LNE 88-08
Final Report

IMPLEMENTATION OF ELECTRONIC DECISION SUPPORT TECHNOLOGY FOR APPLE PRODUCTION

funded by

The National Research and Extension Program on Low Input Agriculture Cooperators: Northeast Region

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This is a final report of the project "Implementation of Electronic Decision Support Technology for Apple Production" funded under the Low Input Sustainable Agriculture Program of USDA/CSRS (Project LNE88-8).The project duration was July 1, 1988 to June 30, 1990.

The midterm report (Appendix 1) describes accomplishments from the beginning of the project until May 1989. This time period contained field testing which occurred during the 1988 apple growing season and winter 1988-89 extension educational season. The remainder of the results are described in several documents; a Master's Thesis "Adoption of an Expert System by Apple Growers: A Test of a New Model", written by Timothy Bowser (Appendix 2); a paper entitled," Economic Evaluation of an Expert System for Apples", presented by Andrew Laughland (Appendix 3) at the annual meeting of the American Agricultural Economics Association in August, 1990; and, a chapter entitled " Expert Systems: An Aid to the Adoption of Sustainable Agriculture Systems" published in 1991 in Sustainable Agriculture Research and Education in the Field by the National Academy of Sciences (Appendix 4).

A proposal to the Low Input Agriculture Program, Northeast Region of USDA/CSRS to implement Phase II of this project was denied funding.

APPENDIX 1

EVALUATING ELECTRONIC DECISION SUPPORT IN THE FIELD:
A PROGRESS REPORT ON THE APPLES EXPERT SYSTEM PROJECT

Submitted to the
Low Input Sustainable Agriculture Program
United State Department of Agriculture

June 15, 1989

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This is a progress report that describes the accomplishments of the first year of a two year project. The first section of this progress report describes the goals and objectives of the project and the accomplishments through November, 1988. The second section describes accomplishments from December, 1988 through May, 1989.

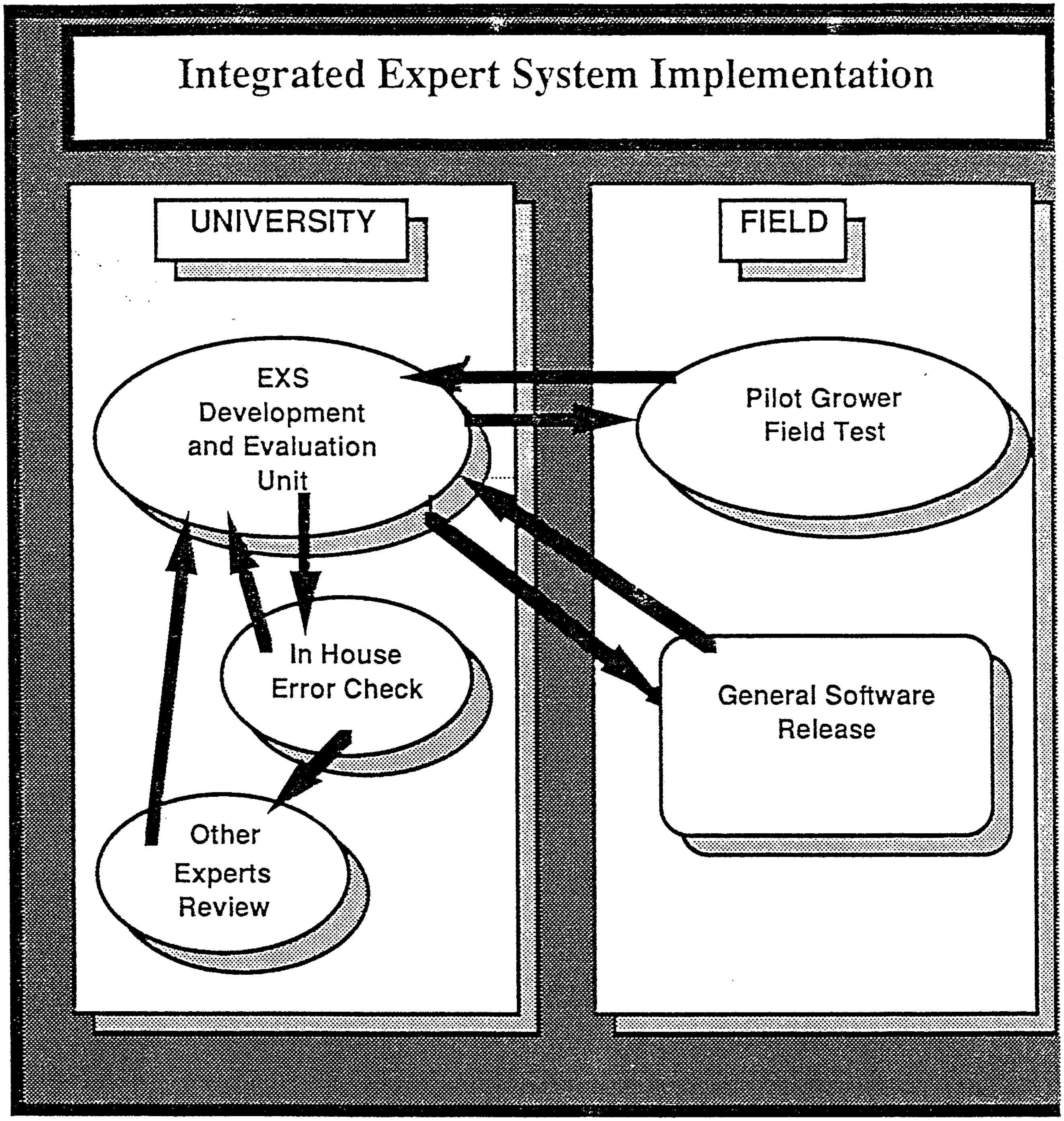
Penn State University is the coordinating institution in the Northeast for this evaluation of expert system decision support technologies for apple production. Also cooperating are researchers at the Universities of Massachusetts and Vermont and the Rodale Research Center. This cooperation will aid in the development and evaluation of regionally appropriate systems and make these efforts as efficient as possible.

1. Goals and Year 1

The goals of this study are manifold. Foremost is the development of a paradigm for expert system software introduction into commercial agriculture that can be used in Pennsylvania as well as other states in the Northeast. Software modification and maintenance does not end with its initial release. The performance of the software must be constantly monitored. Integral with this approach is obtaining the opinions and suggestions of the ultimate users of the software early in its development. By incorporating users' suggestions before general software release there is a much higher probability that that the software will be integrated into the agricultural system much faster. Moreover, this introduction paradigm includes measures of the sociological and economic impact of this new technology. This type of information can be used to design technology transfer programs that speed adoption and diffusion.

Another goal of this evaluation project is to field test the software and hardware configurations using a prototype, multilevel evaluation procedure (Fig. 1).

Figure 1



Integrated Expert System Implementation
UNIVERSITY
FIELD
EXS
Development
and Evaluation
Unit
Pilot Grower
Field Test
In House
Error Check
General Software
Release
Other
Experts
Review

Several phases of evaluation have taken place before and during general public software release. First, at the university level, the domain experts and knowledge engineers have checked the system for errors. Next, the systems were checked by university and industry colleagues who are expert in the specific areas covered by the expert system. In some cases, research field plots were used to check the integrity of a system in a controlled agricultural environment. Any deficiencies or errors in the systems were corrected as they were found.

After the university level check, this pilot study arranged to have growers use the systems in actual commercial agricultural situations. During the pilot program software was distributed and pilot study participants were periodically questioned about system performance.

Finally, when all concerned are satisfied, the software will be released through the extension information division of the college. Even after software release various mechanisms will be used to track system performance and obtain suggestions for system improvement.

A third goal for this study has been to create a regional network of domain experts and knowledge engineers in various commodities. In the case of apples, production is similar throughout the Northeast. Differences that do occur have been defined on a biological basis rather than the political/geographical basis. In this way the expertise of several state and federal specialists and the resources of several states have been brought to bear on a few problems. The present evaluation is a coordinated effort among several states in the Northeast.

A fourth goal is to provide a mechanism upon which interdisciplinary programs can be created. Expert systems, since they require an expert to display his or her problem solving logic, are excellent tools for learning across disciplinary boundaries. This displayed logic can also be used to find points of disciplinary integration. This has resulted in the expert system making recommendations in an integrated fashion similar to how the farmer must address problems on the farm. Moreover, it is not only the production agricultural disciplines that are important in this cooperation but also the socioeconomic disciplines which work at the human/technology interface.

Evaluation Plan

The apple evaluation is split into two time periods. The first time period began in July, 1988 and will continue until June, 1989. At the beginning of this time period expert system software was distributed to commercial apple growers in Pennsylvania. During the period the impact of the software has been determined by the administration of a system of surveys. Concurrently, software was distributed to cooperators in other states in the Northeast to prepare them for their own software introduction projects. In the second year, the evaluation will move into a more advanced stage in Pennsylvania and will commence in the other states.

Participant solicitation

Participants were solicited during regular extension educational meetings. Over 140 growers volunteered to participate in the first phase of the evaluation. Of those volunteers, 27 apple growers growers were selected to represent the spectrum of apple production characteristics in Pennsylvania including farm size, geographical location and experience with computers. The participants met with the study organizers for a day and were given instructions, software and, in the case of 14 growers who did not own computers, computers on loan.

Surveys

There were two types of surveys used to gather data about the participants. The first was a baseline survey which was used to describe several aspects of the participants including farmer demographics, business description, socioeconomic status, agricultural practices and histories, attitudes about expert systems and previous experience with the computer. The second type was the periodic survey which was used to track the impact of the expert system on farm decision making over time. Both surveys were done by telephone with the baseline survey being completed in late summer and the periodic surveys taking place in August, October and November. The baseline survey will also be used to categorize impacts based on demographics and structural variables.

Results

As an example of the data being obtained through the surveys the following selected variables from the baseline and periodic surveys of the apple expert system are displayed.

BASELINE SURVEY

Farm size and apple acreage and ownership

- Total farm acreage ranged from from less than 10 trees to more than 800 acres with the average farm between 100 and 400 acres
- Apples made up the vast majority of the acreage
- Most farms (66%) sold at least half of their crop as fresh

- Most farms were single family operations (48%) followed by family owned corporations (39%) and partnerships (9%)
- Most farms were doing well financially (90%) as indicated by their high asset to debt ratios.

Farmer age, education, off-farm employment, farming experience

- Ages of participants ranged from 30 to greater than 70 with the average around 50
- Education ranged from "some high school" to "post-graduate study" with the majority (79%) being college graduates.
- Only 17% reported any off-farm employment for the principal decision-maker
- Most of the farmers (52%) had been farming for less than 20 years although 2 farmers had been farming for more than 50 years.

Decision maker designation, scouting practices, spray practices

- On 44% of the participating farms the husband was the principal decision-maker for crop production decisions while on 32% of the farms decision-making was shared with various individuals including the wife, child, sibling, foreman or board of directors.
- 86% reported that they routinely scouted their orchards for various reasons.
- An average of 13.6 (range 1-20) pesticide sprays were applied for complete sprays and up to 30 sprays for alternate row middle sprays

Prior computer use

- Six participants (25%) had no computer experience before this study while 20% had used computers extensively.
- 83% stated that they owned computers and that those computers were used in their fruit business

Attitudes about environment

- Issues rated as very important to the participants included protecting water quality, preventing soil erosion, protecting workers from pesticide contamination, pesticide drift and farm profitability.
- A majority (74%) thought that pesticides, if used properly, were not a threat to the environment
- A majority (68%) felt that fertilizer and pesticide expenses could be reduced by more precise applications, and the time, cost and effort to gain the increased precision would pay off.

Attitudes about information and expert systems

- Only 50% felt that they could find the answers to farm problems quickly

- A majority (55%) would consider modifying their pesticide practices, but were not sure that they knew enough to safely make the changes.
- Only 52% felt that with the availability of extension specialists, chemical company field reps and their own knowledge there was not any problem that they could not find an answer for.
- Asked to list the "selling points" of expert systems in order to recruit other farmers to their use, a majority of the participants listed as "very important" the following; always available to give a recommendation, and that the systems were easy to use.

PERIODIC SURVEY

System usage

- System usage was highest during the growing season (in August 73% of participants used system at least once) and declined in October (35%) and November (10%).
- Average number of times per month used also declined: August (7.4 times), October (2.4), November (0.24).
- Total time that the system was used also declined with the season: August (111 hours for 222 sessions), October (11 hours for 56 sessions), November (3 hours for 7 sessions).
- Of those that used the system, most accessed it for solving actual field problems in August and October while accessing the system for hypothetical problems or learning how the system worked remained at a steady level in all survey periods.

Usage by module

- The insect management module was the most used, but its usage declined as the growing season ended.
- Insect management recommendations sought were found more than 85% of the time
- Insect management recommendations were carried out at least partially more than 85% of the time
- The weed control module was used the next most frequently (about 60% of participants).
- The weed information sought was found about 65% of the time
- Weed recommendations were implemented at least partially about 30% of the time
- Disease diagnosis, nutrient deficiency analysis, leaf analysis and the tree spacing advisor were accessed less often.

Practice change and monitoring stimulation

- In August, over 45% of the participants stated that the expert system had caused them to effect some change in their production practices.

- In August, over 80% of the participants stated that the expert system has stimulated them to monitor their orchard more closely because they more clearly recognized the value of monitoring information

Information sharing

- Up to 50% of the participants in any one survey period reported that they shared expert system recommendations with a neighboring farmer.

Utilization of other information sources

- Other information sources were still heavily utilized by the participants. These included extension agents and specialists, agricultural chemical dealers, private consultants, other growers and various extension publications.

Hardware or software problems

- Hardware or software problems were experienced by 40% of the participants in the first survey period but this rated dropped off to 0% by the third period

Conclusions

The results of the baseline survey revealed that the participant group was diverse when measured according to farm size, apple acreage, participant age, farming experience, computer experience and education. The large majority of farms were financially successful. It was the purpose of this first year's efforts to work with a diverse group so that the widest range of impacts could be gathered. In coming years the participant population samples will be stratified using some of the descriptive variables.

Another purpose of the baseline survey was to determine how production and pest management decisions were presently made on the farm. This was done in order to document any future changes that could be attributed to expert system impact. We found that decisions on fruit farms were made by one, or at most a few, persons on a farm. Moreover, these decisions were made in light of a substantial amount of monitoring information and advice from many outside sources including extension, consultants, the literature and neighbors. However, even with this rather sophisticated decision-making system, growers still claimed on the periodic surveys that they could gain even more efficiency in their production practices if the information was available on a timely basis to aid them. They further pointed out that the expert system had stimulated them to gather this extra information because the value of the information was made more apparent. Moreover, even at this early time in the study, participants reported actual practice change due to information supplied by the expert system.

Another measure of the impact of a new knowledge or a new technology is a change in attitudes about various issues. A change in attitude about a process can be thought of as a precursor to practice change. A majority of our participants were very concerned about the detrimental effect of farming practices on environmental quality, but most thought that present-day practices, if performed properly, were not threatening to the environment. Improving the performance of proper farm practices is partially dependent on the availability of information about the consequences of practice change. With this information a grower could change his or her practices without incurring unacceptable risk. Many participants felt that information was available, but finding it quickly was a barrier to practice change. The participants thought that expert systems may provide easy access to this information store.

The periodic survey allowed us to track system usage over time. Several trends were noted such as a decrease in system use as the growing season waned. This was due in part to a lack of awareness on the part of the participants about the full range of modules that were available and the fact that the system could be used as a learning tool by posing hypothetical situations. When this decrease in use was noted, a letter was sent to the participants reminding them of all of the uses of the expert system. This situation also alerted us to emphasize all of the expert system facilities in our next introductory seminars to next year's participants.

Individual modules also showed trends in usage, ability to find needed information and propensity to carry out the recommendations. This is invaluable information for the domain experts and knowledge engineers to help pinpoint problems that can be corrected before the next growing season.

Finally, one of the goals of the present study is to develop some process statistics about the field evaluation of expert systems. One area of process statistics is tracking hardware and software problems. A pleasant aspect of expert system software is the ease of update or changing the program code. At the beginning of the evaluation many participants had problems with software or hardware. However, we were able to address these problems quickly and had usually fixed them within three days after hearing of them (participants were urged to call in if a software bug was found). Amended diskettes were then sent to all participants by mail. By the end of the season all hardware and software problems were solved. The presence of a support structure staffed by personnel who can answer questions and solve problems quickly lends confidence to the growers use of computer software. Maintaining this support structure is well worth the expense.

