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From the Director

On-Farm Research

The state of the State is not good. The projected budget deficit appears to be in the area of $12 to $13 billion. Ultimately, some combination of tax increases and budget cuts will probably work its way down through most public agencies, including the University. There is a real cost/price squeeze in the UC's Division of Agriculture and Natural Resources (DANR). In many cases, more is being asked of the university community, while resources to do the work are being reduced. If the mission of the DANR is to provide the research and education necessary to help manage the State's landscape in a fashion that is sustainable, then new ways of gathering information or research may be needed.

On-Farm Answers?

The answers to many problems facing agriculture are actually on many of California's farms. We need a methodology that is acceptable to both the scientific and farming community that will help speed the collection and analysis of on-farm information. If we had such a method, then on-farm research and practical experience would become a real asset used by the University community and others. This observational, intuitive, and scientific information is available if we are willing to develop the tools and use an open mind in evaluating it. The development and use of this information presents the scientific community with a major resource.

Farm Statistics

In this issue SAREP information Systems manager **Jill Auburn** presents information on a relatively new approach to appropriate statistics for on-farm information (see page 5). The UC Sustainable Agriculture Research and Education Program will attempt to help develop this information so we can rapidly address many of the critical resource and production issues that California farmers face. We see this as a way to move agriculture's agenda forward in a way that is compatible with both good science and good farming. -*Bill Liebhardt, director, UC Sustainable Agriculture Research & Education Program.*

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Grasses/Legumes: Dream Team

by Robert L. Bugg, UC SAREP and Rick Miller, UC Davis agronomy & range science department

What would Gilbert have been without Sullivan? Laurel without Hardy? In the most highly-accomplished and acclaimed duos, it is difficult to define one collaborator apart from the other. Somehow, synergy can make the whole greater than the sum of the parts. An outstanding example is the grass-legume collaboration. Grasses and legumes have key roles to play in agriculture, and they often function best in tandem.

As vegetarians know, grains derived from grasses (barley, corn, millet, oats, rice, rye, wheat) and legumes (beans, lentil, peas) complement one another. Alone, neither group provides the balance of amino acids optimal for the human diet; together, they provide a high quality source of protein. It is no coincidence that for millennia, native peoples of the Americas have grown corn and beans side by side, as Africans and Asians have grown cowpeas or hyacinth bean in polycultures with sorghum or millet. But there is more basis to such combinations than human dietary needs alone would indicate.

In conjunction with other key collaborators (Rhizobia bacteria that are housed in root nodules), many types of legumes can convert atmospheric nitrogen into protein. Few other plant families fix significant amounts of nitrogen, so legumes are a key component in sustainable farming systems. Leguminous cash crops (beans, cowpeas, lentils, peanuts, pigeonpeas, garden peas) or forages (clovers, medics, vetches) require little or nothing in the way of added nitrogen fertilizer. Sometimes the residues of these crops can contribute substantial nitrogen to following crops. Leguminous cover crops plowed down as green manures can provide nitrogen to associated non-leguminous crops.

Root Systems

Legumes often have relatively simple root systems, dominated by a central taproot and often heavily nodulated. Many legumes have symbiotic relationships with fungi that produce mycorrhizae (literally "fungus roots") that ramify through the soil and can help the plant obtain scarce nutrients (e.g., phosphorus). Grasses may have mycorrhizae as well, but typically rely on dense masses of fibrous roots. These improve soil structure by exuding polysaccharides that stimulate soil microorganisms which in turn exude gums that aggregate soil particles. The fine roots of grasses also bind soil crumbs directly. The formation of waterstable soil aggregates leads to increased water infiltration and retention, reduced run-off and erosion, and retention of nutrients. Grasses can make efficient use of nitrogen already in the soil, because their roots are adept at scavenging nitrogen that might otherwise leach from the soil as nitrate and perhaps contaminate ground or surface waters.

Expensive Metabolism

Nitrogen fixation is metabolically expensive; left to their own devices, legumes assimilate preexisting soil nitrogen before symbiotic fixation occurs in the nodules. But because grasses are typically more efficient at competing for soil nitrogen, legumes grown in mixtures with grasses are forced to obtain higher proportions of nitrogen by fixation. Total amount of nitrogen fixed by legumes may be increased by the inclusion of grasses. Grasses can sometimes obtain nitrogen through mycorrhizal links to the nitrogen-fixing nodules of legume roots. Grasses contribute carbohydrates to the mycorrhizal association and in return receive fixed nitrogen, phosphorus, or other nutrients accumulated by adjacent legumes, again reducing the need for fertilizers. Grasses (barley, oats) are commonly interseeded as "nurse crops" with certain legumes (alfalfa, sour clover, sweet clovers), because they aid in weed control. Oats can even help suppress weeds when seeded into established alfalfa strands.

The use of grass-legume mixtures also enables a cover crop to respond to spatial variation in soils and perhaps in time to reduce their heterogeneity. In nitrogen-poor areas, legumes will tend to dominate, whereas grasses will do relatively well in areas rich in nitrogen. This points up the importance of feedback loops in sustainable agriculture. Nitrogen fertilizer is an important input in the simplified, "leaky" systems that are more common in conventional agriculture. Such inputs are much less important to tighter, more complex agroecosystems.

