Temporal and Diagnostic Mortality of Beet Armyworm Larvae to Selective Insecticides in Head Lettuce

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Abstract

Several new insecticide chemistries were evaluated and compared with standard chemistries for temporal and diagnostic mortality of beet armyworm in lettuce. Field and lab bioassays of small and large armyworm mortality were conducted at pre-thinning, thinning, postthinning and harvest stages of lettuce. Results from both the field and laboratory indicated similar trends for the temporal activity of the products. The compounds with translaminar activity (Alert, Success, and Proclaim) appear to be have the most rapid "knockdown activity" with 100% mortality consistently occurring by 1-2 DAT. Because of their rapid activity, a large proportion of larvae are found dead on the plants. The products that need to be ingested to cause larval mortality (Larvin, Confirm, Neemix, Crymax, Cryolite, MP 062) generally varied significantly in temporal mortality and in efficacy against larvae. Unlike the translaminar products, a large proportion of larvae on were often found missing from treated plants. The results of this study provide basic guidelines concerning the activity and assessment of the performance of these materials in the field. PCAs and growers will ultimately be able to develop specific use patterns for these materials within their individual lettuce pest management programs.

Introduction

The number of effective insecticides currently available to growers for insect control in desert lettuce production is relatively small compared with other crops. Furthermore, with the recent passage of the Food Quality Protection Act, the lettuce industry in Arizona could possibly be facing the loss of a number of important insecticides. A recent example would be the withdrawal of Phosdrin from the vegetable market. Fortunately, the loss of Phosdrin for aphid control on lettuce coincided with the registration of an effective alternative product (Admire). Consequently, there is speculation that some of the more broadly toxic compounds may be removed from the market in the next few years. The organophosphate and carbamate insecticides (ie. Lannate, Orthene, Larvin, Endosulfan, Monitor, Diazinon) are being targeted as prime candidates for reduced usage. As these older chemicals are lost, the introduction of replacement products that can live up to both regulatory and grower standards will be critical.

The Arizona vegetable industry is fortunate that there are several new insecticide chemistries currently being developed that offer novel modes of action and selective activity. Some of the most exciting breakthroughs in agricultural chemicals have come in the last few years with the development of several new classes of chemistry for the control of lepidopterous pests such as beet armyworm. These insecticides are similar in that they are relatively selective for worms, and safe to use and apply. This has been achieved through both mode of action and type of activity. Of the compounds tested, most of them are new chemistries with independent modes of action (neurotoxic, metabolic, and insect growth regulators). Several posses translaminar activity, where the foliar spray penetrates the leaf surface providing toxicity through contact and ingestion. Many of the others that they be ingested to be toxic to larvae. For more details on these compounds refer "Review of New Insecticides Under Development for Vegetable and Melon Crops" found in this report. Although currently in the developmental stages, these new products will probably be available for use in lettuce in the next 1-2 years. The objectives of this study were to compare and document the temporal and diagnostic mortality of several new and currently available insecticides against beet armyworm larvae after they have been applied to lettuce in field and laboratory tests.

Materials and Methods

Lettuce, *Lactuca sativa* L., 'Empire' was direct seeded into double-row beds on 30 Aug at the Yuma Valley Agricultural Center, Yuma, Az. Each plot consisted of four, 30 ft long beds spaced 42 inches apart and bordered on each side by an untreated bed. Plots were arranged in a completely randomized block design with 4 replicates. Treatments, formulations and rates consisted of the following:

Treatment	Rate / acre
Lannate 90S	0.75 lb AI
Larvin 80DG	0.75 lb AI
Alert 2EC	0.15 lb AI
Confirm 2F	0.13 lb AI
Success 1.6DE	0.09 lb AI
Proclaim 0.16EC	0.0075 lb AI
Neemix 4.5EC	1 pt prod.
Crymax WDG	1 lb prod.
MP062 WDG[a]	0.065 lb AI
Prokil Cryolite[a]	10 lb prod.
Untreated control	--

[a] These products only tested in Trial 4.

Field Bioassays. Foliar applications of the treatments were made with a hand-held CO_2 sprayer operated at 50 psi, delivering 20 gal/ acre in a banded or directed, broadcast spray (Table 1). Spreader-sticker (Latron CS-7) was included in all spray treatments at a rate of 0.125% of the total volume. Four separate field trials were conducted. Mortality of beet armyworm larvae was investigated by marking plants within each sprayed replicate and making daily counts of larval mortality. Five individual plants in each replicate that contained at least 2 live larvae were identified and marked. A minimum of 10 larvae per replicate were used in the study. Marked plants were sampled by direct observation for the presence of dead, live or absent larvae for five consecutive days following each foliar application. Larvae were considered dead if they did not respond to touch or were visibly desiccated. Larvae were considered live if they responded to touch by moving. Larvae were considered missing if they could not be found on or beneath the plant during inspection. Field diagnostic mortality was calculated by determining the % dead, alive and missing larvae on tagged plants after the 5 day exposure to treated plants. Temporal mortality was calculated by dividing the number of dead and missing worms for each consecutive day from the total number of worms present at the beginning of the study. Data were converted to percent alive, dead or missing larvae and transformed using an arsine transformation. Differences between treatments was determined using a 1-way ANOVA and $LSD_{0.05}$.

