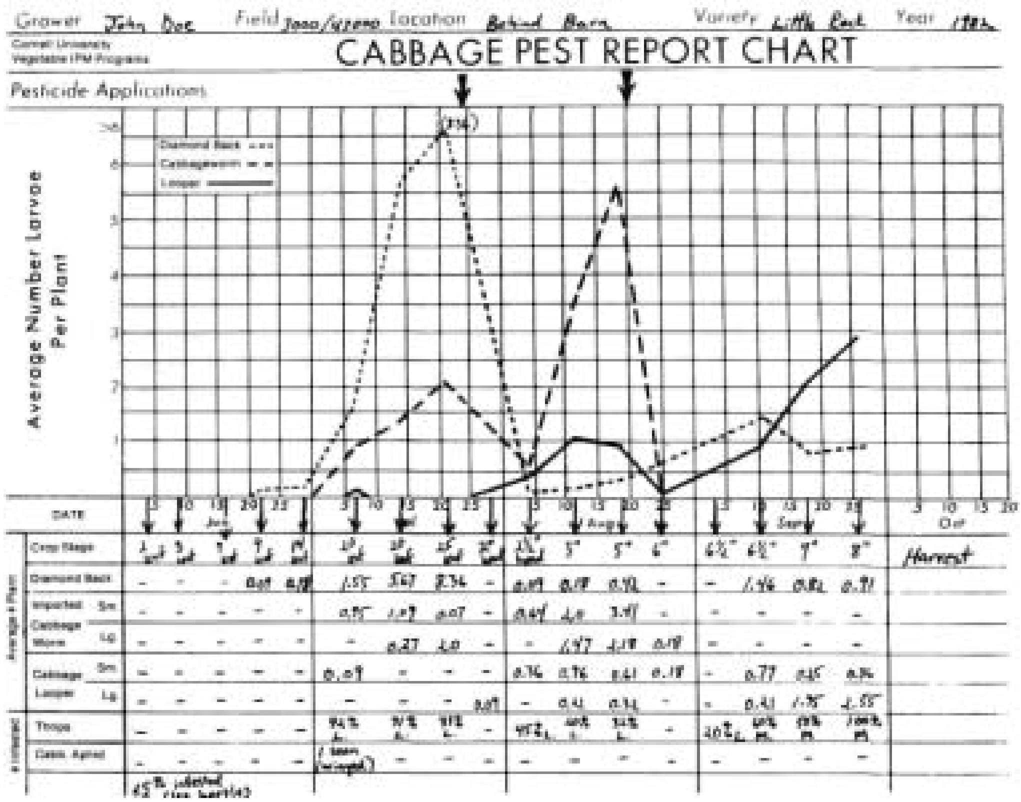


Fig. 1—Chart used in the Cabbage IPM Program for reporting field monitoring data.

1979, treatment decisions were recommended by the Cornell Cabbage IPM Advisory Committee and averaged 2.0 lepidopteran larvae of any size or species per plant. Based on observations and tests from 1979, higher threshold levels were developed and used in 1980 and even further refined for 1981 and 1982. The development of these thresholds involved serious consideration of the effect of lepidopteran feeding on cabbage grade. In 1980, an evaluation of grade slips from 316 loads showed that green tissue accounted for 91 per cent of all cull material, whereas only one load was downgraded for insect damage, the result of a thrips infestation (Table 1). Green tissue is a quality defect in processing cabbage since it causes discoloration of the sauerkraut, and mandatory removal of this green tissue also effectively removes lepidopteran feeding damage. Under normal population pressures, Lepidoptera confine their feeding to the frame or peripheral green head leaves; therefore strict control is not cost effective, and only a potential reduction in head weight would make an insecticide treatment worthwhile. In upstate New York, populations of foliage feeding cabbage pests are not as important in reducing yield as soil and climatic factors (12). Additionally, as the plant produces more leaves, it can withstand more insect damage without yield loss. This is the rationale for proposing

Table 1. Mean % cull material, by weight, of 316 loads of processing cabbage harvested from 14 commercial fields, Ontario County, New York, 1980.