Another part of the process is maintaining contact with the participants who are pilot testing the systems. Farmers are sometimes difficult to contact by telephone, but considering the alternative survey approaches, mail or personal interview, the telephone was the best approach. For the baseline survey the average time for an interview was 38 minutes. The periodical survey took an average of 15 minutes per interview. It took an average of 5 calls to contact a participant.

2. YEAR TWO

The second season's evaluation, which began in April, 1989 was greatly expanded from the first year. Incorporating suggestions received from the cooperating growers, the LISA proposal reviewers, and our own assessment of the first year's work, we expanded the project to include:

- Facilitated meetings with cooperating growers;
- A survey of county extension agents;
- Selection of a control group to compare with expert systems users;
- A simplified survey system;
- Activity time monitoring;
- Partial budgeting analysis to determine economic impacts;
- Creation of a bulletin board/ electronic mail network among growers and researchers;

Most importantly, we greatly modified the expert system itself in response to cooperating grower comment.The major modification was made in the pest management section. In the past, insecticides were over used due to lack of knowledge about the pest biologies, the impact of predators, parasites,weather, and cultural practices on pests, and of the intricacies involved in the judicious use of pesticides. This problem of lack of pest management knowledge should be ameliorated by the newly designed expert system.

ApplES was designed to view the apple orchard as a complex and integrated system, in which altering one component often results in changes in the rest of the system. Just as a manager has to deal with the orchard in this manner, the goals of the ApplES structure was to consider the orchard as a whole, and make management recommendations accordingly instead of making individual recommendations based on independent components.

Originally, the expert system consisted of three main components: Insects, diseases, and horticulture. Since each porogram fits onto one disk, a top level calling module provided a main menu to call each of the three main modules. Recently, the insects and disease modules were fully integrated so the program consists of two separate executable programs; one for the combined insect and disease management, and one for horticultural practices.

Profiles

The apple management program is based on orchard blocks. A block is the largest unit of an orchard within which consistent decisions are made. Information about the block is stored in two separate files, called profiles, and each block has its own profiles. The use of profiles eliminates the need for the user to enter information about the orchard that does not change frequently. The profile also allows the histories of individual blocks to be stored separately. The background profile consists of details about the orchard block that would not change from day to day. For example, the location of the block will not change at all. The tree varieties in each block, the age of the trees, and insect problems form the previous years remain fixed until the end of the growing season. The dynamic profile contains information that either needs to be updated on a more frequent basis or at least has the potential for changing. For example, weather information will change often. Crop load and market destination may change due to a number of environmental factors that alter the quantity and quality of the crop. Information (besides weather) that changes from day-to-day is asked with each new session and not stored in a profile.

The management program can either be initiated directly from the profile, in which case all profile information will automatically be loaded into the program, or else the user will be asked if a profile needs to be loaded. The user can either choose a previously defined profile or create a new one.

The Integrated Pest Management Module

The user has the option of looking at an individual pest problem or running the IPM module, which considers each orchard block as an integrated system where management of each component will affect other components. The structure of the integrated insect and disease management module is shown in Figure 2.

The program first determines if the the insect and mite populations are over thresholds that will require control. It then calls a chemical management module to establish pesticide application priorities . With the help of the expert system the user now builds a recommendation by considering pesticide efficacy and appropriateness, timing, days-to- harvest, and tank compatability. If the mite population is over threshold and predators are not sufficient to control the mites, miticide rates are determined. Insecticide rates are then determined for the primary insect over threshold (ie. the most damaging). If the primary insect control is effective for all secondary insects, no more insecticide compounds will be considered. Otherwise, the module will determine other compounds and rates to control the secondary insects. Steps similar to those described in the preceding paragraph are taken to determine the disease-pesticide recommendations.

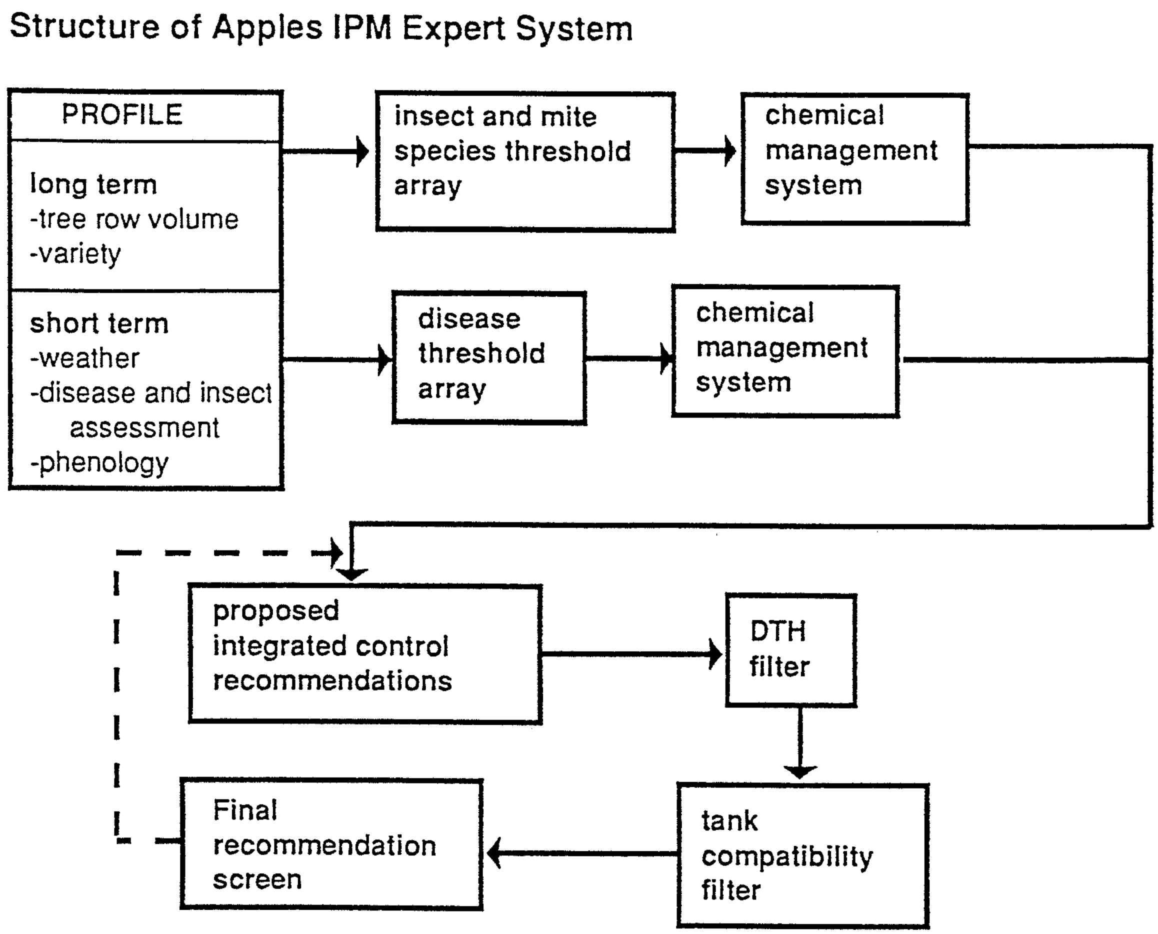
The program has now determined an array of miticides, insecticides, and fungicides that will control the pest problems in the orchard block. The array of pesticides is then checked against the days-to-harvest rules. Certain pesticides can not be applied within a certain period of time before harvest, and that period varies between materials. The program checks the current date and the estimated harvest date, then eliminates any materials that are illegal to use during that time. Most growers mix pesticides into a single tank applicatin. The final filter for the pesticide array is to determine tank compatibility between pesticides. Any incompatible chemicals are removed from the array. The user is given a choice of selecting from a list of the remaining pesticides.

Rates for the chosen pesticides are printed to the screen. The screen generally recommends a tank mix of a fungicide to control diseases, a miticide to control mites, a primary insecticide to control the most damaging insects, and a secondary insecticide to control any insects that are over threshold and are not controlled by the primary insecticide. After reviewing the pesticides and rates, the user has the option of asking for a different combination of pesticides for the same pest problems. This option is available since there ar many pesticide combinations that may be suitable.

Cooperators Planning and Review Meeting

The 1988 season for the ApplES Expert System Project was wrapped up with a facilitated meeting of cooperating growers, researchers, and extension personnel in February 1989. The purposes of the meeting were primarily to review the year to date, provide the growers with an opportunity for in-depth discussion about improvements in the program, and to collectively plan

Figure 2: The integrated pest management module structure.



for the upcoming year. In addition, a major benefit was to bring growers from 13 counties in Pennsylvania and researchers and extension agents from three states together to interact for the first time.

During a morning session the nominal group technique was employed with the growers group to solicit any suggestions growers had for improving either the software itself or the field evaluation process. This technique was used because it was felt to be the most effective way to get input from each individual within a group setting. Recommendations were distilled and ranked by growers according to importance during an afternoon session. Results of this group process are included in Appendix 2. During an evening session and the following day, cooperating researchers and extensionists reviewed the recommendations and discussed ways to incorporate them into the next years plan of work. Changes in the software and evaluation process are outlined in corresponding sections below.

Growers and agents also strongly suggested development of more economic information into the expert system. A session devoted to procedures for collecting relevant budget data yielded an additional step in the proposed "Analysis of farm level economic impacts" objective (#2). The additional economic information to be collected is described in the "Time monitoring and basic economic questionnaires" section below.

Researchers and extensionists from Penn State University, University of Massachusetts, University of Vermont, and the Rodale Research Center met for 1 1/2 days to plan and coordinate the next years program. Additional responsibilities for expert systems development and evaluation are outlined in Appendix 3.

County Extension Survey on Expert Systems for Fruit Growers

A survey attempting to measure the familiarity of county extension agents with expert systems and to solicit feedback on the overall expert systems program was administered in January 1989. The survey was felt to be necessary for two reasons; the realization that many extension personnel were not informed about expert systems development and that some training sessions may be in order; and feedback received that agents in cooperating counties could be better served and utilized by the evaluation process.

The survey was sent by electronic mail to agents with horticultural responsibilities in all 67 county extension offices. Additional questions were asked of agents in cooperating counties.

A response was received from 64% of the county offices. Only 2% of the responding agents had not heard of expert systems. However, 84% said that they were not at all or only somewhat familiar with expert systems for fruit. Over 75% of the respondents indicated that they would be interested in attending an in-service training session on expert systems. The full questionnaire appears as Appendix 4.

Evaluation and Field Test

Selection of control group

During the spring of 1989 the evaluation of the pilot study of the ApplES Expert System was expanded to include a control group a growers who are keeping records but not using the expert system. This control group was selected in order to further investigate the production and socioeconomic changes that may be attributed to the expert system. Collecting similar field data on production practices will enable comparisons between users and non-users of the expert system.

A sample of twenty growers was selected by county extension agents. An attempt was made to match the control group with the users group by county and size of apple operation. The control group cooperators agreed to fill out weekly surveys on time spent monitoring their orchards as well as a basic economic questionaire at preseason and postharvest periods (Appendices 5 and 6). In return the control group will be rotated into the users group for the 1990 season.

Survey evaluation process

A modified version of the monthly survey used to monitor use of the expert system and collect grower feedback has been adminstered for the months of April and May thus far in the 1989 growing season. The process for collecting this information was also modified from last year. Based on feedback from growers at the February planning meeting it was felt that a combination of mailing surveys to growers ahead of time and then telephoning for the data would enhance response and be more convenient for growers.

A system was devised to incorporate this feedback and still provide for timely collection of data. Growers were sent a three-ring binder permanently affixed with instructions for executing the monthly use survey, the weekly time-monitoring survey, and the basic economic questionnaire (see following section). Each month this season the growers have been sent a new set of the respective surveys along with return envelopes. This process enables the grower to fill out the monthly survey at the end of the month whenever she or he has time. Telephone interviewers begin calling on the fifth of the following month for the survey data which can be given by whomever answers the telephone.

This new system has improved response to the surveys and appears more convenient to the growers. Response rates for April and May were 92% and 96% respectively.

Time monitoring and basic economic questionnaires

An evaluation of the economic impact of the apple expert system on cooperators operations was added to this season's field test and evaluation process. Feedback from growers at the February planning meeting indicated that this level of data collection would be unrealistic for most growers. Many growers already maintain pesticide logs that contain most of the data needed for development of an apple budget. A basic economic survey questionnaire (BEQ) was developed from the pesticide record and crop history logsheet of a major commercial apple processor. Additional information to aid in the comparison between controls and users was incorporated into the questionnaire (see Appendix 6).

There were two primary goals in developing the BEQ. First, to reduce the variability among farms as much as possible. To this end growers were asked to select two, mature, healthy orchard blocks, one of the variety Red Delicious, the other primarily the variety York Imperial. This way only one well-defined portion of the farm operation was dealt with at a time and only similar varieties would be compared. In addition, the restriction to mature and healthy blocks eliminated poor yields due to age or improper fertilization.

The second goal was to make data collection as convenient as possible for the growers. Grower feedback at the February indicated a preference for mail-in over telephone surveys and check-off over written responses. The BEQ was constructed and administered in this fashion (see Appendix 6).

The development of the BEQ went through three reviews; first by the research team; next by all the county agents involved in the project; and lastly by selected growers who had expressed interest in its development. This feedback was particularly helpful with the yield and price component which was developed as a two part format to be collected in the spring and the fall.

The cost of time spent monitoring the orchard for pests and using the expert system is also a component of the economic impact being looked at. Specifically, the team is looking to answer the question of whether savings on pesticide applications were being offset by greater costs in management. A weekly time monitoring survey was developed that provides a check-off list for most of the common items monitored. Primarily, it asks how much time was spent monitoring each block and using the expert system. This form went through the same review-process as the basic economics survey. In addition, a related question was added to the basic economics survey of the users group to see what price growers would pay someone to operate the expert system vis-a-vis those performing other farm tasks. Together these questions will give a picture of what each group is monitoring, plus both actual and perceived costs of using the expert system.

Although the results have yet to be assessed, the growers are responding well to the weekly format and are providing very good data.

Creation of a bulletin board/ electronic mail network among growers and researchers

In response to feedback from growers, an electronic users group was formed to improve communications between cooperating growers, researchers, and extension personnel. Using Penn State's PennMail system, the growers are able to communicate with each other, county extension agents, and with specialists on campus via electronic mail. This has helped to make growers more comfortable with the computer and the information they receive.

Of the 27 growers, 14 expressed interest in participating in this new group and were included on the electronic mailing list. These growers, the specialists in horticulture, entomology, plant pathology, and the expert systems coordinator were all placed on a list that is available to everyone by typing APPLES: in the electronic letterhead. This system was set up in March 1989. In that time growers have inititated communications 16 times. These communications have included questions about insects, trapping, use of the computer, and information on the new version of ApplES. The coordinator has sent out numerous informational and update bulletins. The growers are also receiving their own copy of the horticultural newsletter in this fashion. Half of the growers have accessed the system (for messages, responses, PennMail) roughly once a week and the others, once a month. We feel this system has worked well so far and is expected that usage will continue to grow.

Development of Modules and Modification of Developed Modules for New England and Organic Production

Development and evaluation performed by specialists at Universities of Vermont and Massachusetts and the Rodale Research Center also includes assessment of grower and consultant acceptance of ApplES. To date the following progress has been made:

University of Vermont

The ApplES Expert System was evaluated by the IPM specialist and the computer specialist for subject matter and technical validity.

Specialists from Vermont attended a workshop at the PSU Fruit Research Lab to discuss modifications to the system that would make it more applicable to New England apple production.

The ApplES expert system was demonstrated at the annual meeting of the Vermont Tree Fruit Growers Association attended by about 150 people including apple growers, agri-business personnel and representatives of state government. A presentation entitled "Growing With Expert Systems" was made. Growers were surveyed to determine baseline computer use. Their suggestions and comments on how to improve the expert system to facilitate their adoption and use were solicited.

University of Massachusetts

The ApplES Expert System was evaluated by the IPM specialist and a computer programmer for subject matter and technical validity.