Laboratory bioassays. Temporal mortality was similarly assessed using laboratory- reared beet armyworm larvae obtained from a lab culture from the USDA Res. Lab., Stoneville, MS. Egg masses of beet armyworm were received at YAC 5-7 days prior to the each bioassay. The eggs were placed in artificial diet and allowed to hatch. Following each field application (<12 hr; see above), 4 treated leaves from each replicate were collected and placed in 100x15 mm petri dishes. Five, 2nd instar larvae were placed on each leaf and held at ambient room temperature within the lab. A moist piece of filter paper was placed in the bottom of each dish to reduce leaf desiccation. Larval feeding and mortality was assessed daily over a 5-day period. Larvae were considered dead if they did not respond to touch or were visibly desiccated. Larvae were considered live if they responded to touch by moving. Mean % mortality was calculated for each replicate by summing up the number of dead larvae and dividing by the total numbers of larvae. Data were converted to percent alive, dead or absent and transformed using an arsine transformation. Differences between treatments was determined using a 1-way ANOVA and $LSD_{0.05}$.

Results and Discussion

Beet armyworm populations at YAC were very high in the fall of 1996. Consequently we were able to select a uniform sample for the study at each plant stage (Table 1). Field bioassaays were not conducted at harvest because of insufficient numbers of larvae in the field. The results of each bioassay are discussed below:

Trial 1: *Small BAW.* This was a prethinning application (1-2 leaves; 13 days after planting). At 1-DAT (days after treatment) , all treatments had significantly higher mortality than the check, but Confirm and Crymax had significantly lower mortality than all other treatments. By 2-DAT there was no significant differences among insecticide treatments. There were survivors (8%) in the Confirm and untreated plots after 5 days. Mortality was high in the check (70% by 4-DAT). Evaluation of diagnostic mortality showed > 40% of the worms were found dead in the treatments with translaminar (Proclaim, Alert and Success) and contact (Lannate) activity. Few dead worms (0-20%) were found in treatments where compounds that require ingestion (Confirm, Larvin, Neemix, Crymax). No dead worms were found in the Larvin, Crymax and untreated plots.

Trial 2: *Small BAW.* This was also a prethinning application (2-3 leaves; 15 days after application). At 1 DAT, Crymax had significantly lower mortality than the other foliar treatments. At 2-5 DAT, there was no statistical differences in mortality among the spray treatments except Neemix, which had less mortality of small BAW. Similar to trial 1, the translaminar products had the greatest number of dead larvae on plants after 5 days. Crymax, Neemix and Confirm and the untreated had less than 10% dead worms on the plants.

Large BAW. Because of the great deal of variability among treatments and the high mortality in the control, there were no differences among all treatments over the 5 days. Dead larvae (10-80%) were found in only the translaminar compounds and Larvin . Apparently, a large number of large BAW fled from the small plants following the application and settled on the ground or on other plants. In the control, the tagged plants were heavily damaged and presumably the larvae moved to adjacent plants to feed.

Trial 3: *Large BAW.* This was a post-thinning application (8-10 leaves; 30 days after planting). At 1 DAT only Alert and Proclaim provided significantly greater mortality than the untreated check. By 2 DAT, The translaminar treatmens and Larvin and Lannate had statistically higher mortality than the check. By 5 DAT all treatments except Neemix had significantly higher mortality than the check. The Crymax and Lannate treatments only provide 83% mortality 5 days DAT. Significantly greater numbers of dead larvae were found on plants after 5 days in the translaminar treatments. There were no dead larvae found on the Neemix treated and untreated plants.

Trial 4: *Small BAW.* This treatment was applied at thinning stage (3-4 leaves; 18 days after planting. At 1 DAT, 100% larval mortality was observed in the Alert plots. By 2 DAT, 100% mortality was observed in the Lannate, Success, and Proclaim plots. Total larval mortality (100%) was observed in the Larvin plots until 4 DAT and in the Confirm and MP062 plots until 5 DAT. Total mortality was not observed in the Cryolite, Neemix or Crymax plots. Dead larvae exceeded 60% in the plots treated with translaminar and contact treatments, whereas % dead larvae was low in the plots treated with the ingested compounds. No dead larvae were observed in the check, but 18% were found missing

Large BAW. A similar response was found for the large BAW with the exception that Lannate provided only 70% mortality. Less than 10% dead larvae were found on plants treated with the compounds that require ingestion for toxicity.

