TITLE PAGE:

PEST MANAGEMENT GRANTS FINAL REPORT

Contract Number: 99-0214

Contract Title: **Mass Releases of Natural Enemies of Vine Mealybug**

Principal Investigators: **Harry Griffiths / Joe Barcinas**

Contractor Organization: **Foothill Agricultural Research (FAR)**

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<u>Prepared for California Department of Pesticide Regulation</u>

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ABSTRACT:

This is an eleven-month report (effective February 28, 2001) on an effort by Coachella Valley table grape growers, a commercial insectary, University of California, Riverside researchers and extension personnel to implement a long-term reduced-risk pest management system to control recently introduced vine mealybug (VMB) pests by releasing parasites and controlling ants and promoting this approach to all growers and interested parties.

Progress includes: (1) Collaborators have provided all resources needed to establish and operate viable study/validation sites. (2) Insectary parasite production techniques have been modified resulting in up to a 25 times increase in numbers of parasites produced than in previous years, also with significant reduction in contamination of rearing colonies. The significant increase in production of parasites greatly enhances the potential to control VMB with biological control colonization and/or augmentation programs. (3) Yields were significantly higher and VMB numbers and damage were significantly lower in plots where both parasite species were combined and in ant control plots compared with untreated control plots and with ranch averages. (4) Ants were most abundant where there were high numbers of VMB, and reduction in ant numbers combined with parasite releases was closely correlated with reduction in numbers of VMB. (5) A modified spray rig was used to control ants and resulted in significant ant control for several weeks without significant reductions in parasite numbers. Based on results in the year 2000 (cited above) we now plan to additionally assess impact from each parasite species separately each combined with ant control.

EXECUTIVE SUMMARY

The vine mealybug (VMB) was first discovered in the Coachella Valley in Southern California in 1994. It has spread rapidly, causing severe economic damage to table grape vineyards in the region. More recently, it was discovered in the San Joaquin Valley. The University of California Cooperative Extension Viticulture Advisor for Kern County stated, "…at the present time, table grapes in the Coachella Valley are severely impacted, however the spread of this pest into the central valley now exposes over 600,000 acres of grapes to this problem"

Due to the lack of effective native parasites, a dramatic increase in the application of organophosphates (Chloropyrifos, Diazinon, and Dimethoate) and Carbamates (Carbaryl and Methomyl) has been implemented to control the vine mealybug. Each of these pesticides is on the EPA's list of chemicals to be reviewed as required by the Food Quality Protection Act (FQPA) of 1996. Although the USDA and EPA have not listed table grapes as a commodity whose production depends heavily on the pesticides included on the priority list, table grape production will be adversely impacted if the above listed materials are not available. Regardless of the status of these chemicals, a biological, sustainable solution to the devastating VMB is necessary. In essence, there is no effective control for VMB currently available because even pesticides are only marginally effective due to VMB's living under the bark until fruit formation and the protection of VMB by ants.

Three main objectives include: (1) establishing an IPM Innovator Program, (2 producing and releasing 2 parasites, *Anagyrus pseudococcae* and *Leptomastidea abnormis*, and (3) evaluating impact of parasites in reducing damage by VMB (including success in colonization and/or augmentation), and evaluating the impact of ant activity on parasites effectiveness.

The objectives for this proposal are to bring together a voluntary effort by Coachella Valley table grape growers, a commercial insectary, University of California, Riverside (UCR) researchers, and extension personnel for the purpose of implementing a long-term, reduced-risk pest management system for the control of vine mealybug. This will be done by mass-rearing parasites in a commercial insectary, releasing them in commercial vineyards, evaluating their establishment and effectiveness, and widely disseminating the results to encourage others to adopt this IPM approach.

The IPM grape group is well-established and functioning effectively. All land and facilities for the program have been provided by growers in the Coachella Valley. The experimental design consisted of approximately 8 acres in each of 4 farms with 5 treatments on each farm: (1) no treatment of any kind (reference data); (2) ant control only; (3) ant control + parasite releases; (4) parasite releases only; and (5) grower commercial applications.

Rearing and releasing of parasites is proceeding well for *Anagyrus* and *Leptomastidea*. Adjustments were made to the rearing procedures for *Leptomastidea* and production of those parasites is much improved. In summary, from January through October, 2000, nearly 20 million *Anagyrus* and nearly 7 million *Leptomastidea* were produced. More than 10 million *Anagyrus* and more than 3 million *Leptomastidea* were released on 4 farms. *Anagyrus* releases averaged more than 270,000 per week on 4 farms over 39 weeks. *Leptomastidea* releases averaged more than 112,000 per week on 4 farms. These numbers are much higher than ever reported previously for parasite releases against grape mealybugs. The figures demonstrate a convincing capability of this insectary to provide a substantial number of parasites in the future for grower releases over a large area.

Ant control and monitoring of ant species and numbers is producing better than expected results. Ants are being treated with Lorsban using a specially designed spray rig that effectively kills ants without affecting parasites. With pitfall traps and visual observations we have recorded greatly reduced ant numbers in treated areas, up to 4 weeks effective reduction on vines. We have strong evidence from these samples both before and after harvest, that ant control substantially reduces numbers of VMB on vines when parasites are present, based on visual time controlled samples for numbers of VMB. Untreated areas with highest numbers of ants have corresponding highest numbers of VMB. Low numbers of VMB have low damage to fruit and higher yields.

Parasite releases with and without ant control also provide evidence of substantial reduction in numbers of VMB, reduction in damage to fruit, and increases in yields.

Yellow sticky traps to sample parasites have provided evidence that parasites overwinter successfully, are more abundant in release than non-release areas, and spread to non-release areas, especially down wind. *Anagyrus* attack late instar adult VMB and are more abundant in spring temperatures. *Leptomastidea* attack 1st, 2nd, and 3rd instar VMB and are more abundant in hot summer temperatures.

In summary, significant progress has been made in each objective. In objective 1 grower collaborators are participating actively in all phases of this study including providing physical resources and funding that has served as matching funds resulting in additional grant funds being awarded. In objective 2 insectary production techniques have been modified with the result that consistent high numbers (over 100,000 per week) of each of the 2 parasites are now being produced and released each week. In objective 3 ant control alone in the presence of parasites, parasite releases alone, and ant control plus parasite releases have substantially reduced damage from VMB and increased yields compared to untreated controls and to farm averages.

The collaboration and results obtained to date provide high expectations for effective VMB control in the spring preceding harvest.

BODY OF REPORT

A. INTRODUCTION

This proposal continues the work of a diversified group interested in demonstrating an IPM system for the control of recently introduced vine mealybug (VMB) pests. This is being done by mass rearing two parasites (*Anagyrus pseudococci* and *Leptomastidea abnormis*) in a commercial insectary, releasing them in commercial vineyards, evaluating their establishment and effectiveness, finding a synergistic ant control method, and widely disseminating the results. This is a report on results in the second year of this project.

In June of 1994, a previously unencountered VMB pest was discovered in the Coachella Valley and other desert growing regions of Riverside County. This new pest represents a serious economic threat for California table grape cultivations because it feeds on the vines and produces copious quantities of honeydew (upon which mold develops rendering the fruit unmarketable). Additionally, it is a vector for two serious diseases: the grapevine corky bark virus and grapevine leafroll disease. Although the preferred hosts of *Planococcus ficus* (VMB) are apparently grape and fig, the genus has also been recorded as a pest of apple, avocado, banana, citrus, date palm, mango, pomegranate, and ornamentals. Potential thus exists for this pest to move to other crops and cause even more extensive economic damage. It has already spread to the San Joaquin Valley and threatens the entire grape industry in California.

Since 1994, insecticides have been the only significant management tactic used to attempt to prevent or reduce economic losses from mealybug damage. However, because of the mealybug's habit of congregating beneath bark and in other protected places, chemical controls are difficult or ineffective. Use of chemicals also upsets the existing natural balance, causing resurgence of the target pest and secondary pest outbreaks in grapes and other pests in adjacent crops such as alfalfa, citrus, dates, and ornamentals. In many crops, chemical applications rapidly result in resistant pest populations (especially spider mites) for which there are no known control measures.

Introducing parasites of VMB to the Coachella Valley should reduce the levels of overwintering mealybugs. These reduced levels of VMB will result in fewer insecticide applications thus allowing the native predators to increase in numbers and combine with introduced parasites to further lower mealybug numbers. This "field insectary” will maintain a needed level of beneficial insects in the vineyards while reducing environmental and worker risk.

In the Coachella Valley, substantial work has been completed by D. González and J. Klotz, UCR, CDFA, local cooperative extension personnel, and others on whose work we are building. Indigenous parasites attacking the vine mealybug in the Coachella Valley have been identified and assessed for impact. In a collaborative survey in 1994, 1995, 1996, 1997, and 1998 between University of California researchers, CDFA, and Riverside County personnel, low levels of native parasites of mealybugs were found.

An assessment of predator impact against VMB was made in 1998 in collaboration with CDFA personnel. Spiders appear to be the principal predators of VMB followed by green and brown lacewings and possibly coccinellids. However, there remains a definite lack of effectiveness by native natural enemies, by themselves, in the Coachella Valley.

