

Comparison of Sampling Methods for Estimating Western Flower Thrips Abundance on Lettuce

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Abstract

Several relative sampling techniques (direct visual counts, beat pans and sticky traps) were compared to absolute counts (plant wash) to determine sampling reliability for estimating western flower thrips population levels in lettuce. In numerous plantings of experimental plots of head lettuce, the relative sampling methods indicated similar thrips population trends throughout the season and all relative estimates of abundance were significantly correlated with absolute densities. However, both relative methods could only account for a proportion of the adult thrips infesting head lettuce plants, where they estimated about 30% of the actual absolute population. For larvae, beat pan sample estimated about 18-20% of the actual population density, whereas direct visual counts accounted for less than 10% of the thrips present. Comparison of sampling methods in insecticide efficacy trials indicated that beat pan and direct visual counts did not always accurately estimate treatment differences for adult. For densities of thrips larvae however, beat pan and visual counts methods did consistently provide accurate estimates of treatment differences in efficacy trials. Overall, both beat pan and direct visual count procedures are reliable thrips sampling methods that will generally provide precise estimates of thrips abundance necessary in lettuce pest management programs. Furthermore, these methods, and the beat pan in particular, also may serve as effective research tools that provide reliable estimates of treatment differences.

Introduction

Desert lettuce production remains highly dependant on the availability of effective IPM programs. The recent registration of several reduced risk insecticides now provides lettuce growers with a number of tools to effectively manage most insect pests (i.e., whiteflies, worms, aphids, and leafminers). However, thrips continue to cause problems, both for domestic and foreign market opportunities. Because of the lack of empirical information on their biology and ecology, thrips may be the most important economic pest of winter lettuce grown in the desert. At the present time, lettuce growers rely almost exclusively on two insecticides, Lannate and Success, for their control. Not only is this approach expensive, but also places the industry at risk because of the increased threat of thrips developing resistance to these insecticides.

A significant research effort has been made to evaluate insecticide alternatives for thrips control; however, very little information is available on the biology and ecology of thrips in desert cropping systems. As a pest, thrips are unique on desert lettuce compared with other growing regions such as coastal California regions, Hawaii, or Florida where they are important disease vectors. Because thrips have become an important pest of lettuce in the past few years, information needs to be generated that is specific to the desert lettuce. This includes the development of sampling methods that can accurately and reliably estimate thrips densities. A reliable sampling protocol is essential for both studying the population dynamics of thrips in experimental plots as well as assessing population abundance in commercial lettuce fields for making management decisions. Ultimately, a dependable sampling plan is required before a viable pest management program for thrips on lettuce can be developed. Thus, with the objective of ultimately developing a pest management approach that would enhance our present chemical tactics, this project was conducted to begin examining the sampling methods for estimating thrips abundance on lettuce.

Materials and Methods

Comparison of Sampling Methods in Experimental Plots. Plots were established to provide untreated lettuce plants where the relative abundance of thrips populations could be estimated comparatively using each sampling method. Sampling was conducted in six separate plantings of head lettuce in 2002-2003 at the University of Arizona, Yuma Agricultural Center, Yuma, AZ. Varieties for each experimental plot were planted on the following dates: (PD 1) 'Wolverine' on 10 Oct; (PD 2) 'Grizzley' on 29 Oct; (PDS 3) 'Bubba' on 14 Nov, (PD 5) 'Diamond' on 3 Dec; and (PD 6) 'Diamond' on 12 Dec. On each planting date, lettuce was direct seeded into double row beds on 42 inch centers. Each planting was 16 beds by 150 feet long (0.2acre) and further divided into four plots of approximate equal size to provide replications for each sample method. Plot establishment and maintenance were similar to those used in commercial practices, with the exception that no pesticides were applied.

Comparison Of Sampling Methods In Insecticide Efficacy Trials. The sample methods were evaluated in plots that received applications of insecticide shown to be effective in controlling thrips. Insecticides were applied on various timings depending on the efficacy trial. Four separate trials were conducted in the spring of 2003 at the Yuma Valley Agricultural Center to compare sampling methods in small plots of insecticide treated and untreated head lettuce and romaine. The planting date for each study included: 'Diamond' was planted in Head Lettuce I-west and Head lettuce II on 3 Dec, 'Diamond' was planted in Head lettuce II on 12 Dec, and 'PIC 417' was planted in Romaine on 10 Dec. Plots in each trial consisted of four beds, each bed 42 in wide and 50 ft long with a 7 ft buffer between plots. In all tests, the foliar applications were made with a CO₂ operated boom sprayer operated at 60 psi and 27 GPA. A directed spray (nozzles directed toward the plants) was delivered through 3 nozzles (TX-10) per bed. The sample methods were evaluated in plots that received applications of insecticide shown to be effective in controlling thrips. Insecticides were applied on various timings depending on the efficacy trial.

Head Lettuce I West trial: Treatments were arranged in a randomized complete block design and replicated four times. The treatments consisted of an untreated control and two spray treatment regimes: 1) sprays applied at 7 day intervals and 2) sprays applied at 14 day intervals. The insecticide treatment regime used consisted of alternating between Lannate (0.75 lb/acre) mixed with Mustang (4 oz/acre); and Success (5 oz) mixed Mustang (4 oz) on each application. Both spray interval treatments were initiated on 19 Jan using the Lannate mixture first. The final spray in Treatment 1) was applied on 10 March and in Treatment 2) on 3 March.

Head Lettuce I East trial: Treatments were arranged in a randomized complete block design and replicated four times. The treatments also consisted of an untreated control and two spray treatment regimes: 1) 3 -spray applications delivered at 7 day intervals on 19, 26 Jan and 2 Feb and; 2) 2 sprays applied at a 14 day interval on 19 Jan and 2 Feb. The insecticide treatment used consisted of Success applied at 10 oz.

Head lettuce II and Romaine trials: Treatments were arranged in a randomized complete block design and replicated four times. The treatments consisted of an untreated control and four spray treatments: 1) Success applied at 6 oz; 2) Success applied at 10 oz; 3) Success at 5 oz mixed with Mustang at 4 oz; and 4) Lannate at 0.7 lb with Mustang at 4 oz. In the head lettuce trial, 2 applications were made on 26 Jan and 8 Feb, and in the Romaine on Jan 28 and 8 Feb.

Sampling Techniques. Three sampling techniques were used to estimate thrips abundance on lettuce relative to absolute counts. First, direct visual observations (Direct counts) of whole lettuce plants were made for relative estimates of thrips numbers. On each sample bout, five whole plants (n=20 per sampling bout) were selected at random in each plot and removed from the soil at ground level. On thinning, heading and pre harvest stage lettuce, direct counts consisted of counting all thrip adults and larvae observed on plants within a 2 minute period, beginning in the terminal area of the plant and working down the plant towards the older, basal leaves. Two people were used to collect the data; one person to count the thrips and another person recorded numbers and kept time. On samples collected at harvest, counts of heads and frame leaves were conducted separately. Counts consisted of 2 minute observations of heads beginning with the first 2 wrapper leaves and then working down towards the core. Count on frame leaves consisted of sampling the older leaves, beginning with lowest leaves. Samples were taken between 0900-1100 h.

The second relative sampling technique consisted of a Beat Pan method used to dislodge live thrips from plants. On each sample bout, five whole plants (n=20 per sampling bout) were selected at random in each plot and individually removed from the soil at ground level. Plants were then beat vigorously against a screened pan for a predetermined duration (5-10 hits for upper and lower plant portion). The pan measured 2" H by 15" L by 8" W and covered with meshed screen with 0.5 spacing. Inside of the pan was a yellow sticky trap (6" by 6") to catch and retain dislodged thrips. On samples collected at harvest, counts of heads and frame leaves were conducted separately. Head samples consisted of the head, with cap leaf and 2 wrapper leaves. The head was then split in two and beat against the screen

also. Frame lead samples consisted of removing the head and 2 wrapper leaves and exposing as many leaves as possible while then beating the plant vigorously. Sticky traps were immediately covered with clear plastic and then taken to the laboratory where adult and larvae were counted under 10-20X magnification.

The third relative sample involved placing Yellow sticky traps and Blue sticky traps (3" by 5" in size) at canopy level within each plot. On each sample bout, a single yellow and blue sticky trap was set 6 ft from each other near the center of each plot. Traps were kept in the plots from 0600 h to 1700 h. Following each trapping period, traps were taken into the laboratory and the numbers of adults on the entire trap surface were counted under 10-20X magnification.

