Chemical Control/New Products

FIELD AND LABORATORY TRIALS AGAINST WESTERN TENTIFORM LEAFMINER

Elizabeth H. Beers and Peter D. Himmel
Washington State University Tree Fruit Research and Extension Center, Wenatchee, WA

Keywords: Actara, thiamethoxam, Provado, imidacloprid, Intrepid, methoxyfenozide, Success, spinosad, Agri-Mek, abamectin, Orchex, oil, Raynox, particle film, Surround, kaolin, Avaunt, indoxacarb, western tentiform leafminer, *Phyllonorycter elmaella, Pnigalio flavipes*

Abstract: Various insecticides were tested against leafminer in a heavily infested apple orchard near Brewster, Washington. Of the treatments tested, only Success + oil (peak sapfeeder) and Agri-Mek+oil (early tissuefeeder) were effective in reducing leafminer populations. There is some evidence to support changing the recommended timing to somewhat earlier than the traditional 10% tissuefeeder stage. Two greenhouse bioassays were performed by releasing 500-700 adult leafminers into cages containing 24 potted apple seedlings (4 treatments x 6 reps). Treatments were applied either prior to introduction or at various times throughout the larval development period. Surround, Raynox and Intrepid when applied pre-exposure to adults gave ≈50% suppression of the numbers of total and live mines. In the Intrepid treatment, it appeared that if the larvae survived until the tissue feeder stage, they survived the treatment; most of the mortality occurred at the sapfeeder stage. Avaunt, applied either during the egg or sapfeeder stage, did not reduce leafminer populations in relation to the check. The standard treatment, Success plus oil targeting sapfeeders, reduced the resulting population to a very low level.

This test was designed primarily to test new materials (e.g., Actara) against second generation leafminers, the primary period of control for this pest. This test emphasized timing and, to a lesser extent, rates of the various materials. Agri-Mek and Success were the standard treatments, although they were applied at different times.

Materials and Methods - Field Trial

The experiment was conducted at the Richard Thomassen block, Brewster, WA. The block was composed of 'Delicious' apples with 'Golden Delicious' pollenizers. Row spacing was 18-20 ft, and tree spacing was variable due to interplanting. Each plot consisted of 3 rows with 8 trees/row. Samples consisted of 50-80 leaves/replicate, confining the samples to the center trees in the center row of the plot. Samples were taken pre-treatment and ca. weekly posttreatment through ca 15% emergence of the adults of the second generation. The leaves were taken from the mid-shoot of the current year's extension growth to avoid empty (emerged) mines of the first generation (typically found on the cluster leaves and the lower 1/3 of the terminals). Similarly, the distal 1/3 of the terminals was also avoided since these leaves were, in some cases, too recent to have been available to the ovipositing females of the 2nd generation. Leafminer and parasitoid (primarily *Pnigalio flavipes*) populations were evaluated by counting all mines on the sample and then dissecting a minimum of 100 mines and recording the stage and status (dead or alive) of the leafminer or parasite. Eggs were counted in a separate evaluation that examined leafminer phenology.

Treatments were applied with a Rears Pak-Blast® (Rears Mfg., Eugene, OR) sprayer calibrated for 200 gpa on 3 dates (23 June, 30 June, 6 July). The timings were designed to target the sapfeeding stage of the second generation, with the earliest timing at ca. 50% sapfeeders, the middle timing ca. 100% sapfeeders, and the last timing 10% tissuefeeders (the standard timing) (Table 1).

Table 1. Leafminer phenology on or near the day of application, Brewster, WA 2001

Date of Sample	Spray timing	% egg	% sap	% tissue feeder	% pupae
23-Jun	Early	27%	56%	0%	0%
28-Jun	[Mid]	4%	92%	0%	0%
6-Jul	[Late]	0%	80%	14%	0%

The experimental design was a randomized complete block with 15 treatments and 4 replicates. The plots were randomized on the basis of the geographic blocks. Prior to analysis, data were examined for homogeneity of variance using Levene's (1960) test. If variances were heterogeneous, data were transformed ($\ln[y+0.5]$) (or the arcsine$\sqrt{y}$ for % parasitism) with treatment mean separation using the Waller-Duncan *k*-ratio *t*-test (SAS Institute 1988).