Dr. Gonzalez completed field cage and open field evaluation studies on imported parasites over summers in 1996-1998 in vineyards in the Coachella Valley. The *A. pseudococci* from Spain and the *Leptomastidea* from Israel provided exceptionally outstanding results over the past two years and significantly better results than the *Anagyrus* indigenous to the Coachella Valley. Data obtained by D. Gonzalez in parasite evaluation trials in 1998 showed that harvest yields in pesticide-untreated plots were comparable or greater than yields in adjacent commercial vines receiving two applications of Methomyl. Movement of parasites has been confirmed from release to non-release areas with far greater numbers in release areas, based on data from yellow sticky traps.

Also, in preliminary trials, ants were found interfering with parasitization of mealybugs. Our preliminary results are supported by earlier reports that ants interfere significantly with parasite impact on mealybugs. The most common ant pest in the Coachella Valley vineyards is a field ant, *Formica perpilosa*. This species thrives in the irrigated desert conditions characteristic of this region, and nests in large colonies at the base of the grapevines, where it is in close proximity to its major source of honeydew, the Vine Mealybug. *F. perpilosa* is a very active and aggressive ant. The other common pest in Coachella vinyards that tends and protects mealybug species is the southern fire ant, *Solenopsis xyloni*. Several bait materials and various techniques are being tested for ant control.

In several other countries, VMB populations are biologically controlled by several parasites. Therefore, work is being done to introduce exotic parasites to areas where mealybugs are unchecked.

The goal is to develop an environmentally safe management program for a new and economically devastating pest of grapes. **The objectives are: (1)** to establish a functional IPM Innovator Program using guidelines provided by the DPR and CalEPA. This IPM Innovator Group is also responsible for disseminating interim findings and final results of this project for implementation industry-wide. **(2)** to rear and mass release two species of mealybug parasites on a multi-farm scale and **(3)** to assess the effectiveness of the parasites against VMB and evaluate the status of colonization and/or augmentation success. Part of the evaluation also includes the impact of ants on parasite effectiveness.

Specific Tasks for each Objective

OBJECTIVE 1: The IPM grape group is in place and operational because of the common interest in solving the VMB problem and the constant outreach and communication efforts of the core group. Following commitment of initial funding from DPR and other sources, the project got underway in April 1999. Acreage was set aside and modified to comply with the experimental requirements. Planning sessions and progress reports have been presented to growers as noted in results.

Interim findings are being prepared for presentation to the following publications and organizations: American Vineyard magazine, Grape Grower magazine, California Grower magazine, the California Table Grape Commission, the Riverside County Extension office, the California Desert Grape Administrative Committee, and local government agencies. Eddie Walker of Peter Rabbit Farms is chair of the Innovator Group and is coordinating the information/dissemination activities.

OBJECTIVE 2: The rearing work is being done at Foothill Ag Research, Inc. (FAR), in Corona, California. The rearing procedures being used begins with establishing a host material on which to raise VMB. Once the VMB population is established, the parasites are introduced. As the parasite population grows and thrives, it is being harvested and released into the vineyards.

The mealybug's life cycle involves a number of stages. In order to insure discreet instars of mealybug a crawler rack was developed for the production of vine mealybug crawlers. Each rack produces a uniform stage of VMB crawlers. The importance of a uniform culture is that *L. abnormis* attack mostly the 1st, 2nd, and 3rd instars of the mealybug, while the *A. pseudococci* attack the 3rd, 4th and 5th instars.

Release of parasites is by FAR personnel in the Coachella Valley test plots described below. In Year 1, the first releases were begun approximately three months after funding became available, and they continued through October. Beginning in Year 2, equal numbers of parasites were released in each of 5 fields weekly from February through October. Maximum numbers of parasites were reared from funding available.

<u>OBJECTIVE 3</u>: Evaluation is conducted by University of California personnel. The experimental design in Jan-June, 2000 was a randomized complete block with five treatments each in 4 replications (4 farms, Fig. 1a). Each of 4 growers (members of the Coachella Valley IPM Innovator Group) provided approximately 8 acres untreated with chemicals (except for ant control through skirt treatments) for 5 treatments: (a) parasite release plus ant control, (b) parasite release, no ant control, (c) completely untreated (no ant control, no parasite release), (d) ant control only (no parasite release), and (e) grower commercial pest control treatment (same treatments on all 4 farms). Samples were taken only from the center third of each plot. The outer 1/3 on each side of each plot served as a buffer zone between treatments. Plots were located on the up-wind edge of all farms not adjacent to other vineyards. This minimizes insecticide drift, which readily kills parasites and predators.

Baseline Data: In 1999 and in 2000, pre-treatment VMB, parasite, and ant data were collected for a minimum of 1 week in each of the 4 vineyards.

Chemical treatments (skirt applications) against ants were applied in one of the two parasite release plots and in one of the two untreated (except for ants) control plots (Fig 1a). We used a registered material, Lorsban, for ant control and applying it with a modified sprayer we designed to minimize impact against parasites and predators (Fig. 7).

Evaluation of impact from treatments on mealybugs and yields are based on sampling techniques developed over the past 3 years by D. Gonzalez, the late H. Shorey (Univ. Calif.), J. Ball, and K. Godfrey (CDFA). Evaluation samples were taken every 2 weeks at each farm by D. Gonzalez, a technician from UCR, and two field assistants. Samples were staggered allowing sampling of 2 farms on odd-numbered weeks and 2 farms on even-numbered weeks. Evaluations were based on the following:

a) Relative numbers of parasites were assessed every 2 weeks on each farm beginning one week after first release from February through June by placing 18 yellow sticky traps through the center third of the plots where parasites are released. Traps were left in the field for 2 weeks, and returned to the lab for identification and counts of parasites, and predators. Similar samples were taken from the untreated control plots and from the commercial treatment plots.

b) Mealybug numbers were estimated with visual observations in time-controlled samples. The relatively short time needed to take each sample allowed a greater number of samples with equal or greater sampling efficiency than other methods tested by D. Gonzalez, H. Shorey, J. Ball and K. Godfrey in 1998. We had three samplers taking a total of 18 samples per each of 5 treatments every 2 weeks. Data recorded included number of ants, and mealybugs on trunks and vines.

c) Estimates for ant abundance were taken from pitfall traps and visual observations. The pitfall traps sample ants on the ground, and the visual counts sample ants in the vines. There were 18 pitfall traps in the same location where VMB and yellow trap samples were located. Samples and visual observations were taken bimonthly.

d) Yields were recorded in boxes/acre (18-lb. equivalents) from each of the 5 treatment plots. We also recorded yield from both fruit-washed and unwashed for honeydew removal. Fruit wash was done directly in the field by dipping fruit with honeydew into 5-gal buckets of water and setting them aside to dry. These were packed into separate boxes for recording boxes/acre of washed fruit. Fruit washed is an index of VMB damage.

RESULTS

OBJECTIVES

1. Establish IPM Innovator Program
2. Rearing and releasing 2 species of VMB parasites.
3. Evaluation of the parasites' viability in plots, impact of parasite releases on VMB damage, and on yields at harvest, and impact of ants on parasite effectiveness against VMB.

Objective 1: This objective has been accomplished. The team is in place and functioning effectively. In the year 2000, meetings were held in February (planning session), March (field day workshop to explain objectives and procedures to growers), July (presentation of research results, future plans to IPM Group), presentation of research and future plans to all growers in Coachella Valley at the Annual Meeting in Coachella of the California Desert Grape Growers in November 2000, and a report and planning session for the 2001 season in February 2001.

We have met several times to promote the project and its results, we have contacted other interested parties as trade publications, grower organizations, the Riverside County Agricultural Commissioners Office, and University of California Cooperative Extension personnel.

Objective 2: F.A.R. continues to fine tune mass rearing procedures of the two vine mealybug parasites, *Anagyrus pseudococci* and *Leptomastidea abnormis.* We have met our objective for this project and are on budget.

The production of the *Anagyrus* has exceeded the amount requested by UCR. However, there have been production problems with the *Leptomastidea.* We are continually working to identify the cause or causes of the inconsistent production of this parasite.

The *Anagyrus* will host feed on 1st instars and lay eggs on 2nd instars through adults. However, they produce mostly males, as much as 80%, on the 2nd and 3rd instars. On the 4th and 5th instars mostly females are produced, 60 to 70%.
The *Leptomastidea* lays eggs on the 1st instar producing 80% males. On the 2nd and 3rd instars they produce 60 to 70% females. They do not attack the 4th and 5th instars of the mealybug.

Crawler production, the most vital part of the culture, is extremely sensitive to microclimates and the quality of the squash. Slight changes in the temperature or humidity can cause severe crawler reduction. Our thermostats for cooling and heating are not accurate enough to maintain a constant temperature of 80ºF. During the summer months we have found that the females mature much earlier. To compensate for this occurrence the rotation of the crawler racks was reduced from every six weeks to every three weeks.

Also, the enclosed mealybug production cabinets are now thoroughly cleaned every two months. This is to further reduce the possibility of contamination. The open shelves are used for a 6 to 8 week period while the cabinets are cleaned and new production is begun.

The mealybug used as the host for the two parasites is now being based on the size or instar, not the numbers of days of infestation. The size of the mealybug can be affected by the temperature. Therefore, during hot weather the mealybug may grow faster than during cold weather. However, as a general guideline we use 10-15 day old mealybug for *Leptomastidea* and 18-28 day old mealybug for *Anagyrus.*

Results in Table 1 document the numbers of parasites released in January – October 2000 in the same locations. In 2001 the releases of the 2 parasite species will be in 2 separate plots, both with ant control (Fig. 1c). These numbers released are much higher than any MB releases reported at any time in any other place. These numbers represent an excellent rearing capability of FAR insectary.

