Pest Management Grants Final Report
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Integrating Biological Control

Into the

IPM Reference Field Monitoring Program

in Processing Tomatoes,

With Selective Aphidicides and Releases of

Predatory Insects

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Integrating Biological Control Into an IPM Reference Field Monitoring Program in Processing Tomatoes, With Selective Aphidicides and Releases of Predatory Insects

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Abstract

This IPM Reference Field Monitoring (RFM) Development Project provides technical assistance and free consultations to processing (canning)-tomato growers wishing to reduce their reliance on synthetic chemical inputs. We documented a 50% reduction in toxic pesticide use since initiation. This project explores innovative means of developing and disseminating findings in an "an open book" fashion.

The program provides real time pest management information from RFM grower participant fields, while simultaneously conducting applied research. This is accomplished with a specially designed newsletter sent to over 500 tomato growers and related professionals in the Sacramento Valley community and field teams who visit growers fields regularly and on-call. The project's findings have appeared in numerous newspapers and farm press magazines.

An analysis of pesticide use reports reveals that in the last 3 years (1996-1998) the participating growers sprayed their acreage less than half as often compared to their peers. Efforts to inform growers, researchers and other members of the Processing Tomato community were made by increasing the distribution of six issues with up to 500 copies per issue of the newsletter, ***Through the Tomato Vine*** (see attachments). A Technical Working Group was formed and meetings were held each year, two in 1998. Many individual grower meetings were held in the field or in the grower's office. A breakfast meeting was held for Pest Control Advisors and growers and one presentation was given at UC's AgTech '98 field day. This last season three growers used Bt's, all successfully.

Each season we closely monitored late season fields (harvested after September 1) of about 10 cooperators totaling at least 3,000 acres. Most fields harvested before this date should not have to be treated for aphids, worms or stinkbugs. The most significant change observed from 1997 to 1998 is the switch from excessively late treatments in '97 to very early treatments in '98. Unstable weather patterns contribute to grower/PCA decision-making as well as strong risk aversion behavior.

In 1997, 41% of the fields were treated too late, at a pest infestation level well above any action threshold. Excessively late treatment can lead to yield reductions. In 1998, 36% of the fields were treated well before any threshold was reached. Excessively early treatments can lead to insecticide resistance and destruction of the beneficial insect fauna. For the non-treated fields the data remained the same in the two seasons - 12%, as it did in those fields where treatments occurred when the BIRC threshold was reached, 14 to 17%.

Two potato aphid-monitoring methods were examined for precision and accuracy in 1997 and 1998. The study was done on-farm in 100 fields encompassing 5000 acres, 15 varieties, and includes the work of 3 field scouts. Data show a leaflet-based presence-absence method is more accurate at the same level of precision and cost compared to the present leaf based presence-absence method, promoted by the University of California. The analysis also indicates that to collect representative data, upper and lower leaflets on vines should be examined. The treatment threshold, which has been derived observationally from cooperating growers and their pest control advisors is reached at 37% aphid positive leaflets or 2 aphids/ leaflet. The current UC recommended threshold lies at 50% leaves infested which corresponds to 25% aphid positive leaflets or an average of 1 aphid per leaflet.

A preliminary study examined predator prey relationship between the potato aphid and the green lacewing in on-farm field trials in the Sacramento Valley, California. Commercial sources of lacewing populations can be established with egg releases (at 2 eggs per plant) even when potential egg and larval predators like damsel bugs are present. Field cages were used to measure aphid population growth (mean 17% per day) and aphid consumption by lacewing larvae (13 aphids per day). Under these conditions a release of 2 lacewing eggs per 50 aphids should be sufficient to control the aphids as long as lacewing mortality after release is not excessive.

A feasibility study using a small fixed wing model airplane modified to distribute commercially produced lacewing eggs was successful on a 10-ac field. Although the eggs were released late (at the 93% aphid leaf infestation level), and carried out in high winds, the aphid population dropped steeply after 10 days. This release is the first one known to quantify populations before and after a LWE release against the potato aphid in processing tomatoes.

Subsequent studies of feeding rates of green lacewings (*Chrysoperla carnea*) and lady beetles (*Hippodamia convergens*), and hand applied augmentative releases of lacewings, were conducted on different farms in small replicated plots. These studies provide an initial estimate of Green Lacewing predation rates under field conditions, showing the feasibility of using commercially produced lacewing eggs (LWE). Specifically, we estimate that at two LWEs/plant a 50-ac field could be treated for between $12 and $24/ac. This is based on LWE egg costs of $0.75 to $1.50/1000, assuming considerable larval losses after release. Such costs are competitive with existing treatments. These studies also pointed out the need to have a quick and easy method to confirm an adequate hatching rate prior to or as part of any further studies. Further studies will also need to be arranged with the supplying insectaries for release at early aphid growth stages.

Three publications on this work are in draft form (see attachments). Numerous policy suggestions are discussed in the main report while the attachments contain more detailed results.

Integrating Biological Control Into the IPM Reference Field Monitoring Program in Processing Tomatoes, With Selective Aphidicides and Releases of Predatory Insects

Introduction

This project develops applied sampling, decision-making systems and biological controls for late season pests of processing tomatoes, including the potato aphid, various larval lepidopterans, particularly the beet armyworm, and stinkbugs in the Sacramento Valley, California. These applied research components are imbedded within a Reference Field Monitoring System (RFMS) which provides near-time sampling data to growers in exchange for use of their fields, their cooperation in trying new procedures, and information about their pest control and overall management system, particularly spray records and yield data.

Over the last season we also emphasized work on outreach to growers and other members of the processing tomato industry in the Sacramento Valley. Improvements were made and circulation increased of a through improvements and increased circulation of a newsletter (***Through the Tomato Vine;*** see attached). Reports were made to the Technical Working Group and meetings were held with individual growers. Thus, the RFM system reports on findings to up to 500 local growers and industry members much faster than through normal research channels. Three publications summarize work on sampling for the potato aphid, use of commercially produced lacewing eggs (***Chrysoperla carnea***) and pesticide use reduction obtained by cooperating growers. The summary below covers more of the programmatic administrative aspects, having policy ramifications.

Problems Addressed

The overall problem addressed is to develop a means for introducing Integrated Pest Management (IPM) framework and methods to highly risk aversive growers resistant to change. The need for this framework and for IPM methods results from a combination of factors, which together create a solid wall of resistance to beneficial change. These factors include cheap insecticides, lack of adequate decision-making systems, lack of applied research on alternatives to existing insecticides, the perceived need for air applications rather than ground applications, premature treatments from poorly developed action levels, insurance applications and a propensity to use combination treatments "for the ride". The latter refers to unneeded treatments added to another application in order to save the cost of an extra air application at a latter time. To this list must be added poorly researched and implemented sampling systems, judging by PCA statements indicating existing sampling systems are not used because it takes too much time and do not fit into their field checking schedules. The reference here is to the presence-absence sampling system recommended by Cooperative Extension, which is based on fruitworm egg monitoring.

Domination of advising to growers by sales personnel for local pesticide distributors creates the most formidable barrier to new information, particularly if such information will lead to reduced sales. This factor cannot be underestimated as many of these relationships are long term and highly personal. Such existing personnel relationships not easily changed by scientifically based IPM programs. Growers believe that PCA advice is free as no direct charges are made for monitoring. Lastly, there is a lack of selective aphidicides or sufficiently researched biological controls for suppressing the potato aphid, which would function without disrupting subsequent potential pests such as the beet armyworm and the tomato fruitworm.

Background: Project History

Integrated Pest Management (IPM) in processing tomatoes in the Sacramento Valley has a good reputation due to previous work and reports by UC, Davis researchers and extension agents. Early work probably changed the spray patterns for late season pests away from treatments aimed at the tomato fruitworm, which is now under biological control or is controlled by late season insecticides aimed at other species, particularly the potato aphid, ***Macrosiphum euphorbiae***. Late season is defined as tomato fields harvested after September 1st. Fields harvested prior to this period seldom need treatment for potato aphids.

After a spray with sulfur for the russet mite the next pest species to arise is the potato aphid, thus the potato aphid is the key arthropod pest in the late season crop at this time. This judgement is made because: 1) treatments aimed at it are the first of the late season complex, 2) such treatments have the potential to disrupt other species under biological control, and 3) if the potato aphid could be brought under biological control few if any treatments would be necessary for other late season pests on most fields.

The approach taken by the project over the last four years has been to incorporate previous research, new findings from project fieldwork, Pest Control Advisor (PCA) experiences and grower practices into a whole system of decision-making and treatment. The project's own applied research made contributions through the development of new sampling systems and evaluations of treatment methods, as well as innovating the Reference Field Monitoring (RFM) concept.

When work started in 1994 there was concern about pesticide residues in surface waters, particularly the herbicide treflan and the insecticide diazinon, among other biocides. Consequently, the regional EPA office funded initial efforts to use an 'epidemiological approach' for problem solving. This means that one searches for causes and then works at solving problems at the source. In this case the problem solving approach would be an IPM program or collection of programs encompassing a watershed. Although such an approach is logical from an ecological view it was never tried previously, and to my knowledge there is no example, even now. As you will see by the short history below we did not get very far, either. Surface water contamination remains a continuing chronic problem.

The sources of the water contamination in this case were probably orchards and alfalfa fields. The data for excluding other sources was more a function of lack of water sampling for pesticides rather than any logical considerations excluding other crops.

At that time, one of the main sources of herbicide entry into surface waters in the Solano/Yolo county area was thought to be the drainage systems managed by the Resource Conservation District (RCD) in Solano Co. Although we conducted pilot work on revegetating levee slopes, this never developed into an IPM program. Without regulatory pressure the RCD would not focus on the need to drastically cut herbicide use, although such a goal was within reach technically.

An RCD based approach was also reasonable since growers and the USDA jointly fund such systems and the Soils Conservation Service provided technical support. Getting growers together to do anything collectively is always hard, and with annual crops on mostly leased land, particularly difficult. Having a grower organization to work with initially looked like a good idea.

Many areas in Solano/Yolo Counties had been leveled using Federal funds as a way to encourage growers to move away from low economic sheep grazing to row crops. This upgrading of the land base was the basis for forming the RCD in this area. The EPA connected us with the RCD personnel. The Solano RCD arranged for a meeting with potential growers who might be interested in implementing an IPM program. Although orchards were not highly important in Solano Co, alfalfa was important from an area-wide perspective and because of the pesticides used in the crop. Consequently, alfalfa was the focus of early interactions with growers in mostly Solano County.

After an initial meeting with some of the leading growers where we assured them that any data collected on their properties or about their operations would not be used against them, we set up individual meetings. From these meetings came the conclusion that to affect pesticide use in the county one must work on the most important crop. Grower after grower emphasized that he first chose which acreage was to grow tomatoes and then apportioned the remaining acreage to alfalfa, sunflowers, safflower or something else. The most important crop from an economic view was not alfalfa but processing tomatoes.

One must begin any implementation project where there is a chance of being successful. It looked like processing tomatoes would be a better starting crop than alfalfa because it had a reputation as a leading IPM crop based on the work that Frank Zalom and his associates at U.C. had published about processing tomatoes.

We reviewed this work in an IPM Practitioner article (Olkowski and Olkowski 1996) and concluded that on a world-wide basis this crop was the only example where a natural enemy component figured critically in any IPM program developed up to that time. This assessment was based on Hoffman's work showing how percentage egg parasitism by ***Trichogramma pretiosum*** figured in deciding whether one should treat or not treat for the key late season pest - the tomato fruitworm, ***Heliocverpa zea*** (see Hoffman et al. 1990).

How this project developed further is instructive and I believe representative of the general state of affairs regarding IPM in California. If California is a leader in IPM development in the US, it also tells what a miserable state of affairs IPM is in overall. This message is difficult to discern from University personnel who generally do little direct work with growers and who generally are not critical of existing practices.

Much of our previous IPM implementation work had started with an assessment of actual pesticide use since this gave us two important parameters: estimated costs of treatment and a priority list of target pests. Although simple in concept, this objective proved impractical. After further interviews we realized that pesticide use reporting at the state level was then about two years behind actual use, and that county data was out of reach of our project economically, since it required us to go through the forms filed by PCA's and growers individually. At that time these two sets of forms were filed at the County Agricultural Commissioners office in two different groups and no summary was available with the needed detail. Nor was any disk copy from which we could make further analysis. At one time we received an estimate of $500 for state records of pesticide use by about 15 growers in the two counties: Yolo and Solano. This was not cost effective for us. Later this information became available by disk or over the wire, but it is still excessively delayed. Today country data is available in December but the state data is 3 years delayed.

The information specifying target pests was also useless and confusing, especially regarding mixed applications, a common form of delivery. What pesticide use records were available did not identify the specific target pests. Thus, we could not unravel whether fruitworms, other worms, or potato aphids were the precise target of late season insecticide applications. The UC manual (3rd ed.) on processing tomatoes says the fruitworm was the most important target pest. Although this seemed logical since this species was the subject of tomato sampling at grading stations, it is actually misleading.

We were regularly told by growers justifying their pesticide use that if 2% worm damaged fruit was found during sampling whole loads were rejected. Many late season applications were mixtures, or individual insecticides such as methomyl, which could kill all the late season pests. However, which pests actually were the target of the treatments could not be determined by checking pesticide labels for logically targeted species. Local PCA's were of little help since they were not required to be precise on their recommendations, nor obliged to help, since we were viewed as potential competitors. The local extension agent seemed similarly perplexed although he pointed out that aphids seemed to be building in importance over the last few years. Local researchers were focusing attention on stinkbugs, which after successful parasitoid importation relegated the native stinkbugs again to relatively minor pest status (see Hoffman et al., 1991).

Interviews with individual local PCA's added further confusion. They reported that actual use of UC recommended sampling system, i.e., 30 leaf based presence-absence, was unreasonable since it required too much time. The best PCA's interviewed had been a part of an earlier U.C. effort implementing IPM sampling for the fruitworm. This effort may have actually greatly reduced pesticide use, since the fruitworm was no longer considered by some PCAs to be an important pest. This was confirmed over the next year or two as we conducted further fieldwork.

Materials and Methods

The main objective at first was to concentrate on developing adequate sampling systems for all the late season pests, because such systems are needed before any alternative management methods can be evaluated. We started by first using the published and recommended sampling systems (Zalom et al. 1990). Over the four-year period the basic approach has been to adapt sampling methods developed by researchers, or those already in use in other crops for processing tomatoes. Thus, the leaf sampling system recommended by UC, Cooperative Extension was modified to include upper and lower plant samples, again modified to reduce amount of time by sampling only the undersides of apical 5 leaflets on 30 leaves.

Finally, we developed an improved leaflet based presents-absence sampling system (Wittenborn and Olkowski 1999). This sampling system is combined with shake sampling to detect worms and stinkbugs as well as natural enemies to aid in decision-making.

Shake sampling uses the "cafeteria tray" methods developed by Zalom for stinkbugs (Zalom et al. 1995), in an expanded form. More specific methods are described in a series of specific studies in the attachments, which focus on the work performed in the 1997 and 1998 seasons. Sampling systems were initially described in Olkowski and Olkowski 1996.

Results

After four years of fieldwork we have established the following:

1) The key pest of processing tomatoes in the Sacramento Valley at present is the potato aphid, *Macrosiphum euphorbiae*. It is responsible for most late season insecticide use.

2) The existing sampling system recommended by UC Cooperative Extension encourages unnecessary and early treatment of this pest, and does not include any natural enemy assessment.

3) Using Bacillus thuringiensis (Bt) products can control late season worm pests. Only a few growers now use Bt. U. C. Cooperative Extension pesticide recommendations do not emphasize the enormous difference between materials that spare natural enemies and conventional broad spectrum materials, and where we have been present actually indicate that Bt is ineffective. It's not that Bt's aren't favorably mentioned in their publications but few grower reads these. The important thing is what they say at the field days. There they push the chemicals. Those growers who do use Bt do so effectively.

4) Many of the late season fields do not need to be treated for the potato aphid if the action level and decision-making system we developed is used for deciding treatments rather than the UC system. A few progressive growers already use our system to their advantage. Although we have not done a complete study of cost effectiveness of this method we can say that it takes the same time as the UC method but is more precise and accurate which in

turn lets on up the threshold a little bit which can save money if the growers chooses to rely on it.

5) Some organic processing tomato growers can produce without aphid or important worm problems in the same areas where conventional growers use insecticides and have pest problems.

Further, after pilot studies using nontoxic selective neem oil products (Neemix® and Trilogy®), we concluded that insecticide coverage was the principle limiting factor in making these novel product effective. This conclusion is also relevant to conventional insecticide use, and more importantly to many alternative materials of a less toxic nature such as soaps, oils, and microbials. Ground applications have the potential to improve coverage of any type of pesticides as well as reduce drift. Specially modified ground applicators are needed to apply alternative materials and to make conventional materials "more effective". An example is the air boom (i.e., FMC) sprayer. Modifications to this type of sprayer will also make it more effective. Other types of sprayers (e.g., electrostatic sprayers) are not available locally at this time.

Near-term natural enemy impacts on the potato aphid cannot yet be made precise within an overall decision-making system. However, judgements about impact on growing aphid populations can be made regarding short-term tolerance and continued monitoring. In this way, with more frequent field visits some fields can be left untreated. Further, if a minimum of 5 weeks prior to harvest period is used as a no treatment period many more fields can be left untreated. The latter assessment was derived from unpublished studies showing no yield losses during such a period with the variety Alta on good University land (Zalom, 1996, unpublished CTRI Annual Reports).

Discussion

This project had to face a lack of interest in a collaborative relationship with UC researchers and extension agents. This slowed progress. Competition for limited funds, grower's attention, and pesticide promoting advice from local PCA's and occasionally Cooperative Extension limited our ability to accelerate program development.

The RCD's were only moderately helpful. Although the programs operated by the Yolo and Solano Co. RCD's are complementary, the personnel lack expertise and experience in development of IPM programs. Staff from both RCD's and the related Natural Resource Conservation Service (NRCS) were helpful to this project and the provision of a meeting place where growers and researchers could meet greatly helped facilitate communications within the local community. These organizations are more helpful toward developing IPM programs than Cooperative Extension, in our experience. Of course, this situation could be different in other areas since only a few people are involved in these situations and great differences exist amongst such personnel and local agencies.

Cooperating processing tomato growers showed little orientation toward mutual help and interaction in comparison to almond growers in the BIOS project run by CAFF, for example. Competition and economic risks are undoubtedly higher with row crops, which could account for some of this lack of interest.

Repeated efforts to obtain funding for this project from SAREP were unsuccessful. The SAREP program funded by the state is based on the successful CAFF almond project, but is limited in scope by its program constraints to heavy involvement of growers. This alone could exclude an RFM approach with its service oriented individual consultation to growers by IPM specialists. A broad range of grower interaction systems could increase possibilities of finding useful approaches for IPM development, a vital need.

Rapidly updated pesticide use data, including target pests, could accelerate IPM development by pinpointing the most important and critical key pests for IPM program development. If such information were available by crop and region, particularly in summary form, priorities for research on a statewide basis could provide a yardstick for assessing University and commodity funded research priorities. Presently, it is difficult to discern how research is selected. In many cases it appears as if long-standing personal relationships have a major role in selecting research rather than stated priorities. Getting more actors into the applied research system could broaden developments and provide a source of funding for entry level independent Bio/IPM advisors starting careers.

Lack of personnel to design IPM programs in the private sector limits developments to University personnel who do not have the incentives to put in place realistic sampling and decision-making systems. Biological control does not get adequate attention nor does actual IPM program development. Individual researchers may get particular projects funded which may make a contribution toward IPM program development but whole program development is virtually unfunded. An exception may be the Sustainable Agriculture Farming Systems Project at UC Davis which compares different horticultural systems within the crop rotation sequences that include processing tomatoes over a 12 year period. Although many aspects of this project are relevant to commercial fields the project operates on University experimental station fields and its results may take a long time to influence growers.

If this project is not funded further the investment was lost except if the lessons learned are incorporated into policies which change the infrastructure. By infrastructure we include incentives for UC researchers and extension agents to develop and implement complete practical IPM programs, and their components, particularly least-toxic selective insecticides and biological controls. Infrastructure also includes UC and state college education programs aimed to develop personnel who can and will assume private biologically intensive (BioIPM) advising roles. Most critical are regulatory changes forcing use of alternatives (BT is an example), pesticide use data improvements, and changes in funding to include any and all program types which can encourage development and use of IPM programs aimed at toxic pesticide reduction.

Most late season applications are made by air since ground applications destroy fruit and require closing drainage ditches, a procedure which growers dislike, and which is not cost-effective near harvest. Yet some growers already close ditches near the end of the season in order to push vines out of irrigation furrows in a practice called "vine training". Others never create ditches, using sprinkle irrigation the whole season. Although these growers are a minority they demonstrate that there are other ways to produce this crop that are compatible with ground applications of novel less-toxic materials and are economically feasible. Local organic producers are other examples. Green labeling programs, modeled after the Organic Labeling Programs in existence throughout North America and Europe could be used to encourage real IPM implementation with existing technology.

Air applications require materials with long-term residual life and/or fuming action since coverage will always be a problem when air applications are used. Banning air applications would force use of ground rigs and encourage a more thrifty and reduced use of pesticides. Banning would not remove the need to treat most late season fields for potato aphids. Late season treatment could take advantage of more environmentally sound materials if pesticide application research were directed toward making such materials cost effective. An augmentative biological control treatment method, mass release of commercially applied lacewings could provide a much-needed aid for late season potato aphid control but still needs further work to make it a scientifically supportable method.

