Challenges in implementing spinosad diamondback moth resistance management strategies in intensive vegetable growing areas in Asia

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Abstract

Success® contains the active ingredient spinosad and was registered in 1998 for the control of diamondback moth (DBM) Plutella xylostella (L.), in Asia. It has a unique chemistry and mode of action, no known cross-resistance to other compounds, a high level of activity against DBM, a short residual period and large margins of safety for mammals, birds, fish and most beneficial insects. These characteristics make it a highly desirable compound to be used in vegetable crops and other IPM friendly programs.

Besides DBM, field and laboratory testing of spinosad has proven that it is effective on almost all other Lepidoptera, Thysanoptera, some Coleoptera and Diptera. Dow AgroSciences developed an Insect Resistance Management program prior to product launch to prolong the product’s life and help growers cope with the resistance issue. Steps taken included labelling and/or governmental recommendations that limit applications, establishing insect susceptibility baselines on key pests prior to introduction, post launch monitoring for shifts in sensitivity and need for corrective measures, controlling supply, pricing appropriately and providing training for customers and centres of influence to promote the importance of IRM.

Our experience so far has been mixed. In areas with good educational systems and cost effective rotational products, we have good acceptance. In areas that lack effective educational networks, farmers tend to use Success® repeatedly without alternating with other compounds. The pricing appeared to deter frequent use, but also encouraged cross border trading and use of sub-optimum rates. Economic returns and continuous crucifer production are the main factors in determining the use of the product. Areas with continuous crucifer production by many small farmers with inadequate grower education networks and high economic returns for pest free vegetables, will develop resistance problems. Delaying or not introducing product had limited effect since cross border smuggling was occurring. State sponsored education and development of more sustainable programs that have crop rotations are the long-term answer, however, manufacturers can assist and have an impact with the education efforts and progress is being made.

Introduction

Spinosad or Success®, a newly introduced product by Dow AgroSciences (DAS), is the first member of the naturalyte class of products. It was first introduced for control of diamondback moth (DBM), Plutella xylostella, in Asia. It belongs to the family of naturally derived compounds called spinosyns. Spinosad has a novel mode of action. It works by affecting the nicotinic acetylcholine receptors on the postsynaptic nerve cell (Sparks et al. 1996).

The diamondback moth is one of the most destructive pests of cruciferous vegetables on a global scale. The larvae feed on the foliage from seedling stage to nearly harvest. Yield loss due to the pest is a common phenomenon faced by vegetable farmers. DBM develop fast and lay eggs in early stages of the adult phase and the life cycle is only about 3 weeks in the tropical climate (Khoo et al. 1991). Commercial vegetable farmers have resorted to using insecticides to protect their crops from the highly prolific and voracious DBM since effective compounds could provide quick and highly effective control. Other viable methods of control are considered slow or deemed ineffective by the farmers since damaged plants bring considerably less value in the market.

DBM has been well documented in its ability to develop resistance to insecticides due, in part, to the intensive use of the control agents in vegetable growing areas and an inherent adaptability. Our surveys in
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the major centres of vegetable growing areas of Malaysia, Indonesia, Thailand and the Philippines found that the cabbage farmers commonly apply insecticides every 3–5 days. It is not uncommon for 12–16 sprays to be applied in a crop season of 80–85 days, to manage the pest so that the crops produced are minimally damaged and are acceptable to the market. It is also not uncommon for four or more sequential crucifer crops to be produced, resulting in 60 or more selections on the DBM population with insecticides in a calendar year.

DAS has developed regional pest specific Insect Resistance Management (IRM) plans for spinosad and the company has set an ambitious target to protect spinosad market viability for 20 years. This paper serves to document the plans and recommendations that have been implemented by DAS and also to solicit other interested groups to collaborate with the organisation in the IRM programs.

**Dow AgroSciences insect resistance management plans**

The strategic direction within DAS comes from a team called the Global Insect Resistance Management Team (IRMT) with representatives from the major DAS Business Geographies throughout the world. The team was first established in 1994 as the North American Team and was gradually expanded to include all the geographies in 1998. Under the direction of this team, all country commercial teams have to develop a Resistance Management plan prior to market launch of spinosad. The plan has a comprehensive list of recommendations, but it is focused on four major components:

1. Labelling clearly product use direction and/or with governmental recommendations
2. Establishing insect susceptibility (LC50) baselines for key pests and monitoring plans for future review and corrective measures
3. Pricing appropriately with optimum supply strategy
4. Transferring technology and training customers and centres of influence to promote the importance of resistance management

The Country teams had their resistance management plan reviewed and approved by the IRMT prior to launch. Accountability for initiating reviews of the resistance management plan is clearly identified with a technical expert designated by the company. The technical expert initiates audits of the life cycle of the product from a technical point of view and together with inputs from the functional experts within Research and Development, recommends technical strategies (e.g. registration, formulation, biology) to the Business Management Team.