Seasonal Specialties

Grasses and legumes may divide a resource temporally as well as spatially. In the southern United States, warm-season perennial forage grasses (Bahia grass, Bermuda grass) can be grown in conjunction with cool-season annual forage legumes (arrowleaf clover, crimson clover, subterranean clovers). The warm-season perennial grasses make use of the Hatch-Slack process, an alternative photosynthetic pathway that is advantageous under hot, dry conditions. No legumes share this pathway. By contrast, the legumes mentioned grow well during cold, cloudy weather. This permits year-round forage production, and a reduced need for nitrogen fertilizers. As a counterpart to the foregoing example, the alfalfa-oats combination mentioned earlier matches a cool-season annual grass with a warm-season perennial legume.

Above-ground structural differences can also lead to complementarity. For example, hairy vetch is often grown in combination with cereal rye or with oats, because these grasses provide structural support to the vining vetch.

Green Manures

When grown as green manures, legumes typically have a lower carbon-to-nitrogen ratio than do grasses, and grasses often contain higher proportions of lignin, which is resistant to decay. Moreover, leguminous residues are often more palatable to earthworms than are those of grasses. Together, these factors can lead to quicker disappearance of leguminous residues, the quick liberation of nutrients, and their prompt availability to associated cash crops. By contrast, the slower breakdown of lignin-rich grass residues may lead to the formation of humus, which contributes to improved cation exchange capacity and better long-term nutrient availability.

There is much interest among California growers in using cover crops to provide habitat for beneficial arthropods. Grasses are typically wind pollinated, and produce large amounts of windblown pollen, mainly during the spring. Windblown pollen can be an early-season food source to predatory mites (e.g., *Euseius* spp.) that are important in the control of citrus and avocado pests, and it is also used by certain parasitic wasps. By contrast, legumes are often insect pollinated, and can provide pollen and nectar to flower-visiting insects (bees, wasps, and flies). Several legumes (clovers, sweetclovers) are important honey plants, and some (bell bean, common vetch, sweetclovers) provide nectar to predatory and parasitic insects important in biological control of pests.

Studies in southern Georgia indicate that during late winter and early spring, cereal rye hosts bird-cherry oat aphid, whereas hairy vetch later harbors abundant pea aphid. Populations of lady beetles were observed to build up early on the cereal rye, and later move to the hairy vetch.

Not All Compatible

Based on this glittering panegyric to grass-legume mutualism, one might be tempted to infer that all grasses are eminently compatible with all legumes. Such is not the case: In interactions between groups as diverse as the grasses (Poaceae: 8,000 species worldwide) and legumes (Fabaceae: 18,000 species), many combinations are simply non-starters. This is not surprising in light of the wide range of environmental optima and tolerances within each family. Sometimes the associations require fine tuning through management. Varieties that harmonize best with one another should be selected to maximize the value of microbial and plant coevolution, with application to sustainable farming systems.

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More On-Farm Research: Another Approach

Jill Auburn, SAREP

In Sustainable Agriculture News (Vol. 3 No. 2, Winter 1991, *On-Farm Research & the Transition)*, we reviewed conventional concepts of experimental design and analysis that may be useful for on-farm experiments. Those methods are appropriate for studying the effects of experimental treatments, assuming that the measurements taken in different plots are spatially independent. Common sense tells us, however, that measurements taken nearby one another in a field might be related. By ignoring that possible relation, the conventional approach "throws away information about patterns in space and time," according to **Don Nielsen**, UC Davis professor of Land, Air and Water Resources and chair of the agronomy and range science department. Nielsen introduced SAREP staff to geostatistics, an approach not usually used in what he terms "aggie" statistics.

Basic Concepts

This article presents some basic geostatistical concepts drawn from Nielsen's presentation to SAREP staff and from a paper by Nielsen, Tillotson and Vieira (1983). It is an overview and introduction to the concepts and some of their applications, rather than a thorough guide to using these method.

Most growers are aware of the variability of their fields, and may therefore be skeptical of the applicability of some experimental results. Researchers are aware of this variability too, but they haven't had the tools to include it in their experiments. Geostatistical methods provide additional tools to describe and analyze spatial variability. These methods involve intensive sampling along a line or in a grid pattern, rather than in randomized, replicated treatments.

Geostatistics is important to sustainable agriculture in two ways. First, geostatistical methods can improve researchers' ability to lay out experimental plots and take samples more effectively. Researchers usually try to put their field experiments in representative areas in a field. They also choose plot sizes that seem large enough to ensure independence between plots, yet are not so large that each plot contains too much variability. Geostatistics can provide a basis for making these decisions more soundly.

Secondly, many growers want to know why plants in a particular field, or area of the field, are healthier than others. They also want ways to predict where in the field a problem may occur. Conventional research designs have determined many factors that affect plant health and productivity, but they are able to study only a limited number of variables at a time. As a consequence, it has often been left to the grower to determine how these factors interact in the field. Geostatistics can be used to describe and monitor plant and soil health characteristics as they occur together in the field.

