Implementing of an IPM programme for vegetable brassicas in New Zealand

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Abstract

In New Zealand, increasing levels of resistance in diamondback moth (DBM) to recommended synthetic pyrethroid and organophosphate insecticides were monitored for five years in vegetable Brassica crops until in 1997 they were associated with control failures in three regions. Subsequently, Crop & Food Research initiated a two-year IPM implementation programme with financial assistance from government and industry, including agrochemical companies. The IPM programme emphasizes the use of a reduced spray programme developed in the early 1990s based on a crop scouting system using presence/absence per plant of the major pests and a proven action threshold for cabbage. Further research has reconfirmed this cabbage action threshold, and broccoli and cauliflower action thresholds have been developed. The implementation phase involved training scouts and crop managers in insect identification and crop scouting techniques, and incorporated an accreditation system for trainees and a crop management recording system to document insecticide use in the IPM crops. Demonstration sites in three of the main Brassica growing regions were used for grower field days and to compare IPM practices with conventional pest management. Levels of resistance in DBM to the commonly used groups of insecticides were monitored and resistance levels were compared within a region as well as between regions. The IPM programme also recommends an insecticide resistance management rotation strategy with different chemical groups assigned to two different seasonal windows as well as the preferential use of selective insecticides to preserve natural enemies. An independent survey in November 2001 reported that 80% of growers in the main Brassica-growing region were using IPM and 96% were using crop scouting. Crop management records from IPM crops show an average saving of at least 50% in insecticide use compared with conventional crops.

Keywords
diamondback moth, integrated pest management, insecticide resistance

Introduction

Vegetable brassicas are the predominant fresh vegetable crop by area in New Zealand and have been one of the crops most frequently sprayed for pests. These frequent applications of insecticides led to the development of insecticide resistance to a level that has produced control failures for the key pest, diamondback moth (DBM), Plutella xylostella (Cameron & Walker 1998) and over-reliance on insecticides threatened the sustainability of Brassica crops. To counter this trend, an integrated approach to the control of pests in brassicas has been developed over the past ten years by Crop & Food Research (previously the Department of Scientific and Industrial Research (DSIR)) with funding from government and the New Zealand Vegetable and Potato Growers Federation (Vegfed). This integrated pest management (IPM) programme emphasizes the use of reduced spray programmes, alternation of insecticide groups, application of selective insecticides to preserve natural enemies, monitoring of insecticide resistance in DBM and improved communication with the industry.

The use of action thresholds and crop scouting in brassicas had previously been demonstrated to reduce pesticide applications by an average of 60% while improving crop quality (Beck et al. 1992). This research defined an infestation level at which spraying is economic (Beck & Cameron 1990) and provided an efficient crop scouting method to detect damaging populations (Beck & Cameron 1992). The scouting technique uses a “percent infested” threshold, which avoids the need to count pests and is easy for growers to use (Berry 2000). This technique was successfully demonstrated in commercial crops (Beck et al. 1992), but growers relied on increased levels of preventative sprays until insecticide applications began to fail to give control. An analysis of long-term trends in resistance from 1993 showed that by 1997, resistance in DBM to a standard synthetic pyrethroid, lambda-cyhalothrin, had reached levels in three regions well in excess of those associated with control failures in North America (Cameron & Walker 1998). The levels of
resistance recorded for the standard organophosphate, methamidophos, were also likely to cause control failures (Cameron et al. 1997).

The need for a specific implementation phase is crucial to the success of IPM programmes. Reviews of the world literature (e.g. Wearing 1988) indicate that successful adoption requires proof of both the IPM technology and an IPM implementation system, and emphasizes that the implementation phase requires repeated demonstration trials and training. For this purpose, an IPM implementation project proposal was developed by Crop & Food Research and funded by Vegfed and Technology New Zealand, a government agency. Funding was restricted to two years and the project began in November 1998. The project was based in Pukekohe, south of Auckland, the main vegetable Brassica-growing region in New Zealand, and in two regions on the east coast of the North Island, Gisborne and Hawke’s Bay. The main objectives, activities and outcomes of the project are summarized.