Absolute population abundance was determined by using whole plant washes. On each sample bout, five whole plants were selected at random in each plot and individually removed from the soil at ground level. Then each plant was placed individually into a 5 gal plastic container and immediately sealed with a removable lid. Each container contained a solution of 3 gal water, 2 oz of dilute liquid detergent and 5 oz of ethanol. In the laboratory, the plants were vigorously agitated in each sealed container for 30 sec intervals over the course of a 2 hr period. Following extended agitation, the aqueous contents of the container were poured and filtered through a fine meshed coffee filter (500 mesh) which was held by a no.30 metal sieve. Plants were then dissected and each leaf from each plant was thoroughly washed with water within the confines of the container and funneled through the meshed filter. After washing all plant parts and straining the remaining water, filters were placed on 12" diameter paper plates and placed in 2 gallon plastic bags. Bagged filters were placed into a freezer for 24 hrs, after which all thrips adult and larvae on each filter were counted under 10-20X magnification.

Statistical Analysis. The association of thrips abundance from the three sampling methods and absolute counts from plant washes was measured with Pearson's correlation coefficient. Sampling precision for the three methods was estimated in each field by calculating the relative variation (RV) on each sampling date. The RV values were calculated as $RV = (SEM/mean) 100$, where SEM=standard error of the mean. To compare differences in relative variation between sampling methods, mean RV values were calculated by averaging the weekly RV estimates in each field and compared using analysis of variance and the Ryan-Einot-Gabriel-Welch Multiple Range Test. Sampling efficiency was also calculated for each technique as the relative net precision (RNP) where $RNP = 100 / [(RV_m)(c_u)]$, where RV_m =mean relative variation and c_u = cost in minutes to count thrips abundance on an individual sample unit, or mean search time. Larger RNP values indicated greater sampling efficiency. Mean RNP and search times were calculated for each sample method in the experimental plots to provide a wide range of adult densities. Data collected from the chemical trials were first transformed to $\log_{10}(x+1)$ before statistical analysis because of large differences in variances among treatment means. Differences in thrips counts among insecticide treatments were determined with a repeated-measures analysis of variance (ANOVA) and paired t-tests. The model was used to test for insecticide treatment main effects along sampling dates. When differences were found, means were separated by the Ryan-Einot-Gabriel-Welch Multiple Range Test.

Results and Discussion

Evaluation of Sampling Methods in Experimental Plots. In general, the beat pan and direct count sampling methods indicated population trends similar to the plant washes throughout the season in experimental plots (Fig 1-3). As expected, plant washes consistently estimated the greatest number of adults and larvae per sample. In most cases, estimates of thrips abundance was greater for beat pans than for direct visual counts. For all methods, populations were low early in the season and increased as the plant matured. Populations peaked for in PD 3 and 4. Between the two sticky traps, blue cards usually caught more thrips than yellow cards, particularly when adult populations were high (Figure 4).

Linear correlations were significant for the comparisons between the relative estimates and the plant washes (Fig. 5-7). All sampling methods were significantly correlated with the absolute estimates of thrips obtained with the plant washes, although the beat pan showed stronger correlations than either direct counts and sticky traps. Similarly, a strong correlation was observed for adult abundance measured with between yellow and blue sticky traps.

Mean thrips abundance and RV values calculated from beat pan, direct counts and plant washes varied with crop stage and thrips lifestage. (Table 1-3). For adults, abundance was low at thinning stage, but significantly lower in direct counts. At subsequent crop stages, abundance was greatest in the plant washes, and in some cases, had lower RV values. Peak abundance was observed at the early heading stage. Similar trends were observed for larvae and total thrips abundance, but peak abundance was measured at harvest stage. RV values did not vary as much among

the methods for larvae at the crop stages as was observed among adults. RV values calculated for the sticky traps were generally much higher than observed for the other methods and often exceed a value of 100. Estimates of RNP from the experimental plots varied with thrips abundance and sampling method (Table 1-3). With the exception of the fixed 2-minute search time for direct counts, sampling costs (mean search times) were directly proportional to increases in thrips density, resulting in higher sampling efficiencies for the beat pan methods relative to plant washes. RNP values for direct counts were consistently higher across all thrips life stages and head lettuce crop stages.

Reliability of Sampling Methods in Efficacy Trials.

Head Lettuce I West and East trials: Thrips adult and larvae numbers per plant were measured on 6 Feb following 2 and 3 sprays for the 14 and 7 day interval treatments, respectively (Table 4). Plants had not begun to yet form heads. Although the absolute estimates (plant washes) of adult and larvae thrips numbers were greater than direct count or beat pan sampling, all three methods estimated similar differences among the three spray treatments. There was some discrepancy among methods in the estimation of treatment differences for total thrips where direct counts indicated significant differences between the two spray regimes. Similarly, comparison among the sampling methods in control (% reduction of thrips compared with the untreated control), indicated that direct counts significantly underestimated control of total thrips (Fig 9 A). In the Head Lettuce- I East trial all three methods estimated similar differences among the three spray treatments (Table 6), and similarly provided comparable estimates of thrips control for each treatment (Fig 9B).

At harvest stage in the Head Lettuce I-West trial, the sampling methods provided more variable estimates of treatment differences of thrips adults and larvae (Table 5). Both the direct count and beat pan methods incorrectly estimated treatment differences of adults and larvae relative to the absolute plant wash estimates. For adults, both methods failed to detect higher numbers in the 7 day regime, and failed to detect differences in larvae numbers between the two spray regimes. Comparisons among the sampling methods for thrips control in the 14 d spray interval treatment indicated that direct counts significantly overestimated larval control, and both relative methods overestimated estimated total thrips control (Fig. 9C). All three sampling methods provided similar estimates of thrips control in the 7-day spray interval treatment.

Head lettuce II and Romaine trials: In both crops, the beat pan method provided different estimates of treatment differences for adult thrips (Table 7-8) . Beat pan sampling in head lettuce indicated that both Success +Mustang and Lannate +Mustang treatments had significantly lower adult numbers than the untreated control, whereas the absolute plant wash counts estimated no differences among treatments. Similarly, in the romaine trial, beat pan sampling estimated that thrips adult numbers in the Success 10 oz treatment did not differ from the untreated control, whereas treatment differences between the Success treatment and check using plant wash sampling were significant. Both sampling methods provided comparable estimates of treatment differences for thrips larvae (Table 7-8). Comparisons between the two sampling methods for thrips control in the head lettuce indicated that beat pans provided statistically reliable estimates of thrips control for all four spray treatments (Fig. 10A). However, in the romaine trial, beat pan samples significantly under estimated % control of thrips adults in Lannate+Mustang treatment (Fig 10B).

This study showed that relationships between relative sampling methods and absolute counts of thrips abundance were fairly consistent in untreated experimental plots. In most cases, direct visual counts and beat pan sampling provided comparable measures of changes in population abundance through the cropping season and were strongly correlated with absolute densities. However, both relative methods could only account for a proportion of the thrips infesting head lettuce plants. Based on linear regressions (Fig 5-6), beat pan sampling and direct counts were only able to estimate about 30% of the actual absolute population. This discrepancy between estimates was even greater for larvae. On the average, beat pan sample estimated about 18-20% of the actual population density, whereas direct visual counts accounted for less than 10% of the thrips present. This information clearly illustrates the cryptic nature of immature thrips and reflects their life cycle on lettuce. More importantly, PCAs should be aware that their discovery of light-moderate numbers of adults and thrips on lettuce may indicate a larger number actually present within leaf margins deep within the plant interior.

Individual adult thrips captured on sticky traps did not always represent the same populations estimated with beat pan and direct counts. Sticky trap counts may reflect both trivial movements within the field, as well as dispersing adults moving in and out of fields. Trap counts are also influenced by the attraction of whiteflies to color. In this study, thrips were generally more attracted to the blue traps, but yellow traps reflected comparable changes in population abundance throughout the season and were strongly correlated with trap counts for blue traps (Fig 8).

Unfortunately, adults estimates with both traps were poorly correlated with absolute densities found on plants.

Conclusions drawn from the RV and RNP estimates depend on the specific needs of the researcher and should be carefully interpreted. Plant washes provided the most consistency in sampling precision, but in some cases beat pan sampling provided significantly better precision. Precision for direct counts tended to vary throughout the season and between lifestage. This is not surprising, particularly for adults, considering that plants are handled for sustained periods of time and allow thrips to escape from the plant. In general, sampling precision for sticky traps was inconsistent, probably a consequence of their dispersal behavior within small experimental plots. When considering sampling efficiency in terms of cost, direct counts always provided greater efficiency. This was a direct result of less time was required to sample compared with beat pans and plant washes. For practical reason, direct counts may provide good estimates of relative population abundance.