Spatial Autocorrelation

Common sense tells us that the similarity between a sample point and its neighbor decreases as the two points become farther apart. The spatial autocorrelation coefficient is a way to quantify this relationship: it expresses the relatedness of points separated by an interval of space along a transect. It is always 1.0 at a distance of zero (that is, points are perfectly correlated with themselves), and drops off as the number of intervals between points being correlated increases. The autocorrelogram is a plot of the autocorrelation coefficient versus number of intervals. If it drops off steeply, there is little spatial relationship among points, on the scale being used. If it drops off gradually, it is possible to estimate from one point the expected values at neighboring points. Spatial autocorrelation describes spatial dependence, or how a soil or crop characteristic changes across a field. One of its uses is to determine the required spacing of samples along a transect (or line) so that intermediate values can be interpolated. For example, if your field includes two or more soil types, how many samples do you have to take to make sure you have an accurate picture of the field? Spatial autocorrelation can also be used to determine the size of field plots and the spacing of samples in conventional experimental designs. Without measuring spatial dependence, you don't know for sure that measurements taken in different plots are independent of one another, that a sample taken within a plot is representative of the entire plot, or even that the area in the field chosen for the experiment is representative of the whole field.

Spatial Cross-Correlation

Usually we are interested in more then one variable - for example, how are soil compaction and plant growth related across the field?

A conventional correlation coefficient describes the relationship between two variables as if it were the same across the field. By contrast, spatial cross-correlation expresses the relationship between two variables in a series (when both are sampled along a line across a field.) Like the spatial autocorrelation, the cross-correlation is calculated for each of several intervals between the two variables. When the interval is zero, the spatial correlation is the same as the conventional correlation coefficient; if a significant correlation persists as the interval between the two variables is increased (i.e., one measurement away, two measurements away, etc. along the line), a relationship exists between the two variables over a larger area than the size of each sample. Spatial cross correlation is important when one of the variables is difficult or expensive to measure. In our example, soil compaction may be more difficult to measure than plant growth. Soil compaction can be predicted by plant growth measurements if they are known to be spatially correlated.

Spectral Analysis

Spectral analysis is used to look for regularly repeating patterns across time or space, such as might be found across a field where rows of crop plants occur at regular intervals. In spectral analysis, the power spectrum (variance as a function of the frequency of cycles) is plotted. Peaks in this spectrum correspond to distances over which cycles repeat. In an example by Nielsen (Figure 1), average soil water content was sampled across a field where a crop had been previously grown along furrows one meter apart. Spectral analysis of the data showed significant peaks corresponding to one meter (furrow spacing), two meters (tractor tire spacing), and ten meters (pre-plant border irrigation, or some other traffic pattern.) The significant peak at the two-meter spacing shows a significant effect of tractor traffic (soil compaction) on soil water content. If the peak corresponding to the two-meter spacing had not been significant, the conclusion would have been that tractor traffic was not significantly affecting soil water content in this field.

This example illustrates a geostatistical approach to this question. Alternatively, the problem could have been approached using conventional analysis of data from replicated plots containing furrows, tractor tracts, etc. The plots would have to be laid out with this pattern in mind. An advantage of spectral analysis is that it identifies spatial patterns that the researcher may not know about beforehand.

Cospectral Analysis

Cycles or regularly repeating patterns in the relationship between two variables are shown through cospectral analysis, in which the covariance between two variables is plotted as a function of frequency. Peaks in the cospectrum may identify relationships among two variables in a more sensitive way than conventional correlations of the independent samples, especially when the relationship between the two variables changes across space. The relationships between the abundances of predator and prey insects across an orchard may vary, for example, between orchard floor and tree canopy, or even in a more subtle pattern moving across the two zones. Conventional methods could be used to identify the relationship in different areas, for example by taking measurements in replicated plots in both orchard floor and canopy. The researcher would have to know beforehand, however, where to place the plots to pick up these effects. The advantage of the geostatistical approach is that it can identify spatial patterns whether or not the researcher knows about them beforehand.

The effect of management variable might be studied by arranging plots in a regularly repeating pattern across space, analyzing the data with cospectral analysis. Thus the regular plot layout that was described as inappropriate for conventional statistics in our article in the last **Sustainable Agriculture News** (in which treatments were arranged A-B-C-A-B-C-A-B-C) **would** be appropriate for cospectral analysis.

Other Methods

There are many more methods beyond the scope of this article: The Nielsen paper describes cospectral phase angles and coherence (for relationships between variables whose cycles are out of phase with one another); semivariograms (another approach to describing spatial dependence of neighboring observations); and kriging (interpolating missing points using information from the semivariogram). The other references listed below describe even more methods.

Conclusions

Geostatistical methods can describe patterns in space and time which are, too often, ignored in conventional analysis. These methods may allow us to address questions that are difficult or more expensive to answer with conventional "aggie" statistics. Some of these questions are particularly important to sustainable agriculture, where we often ask "what are the characteristics of a healthy system?"

Geostatistical methods can also enhance our ability to design conventional experiments by providing information about spatial dependence that can be used to determine the appropriate size and layout of experimental plots. No statistical method is a panacea, however. Both conventional and geostatistical methods require that you design the project with an understanding of the system being studied and the method of analysis being used.