Laboratory Bioassays: In general, The bioassays of small BAW reflect the true mortality observed at thinning in the field. The translanminar and Lannate products provided greater than 95% after 1 day, whereas this was not achieved in the Larvin treatment until 4 DAT and in Untreated control the Confirm until 5 DAT. Both Neemix and Crymax were slow in acting and provided significantly less mortality than the other products after 5 DAT. The mortality in the check plots was low in the thinning bioassay and > 20 at the heading treatment. These data support the idea that many of the "stomach" poisons that work through ingestion are slow in acting and allow larvae to leave the plant within 1-2 days following application where a large proportion of them die. Because the translaminar products are much "quicker" acting, a greater proportion of larvae are found dead on the plants.

In summary, Industry has again developed several excellent tools for worm control in vegetable crops. Our study supports previous research demonstrating the excellent activity of these new chemistries against lepidopterous larvae in desert lettuce production. It also illustrates the differences in temporal activity among the new and standard insecticides. More importantly , this information provides basic guidelines for assessing the activity and performance of these materials. Upon registration, PCAs and growers will be able to develop use patterns for the insecticides specific to their individual pest management programs.

Table 1. Spray dates, application types, plant stages and larvae evaluated for the 4 field bioassays in head lettuce, YAC, Fall 1996.

Trial[a]	Spray date	Plant stage	BAW larvae evaluated	Application
1	9/11/96	Prethinning (1-2 lvs)	small BAW (1st & 2nd instar,<5 mm in length)	Banded, (8" band above each seedline. 15gpa).
2	9/14/96	Prethinning (2-3 lvs)	small, & large BAW (>10 mm in length)	Banded, (8" band above each seedline. 15gpa).
3	9/30/96	Postthinning (8-10 lvs)	large BAW	Directed, broadcast spray (42" beds), 20 gpa
4	10/8/96	Thinning (3-4 lvs)	small and large BAW	Directed, broadcast spray (42" beds), 20 gpa
LB1	10/8/96	Thinning (3-4 lvs)	2nd instar laboratory reared larvae	Directed, broadcast spray (42" beds), 20 gpa
LB2	11/11/96	Heading stage (16-18 lvs)	2nd instar laboratory reared larvae	Directed, broadcast spray (42" beds), 20 gpa

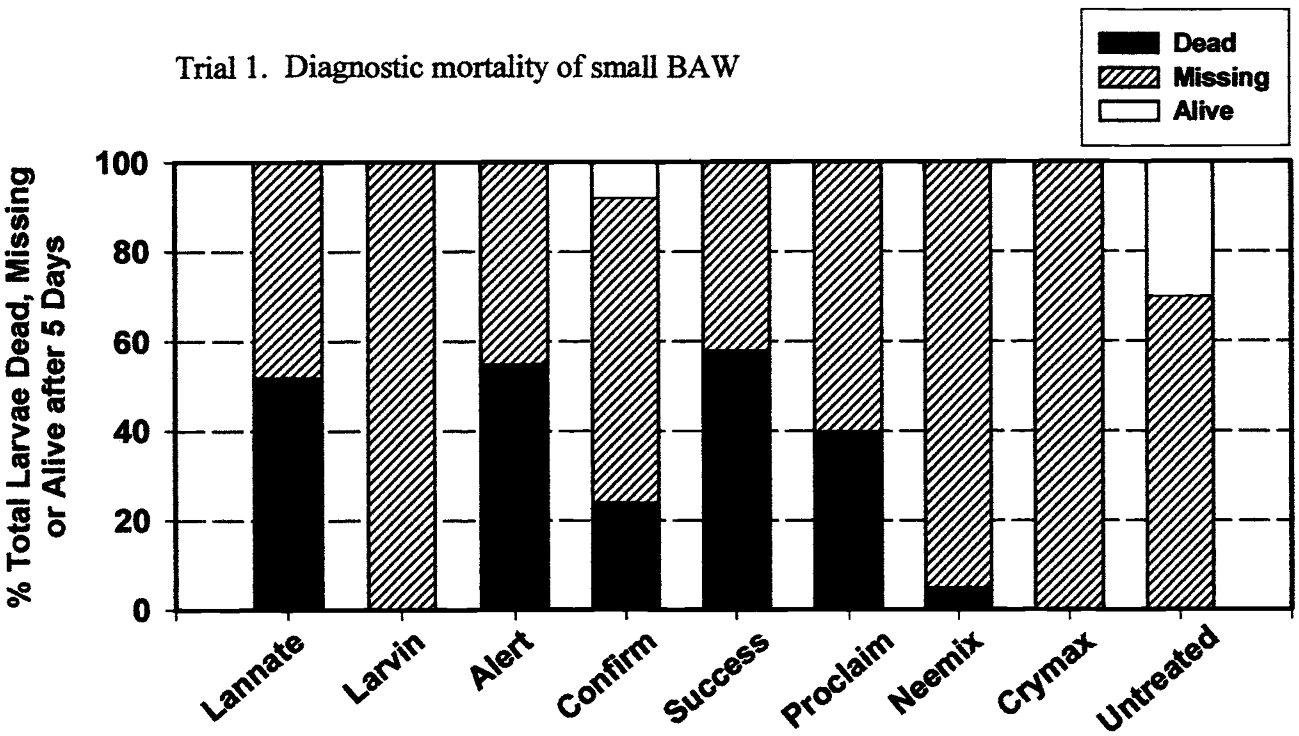
[a] All trials were conducted in separate plot areas., LB refers to laboratory bioassay.