Comparison of sampling methods in the insecticide efficacy trials indicated that beat pan and direct visual counts were not always reliable for estimating treatment differences of adult thrips. The failure to accurately detect differences in adults with these methods was likely a result of both insecticide repellency and inadequate spatial isolation between plots. Inter- and intra-plot movement of adults was likely a major source of error that resulted in adult densities in treated and untreated control plots to be incorrectly estimated. Migration of adults into and out of the experimental plots from surrounding crops and weeds could also have biased the counts. For densities of thrips larvae however, beat pan and visual counts methods did provide accurate estimates of treatment differences. These data suggest that post treatment evaluation of thrips densities will vary between adults and larvae and should be carefully evaluated, especially when pyrethroids have been applied.

In conclusion, relative to the absolute plant wash counts, the beat pan procedure provided better population estimates than either direct visual counts or sticky traps because they more accurately reflected adult abundance on plants and provided acceptable levels of sampling precision. Both beat pan and direct visual count procedures are reliable thrips sampling methods that will generally provide dependable estimates of thrips abundance necessary in lettuce pest management programs. Furthermore, these methods, and the beat pan in particular, also may serve as effective research tools that provide reliable estimates of treatment differences.

Acknowledgments

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Figure 1. Population trends of thrips adults estimated with beat pan, direct counts and plant wash sampling in six experimental lettuce plantings, Yuma Agricultural Center, 2002-2003.

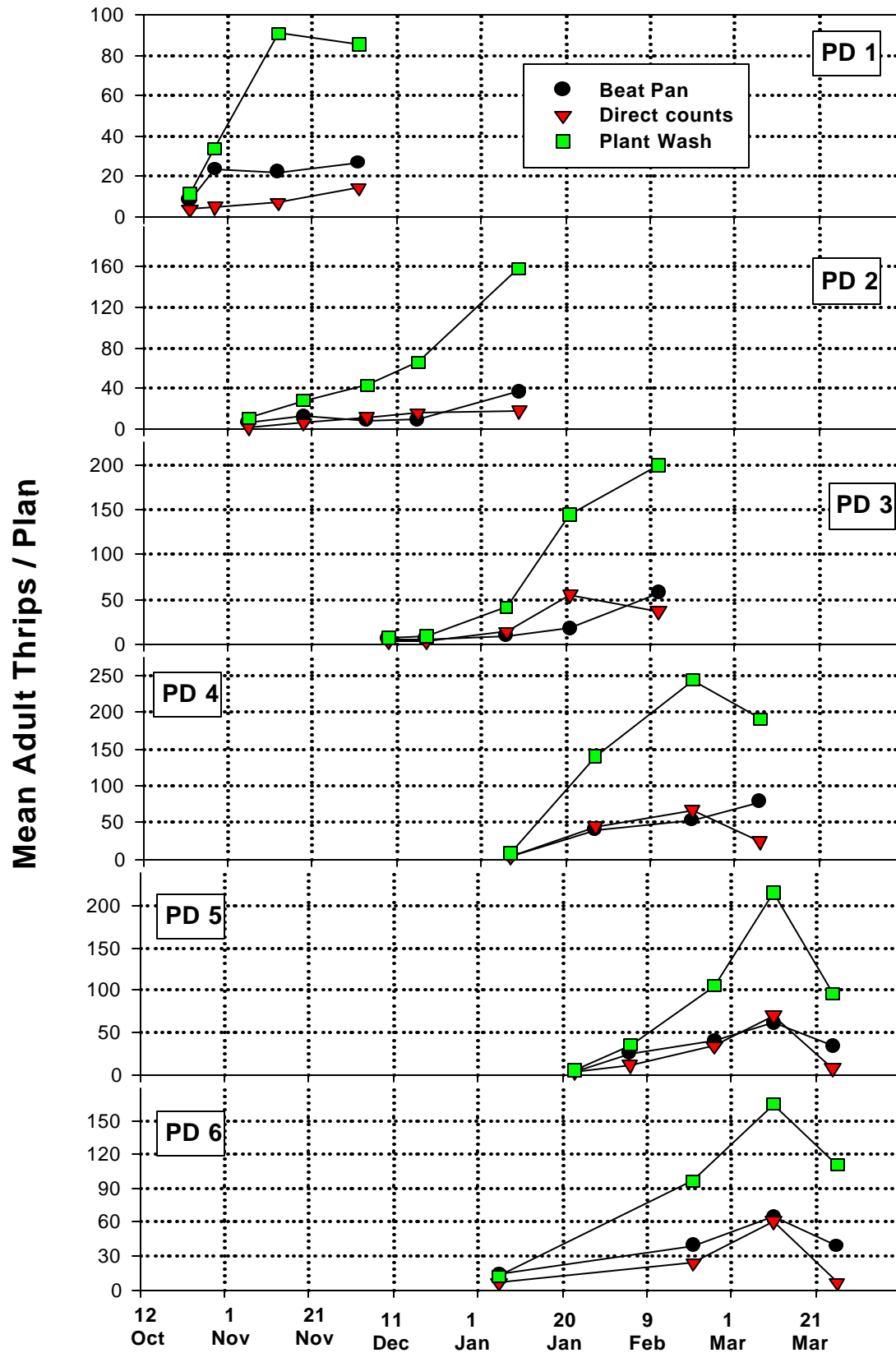


Figure 2. Population trends of thrips larva estimated with beat pan, direct counts and plant wash sampling in six experimental lettuce plantings, Yuma Agricultural Center, 2002- 2003.

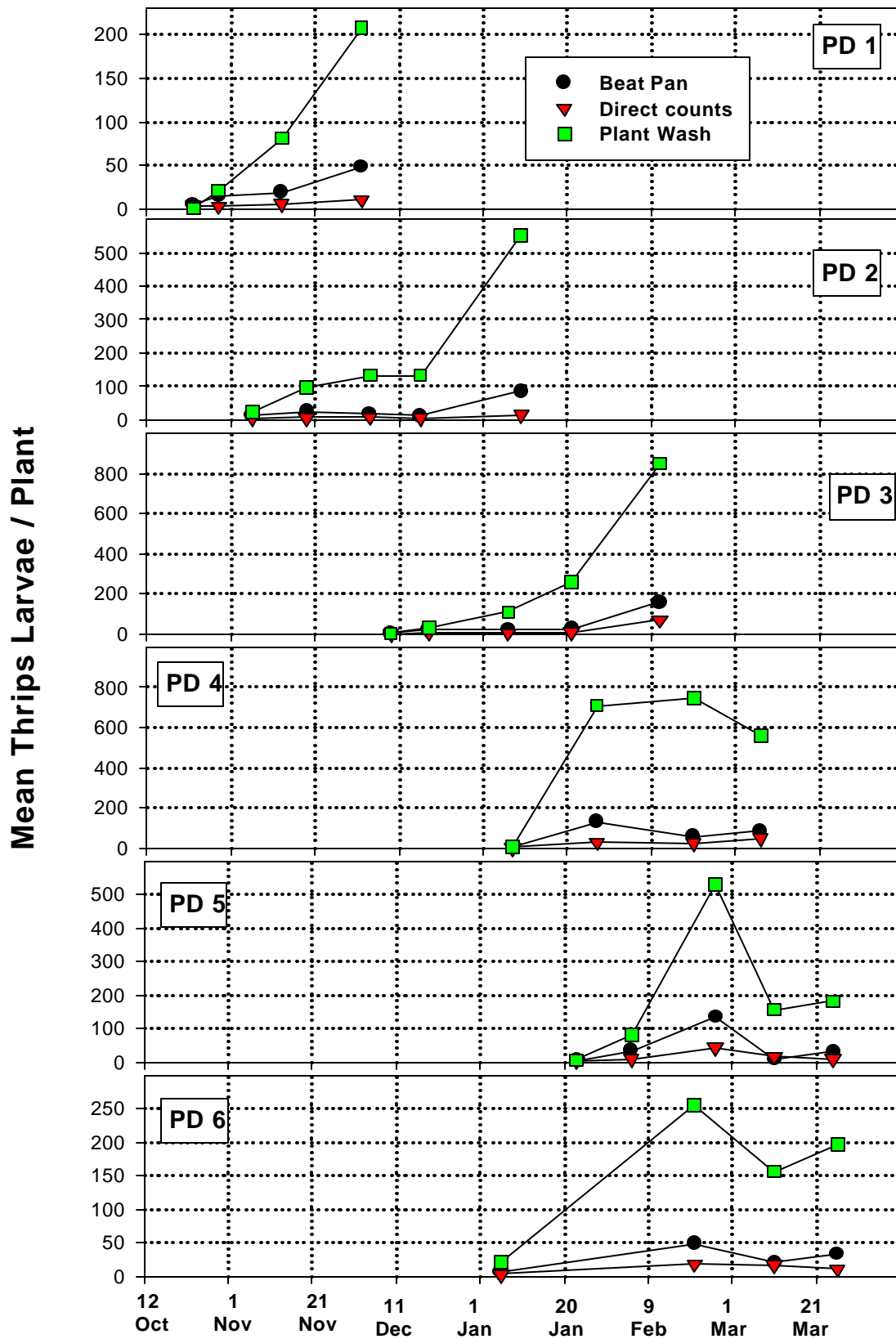


Figure 3. Population trends of total thrips estimated with beat pan, direct counts and plant wash sampling in six experimental lettuce plantings, Yuma Agricultural Center, 2002- 2003.