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New Directions in Almond Pest Management?

by Chuck Ingels, SAREP

Recent developments in the management of two key almond insect pests show promise in allowing growers to greatly reduce or eliminate the use of synthetic insecticides. The pests, navel orangeworm *(Amyelois transitella)* and peach twig borer *(Anarsia lineatella)* have for years plagued growers, although effective integrated pest management techniques have been developed to minimize their damage. Current and potential management strategies differ greatly for the two insects; however, the potential ability to control peach twig borer without disruptive chemicals may have important impacts on navel orangeworm control.

B.t. Research

Peach Twig Borer. University of California researchers, funded by the Almond Board of California, are conducting alternative pest management field trials (Zalom, 1990). Investigators have been testing the efficacy of Javelin®, a formulation of *Bacillus thuringiensis* (B.t.) for control of peach twig borer and navel orangeworm. B.t. is a bacterial insecticide with no toxic effect on mammals. Tests for the control of peach twig borer (PTB) were conducted in Colusa County in 1990. "Although results must be considered preliminary, it appeared that two treatments of Javelin® bracketing bloom....gave up to 80% control," according to the report.

John Edstrom, Colusa County farm advisor, discussed the 1990 results of B.t. studies at the Regional Almond Growers Meeting in Woodland last February. According to Edstrom, four Javelin® sprays applied from bud swell to early leaf were nearly as effective in reducing twig strikes as Supracide®, a conventional insecticide treatment. Spraying at any other time, including late spring or in the dormant season, is far less effective. He said that two sprays, one at the 'popcorn' stage of bloom and one during late bloom is probably adequate. He added that there may be little difference in cost between the two control methods.

According to Edstrom, results from this year's trial look encouraging. But he noted that the best time to apply B.t. may change from year to year. "So far, we have just related the timing to the crop, but this may not be the correct approach- it's the phenology (development) of the insect that matters. We don't know if the phenology of the pest is in synchrony with that of the tree. If so, then the timing of sprays at bloom development is convenient." The researchers will be evaluating nut damage this season. Edstrom cautioned that at this time, growers should **not** substitute standard dormant season sprays with B.t. alone. He said results are only preliminary; additionally, standard

PTB sprays are effective on mite and scale pests while B.t. is not. (**Frank Zalom**, UC Statewide Integrated Pest Management Project director at Davis, said that dormant sprays of oil alone can effectively control mite eggs and offer some degree of control for scale insects as well.) Scale buildup over a period of several years is also being evaluated in the B.t. experiments.

There are several concerns with the use of B.t., including rain at bloom washing off the spray or preventing spraying, and the need for more sprays in the case of an extended leafout period, according to Edstrom. Field resistance to 15 sprays per season of B.t. has been reported (Tabashnik, 1990), but two to four sprays on almonds are not expected to induce resistance.

Navel Orangeworm. Two years of field research on navel orangeworm (NOW) control with B.t. have given mixed results which are not as promising as PTB control. The experiments have been carried out in Butte and Kern Counties using Guthion® and Javelin®, alone and in combination, and at different rates and timings. The results of these studies "confirm the observations of many individuals that no currently registered insecticide provides adequate control of NOW. The only true effective control we can recommend is good sanitation (mummy removal) and early harvest," according to the report. The latter two practices, as detailed by the UC Statewide Integrated Pest Management Project Almond Manual (1985), have been very effective of controlling NOW and in many cases have eliminated the need for in-season insecticide sprays.

Navel Orangeworm Parasites

Another approach to NOW control is beginning to attract the attention of growers and researchers alike. In the 1970's, **Fred Legner**, entomology professor at UC Riverside, found the insect parasite *Goniozus legneri* attacking NOW larvae in the southern Uruguay and Argentina (Legner et al., 1982). In 1979 he began releasing hundreds of thousands of the parasites into unsprayed almond orchards throughout California. In spite of these releases *Goniozus* did not become established in sprayed orchards until recently, probably as a result of dormant and in-season insecticide sprays. According to **Bill Barnett**, area IPM advisor for the central San Joaquin Valley, at least two Reedly and Kingsburg orchards were found to have very large parasite populations in the fall of 1989. Large populations of the parasite were also found in 1990, but not as many as the previous year. "It seems that *Goniozus* is either becoming better distributed or maybe it's adapting to the San Joaquin Valley, because it is more common than it was a few years ago," according to Barnett. The parasite has not yet become well established in the Sacramento Valley, he said.

Another NOW parasite, *Pentalitomastix plethoricus*, was introduced from Mexico by current UC Berkeley Biological Control Division Chair Leo Caltagirone in the 1960s and is now present in many California almond orchards, including those in the Sacramento Valley. In many cases the two species work together to control NOW more effectively than either parasite alone. According to Barnett, however, one of the problems with *Pentalitomastix* is that it does not build up in large numbers until May, after the over-wintering generation of NOW has emerged and laid its eggs. Part of the preliminary work with this parasite was to bring parasitized larvae into the orchard early in the hope that they could emerge earlier, but this method proved to be unsuccessful, Barnett said.