Objectives and outcomes

Objective 1. Refining action thresholds

Field trials undertaken over the main growing seasons of 1998-1999 and 1999-2000 retested the original cabbage threshold and developed thresholds for broccoli and cauliflower. The trials at Crop & Food Research’s Pukekohe Research Station tested thresholds at different crop growth stages and different times of the year and assessed the benefits of reduced spray applications and improved plant quality. Results of trials in year 1 confirmed the cabbage threshold developed by Beck and Cameron (1992) and a new broccoli threshold was proven (Berry, unpublished data). In year 2, the broccoli threshold was reconfirmed and cauliflower thresholds were tested.

The cabbage threshold is: Scout whole plant until head fill, then scout head plus four inner wrappers.

Action threshold for Lepidoptera: 15% infested plants; 12-14% infested, recheck in 3-4 days.

Action threshold for aphids: 10% infested with colonies.

The broccoli threshold is: Scout whole plant until past 6-8-leaf stage, then scout growing tip and inner leaves until floret formation. Protect the floret.

Action threshold for Lepidoptera: Seedling stage (30% infested), 6-8 true leaves to floret initiation (20% infested - growing tip only), then protect the floret (10% infested)

Action threshold for aphids: 10% infested with colonies. Results from trials in the 1999/2000 summer suggested that the threshold for broccoli could not be assumed to be the same for cauliflower, as previously proposed by Beck (1991). Observations of the scouting and harvest assessment data and the timing of insecticide applications suggest that the threshold for cauliflower should be: seedling (30%), 6-8 true leaf – curd initiation (20% - growing tip only); protect curd (5%). Further research is required to confirm this threshold before it can be endorsed. The results from the refinement of thresholds trials have been incorporated into an IPM manual for vegetable brassicas (Berry 2000).

Objective 2. Developing an insecticide rotation strategy

An accepted technique for limiting the development of insecticide resistance is restricting the use of particular insecticide groups to part of the year. Rotating the use of insecticides over an entire area in a “window strategy” based on calendar periods has proven to be an effective resistance management tactic (Roush 1989, Forrester et al. 1993). The implementation of this approach requires regional and national support for an agreed strategy while success requires the participation of a high proportion of growers.

A DBM insecticide resistance management-working group was formed in 1998. The working group comprised of researchers, growers, agrochemical company representatives and other industry personnel. An insecticide rotation strategy, based on options proposed for use in southern Australia, was recommended to ensure that DBM populations are not continually exposed to the same insecticides. This requires growers on a district basis to spray with chemicals in certain groups at certain times of the year (called windows). The strategy has two windows:

Early window - September to late January
Late window - February to August
This divides the year equally into the same number of DBM generations, based on average heat unit accumulations (P. J. Cameron, data not presented). Insecticides are assigned to windows depending on a number of factors, including their mode of action and cross-resistance patterns. Each of the windows includes a range of insecticides to provide a choice for controlling a range of pests (e.g. aphids and thrips) or for preserving natural enemies; Btk and Bta, for example, will kill caterpillars, but are harmless to other insects, including the predators and parasitoids of all the pest insects. This insecticide rotation strategy is presented in Table 1 and was published and updated in the New Zealand Commercial Grower (Walker 2001) and also in the IPM Manual (Berry 2000).

Table 1. Updated New Zealand diamondback moth insecticide resistance management rotation strategy for vegetable brassicas, November 2001

<table>
<thead>
<tr>
<th>Early Window</th>
<th>Late Window</th>
</tr>
</thead>
<tbody>
<tr>
<td>September - late January</td>
<td>February – August</td>
</tr>
<tr>
<td>Apply insecticides only in response to scouting thresholds</td>
<td></td>
</tr>
<tr>
<td>Btk¹</td>
<td>Bta¹ and mixture of Bta &amp; Btk¹</td>
</tr>
<tr>
<td>spinosad (Success Naturalyte®)</td>
<td>indoxacarb (Steward®)</td>
</tr>
<tr>
<td>organophosphates</td>
<td>synthetic pyrethroids</td>
</tr>
<tr>
<td>endosulfan</td>
<td>pirimicarb (aphids)</td>
</tr>
</tbody>
</table>

¹Apply Bt to small larvae on small plants

Objective 3. Training crop managers in insect identification and crop scouting
This objective was to train crop managers and potential commercial scouts in the necessary steps to identify pests, efficiently monitor their populations, assess natural enemies, select appropriate insecticides and apply them with good timing.