Trial 1. Temporal Mortality of Small Beet Armyworm larvae on Lettuce at 1-5 days after treatment (DAT). Thinning stage (1-2 leaves/plant), treatments applied 9/12/96, wet date 8/30/96.

	% larval mortality , small BAW				
Treatment	1 DAT	2 DAT	3 DAT	4 DAT	5 DAT
Lannate	100 a	100 a	100 a	100 a	100 a
Larvin	100 a	100 a	100 a	100 a	100 a
Alert	96 a	100 a	100 a	100 a	100 a
Confirm	70 b	88 a	88 a	88 a	92 a
Success	95 a	100 a	100a	100 a	100 a
Proclaim	90 a	100 a	100 a	100 a	100 a
Neemix	78 ab	90 a	100 a	100 a	100 a
Crymax	67 b	88 a	100 a	100 a	100 a
Untreated	20 c	35 b	65 b	70 b	70 b
P > F	0.0001	0.0001	0.0003	0.002	0.002

Means followed by the same letter are not significantly different (LSD, P<0.05).

Trial 1. Diagnostic mortality of small BAW

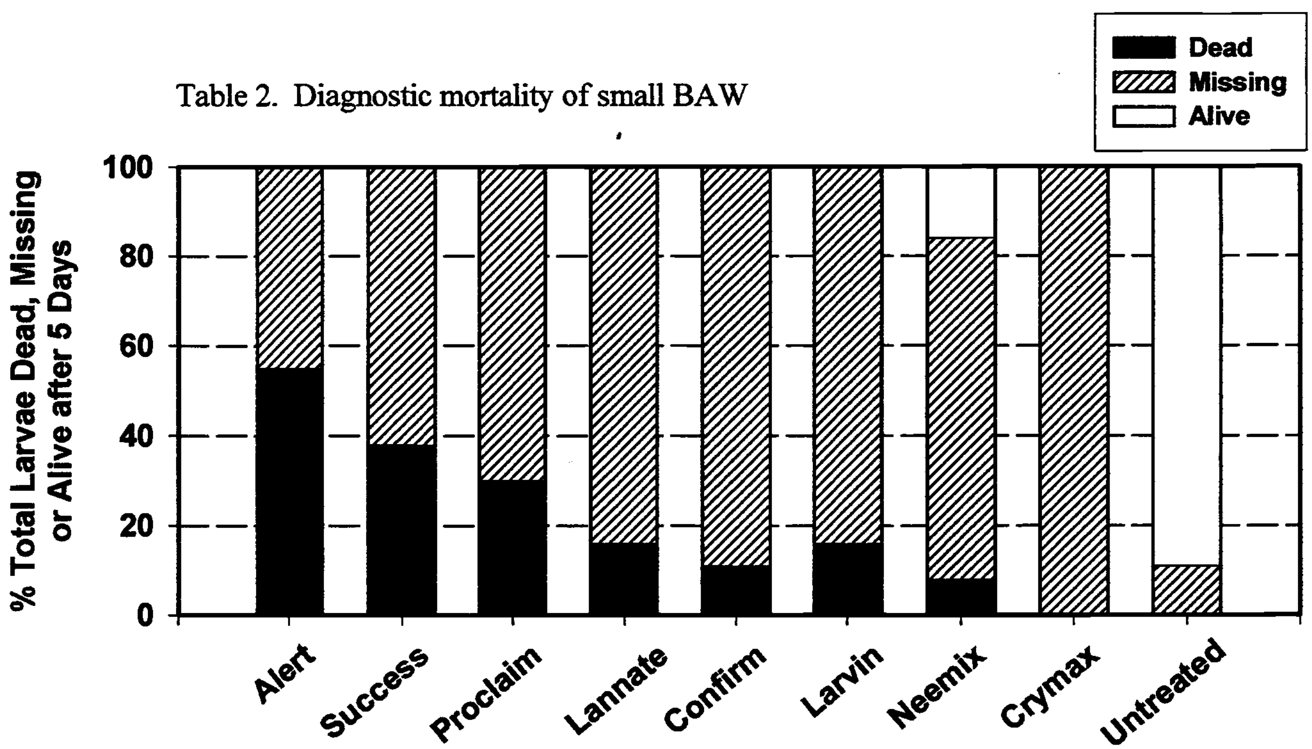


Trial 2. Temporal Mortality of Small Beet Armyworm on Lettuce -Prethinning stage (2-3 leaves/ plant), treatments applied 9/14/96, wet date 8/30/96.