**Countries involved in the IRM plan in Asia business unit**

The countries in Asia participating in the IRM plan are shown in Table 1. Japan and Korea are in a different business unit and thus are not shown here. The table also lists the pests and registered recommended rates to control the pests in the countries concerned (Samsudin et al. 2001). The main target pest in all of the countries is DBM in the crop *Brassica. Spodoptera*, other Lepidoptera and thrips in vegetables and cotton are secondary targets. Recommended rates for the control of DBM vary from country to country ranging from 12 g to 50 g per ha of active ingredient (Samsudin 1998, Samsudin et al. 1999, Downard et al. 2000). The variation in rate is highly linked to the intensity of crop cultivation, pest population density and local agronomic practices. In areas of intensive all year round crop cultivation, the pest populations tend to be high and require a single high rate application or a multiple spray of low rates to control the pest. For example, intensive vegetable cultivation areas like Dalat, Central Vietnam, recommended a higher rate of 30 g ai/ha, whereas a less intensive area like Hanoi, North Vietnam, a lower dose of 20 g ai/ha was recommended. Hanoi area required a lower dose since the pest population is generally low and the crop cycle is usually disrupted by the cold winter (Samsudin & Nguyen 1997). The rate in Thailand is unusually high and explanations are provided in the “LC50 monitoring programs” section below.

**Insect resistance management labelling and/or governmental recommendations**

The main point emphasised here is to treat only when the pest population exceeds a threshold level. It is also stressed to use not less than label rates of any insect control product whether it is applied alone or in tank mixtures. It is recommended to treat most susceptible life stages and target applications against eggs and small larvae. Rotations with other suitable insecticide classes are encouraged to take advantage of beneficial insects. More importantly, the product should not be used on crops or pests other than those stated on the label.
Table 1. Regulatory status and recommended field rates for Success® in Asia

<table>
<thead>
<tr>
<th>Country</th>
<th>Brand name</th>
<th>Registration date</th>
<th>Conc. (g/L)</th>
<th>Crop</th>
<th>Pest</th>
<th>Use rate (g a.i./ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
<td>Success 25 SC</td>
<td>01-Sep-98</td>
<td>25</td>
<td>Brassica chinensis, B. rapa, B. oleracea, B. alboglabra</td>
<td>Plutella xylostella, Spodoptera sp.</td>
<td>25</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Success 25 SC</td>
<td>06-Jan-98</td>
<td>25</td>
<td>Cabbage</td>
<td>P. xylostella</td>
<td>12.5-25</td>
</tr>
<tr>
<td>Thailand</td>
<td>Success 12 SC</td>
<td>08-Apr-99</td>
<td>120</td>
<td>Brassica chinensis</td>
<td>P. xylostella</td>
<td>120-240</td>
</tr>
<tr>
<td>Vietnam</td>
<td>Success 2.5 SC</td>
<td>18-Feb-99</td>
<td>25</td>
<td>Cabbage</td>
<td>P. xylostella</td>
<td>20-30</td>
</tr>
<tr>
<td>Taiwan</td>
<td>Success 25 SC</td>
<td>26-Feb-99</td>
<td>25</td>
<td>Cabbage</td>
<td>P. xylostella</td>
<td>18.5-38</td>
</tr>
<tr>
<td>Taiwan</td>
<td>Success (Conserve)</td>
<td>21-May-99</td>
<td>120</td>
<td>Cabbage</td>
<td>P. xylostella</td>
<td>18.5-39</td>
</tr>
<tr>
<td>PRC</td>
<td>Tracer 48 SC</td>
<td>23-Dec-98</td>
<td>480</td>
<td>Cotton</td>
<td>Helicoverpa armigera</td>
<td>30-40</td>
</tr>
<tr>
<td>PRC</td>
<td>Success 2.5 SC</td>
<td>23-Dec-98</td>
<td>25</td>
<td>Cabbage</td>
<td>P. xylostella</td>
<td>12.5-25</td>
</tr>
</tbody>
</table>

The second point emphasised on the label is to use spinosad not more than two consecutive times per season to avoid treating successive generations. Only two applications to reduce a single insect generation below the economic threshold are permitted. Farmers are advised that if they are uncertain on the generation cycle, they are not to make more than two consecutive applications of an insect control product from the same product class. They are advised to rotate to a different class of insect control product, or use other treatments for the next 30 days.

