Alternative IPM Programs for Management of Lepidopterous Larvae in Fall Lettuce

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Abstract

For a third year, a large block experiment was conducted at the Yuma Ag Center to compare the field performance of several lettuce IPM programs for control of lepidopterous larvae. Conventional, Reduced -risk , Bio-based and Modified IPM spray regimes were applied to control beet armyworm, cabbage looper and Heliothis species throughout the fall growing season. Differences in populations of total larvae among the treatments, relative to insecticide treatments and timing of application were observed at various times during the season. In general, the Conventional, Reduced -risk and Modified IPM approaches provided the most consistent control of lepidopterous larvae following each application. Harvest data showed that the spray regimes had a significant influence of head lettuce yield or quality. Maturity and quality were significantly reduced in the untreated control. An economic analysis shows that net returns varied widely among the management programs at different market prices. In conclusion, this study provides a strong data base to support the need for the development of experimental and biorational insecticide products as alternatives to conventional management programs in desert lettuce production. In addition, it demonstrates the dependance of IPM programs on a broad range of plant protection chemicals and control tactics.

Introduction

The beet armyworm, cabbage looper and *Heliothis* species are the major lepidopterous pests of lettuce in desert growing areas of Arizona (Kerns and Palumbo 1997) . Standard insecticides such as methomyl (Lannate) and thiodicarb (Larvin) combined with pyrethroids (Mustang, Warrior) have been successfully used in controlling this pest complex over the past several years (Palumbo et al. 1993, Palumbo et al. 1994, Palumbo 1996). These products are used frequently during the season, and many speculate that there field effectiveness will soon be reduced under these use patterns. Unfortunately, there are no alternatives insecticides which offer comparable control of lepidopterous larvae. Furthermore, with the recent passage of the Food Quality Protection Act of 1996 (Schreiber 1996), 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.

There are several alternative products available to lettuce growers for management of the lepidopterous complex. However, these consist of biological (Bts), botanical (neem pyrethrum, rotenone) and inorganic (cryolite) insecticides that have been demonstrated to have only marginal activity on beet armyworm and cabbage looper in lettuce (Palumbo et al. 1992, Palumbo 1995). There activity against Heliothis is not known. Several new compounds are currently being developed which offer not only excellent efficacy against these pests, but are also new insecticide chemistries (Palumbo and Kerns 1996). We are uncertain how these alternatives will perform in the absence of the conventional insecticide products under desert growing conditions. However, similar studies to this one have suggested that the Reduced-risk or Bio-based compounds used alone may not provide sufficient plant protection (Palumbo, 1997, 1998). Therefore a large- block field study was replicated for the third year to compare worm management in head lettuce using Conventional, Reduced-risk experimental Bio-based, biorational IPM Programs. In addition, we included a Modified IPM approach which incorporates compounds from all programs.

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Materials and Methods

Lettuce, *Lactuca sativa* L., 'Early Queen' was direct seeded into large blocks on double-row beds on 9 Sep at the Yuma Valley Agricultural Center, Yuma, Az. Each plot consisted of twelve beds, 200 ft long beds spaced 42 inches apart and bordered on each side by two untreated beds. Plots were thinned to a stand on 1 Oct. Experimental plots were arranged in a completely randomized block design with 4 replicates. Treatments consisted of Converntional IPM, Reduced-risk IPM, Bio-based IPM , and Modified IPM programs compared to an untreated control (Table 1).

Spray Applications were made on an as needed basis when population exceeded University of Arizona action thresholds (Kerns and Palumbo 1997). All chemicals were applied by a tractor-mounted boom sprayer delivering 25 gpa at 50 psi. Three, disc-type cone nozzles were used per bed. All chemicals included an adjuvant (Silwet for conventional and reduced risk products, Latron CS-7 for Confirm, Intrepid and Larvin, and Coax for the Bio-Based products) at a rate of 0.125% of the total volume.

Evaluation of lepidopterous larvae control was based the number of live larvae per plant sampled from the center 8 rows of each replicate at 1-3 times per week. The number of samples per replicate varied throughout the season, decreasing as plant size increased (Table 2). The sample unit consisted of examination of whole plants for presence of beet armyworm (BAW), *Spodoptera exigua*, Cabbage looper (CL) , *Trichoplusia ni* , and Tobacco budworm (HEL), *Heliothis virescens* larvae. Each species was characterized as large or small larvae. For BAW and HEL, larvae were considered small if <5 mm in length, large >5mm. For CL, larvae were considered small if <10 mm, large if > 10 mm..