Banning air applications would not eliminate the need to treat for stinkbugs in those local fields where this minor pest occurs. Ground applications would improve worm treatments, however, as well as aphid treatments. Evidence of resistance to the current main late season insecticides, esfenvalerate and dimethoate, including mixtures, is already evident. Just how fast it will build remains to be seen, but the situation is not good. Use of the pyrethroid permethrin seems to be an alternative to the OP dimethoate and the pyrethroid esfenvalerate (sometimes combined) being explored now by PCAs and growers. Increased use of permethrin could lead to worm outbreaks since they are potential secondary pests. Pyrethroids already have a reputation for triggering secondary pests.

Summary and Conclusions

The RFM system is a potential way to introduce and even develop sampling/decision-making systems for IPM programs in processing tomatoes, and by extension, many other crops. This conclusion is supportable by the pesticide use reduction data (see attached) from the cooperators and by the progress made in developing sampling and decision-making systems as well as the applied research done on use of lacewing mass releases and assessment of predation rates. This approach demands little change for initial participating growers and provides in-field demonstrations without the long lag periods necessitated by the need for peer reviewed publications.

New selective insecticides and biological controls are needed for potato aphid management in processing tomatoes. By inference, certain aspects learned from this project appear generalizable to other crops in California. These are: 1) A principle limiting factors for IPM development is the need for incentives for development of accurate and precise sampling systems for key pests that are practical for use by PCA's, particularly private independent PCA's; 2) There is a lack of incentives for IPM development and implementation limiting further potential practical BioIPM research by University personnel; 3) A significant effort needs to be made by combined state regulatory, research and extension personnel to renew efforts to develop practical IPM programs which can be implemented by PCA's; and 4) Educational efforts are needed to provide multi- and transdisciplinary training and orientation toward development of professional IPM program designers, but first the concept needs to be further developed as a distinct field within pest control as a whole.

Useful sampling systems need development with a priority criteria of minimal cost related to reliable representation of actual field populations. Although a minimal cost potato aphid monitoring system was being recommended by Cooperative Extension office it was not used by PCAs and if used good enough to prevent unnecessary treatments and the encouragement of insecticide resistance. The method was based on unpublished research done on University land with a highly susceptible variety, which is no longer grown. An alternative approach to program development starts in the field to implement what is published and then identifies problems for preliminary and then more definitive research. Educational programs now orient most graduates to laboratory work where highly specialized efforts can be produced. Fieldwork requires multidisciplinary knowledge, e.g., horticultural and agricultural production, fertilization, plant disease, nematology and entomology, for example.

Biological control by importation and augmentation can be usefully employed with additional attention in processing tomatoes, particularly against the potato aphid, an introduced pest. Biological control, classical and augmentative, is an overlooked and critical component in a least-toxic approach to crop pest management. Biological control should be the first order of business in every crop since it is the most cost-effective approach. However, until the existing pesticide use is reduced so that enough fields remain untreated in particular regions it is difficult to untangle which target pests should be targets of importation efforts. There is a major need now to reexamine existing IPM programs for the state of the art in regard to natural enemy importation and augmentative projects.

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Appendices.

Newsletters: Through the Tomato Vine, 6 issues all 1999

Feasibility Study of Lacewing Egg Releases for Potato Aphid Copntrol in Processing Tomatoes.

Evaluation of Two Potato Aphid Monitoring Systems in Processing Tomatoes from the Sacramento Valley, California.

Pesiticide Use Patterns of tomato Growers Participating in Bio-Intensive IPM Program vs. Their Peers - Update 1998.

Evaluation of Two Potato Aphid Monitoring Systems in Processing Tomatoes from the Sacramento Valley, California.

By Gisela Wittenborn and William Olkowski

Abstract

Two different potato aphid monitoring methods in processing tomatoes were examined for precision and accuracy. The study was done on-farm over 2 years in 100 fields encompassing 5000 acres, 15 varieties, and the work of 4 field scouts. Tests show a leaflet based presence absence method is more accurate at the same level of precision and cost compared to the present leaf based presence absence method, promoted by the University of California. It also indicates that to collect representative data, upper and lower leaflets on vines should be examined. The treatment threshold, which has been derived observationally from cooperating growers and their pest control advisors is reached at 37% aphid positive leaflets or 2 aphids/ leaflet. The current UC recommended threshold lies at 25% aphid positive leaflets or 1 aphid per leaflet.

The study also examines the question of whether insect monitoring systems derived from homogenous, small plot trials can be the exclusive foundation of large scale industrial monitoring.

Introduction

In the last decade the potato aphid (PA), ***Macrosiphum euphorbiae***, has become the key pest in late season processing tomatoes in the Sacramento Valley. A leaf based presence/ absence sampling system has been promoted by University of California researchers (UC, 1998). However the system has major shortcomings:

- Presence-absence sampling was not effective in differentiating varying infestation levels. Yields were different with similar levels of aphid-infested leaf counts (Pickel et al., 1994).
- The treatment threshold is set low because of the moderate accuracy of the method. Above 50% aphid positive leaves, which is also the treatment threshold, the data become more unreliable.
- Only leaves in the upper canopy are sampled. In 80% of the fields this skews the aphid infestation towards a higher infestation level while it misses fields where the aphid infestation resides in the lower part of the plant.
- Where a grower wants to wait to see if the aphid population declines without intervention this method is unsatisfactory. In cases where leaflet aphid counts indicated a population decline the leaf based presence/ absence did not.
- The method does not incorporate aphid predator nor parasitoid counts into the treatment threshold. Aphid predators can occur in tomato fields at high densities, and may reduce the aphid densities.

High-value crops like tomatoes tend to be sprayed more intensively than low-value crops because of the perceived low cost/ benefit ratio of such treatments. Insecticide use costs start at about $12/ acre by air (includes air application alone of $7.50/ ac). Such treatments are cost effective even at expected yield increases of less than a ton per acre. Such a small yield increase will usually slip through statistical yield data analysis since it is too small to be significant.

Processing tomatoes are now valued at over $50/ton and yield on a state wide average of 33t/ac. Treatment costs for a 50 ac field are $600 (@$12/ac). If an increase of one ton/ac were gained by treatment then the cost/benefit ratio would be 600/2500 or 0.24, providing the grower a net profit of $1900 on a 50 ac field. If only 3 out of 10 fields produce a one ton yield increase (while in 7 fields no yield increase were achieved) treatment cost would be neutralized by the extra yield. Therefore, in case of doubt whether the treatment will result in a yield increase the growers are likely to treat anyway. This way they are probably not loosing money but are sure to reduce the risk of loss. This strategy can be called "Better safe than sorry". This strategy is reasonable when the sampling systems and treatment levels are problematic.

However, at a time where growers and regulators try to reduce reliance on high risk pesticides and use IPM programs it is important to provide growers with the information necessary to evaluate whether the pest population has really reached the treatment threshold. The more comfortable the grower feels about the quality of the monitoring data the more insurance treatments and 'riders' can be eliminated. A "rider" is a pesticide applied not because the treatment threshold was reached but because another treatment is scheduled and applying two materials in one applications saves one application cost.

Methods

In 1997 and 1998 late season processing tomato fields were monitored for aphids in Yolo, Solano and Sacramento County. Each year 50+ fields totaling 2500+ acres, planted in more than 15 different varieties were monitored by 3 field scouts. Two presence/ absence, two enumerative and two combined methods were tested. This article focuses on the two presence absence methods. Their key difference lies in the chosen sampling unit: leaves or leaflets. Tomatoes have compound leaves where each leaf is composed of 5 to 13 leaflets. Shands (1954) found a high correlation between single leaflet counts and whole leaf counts in potatoes which also belong to the nightshade family and have a similar leaf structure as tomatoes. Therefore, leaves as well as leaflets can form representative sampling units. The two methods being compared are described below:

Leaf based presence/ absence method (percent leaves aphid positive: The undersides of 30 randomly chosen leaves from below the highest open flower were monitored for presence/ absence of aphids (see IPM in Processing Tomatoes, 4th ed, 1998). In 1998, in 67% of the sampling events the number of samples was reduced to 15 leaves per field. In these cases the leaf and the leaflet sampling was done on the same leaf. This leaf based method is the UC method.

Leaflet based presence/ absence method (percent leaflets aphid positive): The sampling unit is the undersides of 5 apical leaflets of the compound tomato leaf, 50% from the upper plant (see above), 50% from the lower part of the plant. In 1997 two spot samples were conducted each consisting of the sampling of 3 upper and 3 lower leaves resulting in the sampling of 60 leaflets per field. In 1998 30 random leaves were monitored, 15 leaves from upper and 15 leaves from the lower canopy, resulting in 150 leaflets checked per field. This leaflet based method is the BIRC method.

Both of the above presence/ absence methods were compared to total counts of aphids on leaves or leaflets. These samples are called enumerative and were made by counting all the aphids on the undersides of 5 tip leaflets. This sampling procedure parallels the leaflet based presence/ absence method (%LLA+) (see above). The total number of aphids was then divided by 60 in 1997 and by 150 in 1998 to arrive at the number of aphids per leaflet (#A/ LL).

Precision:
To test the methods for precision the relative variability (RV) (Legg, 1994) was calculated for the enumerative methods. (1998 data only):

RV = (Sqrt (s2/ n))/ m [Sqrt = square root]

where s2 = sample variance, n= sample size, and m = sample mean. The RV for the binomial sampling method was calculated by:

RV = (Sqrt (p*q/ n))/ p

where p = proportion of samples with aphids, q = proportion of samples without aphids and n = number of samples.

RVs were calculated for each sampling event in 1998 and then averaged for the whole year to compare precision (88 data points).

Accuracy
The overall objective of developing a cost effective sampling system is to have one adoptable by PCA's. If the correlation between any of the binomial methods and the enumerative method is tight this would allow to substitute the presence/ absence method for the more accurate but more time costly enumerative method. The data was transformed to its natural logarithm which linearizes asymptotic distributions. Since the data to be transformed include zeros a technical problem arises: the logarithm of zero is negative infinity. In such cases the transformation ln(x+1) avoids the problem. The correlations were calculated with SUPERanova for single and combined data sets of 1997 and 1998. The resulting regressions were tested for covariance between the two years.

Results and Discussion
A good monitoring method should be cost effective (i.e.. low number of samples) and precise and accurate. A large variability of a given measured parameter will necessitate large sample sizes which increases the cost of making a sample. In general, enumerative methods are good at giving an accurate picture of the actual populations size, but because aphid counts are highly variable they necessitate a large sample size. Although presence/ absence methods exhibit less variability they have to be carefully checked for how well they relate to population dynamics. The selection of the sampling unit is critical to reduce cost and to maximize accuracy.

In this study a leaflet based presence absence method is compared with a leaf based one. Tomatoes have compound leaves and therefore leaflets are an option of choice if one wants to study whether a smaller sample unit might relate better to pest population dynamics.

Precision

The results for the precision analysis show that with 30 samples the enumerative method (#A/LL) exhibit a relative variability of around 30% which is somewhat too high for basing insect management decisions on it. As expected the binomial methods perform better at low sample sizes and medium insect presence. The RV at 30 samples equals about 20% for insect presence between 40% to 50% of the positively infested leaves which is the infestation range where treatment decisions are recommended.

Accuracy:
In Fig. 1 and 2 the two presence absence methods are plotted against the corresponding enumerative values. In both years the leaflet based binomial method exhibits a tight relation with the enumerative method while the leaf based values show a diffuse relation. In addition, for the leaf based binomial method 100% presence is already reached at less than 2 aphids per leaflet while the leaflet based values increases slowly with increasing aphid counts per leaflet and does not reach 100% even at 14 aphids per leaflet. This makes the leaflet method a more responsive tool for measuring the population size.

Fig. 1: Relation betweleafletbased presence absence enumerative aphid monitoirng in tomatoes for 1997 1998

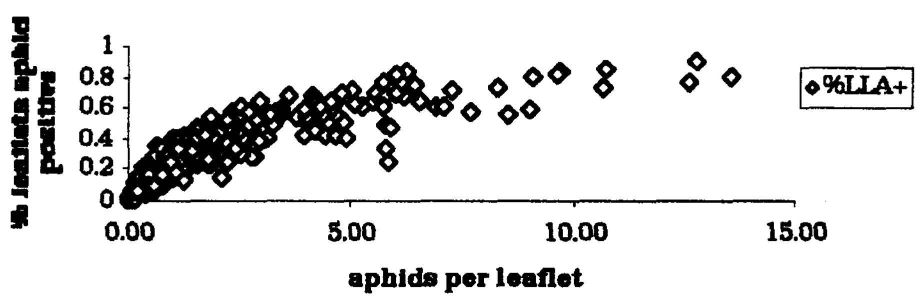


Fig. 2: Relation betweleafbased presence absence enumerative aphid monitoring in tomatoes for 1997 1998

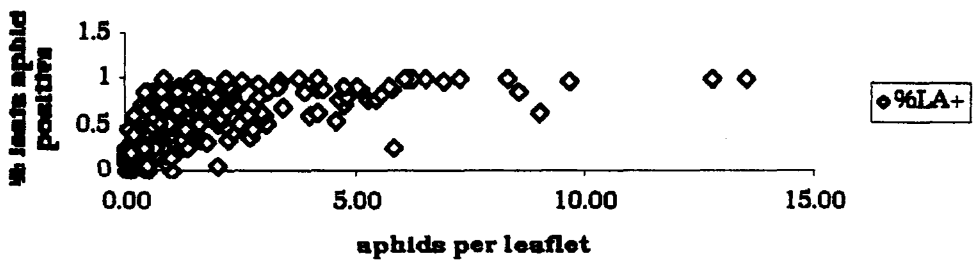


Fig. 3 shows the regression line and the coefficient of determination for leaflet based presence absence and enumerative method. The data has been transformed to its natural logarithm so that one can work with a linear regression. The covariance analysis resulted in no significance for the factor year or an interaction between year and aphid counts. Therefore the data of both years can be combined. The leaflet based method correlates well with the aphid counts with a r2 of 0.84. The regression equation matches 25% aphid positive leaflets to one aphid per leaflet (A/LL), 37% to 2 A/LL and 67% to 5 A/LL.

Fig. 3: Regression of leaflet based presence absence and enumerative aphid data for 1997 and 1998 (302 data pairs transformed to natural logarithm)

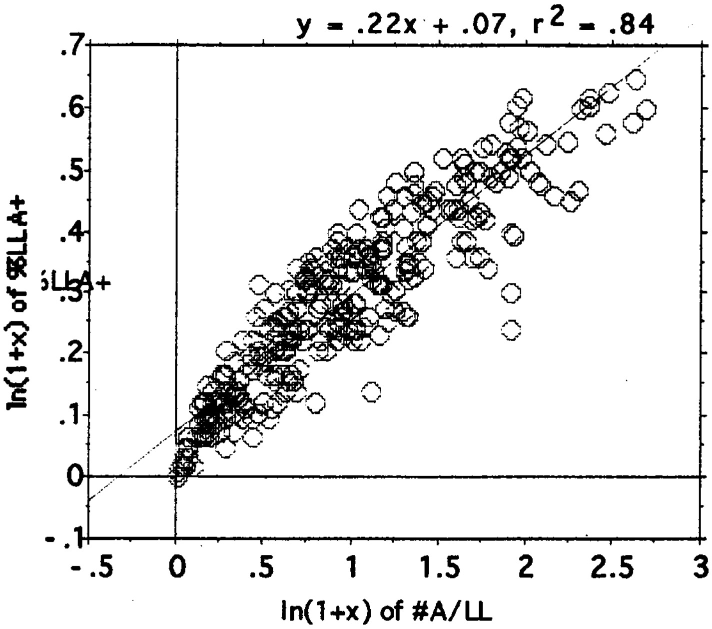
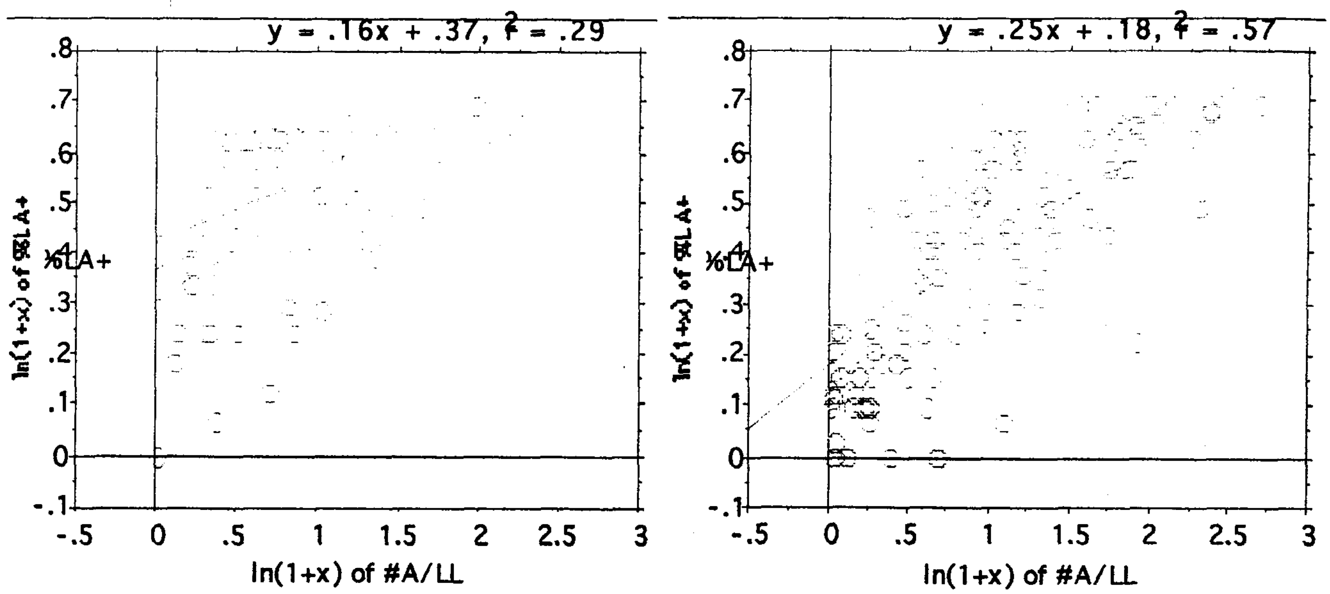


Fig. 4 shows the regression between leaf based presence absence method and enumerative method. The covariance analysis indicated significant differences due to the factor year and interactions between year and aphid counts. In both years the relationship between the two parameters is diffuse and in 1998 only half as many data were collected than in 1997. Therefore differences in the type of data collected each year (like in which phase of the aphid population growth the data was taken) could be a cause for the yearly differences and the interaction.

The leaf based binomial method reaches 1 A/LL at 50% and 5 A/LL at 86% infestation.

Fig. 4: Regression of leaf based presence absence and enumerative aphid data for 1998 and 1997 (68 and 126 data pairs transformed to natural logarithm)



Other researchers have found a better fit between leaf based and enumerative methods (Walgenbach, 1994, Clark, 1998 unpublished). However, in both cases the plot size was small (Walgenbach 98.5 square feet, Clark, 1/3 acre) and only one tomato variety was used. The presented data was obtained from actual tomato fields averaging 50 acres in size, including more than 15 different tomato varieties. Fields of that size exhibit variability in soil texture, fertility, moisture content and soil compaction which in turn will result in differences in plant water and nutrient uptake. These differences will affect the host suitability for the aphids, i.e. their reproductive rates and the most favorable location for the aphid within the plant. In addition there is a strong varietal effect on aphid populations. Some tomato varieties are said to be at least partially resistant to aphids (Kaloshian, 1995). In this way a homogenous university small plot trial can not adequately simulate actual field conditions which are highly variable on many levels.

For presence absence methods smaller sampling units are more responsive to population changes (measured with enumerative methods) in a situation of highly variable counts.

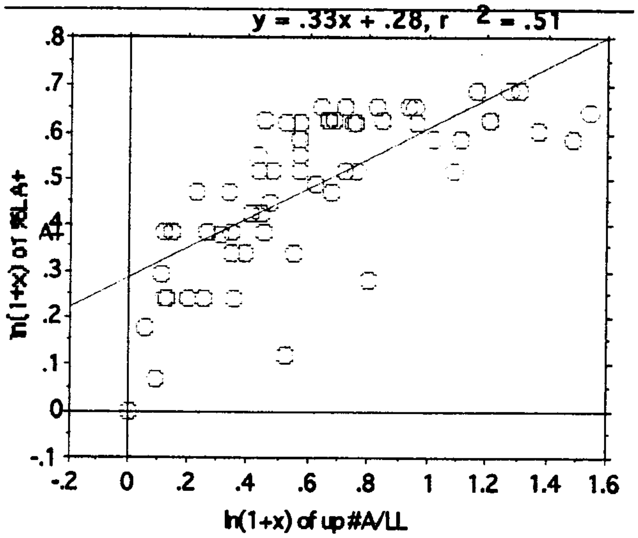
Example: When an aphid population has topped out and commences to decline due to natural causes the aphids will disappear evenly, not leaf by leaf. This means that if a leaf started with 50 aphids, after a week it might still have 10 and after a further week their might be still 2 aphids. In all cases this would have been an aphid positive leaf for more than 2 weeks while the enumerative method would have measured a reduction of more than 90%. The smaller unit leaflet catches the decline at an earlier point in time because the aphid distribution between the leaflets is highly variable and some of the leaflets start out with low aphid numbers. This phenomenon leads to a better correlation between enumerative method and leaflet based binomial method than enumerative vs. leaf based binomial method. (In comparison a chemical treatment with 100% coverage would take every aphid out but the randomly distributed resistant one's. Even if one has incomplete coverage one has a better chance of cleaning whole leafs from aphids, especially the top ones)

Factors due to the monitoring plan that might have increased variability between leaf based presence absence vs. enumerative method:

a) In 1997 the leaf based presence absence samples were taken from different plants than the samples for the enumerative method. However, in 1998 the enumerative method was done on 15 upper and 15 lower leaves. The 15 upper leaves were used parallel for all three methods.