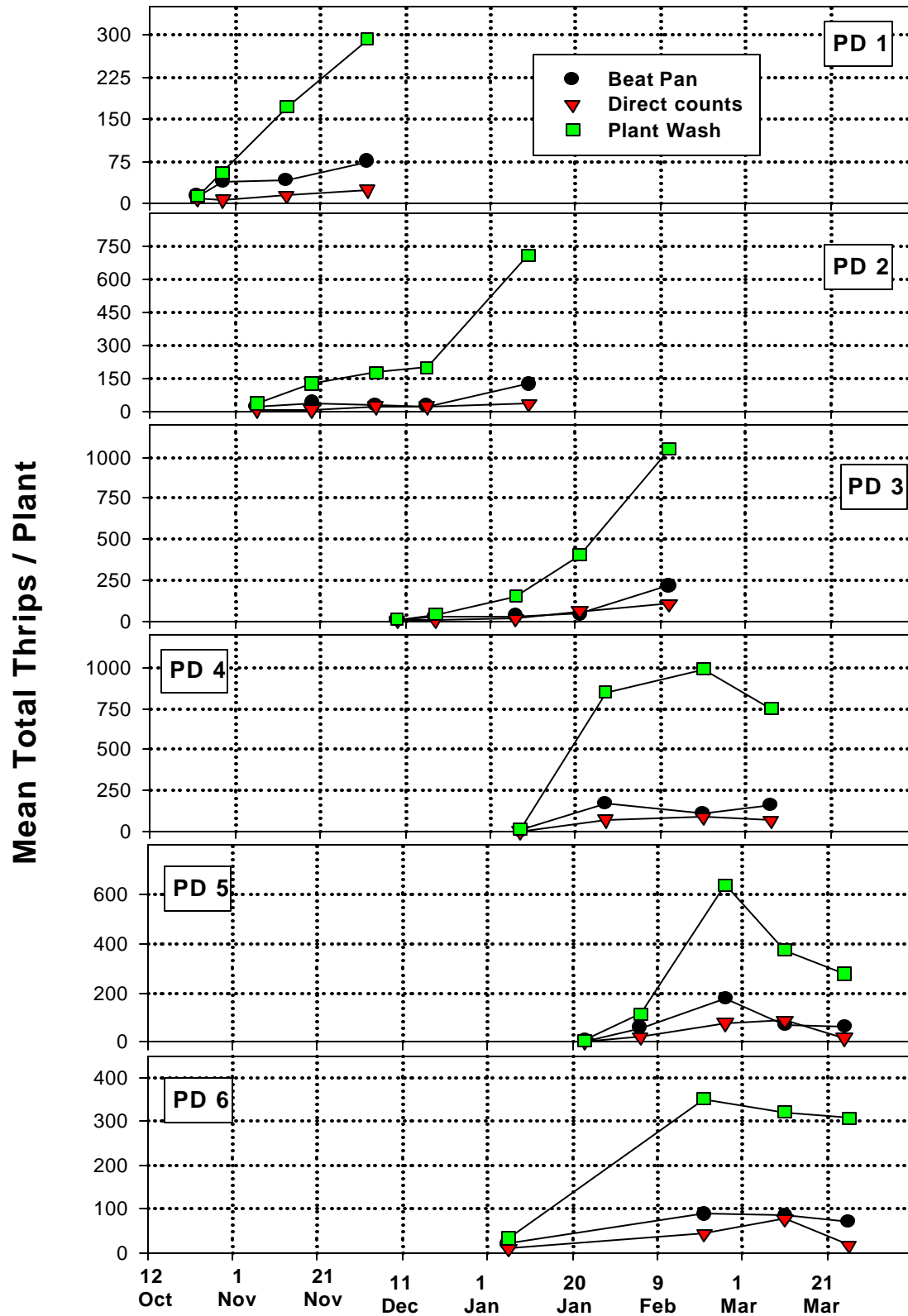


Figure 4. Population trends of thrips adults estimated with yellow and blue sticky traps in six experimental lettuce plantings , Yuma Agricultural Center, 2002- 2003.

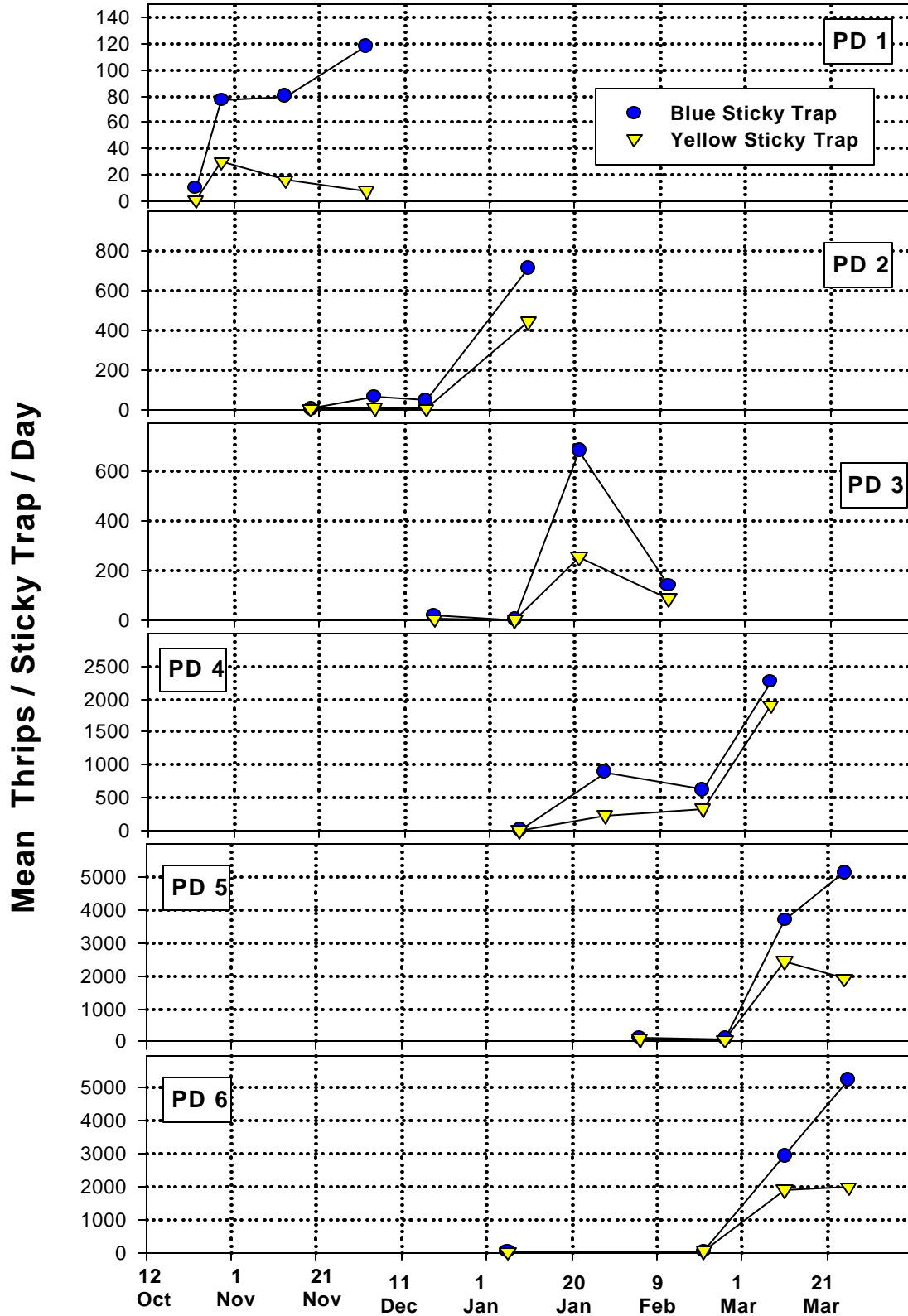


Figure 5. Correlation of beat pan and direct counts of thrips adults with absolute estimates with plant washes.