The effects of larval feeding on plant stand, plant size and growth for each treatment were estimated at thinning (1 Oct), early heading (29 Oct), and harvest (18 Nov) stages. Plant stand was taken by measuring the number of plants within 100 ft on 2 beds within each plot. Plant size and growth was estimated by measuring dry weights (g). Yields were taken when >75% of all heads in the experimental block were considered ready for harvest on 20 November (72 days after planting). Yields was taken by weighing all heads within 30 ft of bed in 3 locations within each replicate. Quality was measured by estimating the % marketable heads based on shape and firmness for each head harvested. If heads maintained a reasonable shape and firmness they were considered marketable (#24s). Each head was also evaluated for the presence of worm feeding damage and contamination. A partial budget analysis was used to conduct an economic assessment of each lettuce management

Results and Discussion

Differences in populations of total larvae among the four treatments were observed throughout the season (Figure 1). In general, the Conventional, Reduced-risk and Modified IPM programs provided the most consistent control of lepidopterous larvae following each application. The Bio-based program did not provide the same level of control as the other approaches, but differed from the untreated control on most samples dates. The population peaked in the untreated check at 20 DAP where numbers averaged greater than 3.5 larvae /plant. (Figure 1). Average population numbers during key periods of plant growth for each Lepidopterous species shown in Table 3, (see Table 2 for description of plant stages). During stand establishment, BAW were most abundant in the untreated check, but CL were clearly present in damaging numbers. All four management programs provided similar control of large larvae. During the post-thinning period, BAW was again the most prevalent species, and in total, Lep larvae were most abundant during the plant growth stage averaging greater than 2 larvae per plant in the untreated check. During heading stage, CL were most abundant, but HEL were also prevalent. The conventional and reduced risk programs appeared to maintain the lowest population levels during this period.

Assessment of larvae and other insect contamination at harvest are shown in Table 4. Differences in larval contamination on wrapper leaves were not observed among the four IPM programs. However, The Modified and Conventional Programs were the only approaches that completely excluded larvae from heads at harvest. Furthermore, these programs maintained trash bug contaminants (thrips, treehoppers, lygus, false chinch bugs, leafhoppers, big-eyed bugs, and lacewing) found in lettuce heads at significantly lower levels than the other IPM programs and the untreated check. Overall, the modified and conventional programs provided excellent control at harvest (Table 4). CL and HEL armyworm numbers increased during the pre-harvest period. Consequently, the Bio-based and Reduced -risk programs did not prevent larvae from infesting heads at harvest when compared with the Modified and Conventional management programs.

Lepidopterous larvae had a significant impact on plant stand and plant growth (Table 5). Prior to thinning the stand, plant densities in the conventional and reduced-risk plots were most consistent. Plant densities in the biorational plots were significantly lower and larval numbers were higher than the conventional program.. As a result of high larval densities, plant stand and plant size were significantly reduced in the untreated plots (Table 5). After the stand was thinned, all IPM approaches had higher plant densities and dry weights when compared to the untreated plots. Larval numbers in the Bio-based plots were not different from the untreated plots, but this did not effect plant density or plant size. At harvest, lettuce plant densities and dry weights did not differ among the IPM programs, but were significantly reduced in the untreated check .

Harvest data showed that the management programs had a significant influence of head lettuce yield and quality (Table 6). Maturity and quality were significantly reduced in the untreated control. The Conventional amd Modified IPM program yielded significantly greatest number of cartons than the other management programs when based on average heads/plot, % marketable heads, % worm damage and % head contamination (Table 7). The Bio-based management program was by far the most expensive, relative to net carton production. Consequently , the economic analysis shows that net returns varied widely among the management programs (Table 8.). The break- even prices for the conventional, modified and reduced risk programs were fairly similar centering around $ 5.50 per carton. The Bio-based program was less profitable averaging about a dollar/carton more to produce a profitable crop. Presumably, growers would receive a premium when these products are used for organic or pesticide-free markets. In conclusion, this study provides data to support that alternative IPM programs exist that can be used for managing Lepidopterous larvae in head lettuce. However, because other pests contaminates typically infest lettuce (Table 4), modified IPM programs using both conventional and reduced -risk compounds may be optimal for desert head lettuce during the fall.