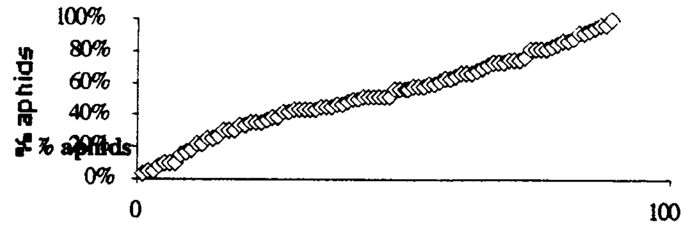
b) The leaf based presence absence method was only conducted with upper leafs while enumerative and leaflet based methods were done on upper and lower leafs. Therefore an analysis was conducted on enumerative data from upper leaflets only. This procedure improved the coefficient of determination to r2 = 0.44. Further, data above 5 aphids/ leaflet were eliminated since this method reaches saturation early, This improved the r2 to 0.51. (see Fig. 5)

Fig. 5: Corrected regression of leaf based presence absence and enumerative method, 1998



This brings up the point whether it is adequate to exclusively sample the upper canopy. In the literature Walker et al., 1984 found for 50 sample dates in 2 years 60% ± .02 of the aphid population in the upper strata. His set-up were small, encompassing University field plots with two locations and two varieties. An analysis of the present data set found on average 52% of the counted aphids in the upper canopy. However, the range spread evenly from 3% - 100% (Fig. 6). In conclusion, the average field does not exist in the practical world of aphid monitoring in processing tomato fields. Therefore, it is advisable to take samples from the upper and from the lower canopy to avoid drawing conclusions from non-representative data.

Fig. 6: % Aphids in the upper tomato canopy, 1998



As a result of this study it seems appropriate to switch from a leaf based binomial to a leaflet based binomial method sampling the upper and lower strata of the tomato canopy. Time spent in the field is equal. The accuracy of the data is significantly better. The 15 upper leaf samples can still be checked for tomato fruit worm eggs.

Growers and PCA's who do not want to make notes in the field can take two hand-held counters, one for counting the leaves checked and the other counting the leaflets that are aphid positive. When 30 leaves have been checked the total number of aphid positive leaflets is divided by 150 (30 leafs x 5 leaflets). The BIRC treatment threshold is reached at 37% leaflets aphid positive equaling 2 aphids per leaflet (or 1 AX). AX is called the aphid index and combines an average number of aphids on all sampled leaflets multiflied by the percentage of the leaflets found positive.

For growers who want to save money and spray less it is very important to collect good data as basis for decision making. The more accurately the monitoring data reflects actual aphid population dynamics the less risk is connected with decision making. If one wants to integrate aphid predator counts into the treatment threshold accurate knowledge of the pest population becomes even more important. If the ratio between aphids and aphid predators exceeds the feeding capacity of the predator they will not have a control effect. Therefore, an error in estimating the pest population can result in yield reduction and economical damage to the grower. The same applies to situations where aphid predators are to be released: the cornerstone for a successful predator release is the correct release rate, based on a good estimate of the prey population.

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Pesticide Use Patterns of Tomato Growers Participating in Bio-Intensive IPM Program vs. Their Peers - Update 1998

Abstract:
The insecticide usage of growers participating for 4 years in BIRC's bio-intensive IPM program in processing tomatoes was compared with the pesticide usage by their peers in the same county. An analysis of pesticide use reports reveals that in the last 3 years (1996-1998) the participating growers sprayed their acreage less than half as often compared to their peers [72% vs. 172%]. More specifically, 1997 was a heavy aphid year resulting in two and a half sprays of insecticides per field in Yolo County in general, whereas BIRC Cooperators treated their fields less than once. In addition, the participating growers used more often low risk materials.

Introduction:
Over the past years the awareness of risks connected with the use of pesticides has grown. Pesticides can have a negative impact on food webs and bio-diversity, as well as directly on humans. Therefore, the interest in bio-intensive IPM programs has increased. Government agencies and private organizations are now funding a number of programs with the intent to reduce the overall exposure to high risk pesticides. In addition, interest from the marketing aspect has arisen under the banner of green marketing. In any of these cases the programs merits have to be evaluated and risk reduction has to be proven. California provides a good basis for this with its institutionalized pesticide use reporting. Growers have to report treatments to the County Agricultural Commissioner's office who collects the data and then turns it over to the California State Department of Pesticide Regulation which produces state-wide summaries.

The described project focuses on the late season pest problems and control strategies in processing tomatoes. Its main difference to current programs is that it takes resident beneficial insects into account as control agents and tries to provide the grower with a higher quality of pest monitoring data. The more precise and accurate the data is on which the grower bases his control decisions the less risk factor has to be added to the treatment threshold. The program also promotes the use of low risk materials like Bts or natural enemy releases.

Methods:
The Pesticide Use Report (PUR) data from 1993 to 1995 were obtained from the Department of Pesticide Regulation (DPR). The data for the whole state of California was downloaded from the DPR web site. The summary data for the counties Yolo and Solano as well as more detailed data on BIRC's collaborators (including field sites in the counties: Yolo, Solano and Sacramento) was specifically put together for us by DPR staff. The DPR data included the category pounds of 'active ingredients'.

The data for the years 1996,1997 and 1998 has not yet been released by DPR. However, in order to reach some preliminary results at this time, the PUR data on county level and on collaborator level were obtained directly from the County Ag Commissioner of Yolo County. This data set did <u>not</u> include the category pounds of "active ingredient". The number of total acres treated is kept throughout all the summary tables and is used in the analysis as percent of the planted acreage.

The studied grower cooperator group consists of 10 growers with whom we have the longest history of contact. Two of the growers have organic fields besides their conventional fields. The organic fields amounted to 1 - 2% of the total studied acreage in any given year.

The data analysis should detect trends in the pesticide use of the cooperator group over time in relation to their peer group which is all the other tomato growers in the county. The analysis starts in 93. BIRC established first contact with them in 1994, with field work starting in 1995. In this way diverging trends would give insights on the impact of the program on the growers. Again for 93 to 95, the most complete and coherent set of data on this group including all their processing tomato fields in Yolo, Solano and Sacramento was available. For 96, 97 and 98 only the data from fields in Yolo County were available. Yolo County acreage comprise about 60% of the total cooperator acreage.

Since the harvested acreage for each grower cooperator from 93 to 98 could not be reconstructed, the planted acreage was determined from the PUR data. Each field that showed up once for a cooperating grower was counted. This assumes that any tomato field is being sprayed at least once. However, not all the planted fields are being harvested. In the statistical reports from CDFA on processing tomato production the difference between planted and harvested acres is on average 1.5%. Also, it was the total tomato acreage of the cooperating grower that is analyzed. Of this total acreage about one third was enrolled in BIRC's monitoring program.

The PUR data situation is not fully satisfying but should be sufficient to give a basis to start a first assessment of the impact the program had on the grower community. The analysis will be updated as soon as more data comes in.

The risk assessment is based on the EPA grouping for tolerance reassessment (Federal Register/Vol. 62. No??/Mon., Aug. 4, 1997/Pre-publication copy). Group 1 pesticides are organochlorines, organophosphates, carbamates and other probable human carcinogens. These materials pose a risk to humans and the environment through direct toxicity as well as chronic effects. Currently the effects of endocrine disruption through some of these materials is under scrutiny. Group 3 pesticides encompass biological pesticides and low hazard-inert ingredients. These materials pose a relative low risk for humans and the environment since they either are narrow spectrum, targeted only on the pest, and/ or break down into non-toxic substances quickly.

The data on harvested acreage and production for the state and the counties comes from the on-line CDFA Statistics Service.

Glossary for Tables

A	Acre
AI	Active Ingredient
Bt	Bacillus thuringiensis

CHC	Chlorinated Hydrocarbon
chem.	Chemical
lb	pound
OP	Organophosphate

Discussion and Results

This analysis of insecticide use in processing tomatoes examines use patterns according to the risk the active ingredients pose to humans and the environment. Of particular interest was the use of narrow spectrum IPM-compatible pesticides. This analysis is especially interesting, since IPM programs were developed for this crop in the late 80's and experts from the industry claim that these IPM programs have been implemented long ago.

Only insecticide use was scrutinized in this analysis. It equals about 2 % of the total active ingredients (AI) used. This does not sound like much, but this group also contains the most toxic and disruptive materials. In comparison, sulfur (used as a miticide and fungicide in tomato production) often constitutes more than 50% of the total lbs of AI applied in processing tomato production, but it is considered a low risk material and is also used as a fertilizer.

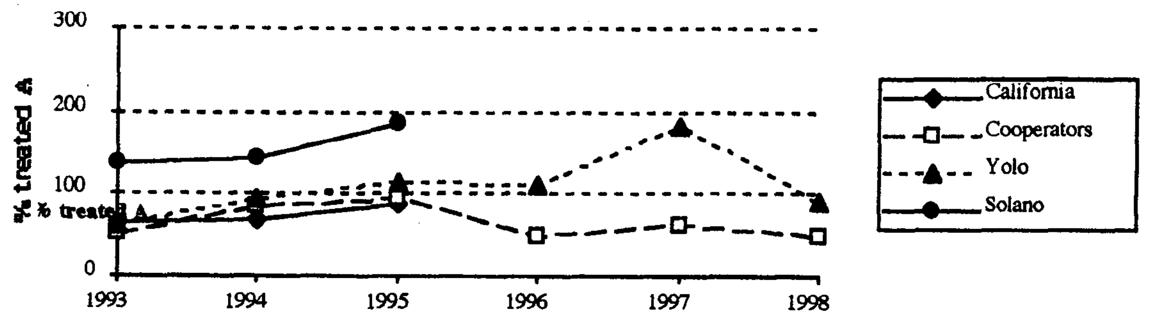
The analysis is based on pounds applied as well as percent acreage sprayed. Changes in pounds of active ingredients should be seen as specific for a product or chemical family. For example the positive impact of growers who make use of reduced application rates, which a Bio-Intensive IPM program might ask for, can be detected. However, research and development has produced materials that are getting more potent and are effective at lower rates per acre. Therefore a overall decrease in pounds per acre does not necessarily mean that the fields were sprayed less. A figure for percent acreage sprayed above 100% indicates that on average fields were treated more than once.

Since tomato acreage and tomato production have been quite variable over the last 5 years, the insecticide use is always reported in relation to the crop acreage or the crop tonnage.

Total Insecticide Use:

A look at the pounds of insecticidal active ingredient applied per acre (Fig. 1) reveals strong differences between counties and the state. In Solano County about a third more insecticides were applied compared to Yolo County or the State of California. However, there are no differences in yields between Yolo and Solano County (tons/ acre) and the pest problems are similar.

Fig. 3: Percent Tomato Acreage Treated with High Risk (Group 1) Insecticides

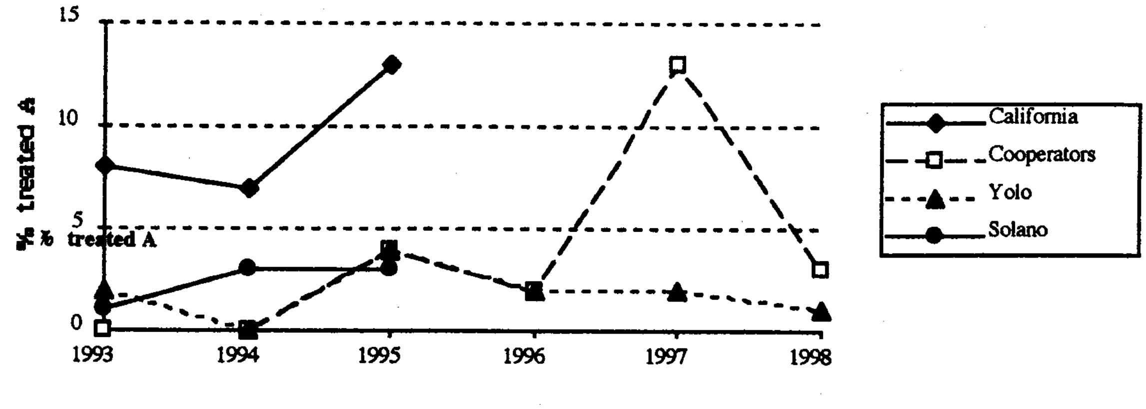


Currently, Group 2 pesticides are dominated by the pyrethroid esfenvalerate, which constitutes more than 95 % by pound or acreage of Group 2. The value of synthetic pyrethroids in an IPM program is limited. They generate a broad spectrum kill-all effect, damaging beneficial populations to a higher degree than the OP dimethoate. However, they are popular when OP resistance shows up in pest populations.

Use of Low Risk Materials (group 3)

Until 1996 the BIRC cooperators showed the same low use of Group 3 materials as other processing tomato growers in Yolo and Solano County. This changed dramatically in 1997 when the % cooperator tomato acreage treated with Group 3 materials increased from 2% to 13% while the use in Yolo County as a whole remained at 2%. Most of the group 3 applications were Bts and to a small part experimental treatments with insecticidal oils and soaps. These applications were the direct result of BIRC's grower education and recommendations. BIRC put special efforts into promoting the use of Bt this year and dedicated one of the summer grower's newsletters to this. We also coached our cooperators individually on the use of Bt when appropriate. However, the Bt treatments dropped again in 1998. An in detail analysis reveals that the growers who used Bts in 1997 are the same using it in 98. Each of them is satisfied with the effectiveness of Bts but had not had that much need for them in 1998. Efforts to promote Bts are being continued.

Fig. 4: Percent Tomato Acreage treated with low Risk (Group 3) Materials



An interesting finding was that on a state wide level Bt is fairly well used (at least if one assumes that four year old data is still accurate). However, according to Bt sales representatives, there seems to be a North/ South divide, i.e., for some reason they cannot sell much of this material in the North. BIRC is determined to remind growers that there is an effective alternative for worm control.

Alltogther these data show a very positive trend among the cooperator group. BIRC is certainly not the only cause for their more conservative pesticide use but interaction with BIRC's staff and actual field monitoring through BIRC helped growers to go this way.

So far the analysis only covers the Yolo County cooperator acreage (60% of the total acreage). The data will be updated as soon as DPR releases the PUR reports for 96,97 and 98.

Feasibility Study of Lacewing Egg Releases for Potato Aphid Control in Processing Tomatoes

G. Wittenborn and W. Olkowski

Abstract

This study examined predator prey relationship between the potato aphid and the green lacewing in on-farm field trials in the Sacramento Valley, California. Commercial sources of lacewing populations can be established with egg releases (at 2 eggs per plant) even when potential egg and larval predators like the damsel bug are present. Field cages were used to measure aphid population growth (mean 17% per day) and aphid consumption by lacewing larvae (13 aphids per day). Under these conditions a release of 2 lacewing eggs per 50 aphids should be sufficient to control the aphids as long as lacewing mortality after release is not excessive.

Introduction:

Processing tomatoes are one of the anchor crops for Central Valley row crop operations. Their production is heavily reliant on high-risk broad-spectrum insecticides (Davis et al. 1998) now under threat of loss due to implementation of the Food Quality Protection Act (Federal Register, 1997).

Most of these insecticides are used on late season pests consisting of the Potato Aphid (PA), various lepidopteran worms and stinkbugs. The potato aphid, *Macrosiphum euphorbiae*, is the key species in this complex because it occurs at high numbers before the others in the complex. On average, late season tomato fields in the Sacramento Valley are treated twice for aphids, worms, stinkbugs, or any combinations. Frequently used materials are dimethoate and methamidophos. Both have been identified by the Environmental Protection Agency as 'risk drivers' and belong to a group of eight organophosphates (OPs) that accounts for most risk from residues in the diet (Classen, 1999). If these materials were taken off the market or strongly restricted, growers will most likely switch to synthetic pyrethroids. However, pyrethroids can be even more harmful to the natural enemy fauna than an OP like dimethoate, triggering secondary outbreaks and in turn more treatments. We have observed treatment failures and secondary pest outbreaks have been documented (Burnham, 1998) with existing materials.

A cost-effective non-toxic alternative for aphid control could change this dreary picture. In a preliminary analysis, we compared the different species of commercially available aphid predators for feasibility of releases under conventional farm conditions. The main criteria used to select amongst them were availability of mechanical application techniques, lag time between release and feeding, mobility, predation rate and price. Lacewings scored best in each category (see attachment):

- Eggs can be applied mechanically (Wunderlich et al., 1998) and hatch within a day or two.

- Besides aphids the voracious highly mobile larvae eat also worm eggs, first instar worm larvae, mites, and other prey, and are tolerant to some insecticides.
- The larvae have excellent searching ability but cannot fly away.
- Green Lacewings, *Chrysoperla carnea* (eggs and larvae) are commercially available in volumes and at prices making inundative releases feasible.

Thus, it was concluded that lacewing egg (LWE) releases have the best potential to be effective in processing tomatoes.

However, Rosenheim and Wihoit (Rosenheim et al. 1993) working in cotton, have shown hemipteran predators in the genera *Zelus*, *Nabis* and *Geocoris* can greatly reduce the effective numbers of released LWE and early LWLs. *Geocoris* and *Zelus* are rarely found in tomato fields in the Southern Sacramento Valley, but nabids can be quite abundant, especially in more mature stands. In addition, tomatoes have a differently formed canopy than cotton, and a different predator-prey complex. If releases are made before nabids become common, this source of mortality can be reduced.

So far lacewing egg releases have not been studied in tomatoes even though lacewing larvae are a part of the natural enemy community found in this crop. Therefore this pilot study focuses on the key issues relevant for any beneficial release: survival of the released lacewings and their voracity.

3. Methods:

3.1 Survival Study:

In both studies aphid populations were monitored before and after the release with binomial and enumerative methods as follows:

- Aphid Index (AX): aphids are counted on 150 leaflets (underside, terminal 5 leaflets of 30 leaves) in the upper and lower canopy of 30 plants randomly selected in the field. The average number of aphids per leaflet is then multiplied by the average percentage of aphid infested leaflets resulting in the AX. This measurement is thought to provide both a density and dispersion combination indicative of potential aphid stress to the plant.
- UC presence absence method: 30 leaves from 30 randomly taken plants are checked for aphid presence or absence. (Leaflets per leaf can vary from 5 to 13; leaves selected from first leaf below the highest flower on high growing stems), or taller vine stems.

- Natural enemy populations were monitored with "shake samples": derived by shaking a plant over a standard cafeteria tray. The specimens for each relevant species/ genera are counted. One sample consists of 10 random sub-samples or tray placements. Trays are placed at ground level below the canopy on one side of the furrow. Data obtained at this plant development stage corresponds to approximately one quarter of a tomato plant's leaves.

The potential aphid predation is assessed using the three following measurements:

1.) APP (Aphid Predator Power, Tamaki et al. 1974): to determine the aphid predator power the number of specimens of each species/ genera found in shake samples are weighted according to their relative aphid consumption according to Tamaki, 1974: (LBA * 8; LBL, LWL, and SYL x 4; M, BB, DB, MBP x 1). [LB - ladybeetles, LW - lacewings, SY - syrphids, BB - big eyed bugs, Gecoris spp., DB - damsel bugs, Nabis spp; A - adult, L - larvae]. The result is then divided by the number of sub-samples.

Note that AM (Aphid Midges), M (Mummies), and MPB (Minute Pirate Bugs) were not described by Tamaki et al. 1974. The above multipliers for these species were attributed according to whether a species/ genus is an aphidophagous or omnivorous predator; higher multipliers are given to aphidophagous species. A mummy only indicates the kill of one aphid, so parasitoids get a lower multiplier. Tamaki gives ladybeetles, which may not be appropriate in this situation.

This approach using aphid predator power (APP) has the following advantages:
a). Aphid infestations are usually accompanied by a number of different aphid predator species. Transforming this complex into one number helps in field evaluations and also makes it easier to compare samples from different fields.
b). The shake sampling methods lacks precision. The transformation into one number compensates for this somewhat.

2. PPA (is a shortened version of APP/A, which is the ratio of Aphid Predator Power (APP), divided by the number of aphids per leaflet (AX). This compares the relative strength of the aphid predator complex vs. the aphid population. It is important to note that the APP is based on shaking of 20 to 50 leaflets (depending on the maturity of the plant) per individual sample (10 are taken per count) while the AX is based on one leaflet (150 of them from 30 leaves).
3. M/A (Mummies / Aphid): Mummies (M) are found on the leaflets as well as in shake samples. Only a portion of mummies from shake samples detaches during shaking so their presence is noted but the counts are derived from leaflet samples. To calculate the ratio M/A the number of mummies per leaflet is divided by the number of aphids per leaflet. Dissections of aphids would be a better way to assess parasitism at an earlier state, but are costly.

3.1.1 Lacewing Egg Release near Winters:

This study was a release with a remote control model airplane equipped with a cargo bay with a variable-opening slit. For the release, the LWE were mixed with corn grit as a filler at 2 quarts of corn grit for 25,000 eggs. 150,000 LWE occupy a volume of 21 ml. Originally it had been planned to apply the eggs at two application rates but high winds made this impossible. 150,000 eggs were deployed on a 10-acre section of a tomato field equaling about 2 eggs per plant.