Cull Category					
Green tissue	Undersized heads [a]	Burst heads	Tipburn	Insect	Total
9.40	0.61	0.14	0.13	0.03 [b]	10.31

a Head diameter < 15 cm.

b Only one sample downgraded for thrips infestation. No loads were downgraded specifically for lepidopteran injury.

Table 2. Treatment thresholds for control of diamondback, imported cabbageworm, and cabbage looper larvae based on cabbage growth stages.[1]

Growth Description	Cabbage Growth Stage	Treatment Thresholds Expressed as Avg. Larval Units/Plant[2] Sauerkraut	Storage/Fresh
Early Vegetative[3]	Stage 4 - 5	0.50	0.50
Cupping	Stage 6	1.30	1.30
Early Head Formation	Stage 7	1.75	0.50
Late Head Formation	Stage 8 - 9	2.50	0.50

1/ Treatment may be necessary sooner than stated above if larval feeding is directly on inner heart leaves or developing head, and/or cabbage growth is poor.

2/ Equivalent to 1 larval unit:
- 1.0 large (longer than |——|) cabbage looper
- 1.5 small (shorter than |——|) cabbage loopers
- 1.5 large (longer than |——|) imported cabbageworms
- 10.0 small (shorter than |——|) imported cabbageworms
- 10.0 diamondback moth larvae of any size

3/ Stricter control will be required in the stages prior to "Early Vegetative".

different treatment thresholds at different crop stages for larvae of the diamondback moth, imported cabbageworm, and cabbage looper (Table 2).

When a control measure becomes necessary, a grower must select the most effective one possible. Based on efficacy data compiled by the pest management program and research screening trials (6), a pesticide selection chart has been developed to help the producer choose an effective insecticide for the specific pests present (Table 3). The comparative effectiveness of each insecticide is ranked, based on the use of recommended rates. The ultimate selection of a chemical by a grower will be based on his prior experience and its cost. The influence of application equipment on insecticide effectiveness was also evaluated (15), and this information was conveyed to growers. The success of an "effective" insecticide is dependent on adequate coverage, proper use of a wetting agent, properly functioning application equipment, and weather conditions.

A portable microcomputer was used by the crop consultant in 1982 as a tool to refine the available information on action thresholds and insecticide efficacy for management of Lepidoptera. Data were entered by the consultant or the scout, and the computer first calculated larval units according to the guide in Table 2. Larval units are a common scale for all the Lepidoptera according to the amount of feeding damage done by each species. An action threshold was then calculated, using a continuous function for the relationship of crop stage to allowable larval units based on Table 2. Since the rate of larval development, and feeding, increases as temperature increases, the threshold was adjusted for temperature. This adjustment was based on temperature-development data for the cabbage looper and resulted in lowering the threshold at higher than average temperatures and raising it at lower than average temperatures. If the larval units were near the threshold, the expected results of seven different insecticide management options were calculated. The calculations indicated the expected larval units after each of these treatments. This was based on a 4-year study of the average effectiveness of the seven treatments on each of the lepidopteran species, as documented by the weekly field monitoring data. It allowed the grower to compare effectiveness of treatments against the species complex present in the field.

The last step in the program was a 7-day forecast of larval units if no treatment was applied. This forecast was derived by a simple model based on the temperature-development data for the cabbage looper mentioned above. It provided the grower with an additional means of timing treatments. The results of the analysis were printed by the microcomputer and presented to the growers in the form displayed in Figure 2.