<u>Objective 3:</u> Funding for this program from DPR has been requested only to support objective 2. However, we include here a report on objective 3 because the results are VERY promising, and they clearly demonstrate and justify the effort and funding provided for objective 2. Funds to support activities reported here under objective 3 are from other grant agencies. No funds from DPR were used to support the activities listed under objective 3.

The timetable is according to schedule. We have very conclusive data from the second year that supports our expectations that parasite releases and ant control can substantially reduce damage and yield loss from VMB. (figs. 2-6, 10, 11)

Naturally occurring low numbers of VMB in 2 of the 4 farms precluded a more expansive demonstration of the efficacy of our treatments (Tables 2 and 3).

A summary of our results follows: (1) ant control appears to be the single most critical aspect of VMB control, (2) augmentation releases of parasites were effective in reducing VMB damage and resulted in increased yields. In the Tudor ranch (Figure 2a) all of our treatments resulted in higher yields than the ranch average and the untreated control. The best estimate of damage was the number of boxes washed for removal of honeydew. At the Tudor ranch, more than 26% of the fruit were washed in the untreated plots versus less than 1% in parasite release plots (Fig 2a, 3)

At the Sunworld Ranch, all of our treatments also resulted in higher yields than the untreated control (Fig. 2b, 4). VMB damage was significantly greater on this ranch than at Tudor's. The ranch average for washed fruit for honeydew removal was 15-20% at Tudor's and at Sunworld % boxes washed ranged between 65-75%.

Mean number of VMB was significantly greater in untreated and in commercial plots than in our plots were we had ant control and parasite release at Tudor Ranch (Fig. 5a), and at Sunworld Ranch (Fig. 5b). VMB are actively moved by ants from trunks to vines in the spring and from vines to trunks after harvest. Thus ant control was critical. At the Tudor ranch, the lowest numbers of VMB were in plots treated with Lorsban for ant control (Figs. 5a, 6a).

At the Sunworld Ranch, the highest numbers of VMB were in plots not treated for ant control, the organic section of the farm (Figs 5, 6b). The lowest number of VMB were from the plot treated for ant control with release of parasites.

Mean number of ants was effectively reduced by using Lorsban and with Admire in baits tested by J. Klotz (Figs 6ab,11ab). Ant numbers were closely correlated with VMB numbers at both the Tudor and Sunworld Ranches where VMB were found abundantly (Figs 5ab, 6ab, 10ab, 11ab).

Rearing and releasing of parasites is proceeding well for *Anagyrus* and *Leptomastidea* (Table 1). Adjustments were made to the rearing procedures for *Leptomastidea* and production of those parasites is much improved. In summary, from January through October 2000, nearly 20 million *Anagyrus* and nearly 7 million *Leptomastidea* were produced. More than 10 million *Anagyrus* and more than 3 million *Leptomastidea* were released on 4 farms. *Anagyrus* releases averaged more than 270,000 per week on 4 farms over 39 weeks. *Leptomastidea* releases averaged more than 112,000 per week on 4 farms. These numbers are much higher than ever reported previously for parasite releases against grape mealybugs. The figures demonstrate a convincing capability of this insectary to provide a substantial number of parasites in the future for grower releases over a large area.

Relative numbers of parasites collected from yellow sticky traps showed similar results to those of previous years. The *Leptomastidea* are collected in far greater abundance during the hottest part of the summer (Fig. 8) whereas *Anagyrus* are more abundant in the cooler parts of the season (Fig 9). Traps also provided evidence that parasites overwinter successfully, are more abundant in release than non-release areas, and spread to non-release areas, especially down wind. *Anagyrus* attack late instar adult VMB. *Leptomastidea* attack 1^{st} and 2^{nd} instar VMB.

Samples of naturally occurring VMB were very low in 2 of our 4 fields as also were the numbers of ants (Table 2, 3) in those same fields. Both of these fields were early yielding varieties and we believe that VMB did not have sufficient time or heat units to build up in numbers as they did in the Sunworld and Tudor ranches, where varieties matured much later.

In July 2000 we changed the experimental design used from January to June (Fig 1a) to a new design (Fig 1b). The new design re-aligned treatments so that our best treatments for reducing VMB during Jan-June 2000 were now located in the previously untreated or chemically treated areas, where the highest numbers of VMB had occurred (Fig 5ab). The purpose of this re-alignment of plots was to test the hypothesis that reduction of ant numbers and parasite releases could effectively reduce numbers of VMB after harvest, as a basis for lowering the VMB numbers that would be there the following season. Our results provided strong evidence that parasite releases and ant control following harvest effectively reduce numbers of VMB (Fig 10ab, 11ab).

In summary, we believe we have gathered significant data on parasite releases against VMB and damage, on seasonal distribution of parasite species, and on ant control impact against VMB abundance and damage. We look forward to the next step in which we will compare releases of *Anagyrus* versus those of *Leptomastidea* both combined with ant control in different treatment areas (Fig 1c).

DISCUSSION

Measures of Success

In February 2000, we held a planning meeting with large number of individuals interested in support of this program (see copy in appendix – minutes of DPR meeting February, 2000).
We promoted Field Day March 2000, Tudor Ranch (see copy in appendix), with a large number of people attending.

In July 2000 a progress report was presented to growers on research findings, and future plan.

In November 2000 we presented an annual report to California Desert Leagues Committee on research results and future plans.

In February 2001 we had a report and planning session for 2001 with the IPM Grape Growers collaborators in our program.

From discussions with growers we are told that many growers and all of our collaborators are now directing minimal insecticide applications at controlling ants instead of VMB. They are using equipment that directs the applications to the base of the trunks, minimizing impact against parasites.

There has been considerable discussion and interest from growers in purchasing parasites to release in their fields instead of using chemicals. We believe there is considerable interest in and acceptance of our results, with less reliance on chemicals to attempt to control VMB.

SUMMARY AND CONCLUSION

The proposed program has a high potential for success based on the following available information:

- There is strong support among Coachella Valley growers for this program. The California Desert Grape Administrative Committee committed $30,000 towards mass rearing and parasite release phase of this program for a third year, 2001-2002.
- State of California, DPR has provided $30,000 towards mass rearing and parasite release phase of this program for a third year, 2001-2002.
- USDA-CSREES has provided $35,434 towards mass rearing and parasite release phase of this program for a third year, 2001-2002.
- Procedures have been greatly modified for mass rearing and release of parasites, resulting in significant increase in parasite numbers produced and released and in reduction of contamination of cultures.
- From many techniques tested, reliable sampling methods are available for measuring treatment effects on VMB, parasites, and ants with relatively large sample numbers and techniques suitable for use by PCA's.
    - Sticky yellow cards to measure relative parasite numbers and movement among treatments.
    - Visual observations in time – controlled samples to estimate VMB numbers on vines.
    - Pitfall traps provide good estimate of ant numbers and species on ground around vines.
- Two parasite colonies were found outstanding from 18 colonies screened in fields over 4 years under a wide range of conditions.
    - Cabesuelos – Spain – *Anagyrus*
    - Jordan Valley – Israel – *Leptomastidea*
    - Larger number of *Leptomastidea* in release versus no release areas
    - Both parasites successfully over-winter.
    - Both parasites move from release to non-release areas.
    - *Anagyrus* prefer old instar VMB and host feed significantly on VMB; prefer spring and fall temperatures
    - *Leptomastidea* prefer young instar VMB, prefer hot summer temperatures.
    - Thus these 2 parasite species complement their combined impact against VMB.
- Ant Control (in collaboration with John Klotz)
    - Reduction in ant numbers closely associated with lower numbers of VMB.
    - Significant reduction in ant numbers with no impact on parasites with Lorsban applied with modified ground rig.
- Damage
    - Dramatically lower in plots where parasites released and where had ant control versus untreated and commercial plots in experiment but especially compared with damage in surrounding vineyards of ranch (our treatments 6-7% damage vs. $\geq$ 65% in surrounding vineyards at Sunworld Ranch, Fig 2b).
- Yields
    - Significantly higher in plots where parasites released and in ant control plots compared with untreated and commercially treated plots in our experiment, and also when compared with yields on vineyards surrounding our plots on 2 ranches having high numbers of VMB (Fig 2ab).
- Usefulness of proposed research
    - Reduce need for pesticide use and cost.
    - Provide viable alternative to pesticide use
        - Enhance BC potential
            - More effective parasites
            - Effective ant control
    - Development of Economic Threshold for VMB
      Experimental design provides for data from 20 plots: this permits an analysis of seasonal numbers of VMB vs damage, and VMB vs. yields.