Specialists from Massachusetts attended a workshop at the PSU Fruit Research Lab to discuss modifications to the system that would make it more applicable to New England apple production. Work on modifying fungicide module and creating root disease module based upon multiple criteria has been inititated.

Work has also been inititated on a diagnostic module that incorporates uncertainity into the decision-making process. Conversion to Macintosh of an expert system for controlled atmosphere apple storage is now in progress with the cooperation of an agricultural engineering specialist.

A pre-systems release survey about computer use and familiarity with expert systems was given to 52 growers at the 1989 Tree Fruit Growers winter meeting. Data is in the process of being analyzed. The PSU expert system was also demonstrated at this meeting. The expert system was also demonstrated at a recent twilight meeting to over 50 people.

Rodale Research Center

The ApplES Expert System was evaluated by the orchard coordinator and the agricultural systems modeler for subject matter and technical validity.

Researchers from RRC participated in a workshop at the PSU Fruit Research Lab to discuss modifications to the system that would make it more applicable to organic apple production. A meeting was also held to discuss development of an informational module for growers who do not want to use chemical methods.

LIST OF APPENDICES

APPLE EXPERT SYSTEM/ LOW INPUT SUSTAINABLE AGRICULTURE EVALUATION PROGRAM

GROWER EVALUATION MEETING
9 February 1989

Nominal Group Process Evaluation Results

The Nominal Group Process was used during a meeting of cooperating growers to make collective judgements about how the program is proceeding. Eighteen growers and county extension agents participated in the NGP. Following are the rankings of responses to questions that were asked. In the last step of the process, participants ranked their top 5 priorities from a list generated by the group. Only responses ranked by at least six participants (33%) were included in this summary.

Question 1 List features of the ExS that you like

Feature	TOT	Ranking 1	2	3	4	5
Easy to use	11	3	0	1	2	5
Site specific recommendations	6	1	1	1	3	0
Integration of difficult disciplines	6	2	0	2	2	0
The potential for improvements	6	2	0	0	2	2

List features of the ExS that you don't like

Feature	TOT	Ranking 1	2	3	4	5
Tedious weather data entry	13	2	4	5	2	0
Incomplete modules & profiles (should state up front)	12	3	0	3	5	1
No escape or undo feature	8	0	2	3	1	2
should bd simpler to operate	6	0	1	1	1	3

Question 2 How might ExS change the way you manage your farm or business especially in terms of improving profitability and reducing the impacts of farm pracitces to human health and the environment.

Feature	TOT	Ranking 1	2	3	4	5
Reduce chemical use & cost	**13**	5	4	1	2	1
Access to timely information	**11**	5	2	1	2	1
Improved consumer education/ public relations	**10**	1	4	2	1	2
Reduce environmental impacts of practices	**9**	0	2	2	3	2
Improved economic decision-making	**8**	2	2	2	1	1
Improve timing of sprays	**8**	1	1	1	3	2
Useful training tool		2	0	2	1	2
Improve use of records	**6**	1	0	2	2	1

Question 3 What would you do to improve our evaluation procedure so that we can discern the true impacts of expert systems on orchard management?

Improvement	TOT	Ranking 1	2	3	4	5
Do surveys by E-mail	**10**	3	5	0	1	1
ExS updates in Fruit Times	**6**	4	1	1	0	0
Mail the surveys, no phone	**6**	3	1	1	1	0
In depth analysis of each mod.	**6**	2	1	1	0	2
Send Q. ahead w/ note of when call will be	**6**	2	0	1	2	1
More face-to-face contact/ feedback	**6**	1	0	2	2	1
More communication between participants	**6**	1	1	1	1	2

APPENDIX 3

COUNTY AGENT SURVEY ON EXPERT SYSTEMS FOR FRUIT GROWERS
ATTENTION AG AGENTS WITH HORTICULTURAL RESPONSIBILITIES

Computerized, electronic decision support programs called Expert Systems have been developed to help apple growers make better decisions about production, pest control, and marketing by substituting high quality, integrated, interpreted information for purchased production inputs.

We are currently conducting field tests on approximately 27 farms in 14 counties to evaluate the effectiveness of the Expert Systems. As part of evaluating the program we would like to find out what level of awareness now exists about Expert Systems among county staff. We are also interested in determining if our communication with county staff has been adequate and, if not, what we can do to improve it.

Please return this questionnaire by electronic mail to BOWSER T: or by surface mail to Tim Bowser, 106 Patterson Building, University Park, PA 16802. This survey will provide us with useful information for future programming regarding Expert Systems. We appreciate your cooperation.

NAME ______________________ COUNTY ____________

COMMODITY RESPONSIBILITIES (ALL) ____________________________

____

1 Where did you first hear of Expert Systems?

1) county meeting
2) trade publication
3) general media (newspaper, etc.)
4) inservice training
5) have not heard of Expert systems
6) other ________________

2 Are you familiar with Expert Systems for fruit?

1) not at all
2) somewhat
3) working knowledge
4) extensive knowledge

3 Have you seen Expert Systems operated?

1) at Extension meetings
2) by specialist
3) by grower
4) never
5) other ____________________

4 Do you know of any growers using Expert Systems in your county?

1) yes
2) not to my knowledge

5 How would you evaluate the current usefulness of Expert Systems as a tool for growers?

1) too simple for "real life" situations
2) adequate information base
3) appropriate level of information for most growers
4) no opinion

6 In the future, I feel Expert Systems will:

1) generate more work for me
2) relieve me of many routine requests for information
3) have no appreciable impact on my work load
4) other (please specify)

7 Would you attend an in-service training on Expert systems?

1) Yes
2) No

From what you now know about expert systems, if you were given the job of recruiting farmers for participation in an Expert Systems program, how would you rate the following selling points:

Expert systems:	not important	important	very important	no opinion
8 helps select the best chemicals for the pest problem	1	2	3	4
9 always available to give a recommendation	1	2	3	4
10 recommendations are specific to growers' situation	1	2	3	4
11 system is easy to use	1	2	3	4
12 it gives reliable recommendations, based on the best information available	1	2	3	4
13 it provides a range of alternatives to any given problem	1	2	3	4
14 helps control yield & quality loss	1	2	3	4
15 increases farm profits	1	2	3	4
16 involves reduced use of pesticides	1	2	3	4

17	reduces environmental damage	1	2	3	4
18	gives an unbiased opinion of pest problems	1	2	3	4
19	frees growers to use their management skills elsewhere	1	2	3	4
20	reduces chances of low yields and profits	1	2	3	4

THE REMAINING QUESTIONS PERTAIN ONLY TO AGENTS WITH COOPERATING GROWERS IN THEIR COUNTY

21 What opportunities have you had to discuss Expert Systems with growers who are involved in the program?

1) at Extension meetings
2) at other meetings
3) at the county office
4) over the telephone
5) have not discussed with grower(s)

Could you estimate the approximate number of discussions you have had?

22 Do you receive any feedback from growers about their satisfaction with the Expert System? If so, what?

23 Do you feel that adequate feedback channels exist between yourself and the Expert Systems program?

1) yes
2) no

If not, how may we improve them?

APPENDIX 4 **Apple Expert System Pilot Study**

Basic Economics Questionnaire Instructions

Explanation

This questionnaire is divided into three parts. Part 1 is a description of your orchard, the equipment you use and how you value time. This information will help us compare among farms and prepare pesticide budgets. Part 2 requests yield information. From your estimates of yield and quality we can begin to estimate the impact of the expert system approach to pest management on profitability. The third part refines the information from part 2 into the standard quality grades to more precisely compare the effect of expert system use on quality and profitability. Since the yield information will not be available until next fall, at the earliest, we ask that you complete and return the first part now. We will return the form in the fall for you to complete part 2 and again in the spring for part 3.

Block Selection

Please select two healthy, mature, producing blocks for record keeping for economic evaluation. For this purpose think of a block as the smallest production unit under specific management practices. One block should be a fresh market variety, preferably Delicious, and the other a processing variety, preferably York Imperial. Some growers will have to substitute other varieties or may only grow for one market or another. We can handle those situations statistically.

Labor Prices

To help us analyze the effect of the apple expert system on profits, we need your assistance in estimating prices for labor and management time. If the individuals performing pest control activities are employees, an estimate of the sum of their wages and the value of employment benefits (such as health insurance and social security) would be appropriate. If you or other family members perform the task, estimate the wages and benefits you would have to pay to have someone else perform the task.

Return questionnaire after completing Part 1

Once you have completed Part 1 (the first two pages), please send the form back to us in the enclosed stamped envelope.

Pesticide Treatment Records

At the end of the season, we will return a completed version of this form to you and ask you to xerox the "Pesticide Treatment and Crop History" forms you maintain for your processors or packers. A sample, modelled on the Knouse Foods form, is enclosed. If you are going to provide us your standard forms, please note in the comments column if Block 1 or Block 2 received the treatment. If you do not maintain this or a similar pesticide log for both blocks, we have provided you with a few blank forms to get you started. Check "No" on the pesticide treatment log question and more blanks will be sent with your next packet. From this information we will be able to give you pesticide use budgets which will compare your experience with expert system users and other growers.

Apple Yield and Price

Remember to keep track of yield and prices from the blocks selected as we will request that information in the fall. Inspection certificates and weight tickets may be convenient sources for some of this information.

Confidentiality

All of this information will remain completely confidential and will not be released or published in any form that would allow your operation to be identified.

Thank you for your cooperation. If you have any questions please call Tim Bowser or Drew Laughland at (814) 865-3143.

2

Apple Expert System Pilot Study
Basic Economics Questionnaire

Grower's Name ______________________________

Part 1 Orchard Description

Block 1 Fresh Market Variety

Block 1 is named ________________________.
Block 1 includes ________ acres.

Block 1 contains the following varieties...

%	Variety	Rootstock	Age
____	Delicious ____________	________	_____
____	________________	________	_____
____	________________	________	_____
____	________________	________	_____
____	________________	________	_____

This block is trained as a: Central Leader ____
(Check one.) Trellis ____
Other ____

Tree spacing:
Distance between trees within the row is ____ feet.
Distance between rows is ____ feet.

Bees are provided at flowering at _____ acres/hive.

Is a Pesticide Treatment Log already maintained for Block 1?
(Check one.) _____ Yes
_____ No, please provide blank forms.

The tractor-sprayer combination used most often in Block 1 consists of:
Tractor: Make:__________________ (example: John Deere)
Model:__________________ (example: #2155)
Horsepower: ____________
(Check one.) _____ 2-wheel drive _____ 4-wheel drive
Sprayer: Make: ____________________
Model:____________________
Size: ________________ gallons
(Check one.) ____PTO ____ Own Engine (______ horsepower)

Block 2   Processing Variety

Block 2 is named ______________________________.
Block 2 includes __________ acres.

Block 2 contains the following varieties...

%	Variety	Rootstock	Age
____	York Imperial	______	____
____	______	______	____
____	______	______	____
____	______	______	____
____	______	______	____

If the answers to the following questions are the same as for Block 1 please check here ____ and go on to the Time Cost question.
If Block 2 differs from Block 1 in these respects please continue.

This block is trained as a: (Check one.)
- Central Leader ____
- Trellis ____
- Other ____

Tree spacing:
- Distance between trees within the row is ____ feet.
- Distance between rows is ____ feet.

Bees are provided at flowering at _____ acres/hive.

Is a Pesticide Treatment Log already maintained for Block 2?
(Check one.)
- _____ Yes
- _____ No, please provide blank forms.

The tractor-sprayer combination used most often in Block 2 consists of:

Tractor: Make:__________________ (example: John Deere)
Model:__________________ (example: #2155)
Horsepower: ____________
(Check one.) _____ 2-wheel drive _____ 4-wheel drive

Sprayer: Make: ____________________
Model:____________________
Size: _______________ gallons
(Check one.) ____PTO ____ Own Engine (______ horsepower)

Time Cost

Please indicate the wage rate, including benefits, of the person performing each of the following production tasks. If the person is not paid a wage (such as a family member), determine the wage rate by estimating how much a person would be paid if hired for that task.

Production Task	Block 1	Block 2
Operating apple expert system program.	$ _______ /hour	$ ________ /hour
Monitoring pest conditions in the orchard.	$ _______ /hour	$ ________ /hour
Operating spray equipment.	$ _______ /hour	$ ________ /hour

This page is for your information only at this time.
You will be asked to provide yield, quality and price
information in the fall

Part 2 Rough Yield Data

After Harvest 1989

Delicious yield from Block 1 was ______ bushels in total.
(Fill in most convenient units.) ______ 20 bu. bins
______ 40 bu. bins

Of this amount ______ bushels were sold for the fresh market
(i.e. delivered to CA storage, packers or wholesalers, or sold retail)
at an estimated average price of $ _______ per bushel
and ______ bushels were sold for processing
at an estimated average price of $ _______ per bushel.

York Imperial yield from Block 2 was ______ hundredweight in total.

Of this amount _______ cwt. were sold for the fresh market
at an average price of $ _______ per cwt.
and ______ cwt. were sold for processing
at an average price of $ _______ per cwt.

****

Part 3 Detailed Yield Data

Spring 1990

Total Delicious yield from Block 1 of _________ bushels
broke down into the following percentages for each grade:

Extra Fancy:	______ %	average price of $_____/bu.
Extra Fancy/Fancy:	______ %	average price of $_____/bu.
Fancy:	______ %	average price of $_____/bu.
U.S. No. 1:	______ %	average price of $_____/bu.
U.S. No. 2:	______ %	average price of $_____/bu.
Other:	______ %	average price of $_____/bu.
Total:	100 %	

Total York Imperial yield from Block 2 of _________ cwt.
broke down into the following percentages for each grade:

Extra Fancy:	______ %	average price of $_____/cwt.
Extra Fancy/Fancy:	______ %	average price of $_____/cwt.
Fancy:	______ %	average price of $_____/cwt.
U.S. No. 1, 2 3/4 up:	______ %	average price of $_____/cwt.
U.S. No. 1, 2 1/2 to 2 3/4:	______ %	average price of $_____/cwt.
U.S. No. 1, 2 1/4 to 2 1/2:	______ %	average price of $_____/cwt.
U.S. No. 2, 2 1/4 up:	______ %	average price of $_____/cwt.
Ciders:	______ %	average price of $_____/cwt.
Culls:	______ %	average price of $_____/cwt.
Total:	100 %	

APPENDIX 5

Instructions for Weekly Monitoring Survey

Explanation

To help us determine the cost of time spent on apple management, please complete and return this one page survey each week during the growing season on the date shown in the upper right hand corner of the form. New forms will be included in each monthly packet.

The survey asks how much time was spent using the apple expert system on the computer, how much time was spent monitoring in the orchard and what diseases, insects or other conditions were being monitored. You will probably be able to recall these activities at the end of the week or you may wish to keep a simple log to aid your memory. We can provide log sheets if it would be helpful.

Monitoring

Monitoring or scouting is the careful, systematic observation of orchard conditions to detect developing problems which may threaten crop yields or quality. Monitoring would include counting mites, looking for scab, sampling fruit for thinning, looking for leaf nutrient deficiency symptoms, etc.

If you have any questions please call Tim Bowser or Drew Laughland at (814) 865-3143.

Thank you.

APRIL 10

Apple Expert System Pilot Study
Weekly Monitoring Survey

Grower's Name ______________________

For the week beginning Monday, April 3, 1989

How much time was spent using the apple expert system this week?
_____ hours _____ minutes.

How much time was spent monitoring the orchard this week in total?
Block 1: _____ hours _____ minutes.
Block 2: _____ hours _____ minutes.

Who did most of the monitoring? (Check one.)
Block 1: ____ Grower ____ Farm Manager ____ Consultant
____ Other Please specify. ________________

Block 2: ____ Grower ____ Farm Manager ____ Consultant
____ Other Please specify. ________________

Please check off below those items the person monitoring was looking for and those s/he found in each block.