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Table 1. Insecticides, Rates (product/acre) and Dates Applied for Each Lettuce IPM program, YAC, Fall 1999.

Application	Conventional IPM	Reduced-risk IPM	Bio-based IPM	Modified IPM
1) 21 Sep	Lannate 0.83 lb Warrior 3.7 oz	Success 4 oz	Pyrellin 2 pts Cryolite 12 lbs Enviropel 12 oz	Lannate 0.83 lb Mustang 4.2 oz
2) 28 Sep	Lannate 0.83 lb Warrior 3.8 oz	Proclaim 3.2 oz	Cryolite 12 lbs Neemix 1 pt Enviropel 12 oz	Success 4.5 oz
3) 1 Oct	Larvin 30 oz Mustang 4.2 oz	–	Cryolite 10 lbs Xentari 2.0 lb	–
4) 7 Oct	Larvin 30 oz Warrior 3.7 oz	Avaunt 5 oz	Neemix 1 pt. Xentari 2.0 lb	Success 6 oz
5) 15 Oct	Lannate 0.75 lbs Ambush 10 oz Thiodan 28 oz	Intrepid 10 oz	Pyrellin 2 pts Agree 2 lbs Enviropel 16 oz	Proclaim 3.2 oz
6) 19 Ot	Lannate 0.83 lb Mustang 4.2 oz	–	Neemix 1 pt Agree 2 lbs Cryolite 10 lbs	–
7) 27 Oct	Warrior 3.8 oz Cryolite 10 lbs Thiodan 28 oz	Success 6 oz	Javelin 1.5 lb Spod-X 3.4 oz Pyrellin 2 pts	Success 6 oz Warrior 3.7 oz
8) 2 Nov	Lannate 0.9 lbs Mustang 4.2 oz Javelin 1.5 lb	Avaunt 5.8 oz	Javelin 1.5 lb Cryolite 10 lbs Pyrellin 2 pts	Confirm 8 oz Mustang 4.2 oz
9) 11 Nov	Lannate 0.9 lbs Mustang 4.2 oz Javelin 1.5 lb	Success 6 oz	Javelin 2 lbs Neemix 1 pt Enviropel 12 oz	Lannate 0.9 lbs Mustang 4.2 oz Javelin 1.5 lb

Table 2. Dates, Plant Stages, and Sample Numbers on Each Collection Date, YAC, Fall 1999.

Sample Date	Days After Planting	Plant stage	Plant size (leaves/plant)	Sample Size (plants/plot)
21 Sep	11	Stand establishment	1	50
25 Sep	15	Stand establishment	2-3	50
27 Sep	17	Stand establishment	3	50
1 Oct	20	Stand establishment	3-4	50
4 Oct	24	Post-thinning	5-6	40
11 Oct	31	Post-thinning	7-8	40
14 Oct	34	Post-thinning	9-10	40
18 Oct	38	Post-thinning	10-12	40
22 Oct	42	Post-thinning	13-14	30
25 Oct	45	Heading	½ “ heads	25
1 Nov	52	Heading	2-3" heads	25
8 Nov	59	Heading	4-5" heads	25
11 Nov	62	Heading	5-6" heads	25
18 Nov	69	Harvest	7" heads	24

Table 3. Average Number of Lepidopterous Larvae Found on Lettuce Plants During Various Growth Periods of Head Lettuce, YAC, Fall 1999.