Standard Control Methods

As noted, the two most important management strategies for NOW in almonds are sanitation and early harvest. Sanitation involves mechanically shaking or hand poling the trees until no more than two mummy nuts remain on the trees of soft-shelled cultivars in January. The fallen mummy nuts then are blown off weed-free berms and shredded or tilled in by March. For orchards in which sanitation is not carried out or where neighboring orchards provide a source of NOW, in-season insecticide treatments are recommended. These sprays usually kill beneficial insects and can result in mite or other pest flare-ups. Therefore, the importance of sanitation cannot be overstated.

The conventional method for controlling PTB has been to annually apply a dormant spray of oil and organophosphate insecticide, such as parathion. Then spring sprays would only be required if the orchard has a history of PTB damage. Dormant spraying has the advantage of controlling other pests like San Jose scale and mites; also, fewer beneficial insects are killed at this time. However, dormant season organophosphate sprays, which are also used on most stone fruits, may be lost as a result of several environmental factors: They pose danger to protected wildlife such as Red-tailed hawks, they have been found in high levels in fog, and they have drifted onto neighboring sites, including vegetable farms.

PTB - NOW Connection?

Preliminary data indicates B.t. **may** be an effective substitute for in-season and dormant sprays for PTB. If so, it may be possible to use NOW parasites with greater reliability. According to Frank Zalom, the parasites may be killed even by the dormant season organophosphate sprays. He said that *Goniozus* spends at least part of the winter between the hull and the nut, so the parasites are more exposed to the fuming action of the insecticide. "We're assuming that these sprays are hurting the parasites but we really don't know," he said. The preliminary success of B.t. for PTB control, along with the uncertain future of dormant season organophosphate applications, point to increased potential for NOW control with parasites.

Little research has been done on the number of parasites required for adequate control of NOW. Furthermore, the recommended practice of leaving a maximum of two mummy nuts per tree does not take into account the presence of parasites. According to Zalom, orchards in some areas now have up to 60 to 70 percent parasitism in the winter. In these orchards, a large number of emerging parasites will seek out the next generation of NOW. If a sufficient parasite population is present, it may be possible to allow far more mummy nuts (and unparasitized larvae) to remain in the trees in the winter. The result may be an equivalent of the maximum two mummy nuts per tree, Zalom said.

If no parasites have been found in an orchard, it may be necessary to release them into the orchard in order to establish a sufficient population. It seems likely that ensuring the establishment of a parasite population by the fall would aid in substantial parasitism of overwintering mummy nuts.

Potential Risks and Problems

What are the risks of not removing overwintering mummy nuts? While virtually no one is yet willing to recommend leaving these nuts, the recent buildup of parasites is causing researchers and farm advisors to think about reconsidering strategies. The primary risk is ending up with severe NOW outbreaks if the parasites are not present or are ineffective. "I'd want to make sure that the grower knows that they have a lot of parasites out there," Zalom cautioned. "One of the main problems is that a dirty orchard becomes a source of NOW for neighbors as well."

Lonnie Hendricks, Merced County farm advisor, also urges caution and said in a January newsletter (Hendricks, 1991) that "the transition could be rocky, but the payoff could be a successful insect management program without the cost of either insecticides or winter cleanup." He noted that there are several conditions that are required to establish such a biocontrol program: "1) a grower willing, able, and determined to take the risk and manage the parasite/prey complex; 2) a pest control consultant to help establish *Goniozus* and to advise with pest management; 3) an orchard already in good balance with minimal sprays and no major existing pest problems; and 4) a good cover crop program to encourage general beneficials." Hendricks (1989) noted that general parasites, such as *Trichogramma* and other wasps, and general predators, such as spiders, lacewings, ladybugs can be very effective in suppressing NOW and PTB. Hendricks has been involved in a SAREP-funded project comparing orchards using six different management systems. In the organic orchard, in which a vetch cover crop is allowed to grow through spring, beneficial insect populations are high while NOW, PTB and other pest insects levels are extremely low. Nut reject levels have been well below industry averages.

While NOW control using parasites may require leaving some mummies in the trees, there could be cost savings if parasites became established and mummy removal became unnecessary. This is especially true in dry winters, in which mummy nuts are more difficult and expensive to remove (moisture-laden nuts fall off more easily). A potential problem is that severe storms may knock most of the mummy nuts off trees, possibly reducing the reservoir of host NOW larvae. However, Barnett noted that those that land on the weed-free strip on the orchard floor remain intact and can still support the parasites. Virtually all nuts that fall onto cover crops disintegrate over the winter (Barnett et al., 1989). Another potential problem is a severe freeze like that in December 1990, which may reduce overwintering parasite populations, according to Barnett.