Materials and Methods - Bioassays

Apple seedlings ca. 0.5 to 0.75 m in height were maintained in a greenhouse until the time of the test. Trees were treated with a dilute solution of dish soap to suppress mites and mildew without leaving residues potentially toxic to other pests. Treatments were applied 27 July with a pressurized hand sprayer to the point of drip and allowed to dry. Trees were placed in an organdy screen cage (103 cm w × 85 cm h × 74 cm d) in a completely randomized design and 587 unsexed adult moths were introduced into the cage. The moths were left in for the duration of the experiment (20 days, 16 August), at which time the resulting damage was evaluated. Leafminer population assessment was made by removing all leaves from the trees and dissecting all mines found to determine stage (sapfeeder, tissuefeeder, pupa, emerged) and status (alive or dead). Eggs were also counted at this time.

Data were analyzed using the Statistical Analysis System (SAS 1988). Data were tested prior to analysis for homogeneity of variance using Levene's (1960) test. Variances found to be non-homogeneous were transformed [ln(y+0.5)] before analysis. PROC GLM was used to conduct an analysis of variance, and treatment means were separated using the Waller-Duncan *k*-ratio *t*-test.

Results and Discussion - Field Trial

Of the treatments and timing tried, only Success+oil (middle timing) and Agri-Mek+oil (late timing) appeared to have any effect on the number of live mines (Table 2, Fig. 1), with the

latter somewhat slower acting. Interestingly, both of these treatments used oil as an adjuvant, although it seems unlikely that this factor alone could be responsible for their success. The timing for the Success treatment, plus the high rate of oil, was probably optimum for this material. While in the past we have recommended the 10% tissue feeder stage as the optimum target for this generation, the peak sapfeeder stage may be more effective. The rationale for the later timing was to allow time for egg hatch to be completed, however, in this trial, egg hatch was virtually complete at the peak sapfeeder timing (Table 1). Parasitism was low initially (due to the lack of appropriate life stages of leafminer) but rose only slightly during the course of the test. Several of the treatments cause a reduction in the percentage parasitism (Provado [E, M, L]; Actara [M, L]; Success [M]; Agri-Mek [L]), although in some cases this was most likely due to a reduction of the host population.

Results and Discussion - Bioassay #1

Leafminers were virtually all in the larval stage at the time of evaluation (Table 3). In the bottom portion of the tree, ≈76% were in the tissuefeeder stage. The lower percentage of tissuefeeder in the top portion of the tree probably reflects eggs that were deposited later, since this foliage was not available at the beginning of the experiment. A few eggs and pupae were found, although none in the controls.

Table 3. Leafminer phenology in the untreated control trees on the date of evaluation (16 Aug 2001)

	% in Stage					
Tree section	Egg	Sapfeeders	Tissuefeeders	Pupae	Emerged	Total live mines/leaf
Bottom	0	24.39	75.61	0	0	2.59
Top	0	53.86	46.14	0	0	1.13

Similarly, mine density was much lower in the top of the trees than in the bottom (Table 4); females had deposited much of their egg load by the time this foliage was available, and generally young tissue is less attractive to ovipositing females.

All three treatments suppressed leafminer populations in comparison to the check (Table 4, Fig. 2), although no statistical difference between treatments was found. The Intrepid treatment (bottom) had a lower percentage of live mines than the other treatment, perhaps pointing to a different mode of population suppression. The mines were formed, but larval survival was reduced, whereas in the case of the PFTs, oviposition was probably inhibited by the presence of the material on the leaf surface. There was also a trend to have a lower percentage of tissuefeeders in the Intrepid treatment (Table 5), although this difference was not significant. It appeared as though most of the mortality occurred in the egg or larval stage with this compound.

Despite the thorough spray, which included the lower leaf surface, the coverage of the leaf surface with the PFTs was visibly irregular and incomplete by the time the leaves were

evaluated. It appeared as though coverage on the lower leaf surface (where leafminer eggs are deposited) was poor in comparison to the upper surface, but even those surfaces had gaps in coverage. It may have been possible for the females to avoid the treatments in part, allowing for more oviposition than if total coverage had been achieved. It is unclear if this is an artifact of the application method or an intrinsic property of the material.

Results and Discussion - Bioassay #2

Leafminers were primarily in the sap and tissuefeeder stage on 27 September, 13 days after the second treatment timing and 23 days after the introduction of moths for oviposition.