	Mean Larvae / Plant											
	Beet armyworm			Cabbage looper			Budworm/bollworm			Total Leps		
IPM Program	small	large	total	small	large	total	small	large	total	small	large	total
Stand establishment to Thinning												
Conventional	0.05 a	0.01 b	0.06 a	0.01 b	0 a	0.01 b	0.01 a	0 a	0.01 a	0.07 b	0.01 b	0.08 b
Bio-based	0.18 a	0.03 b	0.21 ab	0.08 b	0.01 a	0.09 b	0.06 a	0.01 a	0.07 a	0.32 ab	0.05 b	0.37 ab
Reduced Risk	0.01 a	0 b	0.01 b	0.03 b	0 a	0.03 b	0.03 a	0 a	0.03 a	0.07 b	0 b	0.07 b
Modified	0.06 a	0 b	0.06 b	0.04 b	0 a	0.04 b	0 a	0 a	0 a	0.10 b	0 b	0.10 b
Untreated	0.29 a	0.13 a	0.42 a	0.28 a	0.05 a	0.33 a	0.07 a	0 a	0.07 a	0.64 a	0.18 a	0.82 a
Post-thinning to Heading												
Conventional	0.11 a	0.07 b	0.18 c	0.06 b	0.01 b	0.07 b	0.03 bc	0.01 b	0.04 b	0.20 b	0.08 b	0.28 b
Bio-based	0.33 a	0.13 b	0.46 b	0.26 b	0.03 b	0.29 b	0.06 ab	0.01 b	0.07 b	0.66 ab	0.16 b	0.82 b
Reduced Risk	0.13 a	0.02 b	0.15 c	0.16 b	0.02 b	0.18 b	0.04 abc	0 b	0.04 b	0.33 b	0.04 b	0.38 b
Modified	0.11 a	0.01 b	0.11 c	0.17 b	0.01 b	0.18 b	0.01 c	0 b	0.01 b	0.28 b	0.02 b	0.31 b
Untreated	0.63 a	0.40 a	1.03 a	0.47 a	0.40 a	0.87 a	0.10 a	0.11 a	0.21 a	1.20 a	0.92 a	2.11 a
Heading - Harvest												
Conventional	0.01 a	0.07 b	0.08 b	0.01 a	0.01 b	0.02 b	0 a	0.01 b	0.01 b	0.01 c	0.09bc	0.10 c
Bio-based	0.08 a	0.21 a	0.29 a	0.09 a	0.05 b	0.14 b	0.01 a	0.02 b	0.03 b	0.18 ab	0.28c	0.46 b
Reduced Risk	0.01 a	0.01 b	0.02 a	0.01 a	0.01 b	0.02 b	0.01 a	0.04 b	0.05 b	0.03 c	0.06c	0.09 c
Modified	0.12 a	0.02 b	0.14 ab	0.06 a	0.06 b	0.12 b	0 a	0.03 b	0.03 b	0.19 ab	0.11bc	0.30 bc
Untreated	0.08 a	0.25 a	0.33 a	0.11 a	0.54 a	0.65 a	0.05 a	0.17 a	0.22 a	0.24 a	0.96a	1.20 a

Mean followed by the same letter are not significantly different (ANOVA, $LSD_{0.05}$).

able 4. Numbers of Lep Larvae and Other Insect Contaminants on Lettuce Wrapper Leaves and Heads at Harvest, YAC, Fall 1999 .

	Mean Lepidopterous Larvae [a] per 24 Plants								
	Wrapper leaves				Head, cap leaf				Trash Bugs [a] (% infested heads)
IPM Program	BAW	CL	Hel	Total	BAW	CL	Hel	Total	
Conventional	0.0 b	0.0 b	0.0 a	0.0 b	0.0 a	0.0 b	0.0 b	0.0 c	18.3 b
Reduced Risk	0.0 b	0.0 b	0.4 a	0.4 b	0.0 a	0.2 b	0.8 b	0.8 bc	52.1 a
Bio-based	0.3 b	0.7 b	0.0 a	1.0 b	0.6 a	0.3 b	0.3 b	1.2 b	65.6 a
Modified	0.0 b	0.0 b	0.0 a	0.0 b	0.0 a	0.0 b	0.0 b	0.0 c	18.5 b
Untreated	1.4 a	5.0 a	0.7 a	7.2 a	0.0 a	2.8 a	6.0 a	8.8 a	75.7 a

Mean followed by the same letter are not significantly different (ANOVA, $LSD_{0.05}$).

[a] BAW= beet armyworm; CL= cabbage looper; HEL=tobacco budworm/corn earworm.

[b] The means percentage of trash bugs (thrips, treehoppers, lygus, false chinch bugs, leafhoppers, big-eyed bugs, and lacewing) found on or under the cap leaves of marketable heads.