	% larval mortality, small beet armyworm				
Treatment	1 DAT	2 DAT	3 DAT	4 DAT	5 DAT
Lannate	100 a	100 a	100 a	100 a	100 a
Larvin	100 a	100 a	100 a	100 a	100 a
Alert	100 a	100 a	100 a	100 a	100 a
Confirm	100 a	100 a	100 a	100 a	100 a
Success	94 a	100 a	100a	100 a	100 a
Proclaim	84 ab	100 a	100 a	100 a	100 a
Neemix	67 ab	67 b	83 b	83 b	83 b
Crymax	50 b	90 a	100 a	100 a	100 a
Untreated	0 c	0 c	0 c	11 c	11 c
P > F	0.0001	0.0001	0.0003	0.001	0.001

Means followed by the same letter are not significantly different (LSD, P<0.05).

Table 2. Diagnostic mortality of small BAW

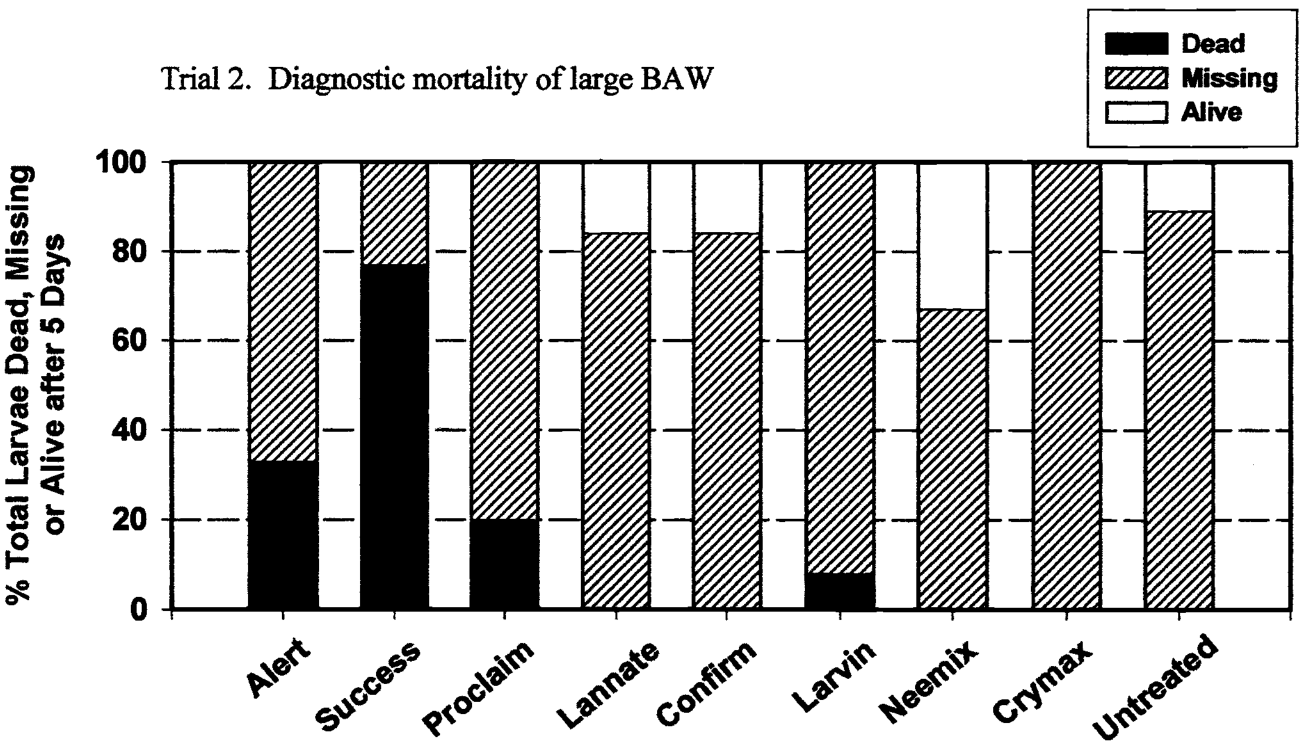


Trial 2. Temporal Mortality of large Beet Armyworm on Lettuce -Prethinning stage (2-3 leaves/plant), treatments applied 9/14/96, wet date 8/30/96.

	% larval mortality, large BAW				
Treatment	1 DAT	2 DAT	3 DAT	4 DAT	5 DAT
Lannate	67 a	67 a	84 a	84 a	84 a
Larvin	88 a	100 a	100 a	100 a	100 a
Alert	100 a	100 a	100 a	100 a	100 a
Confirm	84 a	84 a	84 a	84 a	84 a
Success	88 a	100a	100a	100a	100a
Proclaim	100a	100a	100a	100a	100a
Neemix	33 a	44 a	56 a	56 a	67 a
Crymax	84 a	84 a	100 a	100 a	100 a
Untreated	44 a	55 a	89 a	89 a	89 a
P > *F*	0.25	0.25	0.38	0.38	0.44

Means followed by the same letter are not significantly different (LSD, P<0.05).