Block 1		Block 2		
Looked for	Found	Looked for	Found	
				Diseases
____	____	____	____	Apple Scab
____	____	____	____	Powdery Mildew
____	____	____	____	Cedar Apple Rust
____	____	____	____	Sooty Blotch and Fly Speck
____	____	____	____	Fireblight
				Insects
____	____	____	____	San Jose Scale
____	____	____	____	European Red Mite
____	____	____	____	Green Apple Aphid
____	____	____	____	Rosy Apple Aphid
____	____	____	____	Spotted Tentiform Leaf Miner
____	____	____	____	Tarnished Plant Bug
____	____	____	____	Plum Curculio
____	____	____	____	Green Fruit Worm
____	____	____	____	Tufted Apple Budmoth
____	____	____	____	White Apple Leafhopper
____	____	____	____	Apple Maggot
____	____	____	____	Codling Moth
____	____	____	____	Apple Rust Mite
____	____	____	____	Leaf Rollers
____	____	____	____	Woolly Apple Aphid
____	____	____	____	European Apple Sawfly
____	____	____	____	Stethorus punctum
				Other
____	____	____	____	Weeds
____	____	____	____	Fruit Size for thinning
____	____	____	____	Fruit Size for crop estimation
____	____	____	____	Shoot Growth
____	____	____	____	Other (Please specify.)________
____	____	____	____	Other ________________
____	____	____	____	Other ________________

APPENDIX 2

The Pennsylvania State University

The Graduate School

Department of Agricultural Economics and Rural Sociology

ADOPTION OF AN EXPERT SYSTEM BY APPLE GROWERS: A TEST OF A NEW MODEL

A Thesis in

Rural Sociology

by

Timothy A. Bowser

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Master of Science

May 1990

ABSTRACT

This research explores the role that an information technology, known as expert systems can have on the generation of more sustainable agricultural systems. This exploratory study of an ongoing pilot field test of an agricultural expert system known as ApplES, tests a new model of diffusion which attempts to predict which farmers will adopt and use a given technology. By evaluating the adoption of this expert system for apple production by growers who are field testing it, this research examines a) the validity of the proposed diffusion model; b) which farmers will adopt and use this technology and with what consequences for the implementation of IPM programs which may result in pesticide use reduction; and c) what ultimate contribution expert systems may make toward producing sustainable agricultural systems.

Data for this study were collected from 23 apple growers who field used ApplES in their apple businesses during 1988 and 1989. Growers were interviewed by telephone each month, using a combination of different survey techniques. In addition, data were obtained through face-to-face interviews and during a group meeting.

Results of the study suggest that the model does not fully explain the adoption of the expert system, but that further refinement of the conceptual underpinnings of the model should improve its predictive powers. In addition, the results suggest that expert systems hold significant potential for the development of sustainable agricultural systems through the substitution of information for chemical inputs.

Data also indicate that the diffusion agency must provide increased educational infrastructure with the introduction of this technology in order for it to reach its potential with regard to sustainable agriculture.

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Chapter 1

INTRODUCTION

The sustainability of the commercial food production system in the United States is being questioned at present. Questions of sustainability arise from two primary areas of concern: farm economics, in that industrial commercial farming has become increasingly capital intensive and no longer profitable for a large segment of the farming population; and ecology, in that a heavy reliance upon large scale mechanization and agrichemicals since the 1940s has degraded soil and groundwater resources, disrupted biological processes, and created human health hazards beyond publicly acceptable limits.

Like most commercial agricultural commodities produced in the U.S., the apple industry relies heavily upon inputs of capital and of petrochemical pesticides. Pesticides are used extensively in apple production because apples are a high value crop that is very susceptible to insects and disease, and thus a great economic risk is associated with their production. In addition, social pressure for cosmetically perfect fruit has been promulgated by the agricultural industry as another reason for pesticide use. Thus pesticides are many times considered as the first line of defense by farmers and in cooperative extension and industry educational programs. The use of chemical pesticides in apple production relates to the issue of agricultural sustainability from both an ecological and an economic standpoint. The general public in the U.S. has become increasingly concerned about pesticide residues in food, as exemplified by the recent controversy over the use of the petrochemical growth regulator alar and the EDBC fungicides in apple production. Growers are concerned that many of the chemical pesticides that they are currently dependent upon will be banned from use and cause them to incur significant losses in yield and income (Shabecoff, New York Times, February 5, 1989; Walmer and Glamser, USA Today, May 3, 1989.)

Since their advent and in the earlier years of their use, pesticides used in apple production have been applied according to a routine schedule proscribed by the current state of production knowledge. Recommendations for application rates given by production specialists and consultants have traditionally been high enough to insure effectiveness while minimizing the significant risks of insect and/or disease damage that would lower the economic return on the crop. However, such recommendations are often given for a generalized apple operation and are usually without complete knowledge of a specific operation, its specific microenvironment, or site-specific weather data. This lack of site-specific information has resulted in growers' adopting routine spray practices, many times without adequate knowledge of whether applications were in fact necessary or at what specific and minimum rates for a given orchard. This conservative approach to the use of pesticides has been maintained even though research programs have demonstrated the usefulness of more efficient pesticide application practices and alternative control methods that do not involve pesticide applications.

Such practices present several problems. First, routine spraying schedules were developed in an era of inexpensive fossil fuels; thus petrochemically derived agrichemical inputs were relatively inexpensive as well. During the past twenty years, however, the cost of most pesticide inputs has increased significantly relative to other farm inputs and prices. Reducing agrichemical input usage is seen as one strategy for enhancing farm profitability and sustainability.

A second problem stems from the long-term and excessive use of pesticides in some regions causing significant pollution of soil and water resources (Sloggett, 1981; Strange, 1988; 1989). This agrichemical pollution is being linked to serious ecological and human health problems such as the contamination of drinking water supplies, reduction in soil productivity, and increased introduction of carcinogens into the ecosystem (Strange, 1984b; Coye, 1986). Increasing public awareness and concern about these problems is creating pressure on farmers to reduce their use of pesticides. As well, pressures arising from decreasing levels of soil productivity and pest control, and thus overall biological sustainability, are being brought to bear on farmers in both financial and social contexts.

A third problem with routine pesticide applications has been the increase in pest resistance to chemicals used to eradicate them. Outbreaks of secondary insects have also been a problem attributed to sustained pesticide use and have become a significant problem in some areas and with some crops (Croft, 1983).

A problem which stems indirectly from routine pesticide use, exists in trying to introduce new methods of pest control. Applying pesticides to control pests is a relatively simple technology and requires little in the way of information about field level biological and physical phenomena. The imposition of alternative methods including the more judicious use of pesticides, integrated pest management, biological control, crop rotations, etc., requires more information and more effort to gather and analyze that information. Getting growers to change from their current, simple methods of pest control to more complex systems has proved to be problematic in the past (Rajotte, 1989). This has been a limiting factor in the effectiveness of alternative, non-chemical methods of pest control.

During the 1970s a technology known as integrated pest management (IPM) began to gain prominence in U.S. agriculture (Allen and Rajotte, 1989). IPM was the first cohesive attempt to substitute biological and technical information for chemical methods of pest control. IPM sought to integrate existing means of control with a broader understanding of the interactions of plant, insect and soil physiologies, pest and crop histories, and climatic variables to reduce the amounts of pesticides used. Although IPM has existed for over 60 years it has only begun to be widely adopted in U.S. agriculture during the last 10 years (Blair, 1982; Rajotte et al., 1987b). IPM provided the framework for using production information in pest management decision-making. However, the management of large volumes of data and the efficient sorting through complex pest/crop scenarios to arrive at an optimum decision became problematic.

The introduction of a new electronic decision support technology known as expert systems may, by allowing efficient data management and scenario sorting, enable farmers to more readily adopt IPM-oriented practices. This computer based technology combines state of the art production knowledge with specific farm and field level crop histories and data, as well as high resolution site-specific weather information. Expert systems decision support has the potential to reduce the use of chemical inputs by substituting interpreted, highly integrated, and timely information for these inputs in an accessible format.

The expert systems decision support technology may provide farmers with access to a dynamic range of alternative solutions to specific, up-to-the minute problems that may help them to reduce chemical inputs. However, several questions remain. Which farmers will be inclined to adopt such a technology? Which farmers will be able to effectively adopt this computer based technology? What structural, demographic, or addititonal factors may be related to effective adoption of the technology? Lastly, what actual impact would widespread adoption have on the implementation of IPM programs which may result in pesticide use reduction?

This research will look at an ongoing pilot field test of an expert system known as

ApplES in order to explore which farmers will adopt and use this technology and with what consequences for the implementation of IPM programs which may result in pesticide use reduction.

This research seeks to illumine what role that information technologies, known as expert systems can have on the generation of more sustainable agricultural systems. By evaluating the adoption of an expert system for apple production by growers who are field testing this research will attempt to learn a) which farmers will adopt and use this technology and with what consequences for the implementation of IPM programs which may result in pesticide use reduction and b) what ultimate contribution expert systems may make toward producing sustainable agricultural systems.

The need for a sustainable agriculture will be outlined as defined by the research in order to demonstrate how expert systems technology may fit into such production strategies. The study will then test a component of a diffusion model proposed by Audirac and Beaulieu (1986) which attempts to link the access conditions of a given technological innovation to adoption of that innovation. This component of the model will be tested using the IPM oriented ApplES expert systems as the technological innovation. Twenty-seven apple growers in Pennsylvania were given the ApplES software to use in the field test. Growers completed a baseline survey and usage patterns and any change in production practices of each grower are being monitored over time. Socioeconomic and attitudinal data will be analyzed in order to discover whether the structural characterisitics of an apple growing operation or the grower's attitudes/beliefs are the most valid and reliable indicators of who will adopt this expert system technology and with what consequences. In order to make this determination, survey data gathered from the cooperating growers measuring both structural/personal characteristics and attitudes of the grower about selected issues will be related with various measures of adoption and use of the system.

Chapter 2

NEED FOR SUSTAINABLE AGRICULTURE

> Agriculture has become both a capital and an energy intensive activity. Without major technological breakthroughs, however, the available resources will not be sufficient to meet current or expanded needs of the agricultural production system. Therefore, it is unsustainable.
>
> (Edens, 1985)

With the advent of so-called modern agriculture, hereafter referred to as industrial agriculture, in the U.S. during the 1940s, farming began to evolve into a highly mechanized activity increasingly dependent upon an uninterrupted availability of fossil fuels and other resources. The nature of industrial agriculture has been to transform self-sufficient, regionally oriented farming into commercialized export-oriented agribusiness. This development also transformed U.S. agriculture into an inherently unsustainable enterprise in that it became predicated upon the depletion of nonrenewable resources and the substitution of synthetic, petroleum-derived agrichemicals for pest control and plant nutrient management.

While industrial agriculture has enjoyed undisputed improvements in increasing agricultural output, decreasing labor costs, and initially decreased input costs, the unsustainable nature of it has begun to generate problems and bring costs to bear that were not obvious two decades ago. These problems and costs are at once ecologic, economic, and social (Jackson, 1984; Douglass, 1984).

In order to discuss the need for sustainable agriculture I will review the literature on sustainable agriculture in order to define what it is and how it relates to current ecological and socioeconomic problems in U.S. agriculture today. Next, I will outline the problems of industrial agriculture that could be addressed by sustainable agriculture. In so doing I will be defining what sustainable agriculture is not. Finally, I will discuss the relevance of sustainable agriculture for apple production.

Overview of Sustainable Agriculture

There is no definitive answer to the question, "what is sustainable agriculture. As Douglass (1984) points out, agricultural sustainablity can be defined in different ways and sought through different means. Douglass has identified three basic schools of thought which come to be known as sustainable agriculture: 1) the food-sufficiency school, sustainability as supplying enough food to meet everyone's needs; 2) the stewardship school, sustainability as ecology; 3) and the community school, sustainability as the effects of agricultural systems on the structure and orgainization of rural life (Douglass 1984).

While this typology is somewhat simplistic it does serve to identify three common components of most of the definitions of sustainable agriculture in the literature, which in sum would be, agricultural systems that are ecologically sound, economically viable, and socially just. Sustainable agricultural emphasizes a long-term over short-term perspective, both in creating solutions to agricultural production problems and with regard to the ecological impacts of farm practices.

While the specifics of what sustainable agriculture is vary among the schools of thought identified by Douglass (1984), there exist three primary areas of convergence. Proponents of sustainable agriculture all find soil conservation to be a top priority in the designing of a sustainable system (Berry, 1977; Jackson, 1980; Douglass, 1984; Breimyer, 1985; Bidwell, 1986; Hecht, 1987; Altieri, 1987; Strange, 1989). This is accomplished in a number of ways most notably the halting of soil erosion by use of crop rotations and the creation of farming systems which emphasize species diversity rather than monocultures (Altieri et al., 1984; Gliessman, 1984). Use of these and other agronomic methods also reduces dependence on synthetic fertilizers (Lockeretz et al., 1981; Sahs et al., 1988).

Another common priority among sustainable agricultural theorists is the reduction in use of pesticides to control insects, diseases, and weeds and the substitution of biological controls and programs of integrated pest management (Jackson, 1980, 1984; Douglass, 1984). Synthetic pesticides are petroleum derived compounds whose use has increased threefold between 1964 and 1985 (Sachs and Higdon, 1989). The use of pesticides has caused groundwater contamination and is currently raising questions concerning food safety among consumers (Strange, 1988; Sachs et al., 1987). The effectiveness of pesticides in controlling agricultural pests has been steadily decreasing due to pest resistance and destruction of beneficial predator species, causing significant crop losses for farmers (Dover and Croft, 1984).

A third priority identified in a majority of the literature concerns increasing agricultural productivity as opposed to production (Strange, 1984, 1989; Breimyer, 1986; Madden, 1986, 1988; Altieri, 1987; Allen and Van Dusen, 1988). Emphasis here is placed upon increasing the net income of the farming operation through reduction of purchased inputs and various other costs of production. By reducing dependence upon purchased inputs, smaller scale producers are able to remain competitive with larger producers who are better able to take advantage of capital intensive production technologies (Strange, 1984, 1989; Madden, 1986, 1988; Norgaard, 1987).

These primary areas of convergence reflect the primary goals of sustainable agriculture outlined above: ecological soundness, economic viability, and social justice. It is further instructive to view them in light of current problems facing modern, industrial agriculture.

Ecologic, Economic, and Sociological Problems of Industrial Agriculture

Historically, farmers and agricultural researchers have relied on technological solutions to problems of agricultural production. Farmers utilize capitial intensive technologies such as large-scale, machinery, computers, synthetic fertilizers, and chemical pest control strategies to produce crops and livestock. The farm ecosystem as well as the socioeconomic context of agricultural production has been drastically changed by these and other technologies. Awareness of the ecological consequences of the technologies and methods of industrial agriculture have increased in recent years. Soil erosion, depletion of water tables, pesticide resistance, ground water contamination, and questions about food safety are all outcomes of the industrial agricultural production system (Dahlberg, 1986.)

An increasing amount of evidence suggests that industrial agriculture has depleted significant stocks of the nonrenewable resources which farming is dependent upon. These nonrenewable resources most notably include farmland and groundwater (Allen and Van Dusen 1988).

Farmland is being lost and used up through soil erosion, salinization, soil compaction, loss of soil fertility, and depletion of nutrients resulting from the excessive plowing and harvesting permitted by increased mechanization and large subsidies of synthetic fertilizers (Altieri et al., 1984). The resultant losses of soil nutrients has been compensated for with large inputs of petroleum based fertilizers, particularly as a source of nitrogen. Excessive applications of these fertilizers has significantly contributed to the salinization of farmland in some areas, causing soil poisoning, crop losses, and reduced yields (Cox and Atkins, 1979:300-308).

The excessive use of chemical fertilizers and pesticides has also led to pollution of groundwater resources (Sachs and Bowser, 1988; Strange, 1989) affecting both farm and nonfarm populations directly. In Nebraska it is estimated that approximately one half of the 800 municipal water systems have been contaminated by excessive fertilization and livestock wastes, while in Iowa one-third of the state's wells have been found to be contaminated by pesticide residues (Strange, 1988; 1989).

The amount of groundwater available to agriculture has also diminished under industrial agricultural schemes due to a 300% increase in groundwater use for irrigation during the past 30 years (Allen and Van Dusen 1988). Continual overdrafting of groundwater reserves has led to reduction in groundwater and surface water supplies as well as their degradation in quality (Worster, 1984). As usable supplies are diminished, agricultural operations dependent upon irrigation must bear increased costs for drilling and pumping or contend with decreased yields. (Worster, 1984).