Date	% Egg	% Sapfeeders	% Tissuefeeders	% Pupae	% Emerged
27-Sep-01	0.41	39.04	56.42	4.13	0

The Avaunt application targeting eggs had no apparent effect on subsequent leafminer development (Table 6, Fig. 3). The later application of Avaunt targeting sapfeeders suppressed the population, although not to the same extent as did the standard material, Success, at the same timing.

References Cited

Levene, H. 1960. Robust tests for equality of variances. Chap. 25. *In* Olkin, I., S. G. Ghurye, W. Hoeffding, W. G. Madow and H. B. Mann (Eds.), Contributions to probability and statistics. Stanford University Press, Stanford, CA.

Statistical Analysis Institute. 1988. SAS/Stat User's Guide, Release 6.03 Edition. SAS Institute, Inc., Cary, NC.

Table 2. Leafminer populations before and after treatment with insecticides at various timings, Brewster, 2001

Treatment	Rate fm/ acre	Timing	Mines/leaf				
			25-Jun	2-Jul	9-Jul	16-Jul	23-Jul
Actara 25WG	4.5 oz	Early	3.59 a	5.17 a	5.12 b	5.90 a	5.35 abc
Actara 25WG	5.5 oz	Early	3.08 a	5.10 a	5.79 abc	6.21 a	5.36 abc
Actara 25WG	4.5 oz	Mid	2.58 a	5.40 a	6.71 ab	6.21 a	5.35 abc
Actara 25WG	5.5 oz	Mid	2.97 a	5.61 a	5.80 ab	6.82 a	6.03 abc
Actara 25WG	4.5 oz	Late	2.41 a	5.74 a	7.68 a	7.35 a	7.21 ab
Actara 25WG	5.5 oz	Late	3.22 a	5.78 a	6.80 ab	7.08 a	6.07 abc
Provado 1.6F	8 fl oz	Early	2.11 a	4.59 a	3.57 c	4.91 a	3.83 c
Provado 1.6F	8 fl oz	Mid	3.09 a	5.84 a	5.51 abc	5.67 a	5.85 abc
Provado 1.6F	8 fl oz	Late	3.09 a	5.47 a	6.52 ab	6.41 a	7.49 a
Intrepid 2F	10 fl oz	Early	2.42 a	4.62 a	6.41 ab	6.52 a	5.93 abc
Intrepid 2F	10 fl oz	Mid	3.30 a	4.84 a	5.00 bc	5.83 a	4.93 bc
Intrepid 2F	10 fl oz	Late	3.05 a	6.88 a	6.43 ab	6.40 a	7.66 a
Success 2SC+oil	6 fl oz	Mid	3.05 a	6.73 a	5.90 ab	4.95 a	5.85 abc
Agri-Mek 0.15EC+oil	10 fl oz	Late	2.78 a	5.28 a	6.59 ab	6.67 a	4.95 bc
Check	----	----	3.29 a	5.09 a	6.33 ab	7.28 a	6.94 ab

Early = 23 June; Mid = 30 June; Late= 6 July 2001. Due to variable row spacing, nominal rate/acre may be only 90% of that listed.
Oil was Orchex 796 1% (Success) 0.25% (Agri-Mek) vol:vol.