Trial 2. Diagnostic mortality of large BAW

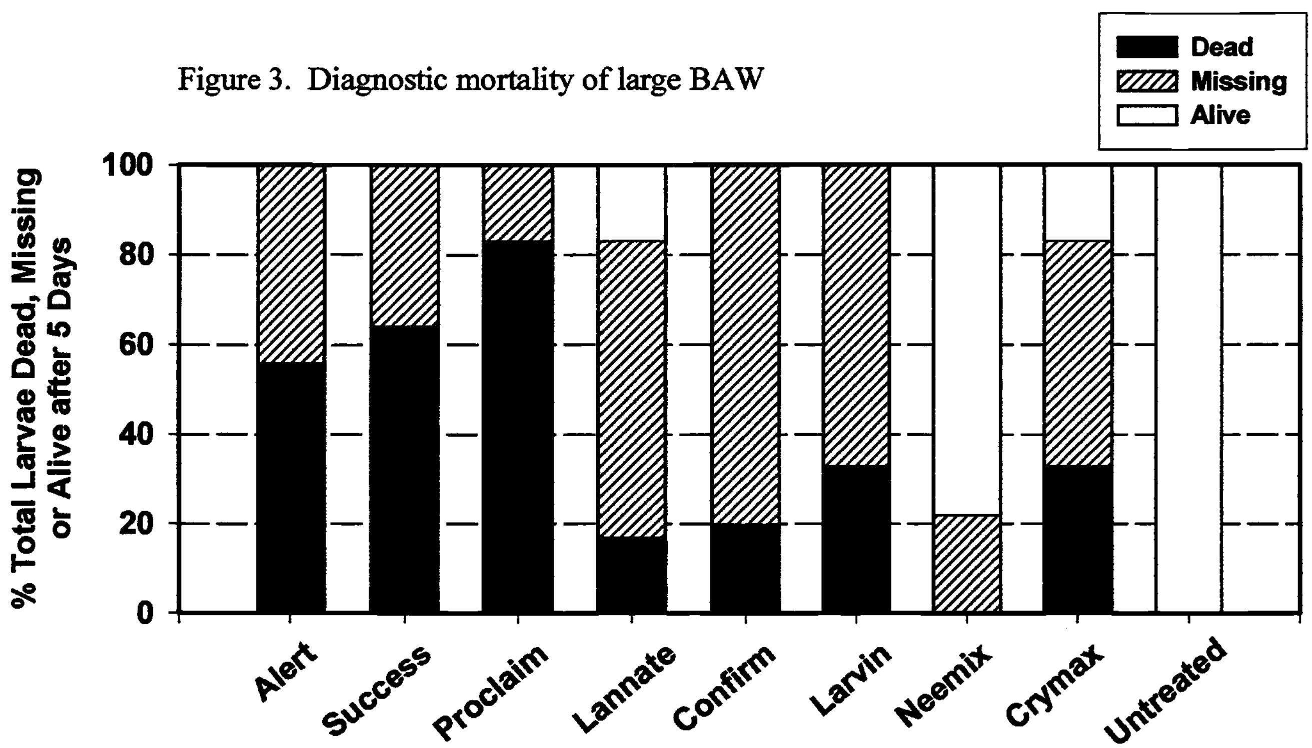


Trial 3. Temporal Mortality of large Beet Armyworm in Lettuce, Post-thinning stage (8-10 leaves/plant), treatments applied 9/30/96, wet date 8/30/96.

	% larval mortality, large BAW				
Treatment	1 DAT	2 DAT	3 DAT	4 DAT	5 DAT
Lannate	25 bc	75 a	83 a	83 a	83 a
Larvin	16 ab	67 a	100 a	100 a	100 a
Alert	100 a	100 a	100 a	100 a	100 a
Confirm	0 c	17 b	81 a	81 a	100 a
Success	36 bc	100 a	100 a	100 a	100 a
Proclaim	67 ab	100 a	100 a	100 a	100 a
Neemix	0 c	0 b	22 bc	22 b	22 b
Crymax	0 c	0 b	67 b	83 a	83 a
Untreated	0 c	0 b	0 c	0 b	0 b
P > F	0.003	0.0001	0.002	0.0001	0.0001

Means followed by the same letter are not significantly different (LSD, P<0.05).