TABLE 1. F.A.R., INC. PARASITE PRODUCTION & RELEASES JANUARY, 2000 - OCTOBER, 2000

DATE	ANAGYRUS PRODUCTION	ANAGYRUS RELEASES	LEPTOMASTIDEA PRODUCTION	LEPTOMASTIDEA RELEASES
WEEK 1/2/00	265,000	0	32,000	0
WEEK 1/9/00	227,000	0	30,500	0
WEEK 1/16/00	268,000	0	45,000	0
WEEK 1/23/00	294,000	0	140,000	0
WEEK 1/31/00	224,000	64,000	98,000	0
WEEK 2/6/00	435,000	192,000	79,000	0
WEEK 2/13/00	452,000	192,000	120,000	96,000
WEEK 2/20/00	408,000	288,000	129,000	96,000
WEEK 2/27/00	354,000	192,000	75,000	96,000
WEEK 3/5/00	590,000	384,000	81,000	0
WEEK 3/12/00	660,000	384,000	136,000	0
WEEK 3/19/00	521,000	384,000	161,000	96,000
WEEK 3/26/00	668,000	288,000	74,000	96,000
WEEK 4/2/00	814,000	576,000	163,000	96,000
WEEK 4/9/00	894,000	576,000	212,000	96,000
WEEK 4/16/00	524,000	480,000	211,000	96,000
WEEK 4/23/00	484,000	192,000	232,000	96,000
WEEK 4/30/00	408,000	288,000	198,000	96,000
WEEK 5/7/00	351,000	192,000	189,000	96,000
WEEK 5/14/00	396,000	96,000	291,000	192,000
WEEK 5/21/00	358,000	288,000	213,000	192,000
WEEK 5/28/00	322,000	192,000	201,000	192,000
WEEK 6/4/00	484,000	288,000	167,000	96,000
WEEK 6/11/00	218,000	0	93,000	96,000
WEEK 6/18/00	242,000	96,000	189,000	96,000
WEEK 6/25/00	476,000	192,000	231,000	96,000
WEEK 7/2/00	240,000	192,000	147,000	96,000
WEEK 7/9/00	281,000	96,000	106,000	0
WEEK 7/16/00	224,000	72,000	48,000	0
WEEK 7/23/00	267,800	96,000	270,000	96,000
WEEK 7/30/00	504,000	288,000	175,000	164,000
WEEK 8/6/00	472,000	240,000	80,000	48,000
WEEK 8/13/00	718,000	576,000	59,000	0
WEEK 8/20/00	276,000	96,000	89,000	0
WEEK 8/27/00	286,000	96,000	198,000	0
WEEK 9/3/00	548,000	192,000	260,000	96,000
WEEK 9/10/00	554,000	288,000	150,000	48,000
WEEK 9/17/00	692,000	336,000	88,000	48,000
WEEK 9/24/00	402,000	240,000	367,000	120,000
WEEK 10/1/00	675,000	360,000	316,000	240,000
WEEK 10/8/00	532,000	360,000	271,000	120,000
WEEK 10/15/00	660,000	370,000	186,000	40,000
WEEK 10/22/00	1,157,000	840,000	364,000	240,000
TOTAL	19,825,800	10,562,000	6,964,500	3,372,000

TABLE 2. MEAN NUMBER OF VMB AND YIELDS, BIANCO RANCH

NUMBER VMB PER VINE ($\bar{x}$ of 18 SAMPLES/WK)

Sample date	Ant control only (N1)		"No" treatment (N2)		Parasite release + ant control (Y1)		Parasite release only (Y2)		Grower com'l Treat (C)	
	V*	T*	V	T	V	T	V	T	V	T
May 8	11	16	13	17	2	2	9	11	1	2
May 21	20	22	1	1	12	13	1	1	1	2
**										
June 3	5	6	3	4	1	1	1	2	1	2
June 18	5	6	2	2	1	1	4	5	2	2

*V (vines) = canes, spurs, cordon
T = total, from v and trunk

** **HARVEST 25-26 MAY**

NO GRAPES WASHED

YIELD DATA – BOXES PER ACRE

1315	1301	1190	1349	1124

OTHER PERLETTE YIELDS (NEARBY): 850-1000

TABLE 3. MEAN NUMBER OF VMB AND YIELDS, WALKER RANCH

NUMBER VMB PER VINE ($\bar{x}$ of 18 SAMPLES/WK)

Sample date	Ant control only (N1)		"No" treatment (N2)		Parasite release + ant control (Y1)		Parasite release only (Y2)		Grower com'l Treat (C)	
	V*	T*	V	T	V	T	V	T	V	T
May 27	4	5	2	3	1	2	7	7	7	8
June 11	2	2	6	7	2	2	3	4	4	4

*V (vines) = canes, spurs, cordon; T = total, from v and trunk

Harvest 26, 30 May: NO Grapes Washed

YIELD DATA (BOXES/ACRE) – NO GRAPES WASHED

593	818	752	694

YIELD FROM PERLETTE IN ADJACENT FIELD: ~ 700-750

Figure 1. Experimental Designs in the same location

a. January – June 2000

COMMERCIAL 1 ADMIRE 1 PROVADO	NO TREATMENT	ANT CONTROL ONLY	BOTH PARASITES RELEASED + ANT CONTROL	BOTH PARASITES RELEASED NO ANT CONTROL

b. June – November 2000

ANAGYRUS RELEASE + ANT CONTROL	LEPTOMASTIDEA RELEASE + ANT CONTROL	ANT CONTROL ONLY	NO TREATMENT

c. Jan – June 2001

BOTH PARASITES RELEASED + ANT CONTROL	ANAGYRUS RELEASE + ANT CONTROL	LEPTOMASTIDEA RELEASE + ANT CONTROL	ANT CONTROL ONLY	NO TREATMENT

Fig. 2a. Yields* from 5 treatments, Tudor Ranch Harvest 5-13 June.