Although control of insect populations is achieved predominately through insecticide use, natural control factors exist in the field that suppress insect populations. These should be conserved when possible. Among these control agents are various predaceous arthropods, namely ground beetles, true bugs, syrphid fly larvae, lacewings, ladybird beetles, spiders, and parasitic wasps and beetles. Parasitic wasps can inflict considerable mortality as in the case of *Diadegma insularis* (Cress), which may parasitize more than 75 per cent of the diamondback moth larvae during the season, and *Cotesia glomerata* (L.) and *Pteromalus puparum* (L.), both of which attack the imported cabbageworm. Microorganisms infect cabbage insect pests and cause mortality, particularly viruses that attack the cabbage looper (nuclear polyhedrosis) and the imported cabbageworm (granulosis) when large populations develop. Infected worms eventually die and

Table 3. Insecticide selection chart used in the Cabbage Pest Management Program.

Pesticide	Flea Beetles	Thrips 1/	Cabbage Aphids	Diamond-back	Imported Cabbageworm	Cabbage Looper
Dipel, Bactur, Thuricide 2/	0	0	0	**	**	*
Lannate, Nudrin	***	*	*	**	**	*
Monitor	***	*	*	***	***	**
Parathion	***	*	0	*	**	0
Pydrin, Ambush, Pounce 3/	***	*	*	***	***	**
Thiodan, Tiovel	***	NK	*	**	**	0
Guthion	***	*	0	**	**	*
Sevin	***	NK	0	-	-	-
Metasystox	-	*	***	-	-	-
Cygon, Defend, Rebellate	-	*	**	-	-	-
Systox	-	*	***	-	-	-
Di-Syston	NK	0	***	-	-	-

Effectiveness: ***=Most; **=Moderate; *=Least; 0=None; NK=Not Known; -=Not Applicable
Pesticide effectiveness based on use at recommended rates.

1/ Materials are evaluated as to their effectiveness after the cupping stage (growth stage 6).

2/ Effectiveness diminished by cool temperatures.

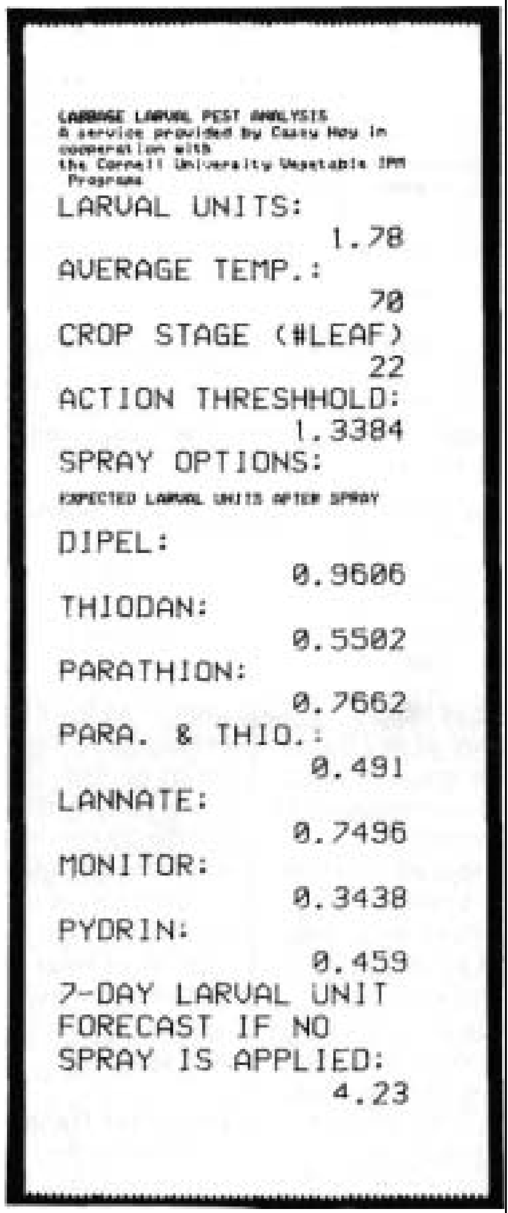
3/ Effectiveness diminished by hot temperatures.

decompose releasing virus particles, thereby disseminating the disease. Research is currently under way that will better define the ecological parameters of specific predators, parasites, and entomopathogens. It is hoped that through proper timing and selection of insecticides the hazards to these naturally occurring control agents can be minimized.