DAS is linking up with some government and non-government organisations to support IPM and crop rotation efforts. In the long run, IPM will reduce the dependency of the farmers on use of chemical product alone to control the pest. Multiple tactics include cultural or biological controls within an Integrated Pest Management program where available and appropriate. In countries where there are Agricultural Chemical Companies that are interested to jointly promote their product with DAS, we will promote rotations of their product with ours.

**LC₅₀ monitoring programs**

As part of the IRM program, the LC₅₀ is established prior to launch to serve as a baseline for future monitoring. A summary of the LC₅₀ values is shown in Table 2. The test method employed is the IRAC No. 7 leaf dip method and the figures are taken at 72 hours after exposure to the chemical.

The LC₅₀ values vary widely, but are within the normal biological variation seen in other geographies. Higher than normal values were observed in Taiwan in 1999, but they did not repeat or continue upward and no explanation is available. The numbers fluctuate between 1998, 1999 and 2000 within the countries, despite the fact that the insect population was gathered from the same district and this is a laboratory test where all the external factors have been excluded. There also seems to be no trend saying that higher recommended field rates (Table 1) will produce higher LC₅₀ values in Table 2. This is evident in Thailand as, despite the high field rate, the LC₅₀ is comparable to the other countries. The high field rate could be attributed to the agronomic factor of heavy mechanised watering of the crops twice a day that reduces the residue on the treated plant.

A typical analysis used to compare the sensitivities across strains by dividing the more tolerant field strains by the most sensitive (usually an inbred lab strain). This number is then reported as a tolerance or resistance ratio with the latter terminology being a more common, but debatable use of the term ‘resistance.’ Differences in responses between populations are expected from normal biological variability, particularly with the very sensitive laboratory colonies. Some of the papers coming out will be reporting 10 to 100-fold differences in toxicity or resistance ratios. The most tolerant strains are still very sensitive to our field rates, however, the results demonstrate substantial biological variability as expected in the field.
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Table 2. LC$_{50}$ values of Plutella xylostella for spinosad at 72 h

<table>
<thead>
<tr>
<th>Country</th>
<th>Compounds</th>
<th>Mean LC$_{50}$ range</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
<td>spinosad</td>
<td>5.84</td>
<td>0.31-0.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>susceptible</td>
<td>0.04</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td>spinosad</td>
<td>NA</td>
<td>0.82-4.45</td>
<td>3.82-7.54</td>
<td></td>
</tr>
<tr>
<td></td>
<td>susceptible</td>
<td>NA</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indonesia</td>
<td>spinosad</td>
<td>0.24-0.85</td>
<td>NA</td>
<td>0.13-0.15</td>
<td></td>
</tr>
<tr>
<td>Vietnam</td>
<td>spinosad</td>
<td>NA</td>
<td>0.0019-0.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philippines</td>
<td>spinosad</td>
<td>&lt;1</td>
<td>NA</td>
<td>0.70-1.711</td>
<td></td>
</tr>
<tr>
<td>PRC</td>
<td>spinosad</td>
<td>0.05-0.1</td>
<td>0.039-0.117</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>susceptible</td>
<td>0.18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taiwan</td>
<td>spinosad</td>
<td>3.4-4.1</td>
<td>4.9-20.5</td>
<td>0.6-0.8</td>
<td></td>
</tr>
</tbody>
</table>

There have been no performance problems related to resistance in the field in Asia. Overall, performance has been excellent. Expectation setting has been the most common problem. A few growers had heard such good things that they had over-optimistic expectations, such as two weeks control or 100% control rather than 95% or so. We have had a few of the standard issues such as spray coverage and some tank mix issues with four and five products in the tank, however, these issues affect other products as well.

Several studies involve the development of susceptibility baselines by surveying the sensitivity of various populations. Some of the studies are sponsored by DAS, but many are independent efforts by university or government researchers. These studies are finding differences in sensitivity, but all are well below the field rates. The natural biological variability does indicate that one could select for resistant strains, but this is true for all compounds.

**Pricing and supply**

Pricing is one of the commercial tools utilised in the IRM strategy to discourage frequent use of spinosad. It is noted that high cost will not discourage repeated application using the same material as long as the vegetable prices are still profitable for the farmers. In theory, however, if the product is priced at a premium level, the end users will find it uneconomical to use the product too often and will be encouraged to use economic thresholds rather than maintenance sprays. A potential disadvantage is that farmers may only resort to spinosad when less expensive products and potential rotation products have developed high levels of resistance and are, therefore, no longer available for rotation.