3.1.2 Lacewing Egg Release near Clarksburg:

This study was a replicated manual release of lacewing eggs from two commercial sources and comparing different release rates and is summarized below. The two insectaries produce eggs with different rearing methods.

Set up:

Total trial area:	0.55 acre
Lacewing egg source:	**A** Beneficial Insectary, **B** Rincon Vintova
1 st release:	**8/5** morning
	hatch rate: 60 eggs of each source in gelatin capsules
2nd release:	**8/12** evening
	hatch rate: on masking tape
Application method:	eggs were manually applied with a brush
Rates:	1 egg/ plant (=**a**); 4 eggs/ plant (=**b**)); no eggs (**K**)
Treatment key:	**2*Aa, 2* Ab, 2*Ba, 2*Bb, 4*K** - 12 plots
Plot size:	30 feet wide = 6 rows; 50 feet length (14' between
plants)	-> = 257 plants/ plot
Buffer	2 rows between the sides and 6 feet at the head
Experimental design:	complete randomized, no stratification
Sampling	Aphid Index: 12 upper and lower leaves per plot,
	Beneficials: 5 shakes per plot

The data was statistically analyzed with Statview. The coefficient of variation was calculated by dividing the standard deviation by the mean. For the hatch rate 60 eggs were taken from each egg source. In the first round they were put into gelatin capsules and in the second round they were applied on masking tape. A yield comparison was performed by randomly weighing the tomato yield of 8 one-meter long row strips in the release site and 8 random one-meter strips in a neighboring field site.

3.2 Voracity Study:

Cages placed over tomato branches in conventional tomato fields were used to measure predation under realistic conditions. Such in-field studies are more reliable than laboratory studies for measuring predation since a more direct relationship exists between field collected data and its eventual use. Three field trials were conducted, one with lady beetle adults (*Hippodamia convergens*, LBA), and two with principally Lacewing Larvae (LWL I and LWL II). In each, tomato vines with 50 to 100 counted aphids and removed volunteer predators were caged in a tapered polyester mesh plant sleeve (height 58 cm, top width 19 cm, base width 50 cm; 'Fiber Air Sleeve', Kleen Test Products) (Cisneros et al. 1997, Rosenheim et al. 1993). The initial number of aphids was chosen so introduced predators could feed unrestricted for a number of days.

Cages were then assigned randomly to the treatments consisting of enclosures with and without one predator for different time intervals (1-3 days). The cages were sealed with tape and stapled at the top and at the base. Each treatment had five replications.

_The data was transformed into daily growth rates (q). The growth rates were calculated two ways (Tamaki, 1974): [a - aphid number; a_1 - aphid number at first day, n - number of days; ln - natural log)

(1) one day trials: average of all ratios $q = a_{t+1} / a_t$

(2) multiple day trials: $q = e^{(\ln(a_n/a_1))/n}$

As an approximation of aphid consumption by the predators the average number of aphids in the predator treatments was subtracted from the average number of aphids without a predator (last day data). The statistical analysis was performed with StatView.

The predator sources were same day field catches for the LBA and LWL I studies. In the LWL II study third instar larvae were purchased from a commercial insectary and pre-fed with aphids prior to release into the field cages. Pre-feeding was to control for starvation and feeding differences amongst the delivered larvae.

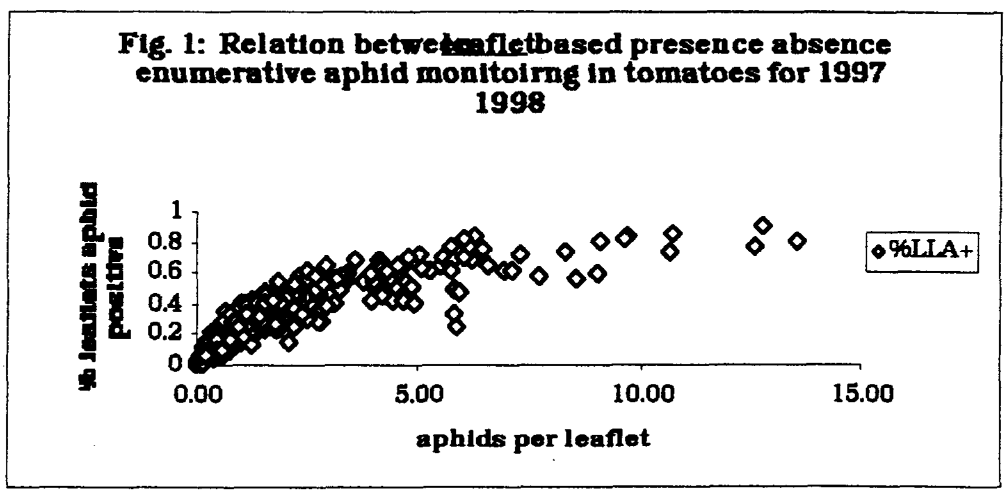
4. Results and Discussion:

4.1 In-Field Survival Study

4.1.1 Release near Winters

The LWE were applied when the aphid infestation was at 93% leaves infested (fruit bulking) (see Figure 1). A 50% infestation had been reached 15 days prior to this (early fruit set). The AX stagnated at about 1.0 for 7 days before the release. The rest of the field was sprayed with dimethoate on 7/9. The APP rose strongly after the release while the AX remained at about one for another 10 days before the aphid population steeply declined (at first pink). The ratio PP/ A started climbing when the aphids where still at their plateau. The ratio of M/ A rose steeply 10 days later, shortly after the aphid decline. It takes about 5 days from parasitoid egg deposition to the development of a black or tan mummy (two parasitoid species are present: ***Ephedrus californicus*** and ***Aphidius colmanni***.

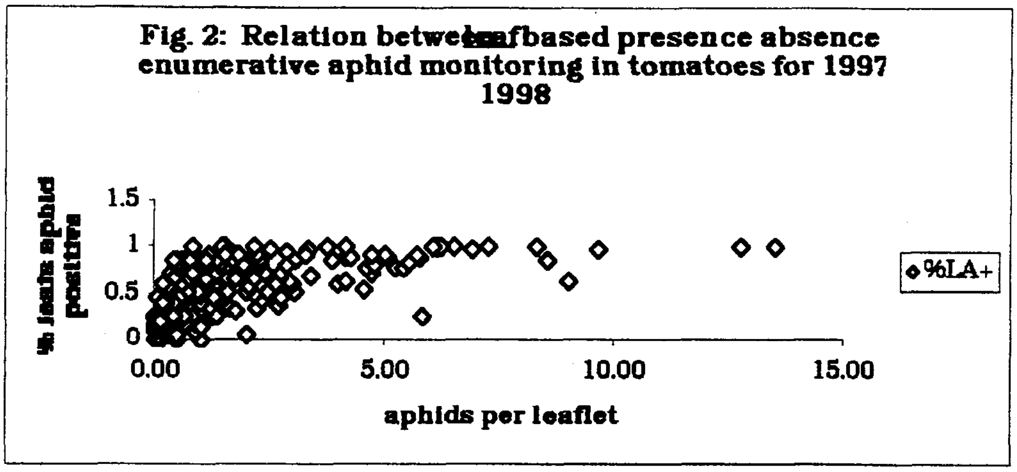
Figure 1. Comparison of Potato Aphid Population Sampling Methods and Measures of Predatory Activity, After a Release of Commercially Produced Lacewing Eggs, Sacramento Valley, California, 1998.



The LWL started appearing in shake samples 3 days after the release and where found at moderate numbers for the following 15 days (see Figure 2). Damsel bugs (nabids) were present at the same time in increasing numbers.

LBA were present at moderate numbers. Aphid mummy counts grew exponentially peaking on the 22 of July.

Figure 2. Natural Enemy Counts After the Release of Commercially Produced Lacewing Eggs, Sacramento Valley, California, 1998.



Due to the numerous other aphid predators it is difficult to assign an exact amount of aphid reduction to the LWE release. Also, the maturation of the crop will have played a role in aphid decline. However, from looking at other fields under similar conditions a major aphid outbreak without the LWE would have been highly likely. Although this release was made under sub optimal conditions it appeared to be effective. Further work with this method of release is warranted.

4.1.2 Release by Clarksburg

The hatch rate for the lacewing eggs was 2% for batch A and 22% for batch B. Since the lacewing larvae finds in the field were also negligible a second release was performed. For the second release the hatch rates were 68% for A and 55% for B. Use of gelatin capsules for egg hatching probably compromised the first hatching assessment. Gelatin capsules may hasten egg drying. The use of masking tape in the second assessment does not have this limitation.

The lacewing counts from the field sampling were tested for dependency on the application rate. No significant relationship was detected. The mean over all sampling data for the high rate was 0.38, low rate 0.75, and control 0.50 lacewing larvae per shake. From this it was concluded that plots had been too small to keep the treatments separate considering the high mobility of the larvae.

The factors date, insectary, and release rate were tested against damsel bug count, aphid index and aphid predator power. Only the differences due to the factor date proved to be significant. The data exhibited high coefficients of variance, averaging for the aphid predator power 57% and for the aphid index 72%.

For further analysis all sampling data was averaged per sampling date. The pest and predator population dynamics are shown in Figure 3. The aphid population peak precedes the predator population peak by about 4 days. The peak population grows well beyond the threshold at an aphid index of one. Ladybeetle and lacewing larvae data are weighed with the same multiplier that was used for the aphid predator power. In this way their relative impact of the predator power is apparent. The lacewing larvae constituted less than a 1/3 of the total predator power. The main predator species were ladybeetle adults and their larvae. The aphid population declined while aphid predators were present at high numbers and increasing, Figure 3.

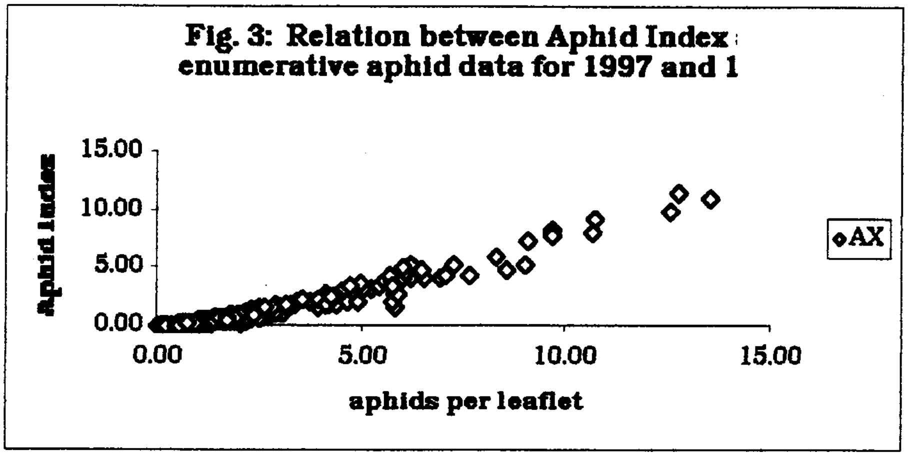


Figure 3.

Table 1 shows that damsel bugs and the released lacewing larvae can coexist. A regression analysis did not reveal any significant correlation between the two. The field harbored a high volunteer ladybeetle population, which is somewhat unusual, since these beetles normally aestivate in the Sierra Nevada's. Resident non-aestivating H. convergens are not well studied and whether they are as effective in consuming aphids as they are in other regions remains a question for further work. However, they do lay eggs and the larva feed to grow. The field had also a strong spider population. Unfortunately the aphid consumption by spiders is unknown for this region.

The daily growth rates of the aphid population indicate a very strong growth of 1.29 for the time just before the second lacewing release. Thereafter, the aphid population declines first slowly and later still, with increasing momentum. This occurs parallel to high predator numbers and increasing maturity of the tomato crop. The growth rates have a coefficient of variation of less than 20%. Enclosures in the same field with aphids exhibited a daily growth rate of 1.05 between August 15 and 17.

The above aphid growth rates are based on aphid counts by leaflet. Since the number of leaves per vine increases until fruit ripening a part of the aphid population growth goes unnoticed with this sampling method during the vegetational growth of the plants. However, it can suddenly become apparent when the vegetational growth stops and the aphid population growth continues.

Table 1. Potato Aphid Predators by Date and Plant Stage, 1998, Sacramento Valley, California.

date	28-Jul	4-Aug	5-Aug	7-Aug	11-Aug	15-Aug	19-Aug	26-Aug	3-Sep
stage	green	green	green	green	1. pink	<50%red	<50%red	<50%red	>50%red
LWL	0	0	nd	0.12	0.03	0.17	0.10	0.28	0.03
DB	0	0.2	nd	0.23	0.23	0.33	0.53	0.93	0.32
LBA	0	0.2	nd	0.07	0.10	0.17	0.07	0.13	0.08
LBL	0	0	nd	0.10	0.25	0.63	0.72	0.75	0.27
S	0	0.4	nd	1.12	1.45	1.25	1.08	2.05	1.42
APP	0	2.8	nd	2.37	2.98	6.73	4.70	6.42	2.82
AX	nd	nd	0.45	nd	2.06	1.62	1.24	0.78	0.02
q(AX)	nd	nd	nd	nd	1.29	0.98	0.95	0.92	0.64
A/LL	nd	nd	1.10	nd	3.45	2.82	2.16	1.53	0.20
PPA	nd	nd	nd	2.16	0.87	2.39	2.17	4.18	14.38
%LA+	27%	53%	nd	nd	93%	nd	nd	nd	nd

Natural enemy data: average count per shake; sample consists of 10 shakes, or cafeteria tray positions.

The natural aphid enemies were an important factor in reducing the aphid population. The released lacewing larvae are most likely the factor that tipped the scale toward aphid decline. Unfortunately the first release did not perform and the second release was conducted when the aphids had reached a population size this number of lacewing larvae could not control. However, since other beneficials were present further aphid growth was prevented.
The overall yield of the field was with 28 tons per acre, somewhat lower than the statewide average of 32 t/ac. Besides insect pests the crop was also suffering from a late blight infestation. The rest of the field was sprayed on August 17 with dimethoate. A yield comparison between the tomatoes in the release area vs. an adjacent field section showed no significant yield difference (17.94 lbs per one-meter strip in LWL release vs. 16.56 lbs per one-meter strip in the sprayed section) at a coefficient of variation of 27%. The pesticide treatment was too late to make a difference since both field sections had comparable aphid presence patterns.

4.2 Voracity Study:

Table 1 summarizes the findings that are of importance for planning a lacewing egg release as well as assessing the potential for aphid control through resident beneficials. A one factor ANOVA showed that the aphid growth rates were significantly reduced by the predators (mean aphid growth rate without predator: 1.17. mean growth rate with predator: 0.83). Differences between predators (LWL and LBA) were not significant (p = .0001, Scheffe F-test). The coefficients of variation were below 20%. Tamaki et al, (1974) found an average daily growth rate for green peach aphid in potato of 1.14 with a CV of 4%.

Table 2. Daily Potato Aphid Growth Rates (q) and Consumption by Predators, Processing Tomatoes (var. 3155, Sacramento Valley, 1998).

(w - with; w/o - without; **PA=potato aphid, LBA=lady bird adult, LWL=lacewing larvae, AM= aphid midge larvae; LWL2, second instar, 3 = third instar, reps=replications)**

Trials:	**LBA**	**LWL I**		**LWL II**		
Starting Date	23-Jul	15-Aug		26-Aug.		
Crop stage	fruit bulking	1-5% red fruit		early fruit set		
Initial # of aphids	50	100		50		
Predator species	LBA	LWL 2. instar	LBL last instar	LWL 3. instar	AM	LWL 3. instar
Duration (days)	1	3	3	1	1	2
PA q w/o predator (# of reps)	1.27 (5)	1.05 (7)		1.23 (6)		1.17 (6)
PA q w/ predator (# of reps)	0.84 (5)	0.93 (3)	0.73 (1)	0.73 (4)	0.85 (1)	-
PA consumption	21	13	27	25	19	-

PA growth rates without predators indicate no correlation with the time in the year but a strong decrease with the maturity of the tomato plant. For the variety 3155, the PA population growth dropped to minimal increases at 1-5% red fruit. This has to be confirmed with additional multiple day studies.

A literature review results in the following predation rates:

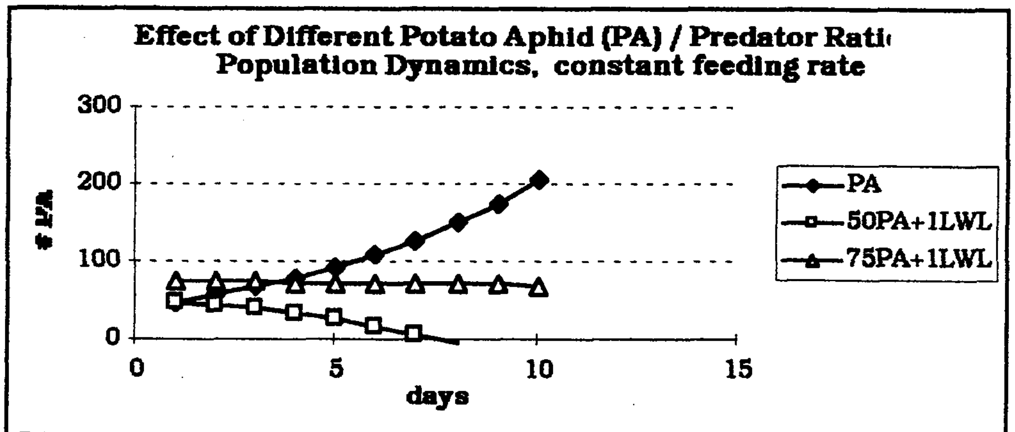
Author	**Predator**	**Prey**	**aphids consumed /day/predator**
Scopes, 1969	*Chrysoperla carnea*, L2	*Myzus persicae*	28.7
Scopes, 1969	*Chrysoperla carnea*, L3	*Myzus persicae*	17.2
Sunby, 1966	*Chrysoperla carnea*, L1-3	*Myzus persicae*	27
Godarzy et al. 1958	*Hippodamia convergence*		32.9
Simpson et al. 1960	*Hippodamia convergence*		89.4

The lacewing larvae results are in the same range as the literature indicates whereas the ladybird beetle data was lower. The present study indicates that the last LBL and LWL instars have a similar aphid consumption rate. Larval aphid consumption by LWL 2nd stage vs. 3rd stage suggest that a predator power multiplier averaging over the larval stages seems appropriate as a baseline. This finding certainly needs confirmation with further work. The one aphid midge (AM) value is also quite interesting since it places AM larvae on par with the better known and observed lacewing and ladybeetle predators. Further study with more replications is needed for confirmation.

The main challenge of the trials was to keep the enclosures sealed as second instar lacewing larvae had a strong tendency to escape. This was not a problem for the relatively larger LBA. Another potential for error are other aphid predators getting into the cage either by being overlooked initially or by moving in later. When such cages were found at "harvest" they were excluded from further analysis.

To improve the understanding of predator releases two simplifying models were constructed based on the data from this study. In Figure 4 the calculated feeding rate was kept constant at 13 aphids per day. This scenario fits the needs of a voracity assessment of a resident beneficial population of lacewing larvae with a stable aphid consumption. The aphids are set at a medium population growth of 17% a day. Under these conditions an initial population of 50 aphids disappear in 8 days but an initial population of 75 aphids remains even though in both cases 130 aphids were consumed. If the aphid population growth is high instead of medium the estimate of the initial population has to be more accurate. In this case the difference in size between a controllable and a non-controllable initial population decreases.

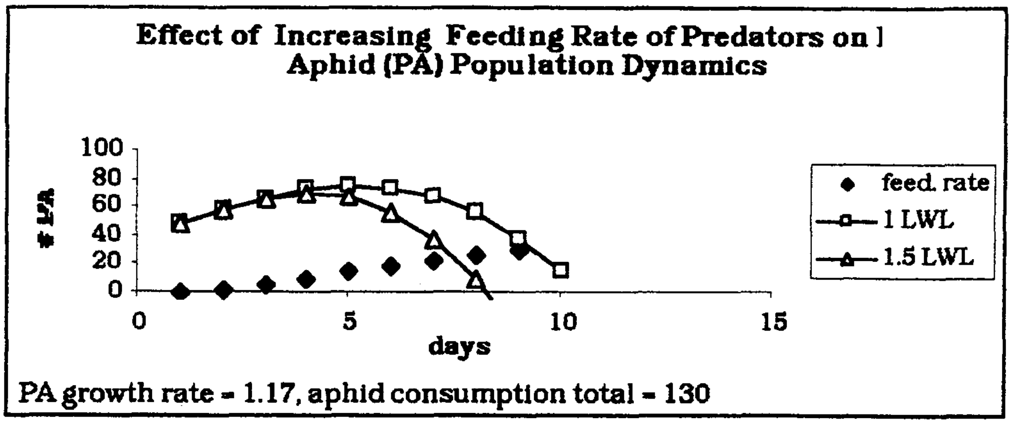
Figure 4.



PA growth rate = 1.17; aphid consumption: daily = 13, total = 130

In the Figure 5 the feeding rate is variable: zero consumption on the first day and a linear increase in consumption thereafter. The total aphid consumption is kept the same at 130 aphids and a medium aphid population growth rate of 17% daily is chosen. This is a model that relates, for example, to lacewing egg releases: the aphid consumption starts at zero and increases from there. Exact feeding rate curves for lacewing eggs from egg to 9-day old larvae under field conditions have not been published. Evidently, differences in feeding rates in the first days would produce the biggest differences in regards to final aphid control. Under the chosen conditions 1.5 lacewing eggs are needed to control the aphids within 10 days. At higher aphid growth rates more lacewing larvae would be needed.

Figure 5.