Other control tactics are being developed by researchers. These are being incorporated particularly in the management of onion thrips Severe onion thrips infestations in 1980 and 1981 were detected by the scout, and in 1980 several loads of cabbage were rejected by processors for fear of USDA discretionary seizure of any thrips contaminated sauerkraut. Through variety trials and documentation of infestations in commercial acreage, considerable information, which can be incorporated into overall management strategy, has been accumulated on varietal resistance to colonization and damage of cabbage by onion thrips (13). Studies were also conducted by Shelton et al (14) to determine the effect of thrips infestation on the finished sauerkraut. The studies showed such a minor effect on the quality of sauerkraut made from even very heavily infested and thrips damaged cabbage that the National Krautpackers Association petitioned the FDA for a reasonable defect action level for thrips contamination in sauerkraut. Once this legislation was granted, it virtually eliminated the need to apply insecticides for the control of onion thrips in processing cabbage. Thus, genetic and legislative measures have been added to the truly integrated arsenal of control tactics for thrips management.

Data-Base Management

Over the first few years of the program a data base for cabbage pest management has evolved that is very useful for research. Most of this information is collected in the course of the field monitoring activities and is stored both as a copy of the report forms, spray records, etc., and in INFO, a data handling program in SCAMP. Selected information can be drawn from the INFO files and analyzed using statistical packages in the PRIME computer. At present, the three general types of information collected and stored by the Cabbage IPM Program are biological monitoring data, pesticide use data, and agronomic data. A discussion of each follows. The largest body of information is biological monitoring data, which includes weekly pest counts, crop stage, and pest distribution. This information is used in studies of crop and pest phenology and pest population dynamics. Each count is identified by date and field number, and the fields are numbered according to the Universal Transverse Mercator grid projection system, which gives them an East-West and North-South coordinate. Using these coordinates, studies of insect migration and regional distribution are being conducted.



CABBAGE LARVAL PEST ANALYSIS
A service provided by Casey Hoy in cooperation with the Cornell University Vegetable IPM Programs

LARVAL UNITS: 1.78

AVERAGE TEMP.: 70

CROP STAGE (#LEAF) 22

ACTION THRESHHOLD: 1.3384

SPRAY OPTIONS:

EXPECTED LARVAL UNITS AFTER SPRAY

DIPEL: 0.9606

THIODAN: 0.5502

PARATHION: 0.7662

PARA. & THIO.: 0.491

LANNATE: 0.7496

MONITOR: 0.3438

PYDRIN: 0.459

7-DAY LARVAL UNIT FORECAST IF NO SPRAY IS APPLIED: 4.23

Fig. 2—Sample of output from a computer analysis for Lepidoptera management in processing cabbage in Ontario and Yates Counties, N. Y., provided to growers by an independent consultant.

The growers, aided and encouraged by the scouts, keep records of all pesticide applications including date, field number, rates, materials, and application methods. These records are used for surveys of pesticide usage. The amount of insecticides used from year to year are compared in terms of dose equivalents, the rate used divided by the Cornell University recommended rate (16), which provide a common scale to compare all pesticides and all of their formulations. At the end of the growing season each grower receives a summary, prepared by a computer program, of all pesticide applications in each of his fields, including the dose equivalents, cost of each application, and a running tally of the accumulated cost (Table 4). Pesticide data can also be related by date and field number to the biological monitoring data to retrieve the pest count before and after each insecticide application and determine the percentage reduction in the population of each pest after the application. These reductions are then tabulated to determine insecticide and application method efficacy.

Growers are surveyed for agronomic information at the beginning and end of each season. At planting time the planting date, variety, market (processing, storage, or fresh), field history, edaphic conditions, plant spacing, and inputs such as tillage and fertilization are recorded. After harvest, any additional management inputs, such as additional fertilizer or irrigation, as well as yield and grade are recorded. This information can also be related to the biological

Table 4. Example of pesticide cost summary provided to growers by the Cabbage Pest Management Program (ACC. COST = accumulated cost; DOSE EQ. = dose equivalents, the rate used divided by the Cornell recommended rate; TYPE = I -insecticide, H - herbicide; GAL/ACRE = gallons of water used/acre; NOZZLE = nozzle type, FF - flat fan; SPRAYER = sprayer type, BM — brush boom; PSI = pounds/square inch sprayer pressure).