The dependence of industrial agriculture upon chemical fertilizers and pesticides is also precariously tied to the depletion of fossil fuel reserves. These inputs are derived largely from petroleum and natural gas, both of which are nonrenewable resources. In addition, the substitution of fertilizers and pesticides for cultural methods and controls was developed during times of relatively inexpensive fossil fuels (Perelman 1977; Pimental and Pimental, 1986; Lockeretz, 1977; 1984; 1986). During the energy "shortages" of the 1970s, prices of fertilizers and pesticides increased dramatically while farm prices remained static (Lockeretz, 1977; 1984). The continued depletion of fossil fuel stocks and the concomitant increase in prices of agrichemicals also indicates the unsustainablility of industrial agriculture (Pimental et al., 1983).

Ecological, Health, and Economic Hazards of Pesticide Use in Industrial Agriculture

The dependence upon pesticides has also caused significant agricultural pollution problems in the form of soil and water contamination (Sachs and Bowser, 1988; Strange, 1989). Research and data on the human health effects of pesticides are still widely debated, but an increasing number of pesticides found to contain known carcinogens are being banned from use (Coye, 1986; Rajotte, 1989). These factors have created an increased interest in pesticide use among the consuming public, which has generated new pressures on farmers.

While excessive accumulations of pesticide residues in soil and water resources and a growing concern among the public about food safety add to the unsustainability of the present industrial system, pesticide use poses serious on-farm biologic and economic problems for farmers as well. Agricultural chemicals alter the agroecosystems in which they are applied, and heavy dependence on these chemicals has resulted in numerous problems. Research has shown a tendency of pest insects, diseases, and weeds to become genetically resistant to specific pesticides over time. At the same time non-target organisms, including natural enemies of the pest, are often destroyed. The resurgence of pest populations and emergence of secondary pest populations has also been caused by use of pesticides (Allen and Rajotte, 1989). In order to control pest species, increased amounts of pesticides are required over time, which increases the cost of production and may exacerbate resistance to the pesticide. With increasing numbers of pesticides being removed from the market and new, more expensive pesticides slow to be approved for use, farmers face difficult choices in controlling pests in an economically efficient fashion. Genetic resistance, continued emergence of secondary pests, and increased costs of new chemicals make heavy dependence on pesticides unsustainable.

Ecologic and Economic Problems Associated with Apple Production

The generalized problems of industrial agriculture outlined above are associated with apple production as well. However, the nature and structure of apple production presents various problems specific to tree fruit production.

Most of the characteristics of apple production which set it outside the criteria of a sustainable production system center directly on pesticide use and thus indirectly on economic viability. Because apple production utilizes perennial crops in the form of deep-rooted trees, resource depletion on the farm level is not significant. Soil erosion is not typically a problem, because of the soil retaining nature of tree roots and a relative lack of plowing. Groundwater reserves vary in how they are effected from a depletion standpoint as irrigation is not yet typically utilized for apple production in the eastern U.S. Groundwater is, however, used extensively for irrigation in the more arid apple growing regions of the western U.S. Soil applied fertilizers used in apple production are only applied every 2-5 years on average and at low rates. Apple production is, however, highly fossil fuel dependent and that dependency will be discussed below.

Pesticide Use in Apple Production

Moreso than any other food crop produced in the U.S. apple production relies on the use of numerous chemical pesticides including insecticides, fungicides, and herbicides. The high susceptibility of apples to insect and disease damage, as well as consumer demand for blemish free fruit accounts for this degree of pesticide use. Chemicals are also used to thin fruit on the tree, control ripening, and to enhance appearance. In 1978, 96%

of the U.S. apple acreage had insecticides applied, more than any other crop. In addition, fungicides were used on 90% of apple acreage and herbicides were used on 45% of apple acres (USDA, 1985).

The primary reason for apple producer's heavy reliance on chemical pest control is tied to the significant vulnerability of the apple tree and fruit to dozens of insect and disease species (Croft,1983). Apple producers rely on chemical pest control not only to prevent reductions in yield caused by insects and disease, but also in order to maintain the cosmetic levels which consumers have come to expect in fresh apples.

Historically, apple producers have used chemical means of pest control since the early 1900s (Allen and Rajotte, 1989) but with the advent of synthetic pesticides, such as DDT, in the late 1940s producers began to significantly increase the rate of pesticide applications (Perkins, 1982). This eventually lead to two unexpected phenomena which have had serious impacts on growers. First, the increased use of pesticides, particularly insecticides, induced a genetic response on the part of the pests known as resistance. Insects which did survive insecticide applications reproduced succeeding generations that were increasingly invulnerable to particular insecticides. In addition to insects, fungi, bacteria, weeds, nematodes, and rodents have all developed resistance to chemical pesticides (Dover and Croft, 1984). Secondly, pesticide use encouraged the emergence of new pests by destroying natural predators and parasites as well as target pests (Perkins, 1982; Allen and Rajotte, 1989). Significant apple pests of today such as mites and aphids evolved because of reduced populations of their natural predators (Sachs and Higdon, 1989).

While pesticides were initially successful in controlling apple pests, they have generated what has been referred to as the "pesticide treadmill" (Van den Bosch, 1978;

Altieri, 1987). In order to control pests and effectively manage resistance and the emergence of new pests, growers have had to continually apply increased levels of new and different pesticides. These new pesticides currently are often more expensive, sometimes more highly toxic, and are more difficult to use. In addition, while crop losses are difficult to estimate, Pimental claims that across U.S. agriculture, crop losses from insect pests increased from 7% in 1940 to 13% in 1978 in spite of a 10 fold increase in insecticide use (Pimental et al., 1978).

These patterns of pesticide use undermine the sustainability of apple production on several ecological and economic counts. Increases in pesticide toxicity, application rates, and application frequency necessary to control increasingly resistant pests may be leading to groundwater contamination. In addition, growers are faced with increased concern on the part of consumers about pesticide residues on apples (Sachs et al., 1987; Shabecoff, New York Times 1989; Walmer and Glamser, USA Today, 1989). The recent controversy surrounding the use of a plant growth regulator, Alar, has shown the economic impact which consumer preferences can have. Alar was reported to be a potential cause of cancer in children. In the first nine months following the initial reports about Alar use in apples, the Washington Stat e Red Delicious industry lost an estimated $23.4 million in sales (USDA 1989). This controversy as well as other events such as the banning of EDBC chemicals has created as special visibility for apples in the eyes of the consumer. Pesticides use in apple production is now specifically a major consumer concern.

Whether certain pesticides are banned from use as environmental hazards or are eliminated by consumer awareness, growers face serious problems in effectively and economically controlling pests. The questionable availability, increasing costs of, and decreasing effectiveness of pesticides all threaten the productivity and economic viability of apple producing operations. Continued routine spraying of pesticides threatens ecosystems, groundwater supplies, and human health.

Information Needs of a Sustainable System of Apple Production

> Agriculture is completing its industrialization just as that era is coming to an end.
>
> (Strange, 1984)

The central issue in sustainable agriculture is not maximization of yield but its long-term stabilization. The ability to achieve sustained productivity will require more than modifying conventional practices and technologies. Achieving such an ability will come from the design of innovative agroecosystems that integrate management, the farm-level resource base, and specific environmental conditions (Loucks, 1977).

Strategies which meet the criteria of a sustainable system of agricultural production will be based upon an interaction of factors such as crop species, rotations, row spacing, soil nutrients and moisture, temperature, pests, harvesting requirements, and other agronomic procedures (Altieri et al., 1984.) However, most farmers, including apple growers, often lack the time or capability to integrate all the information embodied in the production factors listed above. In the realm of pest control, apple production is particularly complex with regard to the numbers and interactions of insect and disease pests. Decisions about control must often be made quickly or treated for on a routine basis. Due to their vulnerable economic situation and the lack of information on non-chemical alternatives, most growers make short-term production decisions to use chemcials rather than long-term decisions that might stabilize pest populations (Bird, 1988). Pesticides offer immediate insurance to threats of insect damage, plant disease, and weed competition.

A sustainable production system for apples that reduces conventional dependence upon pesticides requires the integration of high quality, site-specific information. This information can then be effectively substituted for pesticide and other inputs.

Integrated Pest Mangement

One method of substituting cultural practices and information for pest control inputs which has been used successfully in apple production is integrated pest management (IPM). IPM is defined by Apple and Smith (1976) as: a complex set of behavior, decision-making procedures, methods, technology, and values organized to provide efficient alternative methods of pest management. Allen and Rajotte (1989) have described IPM as " a systematic approach to crop protection which utilizes increased information and improved decision-making paradigms as substitutes for purchased inputs to improve the economic, social, and environmental situation of the farm and society as a whole. Moreover, IPM emphasizes the integration of appropriate technologies such as biological control, chemical control and many others."

Furthermore, many empirical studies have documented that when an IPM system is used, costs for controlling pests are either lower than or the same as conventional or chemical methods, that net returns are greater, and that risk as measured by variability in quality or average level of net return is the same as or lower than that found with the conventional control methods (Rajotte et al.., 1987b).

Despite the demonstrable results of the effectiveness of IPM systems they have not been widely adopted by farmers throughout the U.S. (Grieshop et al., 1988; Allen and Rajotte, 1989; Sachs and Higdon, 1989) although interest in IPM has grown during the latter part of the 1980s (Rajotte et al., 1987b). Because of the complex and chemical-intensive nature of apple production, IPM practices are valuable in helping growers to reduce the amount of pesticides used. However, IPM is itself a complex set of activities which tend to get bogged down in the dissemination process (Rajotte, 1989). While adoption rates may be relatively higher among fruit producers than U.S. agriculture in general, IPM is not a universally accepted practice. The pitfalls of implementing an IPM program run from the technical to the socio-economic (Norton and Mumford, 1988). Growers need added technical expertise, information, and education in order to effectively implement IPM systems (Lambur et al., 1985; Greishop et al., 1988; Sachs and Higdon, 1989).

IPM as a technology contributes to the generation of sustainable agricultural production systems in that it meets several of the criteria outlined above regarding sustainable agriculture. It emphasizes the integration of information and biological processes over inputs derived from nonrenewable resources; by reducing use of chemical pesticides, IPM lessens the impacts to the environment and to human health now being attributed to industrial agriculture; and by reducing dependence upon purchased inputs it contributes to the profitability of a given operation.

Clearly, the wide scale adoption of IPM practices would be a significant component in the design of sustainable agricultural systems. However, adoption of these systems has been negligible prior to the 1980s and is not yet what could be described as significant, when compared to other major agricultural technologies. In addition, although IPM has been discussed as a sustainable system it is still presently extensively reliant upon on pesticides. These issues raise important questions as to whether IPM is truly a sustainable practice in its current state, as well as to the appropriateness of considering it a sustainable system in and of itself. While IPM is a strategy for many people seeking more sustainable methods of pest control, it does not go far enough for others. However, IPM is providing useful strategies during the transition to a more sustainable agriculture. Moreover, objectives of the IPM programs can shift after such a transistion is affected. IPM is a process rahter than a static goal. To date profitability has been the main measure of a successful IPM program. However, the IPM process can be successfully used to attain goals of decreased environmental impact or increased sustainability (Rajotte, 1989). Improvements in adoption rates of IPM as well as further reducing reliance upon chemicals are necessary in the context of sustainable agricultural production systems.

Expert Systems as a Tool for Sustainable Apple Production Systems

The need for utilizing various sources of agricultural and on-farm information in a highly integrated fashion in order to reduce pesticide use and improve farm productivity and profitability has been stated. The need for alternative methods of pest control in apple production in the face of increasing pest resistance and concerns about human health has been demonstrated. A case for implementing IPM programs in apple production as one strategy to meet these requirements has been made.

However, the best means for effectively implementing IPM programs for widespread adoption ar e still being discovered. To overcome the initial complexities of converting to IPM, growers require more education, experience, and technical expertise. In addition, the orchardist faces an overwhelming amount of information which s/he needs to assimilate in order to make decisions about production, harvesting, and insect, disease, and weed control. Traditional agricultural information/decision support delivery systems are discipline oriented packages and thus growers must often integrate various information and data for his/her own orchard (Rajotte et al., 1987a). A recent technological development known as expert systems is capable of providing decision support in an integrated fashion whenever and wherever a grower requires it.

Description of Expert Systems. An expert system (ExS) is a computer program designed to simulate the problem-solving capabilities of a human being who is expert in a narrow discipline or domain (Denning, 1986; Coulson and Saunders, 1987). ExS are able to draw and store inferences from information and are thus often called knowledge-based systems. A form of artificial intelligence, ExS are capable of delivering quantitative information, much of which has been developed through basic and applied research, as well as heuristics to interpret quantitatively derived values or for use when quantitative values do not exist (Coulson and Saunders, 1987).

Expert systems technology can be used as a delivery mechanism in a larger decision support system. By computing sequences of symbols which represent different levels in the solution of a problem, the ExS attempts to represent a common problem-solving pattern: "if conditions, then consequences" (Denning, 1986; Rajotte, 1987). Because an ExS remembers its logical chain of reasoning (Rajotte, 1987) it enables a user to query the system about a recommendation or about why certain information is being requested.

In agriculture ExS can be used to integrate the perspectives of individual disciplines (e.g. agronomy, horticulture, entomology, economics) in a fashion that addresses the day-to-day, ad hoc decision-making processes required of modern farmers. Developed correctly, ExS can become a powerful tool for providing farmers with the readily accessible, highly integrated decision support needed to practice a sustainable system of farming.

The ApplES Expert System. An expert system known as ApplES has been developed to help apple growers make better decisions about production, pest control, and marketing. The system integrates various facets of apple production by substituting high quality, integrated, information derived from three sources (current apple production and IPM knowledge; site specific, farm level data; and weather records) for purchased inputs. A primary emphasis of the ApplES system is to decrease the detrimental environmental impacts associated with pesticide and fertilizer use as well as input costs, thereby improving farm profitability and reducing economic risk.

ApplES was designed to view the apple orchard from an ecological perspective, as a complex and highly interdependent system where the altering of one component results in changes in the entire system. The system mimics the way in which a grower must approach problem-solving in his/her orchard, the goal being to consider the orchard as a whole organism and to make management recommendations in a wholistic fashion rather than making individual recommendations based upon independent components (Heinemann et al., 1989).

Two unique characterisitics of the ApplES program are the relative "user friendliness" of the system and a built-in user feedback loop which facilitates the incorporation of grower/user suggestions for improving the system into updated versions of the program (Heinemann et al., 1989; Rajotte et al., 1989). The two versions of the ApplES system (Macintosh and IBM) were designed so that a person who has never used a computer may operate it. Operation of the system can be accomplished without using the keyboard in the Macintosh version. The grower's use of the system is being continuously monitored and evaluated, which allows direct input into how the system is being developed. The software shell being utilized allows modifications to be made quickly so that updated versions can be distributed to growers rapidly. Developers of ApplES felt that these two components were critical to attaining the goals (Heinemann et al., 1989; Rajotte, 1989; Travis 1989).

These two components contribute prominently to the growers being able to input data specific to their own operation as well as up-to-the minute weather data into the system. With this baseline data in the system, growers may query ApplES about specific problems of pest control, soil fertility, and orchard planting. They may also request indepth supplementary information about an individual insect, disease, or weed and they may ask the system to explain the logic behind a given recommendation (Heinemann et al., 1989; Rajotte 1989; Travis 1989; Crassweller, 1989).

Recommendations are usually given with a range of alternatives, where they exist, thus allowing the grower to combine his/her own preferences and experiences with the recommendation being offered by the system. This combined "package of information" is then used to support the decision-making process of the grower in planning a pest control or other strategy. Examples of the screens appearing in the ApplES program appear as Appendix 1.

ApplES as a Tool for Sustainable Apple Production. Effective use of ApplES provides the grower with specific, IPM-oriented information that s/he may not have had in a usable form previously. This information may tell the grower that certain insect pests are present, but not at economically threatening levels which require application of a pesticide or that conditions for a disease infection period are present and should be dealt with by utilizing less chemical intensive preventative measures rather than chemical intensive reactive measures. This information is substituted for the routine spraying practices that might have occurred without this knowledge. Thus, the ecosystem is spared the application of unnecessary pesticides, while the grower realizes an economic savings derived from not applying said pesticides.