Table 2. cont'd

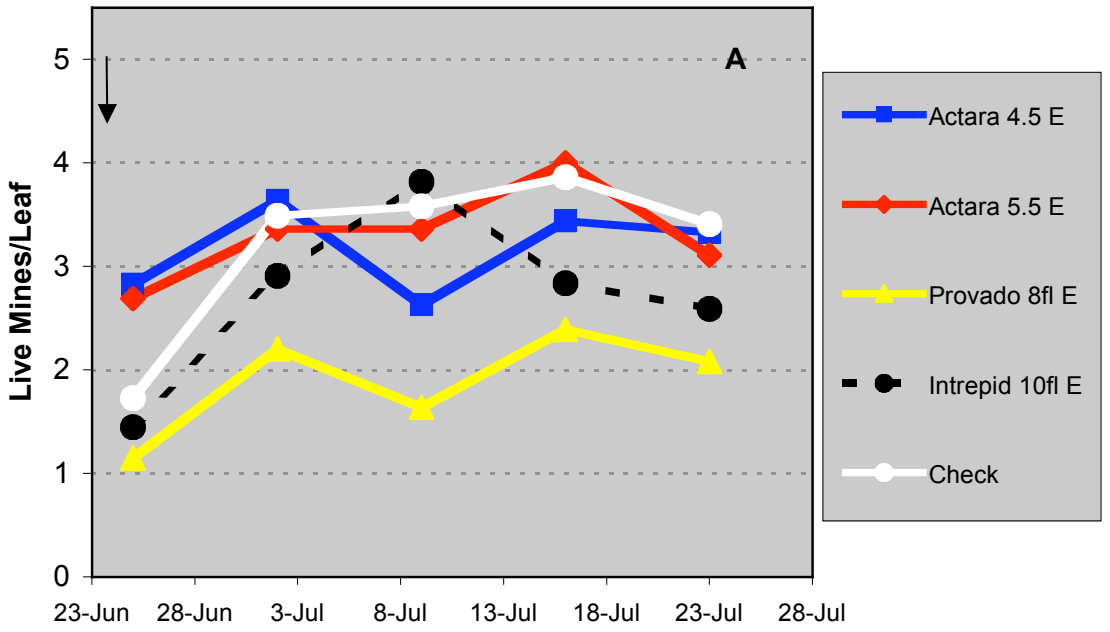
Treatment	Rate fm/ acre	Timing	Live mines/leaf 25-Jun	2-Jul	9-Jul	16-Jul	23-Jul
Actara 25WG	4.5 oz	Early	2.83 a	3.64 abc	2.63 c	3.44 ab	3.33 bcde
Actara 25WG	5.5 oz	Early	2.69 ab	3.36 abc	3.36 abc	4.00 ab	3.11 cde
Actara 25WG	4.5 oz	Mid	2.21 abc	3.82 abc	3.80 abc	3.98 ab	3.25 cde
Actara 25WG	5.5 oz	Mid	2.09 abc	3.53 abc	3.51 abc	4.42 ab	4.35 abc
Actara 25WG	4.5 oz	Late	1.27 bc	3.43 abc	4.76 a	4.47 a	4.94 ab
Actara 25WG	5.5 oz	Late	2.01 abc	3.34 abc	3.71 abc	4.52 a	3.98 abcd
Provado 1.6F	8 fl oz	Early	1.15 c	2.20 bc	1.64 d	2.39 bc	2.08 ef
Provado 1.6F	8 fl oz	Mid	1.12 c	4.35 ab	3.75 abc	3.85 ab	4.17 abcd
Provado 1.6F	8 fl oz	Late	2.32 abc	3.86 abc	3.06 bc	3.81 ab	4.92 ab
Intrepid 2F	10 fl oz	Early	1.45 abc	2.91 abc	3.82 abc	2.84 abc	2.59 de
Intrepid 2F	10 fl oz	Mid	2.54 abc	3.03 abc	3.22 bc	3.26 abc	2.76 cde
Intrepid 2F	10 fl oz	Late	2.00 abc	4.92 a	4.09 ab	3.89 ab	5.17 a
Success 2SC+oil	6 fl oz	Mid	2.10 abc	1.67 c	0.08 e	0.21 d	0.31 g
Agri-Mek 0.15EC+oil	10 fl oz	Late	1.63 abc	3.32 abc	2.56 c	1.35 cd	0.67 fg
Check	----	----	1.73 abc	3.49 abc	3.58 abc	3.86 ab	3.41 bcd