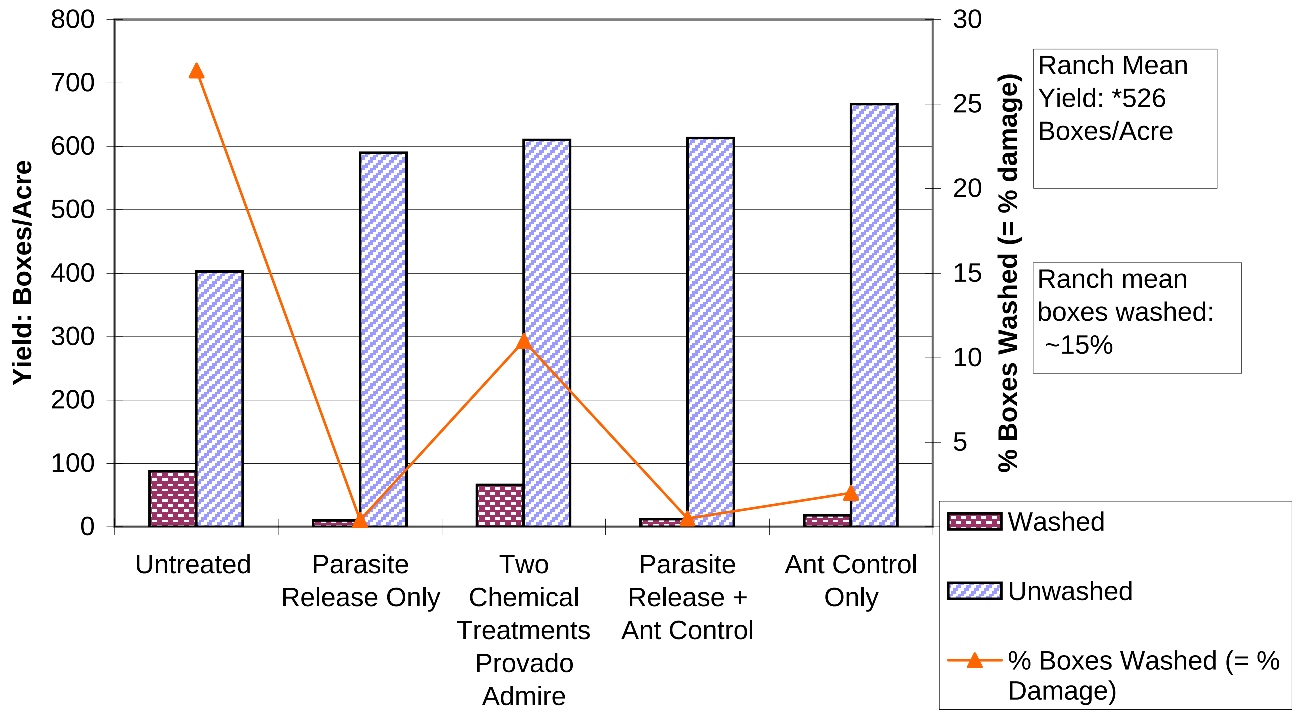
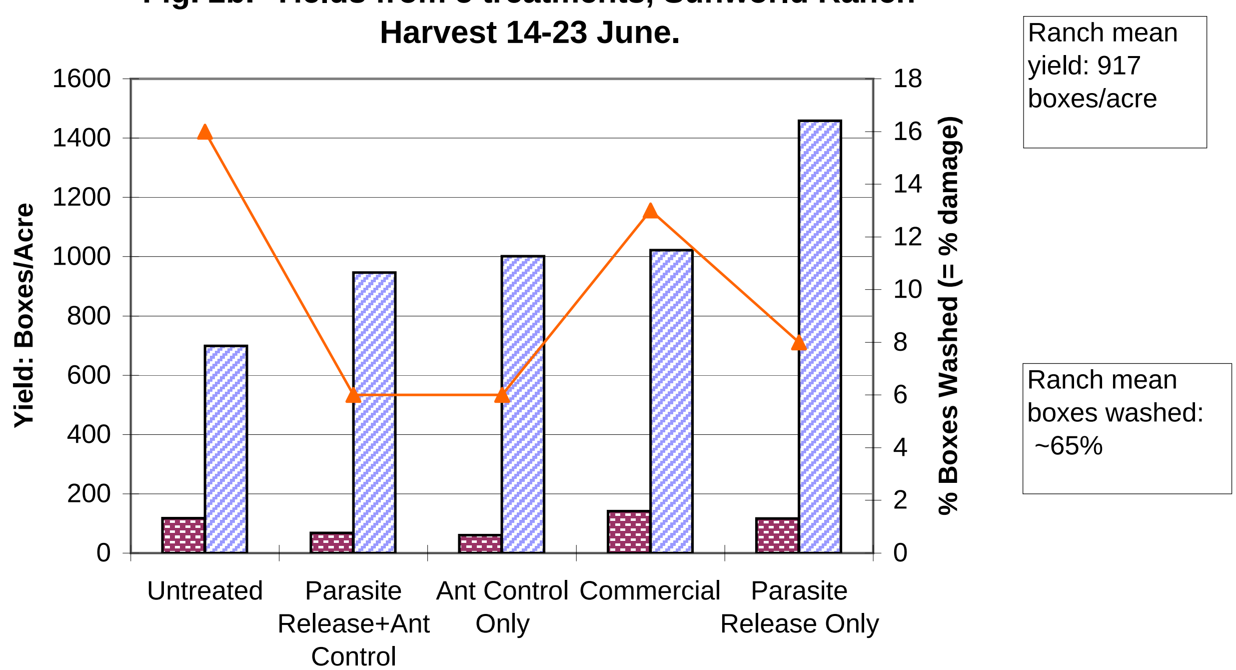
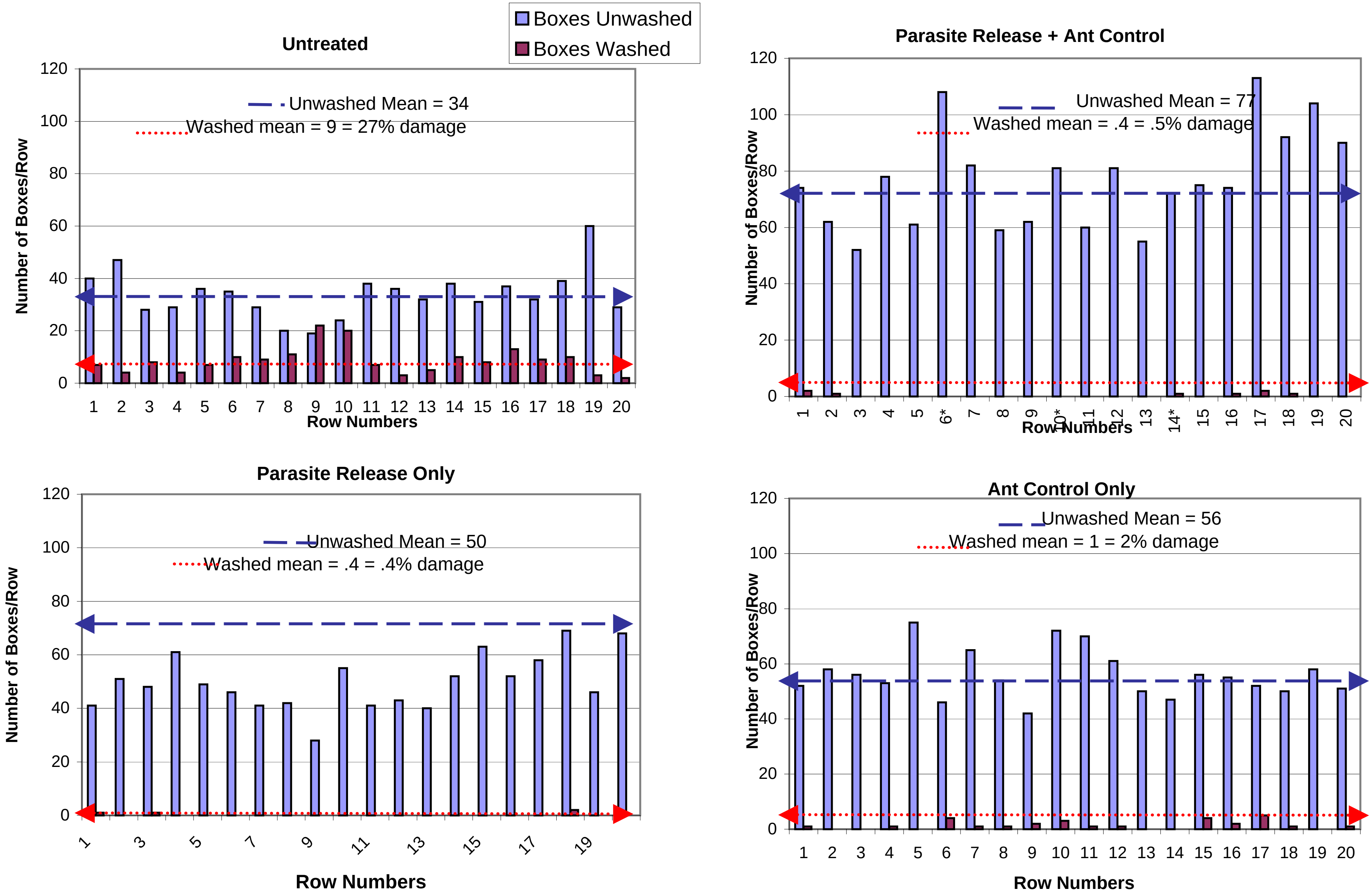


Fig. 2b. Yields from 5 treatments, Sunworld Ranch Harvest 14-23 June.



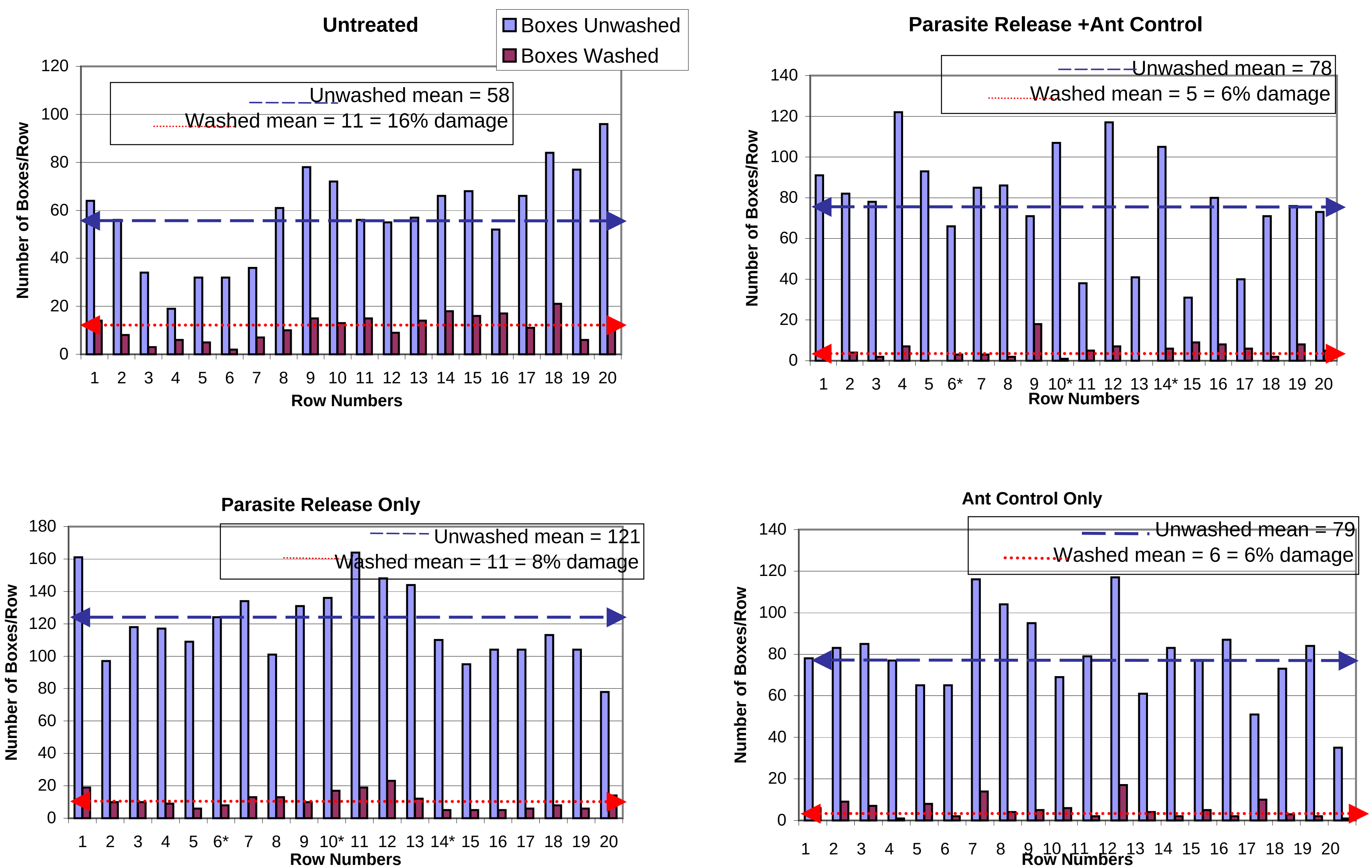
* 4 ranches were included in these trials. Results are given here only for 2 ranches. In the other 2 ranches there were low numbers of VMB and no damage on fruit nor impact on yields.