Secondarily, premium pricing will also make the product uneconomical to be used in other low value crops to control pests. In effect, this tactic will automatically confine the product to the high value crucifers/DBM segment in the ASEAN countries.

On the supply side, control is mainly accorded through the dealer network. The dealers had to undergo the DAS IRM training program to get certification to sell the product. They are trained on the importance of IRM, especially for DBM control. They are one of our partners to impart IRM knowledge to the farmers and they have to abide by the recommendations from DAS or the privileges to sell may be rescinded. Dealers in a particular district are given a limited amount of product to ensure that amounts to a certain area are not oversupplied. An area is given a specific allotment of product based on the detailed calculation of area, crop seasons per year, estimated number of insecticide applications and expected DAS market share according to the IRM target. We have discovered that there are limits to our ability to control supply and that some product will find its way to high value markets if it is available anywhere in the world which is much smaller today in the age of the internet.

**Technology transfer to customers**

Many types of tools were utilised to promote our resistance management program to the farmers and dealers. These included seminars, mini workshops, leaflets, posters and recruiting extension workers. Label description about the resistance management program such as the maximum number of applications per...
season and rotation with other products are highly emphasised to the trainers. Tie-ups with some programs promoted by local government are always encouraged whenever the chance presents itself.

DAS sales teams were trained in the aspects of IRM and they, in turn, will train the farmers and dealers whenever they promote the product in the field. Each sales person is given a set of slides for their sales promotion to include IRM. In the promotion efforts the sales team will also link up with the government extension program and participate whenever they can to promote IRM. Planned joint promotions with other companies that sell suitable DBM control compounds are also underway. DAS is promoting the products of some other companies in rotation with spinosad.

Summary and conclusions
The most pressing issue currently is cross border trading where the product sourced in a country where the purchase price is low is sold across the border to a country with a higher purchase price by dealers for fast profit. This practice is on the rise and has led to certain areas exceeding the allocated limit. As a result of the additional quantity, the farmers are using Success® more frequently than the recommended “not more than two applications per crop season” as stated on the label. If the trend continues, overuse may lead to resistance. In this aspect we are seeking the help of the local regulatory authority to enforce and stem the cross border movement of the product.

Overuse by farmers can also happen due to lack of alternative effective compounds in a given location. Success® has been proven to be highly effective thus the farmers depend on it to protect their crops. High pricing deters frequent use somewhat, but farmers who are growing their products for export purposes are using Success® anyway. The economic return is high and it exceeds the production costs and they do not have to worry about the residue since spinosad can be used right up to the day of harvest.

Another form of offf label usage on the rise is a farmer using the product on pests that are not stated on our label. This will lead to false claims of efficacy failures and unusually high or low use rate to control the unlisted pests. Steps have been taken to communicate to farmers directly on this issue, but logistics problems continue to plague the DAS IRMS communications. We are limited most of the time to dealer level meetings because of the large geography and scattered nature of farms throughout an area.

Interviewing selected farmers occasionally is one of the steps we have taken to establish direct link to them. Survey results indicated that the majority of the farmers interviewed were aware of the history of rapid DBM resistance to pesticides, but on the other hand their main concern is to protect their crop investment. Most of the farmers are not educated enough about selecting pesticides with different modes of action. Rotating pesticides with different MOA to prolong the product’s effectiveness is not common either since farmers are afraid to lose their crops to an unproven product. Enforcement of label recommendation is not easy across large areas and often numerous small farms.

The above points detailed some of the technical and as well as commercial recommendations that have been carried out by Dow AgroSciences to implement Insect Resistance Management strategies. They can be wrapped up under three main categories: identifying and recommending an acceptable use pattern; implementing the use pattern and influencing market share with price and supply and education and the logistics of information dissemination. Our experience so far has been mixed. In areas with good educational systems and cost effective rotational products we have good acceptance. In areas that lack effective products for DBM control and with less effective educational networks, farmers tend to use Success® repeatedly without alternating with other compounds. Fortunately the latter is limited to a few areas close to metropolitan areas such as Bangkok that have a history of resistance development. If the growers in these areas maintain continuous crucifer production, it is only a matter of time before spinosad joins the long line of products that have been lost. However, in the majority of the areas we are making progress in assisting regional experts implement IRM programs that include spinosad as one tool. We are hopeful that the areas affected by severe DBM resistance will be minimal in the future and area wide programs will be adopted in the problem areas.

References