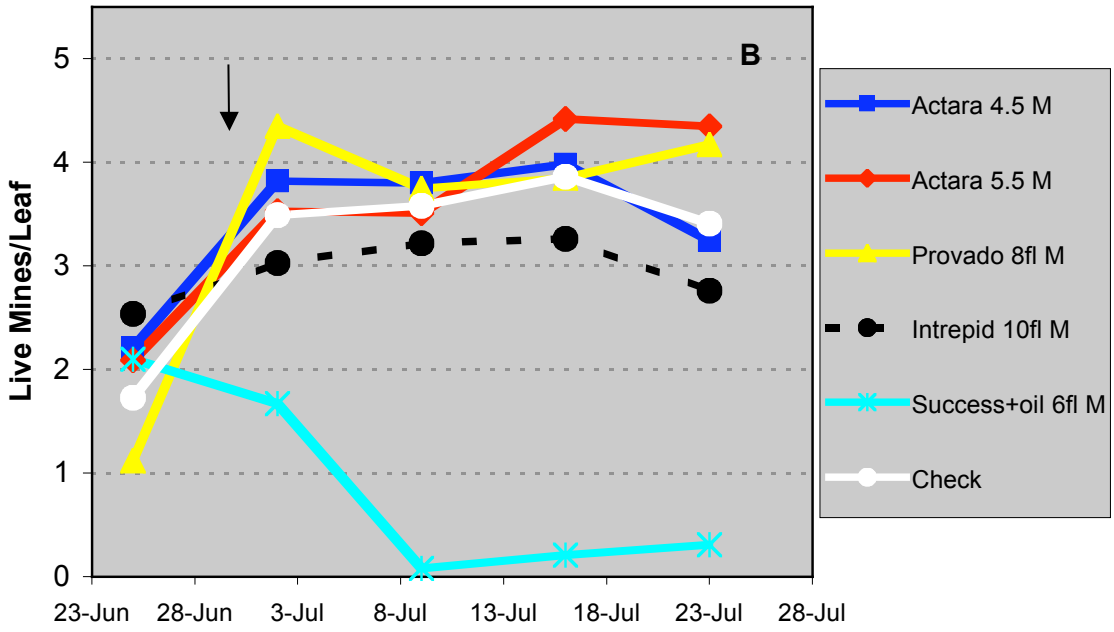
Table 2. cont'd

Treatment	Rate fm/ acre	Timing	% Live mines 25-Jun	2-Jul	9-Jul	16-Jul	23-Jul
Actara 25WG	4.5 oz	Early	77 abc	70 ab	50 abc	58 abc	61 abcd
Actara 25WG	5.5 oz	Early	85 a	64 ab	59 abc	65 a	58 bcde
Actara 25WG	4.5 oz	Mid	86 a	70 ab	56 abc	62 ab	59 abcd
Actara 25WG	5.5 oz	Mid	70 abcd	62 ab	60 abc	64 a	73 a
Actara 25WG	4.5 oz	Late	52 cde	61 ab	61 abc	61 ab	67 ab
Actara 25WG	5.5 oz	Late	64 abcd	59 ab	57 abc	64 a	65 abc
Provado 1.6F	8 fl oz	Early	56 bcde	46 bc	46 bc	48 bc	53 cde
Provado 1.6F	8 fl oz	Mid	37 e	73 a	68 a	67 a	69 ab
Provado 1.6F	8 fl oz	Late	74 abcd	71 ab	47 bc	57 abc	66 abc
Intrepid 2F	10 fl oz	Early	56 bcde	66 ab	58 abc	44 c	44 e
Intrepid 2F	10 fl oz	Mid	78 ab	60 ab	63 ab	54 abc	52 cde
Intrepid 2F	10 fl oz	Late	67 abcd	72 ab	64 ab	62 ab	65 abc
Success 2SC+oil	6 fl oz	Mid	69 abcd	27 c	2 d	4 e	4 f
Agri-Mek 0.15EC+oil	10 fl oz	Late	58 bcde	62 ab	43 c	23 d	15 f
Check	----	----	51 de	70 ab	58 abc	56 abc	50 de

Table 2. cont'd

Treatment	Rate fm/ acre	Timing	% Parasitized mines 25-Jun	2-Jul	9-Jul	16-Jul	23-Jul
Actara 25WG	4.5 oz	Early	0.0 a	1.0 a	6.7 a	11.6 abcd	19.5 abc
Actara 25WG	5.5 oz	Early	0.0 a	0.5 a	4.1 abc	13.0 ab	16.5 abcd
Actara 25WG	4.5 oz	Mid	0.0 a	0.3 a	0.9 c	4.1 ef	13.5 bcd
Actara 25WG	5.5 oz	Mid	0.7 a	0.5 a	1.5 bc	7.0 cdef	8.5 cde
Actara 25WG	4.5 oz	Late	0.0 a	0.0 a	4.2 abc	6.5 cdef	9.1 cde
Actara 25WG	5.5 oz	Late	0.5 a	0.7 a	5.7 ab	4.3 ef	10.1 cde
Provado 1.6F	8 fl oz	Early	0.3 a	0.0 a	4.0 abc	8.0 bcde	14.6 bcd
Provado 1.6F	8 fl oz	Mid	0.0 a	0.0 a	2.8 abc	4.3 ef	11.8 bcde
Provado 1.6F	8 fl oz	Late	0.0 a	0.5 a	4.6 abc	5.1 ef	7.5 de
Intrepid 2F	10 fl oz	Early	0.3 a	0.3 a	2.3 abc	11.9 abc	21.5 ab
Intrepid 2F	10 fl oz	Mid	0.0 a	0.3 a	2.9 abc	13.2 ab	24.8 a
Intrepid 2F	10 fl oz	Late	0.0 a	0.3 a	4.0 abc	6.0 def	13.8 abcd
Success 2SC+oil	6 fl oz	Mid	0.5 a	0.5 a	0.3 c	1.3 f	0.7 e
Agri-Mek 0.15EC+oil	10 fl oz	Late	0.0 a	0.5 a	4.4 abc	9.2 abcde	11.8 bcde
Check	----	----	0.0 a	0.5 a	4.8 abc	14.3 a	24.9 a