Grower Successes

The use of parasites alone for NOW control in almonds has been successful for several California growers. **Hans Bucher**, a grower in Hilmar, Merced County, had almond reject levels of up to 12 percent using conventional practices. *Goniozus* was released into his orchard in the early 1980s. He now intentionally leaves mummy nuts in the trees to the harbor the parasites. He uses **no** insecticides and his NOW rejects run about one to 1.5 percent while his total rejects are about 2.5 percent to five percent. **Duane Jardine**, owner of Jardine Organic Ranch in Paso Robles, San Luis Obispo County, had up to

30 percent NOW damage without insecticide sprays or sanitation before parasites were released into his 60 acre orchard in 1982. He still uses no sprays and reject levels are consistently only one-half to one percent.

Because parasite levels in many orchards are usually low, releases may be required to get them established. **Larry Brown**, president of Bo-Biotrol, Inc. in Merced, said that reject levels from orchards into which several releases are made each year have consistently been at or below the huller average, and sometimes below one percent. Few of these growers use in-season insecticide sprays. *Goniozus* parasites have also been released into walnut orchards, which also suffer severe NOW damage, but they have not become established to date.

The expanding interest in environmentally sensitive crop production has sparked creative solutions by growers and researchers. Recent advancements in the non-disruptive control of key pests may hold the key to sustainable production in many crops.

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ORGANIC FARMERS' METHODS AND PRACTICES

by Lyra Halprin, UC SAREP

Every year California Certified Organic Farmers (CCOF), one of the largest organic certification organizations in North America, collects information about its members. The annual documentation and inspection of every farm in the program includes listing and verifying all methods and materials used in the production and handling of crops and livestock produced. SAREP funded a project that is analyzing CCOF's storehouse of information in order to produce a profile of California organic farmers. One of the main goals of the project, "Organic Farmers' Methods and Practices: A Profile of Organic Farming Systems in California," is to identify production problems and their organic solutions. The information will be useful for both farmers and researchers. Principal investigators **Brian Baker, Mark Lipson**, and **Susanne Altermann** are also evaluating the CCOF certification database as a research tool.

The project was funded by SAREP for $11,350 from May 1988 through June 1990, and was extended through June 1991 with an additional $5,363 grant. Additional support was provided by the Strong Foundation, the Organic Farming Research Foundation and CCOF.

Highlights

Investigators can make only a few generalizations about organic farm management as a whole based on 1989 data analyzed so far. Data show that cover cropping is widely used as a primary technique of soil fertility management. The relative absence of insect and disease problems stands out for both apples and tomatoes, crops that were profiled in detail.

Researchers concluded that the CCOF certification database represents a valuable storehouse of raw data. "It is a significant descriptive tool which can provide the basis for formulating and testing hypotheses about the efficacy and profitability of specific farming practices," they wrote.

Methods

Data on organic farming practices was collected on 476 farms during the 1989 CCOF certification process. The data includes specific management practices or materials used by each farm, and relates each practice or material to a pest problem or "management objective" like soil fertility. General statistics were compiled for the grower population as a whole, including farm size, location and basic soil fertility management. Fertility inputs were further characterized by source. Apples and tomatoes were selected for detailed profiles of production practices and problems. More than 7,200 entries were made to the growing practices database in 1989. Data from 1990 is now being entered.

Profile of Organic Farming in California

CCOF's membership of 522 farms in 1989 was estimated to represent 50 to 60 percent of the state's organic farming operations in both numbers and acreage. Average farm size was 83.29 acres. Figure 1 shows the breakdown of acreage by crop.

Profile of Soil Fertility Management Practices

One interesting fact the project revealed was the number of farmers who use cover crops, Baker said. "There's some debate about the value of cover crops," he noted, "But better than half of the farmers are using them."

Cover crops are used by 56 percent of all CCOF farms, 51 percent of apple growers, and 62 percent of tomato growers.

Soil management practices reported varied according to crop and local condition. Three main sources of basic fertility management available to organic farmers are compost, cover crops and manure. Figure 2 shows the frequency with which these practices were reported.

Many farms use more than one method. Of the growers reporting for 1989, 226 reported the use of compost, while 195 used manure for the fertility management. An additional 270 used cover crops. There were 91 growers who used none of the three methods, many because they were in transition and had not yet developed a soil management program. Some relied on rock minerals, drip or foliar feeds. The researchers note that the remainder could be classified as "organic by neglect."

Compost. Sources of compost varied widely. Most compost was produced "on-farm" with products obtained "off-farm." About one-quarter of all CCOF growers made compost. Commonly listed ingredients include manure, crop residues and vegetative matter. A number of farms used biodynamic or microbiological inoculents for their compost piles. Rock phosphate, gypsum and limestone were also used in compost. Approximately sixty off-farm suppliers provide compost to CCOF growers. Most suppliers are livestock producers who make compost as a sideline. Some are trucking companies or retailers who broker products composted by other operations.

Manure. Manure was listed as a soil amendment by 195 farms. This included the use of raw, aged, sheet-composted or partially decomposed manure. Chicken manure was the primary category. Most manure was obtained off-farm; much of it was mixed with other material or partially composted before being used (see Figure 3). A number of growers said that they were cutting down or eliminating the use of raw manure due to its salinity, weed seeds, variability, and difficulty in handling. (CCOF standards restrict the use of raw manure.)