Fourteen scouts were trained in Pukekohe, six in Gisborne and four in Hawke’s Bay. They undertook continuous, weekly scouting of crops, recording and reporting their findings to growers and giving spray or no spray recommendations using the Crop & Food Research action thresholds and following the insecticide rotation strategy. Trainees who successfully completed the scouting and reporting of two crop cycles and who passed laboratory and field assessments were accredited as crop scouts. If scouts were required by growers to recommend the application of insecticides it was a requirement of their accreditation that they were also “Growsafe” trained. The Growsafe course is a New Zealand quality assurance (NZQA) certified training course on the safe and effective use of agrochemicals.

Objective 4. IPM demonstration sites
The use of crop scouting was demonstrated annually in each region to quantify and illustrate the benefits of reduced spray programmes and insecticide rotation. The benefits were measured from scouting reports and audits by determining the frequency of spray applications, the extent of adoption of the insecticide rotation strategy, the quality of produce and also the degree of insecticide resistance. Demonstration sites were also used for scout training sessions; for practice in crop scouting, insect and disease identification; and for grower field days. Results from Pukekohe demonstration sites showed a 25 to 65% decrease in insecticide use in 1998-1999 and a 40 to 70% decrease in 1999-2000. Results from Gisborne showed a 50% reduction in insecticide use associated with crop scouting.

Objective 5. Monitoring insecticide resistance in diamondback moth
The susceptibility of 11-21 field populations of DBM to five insecticides was tested using a dose response leaf dip bioassay following techniques adapted by Cameron et al. (1997) from Tabashnik and Cushing (1987). Susceptibility levels were compared with those of the standard reference population (Pukekohe 1 strain) in New Zealand, which had not been exposed to any group of insecticides for at least 8 years. Trends were monitored over two years between and within four regions (Pukekohe, Gisborne, Hawke’s Bay and Canterbury; South Island) using a synthetic pyrethroid, lambda-cyhalothrin (Karate®); an organophosphate,
methamidophos (Tamaron®); a Btk product (DiPel 2X®); a carbamate (Lannate®) and spinosad (Success Naturalyte®). Probit analysis was used to estimate the LC50 for each population and the standard population was included in each assay to minimize uncontrolled variables. To determine the degree of resistance, the LC50 of each population was compared with the standard New Zealand population and resistance ratios were calculated. Results for the standard synthetic pyrethroid and organophosphate are presented in Table 2. Some results from 1997 field surveys are also presented for comparison.

Table 2. Lambda-cyhalothrin (Karate®) and methamidophos (Tamaron®) resistance ratios for field populations of Plutella xylostella relative to the standard New Zealand population (Pukekohe 1) at 48 hours

<table>
<thead>
<tr>
<th>Collected</th>
<th>Population</th>
<th>Lambda cyhalothrin</th>
<th>Methamidophos</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LC50</td>
<td>95% CI</td>
</tr>
<tr>
<td>1997</td>
<td>Pukekohe 2</td>
<td>0.006</td>
<td>0.004 – 0.009</td>
</tr>
<tr>
<td>1997</td>
<td>Pukekohe 3</td>
<td>0.167</td>
<td>0.114 – 0.271</td>
</tr>
<tr>
<td>1998</td>
<td>Pukekohe 4</td>
<td>0.014</td>
<td>0.006 – 0.031</td>
</tr>
<tr>
<td>1999</td>
<td>Pukekohe 5</td>
<td>0.008</td>
<td>0.003 – 0.019</td>
</tr>
<tr>
<td>1999</td>
<td>Pukekohe 6</td>
<td>0.005</td>
<td>0.002 – 0.010</td>
</tr>
<tr>
<td>2000</td>
<td>Pukekohe 7</td>
<td>0.010</td>
<td>0.007 – 0.013</td>
</tr>
<tr>
<td>1997</td>
<td>Gisborne 1</td>
<td>0.011</td>
<td>0.004 – 0.023</td>
</tr>
<tr>
<td>1999</td>
<td>Gisborne 2</td>
<td>0.002</td>
<td>0.002 – 0.004</td>
</tr>
<tr>
<td>1999</td>
<td>Gisborne 3</td>
<td>0.001</td>
<td>0.0004 – 0.002</td>
</tr>
<tr>
<td>2000</td>
<td>Gisborne 4</td>
<td>0.012</td>
<td>0.007 – 0.021</td>
</tr>
<tr>
<td>1997</td>
<td>Hawke’s Bay 2</td>
<td>0.006</td>
<td>0.003 – 0.009</td>
</tr>
<tr>
<td>1999</td>
<td>Hawke’s Bay 3</td>
<td>0.001</td>
<td>0.0005 – 0.002</td>
</tr>
<tr>
<td>1999</td>
<td>Hawke’s Bay 4</td>
<td>0.002</td>
<td>0.0009 – 0.003</td>
</tr>
<tr>
<td>2000</td>
<td>Hawke’s Bay 5</td>
<td>0.022</td>
<td>0.012 – 0.041</td>
</tr>
<tr>
<td>1999</td>
<td>Canterbury 1</td>
<td>0.008</td>
<td>0.002 – 0.025</td>
</tr>
<tr>
<td>1999</td>
<td>Canterbury 2</td>
<td>0.017</td>
<td>0.010 – 0.030</td>
</tr>
</tbody>
</table>