A
Live Mines/Leaf
0
1
2
3
4
5
23-Jun
28-Jun
3-Jul
8-Jul
13-Jul
18-Jul
23-Jul
28-Jul
Actara 4.5 E
Actara 5.5 E
Provado 8fl E
Intrepid 10fl E
Check


B
Live Mines/Leaf
0
1
2
3
4
5
23-Jun
28-Jun
3-Jul
8-Jul
13-Jul
18-Jul
23-Jul
28-Jul
Actara 4.5 M
Actara 5.5 M
Provado 8fl M
Intrepid 10fl M
Success+oil 6fl M
Check

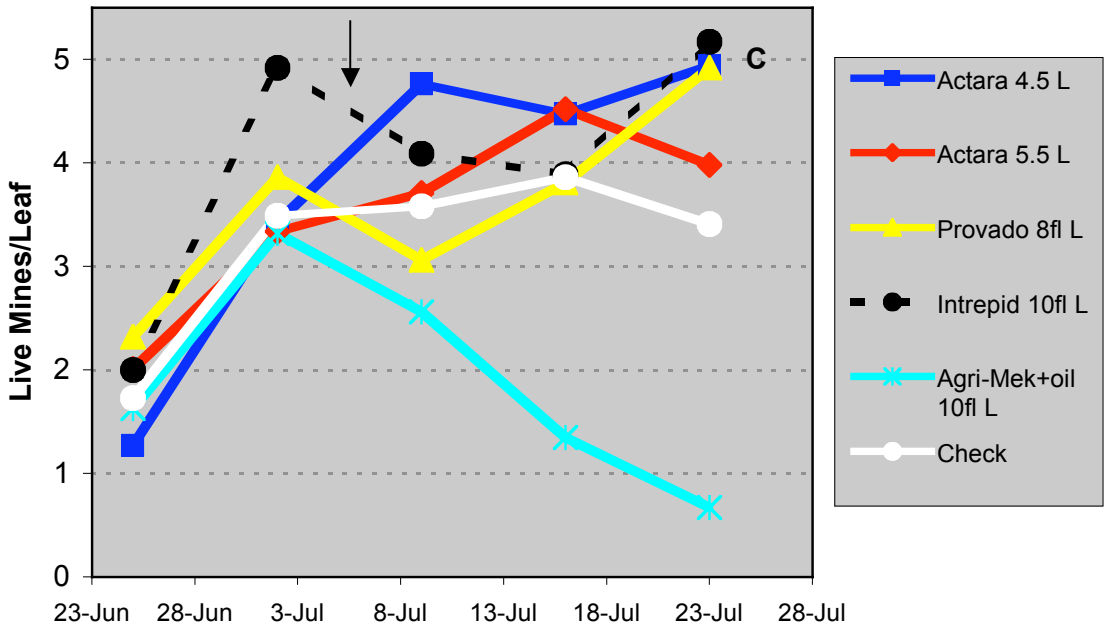


Fig. 1. Live leafminer mines/leaf before and after treatment with insecticides at various timings (A, 23 June; B, 30 June; C, 6 July), Brewster, 2001.

