A Practical Approach for Managing Lepidopterous Larvae with New Insecticide Chemistries in Lettuce

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Abstract

During the past 5 years, the efficacy and field performance of several new insecticides for control of Lepidopterous insects on desert lettuce crops has been investigated in small plot trials at the Yuma Agricultural Center and in produce fields with commercial cooperators. The objective has been to determine how these new chemistries will fit into pest management programs in Arizona. Thus, research programs have been focused on studies to define use patterns for these insecticides chemicals that can be integrated into our local management programs in the most cost-effective way possible. This report was created to provide an overview of the new chemistries being developed, their field activity and characteristics, and guidelines for use in head lettuce. In addition, an approach for sustaining the long-term efficacy of these products is discussed.

Introduction

The number of effective insecticides currently available to growers for insect control in leafy vegetables is rapidly growing. There have been several new insecticide chemistries recently registered for use in Arizona, and several pending registration. All of these products offer excellent activity on the key lepidopterous pests (beet armyworm [BAW] and cabbage looper [CL]) that infest desert vegetable crops. The performance of these products on leafy vegetables has been investigated under desert growing conditions for several years. Our research efforts have been focused on studies to determine how to integrate these new chemicals into our local management programs in the most cost/effective way possible. Based on our understanding of the field activity and characteristics of these compounds, a management approach that defines potential use patterns for each product has been formulated. This report was created to provide an overview of the new chemistries being developed for use in vegetables, and recommendations for their use in head lettuce.

Product Characteristics

This report will focus on five new chemistries that are currently available or pending registration. Table 1 provides specific information that describes the active ingredients, modes of action, primary routes of activity, effective rate ranges, and registration status. The most notable distinction among these active ingredients is that they are all unique chemistries with different modes of action. This includes neurotoxins with different sites of activity, an insect growth regulator that disrupts the molting process, and a metabolic toxin that prevents cellular metabolism. Similarly, the primary routes of activity differs among some products. Several of the compounds posses translaminar, or locally systemic, activity. The insecticides are capable of penetrating the leaf lamina, causing mortality through both insecticide contact and ingestion. Other products have been developed where ingestion is the primary type of activity. Finally, this table describes ranges of rates that have shown to be effective against lepidopterous larvae in numerous field trials.

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Table 1. Insecticides Being Developed for Management of Lepidopterous Larvae in Leafy Vegetables.

Product	Active ingredient	Mode of Action	Route of activity	Effective Rates (oz/acre)	Registration status
Success[7]	spinosad	neurotoxic	translaminar	4.0 - 6.0 oz	Labeled in 1998
Confirm[7]	tebufenozide	IGR, ecdysone agonist	ingestion	8 oz	Labeled in 1999
Proclaim[7]	emamectin benzoate	neurotoxic	translaminar	2.4 - 3.2 oz	Labeled in 1999
Avaunt[7]	indoxacarb	neurotoxic	ingestion, contact	3.5 - 6.0 oz	Pending
Alert [7]	chlofenapyr	metabolic	translaminar	6 - 9 oz	Pending

Field Efficacy

All of the above compounds have demonstrated excellent efficacy against cabbage looper and beet armyworm in small plot field trials. In this section, I will attempt to define specific activity for each active ingredient relative to field performance.

Temporal Mortality. The speed at which a particular active ingredient causes mortality through contact or ingestion can be influenced by mode of action and route of activity. Based on field trials, the temporal mortality of beet armyworm and cabbage looper to the new products under different conditions is shown in Table 2. Most BAW and CL larvae exposed to the translaminar products die within 1-2 days. This is due primarily to both the translaminar activity, and the neurotoxic or metabolic modes of action. Avaunt is slightly slower due to the fact that it requires ingestion. Confirm, relies solely on ingestion of the toxin, often requiring more time to become intoxicated, but is inherently slow due to its molt accelerating mode of action.

Table 2. Temporal Field Mortality of Beet Armyworm and Cabbage Looper to New Insecticides in Lettuce.