1983 N.Y.S. IPM SPRAY REPORT
FOR 3000.47000

DATE	PESTICIDE & FORMULATION	RATE/ ACRE	UNIT	COST/ ACRE	ACC. COST	DOSE EQ.	TYPE	GAL/ ACRE	NOZZLE	SPRAYER	PSI
5/15	TREFLAN 4ECA	1.50	PTS.	9.37	9.37	1.00	H	20	FF	BM	20
5/16	LORSBAN 4EC	2.00	P	9.36	18.73	1.00	I	35	FF	BM	40
6/11	PARATHION 8F	0.25	PTS.	0.78	19.51	0.50	I	30	FF	BM	85
7/19	DIPEL 4L	2.00	PTS.	9.80	29.31	1.00	I	30	FF	BM	30
8/ 6	PARATHION 8F	0.50	PTS.	1.55	30.87	1.00	I	30	FF	BM	30
	THIODAN	2.00	PTS.	7.04	37.91	0.77	I	30	FF	BM	30

FIELDNO	SPRAY TYPE	COST	% OF TOTAL
3000.47000	HERBICIDE	9.37	24.72
	INSECTICIDE	28.53	75.28

monitoring information by field number and is useful in studies of varietal resistance and the effects of cultural practices on pests. The yield and grade information can be used for evaluation of management inputs and validation of threshold models. It is hoped that this information will help pave the way for expansion into a more comprehensive crop management program.

RESULTS AND DISCUSSION

Pesticide Usage

The results of the pesticide use survey for 1978-1982 among kraut cabbage growers are presented in Figure 3. To some extent, these reflect the pest problems in each year. For example, the heavy thrips infestations in 1981, before an FDA defect action level was granted, resulted in increased dose equivalents of parathion, oxydemeton-methyl, and