Table 4. Leafminer populations 20 d after treatment with various compounds

Tree Section	Treatment	Rate/acre (200 gpa)	Rate/ 1 gallon	n	Total mines/leaf	No. live mines/leaf	% Live mines
Bottom	Intrepid 2F	10 fl oz	1.5 ml	6	1.54 b	1.03 b	66.93 c
	Raynox	20 lb	0.5 gal	6	1.27 b	1.16 b	91.35 ab
	Surround WP	50 lb	0.25 lb	6	1.37 b	1.28 b	92.75 a
	Check	----	---	6	3.04 a	2.59 a	85.21 b
Top	Intrepid 2F	10 fl oz	1.5 ml	5	0.35 b	0.25 b	39.70 b
	Raynox	20 lb	0.5 gal	6	0.19 b	0.13 b	13.33 b
	Surround WP	50 lb	0.25 lb	6	0.50 b	0.50 b	83.33 a
	Check	----	---	6	1.47 a	1.13 a	81.85 a

Treatments applied 27 July; evaluated 16 August 2001 with pressurized hand sprayer to point of drip.

Table 5. Percentage of total, live and dead tissuefeeders in the various treatments

Tree Section	Treatment	Rate/acre (200 gpa)	Rate/ 1 gallon	n	Total	% Tissuefeeder Live	Dead
Bottom	Intrepid 2F	10 fl oz	1.5 ml	6	50 a	47 a	2.7 a
	Raynox	20 lb	0.5 gal	6	63 a	61 a	2.0 a
	Surround WP	50 lb	0.25 lb	6	67 a	65 a	1.7 a
	Check	----	---	6	70 a	65 a	4.9 a
Top	Intrepid 2F	10 fl oz	1.5 ml	3	48 a	40 a	8.3 a
	Raynox	20 lb	0.5 gal	2	30 a	30 a	0.0 a
	Surround WP	50 lb	0.25 lb	5	29 a	29 a	0.0 a
	Check	----	---	6	41 a	38 a	2.5 a

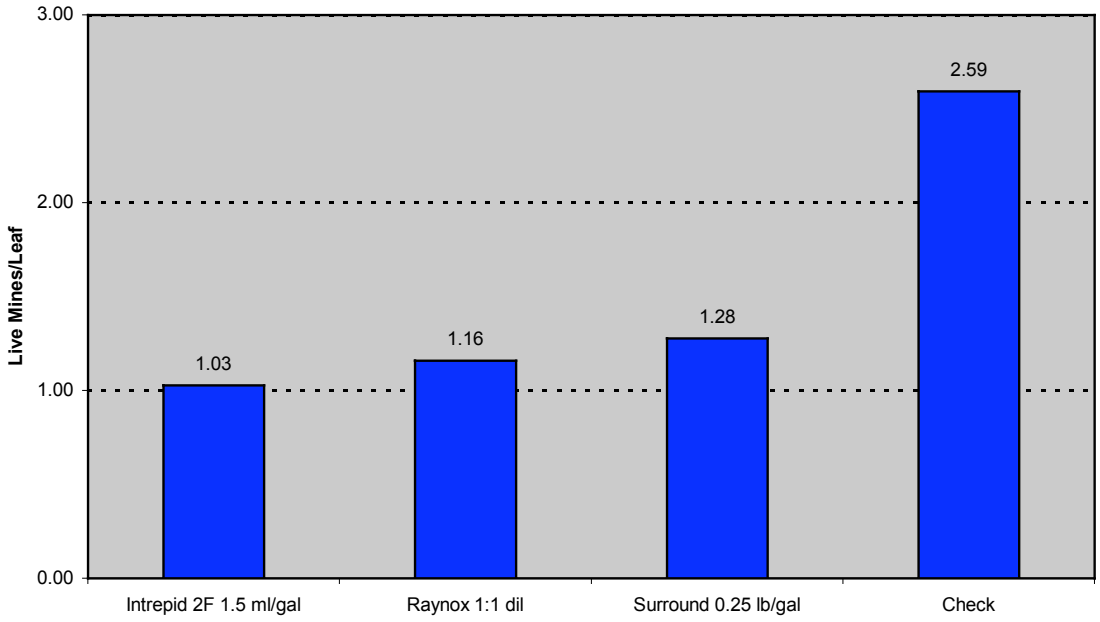


Fig. 2. Live leafminer mines/leaf (bottom portion only).