Conclusions: To arrive at a successful application rate for a beneficial release the following factors have to be assessed: initial pest population and its growth rate as well as knowledge of potential predator egg hatch, predator survival in the field and predator voracity.

A lacewing release has to be performed at an early aphid infestation stage to be effective. A precise and accurate method for aphid monitoring is the presence absence method on leaflet basis. These preliminary results suggest starting releases at about 50 PA per plant (approximately 25% aphid positive leaflets). This allows for some PA population growth during the time while the released LW eggs are completing incubation and hatching. The other advantage for early release is that there are less general predators present that could eat released LW eggs and young LW larvae. A release rate of two eggs per tomato plant can be adopted as an interim working level, allowing for some LW egg and early larval mortality. This release rate assumes the remaining larvae will eat 130 aphids in 10 days. At the usual number of 8,000 plants per acre this would be 16,000 eggs per acre. Prices for small egg purchases are $1.50 for 1,000 eggs, for large purchases prices can go as low as $0.75/ 1,000. Therefore, the per ac price would range from $12 to $24 exclusive of application costs. This is in the range of conventional insecticide costs. Reductions in predator mortality could further reduce the number of LW eggs needed, making releases more cost effective.

These preliminary studies provide data supporting feasibility of inductive LW releases. Further work, however is needed with improved methods for sealing cages, other predators, and more replicates. In addition, evaluation of naturally occurring predators is needed to incorporate predation rates into pest threshold guidelines. Naturally occurring predation is not yet incorporated in the existing treatment guidelines now being used.

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7/24/98

Through the Tomato Vine

Vol. 3, No. 1

BIRC's In-Season Newsletter for Late Season Processing Tomato Growers

This newsletter is a continuation of the "Report to the Grower", produced for the previous 2 seasons as part of the Reference Field Monitoring Project for processing tomatoes. 1998 support for this project comes from the Heller, Crocker, and C.S. Mott Foundations, EPA Region 9, CA Dept. of Pesticide Regulation and the Bio Integral Resource Center (BIRC). The newsletter is issued during the latter part of the processing tomato season when most insecticides are applied. The principle pests during this time are potato aphids, stink bugs and worms.

Highlights of the 1997 Season

Testing Least-Toxic Materials

- Perhaps the most important thing we learned in '97 was that effective alternative materials for potato aphid control exist. However, application equipment traditionally used for conventional, insecticides, with their fuming action, will get unreliable results when used to deliver an alternative contact insecticide. Field tests demonstrated inadequate leaf coverage.

  One alternative material that does work with conventional equipment is Bt for worms. Last season we monitored two successful Bt air applications for armyworm control. Available for worm control for many years, recently manufacturers have substantially improved formulations. Bt is the best material for worms because it is selective and does no damage to natural enemies.

Inoculative Releases of Natural Enemies

- In 1997 we monitored a number of fields where aphid infestations were controlled by natural enemies. In two cases this was aided by inoculative releases of natural enemies.

Possible Aphid Resistance

- Overall, 1997 was a bad aphid year, with a season advanced by 2 weeks or more. Natural enemies in general were low to virtually non-existent in many fields. Fields near wild hill areas were exceptions with good natural enemies. But many other fields were devoid of natural enemies. About 80% of our cooperator's fields were treated. Some fields were sprayed up to 3 times. Part of this probably due to resistance. Avoiding early treatment allows time to see if treatment is necessary. There also were secondary outbreaks of leaf miners. These observations show importance of finding least-toxic alternatives.

Aphids/Yields

- Last season showed again that tomato plants can take a substantial amount of abuse from potato aphids and still have a high yield. One field planted with cultivar 8892 produced 40t/ acre after an aphid leaf infestation of more than 60% had been sustained for over 2 weeks. The aphids reached an aphid index (AX) of 2, which is twice the level at which we normally recommend treatment. Some cultivars such as Alta would show serious damage at this level, particularly during fruit bulking. This 40t/ac field growing 8892 was certified organic. Back when it was managed conventionally it produced an average yield of 30t/ acre.

Pesticide Use Patterns of BIRC Cooperators

- A preliminary analysis of pesticide use patterns indicates that BIRC's grower cooperators used substantially less organophosphate and pyrethroid materials and substantial more least toxic materials (Bts, botanicals, oils, and soaps) than their peers in Yolo county. BIRC experienced increased interest and cooperation from growers and their PCA's in '97 over prior years.

(Continued on next page)

Program for 1998

Based on last season's experience, we will continue using "aphid-counting" rather than "presence/absence" to decide upon treatment. In the early stages of an aphid infestation, monitoring for presence or absence of aphids on 15 or 30 leaves works fine. However, when the infestation goes beyond 60%, actual aphid numbers make all the difference in helping to decide whether to treat, tolerate, or come back and sample again in 3 days. This is especially the case when the aphid numbers decline due to plant maturity or beneficial insects.

The presence/absence approach is not sensitive enough to record when the total number of aphids starts declining. If this trend is promptly recognized, it can help avoid unnecessary treatments. It may indicate that aphids are coming under biological control.

Monitoring of Beneficials

The time to treat is when aphid numbers are building and natural enemies will not catch pest growth in time to prevent intolerable damage. The main difficulty is in evaluating the natural enemies likely impact. When the outcome is uncertain, using lacewings, other natural enemies, or a selective aphicide is appropriate.

The big question with aphid natural enemies is: how much appetite do they have? Fortunately there are some research papers on the subject. From these we hope to develop a system to help with decision-making. One approach is to assign the predators a value based upon how many aphids they can consume in a day or over the span of their life stage. We are working on this problem this season.

Lacewing Egg Releases

We are experimenting with different technologies for release of lacewing eggs. These are produced by a number of commercial insectaries. The eggs should be released just before hatching.

Compared to the release of other beneficials, lacewing eggs have the following advantages:

- can be applied by air or ground
- larvae are mobile and active searchers
- lag time is only 1 to 3 days (time from application to 1st aphid catch)
- active in the field 12 days before entering the non-feeding pupal stage
- 100 - 600 aphids consumed during larval stage (between hatching and pupating).
- price: $0.75 to $2.00 per 1000 eggs

In theory, lacewings can be cost effective. At a leaf infestation level of 50%, one lacewing larvae per plant should suffice to take care of the problem. Since there are 8,000 tomato plants per ac., early releases of 10,000 eggs /ac. are desirable. However, losses at hatching, application and during predation make it necessary to release at least 50% more.

We are experimenting with application by a remote control airplane outfitted with a compartment to hold eggs and a switch to open the unit during flight. Timing made necessary the first release of 150,000 eggs to 10 previously-untreated acres during relatively high winds. The rest of the field was treated with dimethoate.

The remote-control plane is not the equivalent of a crop duster. It is very light and cannot fly close to the ground in high winds. Given the strong breezes, it was not feasible to accurately place 50,000 eggs on one 4 ac plot and 100,000 eggs on an adjacent 4 ac. The next application to evaluate different release rates will need to be made to different field section, far enough separated to prevent drift of eggs between plots.

This plane application method has been pioneered by Morgan Bpwen of Bo-Biotrol, a Merced based company (209-384-2130) which distributes beneficial insects. The costs of applying the eggs for this first attempt was $1.50/1,000 eggs and $100 for the pilot, or $1/ac for over 100 ac. We expect to reduce costs by learning to apply optimal rates of eggs. Although our pilot made the flying seem easy he did stress how much attention it takes to operate the plane. Morgan Bowen, who is supporting the development of this application method, emphasized this, also. A number of planes crashed during the early stages of Bo-Biotrol's development effort.

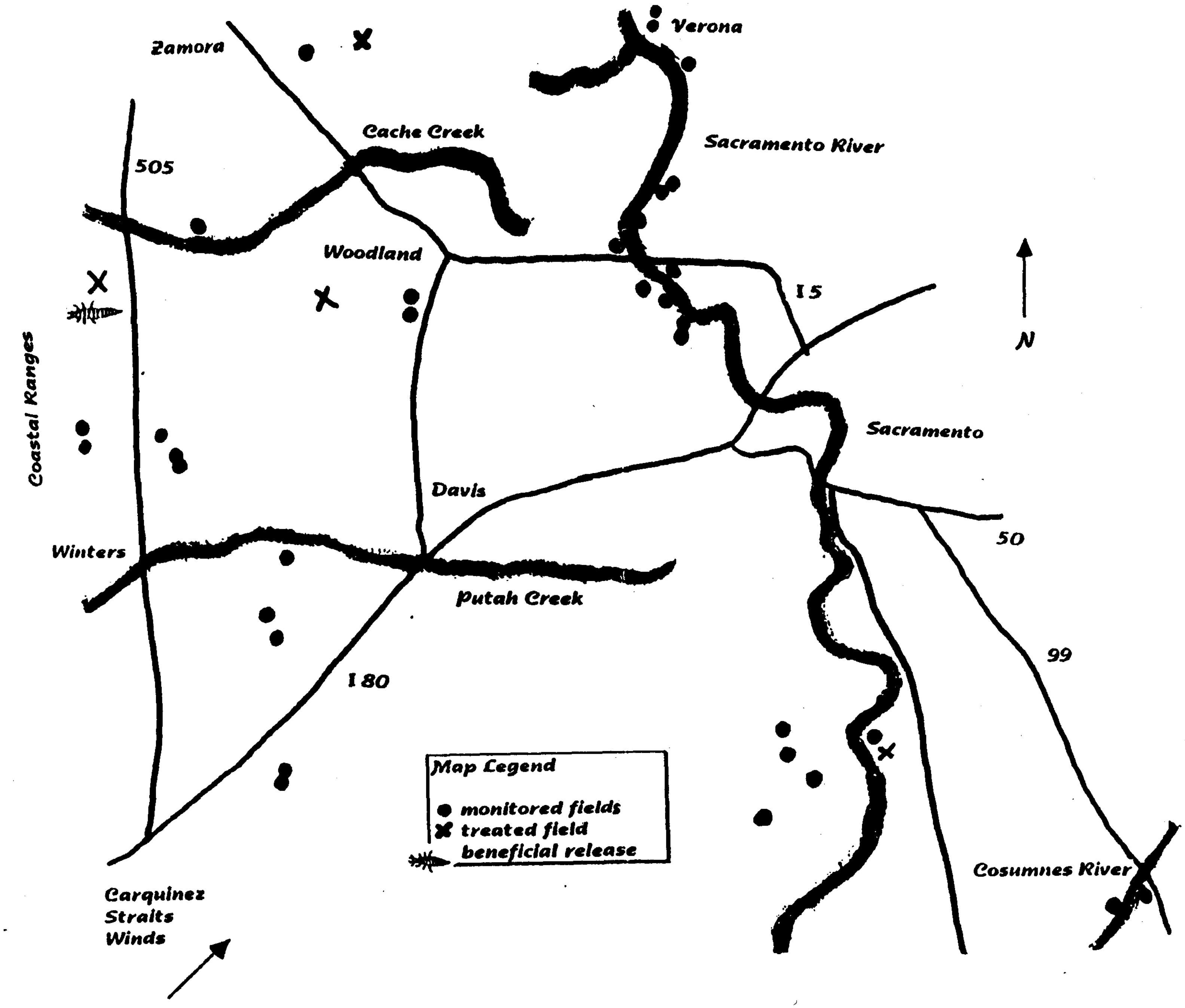
Neemix® Trilogy® Combination

This season we hope to work with advanced sprayer technology that improves coverage. Air boom sprayers and electrostatic sprayers seem to be the best candidates for this.

The Thermo-Trilogy Corp. has increased the concentration of their Neemix® product from the previous 0.5% to 4.5%, an almost 10 fold increase. This material is primarily an insect growth regulator and needs to be applied repeatedly to cover new plant and insect growth. More than 1000 acres were treated last year in fresh market areas in Southern California. These applications were made 3 or more times by ground about a week apart.

(Continued on back page)

Reference Field Monitoring Map 1998



Growers who are interested in applying this material to small acreage should contact us, as we have donated material. The plan is to combine Neemix® and Trilogy® (also from Thermo-Trilogy) which is an oil based product that helps Neemix® absorb into the leaf. It also improves its residual life on the plant.

Aphid Update

As of July 22, aphids are starting to build. Apparently this year's low temperatures kept reproductive rates of the pest at a low level. The wet spring improved wild plant growth, and natural enemies are more abundant than in '97. By July 22ed, of the 58 fields we monitor, 9 were treated with insecticides and 1 had a lacewing release. More growers seem to be using dimethoate without the addition of Asana® (esfenvalerate). This is good since it is less likely to cause new problems.

This year many fields have reduced yield prospects because of early severe late blight and bacterial speck infections. In addition, money spent on disease treatments reduced the remaining amount of money in the pesticide budget. This means that the economic threshold for late season insect treatments should be somewhat higher than usual (i.e. economically prudent to tolerate more aphids or worms).

This raises the question of how strong the yield response of the tomato plant is when under multiple stresses vs. just one. The general rule is treatments for one pest under otherwise optimal conditions result in highest yield and greatest cost effectiveness.

In a situation of multiple stresses, the cost effectiveness of controlling any single stress factor is not going to be as good, since the overall yield is lowered by other factors. Unfortunately, there are no specific sets of data on tomatoes regarding this subject. This leaves the decision-making an art (mix of experience and intuition) instead of a science.

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7/31/98

Through the Tomato-Vine

Vol. 3 No. 2

BIRC'S In-Season Newsletter for Late Season Processing Tomato Growers

Will 1998 Be A Fruitworm Year?

The 1998 season is beginning with more fruitworm egg finds than in the last 3 years we have been field sampling. Since the weather has been unusual, these finds may signal parallel changes in the insect communities. The increased planting of corn and cotton may also be a factor, since the fruitworm also attacks corn and cotton (and peppers). The same insect is called the tomato fruitworm, cotton bollworm and corn earworm.

Sampling Method Being Used

We are using the UC method to determine the number of fruitworm eggs. We begin sampling at least 25 steps into the field and in at least 25 rows from any corner. This avoids the "edge effect". Thirty leaves are selected at random within an area of the field. The leaves are selected by first looking for a leaf and flower which stands out above all the others, and then selecting the leaf below the highest open flower.

Ignore Small Damaged Green Fruit

Weekly sampling starts when there is a significant number of green fruits one inch in diameter (2.5 cm). Smaller infested green fruit will fall from the plant before harvest. The plant compensates, maintaining its fruit biomass.

Recognizing Fruitworm eggs.

When a single white egg with 12 or more distinct ridges radiating from the top is found it is recorded as a fruitworm egg. (See Figure 1, next page). Distinguished these from the flatter, more rotund, looper eggs, usually laid lower on the vine.

Black Eggs Are Parasitized.

After 24 hours fruitworm eggs develop a reddish brown ring. If the eggs are black they have a developing ***Trichogramma pretiosum*** miniwasp inside. These tiny insects mate and lay their eggs inside the eggs of fruitworms, loopers, hornworms and closely related moths. The ratio of black and white fruitworm eggs indicates if treatment is needed.

Wait Two Days For Accurate Count

Take white eggs into the lab/office in a vial and wait two days. Some field collected white eggs will turn black. These black eggs need to be added to the field data to obtain an accurate picture of parasitoid presence. Parasitoid presence will indicate if treatment is economically justified. Check the following table to see if treatment is needed.

Number of	White Eggs							
Black Eggs	4 to 8	9	10	11	12	13	14	15
1		√	√	√	√	√	√	√
2				√	√	√	√	√
3					√	√	√	√
4						√	√	√
5						√	√	√
6						√	√	√
7							√	√
8							√	√
9								√
10								√

From UC web site at http://www.ipm.ucdavis.edu.]

How To Use The Table

If no black eggs are seen, and three or more eggs are found, sample another 30 leaves, then sample again in 3-4 days. If five or more eggs are found, treat. **Preventative releases of T. pretiosum from commercial sources at 100,000 or more/acre may augment early parasitism.**

If You Treat, Use BT

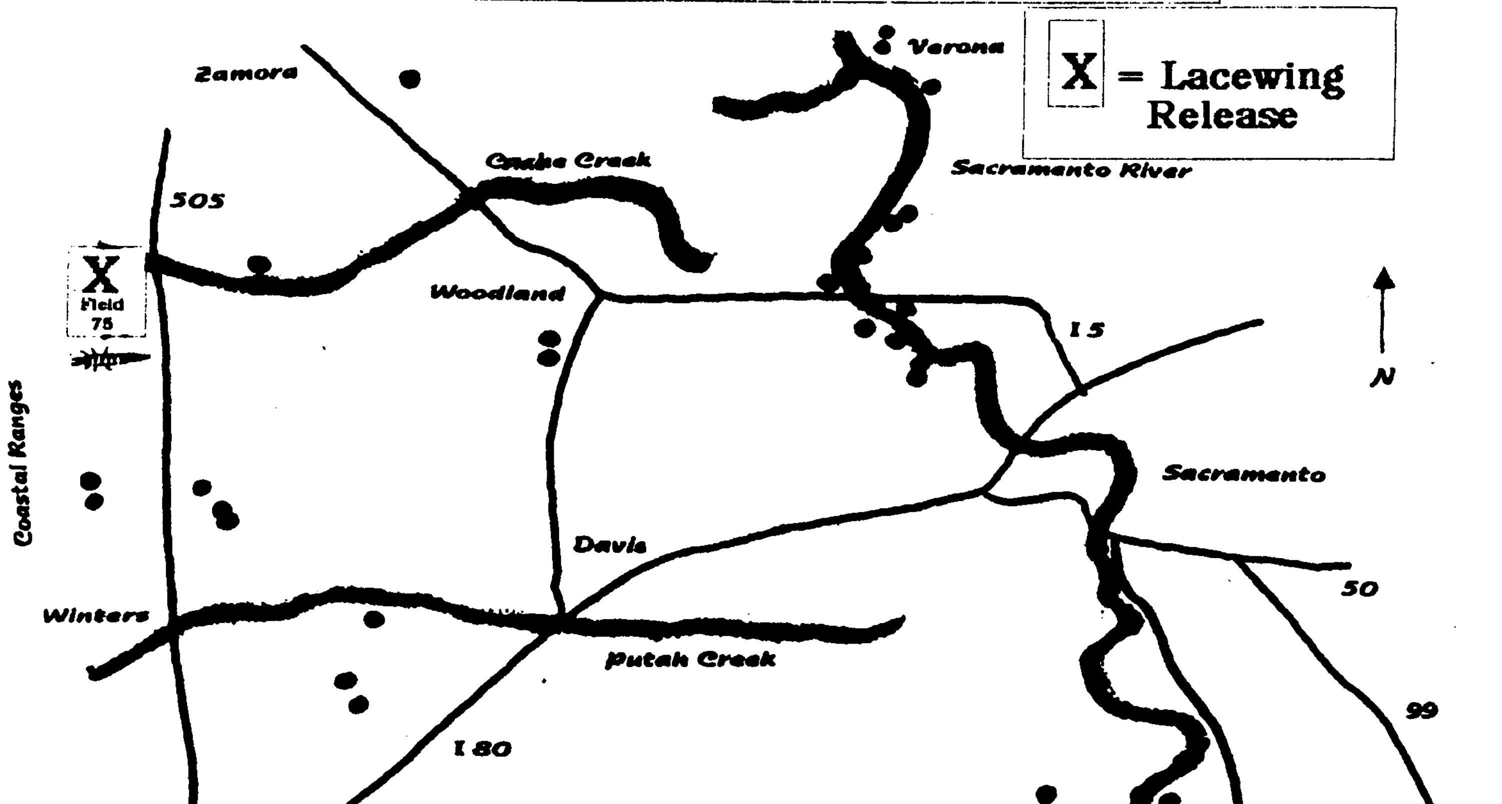
We recommend use of Bt since it is selective and will not disturb existing natural controls. It can be used right up to harvest. There is no reentry interval and it is non-toxic to people. Use of Bt will reduce likelihood that another spray will be needed for secondary pests like leaf miners. Secondary pests arise when their natural enemies are killed by a previous treatment for another pest.

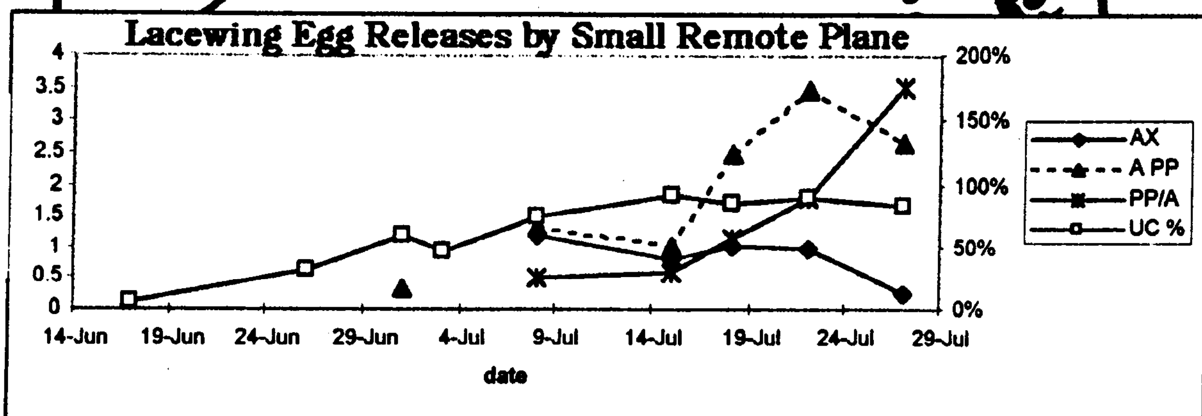
Peak Periods of Parasitoid Egg Laying

In a normal year peak egg laying by the parasitoid occurs in late August or early September. Thereafter parasitism will rise above 90% in many fields. Crops maturing before peak egg laying should be examined for egg parasitism as small larvae can enter fruit.