Table 5. Effects of Alternative Management Programs on plant stand, plant size and lepidoperous larvae numbers at various periods during the season, YAC, Fall 1997.

	Thinning			Early Heading			Harvest		
Treatment	Plants / row ft	Dry wt. (g)	Larvae / plant	Plants / row ft	Dry wt. (g)	Larvae / plant	Plants / row ft	Dry wt. (g)	Larvae /plant
Conventional	5.5 a	5.7 a	0.08 b	1.8 a	10.9 a	0.28 b	1.7 a	36.3 a	0.1 c
Reduced Risk	5.5 a	5.5 a	0.07 b	1.8 a	10.5 a	0.38 b	1.6 a	31.8 a	0.5 b
Bio-based	4.8 b	5.1 a	0.37 ab	1.4 a	9.5 a	0.82 b	1.5 a	38.6 a	0.1 c
Modified	5.7 a	5.9 a	0.10 b	1.8 a	11.0 a	0.31 b	1.8 a	40.9 a	0.3 bc
Untreated	2.8 c	4.3 b	0.82 a	0.5 b	4.1 b	2.11 b	0.5 b	27.2 b	1.3 a

Mean followed by the same letter are not significantly different (ANOVA, $LSD_{0.05}$).

Table 6 Yields and Quality for Head Lettuce Grown Under Various IPM Programs, YAC, November 20, 1999

			% marketable heads		% worm damage		% head contamination	
IPM Program	Avg. no. heads/30 ft	Avg. wt /head (lb)	shape	maturity	wrapper leaves	head, cap leaf	frass	live worms
Conventional	44.4 a	1.6 ab	90 a	84 a	4.6 c	4.3 cd	2.7 c	0 b
Bio-based	44.2 a	1.4 bc	85 a	80 a	18.5 b	12.9 b	12.9 b	5.9 b
Reduced-risk	46.2 a	1.7 a	91 a	81 a	8.8 bc	9.8 bc	5.5 c	3.7 b
Modified	46.5 a	1.8 a	91 a	78 a	3.7 c	1.7 d	0.9 c	0 b
Untreated	35.6 b	1.2 c	68 b	60 b	80.9 a	68.4 a	65.8 a	51.3 a

Mean followed by the same letter are not significantly different (ANOVA, $LSD_{0.05}$).

Table 7. Yields per acre and costs associated with various spray regimes for management of lepidopterous pests on lettuce, YAC, Fall 1999.

IPM Program	Cartons(24)/ acre Gross[a]	Net[b]	No. sprays[c]	Insecticide cost /acre[d]	Application cost /acre[e]	Total cost/acre[f]
Conventional	768 a	613 a	9	378	108	486
Bio-based	760 a	519 b	9	584	108	692
Reduced-risk	798 a	582 ab	7	222	84	306
Modified	806 a	631 a	7	262	84	346
Untreated	615 b	118 c	–	–	–	--

[a] total number of cartons (24s) that could have been potentially packed from field based on ave no. heads per 20 ft (see Table 3).

[b] average number of cartons (24s) that were harvested from plots after individual heads were culled out due to shape, maturity, worm damage and contamination in heads (see Table 3).

[c] see table 3

[d] based on average retail value from 3 local distributors of foliar chemicals applied in each program (see Table 1 for products applied.).

[e] based on cost to apply insecticides by ground ($12.00 for banded application; $11.00 for broadcast application). The first application was applied as a band, all subsequent sprays were broadcast.

[f] Total cost of all chemicals applied during season specifically for Lep larvare including insecticide and application costs.

Table 8. Economic assessment of three lettuce management programs, YAC, Fall 1999.

IPM Program	Expenditures ($ / acre)[a] Harvest costs	Total Growing costs	Beak -even Market Price ($/carton)
Conventional	2010	3495	5.70
Bio-based	1702	3393	6.54
Reduced-risk	1909	3214	5.52
Modified	2069	3414	5.39
Untreated	387	1487	12.60

[a] Marketing/harvest cost calculated from 1998-99 Az Vegetable Crop Budgets, UA Extension Bulletin #AZ1105; Total costs include marketing/harvest cost and growing costs .

[b] Net return calculated from Market price($/cart) for net cartons (Table 3) after accounting for total production costs.