ApplES is a potentially effective tool for sustainable apple production for five reasons: 1) it is delivering IPM derived information and solutions to pest control problems, the benefits of which are outlined above; 2) it is providing this information in a very up-to-date and site-specific fashion unattainable by traditional information delivery systems; 3) this information is always readily available to the grower, relieving dependence upon the accessibility of literature, production records, or human experts, thus enabling the grower to make critical, timely decisions whenever necessary; 4) used effectively, it enables apple growers to reduce their usage of chemical pesticides, thus reducing the negative impacts of apple production on the ecosystem; and 5) it provides more profitability for the grower.

However, it remains to be seen whether apple producers will successfully adopt this new agricultural innovation and with what consequences. The examination of certain sociological theories of diffusion of technological innovations is useful in trying to predict how the adoption process of an expert system for apple production might proceed.

Chapter 3

REVIEW OF LITERATURE: THE ADOPTION OF AGRICULTURAL TECHNOLOGIES

> The underlying issue remains the same, however, understanding the diffusion process for one innovation is not a good basis for generalizing to other innovations. The long-run goals of understanding and prediction remain elusive.
>
> (Fliegel and van Es, 1983)

The introduction of new technological innovations into agriculture has been recognized as a major factor contributing to the significant changes in the structure of agriculture (Goss and Rodefeld, 1977; Perelman, 1977; Rodefeld et al., 1978; Goss, 1979; Fliegel and van Es, 1983; Berardi and Geisler, 1984). This technological transformation has been the object of much social science inquiry, especially within the rural sociological discipline. The dominant theoretical framework for analyzing these changes has been known as the diffusion of innovations (Rogers, 1962; Rogers with Shoemaker,1971; Goss, 1979; Fliegel and van Es, 1983; Audirac and Beaulieu, 1986).

Prior to the latter stages of the 1970s, most work on the diffusion of innovations focused upon the process of rapid introduction of new technologies on farms and the subsequent rates of adoption. This paradigm, referred to as the classical diffusion model, was concerned with the individual as the unit of analysis and largely presumed that an individual's attitudes and beliefs were the best indicators of adoption. A further presumption was that technological innovations had equal and positive implications for those who adopted them. Only in recent years has the emphasis shifted to a concern with structural characteristics as indicators, social systems as the unit of analysis, and measuring the consequences of the diffusion of specific agricultural innovations (Goss, 1979; Fliegel and van Es, 1983; Hooks et al., 1983; Berardi and Geisler, 1984; Audirac and Beaulieu, 1986).

Diffusion of Innovations

Diffusion of innovations is a "multidisciplinary theory of planned social change, change (consequences) that is brought about by the spread of new ideas or new technologies throughout a social system," (Goss, 1979:754) wherein an innovation is defined as an idea, practice, or object perceived as new by an individual (Rogers with Shoemaker, 1971:19). Diffusion is the subprocess by which these new ideas are communicated to members of a social system and consequences are the changes that occur within a social system as a result of the adoption or rejection of the innovation (Rogers with Shoemaker, 1971:7). Goss (1979:767) argues that consequences must be thought to apply to any member of a social system, adopters and non-adopters alike.

There have been two prominent theoretical frameworks in sociological thought regarding the diffusion and adoption of agricultural innovations: the classical diffusion model (Rogers, 1962; Rogers with Shoemaker, 1971:7); and consequences of diffusion of innovations (Goss, 1979). Here I review these two models of diffusion and their significance for distinguishing between types of agricultural technologies. Next I analyze a recently proposed diffusion model which asks the question of whether microcomputers in agriculture represent an inherently different and unique type of innovation and thus require a new model of diffusion.

A Review of Two Theories of the Diffusion of Agricultural Innovations

It has been argued by many rural sociologists that a major contributing factor to change in rural areas in the U.S. is the adoption of new and increasingly complex farm technologies and further, that in order to understand the behavior of rural people, one must analyze the factors that affect the adoption of these technologies (Heffernan, 1972; Rodefeld et al., 1978; Goss, 1979; Buttel and Newby, 1980; Lancelle and Rodefeld, 1980; Berardi, 1981; Poole, 1981; Hooks et al., 1983; Berardi and Geisler, 1984).

Perhaps the most significant technological and organizational transformation of U.S. agriculture has occurred during the middle part of the 1900s. During this period rural sociological research focused on what came to be known as the diffusion and adoption process. At that time the research focus was primarily concerned with the process of introducing new technology at the farm level. Significant among these technologies were farm machinery, particularly tractor related implements, and agrichemicals, including pesticides. This period of research peaked during the early 1960s and began to wane along with the urgency of promoting rapid introduction of new farm technologies into American agriculture; the transformation of U.S. agriculture into an industrial agriculture was almost complete (Goss 1979; Fliegel and van Es, 1983).

Diffusion and adoption research lay dormant until the latter part of the 1970s when a shift in the research focus was stimulated by an increased awareness of the social impacts of innovations. The focus shifted from a concern with technology at the farm level to one which deals with the consequences of widespread adoption of that technology at the societal level (Goss 1979; Fliegel and van Es, 1983).

The Classical Diffusion Model

Research on diffusion and adoption of agriculture innovations in the U.S. began during the 1930s (Goss and Rodefeld, 1977; Rodefeld et al., 1978; Berardi, 1981; Fliegel and van Es,1983; Berardi and Geisler,1984) and was eventually synthesized and integrated by Rogers with Shoemaker (1971) into a paradigm which came to be known as the classical diffusion model (Goss 1979; Fliegel and van Es, 1983).

Classical diffusion research evolved from an intellectual tradition which defined sociological phenomena at the micro-level and thus was predisposed to focusing on agricultural technology as a dependent variable, in the context of identifying antecedents of adoption or nonadoption (Rogers, 1962; Rogers with Shoemaker, 1971; Goss and Rodefeld, 1977; Rodefeld et al., 1978; Berardi, 1981; Fliegel and van Es, 1983; Berardi and Geisler, 1984). The farmer was viewed as an actor in a specifically localized situation, responding to outside stimuli that were, at the time, viewed as unquestioned improvements in agricultural technology (Fliegel and van Es, 1983).

Although some efforts were made to specify distinctive characteristics of particular types of technology during the 1940s, 50s, and 60s (Gross, 1949; Gross and Taves, 1952; Wilkening, 1954; Lionberger, 1960; Rogers, 1962) the emphasis was directed toward explaining the diffusion and adoption from an individual, socio-psychological perspective. In other words, adherents of the classical diffusion model sought to predict the adoption of innovations by individual farmers using the behavioral and attitudinal characteristics of farmers themselves (Rogers, 1962; Rogers with Shoemaker, 1971).

The Rogers with Shoemaker (1971) survey of diffusion research showed an overwhelming tendency for diffusion research to make generalizations using the individual as the unit of analysis. This research orientation may have in part lead to a premise of the classical diffusion model which, briefly stated, is that access to information associated with a particular technology is the principle factor affecting the adoption decision (Goss, 1979; Hooks et al.., 1983). This premise was challenged when shortcomings of the model were exposed in a growing amount of diffusion research that began to take place in developing countries during the 1960-70s (Gotsch, 1972; Havens, 1975; Havens and Flinn, 1975; Goss, 1979; Fliegel and van Es, 1983). A new paradigm began to emerge that was concerned about the consequences of adoption of new technologies at the societal level.

Consequences of Diffusion of Innovations

With the development of industrial agriculture, farm-level adoption lost import as a research issue. Agricultural production was being radically transformed by a plethora of chemical, mechanical, genetic, and management innovations. The introduction of these innovations has been responsible for the displacement of a significant amount of farm labor and for the increase in scale of farming operations that remain. Land and capital resources have become concentrated in fewer and more highly specialized production units. As well, new agricultural technologies have created ecological and natural resource problems unknown a generation before (Berry, 1977; Cochrane, 1979; Jackson, 1980; Berardi and Geisler, 1984; Strange, 1989).

The geophysical, social, economic, and political context into which innovations are now introduced is drastically different from that of 40 years ago (Fliegel and van Es, 1983; Berardi and Geisler, 1984). The classical diffusion model has been criticized as conceptually lacking in its ability to adequately explain the relationship between a technology and the structural consequences to agriculture which result from its diffusion and adoption (Goss, 1979; Fliegel and van Es, 1983; Berardi and Geisler, 1984).

Goss (1979) has argued for the further study of the consequences of diffusion of innovations and proposed a framework for the study of consequences that reformulates the Rogers with Shoemaker (1971:318-345) treatment of the classical diffusion model. Goss' model differs in that it takes a sociological rather than individualistic or behavioristic perspective. He argues for utilization of social systems as the unit of analysis, measuring the change that occurs within them. Whereas the classical model is concerned with the consequences of innovations, Goss proposes diffusion/adoption as a structural process, concerned about the consequences of the diffusion process itself (Goss, 1979).

This perspective allows structural factors (such as land, capital, credit availability, farming experience, etc.) to be considered as causes of adoption or non-adoption (Fliegel and van Es, 1983) as an alternative to farmer beliefs and attitudes. Research on the consequences of diffusion also changes the emphasis from that of evaluating the effectiveness of a change agent in stimulating adoption, to an evaluation of diffusion theory itself (Goss, 1979:769).

By taking this broader perspective of the diffusion of technology to include the consequences of adoption, Fliegel and van Es (1983:24) conclude that there is "considerable scope for a sharper focus on types of technology," rather than aggregating all "agricultural technologies" as innovations. This focus allows for distinction between technologies which benefit the individual directly, and those which impact the larger society most directly (Fliegel and van Es, 1983).

Diffusion/Adoption of microcomputers in agriculture

Dillman (1985), in his discussion of expanding information technologies and their potential impacts on rural society, noted that one of the more important issues related to the emerging rural information infrastructure is the ability of individuals to effectively utilize information technologies. He asserts that one of the more critical research issues facing rural sociologists is to ascertain "who adopts what information technology for what reasons and who does not with what consequences" (Dillman, 1985:13).

One of the emerging information technologies discussed by Dillman is microcomputers. The increasing use of microcomputers in agriculture has been noted (Harsh, 1978; Shaffer, 1978; Diesslin, 1981; Fuller, 1982; Bultena and Hoiberg, 1983; Audirac and Beaulieu, 1986). At the farm level, there are currently two types of microcomputer applications. One is for production control, providing labor saving functions, such as automated, computerized livestock feeding systems and irrigation systems that function automatically according to computer programs. The second application provides decision-making support in the form of increased managerial capacities such as record keeping, production planning, feed ratios, or crop budgeting (Audirac and Beaulieu, 1986).

Audirac and Beaulieu (1986:60) argue that the microcomputer will have important future impacts on the structure of agriculture by increasing the demand upon farmers to acquire advanced levels of technological and scientific knowledge. Further, they raise the issue of whether on-farm, computer-related activities will require a capital-intensive operation, which in turn raises questions about the consequences of microcomputer diffusion/adoption (Audirac and Beaulieu, 1986:61).

Audirac and Beaulieu Model

In order to study the diffusion of microcomputers in agriculture, Audirac and Beaulieu (1986) propose a new model of the diffusion process. They have conceptualized the diffusion of innovations as a structural process, affected by what they define as "access conditions." These access conditions result from (1) research and development of technological innovations, (2) the intrinsic characteristics of the technology, and (3) the distributional characteristics of the innovation. The Audirac and Beaulieu thesis is that potential adopters of microcomputer technology will respond more to access conditions than to attitudinal variables (Audirac and Beaulieu, 1986:60).

In setting forth their model, Audirac and Beaulieu (1986) draw from Brown's (1981) market and infrastructure perspective (MIP) to outline a framework of diffusion/adoption which they describe as " a process by which innovations and the conditions for adoption are made available to individuals and institutions." This they refer to as the "supply side" of the diffusion process (Audirac and Beaulieu 1986:63). In this model the diffusion process consists of three primary activities. First, the propagator of the innovation develops an infrastructure by creating a network of diffusion agencies through which the innovation will be distributed. Next, the agencies use strategies such as promotions, price, and market selection to induce adoption by the target population. Thirdly, the adoption of the innovation becomes possible when the potential adopter's structural/demographic characteristics match the access conditions for adoption (the "demand side" of the adoption/diffusion process (Audirac and Bealieu, 1986:63).

The Audirac and Beaulieu model refers to what Brown's (1981) MIP calls the supply side of diffusion as the distributional characteristics of the innovation; the process and infrastructure set up to make an innovation available for adoption. These distributional characteristics, along with the instrinsic characteristics of the technology itself influence and define the access conditions for adoption of the technology (Audirac and Bealieu, 1986:63).

Audirac and Beaulieu state that the adoption of personal computers in farming is conditioned by the combined effect of three factors: 1) the characteristics of the research and development of the innovation; 2) the distributional characteristics of the innovation; and 3) the intrinsic characteristics of the technology. In the case of the present study the research and development of the innovation (ApplES expert system) was conducted by university research and extension staff, the innovation will be distributed through extension channels, and the intrinsic characteristic of the innovation is knowledge intensiveness, as applied in management applications.

Given these three factors, Audirac and Beaulieu conclude that there is a common point of convergence that make the adoption of personal computers in farming a "firm innovation" (Audirac and Beaulieu 1986:71). Consequently they feel that the characteristics of a farming operation as a business firm provide more reliable indicators of microcomputer adoption than do the personal, behavioral, and psychological orientations that have been relied upon in the past (Hooks et al.., 1983).

It is this conclusion that will be tested by this study with regard to the adoption of the ApplES expert system decision support software: the structural characteristics of an apple production enterprise and the demographic characteristics of the apple grower are more reliable indicators of adoption of the ApplES expert system than are the growers' attitudes toward pesticide use, environmental degradation, human health, and expert systems.

Drawing from nine surveys administered to apple growers who are using the ApplES expert system, four variables measuring use and adoption of the expert system will be related to fourteen variables which measure various structural/demographic and attitudinal characteristics. Ten independent variables were selected from a farm baseline data survey of expert systems users to represent an individual grower's structural/demographic characteristics. Variables such as farm size, farm ownership, pesticide costs, grower education, age, and previous computer experience will be related to the dependent variables measuring use and adoption. Four attitudinal measures taken from the same survey will be related to the dependent variables as well. These variables measure attitudes toward environmental issues, pesticide safety, health risks of pesticides, and expert systems.

The structural/demographic variables were selected to represent the access conditions necessary for adoption of this technology, according to the Audirac/Beaulieu model. According to the model, by examining how well these structural/demographic variables match the access conditions of the technology we cam predict the likelihood of adoption. Specifically, the larger the scale of the operation, the higher the level of education and farm experience of the manager, or the higher degree of computer experience of the manager the more likely is it that the expert system will be adopted. Conversely, operations of smaller scale, operated by lesser experienced managers, or those without previous computer experience would be less likely to adopt this technology, according to the model.

The reliance of the Audirac/Beaulieu model on both structural and personal demographic characteristics seemingly borrows from both the classical diffusion model, with its emphasis on individualistic and behavioristic traits, and the consequences of diffusion of innovations model with its focus on structural processes and consequences.

However, the manner in which the Audirac/Beaulieu model operationalizes the demographic variables lends them more to a construction of a fuller structural conceptualization of a given farm operation as a business firm. For instance, educational level attained, computer experience, or the number of years in farming may be indicators of the level of business structure in a farm operation. The personal demographic characteristics taken as variables in this study are operationalized in accord with the Audirac/ Beaulieu model.

In keeping with the constructs of the classical diffusion model the attitudinal variables were constructed to measure grower concern about the impact of farming on the environment, pesticide reduction, health and safety risks from pesticide use, and confidence in expert systems. These variables are all conceptually related to ApplES and are taken to represent the type of psychological and behaviorial characteristics which the classical diffusion model would hypothesize would explain adoption of the expert system. It could be theorized that a grower with higher scores on these measures could be disposed to adopt the expert system more than one with low scores.

While the Audirac/Beaulieu model discusses adoption as a dichotomous proposition of either adoption or nonadoption, this study differs somewhat in that it will examine varying levels of adoption. These levels will be, for purpose of analysis, categorized as either adoption or nonadoption.

Chapter 4

METHODOLOGY

In this study I will test the component of the model proposed by Audirac and Beaulieu (1986) which links adoption of a technological innovation to the matching of the access conditions of the innovation with the structural/demographic conditions of the potential adopter. This component will be referred to as the "access conditions component" hereafter. This component of the model will be tested using the IPM oriented ApplES expert systems described above as the technological innovation.