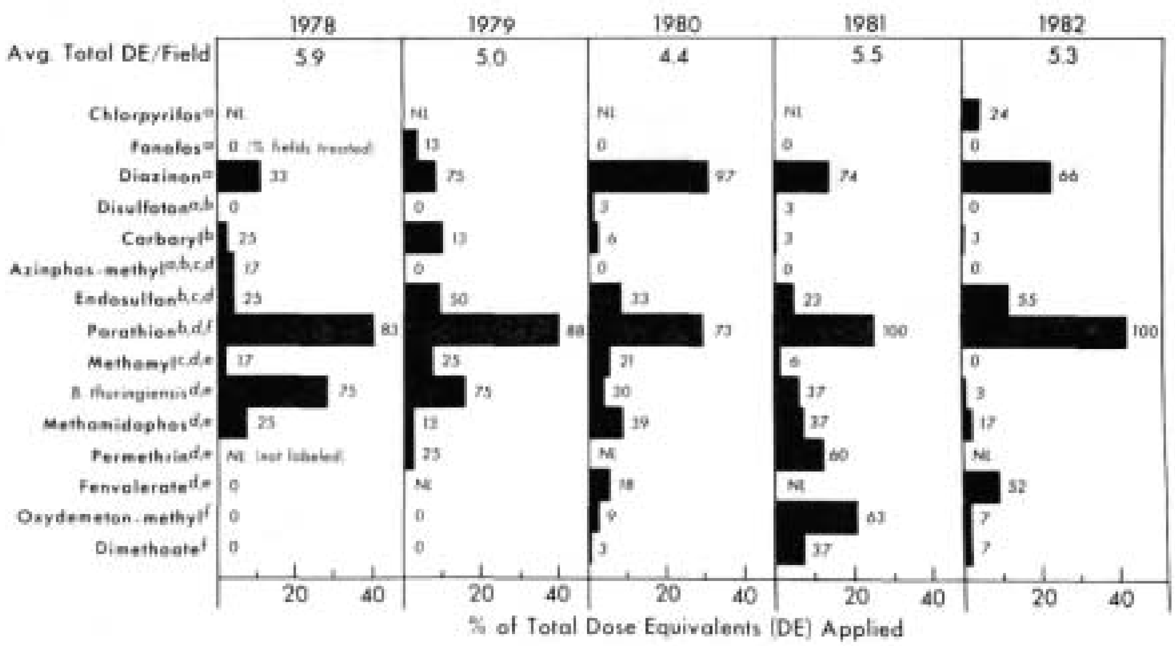


Fig. 3—Insecticide usage by Cabbage IPM Program participants as measured by dose equivalents. Ontario and Yates Counties, N.Y. (Insecticides applied mainly for control of [a]cabbage maggot, [b]flea beetles, [c]diamondback moth, [d]imported cabbageworm, [e]cabbage looper, 'thrips.)

dimethoate. The results also reflect the availability of some materials. Chlorpyrifos was labeled in 1981, and some growers began to use it in 1982. The synthetic pyrethroids, permethrin and fenvalerate, were alternately given section 18 emergency use exemptions until fenvalerate was labeled in 1982. The use of these materials increased as they became available and their effectiveness became known.

The most important test of the usefulness of the program is the effect it had on the growers practices. Figure 4 shows the changes in average amount of insecticides, in dose equivalents, used for control of Lepidoptera per field, and in the average effectiveness of those insecticide applications against the Lepidoptera. The dose equivalents of insecticide applications applied against Lepidoptera decreased by 49 per cent from 1978-1981. The slight increase in 1982 was due to the more frequent use of the inexpensive and apparently synergistic combination of parathion and endosulfan for heavy infestations of diamondback moth and imported cabbageworms. The average effectiveness of all applications increased by over 50 per cent from 1978 to 1981 and 1982.

These changes can be attributed to improved selection and timing of insecticide treatments based on field monitoring information and interpretive information provided by researchers, IPM personnel, anc the consultant. Field monitoring included population densities for each of the three Lepidoptera, thus alerting the grower to select the most effective material for the species complex present in the field. This emphasis on selection increased the effectiveness of applications and also resulted in a decrease in the indiscriminate use of insecticide combinations, thus lowering the dose equivalents per field. Timing insecticide applications according to increasingly higher thresholds resulted in progressively fewer applications and decreased the dose equivalents applied per field without lowering the quality of the cabbage. Higher thresholds also allowed a higher percentage of the insect population to pass from the egg to the more vulnerable larval stage.

Benefits of the Program

The insecticide usage data in Figure 4 demonstrated that the program was successful in that growers did adopt more efficient crop production practices that reduced insecticide use. This also reduced human and environmental hazards and increased the effectiveness of insecticide applications. Reduced insecticide use provides a direct monetary benefit easily recognized by growers. Other benefits are sometimes not as easily recognized but may also have contributed to the growers acceptance of, and willingness to pay for the program, and their adoption of sound pest management practices. Reduced insecticide use can also help retard the development of pest resistance to insecticides. The field monitoring service frees the grower's time for other important tasks. At the same time, it gives him peace of mind in knowing his fields are being checked. Because intensive monitoring is done by a trained scout, the grower receives an accurate identification of pests. Serious pest problems can be detected before extensive damage occurs. University research and extension personnel also receive regular reports on each field, allowing them to better serve the farmer, particularly in emergency situations. Finally, the farmer himself can evaluate the effect of any control measures on pests by comparing the pest counts before and after the treatment.