	Days to achieve > 90% larval mortality [a]					
	Beet armyworm		Cabbage looper			
Product	small larvae (<5 mm)	large larvae (>10 mm)	small larvae (<10 mm)	large larvae (>15 mm)	small plants (thinning)	large plants (heading)
Alert	1	1	1-2	1-2	1	3
Success	1-2	2	1-2	1-2	2	3
Proclaim	1-2	1-2	1-2	1-2	2	3
Confirm	3-4	5	4-5	5	4-5	>5
Avaunt	3	2-3	2	3	2	3-4

[a] mortality was recorded as either dead or missing from the plant during a 5 day period following treatment.

Temperature and plant size can also influence temporal field mortality, particularly for cabbage looper. On small plants, mortality is generally rapid regardless of temperatures. However, we have observed that on larger lettuce plants (heading-harvest stages), more time is required to achieve larval mortality. This is due in part to cooler temperatures that slows insect activity during this phenological lettuce stage (Nov-Mar), as well as the cryptic feeding behavior of CL.

Diagnostic mortality. Similarly, we have observed variation in the expression of mortality of these active ingredients. Following spray applications of the translaminar products (Success, Proclaim, Alert), we consistently find a large number of dead larvae on or underneath treated plants. Our trials have shown that 60-75% of worms exposed to these product die quickly on the treated plant. Lannate (methomyl) expresses similar post-treatment activity. We feel this is directly related to their quick knockdown activity. In contrast, following application with Confirm, it is common to find very few dead worms (10-15%) on treated plants. Because larvae quit feeding after ingestion of Confirm, we speculate that many of the larvae leave treated plants after ingestion and succumb to the toxin. Avaunt has shown to leave about 40B50% dead on plants after exposure. This is consistent with its neurotoxic mode of action and ingestion activity.

Residual Field Efficacy. Studies conducted in 1997 and 1998 provided data that define the residual field efficacy for these products. Replicated trials clearly demonstrated that the new active ingredients consistently provided residual efficacy (>90% control) against CL/BAW for at least 7 days following spray applications. Overall, Success appeared to provide the most consistent residual activity on newly emerging small larvae and larger larvae present on plants at application. Confirm, appeared to be somewhat inconsistent, but overall, residual control was similar to Success. The slow-acting mortality associated with this IGR can make assessment difficult following treatment, especially for small larvae. The newer compounds Proclaim and Avaunt, showed good residual efficacy for 7 days, and will be a welcome addition to the growers insecticide arsenal. The fact that all of these compounds are effective against large larvae, in part explains their consistent residual activity on lettuce.

Commercial Field Performance. Larval control for three of these products has been extensively evaluated in commercial lettuce fields. Success, Confirm and Alert have all been used by PCA and growers on head lettuce under various registrations (sales EUP, Section 18, and Section 3). The large-block field studies we conducted with growers have closely corroborated our small-plot results. Although Proclaim and Avaunt have yet to be evaluated in commercial field trials, we expect that they will perform as well or better than in our experimental trials.

Application Timing / Assessing Larval Control

We know a great deal about these new insecticide chemistries, but there are several insect-related factors that can influence their performance. An understanding of BAW/CL field biology may provide some insight for using these active ingredients in a cost-effective manner.

Non-specific Larval Susceptibility. Studies have shown that the new compounds have excellent efficacy on both small, neonate larvae and larger larvae alike. This is quite different from the OP, carbamate and pyrethroid chemistries, which are primarily effective against neonate and 2nd instar larvae. We speculate that this is due to chemical and biological factors. First, the new modes of action are inherently toxic to these insects at lower use rate. It is highly doubtful that BAW or CL larvae have developed any significant insensitivity to the compounds yet. Second, the routes of activity of the new compounds do not rely primarily on contact activity, but rather utilize both ingestion and contact activity. For instance, when the translaminar products are applied to foliage, the active ingredient moves into and across the leaf tissue, forming a reservoir of toxins on and within the treated foliage. This exposes the larvae to a much greater amount of active ingredient and higher chance for intoxication. The rate of foliage consumption is greatest for older, larger larvae, and can potentially consume greater amounts of active ingredient.