Socioeconomic and attitudinal data will be analyzed in order to discover whether the structural/demographic characteristics of an apple orchardist and her/his apple operation or the apple grower's attitudes/beliefs about selected issues are the most valid and reliable indicators of adoption of this expert system technology. The data used in this analysis were obtained from a baseline survey and series of monthly surveys of growers participating in a pilot field evaluation of the ApplES expert system, from feedback during a winter meeting of participants, and from limited interviews and telephone conversations with participating growers.

Implementation of the Field Test and Expert Systems Evaluation

The establishment of the ApplES expert system program in 1987 by researchers from several disciplines at Penn State was described above. In addition to providing apple growers with a tool to assist them in integrating and interpreting production information from many sources, this project has as a goal the development of a paradigm for expert system software introduction into commercial agriculture that can be used in Pennsylvania as well as other states. To reach these ends, a field test and evaluation program was initiated in 1988 in order to determine the usefulness and acceptability of the program to apple growers.

Both the field test and evaluation were quite experimental in nature in that a) such field testing of expert systems had not been done at the time this project was initiated; b) the evaluation was to be ongoing, and would evolve over time, as the technology and the field test matured, in order to accomodate changes wrought by user input as well as programming advances. It was also expected that the evaluation itself would point to unanticipated issues that would require attention after the evaluation had begun. Because no prior model for evaluating expert systems in the field existed and all useful data collection could not be anticipated at the outset, a decision was made to design a great deal of flexibility into the evaluation process and to incorporate mechanisms into it which made grower/user input easily offered and attainable beyond the formal survey process.

In addition to the specific survey questions open ended survey questions led to important discussions with grower/users about the expert system and needed modification. As well, other informal discussions between grower/users and the author, both face-to-face and by telephone, took place throughout the time of the evaluation. In addition, a winter meeting of all participants provided further input from grower/users. Various nominal group discussion techniques were employed during this meeting to elicit grower/user comments, suggestions, and recommendations in a detailed, prioritized fashion. This process provided excellent feedback to systems programming staff for improvements in the system/user interface as well as valuable insights into how the growers were perceiving and using the system.

In the field test itself, twenty-six growers were given the ApplES software to use in the day-to-day operation of their orchards. Eight of the growers who did not own computers were also loaned a Macintosh SE for use during the project. In return, growers agreed to use the software and record problems they encountered, as well as suggestions and criticisms. They also agreed to fill out a detailed farm baseline survey and to be surveyed over the telephone once a month regarding their use of the system.

Because the user/cooperators in this study volunteered for participation, some selection bias occurs in this sample. However, it is not felt that this bias poses significant problems to the validity of this research for three primary reasons. First, the groundbreaking nature of this project; no other growers have had experience with the expert system outside the experimental group. Second, the vast majority of apple production in Pennsylvania occurs in the southeast portion of the state. While variation in scale among operations certainly exists, the favorable agroecological attributes and extant level of specialization combine to create a relatively homogenous apple industry. Third, in selecting participants great attention was given to geographic and scale representativeness from apple producing areas outside the southeast. Last, the sample was selected to reflect all levels of computer experience and ownership as possible. Participants range from a grower who had never used a typewriter to growers who have fully integrated computers into all phases of their apple producing business. While the sample may be biased in that it is somewhat self-selected, it is thought that providing a representative sample of apple producers was more important to the nature of this study.

Description of Sample

The selection of the sample was done with non-random sampling techniques. Initial demonstrations of the expert system were given to growers at extension meetings during the winter of 1987-88. Surveys were distributed at these meetings in order to determine which growers would be interested in participating in the pilot field test evaluation of the system. Over 140 individuals responded to the surveys. The final sample of growers to be used for the field test was selected from the returned surveys by the extension specialists involved in development of ApplES, with input from county extension agents. Twenty-three growers and three field consultants were selected to participate in the field test evaluation. The criteria used for selection were based upon achieving a diverse sample that represented the spectrum of apple growing operations in Pennsylvania. Characteristics such as the acreage, yields, and the geophysical location of an operation, as well as a grower's age, education, and experience with computers were considered in selecting the sample.

It must reiterated however, that this sample consists of growers who volunteered for the project which engenders some selection bias. While this fact will be duly noted in the analysis of results it is not considered to be a significant drawback given the experimental and unique nature of this research.

Data Measurement Procedures

The ongoing evaluation of the field test has been conducted with two different types of grower surveys. The baseline survey collected farm level data about each grower and her or his operation. This survey was administered once at the outset of the field test. The periodic survey documents each grower's use of the system and has been administered each month throughout the growing seasons of 1988 and 1989.

In addition a strong emphasis of the project has been to actively incorporate the cooperating growers into the feedback loop of systems development and modification. Grower input has been systematically solicited and growers have been frequently updated with the project's progress in the following manner: direct communication with researchers; use of modified and updated versions of the software; and discussions during a meeting of all project participants in the winter of 1989. Feedback received from growers have provided invaluable insights and suggestions for improvement not only of the software itself, but in the evaluation process as well.

Description of the survey instruments used

A periodic survey of system use was administered by telephone during each growing season for 1988 and 1989. In 1988 the survey was administered only three times during the growing season due to delays in the production of the actual expert system software and its subsequent distribution to participating growers. During 1989 the survey was administered beginning in April and continued for each of the five months of the growing season prior to the beginning of the harvest. The data presented from the periodic survey is based on eight monthly surveys administered over the second half of the 1988 growing season and the entire 1989 growing season.

This survey was designed to track grower usage patterns and to monitor the following changes over time: which growers were using the system and how intensively; for what purpose(s) is the system was being used; what individual system modules were being utilized; and changes in production practices pertaining to pesticide use and monitoring of orchards for pests. The periodic survey appears as Appendix 2.

The growers were contacted by interviewers during the first week of each month and asked for data pertaining to the previous month's use. During the 1988 growing season growers responded to questions asked by the interviewers over the telephone. Interviewers experienced great difficulty in reaching growers at convenient times in order to survey them. The response rate was lower than expected (78.1%). During the 1989 growing season this approach was modified in response to grower feedback. A copy of the survey form on which the interviewers collected the data was mailed to each grower at the beginning of the month for which the data was being collected. Growers filled out the survey forms prior to the fifth of the following month so that the information could be accessible to whomever answered the telephone when the interviewers called. This system functioned quite well, took less of the growers' time, and as a result, the response rate improved dramatically (87.7% throughout 1989).

The baseline farm data survey was created by the author with input from researchers and specialists in rural sociology, entomology, horticulture, plant pathology, and agricultural economics. The purpose of this survey was to obtain information pertaining to grower age, education, farm tenure, agricultural experience, computer experience, decision-making processes, information sources, as well as attitudes towards pesticides, environmental issues, human health issues, and expert systems. In addition, information was collected on the structural characteristics of each individual farm: crops and livestock produced, crop acreages, apple yields, crop and pest histories, labor requirements, and farm financial status.

The baseline survey was administered by telephone interviewers during the early part of the 1988 growing season. Growers were informed of the baseline survey, and the types of information which would be sought, at the time they were invited to participate in the project. A follow-up letter was sent to each grower two weeks prior to initiation of the survey process reminding them that the survey would take approximately 45 minutes and might require the accessing of certain basic farm records. One week later growers were contacted by telephone in order to set up a convenient time to conduct the survey in the following week.

In spite of the pre-survey notification response to the survey process was very slow and took three months instead of the intended three weeks. Some growers appeared to be reluctant to spend the amount of time needed to complete the survey and others were reluctant to provide the kinds of information being sought. Interviewers were repeatedly put off to future times. Attempts to survey growers continued until the onset of the harvest at which time it was temporarily suspended. Immediately following completion of the harvest the survey was sent, along with a letter stressing the importance of the data to the entire project, to the remaining growers. This approach was implemented based upon feedback received from several growers who felt that it would be easier for them fill the survey out and return it by mail. This approach yielded additional, but not a complete response. Two follow-up letters were sent during the January and February of 1989 to the remaining growers. The data described here results from 19 of 23 (82.6%) growers. The three consultants were not surveyed for the baseline data as they do not operate individual farms. They did provide use data in the periodic surveys. The baseline survey appears as Appendix 3. The data utilized for this research are described below.

The dependent variables are based on responses to the periodic survey and will measure the level of adoption of the expert system by the growers. Two of the dependent variables from the periodic survey are taken to measure one form of adoption here referred to as "actual use of the system." "Actual use of the system is" operationalized by: 1) the total number of times the system was accessed by each grower and; 2) the total hours each grower used the system. These variables have been derived by summing the total number of times used and the total hours used from all eight periodic surveys. For purposes of analysis growers who have accessed the system less than 16 total times will be classified as "low" users and those accessing 16 total times or more will be classified as "high" users. Sixteen is used for the cut-off as it represents an average access of two times per month. Similiarly, for hours used, less than eight total hours is classified as "low" use and eight or more hours as "high" use. Eight hours represents one hour of use per month.

Two other variables taken from the periodic survey measure another form of adoption here referred to as "change in production practices." "Change in production practices" is operationalized by the responses to two questions: 1) "Has the use of the system changed your spray practices or other practices in the past month?" The possible responses to this question being "no change," "some change," and "great change." Responses were scored as "no change"=0 and "some change=1, with a possible score ranging from 0-8. (Only one response was ever reported as "great change." This was scored as "some change.") These scores were then summed for analysis with scores of 0-1 classified as "low" change and 2 or more classified as "high" change; and 2) "Did use of the ExS stimulate you to more closely monitor your crop (for pests)?," with the possible responses being "yes" or "no." Responses were scored as "no "=0 and "yes"=1 with a possible score ranging from 0-8. These scores were then summed for analysis with 0-2 classified as "low" monitoring and 3 or more as "high" monitoring.

The "actual use of the system" measures and the "change in production practices" measures will be related with selected variables which measure: structural characteristics of each operation; demographic characteristics of the grower; and grower attitudes about selected issues. These variable will be taken from the baseline survey, discussed below.

The independent variables selected from the baseline farm data survey are of three types. The first type is derived from farm structural characteristics: 1) total acres in operation; 2) total acres of apple orchards in operation; 3) average yields per acre in bushels; 4) pesticide costs per acre; and 5) type of farm enterprise ownership. The second type pertain to grower demographic characteristics: 1) age of grower; 2) level of education of grower; 3) number of years in farming; and 4) prior experience with computers. The third type of independent variable is constructed from the questions which measure the grower attitudinal responses to four series of questions. These series deal with the following issues: 1) grower attitude toward the environmental impacts of farming; 2) grower attitude toward the environmental impacts of pesticides; 3) attitudes toward perceived risk of pesticides on human health; 4) opinions about characteristics of expert systems.

Grower Demographics. Selected demographic characteristics about each grower were collected in the following manner. Grower age was determined by asking the age of the primary decision-maker of each operation. Growers were asked the number of years that they had been involved in farming. The level of formal education of each grower was ascertained by asking growers to respond to a six point nominal scale ranging from "some high school (or less)" to post graduate study. Growers were asked to rank their previous experience with computers as "none," "very little," "some," or "extensive."

Farm/orchard Structural Characteristics. Data was also collected on the structural characteristics of each operation. Growers were asked the total number of acres which they farmed, as well as the total number of acres planted in apples. Growers were asked to report how many bushels of apples per acre they produced. Growers were asked a variety of questions concerning their spray application and pest scouting practices.

Description of Questions Measuring Selected Grower Attitudes. According to the Audirac and Beaulieu model there has been too much reliance on individual attitudes and beliefs as indicators of the probability of adoption. A series of questions were asked of growers that pertained to: 1) generalized issues of the environmental impacts of farming; 2) the health risks associated with pesticide use; 3) the impact of pesticides and other purchased inputs used in apple production on the environment; 4) the grower's opinions about effectiveness of expert systems. In each series of questions, growers were responding to a nominal scale that ranked their concern about or the relative importance of each item (see Appendix 2).

The series of questions pertaining to farming and the environment consists of five issues for which growers were asked to rank the importance. The five issues were: 1) profitability in agriculture; 2) protecting water quality; 3) conserving soil from erosion; 4) effects of pesticides on workers; and 5) drift of agricultural chemical sprays. For each question the responses were assigned a score ranging from 0-4 for "not important" to "very important."

The series pertaining to the health risks associated with pesticide use asked the growers to respond to the question, " Are you concerned that the use of agricultural chemicals pose a health risk?": 1) in the nation; 2) in Pennsylvania; 3) in your county; 4) on your farm. For each question the responses were assigned a score ranging from 0-4, "not at all concerned" to "very concerned."

For the series pertaining to the impact of pesticides used in apple production on the environment, growers were asked to respond to nine statements by ranking the degree to which they either agreed or disagreed with it. For each question the responses were assigned a score ranging from 1-5 for "strongly disagree" to "strongly agree." The statements which the growers were asked to respond to are: 1) I am confident that agricultural pesticides, if used as directed, are not a threat to the environment; 2) We cannot be too careful when it comes to putting new pesticides on the market; 3) Should groundwater supplies become contaminated, I am confident scientists will develop ways to purify them; 4) We already have too much regulation on the use of agricultural chemicals; 5) So little pesticide residue ever enters the groundwater, it could never pose a health risk for humans; 6) Instead of worrying about the effects of pesticides we should spend more effort in solving other problems in farming; 7) Although some farmers could reduce pesticide expenses by more precise applications, for me these savings probably would not justify the added time, cost, and effort; 8) Pollution control requirements have gone too far; they already cost more than they are worth; 9) Protecting the environment is so important that the requirements cannot be too high, and continuing improvements must be made regardless of the cost.

The final series pertains to growers' opinions about the effectiveness of expert systems. Growers were asked the question, "From what you know now about expert systems, if you were given the job of recruiting other farmers for participation in an Expert Systems program, how would you rate the following selling points:" For each of the 13 statements the responses were assigned a score ranging from 0-3 for "not important" to "very important" or "no opinion." The statements which the growers were asked to resond to are: 1) helps me select the best chemicals for the pest problem; 2) always available to give a recommendation; 3) recommendations are specific to my situation; 4) the system is easy to use; 5) the system gives reliable recommendations based on the best information available; 6) the system provides a range of alternatives to any given problem; 7) helps control yield and quality loss; 8) increases farm profits; 9) involves reduced use of pesticides; 10) reduces environmental damage; 11) gives an unbiased opinion of pest problems; 12) frees you to use your management skills elsewhere; 13) reduces chances of low yields and profits.

Methods of Data Presentation

The data collected from the growers is presented in several forms. First, the growers will be described in terms of the demographic, structural, and attitudinal characteristics outlined above. Next, the growers' expert system use patterns and practice changes will be described. The variation in grower use will also be described.

Due to the small, non-random sample and the experimental nature of this study, sophisticated statistical tests would not be appropriate. The limited sample does not allow for any multivariate analysis. Instead, the independent variables derived from the baseline survey data will be related in a bivariate fashion with the dependent variables in order to describe who is using the system and who is changing practices, in terms of structural/demographic and attitudinal characteristics. While the sample size does not provide a sufficient N to obtain significance using a simple Chi Square test even in bivariate analysis, these relationships will generate descriptive relationships that can be examined as indicators of who is likely to attempt to use the expert system and ultimately to adopt it.

These relationships will provide the basis for a discussion of the validity of the access component of the Audirac and Beaulieu model. Chi-Square will be reported where significant.

Chapter 5

RESULTS OF THE STUDY

The material presented in this chapter is divided into two major sections. The first part of the chapter characterizes the growers in terms of their actual use of the system, their practices change patterns, and general individual and farm background. The second section reports the relationships between the use/practice data and the personal/farm data.

System Use and Practice Change Characteristics of Growers

In this section I will present characteristics of actual grower system use and practice changes resulting from use of the system as documented and tabulated from the eight periodic surveys.

General system useage patterns

The number of times and amount of time which the expert system is used are important indicators of adoption of the expert system. However, contrary to what the model might predict the data do not show an adoption/nonadoption dichotomy, rather a continuum of varying levels of intensity of useage. Only 7.7% of the user/growers did not use the expert system at all. Useage varied from less than once a month (19.2%) to four or more times per month (23.1%).

In Table 1 are displayed two measures of the frequency of use of the expert system, the total number of times which individual growers accessed the system and the total number of hours they used the system. Both measures are summations of the data from the eight one-month periods from which the study collected data. All 26 participants are included in these measures. Table 2 displays two measures of the frequencies of changes induced by use of the system.