Continued on next page.

Reference Field Monitoring Map - 1998





Field 75 reached the UC control threshold around the 1st of July and the BIRC one around the 8th of July. The grower opted for a conventional treatment. However, with the repeated aphid treatments from the last year in mind, he also wanted to try something new and left 10 acres unsprayed.

Considering the already existing beneficial population in the field BIRC suggested to try a lacewing egg release on the untreated section. On July 15 lacewing eggs were released with a remote control airplane at a rate of approximately 2 eggs per plant.

The aphid predator and parasitoid counts increased strongly after this. Main species were the lacewing larvae, lady bird beetle and parasitic wasps (black mummies).

After the 22 of July the aphid numbers started to drop and are now well below the treatment level while the ratio of aphid numbers to aphid predators is still rising. The data shows again that the presence absence method (UC %) was not able to detect this strong decline in aphid numbers, since still most of the leaves have aphids present but at very low numbers.

As you see, the actual aphid numbers (AX) are on a significant decline while the presence absenc percentage (UC) is still remaining at a high level. At the same time the natural enemies of the aphids have also peaked out. However the ratio of natural enemies to aphids is still increasing. This indicates that the aphids are disappearing more rapidly than their natural enemies.

Corky-Surfaced Damage
Larger larvae can eat large chunks out of fruit. However, any damage that heals with a corky surface is not scored as damage.

For color pictures of these parasitized eggs see the newly revised U.C Statewide Project. 1998. Integrated Pest Management For Tomatoes (4th edition) UC ANR Publication 3270. You can also connect and download pictures and other information about tomato pests from the UC web site at http://www.ipm.ucdavis.edu.

Sample Potato Aphids At The Same Time
If one aphid is found anywhere on the leaf, that leaf is scored positive. In the past, UC recommended treatment when 50% of the leaves are scored positive. In our opinion this leads to treatment too soon with harm to natural enemies in the field. The revised edition of the tomato IPM manual suggests treatment be considered when 60% or higher are found to be positive on susceptible cultivars. This still probably does not go far enough.

Loopers are Beneficial
Loopers only feed on vegetation and do not damage fruit. They should be regarded as sources of natural enemies since many species which attack it also attack other worm pests. A single looper egg, for example, will provide food for many egg parasitoids which then can attack the more serious fruitworm. If larval looper populations get extremely high, and you fear excessive leaf loss, treat with Bt.

Solving the Potato Aphid Problem

There are 3 ways to handle the late season potato aphid problem on processing tomatoes: 1) treat without regard for natural enemies, 2) treat when natural enemies are few and will not adequately suppress the aphid population, and 3) import additional natural enemies. The first option is not economical and will lead to insecticide resistance and an ever-changing need to find new insecticides. It requires the least investment in monitoring and is most commonly used. The second option is being pursued by the staff of this project. The third will be discussed further in another issue.

In order to use option 2 and 3, one needs to be able to identify and understand the role of each of the natural enemies found in tomato fields. The following provides an introduction to the most important species or groups of natural enemies along with some generalizations about their biology and behavior. We will provide more information about natural enemies in future issues.

Predators, Parasitoids and Pathogens

Predators
It is convenient to divide the natural enemies into three groups: predators, pathogens, and parasitoids. Predators consume their prey leaving no or little residue. They usually eat more than one prey in a single meal, and are generally larger than their prey. Ladybeetles are the most important aphid predators in tomatoes.

Pathogens
Pathogens are microbes which cause disease. They can spread rapidly though a pest population. Many individual microbes are needed to kill a single prey. Gaining entrance through the skin, mouth or other openings, they take time to debilitate and finally kill their host. This spring provided many opportunities to see fungal-killed aphids. These become discolored, appearing light brown. Push the aphid with a pencil tip and you will see it is dead.

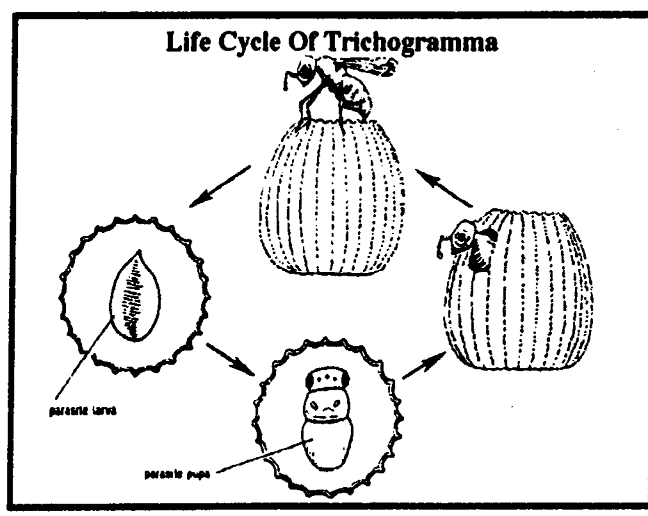


Figure 1. Line drawing from Flint, M.L. 1990. *Pests of the Garden and Small Farm*

Parasitoids
The term parasitoid refers to a large group of species which has characteristics of both predators and pathogens. They are unappreciated, poorly studied and important in biological control. Most parasitoids are related to bees, ants and wasps in the order hymenoptera. They are sometimes called "miniwasps" to distinguish them from yellowjackets and other larger fear-inducing insects, commonly referred to "wasps".

Continued on back page

Miniwasp parasitoids seldom have common names. They are usually smaller than their prey. The flying adult females lay eggs on or in the host, piercing the pest's skin with a sharp ovipositor. The worm-like larvae that hatch consume the pest. Since parasitoids kill their host rather than debilitate it over a long period, they operate like predators rather than a true parasites.

Potato Aphid Parasitoids

There are two parasitoids attacking the potato aphid, *Aphidius colmani* and *Ephedrus californica.* The former produces brown, discolored dead aphids, called mummies, encased in the old aphid skin. The latter produces black mummies. The brown mummies occur mostly in the inner canopy. The black ones may occur anywhere, but favor the outer canopy. We have made observations suggesting that fields with low aphid numbers (<50% leaf infestations), with mummies visible, may not have to be treated. Usually their aphid indexes remain below 2. However, further observations are needed.

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8/14/98

Through the Tomato-Vine

Vol. 3 No.3

Report From The Field

FRUITWORMS

No further eggs were found during the past week. Monitoring is continuing.

APHID UPDATE:

This season, 10 growers have enrolled a total of 46 fields in the cooperative program, approximately 2500 acres.

There is often more than one cultivar in a field. Each cultivar, plus the 10 acres in the lacewing-release treatment, is monitored as a separate field section. A total of 65 field sections are being monitored. These field sections include 17 different cultivars.

Treatments / Action Levels

As of August 4, twenty of these field sections, (31%), had been treated with conventional insecticides. Nineteen of those were treated too soon, i.e. before the action level was reached. (Insecticides used were dimethoate (Cygon®), Asana®, Monitor®, Ambush®, and Lannate®- singly or in combination).

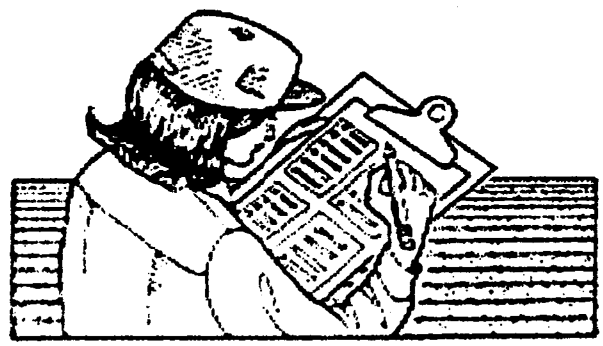
Of the fields already treated by that date, ten, or 50%, were treated before the U.C. action level was reached. (U.C. action level: 50% of 30 leaves infested with at least one aphid.)

Of the remaining 10 field sections treated, 9 were treated before they reached the BIRC action level. One field section had reached the BIRC action level. (BIRC action level: 1 aphid per leaflet, 150 leaflet sample).

Forty five field sections continue to be monitored, including the one that was successfully treated with a lacewing release delivered by a small-scale, remote controlled airplane. For more information on the field treated with lacewings, see Page 3.

Why Not Treat Early?

Treating too soon with conventional insecticides can waste money, increase the speed at which pests develop resistance to insecticides. Premature treatments also may cause further problems in this or future seasons by killing natural enemies of the pest, potential other pests in the same crop, or in other crops. ***However, selective insecticides or lacewing releases are helpful if used early.***



Monitoring pays

Can You Save Money By Hiring An Independent Pest Control Advisor?

Treatment recommendations are usually provided to the grower at no direct cost by pesticide and fertilizer distributors. ***Why would you want to pay an independent PCA in addition?***

Upon request, a hired PCA can give you detailed monitoring, counting natural enemies along with pests. This can actually save you money. Detailed monitoring will eliminate unnecessary (premature) treatments by alerting you to situations where natural enemies are catching up to the pests.

Won't cost of detailed monitoring equal the amount you save? No, our studies show this kind of monitoring is cost effective.

For three years, we have been monitoring approximately 3000 acres each year of late-season processing tomatoes in Yolo, Solano, and Sacramento Counties. Even in 1997, which was the worst aphid season since 1995, when we started monitoring, it was economically justified to monitor using BIRC's methods.

Continued on next page.

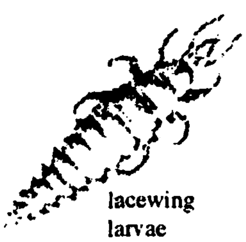
BIRC's Field Sampling Method

The BIRC system of monitoring natural enemies as well as the target pest is called Bio-Intensive. This method combines the UC system and additional counts, enabling estimates of aphid densities and extent of total vegetation infested. We use an aphid index (AX) to summarize our findings. At the level of 1, roughly one aphid per leaflet, we recommend considering treatment.

We also use "shake" samples based on research of UCD entomologist Frank Zalom and associates. Developed primarily for sampling stink bugs, we also use it for worms and natural enemies. Thus, we count leaves infested, aphid numbers, and natural enemy numbers, and get data useful for deciding on treatments for aphids, stinkbugs and worms.

This is a list of the natural enemies observed and recorded with this type of monitoring:

Leaf Counts include:	**Shake samples include**
aphids	stinkbugs
aphid mummies	worms
aphid gall midges	aphid mummies
	ladybeetle adults, larvae
	lacewing larvae
	syrphid larvae
	aphid midge larvae
	minute pirate bugs
	big-eyed bugs
	damsel bugs
	spiders



lacewing larvae

U.C. Recommended Monitoring System

UC is recommending use of a sampling system initially designed to detect fruitworm eggs and adapted for aphid sampling. This system only counts the leaves infested. If one aphid is found on the 7-11 or so leaflets on a sampled leaf it is scored as an infested leaf. When 15 out of 30 leaves are infested the recommendation is to treat. These trials were done with the highly aphid-susceptible variety Alta, not representative of other varieties. This treatment level is usually too low unless the field has a poor natural enemy level, then it is useful as an early inexpensive indicator. This method does not sample natural enemies.

What Are the Justifications and Disadvantages of the U. C. Monitoring System?

Such presence-absence sampling is justified by saving monitoring time, hence minimizes costs of collecting the information needed to make a decision. The goal is a good decision which minimizes costs of collecting the information. But the critical information missing from the UC method is estimates of natural enemy numbers. Lack of this information can lead to premature treatments.

Cost/Benefit Analysis for Bio-Intensive Monitoring

Our calculations include only the late season pests and the fact that pest infestations vary from field to field with a range of severity. Therefore, when you hire a PCA to monitor your fields he or she will not need to visit every field every week all season.

Situation I: standard procedure, grower does not pay for monitoring
Situation II: bio- intensive monitoring, i.e. monitoring costs in addition to treatment costs

Example: Grower has 500 acres of late season tomatoes in ten 50-acre fields.
Dimethoate -$12.25 (includes air application)
Pyrethroid$ - $19.25 (includes air application)
Extra cost for intensive monitoring per field - $15.00 (50 acre field)

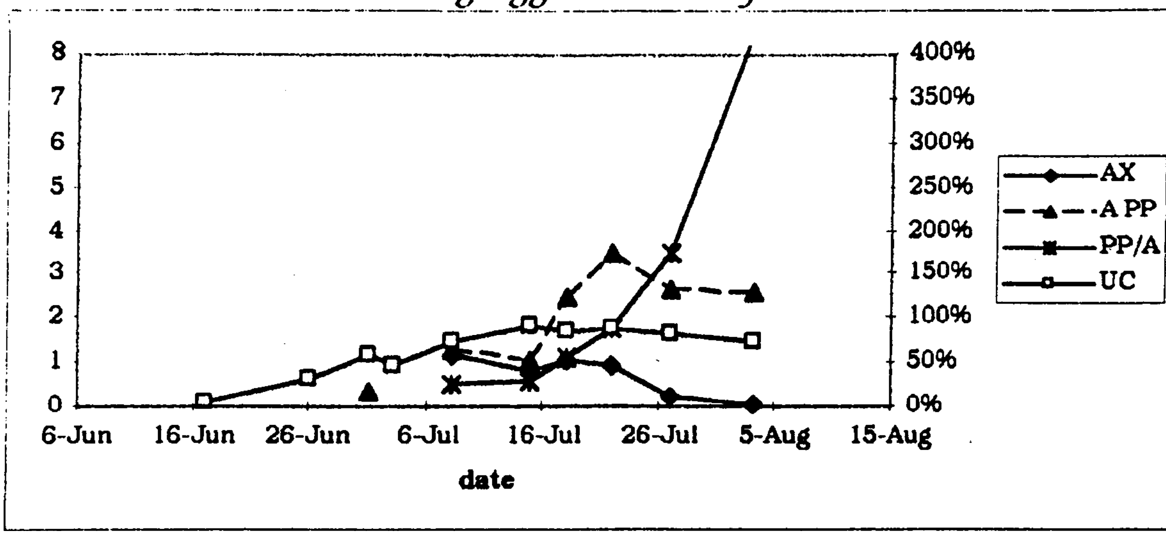
<u>CASE I - Pest Condition : Heavy Aphid Pressure</u>
Situation I - 65% of planted acreage treated with dimethoate - $3,981; 65% of planted acreage treated with pyrethroid - $6,256. TOTAL COST: $10,237.
Situation II- 35% of planted acreage treated with dimethoate - $2,205; 30% of planted acreage treated with pyrethroid - $2,288; 70% monitored 7 times - $735; 30% monitored 10 times - $450. TOTAL COST: $ 5678
Intensive monitoring saves $4559.

<u>CASE 2 - Pest Condition: Low Aphid Pressure</u>
Situation I - 50% of planted acreage treated with dimethoate - TOTAL COST: $3,063.
Situation II - 30% of planted acreage treated with dimethoate - $1,838. 70% monitored 10 times - $1,050. 30% monitored 7 times - $315 Monitoring costs - $1,365. TOTAL COST: $3,203.
Under low aphid pressure, intensive monitoring costs $140. more.

Conclusion, if the average year is somewhere between a high and low aphid pressure year, then the grower who does intensive monitoring saves money. Also, intensive monitoring reveals stinkbug and worm problems. Further, reduced use of insecticides reduces development of insecticide resistance, and reduced use of broad spectrum insecticides prevents secondary pest outbreaks.

Grower and PCA feedback on this analysis is welcome.

Lacewing Egg Releases by Small Remote Plane



APP - number of predators per shake.

PP/A - predator power divided by aphid numbers.

Field 75 reached the U.C. threshold around the 1st of July, and the BIRC level around the 8th of July. The grower opted for a conventional treatment. However, with the repeated aphid treatments from the last year in mind, he also wanted to try something new and left 10 acres unsprayed.

Considering the already existing beneficial population in the field, BIRC suggested trying a lacewing egg release on the untreated section. On July 15 lacewing eggs were released with a remote control airplane at a rate of approximately 2 eggs per plant.

The aphid predator and parasitoid counts increased strongly after this. The main natural enemy species were lacewing larvae, ladybird beetles and parasitic wasps (black mummies).

After July 22 the aphid numbers started to drop and are now (Aug 13) well below the treatment level. The ratio of predators to aphids is still rising.

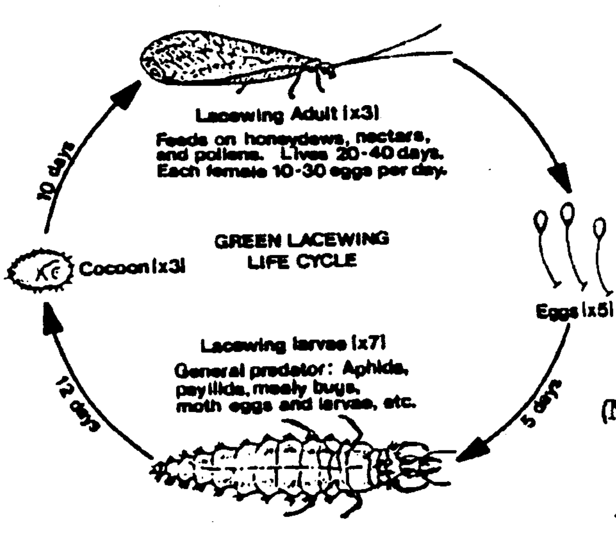
The data shows again that the U.C. presence absence method was not able to detect this strong decline in aphid numbers.

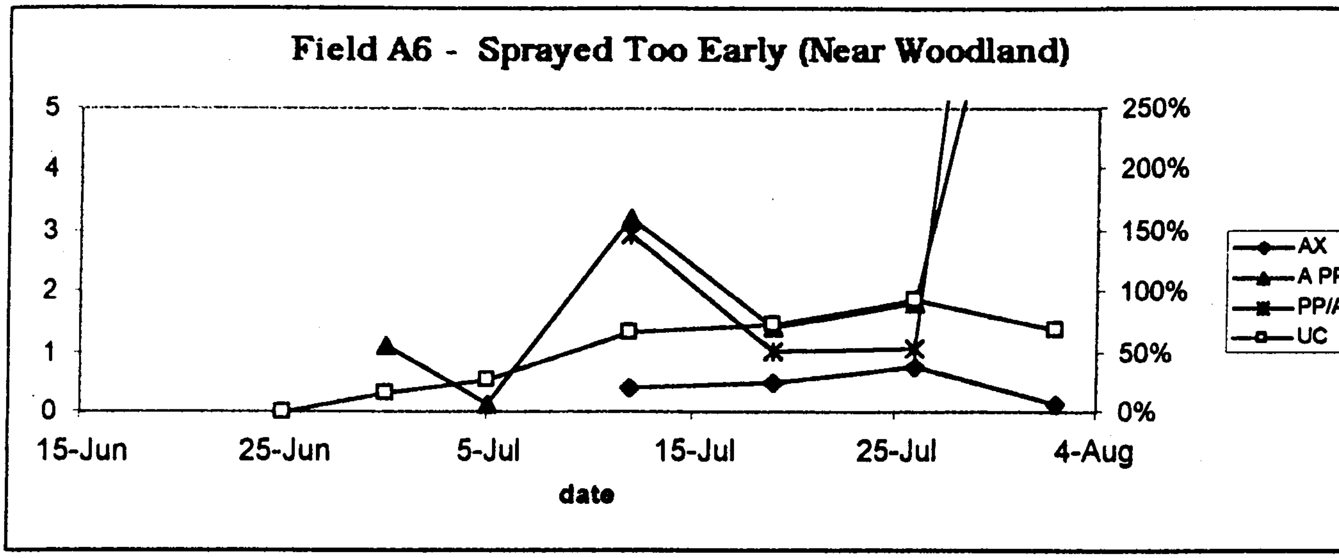
As Much As You Ever Wanted To Know About Lacewings - And More!

Common NAme	Scientific NAme	# Eggs/ Female	Specifics	Egg (d)	Larvae or Nymphs (d)	Pupae (d)	Adult (d)	Notes
Green Lacewing (GL)	*Chrysoperla carnea*	200-1000 (5), lay eggs on silken stalks	Development Time	3-6 (10)	2-3 weeks (10), 12 days (5), young larvae susceptible to desiccation (10)	10 (5), 10-14 (10)	20-40 days	tolerant to Cygon etc. (2)
		lifecycle under 4 weeks when warm, 2 to 3 generations per year (3)	Diet	NA	aphids, mites, thrips, whitflies, moth eggs & larvae, leafminers eggs (10)	NA	honeydew, nectar, pollen	Do not apply pesticides within 3-4 weeks (4)
			Aphid Consumption	NA	60/ hour (4), 100-600 (10)	NA	none	copper fungicides might be toxic
			Mobility/ Searching	NA	good searching very mobile	NA	long dispersal flights, regardless of food supply	
			NAtural Occurrence	stalked on leaves		in soil (3)	flowering plants, night active	
			BIRC Monit.	leafs	shakes	NA	(shakes)	
			Release Rate (per acre)	5-50K	250 - 500 2 or 3 times (4)	NA	NA	
			Lag Time	3	0	NA	6	
			Application Technique	spreader, spray rig (9), cards	by hand	NA	NA	
			Price	50K@$125a or $90 h	500@$30 a			

In this chart
A = acres
D = days

(Numbers in parentheses are references - available upon request.)





Field A6. While last year growers had a tendency to spray somewhat late, this year growers sprayed early, at an aphid pressure substantially lower than in 1997. The aphid population in this field climbed above the UC control threshold at 50% aphid positive leaves. Meanwhile, the BIRC counts (AX) did not reach the action threshold of AX = 1. The field had also a very active community of aphid eaters, especially ladybeetles, and parasitoid mummies. The grower watched this for a while, but then lost his patience. Even though the aphid population showed the first signs of a decline, the grower decided to spray anyway, on August 4.