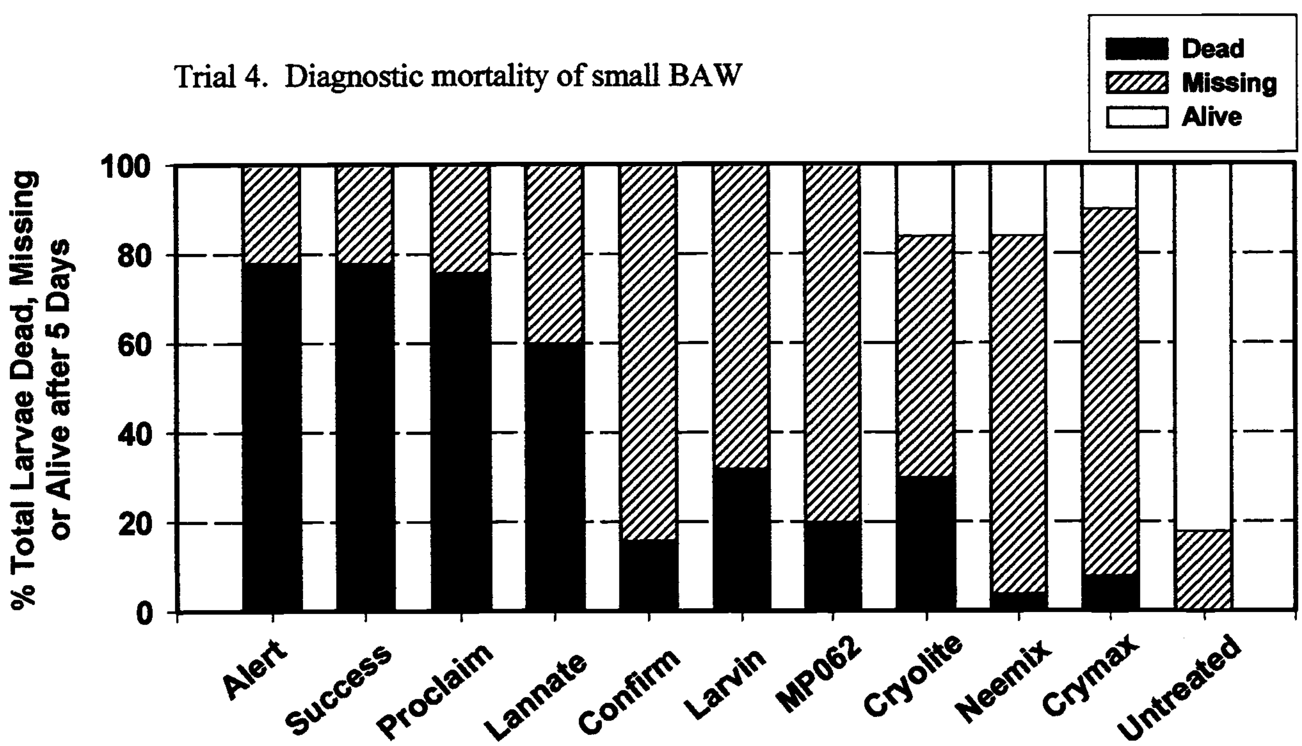
Figure 3. Diagnostic mortality of large BAW



Trial 4. Temporal Mortality of Small Beet Armyworm Larvae in Lettuce, Thinning stage (3-4 leaves/plant), treatments applied 10/8/96, wet date 9/21/96.

	% larval mortality, small BAW				
Treatment	1 DAT	2 DAT	3 DAT	4 DAT	5 DAT
Lannate	80 ab	100 a	100 a	100 a	100 a
Larvin	50 bcd	90 ab	90 ab	100 a	100 a
Alert	100 a	100 a	100 a	100 a	100 a
Confirm	14 de	58 bc	88 ab	88 ab	100 a
Success	85 ab	100 a	100 a	100 a	100 a
Proclaim	93 a	100 a	100 a	100 a	100 a
DPX MP062	20 cde	70 abc	95 a	95 ab	100 a
Cryolite	42 cd	75 abc	75 bc	84 b	84 b
Neemix	50 bc	50 c	70 c	85 b	85 b
Crymax	24 cde	42 c	68 c	85 b	90 ab
Untreated	0 e	0 d	0 d	0 c	18 c
P > F	0.0001	0.0005	0.0001	0.0001	0.0001

Means followed by the same letter are not significantly different (LSD, P<0.05).