Fig. 3. Number of boxes of grapes washed and unwashed, Tudor Ranch, June 2000



* Parasite release rows

Fig 4. Number of boxes of grapes washed and unwashed, Sunworld Ranch, June 2000.



* Parasite release rows

Fig. 5a. Mean number of vine mealybug (VMB), Tudor Ranch. Harvest 5-13 June.

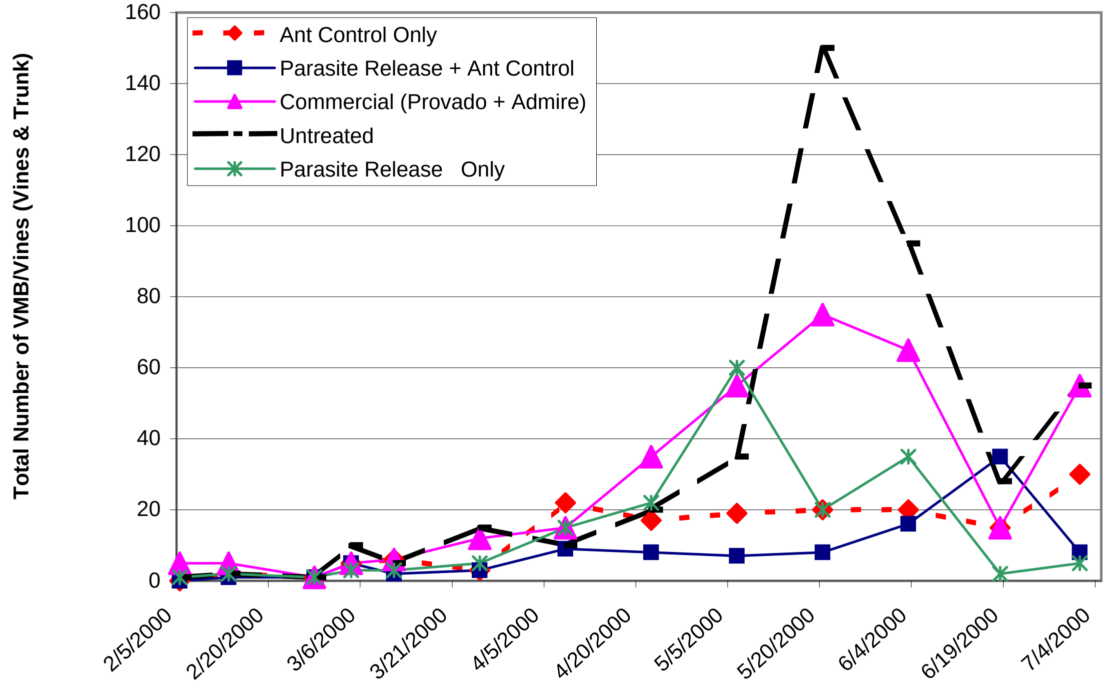


Fig 5b. Mean number of vine mealybug (VMB) Sunworld Ranch. Harvest 14-23 June.

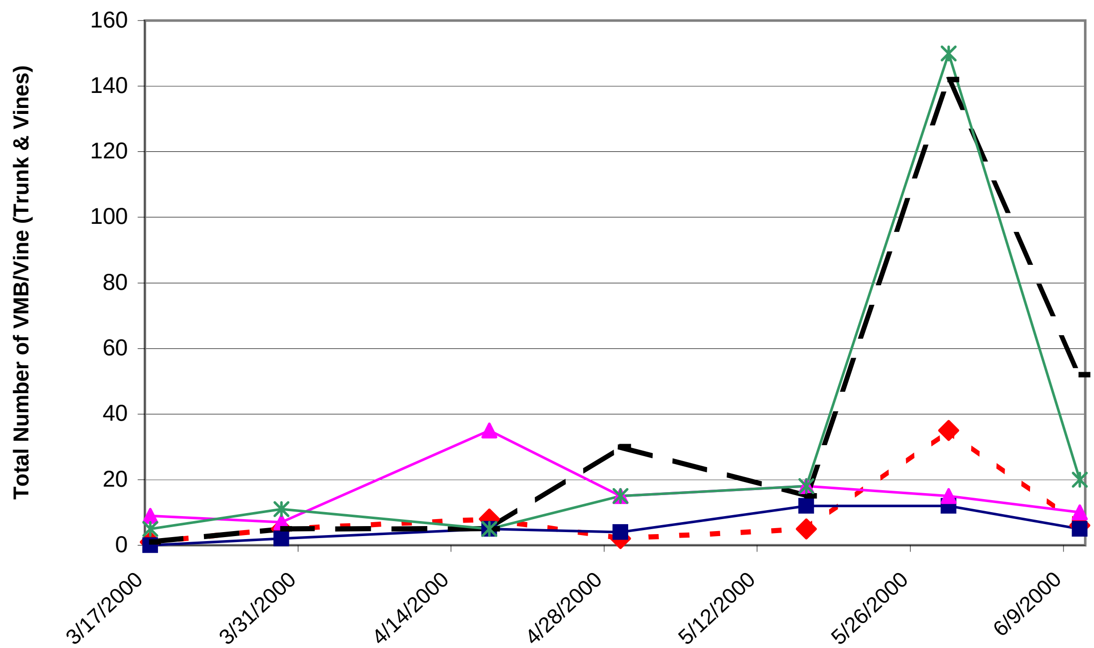


Fig 6a. Mean number of ants from Tudor Ranch. 2000

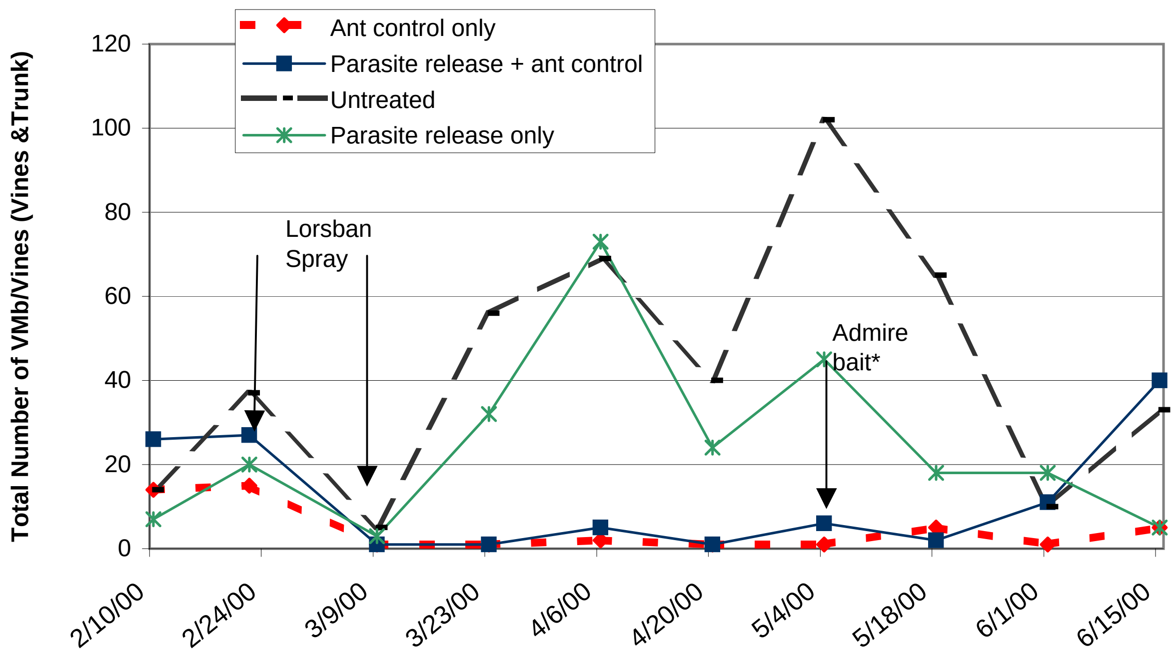
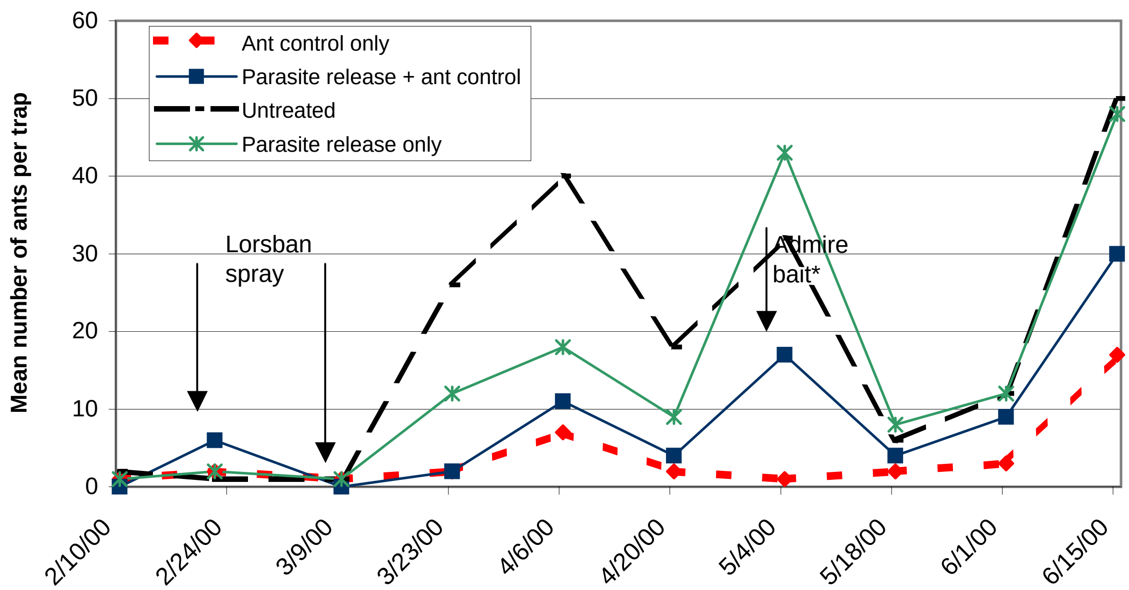