Cover Crops. Cover Crops were used by 270 CCOF farms. Data from 1989 show cover crops are used by 56 percent of all CCOF farms, 51 percent of apple growers, and 62 percent of tomato growers. The use and reporting of cover crops varied widely, as some growers were experimenting with several types and listed up to six different cover crops and seed mixes. Others used cover crops for specific situations, for example, different cover crops for orchard, summer open ground and winter open ground. Some gave specific varieties, while others provided only generic information.

Table 1 is a summary of the most widely used cover crops. Vetch is the number one choice, with purple vetch the most commonly cited variety. Vetch is often used in a mix, most frequently with barley, bell beans, clover, oats, peas and/or rye. The most popular mix used by CCOF growers includes bell beans, Austrian winter peas and vetch, followed by bell beans, clover and vetch.

Growers on 38 farms also referred to various forms of resident vegetation, or weeds, as a 'cover.' Resident vegetation most frequently listed as beneficial included bur clover, lupine, mustard and native grasses. Most established long-term organic producers had planned rotations that included cover crops.

Cover crop varied widely. Table 1 shows that variation.

***Table 1.* COVER CROPS USED BY CCOF GROWERS - 1989**

Cover Crop	Alone	Mix	Total
Vetch	50	59	109
Clover	55	37	92
Bell Beans	39	46	85
Rye	23	21	44
Oats	14	27	41
Fava Beans	17	9	26
Peas (Austrian)	5	19	24
Peas	5	17	22
Buckwheat	15	5	20
Barley	11	7	18
Alfalfa	13	2	15
Beans	8	4	12
Wheat	7	3	10
Mustard	6	4	10
Cowpeas	5	2	7
Sudangrass	3	0	3
Lupine	1	2	3
Various Legumes	9	0	9
Various grains & grasses	4	3	7
other	5	2	7

Investigators noted that perennial crop producers showed less variation in their selection and management of cover crops. Selection depended less on the season and more on whether the cover competed with weeds, and not the crop. Permanent covers and reseeding varieties were also popular. Once a cover crop has been established, the amount of management time declines, investigators noted.

Apples, Tomatoes Profiled

Apple and tomato production problems and practices were profiled in detail. Investigators reviewed soil management practices, insect pests, preventive practices, diseases, and weed control for the two crops. Extensive information and more than 20 tables of information were compiled from the CCOF database and are available from the addresses noted at the end of this article. Of special note: 31 percent of apple growers reported no insect problems and 64 percent reported no disease problems; 53 percent of tomato reported no insect problems, while 47 percent reported no disease problems. (Most of the operations that reported no insect problems were mixed fruit and vegetable operations where apples were not the predominant crop grown. Operations that were monoculture apples were the hardest hit by insect problems.)

Conclusions

Baker noted that in addition to continuing data entry and analysis, the project will continue to grow and include more in-depth analyses of specific issues.

"There are regional barriers to the adoption of organic practices," he said. "It's hard to tease them out of the data." For example, in the regions with little animal production, manure is limited. Growers in those regions may use more cover crops rather than compost. "Conversely, some areas might have a terrible water shortage and very little ability to irrigate a cover crop. We can break that out regionally or by practices," he said.

Baker said farmers will find systems analysis of the data even more helpful than individual crop analysis because very few organic farmers grow just one crop.

"But we need to develop some protocol for looking at these systems and the interactions between crops, "he said. "We haven't done any real statistics with this data. We've got rough sketches of what's going on the farm, but we haven't been able to go in depth, given our limited time and budget."

He said another goal of the project is to study the transition to organic farming practices. "We'd like to look at growers' practices over time. In the next phase of the study we might look at growers who were in their first year of organic production in 1989 and compare that data to their growing practices in 1990."

Baker said the project is "identifying the production problems and some of the solutions to those problems that have historically prevented farmers from adopting organic techniques." As the data analysis continues, he noted, farmers and researchers will receive more useful information.

To receive a copy of the most recent update of this project, contact Brian Baker at CCOF, P.O. Box 8136, Santa Cruz, CA 95061, (408) 423-2263. Copies are also available from UC SAREP, University of California, Davis, CA 95616.

Figures 1, 2, and 3 are not available

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Sources of Funding

UC SAREP Grants for Economics, Public Policy

UC SAREP will offer a Request for Proposals in 1991-92 devoted to social, economic, and public policy analysis of food and agricultural systems. We are seeking proposals that address the relationship between the transition underway in farming practices and the political, economic, and social dynamics of the broader food system. Proposals will examine public policies, economic arrangements, and the social institutions to determine in what ways they are, or are not, compatible with the goals of sustainable agriculture, and how necessary changes might be implemented. They would also consider how the choice of production practices influences the character and viability of rural communities, the conditions of labor, human health and nutrition, and the quality of democratic decision-making processes.

We expect to release RFP in mid-July, with proposals due by October 1, 1991. (If you receive **Sustainable Agriculture News**, the RFP will be mailed to you.) Grants will be awarded on December 1, 1991. Total funding for this RFP will be approximately $50,000, with no single award to exceed $25,000. Multi-year projects will be accepted, although funding beyond the first-year is subject not only to evidence of progress but funding availability. For more information, write UC SAREP, University of California, Davis, CA 95616, or call (916) 752-7556.