Future of the Program

Despite the considerable progress made so far, a great deal of research will be necessary to efficiently integrate multiple control tactics for the management of cabbage pests in New York. We still cannot accurately estimate the relationship of pest population density to economic loss. This is required to evaluate the need for

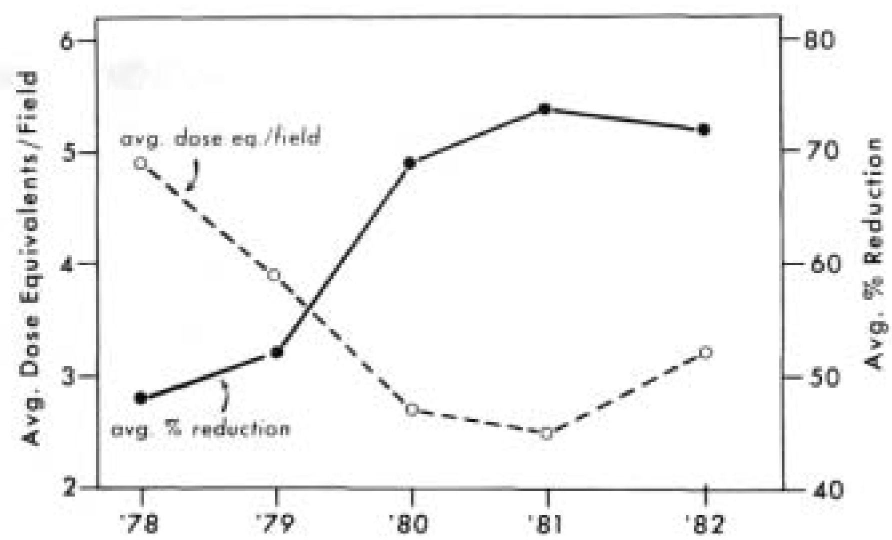


Fig. 4—Amount of insecticides used and efficacy of insecticide treatments for control of Lepidoptera obtained by Cabbage IPM Program participants Ontario and Yates Counties, N.Y.

and value of control measures. For Lepidoptera, enough information exists to estimate an approximate, but useful, action threshold; for diseases, however, particularly storage diseases, none of this information exists, and growers must treat prophylactically with fungicides and bactericides. The effect of weeds on yield is not fully understood. Consequently, the value of cultivation and hand weeding cannot be determined. Research is still lacking on pesticide application methods, application rates, the relationship of environmental conditions to the effectiveness of pesticides, and monitoring the buildup of resistance to pesticides. Host plant resistance to insect pests is an effective means of reducing the cost of pest management and should be considered by growers when varieties are selected. Development of commercial varieties resistant to the major disease and insect pests should have more priority in the program. ^ With more study, biological control techniques might provide another cost effective management strategy, particularly for processing cabbage. For example, we are presently evaluating the use of a granulosis virus for control of *P. rapae.* Inoculative release of egg parasites for Lepidoptera and predaceous mites for onion thrips control is currently being explored in the Netherlands. It might also be useful here. A major gap still exists in our understanding of area-wide problems, such as dispersion and migration of Lepidoptera and thrips.

These gaps in research point to the need for the University and the private sector, including agribusiness personnel, independent consultants, and growers, to continue developing improved pest management systems. Those involved in pest management services in the private sector must provide quality information to best serve the needs of the farmer. The University develops information through research and provides it to growers through extension; therefore, it has the same goal as the private services. Because they each provide the grower with different but complimentary information, continued and even increased cooperation between the University and those involved in private pest management services is one way to provide continually improved information to the grower.

A unique opportunity to facilitate that cooperation exists in the rapidly expanding field of microcomputer technology. The use of microcomputers is becoming commonplace, particularly in businesses that deal with information. Technology is currently available to link those computers together to transfer information. If such a link can be established between microcomputers in the private sector and the University computer, information can be traded with minimal effort. Information transferred from the private sector to the University would be crop production, pest monitoring, and environmental data from individual commercial fields. University extension can thus stay informed of events in the field, and research personnel can use the information to validate models or compare results of their studies with results in commercial fields. The information returned to the private sector is processed data, which enables those in the private sector to provide additional information ultimately benefiting the farmer. The result would be a rapid, cyclical flow of information, routed through private pest management services, from the farm to the University and back to the farm.

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