Fig. 6b. Mean number of ants from Sunworld Ranch. 2000



* Bait applied only to ant control + parasite release plot

Fig. 7. Spray-rig for Lorsban to control *F. perpilosa* in grape vineyards

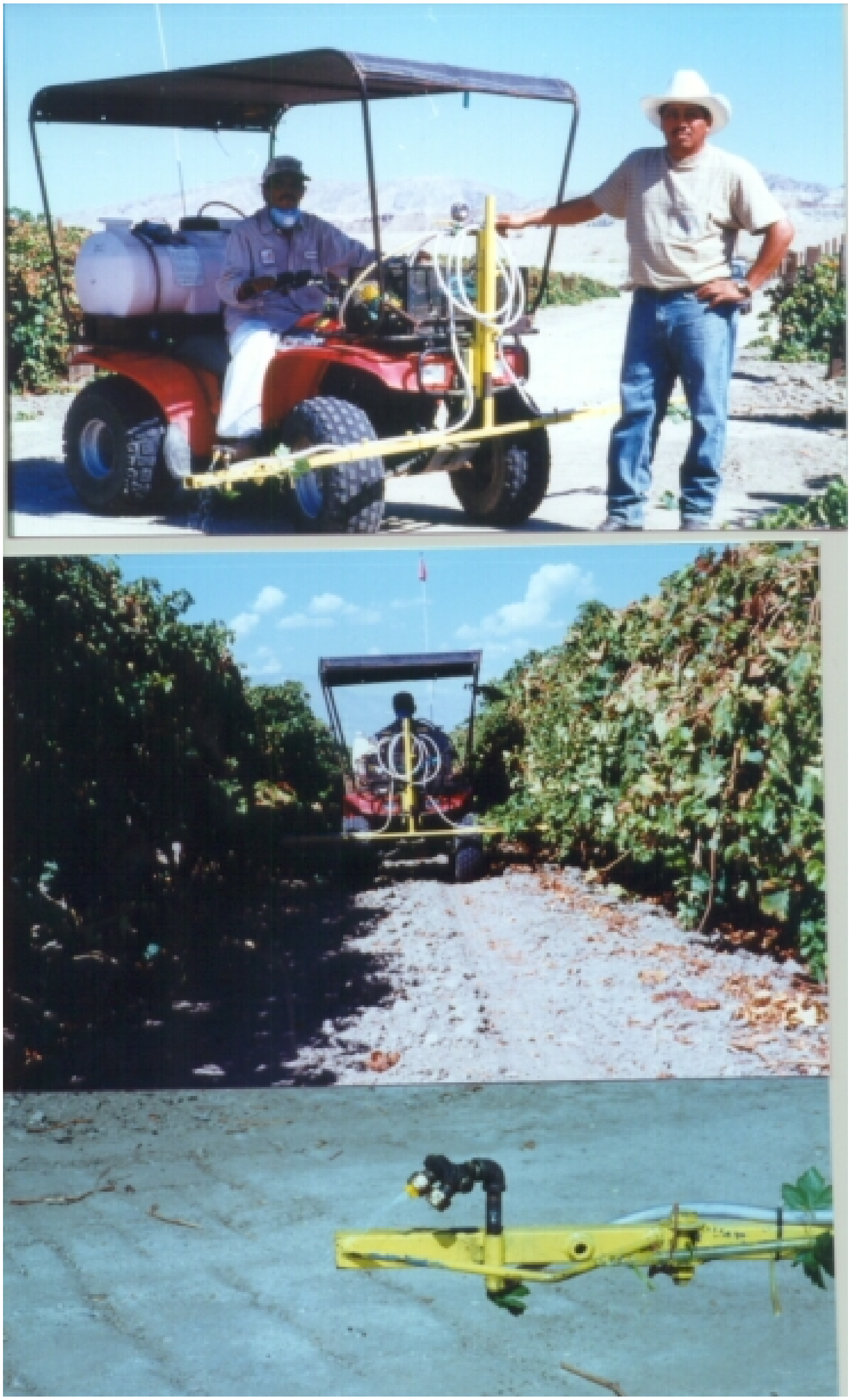


Fig. 8. Mean Number of Leptomastidea/Card Jan - June, 2000.