Application Timing. This wider-range of activity on larvae can influence timing of applications. Optimal spray timing for effective control of BAW and CL larvae has been primarily directed at newly hatched larval populations. With the new chemistries, PCA s and growers may perceive that timing is not as important because large larvae can be easily controlled. However, timing applications at neonates and small larvae is still highly recommended, particularly during the pre- and post-thinning lettuce growth stages. Laboratory studies have shown that CL and BAW larvae consume large amounts of foliage during the 3rd larval instar (see 1999 Vegetable Report). Delays in control can equate to increases in plant injury. Field studies have shown that plant damage from larval feeding before thinning resulted in significant reduction in plant size and stand following thinning. Furthermore, this injury resulted in greater variability in head size and maturity at harvest. Therefore, whenever possible insecticide applications for larval control should be timed when the populations is least damaging. Because all these products possess good residual efficacy, larvae hatching after applications should be controlled.

Post-treatment Assessment of Control. Evaluating larval control following a spray application will differ among the compounds, and it is important to understand the characteristics of the specific active ingredient. For the translaminar products and Avaunt, assessment can be made largely on the presence of dead larvae and absence of feeding damage. However, for Confirm and other non-neurotoxic compounds that require ingestion, assessment of control should be based on feeding damage and symptoms of larval intoxication. Although large numbers of dead larvae are not usually found on treated plants, it is not unusual to find live, intoxicated larvae during the first 3 days following treatment. Intoxicated larvae may appear sluggish, off-color, and often have malformed head capsules. However, these symptoms are not always easy to recognize. More importantly, when larvae are found on Confirm treated plants, fresh feeding damage should not be found.

Because these compounds are active on all instars, larvae size following application can be used to assess product performance. Table 3 provides a range of estimated larval ages relative to measurements of larval length. This data was generated from laboratory studies on head lettuce at 2 constant temperatures, 86F (average for Sep) and 72 F(average for Oct). This information can be used as a guide for estimating larval age based on larval size (see 1999 Vegetable Report) Note: larval development in the field may be slightly slower with fluctuating day/night temperatures, and can require 1-2 days longer to complete development. Knowing the relative age/size structure of the BAW/CL population before treatment, may allow for estimating product performance at 4-5 days post-treatment, based on the larval sizes found in the field.

Table 3. Larval Age of Cabbage Looper and Beet Armyworm Relative to Larval Size at Two Temperatures.

Cabbage Looper Larvae				**Beet Armyworm Larvae**			
86 °F		72 °C		86 °F		72 °C	
Length (mm)	Age (days)	Length (mm)	Age (days)	Length (mm)	Age (days)	Length (mm)	Age (days)
3	neonate	3	neonate	3	1-2	3	1-2
6	1-2	6	2-3	6	2-3	6	3-4
9	2-3	9	3-4	9	3-4	9	4-5
12	3-4	12	5-6	12	4-5	12	5-6
15	4-5	15	6-7	15	5-6	15	6-7
18	5-6	18	7-8	18	5-6	18	7-8
>21	>6	>21	>8	>21	>6	>21	>8

Selectivity. The new active ingredients are primarily efficacious against lepidopterous larvae, but in some cases, they have activity on other insects (ie. Success is efficacious against leafminer and thrips at higher rates). Because of their selective modes of action and routes of activity, we have observed little efficacy against lepidopterous adults (moths). This has been observed directly in laboratory mortality bioassays. However, mixtures with pyrethroids were shown to increase mortality and reduce oviposition. Similarly, in field trials we have seen little suppression of oviposition following treatment compared to Lannate+Pyrethroid combinations.