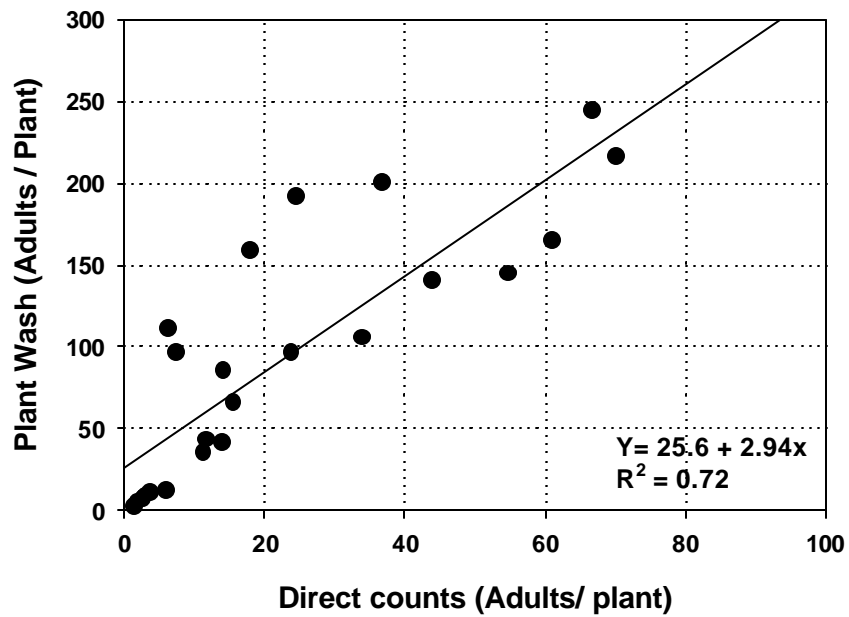
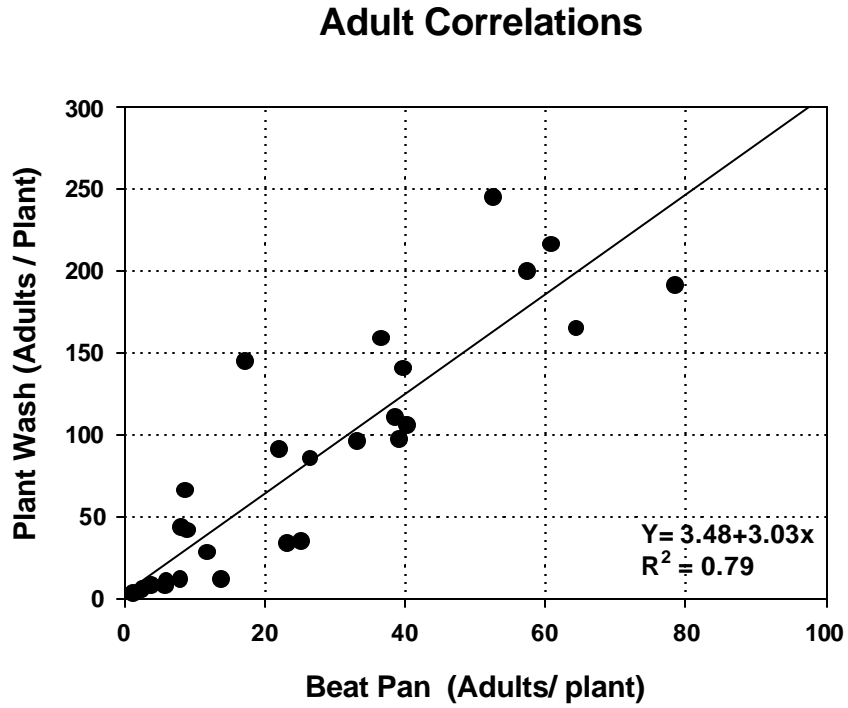


Figure 6. Correlation of beat pan and direct counts of thrips larvae with absolute estimates with plant washes

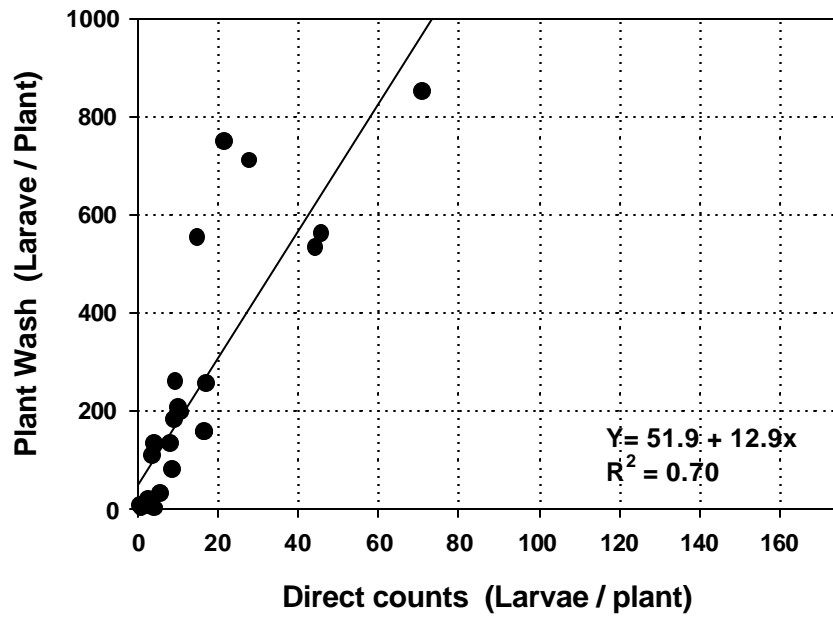
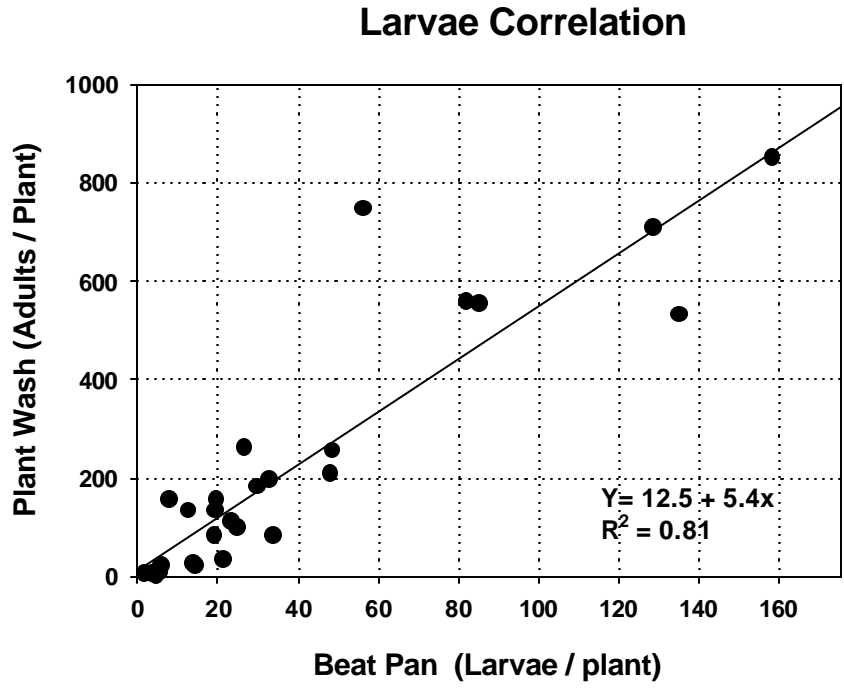


Figure 7. Correlation of beat pan and direct counts of total thrips with absolute estimates with plant washes