* significantly more resistant at the 95% significance level, # significantly more susceptible at the 95% significance level

Trends suggest that synthetic pyrethroid resistance is variable both between and within regions. Populations tested from Pukekohe (population 8) and Hawke’s Bay (population 5) had levels of resistance that may be associated with control failures in the field. It is noteworthy that Pukekohe populations 5, 6 and 7 were collected within four kilometres of each other and had resistance ratios varying from a 2.3 to 29.2 fold difference from the standard population. These results demonstrate that resistance levels may be quite variable within a relatively small area. Two field populations (Gisborne 3 and Hawke’s Bay 3) were more susceptible to lambda-cyhalothrin than the standard population. This is plausible because the susceptibility of the standard population has previously been compared with a standard susceptible north American DBM population (Geneva 88) collected from cabbage near Geneva NY. This New Zealand population (Pukekohe 1) was ten times more resistant to permethrin at the LC50 than the Geneva 88 population (Cameron et al. 1997). In addition, the susceptible population from Hawke’s Bay (Hawke’s Bay 3) was collected from an area that had been in organic production for ten years and where there had been little or no exposure to synthetic pyrethroid sprays.

Resistance levels to the standard organophosphate insecticide, methamidophos, appear to be relatively stable with a maximum of 4.4 fold resistance (Table 2). The range of resistance ratios for 13 field populations to the standard Btk (DiPel 2X®) was 0.4 to 2.4 fold. The resistance ratios for 11 populations ranged from 0.88 to 6.4 fold for the carbamate, methomyl, and 1.01 to 3.57 fold in 15 populations for spinosad (G.P. Walker and N.A. Berry, unpublished data).
Discussion

Action thresholds

Existing action thresholds have been improved to recognize different and more vulnerable plant growth stages, and now include thresholds for broccoli and proposals for cauliflower thresholds. The new IPM system reduces selection for insecticide resistance by defining pest thresholds that ensure spraying is initiated only when necessary. To detect these economic thresholds, efficient crop sampling systems developed by Beck (1991) have been instigated and methods are published in the IPM manual (Berry 2000).

Natural enemies

Reduced spraying and use of more selective chemicals have increased the control provided by natural enemies (G. P. Walker, unpublished data). Spray decisions can be modified to recognize the presence and build-up of these natural enemies. For example, if a pest population is close to the action threshold, but parasitoids and/or predators are in abundance, experience suggests that spraying may be delayed and the crop reassessed at a later stage.

Insecticide resistance in DBM

A key issue for the industry is managing or mitigating the effect of insecticide resistance in DBM. This can be achieved by growers and scouts adhering to the insecticide rotation strategy. Our surveys show that resistance levels vary within a region as well as between regions and between years. Therefore, growers need to be kept up to date with the insecticides that are working, and the locations and levels of resistance present. Continuous monitoring of levels of resistance in the field is necessary to provide growers and consultants with updated information.