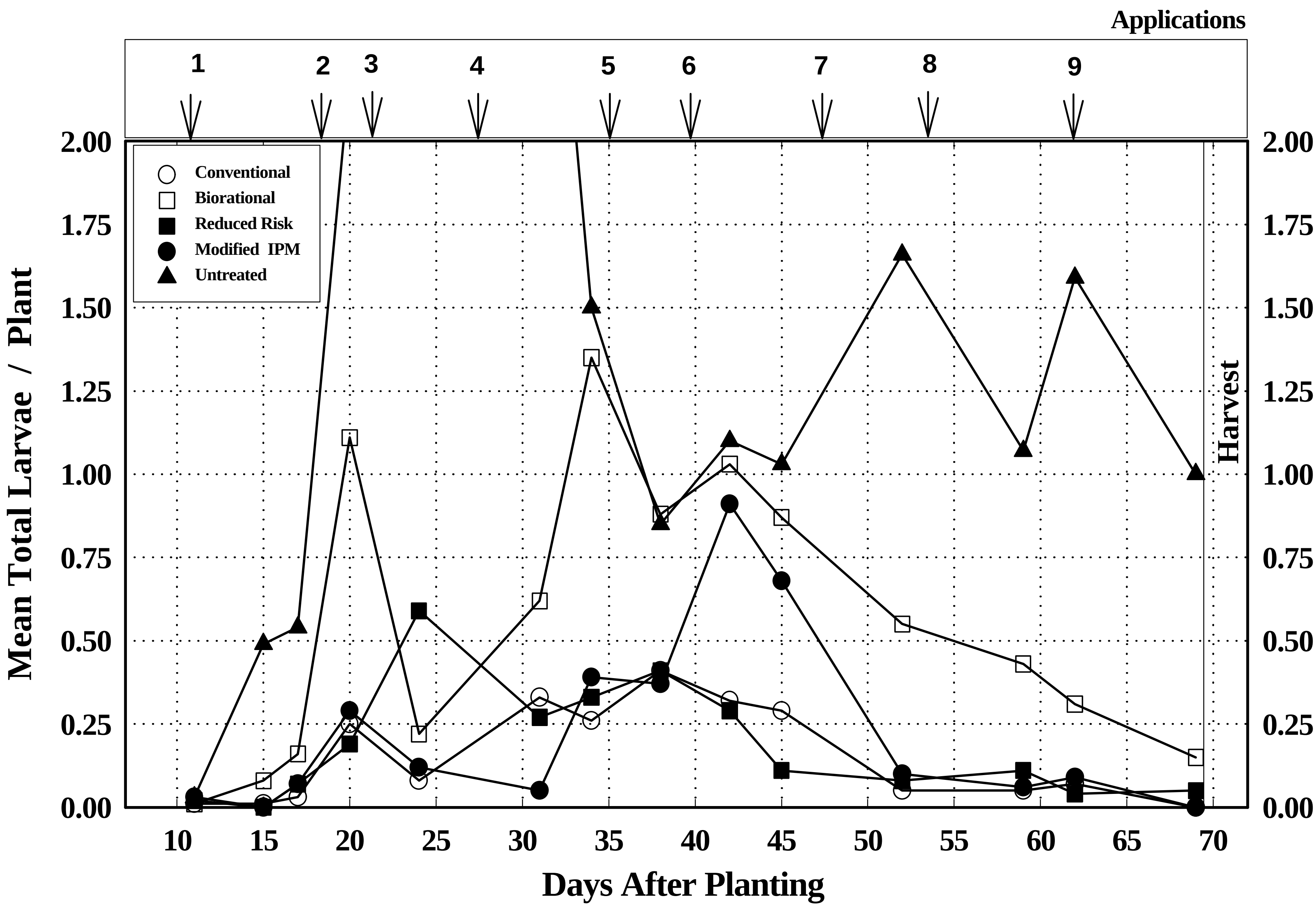

Figure 1. Total Lepidopterous Larval Populations Relative to IPM Program, and Timing and Frequency of Spray Applications in Head Lettuce, YAC, Fall 1999 (see Table 2 for description of sprays applied in each IPM program at each spray application indicated by numbered arrows above).