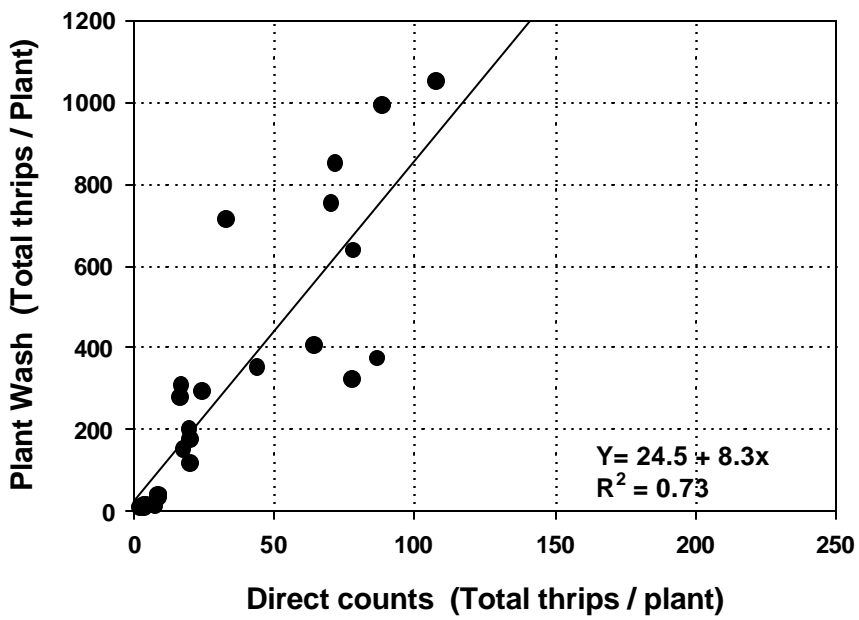
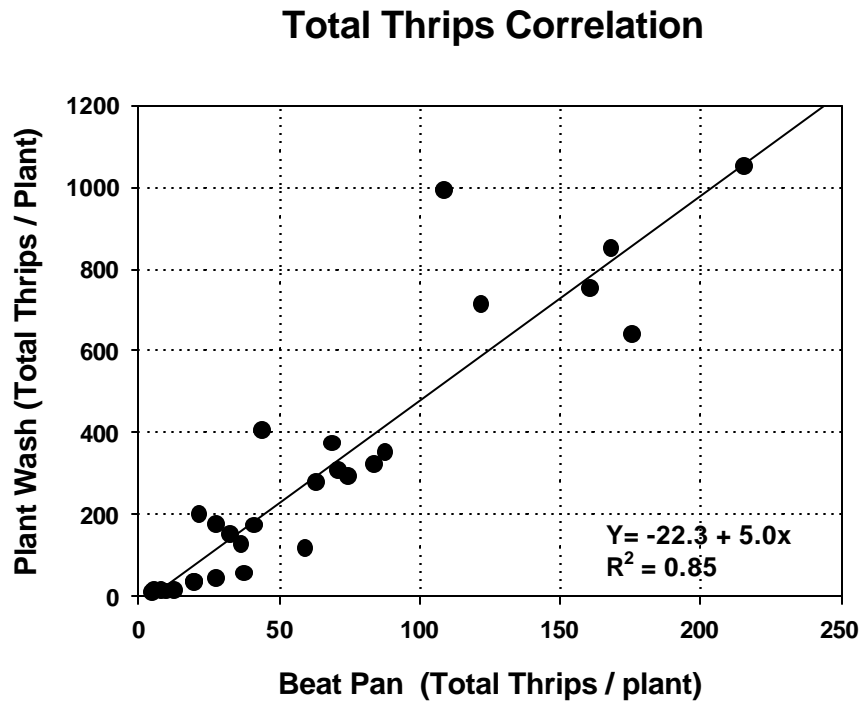


Figure 8. Correlation between blue and yellow sticky traps with absolute estimates of thrips with plant washes

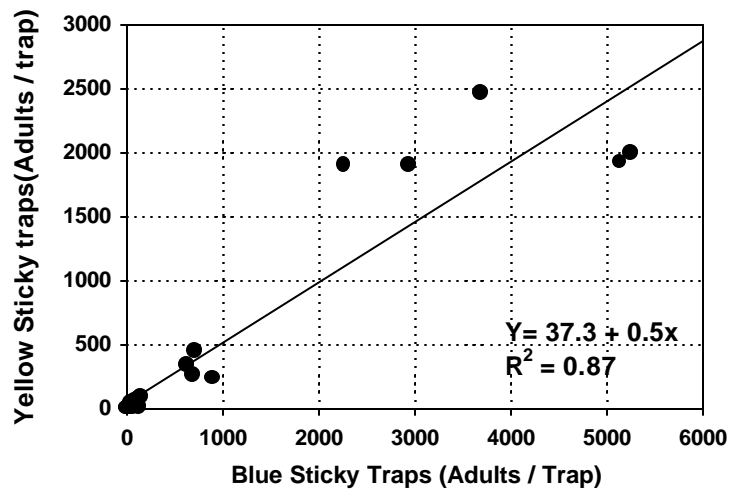
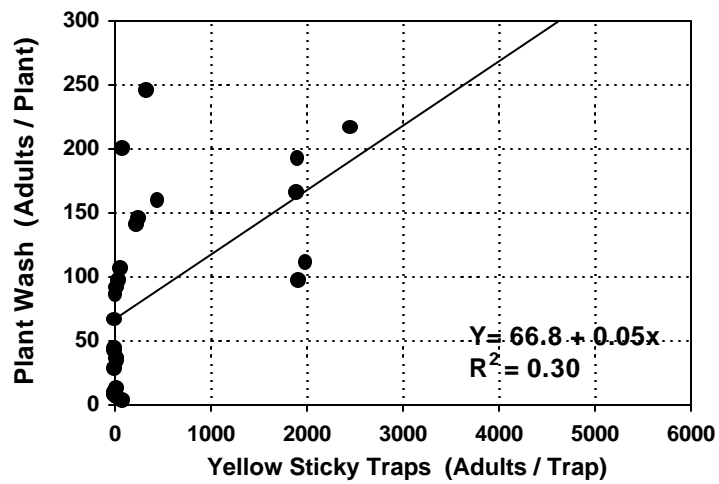
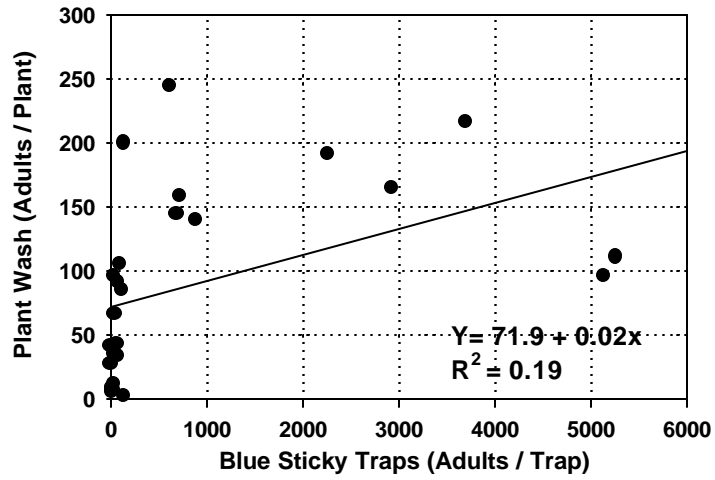


Table 1. Seasonal mean number of thrips adults per plant, RV and RNP values associated with 3 sampling methods on crop stages in head lettuce, Yuma Agricultural Center, 2002-2003.

Crop stage	Sampling method	Mean \pm SD	RV \pm SD	Cost ^a	RNP ^b
Thinning	Beat pan	6.6 \pm 4.3 a	18.7 \pm 2.7 a	0.07	76.9
	Direct count	3.2 \pm 1.6 b	20.6 \pm 4.8 a	0.04	121.9
	Plant wash	8.5 \pm 3.5 a	15.0 \pm 9.2 a	0.25	26.3
Pre-heading	Beat pan	27.4 \pm 14.5 b	10.6 \pm 4.8 b	0.16	58.8
	Direct count	21.2 \pm 15.6 b	18.6 \pm 4.9 a	0.04	133.3
	Plant wash	74.2 \pm 46.2 a	10.9 \pm 5.6 b	0.45	20.4
Early heading	Beat pan	37.8 \pm 24.4 b	12.9 \pm 5.0 a	-	-
	Direct count	46.5 \pm 26.3 b	9.4 \pm 6.1 a	-	-
	Plant wash	154.4 \pm 69.2 a	8.3 \pm 2.2 a	-	-
Harvest - Frame	Beat pan	22.4 \pm 8.0 b	18.1 \pm 4.7 a	0.18	31.3
	Direct count	6.2 \pm 2.8 b	29.6 \pm 14.0 a	0.04	55.5
	Plant wash	80.5 \pm 32.8 a	10.1 \pm 2.0 b	0.70	14.1
Harvest - Head	Beat pan	22.9 \pm 12.2 b	12.2 \pm 5.5 a	0.22	38.5
	Direct count	11.7 \pm 9.3 b	13.7 \pm 7.5 a	0.04	181.8
	Plant wash	59.8 \pm 20.4 a	15.3 \pm 6.3 a	0.75	8.7

Means followed by the same letter are not significantly different (*AOV*, $p < 0.05$)

^a Cost (mean no. person-hours to collect and process each plant sample).