In case of doubt about a treatment, it is a good idea to leave a portion of the field untreated, continue to monitor and compare the yield in the end. The BIRC team will be happy to assist with this task.

In the chart above, APP = number of predators per shake and relative number of aphids eaten. PP/A is predator power divided by aphid numbers.

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A non-profit membership institution providing education and research on integrated pest management.

Members receive *The IPM Practitioner* and *Common Sense Pest Control Quarterly*

8/24/98

Through the Tomato-Vine

Vol. 3 No.4

Report From The Field

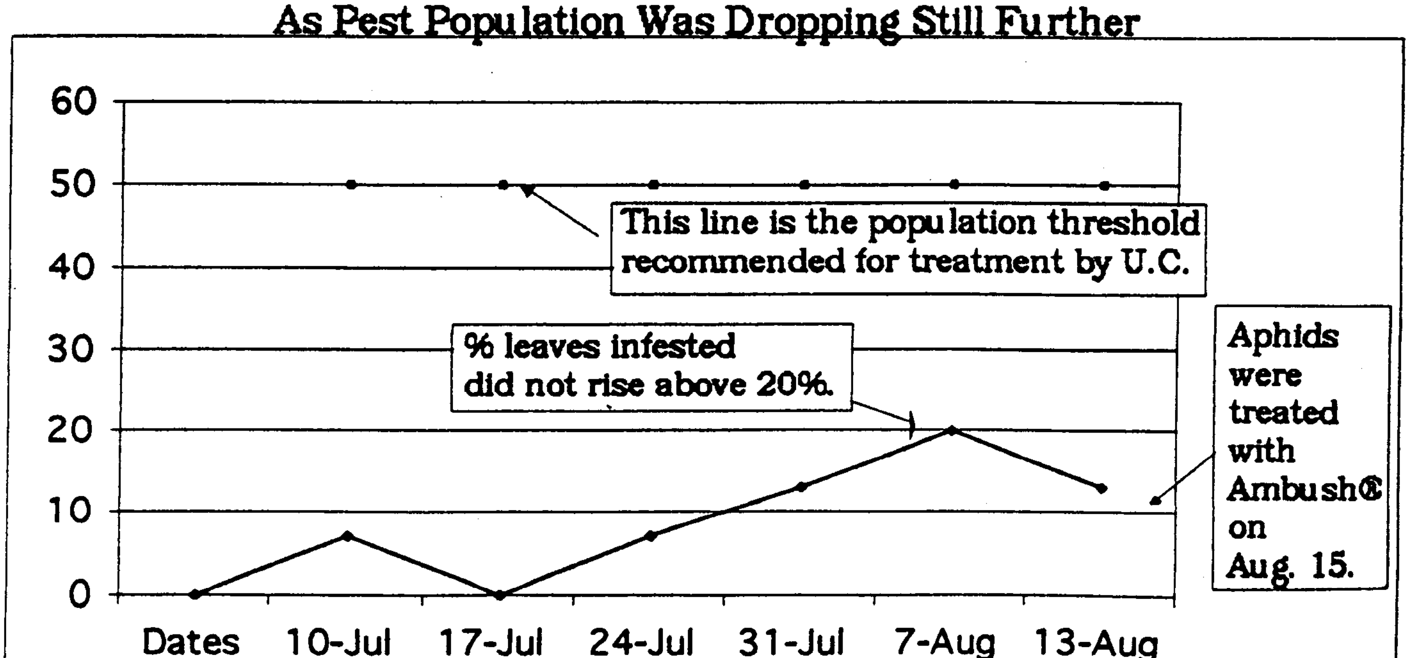
Percent Field Sections Treated To Date
Overall by Aug. 21, thirty field sections have been treated out of 52 being monitored (30/52 = 58%). This compares with 31% treated up to Aug. 4. Of the thirty treated field sections, 16 correspond to the U.C. or BIRC thresholds (16/30 = 53%).

Fruitworm Problems Did Not Materialize
Initially we found fruitworm eggs in our 30-leaf samples. Fortunately, problems did not develop. These first eggs were probably laid by adults maturing from overwintering larvae. Since eggs were present, but no outbreak of caterpillars has so far materialized, we assume this species is under biological control. Fruitworm is not the problem it was years ago. Now armyworms need watching.

Some Growers Treat Too Early
Since the last newsletter 8/14 (Vol. 3, No.3) growers have demonstrated a little more confidence in monitoring rather than rushing to preventative treatments. Nevertheless, in the interval since that report, there have been examples of extremely early treatments, and also treatments for worms not matched by actual quantitative sampling results.

For example, Grower 10 (field 100, variety 3155, north of Sacramento) treated when the measured UC sample indicated almost no aphids present (13% aphid infested leaves out of 30 leaves sampled). See Chart A, below. There are other examples of fields being sprayed although virtually no aphids or worms were present in quantified samples.

Chart A - Treatment of Aphid Population Much Below U.C. Action Threshold, As Pest Population Was Dropping Still Further



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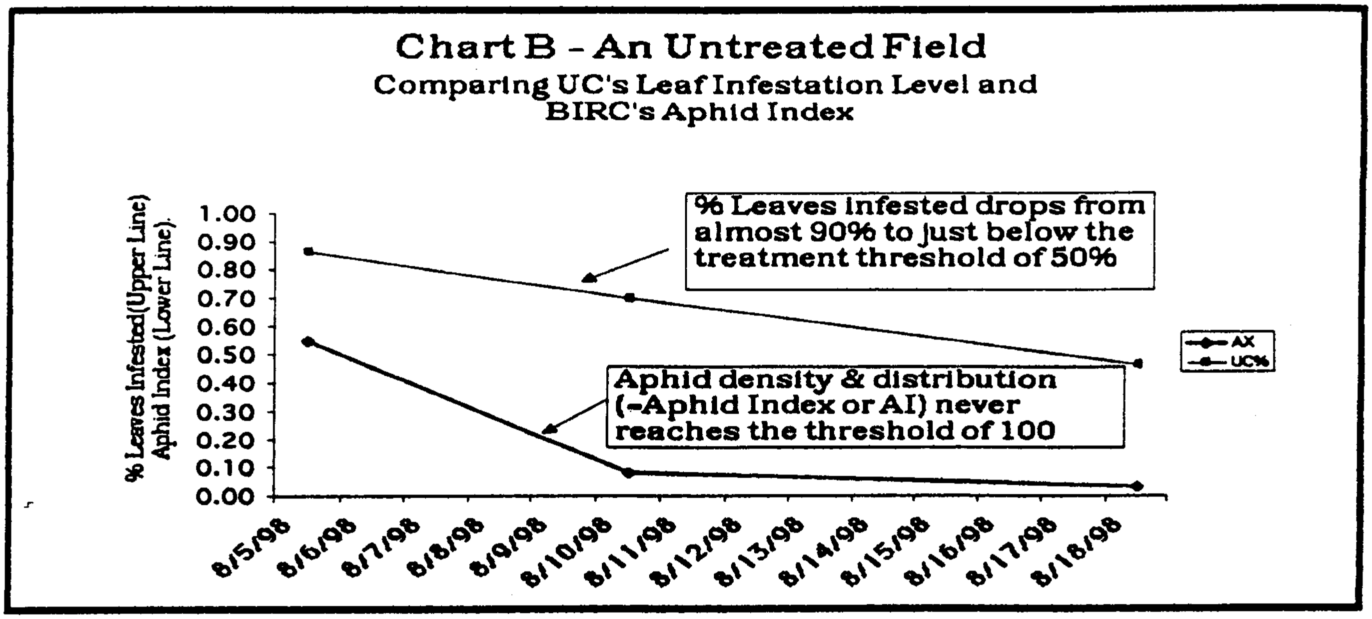
Fortunately, there also were appropriate responses to monitoring data, see Chart B (Grower 5, field 14B, variety 3155, north of Woodland). Among our cooperating growers there is a wide range of responses to insect pest threats. Decision to use pesticides varies by farm. In about half the cases, treatment is not related to action thresholds.



Preventative Treatments Are Costly
It is understandable that preventative treatments occur considering all the factors a grower must think about in producing a crop. Pest control is only one among many considerations. A single treatment of one material by air is comparatively inexpensive. However, costs increase when one early, unnecessary, treatment leads to additional treatments because of natural enemy kill. Serious problems occur when materials are lost due to resistance development.

Are You Using IPM ?
Application of IPM thinking and methods occurs when growers aim to save money by using quantified samples and thresholds for treatment actions. We presented evidence in the last issue showing that savings can accrue if treatment thresholds are used. The final question is: **Will growers use IPM methods to put money in their pockets or invest it in "insurance" treatments of dubious value?**

Worm Control with Bt's

Bt products are now the state-of-the-art alternative to organophosphate- and pyrethroid-based materials for worm control.

The benefits of Bt use are:

- Effective control of worm (caterpillar) pests at costs comparable to conventional insecticides.
- Preservation of natural enemy populations to assist in pest control and suppress secondary pest flare ups.
- Improved management of pest resistance to insecticides. Using insecticides with different modes of action slows resistance development.
- Safety. Bt has low mammalian toxicity, a short re-entry and pre-harvest interval, and therefore, low liability for the user.

San Joaquin Valley Growers Ahead
So far growers in the Sacramento Valley have been slow to use Bt's. According to DPR's Pesticide Use Reports, as well as Bt sales representatives, growers in the San Joaquin Valley are using substantially more Bt for worm control.

Big Changes In Bt Formulations
Five years ago Bt's were not very reliable. However, intensive work on making the product competitive has now paid off. The Bt products now available are not limited to one toxin but can contain up to three bio-engineered toxins. New formulations have improved coverage and persistence in the field. Some products use an encapsulation system that lengthens effective residual life 7-10 days.

Currently the wide variety of Bt products on the market can cover nearly any situation. If worms are still in early instars (small larvae), the inexpensive products will be effective. The more sophisticated formulations, costing slightly more, also kill later instars and problem worms such as armyworms. This wider spectrum of activity, and increased potency is due to the use of multiple toxins in a single product.

The Worms Stop Eating

Bt toxins do not kill immediately. Although still present and appearing unharmed, the caterpillar larvae stop eating shortly after they eat the Bt residue on the leaf. Over the next one to five days, the larva's digestive system is disrupted, resulting in starvation and death.

During monitoring after Bt spray, BIRC field staff has been collecting live caterpillars and putting them into containers with leaves. So far they have all died. This is a test you can do yourself if you want to check on Bt spray efficacy.

Coöperating Growers Satisfied With Bt Results

So far, our cooperating growers are all fully satisfied with results of their Bt treatments targeted at armyworms, fruitworms and cutworms.

Predator Power Field Studies

Natural enemies of the potato aphid in tomatoes are important in aphid control. However, a literature search did not uncover data describing quantitative prey/ predator relationships on this crop. To increase effectiveness and reliability of our beneficial counts and beneficial releases, we started field studies to determine how many potato aphids different predators eat on processing tomatoes. We are looking at naturally occurring, as well as released, natural enemies.

Enclosures Confine Aphids and Predators

We are using "sleeve cages" enclosing vine stems. One stem per plant is enclosed. Each sleeve cage enclosure is white gauze, 22 x 8 x14 inches. In each sleeve cage are a known numbers of aphids. Predators are released randomly in half of the enclosures.

How Fast Does The Population Grow?

What is the effectiveness of the different predator species at decreasing potato aphid numbers? We are measuring the growth rate of aphids with and without natural enemies under actual field conditions in the Sacramento Valley.

Preview of early findings.

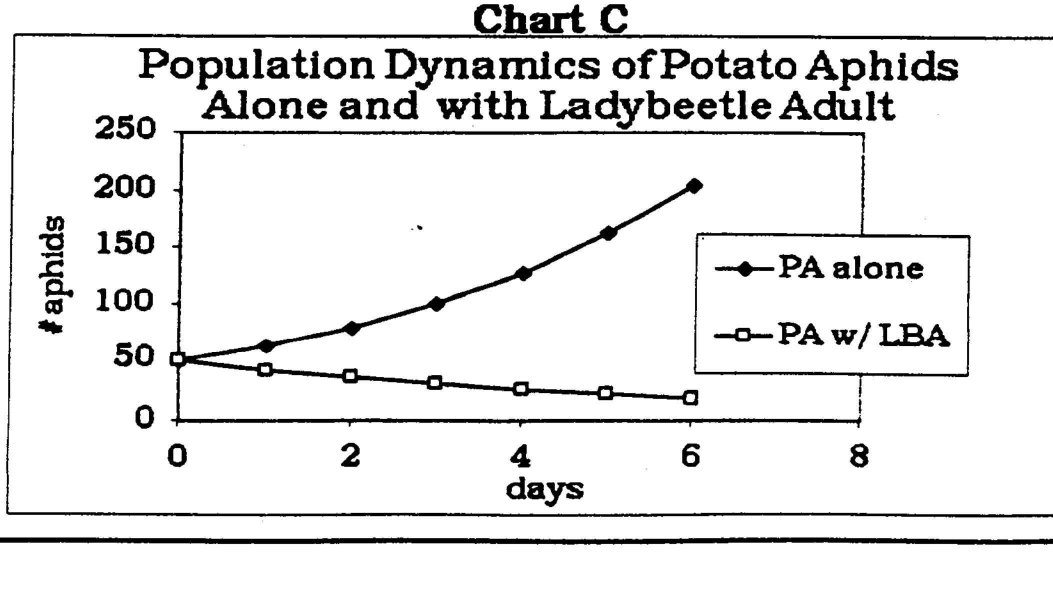
One trial involved lady beetle adults (LBA). In the morning, the aphids on ten stem were counted and adjusted to 50 to 70 aphids each. Five predator specimens were collected from the field, and one each was placed in randomly selected enclosures. Twenty four hours later the trial was terminated as the field was treated. The sleeves were removed and aphids counted.

The average population growth rate of the aphids without predators was 1.24 aphids (124%). With a predator present the growth dropped to 0.84 aphids (84%) in the same number of hours. On average, the LBA consumed 26 aphids on that day. This is a relatively low number for predator effectiveness. The temperatures were high (100° F.). LBA reduce their feeding activity at high temperatures while aphids increase their reproductive rate.

Release Natural Enemies Early

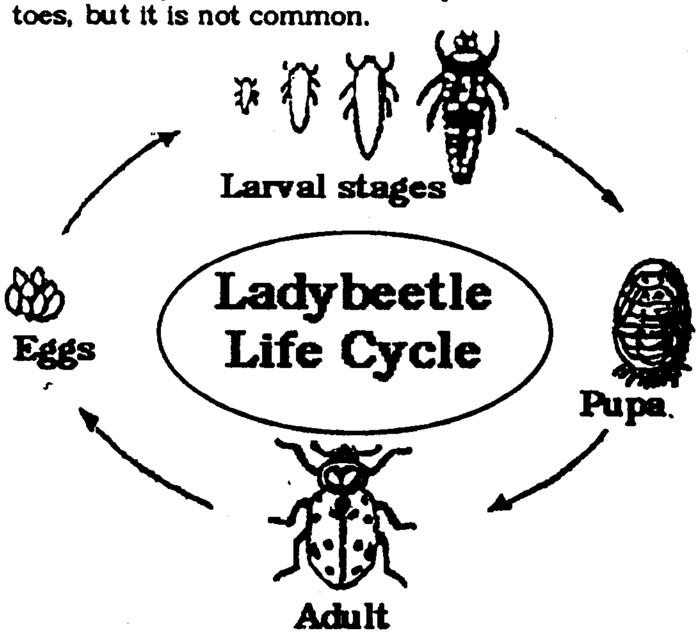
Chart C shows the consequences at six days using the above growth rates. The aphid population without a predator quadrupled in this time. With the predator, the aphid population was cut substantially. But once the aphid population is large, it takes too long for predators to reduce it to tolerable numbers. Natural enemies must be released early in the season, while aphid populations are low, to be satisfactory.

Chart C



Ladybeetles

There are about 400 ladybeetle species in North America. The species vary in their preferred prey. The convergent ladybeetle, *Hippodamia convergens*, is the most common in tomato fields. Both adults and larvae are highly visible when they occur. We occasionally have seen another species in the tomatoes, but it is not common.



The convergent ladybeetle is the popular ladybeetle of commerce. The species name "convergens" refers to the two lines converging on the second body segment, the thorax, just behind the adult head.

Don't Count On The Dots

The well-recognized dots on the wing covers may vary in numbers or may be missing. The eggs are orange and laid in a group, standing up on leaf surface. The larvae are black with orange spots and also feed on aphids. Adults need water, and feed on pollens, some fungi and honeydew as well as aphids and possibly other small insect species and occasionally eggs.

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PM 25 AUG 1998

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A non-profit membership institution providing education and research on integrated pest management.

Members receive *The IPM Practitioner* and *Common Sense Pest Control Quarterly*

9/18/98

Through the Tomato-Vine

Vol. 3 No. 5

Report From The Field

Table 1. shows once again that wasteful pesticide applications can be avoided by the monitoring method we are recommending.

Use the faster U.C.'presence/absence' sampling only up to the 50% infestation level. Then switch to using the aphid index (AX). The aphid index takes natural enemy presence into consideration. This can make all the difference in accurate prediction of treatment threshold.

Grower M. (North of Woodland.)

The field shown in Table 1 is an example of an aphid infestation that was distributed evenly throughout the entire field. The presence/ absence sampling method (UC) shows that after July 20 (during fruit bulking) most of the leaves had at least one aphid. However, aphid counts (AX- aphid index) show the actual aphid numbers stayed fairly low. This is why we suggest to growers and PCA's to use the presence/ absence method only up to the 50% infestation level. Thereafter, it is important to know whether further increases in aphid numbers occur in order to determine if treatment is desired.

Spraying can be delayed until an AX of 1 is reached. This gives the beneficial insects a chance to develop and also provide more time for the plant to grow out of its aphid-supporting stage. The latter was the case in this field. The field had beneficial insects but at relatively low numbers. The collapse of the aphid population occurred when 50% of the tomatoes had turned red.

Our working hypothesis is that the aphid resistance of tomatoes increases with crop development stage after the susceptible fruit bulking stage. The more mature the plant gets the less they match the food requirements of the aphids. The strength of this resistance and the stage when it develops varies by tomato variety. Nitrogen fertilization levels most likely also increases aphid growth but field evidence for this association is only theoretical at present.

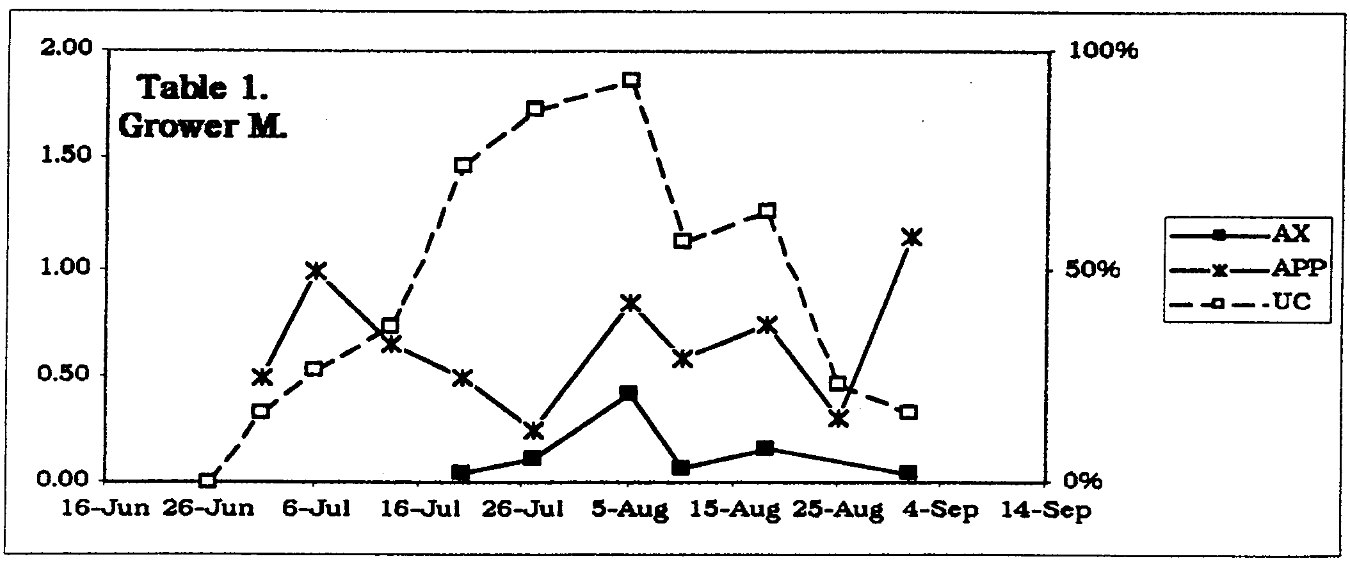


Table 1. Grower M.

AX - aphid index: aphid counts from 150 randomly selected leaflets from 30 randomly selected plants (plotted from the left axis).

APP - number of aphid predators shaken from 10 randomly selected plants (left axis).

UC - number of positive infested leaflets out of thirty randomly selected leaves on 30 randomly selected plants (plotted on right axis).

Parasitoids Of The Potato Aphid

Parasitoids are parasite-like natural enemies. They differ from true parasites in that they kill their host. Adult aphid parasitoids are minute flying insects related to bees. Like bees they are easily damaged by conventional pesticides.