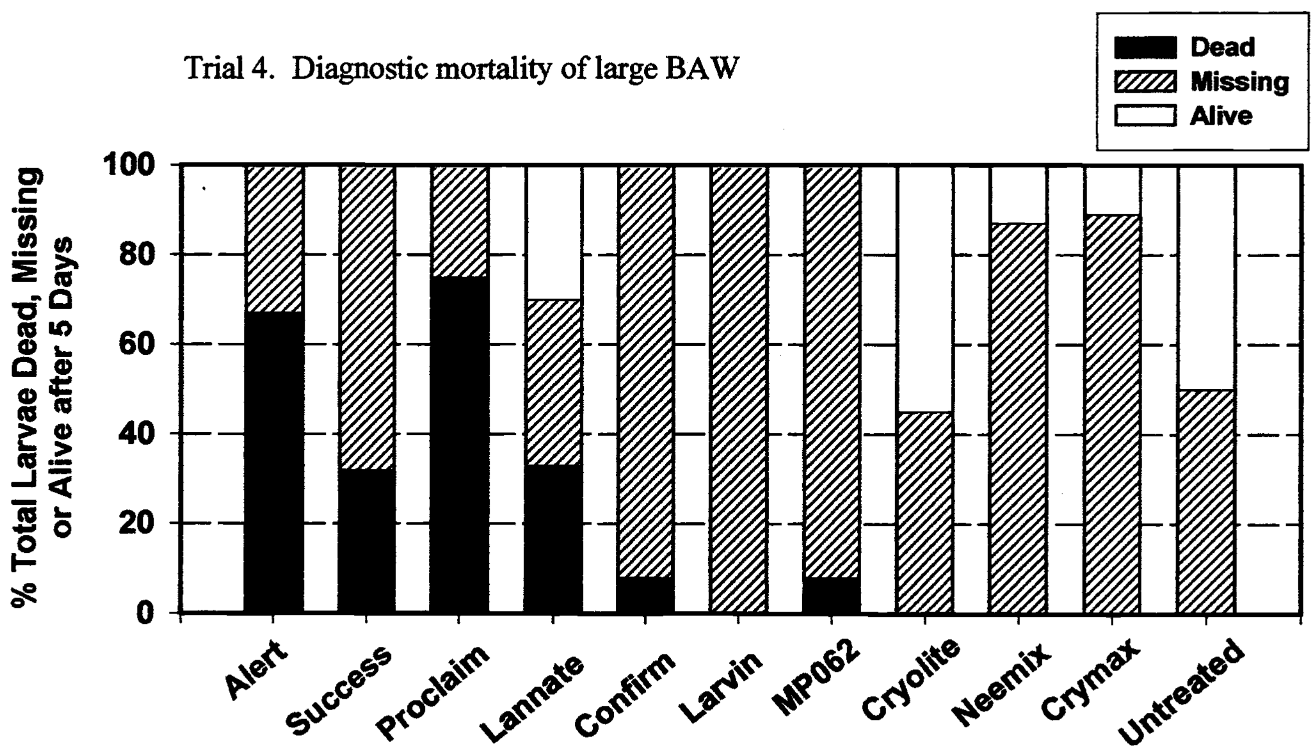


Trial 4. Temporal Mortality of Large Beet Armyworm Larvae in Lettuce, Thinning stage (3-4 leaves/plant), treatments applied 10/8/96, wet date 9/21/96.

	% larval mortality, large BAW				
Treatment	1 DAT	2 DAT	3 DAT	4 DAT	5 DAT
Lannate	70 abc	70 abc	70 ab	70 a	70 a
Larvin	75 abc	100 a	100 a	100 a	100 a
Alert	100 a	100 a	100 a	100 a	100 a
Confirm	44 bcde	68 abc	92 ab	100 a	100 a
Success	85 ab	96 a	96 ab	100 a	100 a
Proclaim	100 a	100 a	100 a	100 a	100 a
DPX MP062	64 abcd	100 a	100 a	100 a	100 a
Cryolite	17 de	28 cd	28 c	44 bc	44 c
Neemix	30 cde	50 bc	78 ab	86 a	86 ab
Crymax	44 bcde	44 cd	55 bc	88 a	88 ab
Untreated	0 e	0 d	22 c	22 c	50 bc
P > F	0.008	0.002	0.003	0.0005	0.02

Means followed by the same letter are not significantly different (LSD, P<0.05).

Trial 4. Diagnostic mortality of large BAW



Lab Bioassay - Thinning stage. Temporal Mortality of Beet Armyworm larvae on Lettuce. Treatments applied 10/9/96, wet date 8/30/96.

	% larval mortality				
Treatment	1 DAT	2 DAT	3 DAT	4 DAT	5 DAT
Lannate	93 a	99 a	100 a	100 a	100 a
Larvin	75 b	88 b	98 a	100 a	100 a
Alert	99 a	100 a	100 a	100 a	100 a
Confirm	8 c	27 c	93 a	97 a	100 a
Success	96 a	99 a	100 a	100 a	100 a
Proclaim	97 a	100 a	100 a	100 a	100 a
Neemix	4 c	4 d	12 c	24 c	54 c
Crymax	3 c	14 d	51 b	67 b	78 b
Untreated	3 c	3 d	5 c	7 d	7 d
P > F	0.0001	0.0001	0.0001	0.0001	0.0001

Lab Bioassay - Heading stage. Temporal Mortality of Beet Armyworm larvae on Lettuce. Treatments applied 11/11/96, wet date 8/30/96.

	% larval mortality				
Treatment	1 DAT	2 DAT	3 DAT	4 DAT	5 DAT
Lannate	90 a	99 a	100 a	100 a	100 a
Larvin	89 a	98 a	100 a	100 a	100 a
Alert	95 a	100 a	100 a	100 a	100 a
Confirm	28 bc	82 ab	93 a	97 a	100 a
Success	94 a	100 a	100 a	100 a	100 a
Proclaim	96 a	99 a	100 a	100 a	100 a
Neemix	13 cd	26 c	38 b	43 b	65 b
Crymax	37 b	70 b	88 a	88 a	90 a
Untreated	2 d	12 c	22 b	22 b	22 c
P > F	0.0001	0.0001	0.0001	0.0001	0.0001

Means followed by the same letter are not significantly different (LSD, P<0.05).