^b RNP=Relative net precision = 100/(RV x cost)

Table 2. Seasonal mean number of thrips larvae per plant, RV and RNP values associated with 3 sampling methods on crop stages in head lettuce, Yuma Agricultural Center, 2002-2003.

Crop stage	Sampling method	Mean \pm SD	RV \pm SD	Cost ^a	RNP ^b
Thinning	Beat pan	5.8 \pm 4.3 a	34.5 \pm 12.7 a	0.07	41.4
	Direct count	2.2 \pm 1.3 a	36.3 \pm 15.0 a	0.04	68.9
	Plant wash	10.2 \pm 9.8 a	35.6 \pm 22.9 a	0.25	11.2
Pre-heading	Beat pan	62.5 \pm 54.9 b	19.3 \pm 8.9 a	0.16	32.3
	Direct count	16.9 \pm 16.7 b	29.0 \pm 12.3 a	0.04	86.2
	Plant wash	287.3 \pm 274.3 a	17.8 \pm 10.7 a	0.45	12.5
Early heading	Beat pan	23.8 \pm 17.2 b	17.2 \pm 6.8 ab	-	-
	Direct count	12.5 \pm 6.9 b	22.0 \pm 5.5 a	-	-
	Plant wash	255.6 \pm 10.2 a	10.2 \pm 6.4 b	-	-
Harvest - Frame	Beat pan	43.1 \pm 28.7 b	14.7 \pm 11.4 a	0.18	37.8
	Direct count	20.1 \pm 21.8 b	16.9 \pm 11.4 a	0.04	147.9
	Plant wash	278.8 \pm 200.5 a	14.2 \pm 5.9 a	0.70	10.1
Harvest - Head	Beat pan	29.7 \pm 19.7 b	16.6 \pm 8.3	0.22	27.4
	Direct count	6.9 \pm 4.6 b	21.1 \pm 10.1	0.04	118.5
	Plant wash	145.6 \pm 76.0 a	16.3 \pm 6.1	0.75	8.2

Means followed by the same letter are not significantly different (*AOV*, $p < 0.05$)

^a Cost (mean no. person-hours to collect and process each plant sample).

^b RNP=Relative net precision = 100/(RV x cost)

Table 3. Seasonal mean number of total thrips per plant, RV and RNP values associated with 3 sampling methods on crop stages in head lettuce, Yuma Agricultural Center, 2002-2003.

Crop stage	Sampling method	Mean \pm SD	RV \pm SD	Cost ^a	RNP ^b
Thinning	Beat pan	12.4 \pm 6.6 ab	14.7 \pm 6.0 a	0.07	97.2
	Direct count	5.4 \pm 2.5 b	14.1 \pm 4.2 a	0.04	177.3
	Plant wash	18.6 \pm 11.8 a	17.5 \pm 10.0 a	0.25	22.9
Pre-heading	Beat pan	89.9 \pm 66.9 b	13.5 \pm 5.4 a	0.16	46.3
	Direct count	38.6 \pm 31.0 b	14.5 \pm 4.1 a	0.04	172.4
	Plant wash	361.4 \pm 318.5 a	12.7 \pm 5.5 a	0.45	17.5
Early heading	Beat pan	61.6 \pm 32.0 b	9.8 \pm 3.9 a	-	-
	Direct count	58.9 \pm 32.8 b	9.9 \pm 4.5 a	-	-
	Plant wash	410.0 \pm 299.5 a	8.2 \pm 4.0 a	-	-
Harvest - Frame	Beat pan	65.5 \pm 32.4 b	11.5 \pm 6.1 a	0.18	48.3
	Direct count	26.3 \pm 23.8 b	14.3 \pm 7.3 a	0.04	174.8
	Plant wash	359.2 \pm 227.8 a	11.2 \pm 4.4 a	0.70	12.8
Harvest - Head	Beat pan	52.1 \pm 29.0 b	12.4 \pm 4.3 a	0.22	36.7
	Direct count	18.7 \pm 13.0 b	12.4 \pm 4.9 a	0.04	201.6
	Plant wash	205.4 \pm 94.5 a	11.3 \pm 3.5 a	0.75	11.8

Means followed by the same letter are not significantly different (*AOV*, $p < 0.05$)

^a Cost (mean no. person-hours to collect and process each plant sample).

^b RNP=Relative net precision = 100/(RV x cost)

Table 4. Mean number of thrips per plant estimated by 3 sampling methods in insecticide efficacy trials, Yuma Agricultural Center, Head Lettuce - I West (6 Feb, Pre-heading stage)

Spray Interval ^a	Avg. no. Thrips / plant								
	Adult			Larvae			Total thrips		
	Direct	Beat	Wash	Direct	Beat	Wash	Direct	Beat	Wash
14-day	3.8 b	5.2 b	8.3 b	2.8 b	1.9 b	6.7 b	6.7 b	7.1 b	14.9 b
7- day	2.0 b	2.7 b	4.8 b	1.2 b	1.7 b	3.5 b	3.3 c	4.3 b	8.3 b
Untreated	10.7 a	11.8 a	28.3 a	9.4 a	13.3 a	45.6 a	20.2 a	25.2 a	73.9 a

Means followed by the same letter are not significantly different (p<0.05)

^a 7-d ay spray interval received 3 applications; 14 day spray interval received 2 applications prior to sample.

Table 5. Mean number of thrips per plant estimated by 3 sampling methods in insecticide efficacy trials, Yuma Agricultural Center, Head Lettuce - I West (12 Mar, Harvest stage)

Spray Interval	Avg. no. Thrips / plant								
	Adult			Larvae			Total thrips		
	Direct	Beat	Wash	Direct	Beat	Wash	Direct	Beat	Wash
14-day	7.1 a	26.0 a	88.8 b	3.3 b	31.8 b	173.6 b	10.3 a	57.8 b	261.7 a
7- day	9.3 a	30.0 a	128.8 a	2.5 b	21.7 b	103.8 c	11.8 a	51.3 b	232.6 a
Untreated	6.0 a	27.0 a	60.7 b	12.3 a	58.5 a	264.3 a	18.3 a	85.5 a	325.5 a

Means followed by the same letter are not significantly different (p<0.05)

^a 7-d ay spray interval received 8 applications; 14 day spray interval received 4 applications prior to sample.

Table 6. Mean number of thrips per plant estimated by 3 sampling methods in insecticide efficacy trials, Yuma Agricultural Center, Head Lettuce -I East- (6 Feb, Pre-heading stage)

TMT	Avg. no. Thrips / plant								
	Adult			Larvae			Total thrips		
	Direct	Beat	Wash	Direct	Beat	Wash	Direct	Beat	Wash
2 Sprays	2.6 b	3.8 b	6.6 b	0.7 b	1.9 b	4.9 b	5.5 b	5.7 b	11.5 b
3 Sprays	4.8 b	3.6 b	6.3 b	0.6 b	1.0 b	4.3 b	3.1 b	4.7 b	10.6 b
Untreated	12.8 a	15.5 a	29.9 a	9.4 a	12.4 a	49.7 a	22.3 a	27.9a	79.6 a

Means followed by the same letter are not significantly different (p<0.05)

^a 7-d ay spray interval received 3 applications; 14 day spray interval received 2 applications prior to sample.