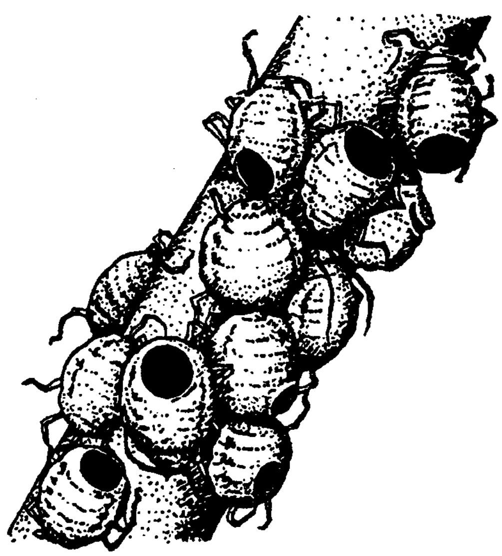
Parasitoid Eggs Are Laid Within The Aphid.

After mating, the adult female parasitoid searches for aphids among the foliage. She lays a single egg within each aphid she finds. One adult parasitoid can lay many eggs. The egg hatches and the larval parasitoids eat the aphid from the inside. As it dies the aphid mummifies - becomes a stiff shell, usually changing color. The colors vary according to the species of parasitoid that has killed the aphid.

Learn To Spot The Emergence Hole

When fully developed, the larvae makes it's cocoon within or just beneath the aphid. Within the cocoon it metamorphoses into the adult mini-wasp. When the change is complete, it eats a hole in the aphid mummy and flies away to find a mate and lay eggs in more aphids. Figure 1 shows a colony of aphids that has been mummified by larval wasp parasitoids. The holes tell you that the wasps have already left to find more aphids. These holes are usually visible without a magnifying glass.

Fig. 1 Aphid mummies showing emergence holes



The Advantage Of Host-Specificity

The most valuable parasitoids are host-specific. That means they can continue to exist only if they find the species necessary for their survival. Thus they continue to search for and parasitize their specific aphids even when there are very few left alive. Parasitoids that are not so host-specific are apt to move on to another aphid species when one species becomes less plentiful. They do not have the same impact that the host-specific parasitoid do. The parasitoids we have on the Potato Aphid falls in this latter category. In this sense they function more like the adult ladybeetle which can also eat more than one species of prey and may fly off if the aphids become scarce.

Two Potato Aphid Parasitoids

There are two parasitoids attacking the potato aphid in Northern California, but they are not effective throughout the area. The parasitoid that produces a black mummy, *Ephedrus californicus*, is probably native to California. The other parasitoid, *Aphidius colmani?*, makes a brown mummy. It has only moved over to the potato aphid in recent years and its identification needs to be confirmed.

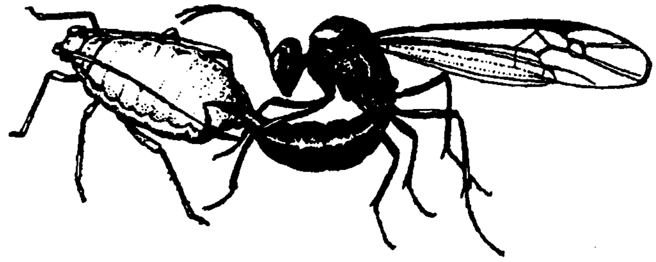
Biological Control Efforts

Our observations in the Sacramento Valley tomato fields indicate that the predatory insects are more effective than the parasitoids currently found here. Never-the-less, the parasitoids do contribute some additional pest suppression. The best strategy for enhancing biological control in the Valley tomato fields is to use chemical controls only when and where pest population size and natural enemy counts indicate that they are necessary. Then, to choose materials and timing that will be least-damaging to the natural enemies. In addition, early augmentative releases of lacewings appear to be effective. Planting field borders with flowering plants that provide nectar and pollen for the beneficials is also desirable.

The Alfalfa Connection

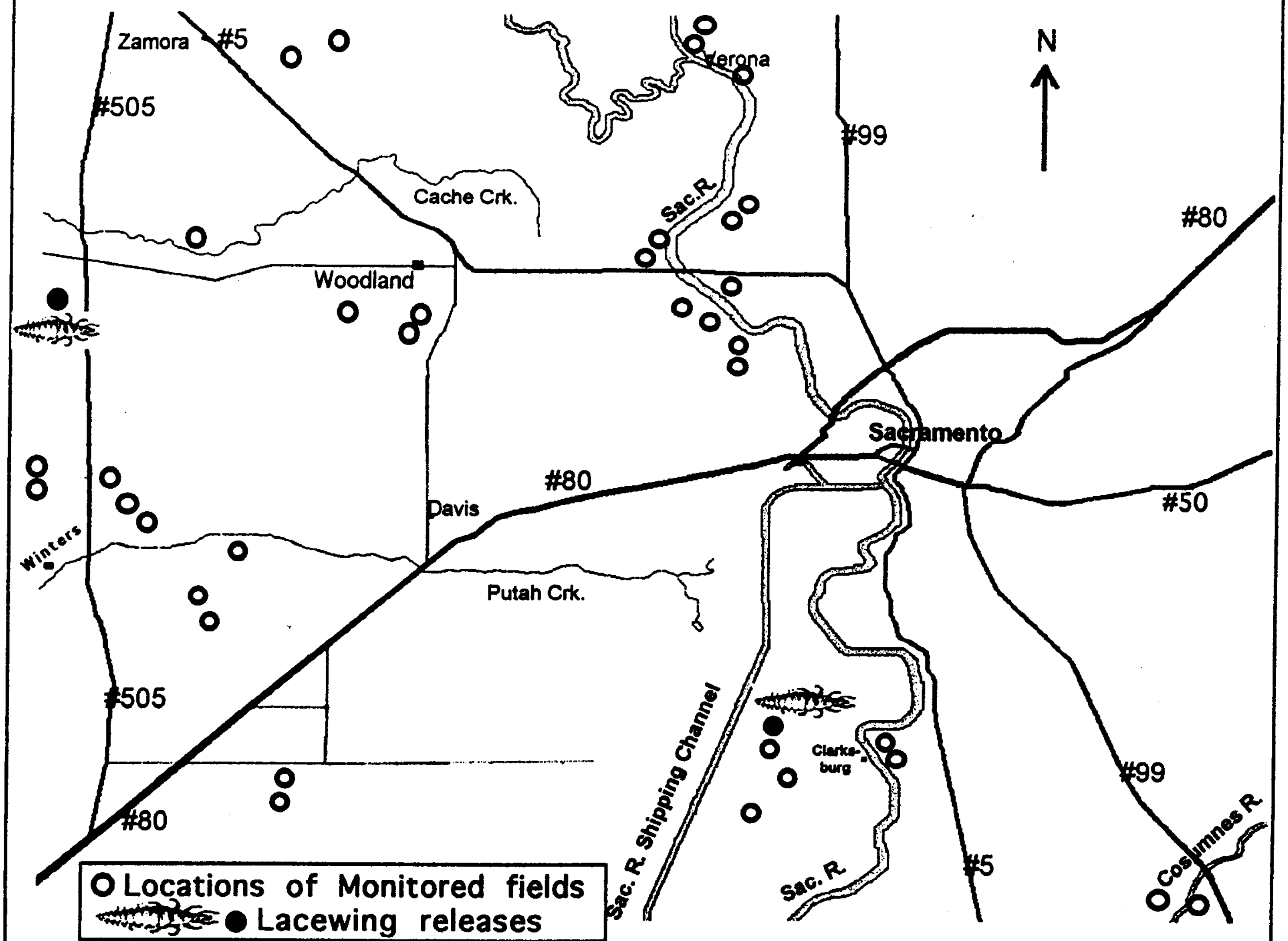
As the parasitoid, *E. californicus* is known to attack the pea aphid in alfalfa fields, insecticide use in alfalfa can affect the presence of this natural enemy in tomatoes. Ideally pest control would be carried out from the perspective of all the crops being grown in a region, rather than piecemeal as it is now. At the least a whole-farm approach would be desirable. But at present, even this is usually found only on organic enterprises.

Fig 2. A parasitoid placing its egg within an aphid.



REFERENCE FIELD MONITORING MAP, 1998

10 growers have enrolled a total of 46 fields in the cooperative program, approximately 2500 acres.



Time To Plan Cover Crops

Cover crops are an investment for the future. Your single most important capital is your soil. Soil health is the key to crop performance. Pampering the soil once in a while pays off in the form of tangibles such as reduced need for nitrogen fertilizer. It also pays off in improved soil structure (breaking up of compaction from heavy farm machinery, etc.), better water infiltration and reduction of top soil erosion.

The Soil As A Sponge

A healthy well structured, non compacted soil acts like a sponge. Instead of having standing water on top of your field after a winter rain, it infiltrates into the soil. Some water is held in the pore space between soil particles. Some water is drained through holes made by earthworms and other soil organisms. The result is deep drainage for the overflow, which than recharges the aquifer. The end result is that you can get on your ground earlier in the spring. You also can keep more water in the valley instead of sending it along with your valuable top soil on the fastest way to the ocean through ditches and rivers.

Early Fall-Planted Cover Crops

Late summer-early fall-planted cover crops add organic matter to your field. The necessary irrigation provides water at a time where other fields are dry. UC research in the Sustainable Agriculture Farming Systems (SAFS) project has shown that this specific difference supplies you with extra nutrients in the spring.

Continued on next page.

Cover Crops - Contionued from previous page.

Here Is How They Work

Water, organic matter and warm temperatures boost the soil microbial life in late summer and early fall. The soil microbes use residual nitrogen from the preceding crop as fuel for processing organic matter and to multiply. This has the extra benefit of preserving nitrogen through the winter from leaching and denitrification. In the spring, microbe-eating nematodes feed on this rich microbial food supply and provide your plants with digested nutrients.

The SAFS Mix

At the SAFS project the following summer cover crop mix is planted:

15 lb. Sorghum Sudan grass

30 lb. Cowpeas

30 lb. Lablab

Lablab is expensive and difficult to get and can be replaced by 10 - 15 lb. of vetch.

Flail Mow And Incorporate In Spring.

This mix is designed for soils poor in organic matter. The grass thrives on residual nitrogen and provides a lot of roughage while the legumes fix nitrogen from the air. In most cases this mix grows so well that is will smother any germinating weeds. However, if weeds are threatening to set seeds, mow before they do so. Otherwise, the biomass can be flail mowed in spring and incorporated with a disk or plow. You should plan at least two weeks between incorporation and planting/ seeding of the following crop.

Avoid Herbicides

We strongly advise against using herbicides to kill the cover crop. It is an unnecessary expenditure Flail chopping and disking will take care of whatever growth there is. In addition, herbicides can have adverse effects on the microbial life in the soil and threaten the whole investment.

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1/5/99

Through the Tomato-Vine

Vol. 3 No. 6

Report From The Field

1998 Summary Late Season Pests

The early season was exceptionally cool and wet with serious late blight problems. By late season the weather pattern normalized somewhat. The principle late season pest problem is the potato aphid, but stink bugs and worms can also trigger treatments.

Over the last two seasons we closely monitored late years fields (harvested after September 1) of about 10 cooperators totaling 3,000 acres. Most fields harvested before this date should not have to be treated for aphids, worms or stinkbugs. The most significant change observed from 1997 to 1998 is the switch from late treatments in '97 to early treatments in '98 (Table 1).

Table 1: First Late Season Insecticide Applications* in Relation to Action Thresholds, 1997 vs. 98. (% of fields).**

Treatment	1997	1998
not treated	12%	12%
Below UC threshold	4	36
At UC threshold	14	15
At BIRC Threshold (Total)	34	21
High toxicty	12	13
Low toxicity	10	5
Lacewing release	6	3
Above BIRC threshold	41	16

* Potato aphids, worms, stinkbugs
** UC's level: 50% leaves infested with one aphid BIRC's level: one aphid per leaflet

Whereas in 1997 41% of the fields were treated at a pest infestation level well above any action threshold, in 1998, 36% of the fields were treated well before any threshold was reached. Note that for the non-treated fields the data remained the same in the two seasons - 12%- as did those fields where treatments occurred when the UC threshold was reached (14 to15%).

No botanicals were used in 1998 as no cooperator could meet the specifications laid down by the producer of the neem oil products we evaluated in previous seasons (i.e., Neemix®). These specifications were 2-3 ground treatments about one week apart, roughly what has been working for fresh market tomatoes

The Cooperators' average yield was 30 tons per acre in 1998, 2.6 tons more than in 1997. The main reason for this yield increase is the reduction in late insecticide treatments. We recommend against late treatments.

Those who treated early had to treat their fields up to four times. Frequent treatments destroy the beneficial fauna and also accelerated the development of insecticide resistant pest strains.

BIRC is working on the development of cost effective releases of natural enemies against aphids in order to avoid such undesirable consequences. Bt's have already proven their effectiveness for worms without causing resistance or disruptions of natural controls. However, unlike fresh market tomato growers, processing tomato growers have been slow to adopt this more advanced pesticide technology.

Why The Shift To Early Treatment ?

Early treatments are those which occur before the U.C threshold. The BIRC threshold is ***ONE aphid per leaflet (at 100% leaflet infested).*** Late treatments are those well above the BIRC level. See previous newsletters in this series for further explanations of this level.

We think the shift to early, premature treatment is occurring for a number of reasons including:

1) insurance mentality dominating decision-making,
2) lack of good methods for monitoring,
3) confusion about treatment thresholds,
4) late adaptation to unstable weather patterns because of lack of monitoring.

These reasons are discussed further below.

Response to Unstable Weather

Unstable weather and the inability of growers to adapt with suitable strategies is one of the principle ways farmers are stressed and driven out of business. Stress in this context is psychological and economic. This is evident from US experiences over the last few years with massive flooding in the mid-west and local stresses from hail storm damage and excessive rainfall.

In 1997 the hot dry season brought about high early aphid populations with few natural enemies. The result was first a late response and then, in '98, a too early response.

The delay in making applications occurred because the aphid populations were two weeks early and virtually without natural enemies in many fields. Low natural enemy populations occurred from lack of spring rains which normally produce good sized aphid populations in non-crop and early season crops. These early aphid populations are the food sources for predators and parasitoids which later help control late season potato aphids.

In 1997 growers who apply by ground could not get materials on fast enough to all the fields needing treatment in the reduced treatment time window. The queue for aerial treatments was too long for some growers who watched aphid populations grow exponentially above already known excessive levels before finally getting their treatments on.

In 1998, with a cool wet spring, the opposite occurred. Although the early season disease pressure was high necessitating repeated fungal and bacterial suppression, natural enemies of insect pests were also high earlier than normal. Since natural enemies are not part of the monitoring system used by most growers and their PCA's, worries over erratic weather and high early pest control costs rsulted in additional insurance treatments. The balance sheets for the '98 season are going to be hard to take. The few organic growers, on the other hand, seem to be doing well with tomatoes. Some smart conventional growers are avoiding late season tomatoes, altogether.

Good Monitoring - IPM:

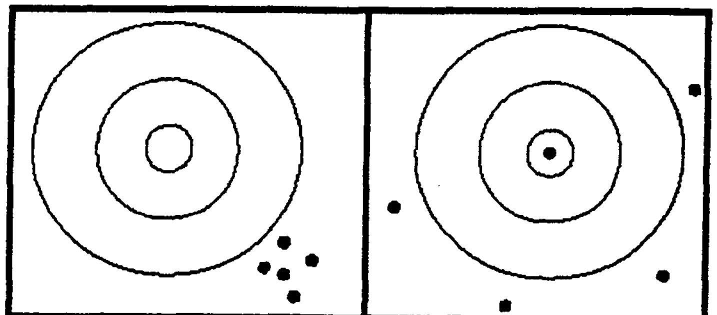
Apropriate Response To Unstable Conditions

Genuine IPM uses a quantitative sampling system that is accurate and precise, and includes natural enemies to determine IF and WHEN treatments are needed.

The ACTION LEVEL is the pest population level at which treatments are applied. If treatments are needed a least toxic treatment method should be used first. **Just walking the fields and deciding upon treatments without quantitative sampling is not IPM.** A brief walk in a field can be called scouting, but this should not be confused with IPM.

At present, excepting a few conscientious growers, in the counties we have been monitoring, decision-making in late season processing tomatoes seems to rest almost entirely on casual scouting reports. The use of scouting is a good starting place to build upon toward IPM. However, the reluctance to adopt more beneficial-insect-sparing technologies is also an important missing component.

Genuine IPM could be an important part in grower response to weather instability. The grower's footprint in the field is not enough. The footprints, yes, but also pencil and paper. Quantification forces precision. Learning from the results leads to accuracy, and eventually to a risk reducing IPM.



High Precision Low Accuracy — **Some Accuracy Low Precision**

Threshold Confusion Leads to Insurance Applications

Some growers and PCA's may be confused by the 50% Action Level recommended by UC extension. Although we have adapted this treatment level to time mass release of lacewings as an interim procedure, we do not recommend using this threshold because it does not include any natural enemy assessment. Although fast and easy, it leads to premature treatments which, eventually, will lead to insecticide resistance and later to treatment failures.

The first signs of resistance will be multiple treatments where previously single treatments were sufficient. Shifts to new insecticides and combinations are also signs. In fact, that is what is currently happening. With the use of Ambush®, sometimes in combination with other materials, widespread insect resistance could be near. Ambush®, a pyrethroid, may also lead to secondary pest problems. Pyrethroids, in general, have a reputation for causing secondary pests.

Where Can Growers Go From Here?

Forming a grower-run Cooperative to hire and manage an independent pest control advisory service would be ideal at this stage, since IPM development in processing tomatoes is a pioneering effort from the viewpoint of existing IPM independents. A successful model exists in the form of the Fillmore Citrus Cooperative, established in 1922 and still going.

In general, IPM is further advanced in fruits and nuts than in field and row crops. It only takes a couple of progressive growers to start breaking out of the rut in each crop.

There is no reason why a grower could not learn to do his/her own monitoring or to hire their own scout who can learn the systems we have developed. Graduate students at the agricultural colleges might be suitable since they could also do some applied research on biology and control and could use the support.

Although we have only worked at developing an IPM system for late season processing tomatoes since 1994, ours is the only written and tested series of experiences in this crop in the Sacramento area. We are developing a manual to document what we have learned.

Green Labeling Can Help IPM Implementation

Green labeling programs are being started in many crops to market produce grown according to environmental standards. Usually these are based on IPM systems. The green label development is patterned after Organic Labeling or certification programs, which are growing exponentially. Both approaches set production standards resulting in easily identifiable labels for consumers who pay a premium for a "better, less environmentall-damaging product". Grower's benefit with greater returns to compensate them for the higher costs of production specified by the certified or IPM programs.

A Green Labeling Program for processing tomatoes could use cover crops, IPM monitoring and treatment guidelines, least-toxic insecticides like Bt for worm control, and slower release fertilizers, for example. Growers could choose from a menu of options getting a score for each option adopted. A minimum score would permit marketing under the label. This is the way some of the existing "green labeling" programs are now operating, for example: "Fish Friendly", "Salmon Safe", and "California Clean Growers".

Market researchers (Hartman Group) estimate that 48% of the American population is interested in purchasing environmentally friendly products. At the same time, growers have an increasing interest in reducing pollution.

The drawback is that currently very few consumers know what IPM stands for. However, studies do indicate that after proper education, consumer's verbal commitment to buy IPM products increased, including the willingness to pay a 10% premium. These kind of market surveys are certainly no guarantee of being able to sell a new product but they show there are potentially significant numbers of buyers for this kind of product if it is marketed right.

The main issues are the credibility of the certification program and how to measure the positive impact it is supposed to produce. In response, growers and supermarket chains have joined with Land Grant Universities and environmental organizations. Programs go along with University IPM programs or specifically state they are bio-intensive IPM based.

The Central Coast Vineyard Team has developed a very interesting approach. A group of growers, extension agents, university affiliates and private consultants generated a detailed positive point system. Divided into different categories like soil management, water management, pest management etc., growers achieve points according to the environmental friendliness of the growing methods chosen. The involvement of the growers in the process guarantees that every method is going to get practical scrutiny regarding the points allocated. This approach allows for maximum flexibility.

Cornell University in Upstate New York claims IPM certified growers attain a 50% pesticide use reduction. This is certainly possible in processing tomatoes in Southern Sacramento Co. based on a recent pesticide use analysis BIRC conducted. We compared IPM program cooperators with their county peers in Yolo County. The result was an approximately 50% use reduction in the cooperator group compared with the average pesticide usage. This was without the incentives of higher returns!

Green labeling programs have their critics. Some conventional growers contend that there is no harm done using pesticides since they are all EPA approved. This does not account for the fact that legally used pesticides are contaminating ground and surface waters.

On the other end of the spectrum organic marketers see IPM labeling as a marketing scheme that is trying to cash in on their pioneer work. The important thing is that labels and informational leaflets clearly state what the program is going to deliver. Organic produce is still a minor part of the market and may remain so into the future.

Another criticism is that people feel squeamish about talking about pesticides at the point of sale. However, consumers disturbed by the thought of pesticides are probably already buying organic. The remaining 95% of the consumers will make a decision based on personal values and their budget as to whether they want to buy this new product. Product information certainly results in a diversification of the market but does not have to be divisive. In those terms biointensive IPM labels result in a value-added product.

New marketing strategies are most appealing to innovative individuals who are looking out for opportunities that will enhance their market position in a sustainable way.

For further information about green labeling programs consult the websites below:

- www.nysaes.cornell.edu:80/ipmnet/indyintro.html
- www.scs1.com/
- www.pmac.net/lisalef.htm
- www.pmac.net/potatoipm.htm
- www.pmac.net/ipm.mark.htm

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