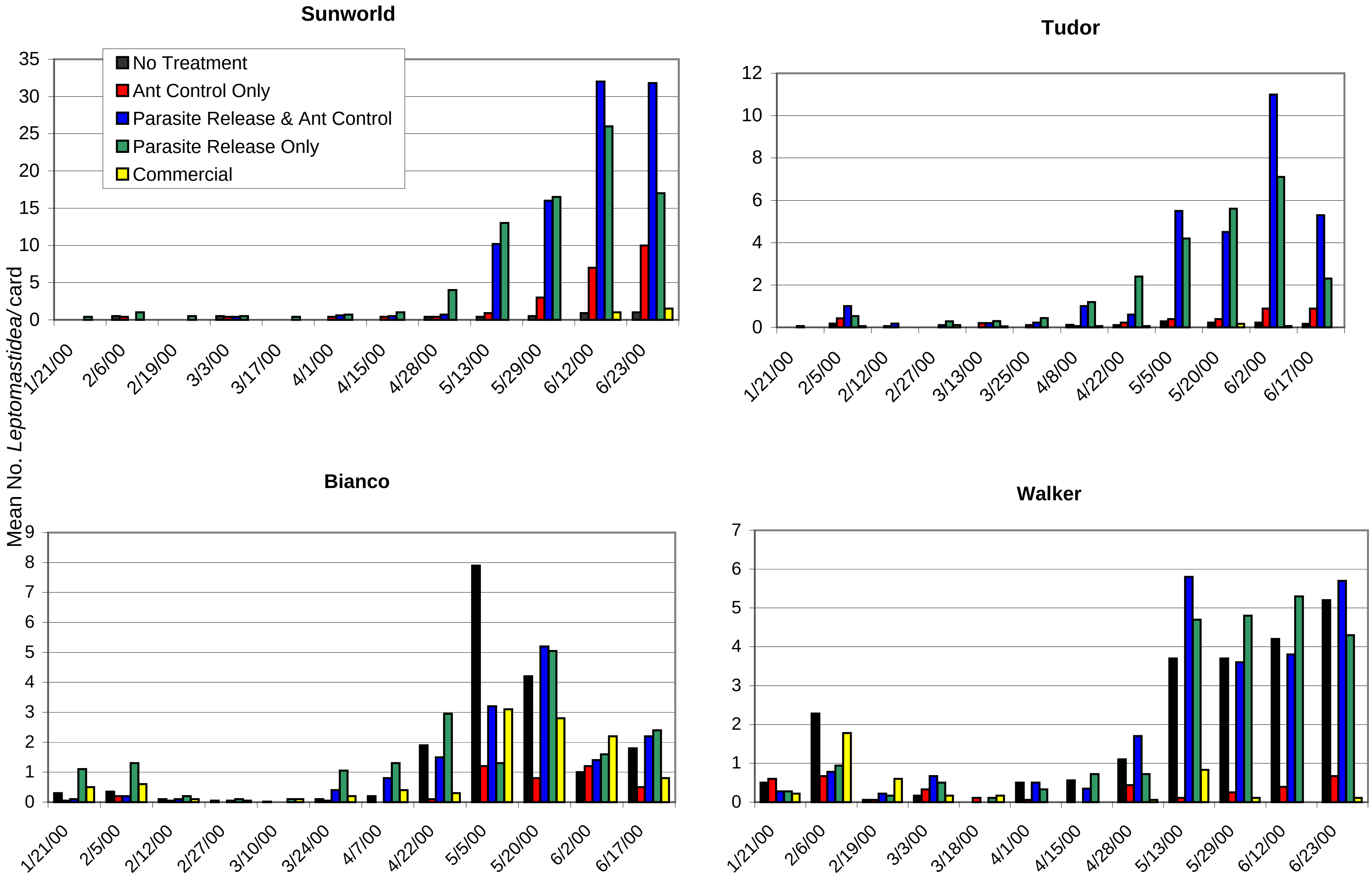


Fig. 9. Mean Number of Anagyrus/Card. Jan-June 2000

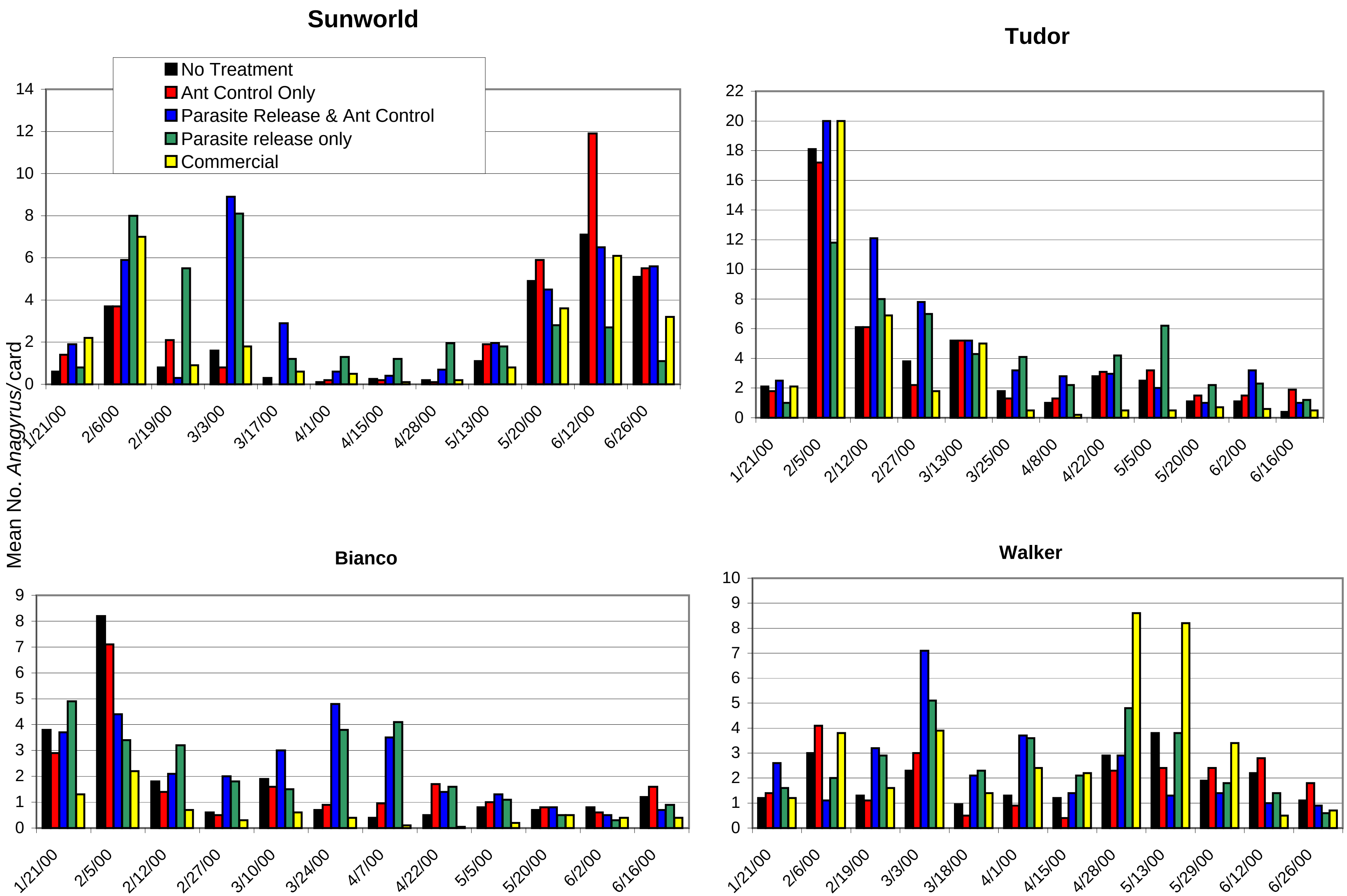
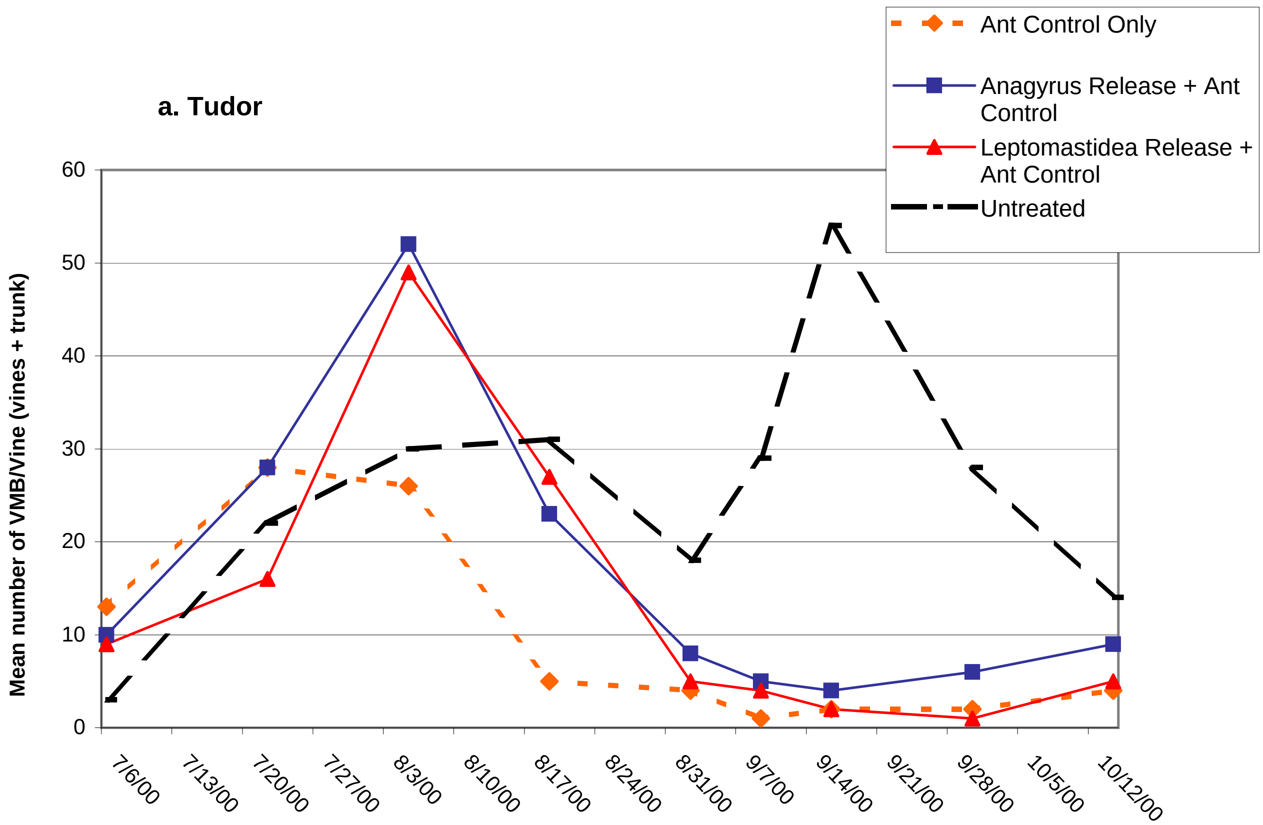


Fig. 10. Mean Number of Vine Mealybugs Summer-Fall 2000

a. Tudor



b. Sunworld

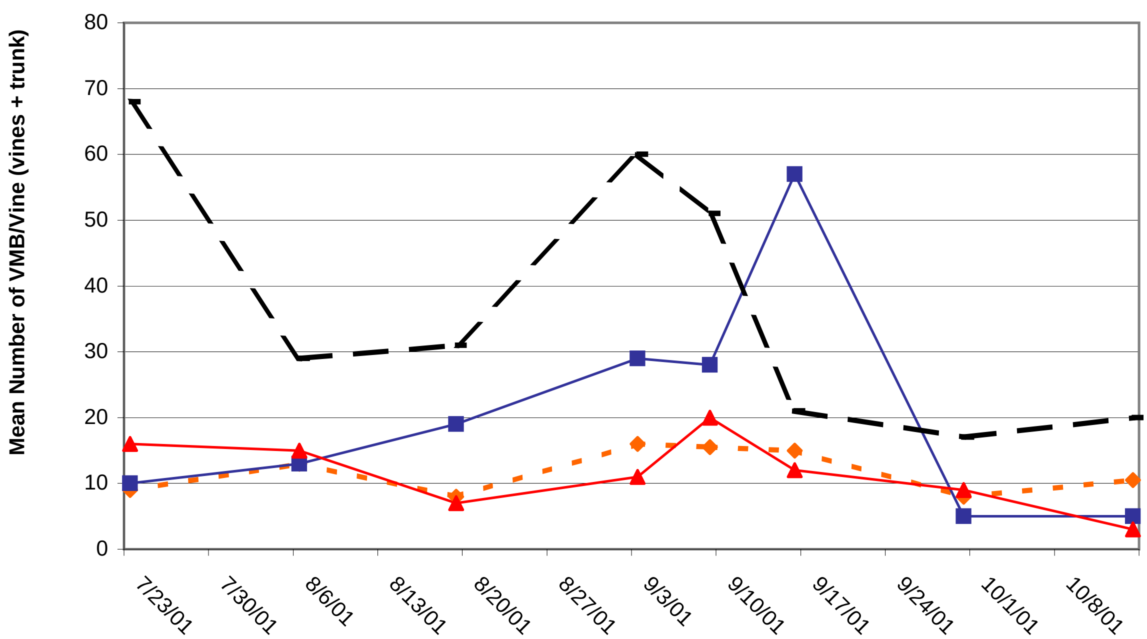


Fig. 11. Total Number of Ants from Pitfall Traps from 4 Treatments Summer-Fall 2000