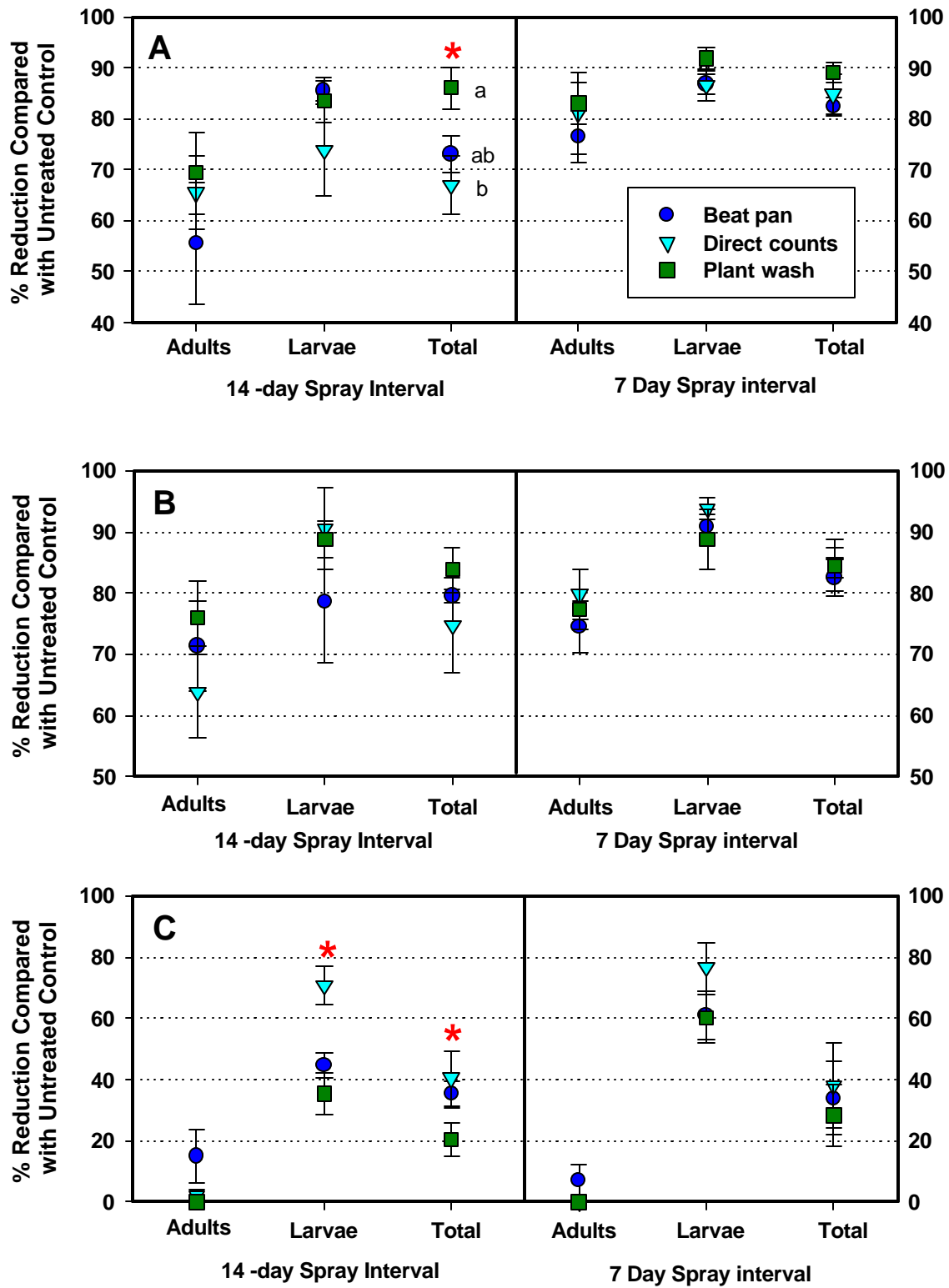


Figure 9. Average % control of thrips following two spray regimes on head lettuce as measured by beat pan, direct counts and plat wash sampling A=Head Lannate I -West (pre-heading stage); B=Head Lettuce - I East (Pre-heading stage); C= Head Lettuce -I West (Harvest stage)
 * =significant treatment differences, Dunnetts Test ($p < 0.05$)

Table 7. Mean number of thrips per plant estimated by beat pan and plant washes sampling in an insecticide efficacy trial, Head Lettuce II (early heading stage)

TMT	Avg. no. Thrips / plant			
	Adult		Larvae	
	Beat	Wash	Beat	Wash
Success 6 oz	21.7 ab	70.2 a	11.4 b	55.3 b
Success 10 oz	18.2 abc	69.2 a	11.1 b	29.1 b
Success 5 oz + Mustang 4 oz	14.6 bc	41.6 a	11.8 b	44.1 b
Lannate 0.7 lb + Mustang 4 oz	11.1 c	56.6 a	5.7 b	35.8 b
Untreated	22.8 a	71.3 a	54.3 a	240.4 a

Means followed by the same letter are not significantly different ($p < 0.05$)

Table 7. Mean number of thrips per plant estimated by beat pan and plant washes sampling in an insecticide efficacy trial, Romaine (Pre-harvest stage)

TMT	Avg. no. Thrips / plant			
	Adult		Larvae	
	Beat	Wash	Beat	Wash
Success 6 oz	11.4 ab	53.7 a	7.0 b	33.9 b
Success 10 oz	10.2 abc	38.4 b	5.9 b	19.0 b
Success 5 oz + Mustang 4 oz	7.6 c	26.3 c	8.3 b	45.6 b
Lannate 0.7 lb + Mustang 4 oz	8.4 bc	26.6 c	3.9 b	23.8 b
Untreated	12.1 a	55.2 a	52.2 a	209.5 a

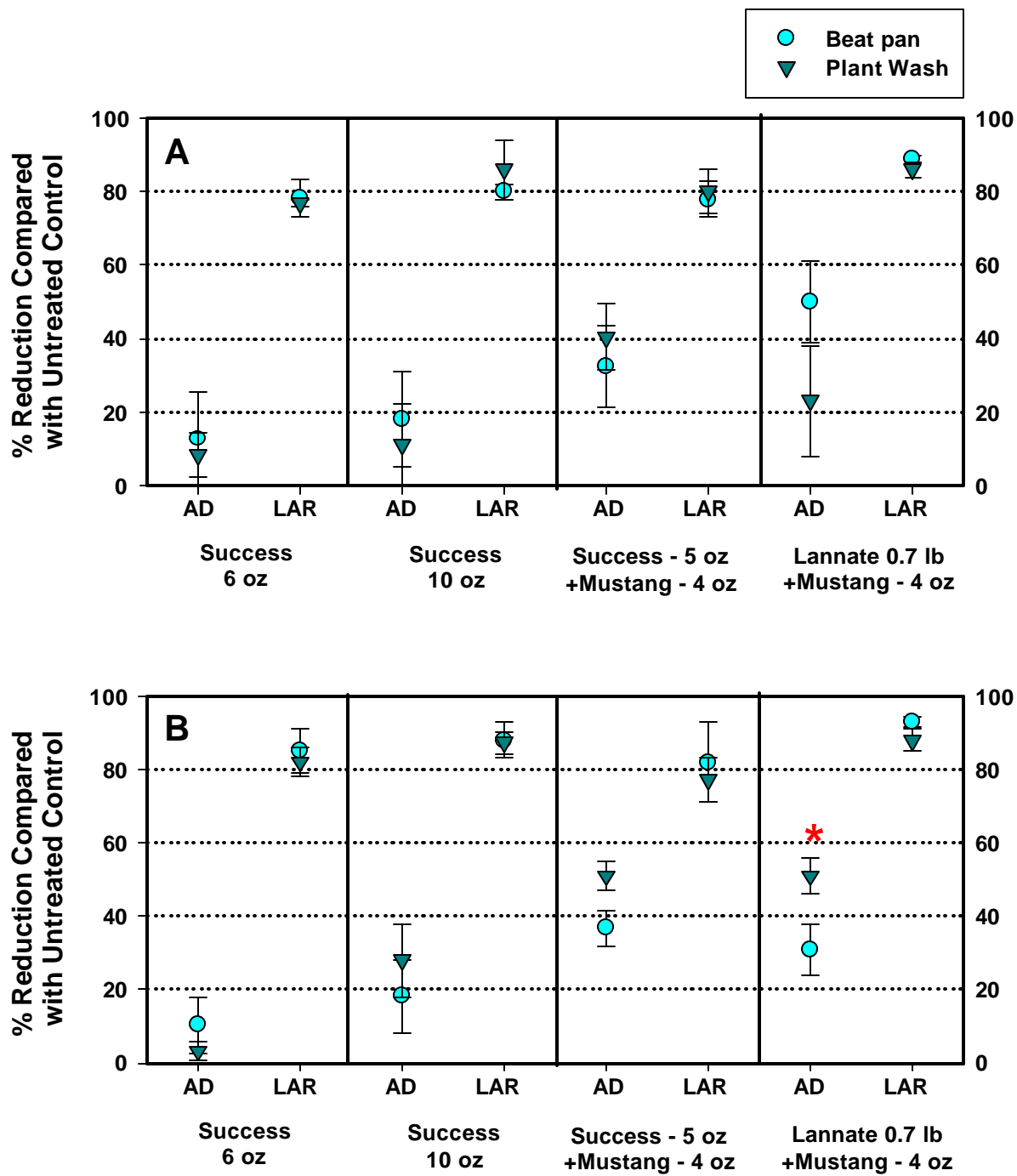


Figure 10. Average % control of thrips in insecticide treatment on head lettuce as measured by beat pan and plant wash sampling. A=Head lettuce II (Early heading stage); B= Romaine (pre-harvest stage). * =Significant treatment differences (paired t test, $p < 0.05$).