Industry uptake of IPM for fresh market brassicas

In November 2001, an independent survey was undertaken to quantify the uptake of the IPM programme. Thirty Brassica growers in the Pukekohe region, those who contribute the large majority of the brassicas grown in the region, were asked a series of questions. Their responses are listed below.

- Are you scouting or having your crops scouted? – 29/30
- Are you using the Crop & Food Research action thresholds? – 24/30
- Are you using the recommended insecticide rotation strategy? – 27/30
- Are you rotating Success® and Steward®? – 24/30
- Are you rotating Btk with Bta or mixtures of Bta and Btk? – 17/30
- Are you using a scouting/consulting company? – 17/30

Using an IPM adoption definition that required the growers to answer yes to questions 1-4, 24 of 30 growers (80%) were considered to be using IPM and 96% were scouting their crops. In the other major Brassica-growing region, Gisborne, one company (Leaderbrand) now dominates the Brassica production in the district (growing 1000 ha of broccoli yearly). In Gisborne, more than 90% of the Brassica crops are being grown using the Crop & Food Research IPM programme. In Hawke’s Bay, vegetable brassicas are not grown extensively, but key growers who were involved in the project are seeing the benefits of reduced spraying and are more confidently withholding sprays. They report a 50% reduction in insecticide use.

Benefits

We have demonstrated reductions in insecticide applications as well as increases in the use of more selective insecticides. The benefits of this approach include reduced selection pressure for insecticide resistance in pests as well as reduced exposure of applicators and reduced applications to adjacent cropping or non-cropping areas. In addition, appropriate rotation strategies extend the lifetime of new insecticide groups. Increased activity of biological control agents is associated with reductions in the need to spray. Finally, growers have benefited from improved marketing images for their crops as well as economic savings, mainly from reduced costs of insecticide applications.

Dollar savings are difficult to estimate. However, if the number of sprays required is reduced by 3-4 applications per ha, this reduction saves about $350 per ha. Costs of scouting at $30 per hour and savings from reduced spraying give a net saving of $125 per ha. About 4000 ha of cabbages, cauliflowers and broccoli are grown each year in New Zealand and approximately 65% are managed using IPM, giving total
savings from IPM scouting of crops of NZ$325,000 per year, not including qualitative benefits for the environment, worker health and in marketing.

**The future for IPM in brassicas**

The key to the success of the IPM programme is based on increasing uptake by growers who are prepared to continually monitor their crops, minimising the use of insecticides, and utilising the benefits of the insecticide rotation strategy in an area-wide, coordinated manner. The Crop & Food Research IPM programme for vegetable brassicas is now sufficiently developed for use by all cabbage, cauliflower and broccoli growers in New Zealand. For this technology to be continuously available to growers and other industry personnel (scouts, etc.), a key requirement will be to have adequately trained trainers available to train scouts to an acceptable standard.

**IPM manual**

The IPM manual for vegetable brassicas was published in November 2000 (Berry 2000). It documents the components of IPM in vegetable brassicas and includes photographs of all the insect pests and plant diseases and their natural enemies, methods and control strategies. It provides a standard reference against which the procedures used in a particular crop can be verified and audited as necessary. This manual ensures that the basis of decisions for the current programme and the improvement of any features for future modified IPM programmes are fully documented. It also provides a medium for accrediting scouts and involving growers, Vegfed and agrochemical companies in continually improving the technology in this programme.

In summary, IPM is now a major part of *Brassica* crop management, allowing year round sustainable production of high quality vegetable brassicas. The New Zealand vegetable industry is now in the unique position of being able to manage resistance and retain the use of insecticide groups that are now failing in some regions overseas.

**Acknowledgements**

We acknowledge the contribution of the New Zealand DBM resistance-working group. Tim Herman contributed to scout and grower training and with Rebecca Bush supported the field research. We thank Fruitfed Supplies and Seed and Field Services for their independent survey work. We gratefully acknowledge the *Brassica* growers involved, in particular: Mike Arnold, Mike Parker, Robert Joe and Howe Young. We acknowledge the financial support from Technology New Zealand, Vegfed, Fruitfed Supplies, Franklin Sustainable Project, Bayer New Zealand, Dow AgroSciences, Aventis CropSciences, Nufarm and Cropcare Holdings. We also thank Andrew Wallace for his contributions to the statistical analysis.

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