$1000 Organic Farming Article Award

The Organic Farming Research Foundation announces the availability of a $1,000 award for the best article published in 1991 aimed at educating the general public about organic farming . Articles must be published between January 1, 1991 and December 1, 1991 in a regularly published newspaper, journal or magazine. Applications for the award should include: 1) 15 copies of the article as published, including date published and page numbers; 2) name, address, and telephone number of the author(s); and 3) information about the periodical in which it was published, including exact title, how long it has been in publication, purpose and audience, circulation, and other pertinent facts (15 copies). Applications must be received by mid-night, January 10, 1992 at Organic Farming Research Foundation, P.O. Box 440, Santa Cruz, CA 95061. Questions may be directed to the Foundation at (408) 426-6606.

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Resources

Sustainable Ag Guide
Sustainable Agriculture in California: A Guide to Information, by Steve Mitchell and David Bainbridge, is hot off the press. This 200-page guide is aimed at helping farmers, ranchers, researchers, farm advisors, planners, gardeners and consumers find information about sustainable agriculture. Specific topics include cover crops, ley farming, agroforestry, range management, weed and pest control, specialty crops, gardening, on-farm research, and farm worker safety. Order Publication No. 3349, available for $12 from UC ANR Publications, University of California, 6701 San Pablo Ave., Oakland, CA 94608-1239, or call (415) 642-2431.

Symposium Proceedings
Proceedings/Sustainable Agriculture in California: A Research Symposium, includes 23 papers ranging from practical crop production and pest control systems to developing computerized information distribution systems, and transcripts of a panel discussion on sustainability. From the spring 1990 SAREP symposium on sustainable agriculture research and extension. Publication No. 3348, available for $15 from UC ANR Publications, ordering information above.

UC SAREP Progress Report
Progress Report: 1986-1990, reviews the work of UC SAREP. It includes summaries of the 51 SAREP funded projects. Free copies are available from UC SAREP, University of California, Davis, CA 95616, (916) 752-7556.

Technical Sustainable Ag Newsletter
Components, the technical newsletter of UC SAREP, presents a wide range of research and information on topics of interest to researchers, farm advisors, and other agriculture consultants. It includes technical summaries and notes based on journal articles, books, reports, and material presented at meetings, conferences, and workshops. Free sample issue or subscriptions available from UC SAREP, ordering information above.

Small Farm Newsletter
Small Farm Newsletter, a free bimonthly newsletter published by the UC Small Farm Center, reports on the latest UC research, farm profiles and resources of interest to the small farm community. Available from Small Farm Center, University of California, Davis, CA 95616, (9160 757-8910.

State Agriculture Programs Case Studies
Statewide Sustainable Agriculture Programs: Case Study, University of California's Sustainable *Agriculture Research and Education Program*, details the history and operation of UC SAREP. Americans for Safe Food, a project of the Center for Science in the Public Interest, produced the study and is distributing it to promote similar programs in other states. Also available: *Financing Alternative Agriculture: Case Study, Minnesota*

Department of Agriculture's Sustainable Agriculture Loan Program; Taxing Pesticides to Fund Research for Sustainable Agriculture: The Iowa Model; Creating Alternative Markets for Locally-Grown Food: Case Study, Texas Department of Agriculture's Direct Marketing Program; Truth in Produce: Maine's Successful Efforts to Keep Consumers Informed. Case studies available for $5 each (checks payable to ASF) from Legislative Kits/ASF, 1875 Connecticut Ave. NW Suite 300, Washington, DC 20009-5728.

Agriculture & Pesticide Use Report
Harvest of Hope: The Potential for Alternative Agriculture to Reduce Pesticide Use, is a new report by the Natural Resources Defense Council (NRDC). The result of more than two years of study, the report documents the extent of water contamination by agricultural chemicals and identifies crop-specific alternative farming methods that could reduce the use of pesticides. Report advisory committee members include SAREP director **Bill Liebhardt**, SAREP PAC members **Ed Sills** and **Judith Redmond**, and former PAC members **Steve Pavich** and **Bob Cantisano**. Copies are available for $19.95 (checks made out to NRDC) from NRDC Publications, 40 West 20th St., New York, New York, 10011, or by calling (800) 235-7177.

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UC SAREP HONORED AS SUSTAINABLE MODEL

UC SAREP has been recognized as a model environmental program by Renew America, a non-profit environmental education organization, and chosen as a case study for state sustainable agriculture programs by the Center for Science in the Public Interest (CSPI).

The Renew America recognition resulted from SAREP's participation in "Searching for Success," a national campaign to identify, reward and promote successful environmental programs. Programs identified in the search are reviewed by the technical staff of national environmental organizations and are included in the Environmental Success Index, a directory designed to provide the public with working solutions to pressing environmental problems.

Americans For Safe Food, a project of CSPI, profiled SAREP in an extensive case study which is being distributed to promote similar programs in other states. SAREP was identified as a model of sustainable agriculture research and education programs. Copies of the case study are available for $5 by writing Legislative Kits/ASF, 1875 Connecticut Ave. NW Suite 300, Washington, DC 20009-5728.

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