These compounds are also efficacious against other lepidopterous larvae on lettuce, with the exception of Confirm, which has shown inconsistent activity against corn earworm/tobacco budworm in field trials. In addition, corn earworm larval mortality to Confirm was poor in a laboratory bioassay.

Insecticide Use Patterns

We presently have a great deal of information on the new chemistries and their fit in lettuce pest management programs. These products have specific use patterns on head lettuce relative to their unique characteristics. This would include temporal mortality, residual efficacy, route of activity, efficacy relative to application method and interaction with larval development and feeding behavior. Table 4 was constructed from data gathered over the past several years and suggests uses for each compound for the protection for lettuce crops.

Table 4. Suggested Insecticide Use Patterns for Control of Lepidopterous Complex on Fall Lettuce in the Desert

	Stand Establishment		**Post-thinning / Pre-heading**			**Heading-Harvest**		
Insecticide	*Coty -1 lf*	*2-4 lf*	*4-8 lf*	*9-14 lf*	*Pre-heading*	*Head <2"*	*Head 2-4"*	*Head >4"*
Success								
Confirm								
Proclaim								
Alert								
Avaunt								
Lannate								
Larvin								
Orthene								
Bt								

Insecticide has demonstrated good efficacy as stand-alone application

Pyrethroid should be combined for additive and/or broad spectrum activity.

This table is organized by identified stages in plant growth throughout the crop season. The fit within the table for each active ingredient corresponds with its recommended use. The older active ingredients are included because of their broad-spectrum activity, larval efficacy and utility in sustaining long-term efficacy of all products. Furthermore, recommended tank-mix combinations with pyrethroids are identified. A short summary of the rationale used in developing this table follows:

Thinning Stage: Depending on population pressure and temperature, 1-3 applications may be required for larval control during this period. It is assumed that many applications will be by air because of sprinkler irrigation and wet fields during this period. Lannate+pyrethroid is the logical choice for initial control at stand establishment because of the excellent contact and ovicidal activity, broad-spectrum efficacy against many soil-dwelling pests, and proven efficacy by air. Alert and Success have demonstrated good activity against BAW/CL by air, but should be used after germination because of selective efficacy. If leafminer is also a concern, Success at higher rates should be used. Proclaim, currently does not have an air label, but will probably be an option once registered for air use and field validated.

Post-thinning / Pre-heading stage: All of the compounds are options for control during this period. The opportunity to use ground application equipment is also greater. Confirm use should be directed towards the post-thinning period, and addition of pyrethroid should be used thereafter because of its inconsistent performance on budworm/bollworm. Larvin, Bt, and Confirm should be applied with ground equipment whenever possible.

Heading-Harvest stage: perhaps the most important period in which plant protection is required. Fewer options, but several effective compounds are available. Addition of pyrethroid with all active ingredients is recommended for treatments 7-10 days before harvest to enhance control of small larvae and miscellaneous pests such as beetles, plant bugs and thrips.

Sustaining Product Efficacy

The above table provides to growers insecticide options available for management of lepidopterous larvae during the growing season. It should also serve as a guide to PCAs and growers for avoiding the overuse of a single product, and as a reference for rotating chemistries throughout the season for the purpose of maximizing and sustaining product efficacy.

Additional tactics should be practiced to avoid the development of resistence by lepidopterous larvae to any of these new active ingredients. First, avoid making more than 2 consecutive applications of the same active ingredient to the same field. This also includes pyrethroids whenever possible. An alternative active ingredient should be applied before reapplying the first active ingredient. Do not apply active ingredient below labeled rates. Finally, avoid tank-mixtures containing 2 or more of the new chemistries when controlling lepidopterous larvae. Not only is this expensive, but generally not necessary based on past performance.

Ideally, these strategies will optimize control of the Lepidopterous larval complex and maximize the longevity of all these compounds. I recognize that in certain situations, these management practices may be difficult to implement, but emphasize that they may be necessary for the long-term sustainability of these valuable chemistries on desert lettuce crops.