Table 6. Survival of leafminers after treatment with Avaunt and Success in a caged potted tree bioassay, 2001

Treatment	Nominal rate/acre	Rate form./ gallon	Target: date treated	n	Whole tree mines/leaf	% Live[x]	Live mines/ dissected leaf
Avaunt 30DG +Orchex 796	6 oz + 1% vol/vol	0.9 g +1.2 fl oz	Eggs; 7 Sep	6	1.34 a	81.0% a	1.85 a
Avaunt 30DG +Orchex 796	6 oz + 1% vol/vol	0.9 g +1.2 fl oz	Sap; 14 Sep	6	0.90 a	53.2% b	1.22 b
Success 2L +Orchex 796	6 fl oz + 1% vol/vol	0.9 ml +1.2 fl oz	Sap; 14 Sep	5	0.90 a	8.8% c	0.14 c
Check	-----			6	1.19 a	65.7% b	1.60 ab

Moths introduced into cage 4 Sep.

[x]Data transformed prior to analysis [y=arcsine(square root(y)] due to nonhomogenous variances.

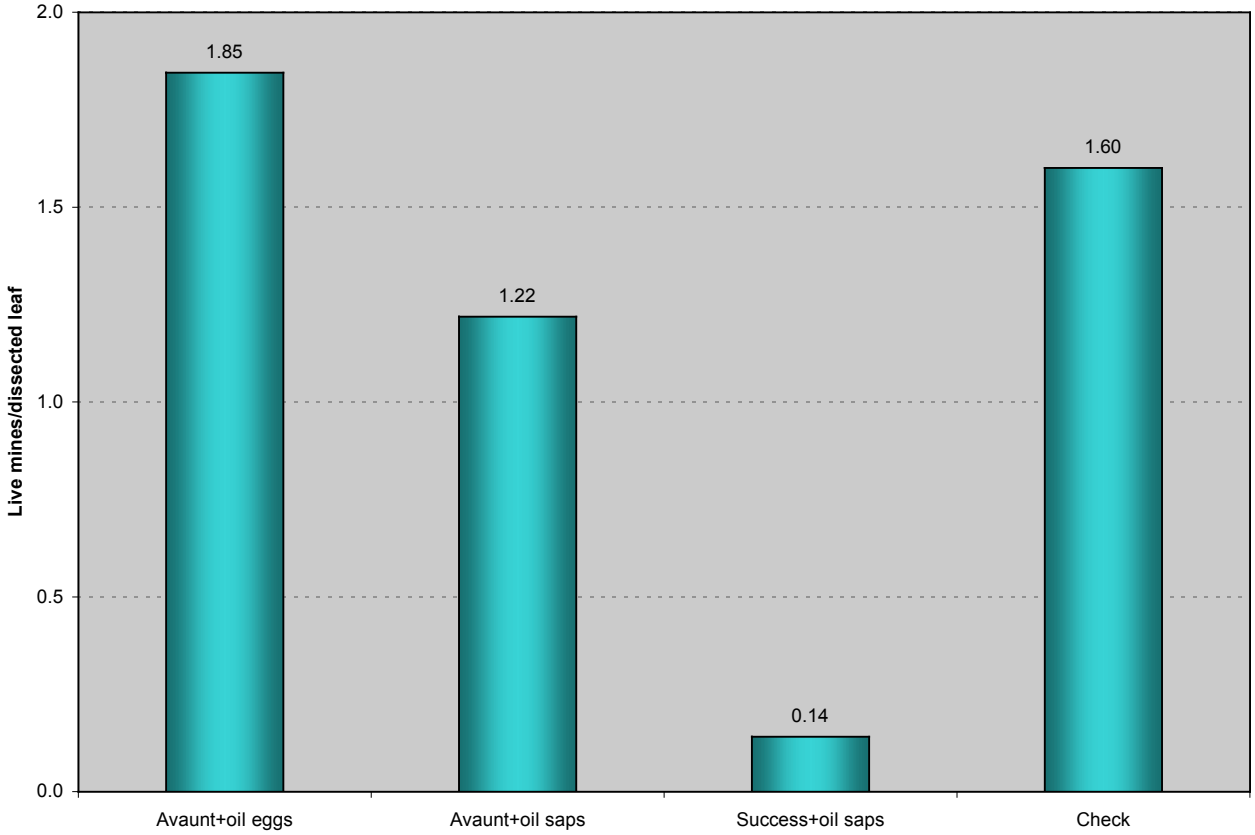


Fig. 3. Live mines following treatment with Avaunt or Success at two timings, greenhouse bioassay, 2001.