The first measure, the number of times which the growers accessed the system, represents the number of times which an individual grower actually turned on and used the system, regardless of the duration of the session. This measure shows that 7.7% of the growers did not use the system at all, 53.8% of the growers used the system less than two times per month, and 23.1% used it four times or more each month.

The second measure in Table 1 represents the total number of hours which the system was actually used by the growers. Again, 7.7% did not use the system at all, 42.3% of the growers utilized it for less than six hours, and 26.9% used it for more than 10 hours.

Total use of and total hours using the system varied a great deal by year and time of year. Figure 1 shows the percentage of growers who accessed the system each month. This variation is explained in two ways. The growers did not receive the system for use until late July 1988. A very high percentage of growers accessed the system during August 1988 (73.3%) because they were trying it for the first time. Use of the system in August 1989 (31.8%), more accurately reflects the lower need for information a grower would have just prior to harvest. The percentage of growers using the system falls precipitously during October (34.8%) and November (10.3%) of 1988. During 1989 after having the system to review throughout the winter months, system

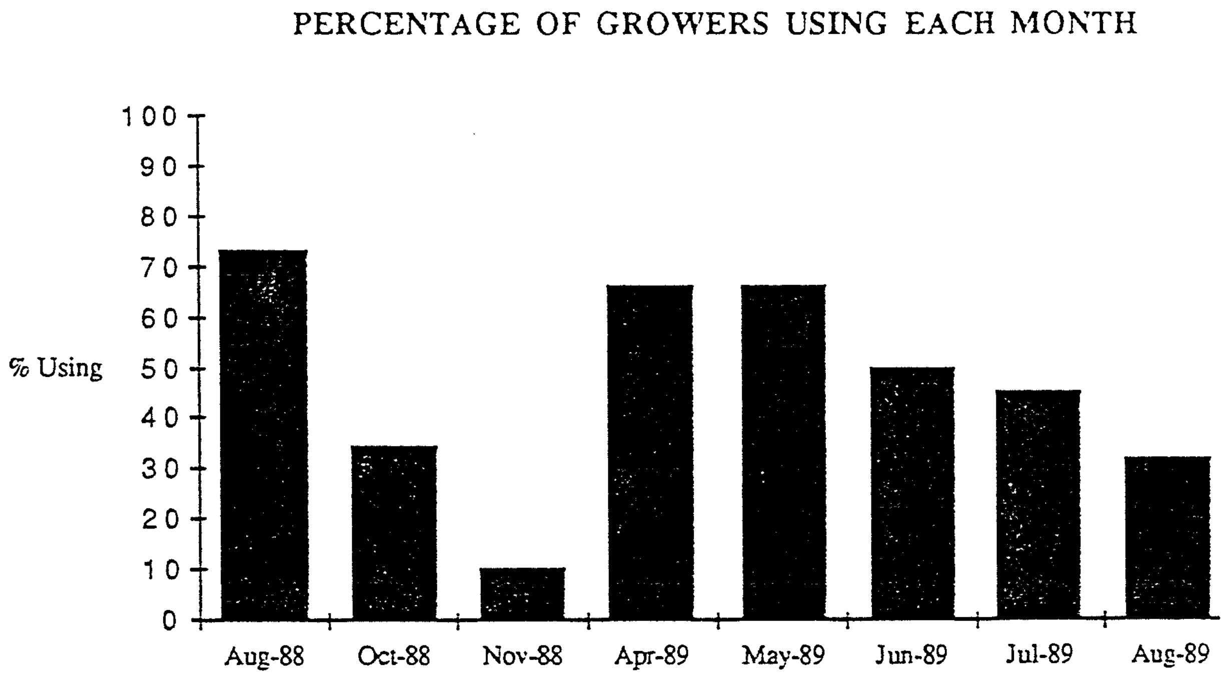
Table 1. ApplES EXPERT SYSTEMS USE CHARACTERISTICS OF GROWERS

System Use Characteristics	Percent of growers (n=26)
Total number of times system accessed by grower	
0	7.7
1 - 9	19.2
10 - 15	34.6
16 - 29	15.4
30- 110	23.1
Total number of hours system used by growers	
0	7.7
1 - 3	26.9
4 - 6	15.4
7 - 9	23.1
10-40	26.9

Table 2. ApplES EXPERT SYSTEMS ADOPTION CHARACTERISTICS OF GROWERS

Production Practice Change Characteristic	Percent of growers (n=23)
Number of times reporting some change in practices, per grower	
0	34.8
1	21.7
2	26.1
3	17.4
Number of times system stimulated increased pest monitoring, per grower	
0	17.4
1	26.1
2	4.3
3	21.7
4	21.7
6	4.3
7	4.3

Figure 1. Percentage of Growers Using the System Each Month



use was high in the spring months and gradually decreases as wase expected due to the heavy IPM orientation of the expert system the higher need for IPM information in the spring months.

Figure 2 shows the variation among all growers for average times accessed per month. Figure 3 shows the average hours of use per month of growers who accessed the system only. In both cases a similiar pattern of variation occurs as was described in the preceding paragraph. Although Figure 2 does show a slight trend toward increasing average system use, it is significant to note the opposite trend in average hours used as shown in Figure 3. On the average growers are using the system fewer times but for longer durations earlier in the growing season than later. This may be explained by the differences in types of information needed at different points in the growing season. Earlier in the season growers are more involved in planning and scheduling for the season's work, requiring more intensive and in-depth use of information sources, whereas during the summer months they are more involved in crop maintenance and troubleshooting and may be doing more of the "double-checking" of their own knowledge mentioned above.

Discussions with user/growers revealed other variables effecting use of the system which were not uncovered in the survey process. Because the expert system itself was in an evolutionary state, with new modules being added to it throughout the course of the field test, some growers remarked that they felt as though they had "fallen behind" if they did not dedicate what they perceived as significant time to relearning the system each time an update was sent out to them. Consequently, their useage would drop off although the reasons for this might not show up on the telephone surveys.

Figure 2. Average times Accessed Per Month: All Growers

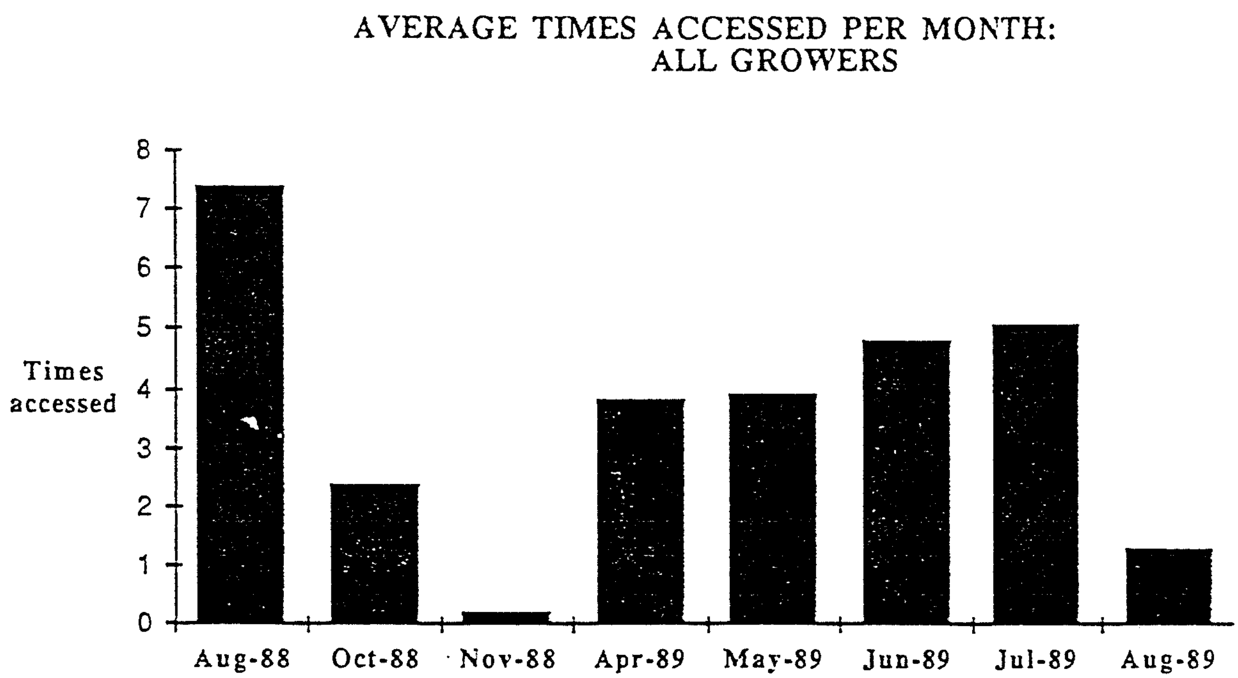
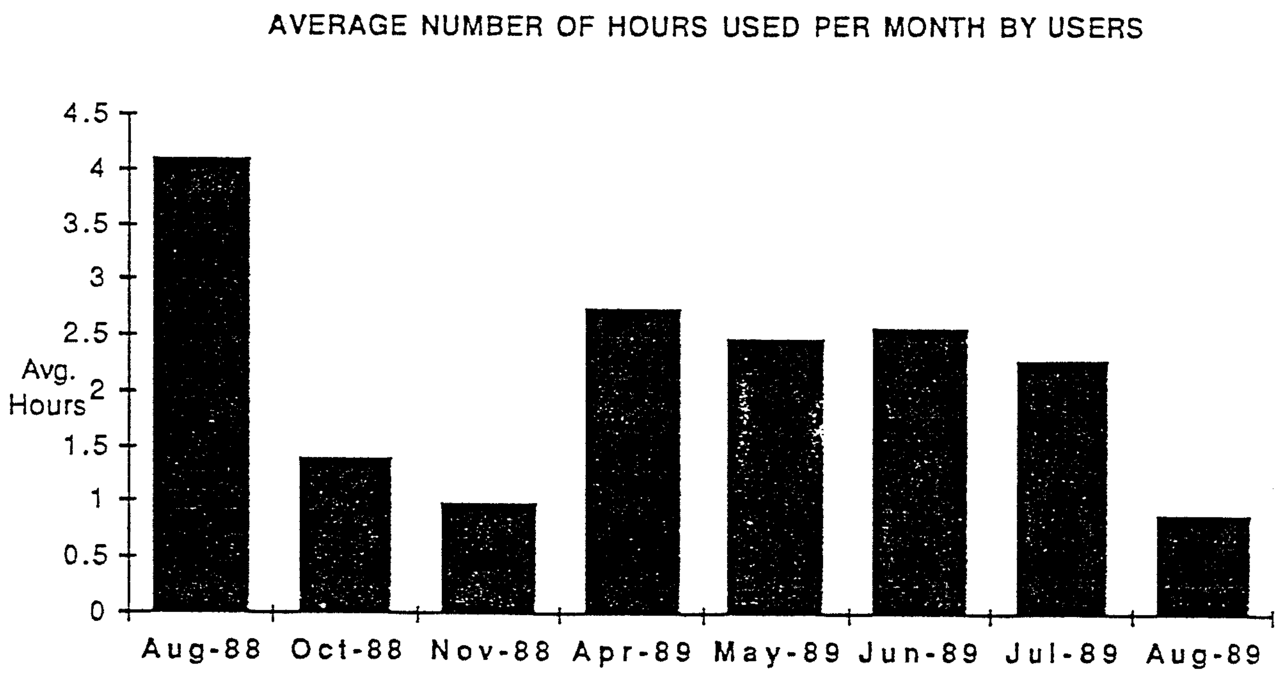


Figure 3. Average Number of Hours Used Per Month: Users Only



As well, some growers with low rates of use indicated that they had never taken the time to really learn how to use the expert system or their computer and had done little more than occasionally skim through the program to see what it was like. This points most likely to inadequate levels of training on use of the system for some participants, particularly for those without a high degree of computer experience.

Another factor which became apparent in conversations during the second season was a result of resource constraints beyond the scope of the project. Prior to the second season far more progress was made in updating the Macintosh version of the expert system than the IBM (DOS) version. Users of the IBM version soon complained of having become more "advanced" than the system and their useage levels dropped until additional modules were incorporated.

Perhaps a more significant insight into usage patterns was gleaned from open ended questions or comments during the telephone interviews. After the initial period of getting acquainted with the system, two opposing patterns of use began to emerge based on grower comments. One group of growers remarked that the system was too cumbersome for quickly finding an answer or piece of information. Another group seemed to be reporting that they were primarily using the system as a quick reference or decision validation regarding a specific problem. In both cases a fundamental lack of understanding of the depth and breadth of the capabilities of the system existed. These comments gave more meaning to the adoption data being collected by the surveys and alerted the evaluators to the need for more educational programming concomitant with the system updates.

The statistical measures cited above as well as the anecdotal evidence discussed, taken together, form one aspect of adoption, use of the innovation. While number of times accessed is an important variable because it shows how frequently the system is being used, the actual amount of time spent using the system may be a more significant indicator of adoption of the innovation. As noted, some growers reported using the system primarily as a quick validation of their own knowledge regarding a decision, thus these growers would report a relatively high number of accesses and a low number of hours used. Conversely, the growers reporting high numbers of hours using the system are presumably more fully engaging the logic of the system in their decision-making process.

General Practice Change Characteristics

The degree to which growers follow the recommendations presented by the expert system is a second aspect of adoption. Table 2 displays two measures of the frequencies of changes induced by use of the system: any change in growers' production practices; and increased pest monitoring. Both measures are derived from the eight monthly surveys, but include only the 23 commercial growers and none of the consultants.

The first measure is a sum of the number of times a grower indicated that use of the expert system had stimulated some change in her/his production practices. Over the course of the eight survey months, 65.2% of the growers indicated that they had changed standard production practices in some way during at least one month. Of these growers, 17.4% indicated some change during three different months of the eight survey months. A significant number of the sample (65.2%) have engaged a new and untried technology and have been stimulated to change production practices as a result. In most cases these practice changes were reported as being some type of reduction in spraying of pesticides.

This type of change in practice occurred very little during the first year. Many growers indicated during conversations or on open ended survey questions that they were not at a point where they trusted the system enough to cut back on pesticide application rates. During the second year, more growers reported that they either were reducing spray rates or not applying a spray at all in situations where they normally would. Comments from these growers indicated that they had achieved a better understanding of the expert system's logic in making recommendations and were more comfortable with the economic thresholds which the system based its recommendations upon.

The second of the practice change characteristics displayed in Table 2 is a sum of the number of times that a grower was stimulated by the expert system to go to her/his orchard and scout for a pest (monitoring). Scouting for pests is considered to be one of the most significant activities encompassed in an IPM program (Rajotte, 1989). A large majority of growers (82.6%) reported that the system stimulated them to monitor their orchard in addition to what they would normally do at least once. 30.3% were stimulated to monitor four or more times. As the majority of pest monitoring occurs during April, May, and June these numbers take on more significance when viewed as a subset of the eight observations. As a measure of adoption of the system, pest monitoring, an integral component of IPM was induced by the expert system in a significant percentage of growers.

Conversations with grower/users indicate that this change in practice evolved gradually at first but became much more frequent as grower/users develop trust in the system. Some growers indicated that they were stimulated to scout for pests because the system required that piece of information in order to make a recommendation. However, several growers remarked that the system helped them to better understand why scouting for pests provided critical information for their decision-making process.

The changes in practices discussed above were occurring as grower/users began to substitute information for purchased inputs, in this case, pesticides. The substitution of information for inputs was stimulated by the expert system, which enabled the grower/user to rapidly collect, integrate and interpret the information with more confidence than previously.

Structural, Demographic, and Attitudinal Characteristics of Growers

Demographic Characteristics

As can be seen in Table 3, the sample of growers (these figures do not include the three consultants) is an average age of 48, which is comparable to the average age of the general Pennsylvania farm population, 49.8 (Sachs, 1982). However, 38.6% of the growers in the sample are between 33 and 44 years of age. The sample is highly educated relative to farmers in Pennsylvania, with 78.9% having at least one college degree. The average grower has been involved in agriculture for 27 years, with 72.7% having 20 or more years experience. The majority (63.1%) of growers have had at least some experience working with computers prior to their involvment in this project, while more than one-fourth (26.3) have had extensive experience.

Structural Characteristics

In Table 4 we can see the structural makeup of the apple orchards involved in the project. The average farm size of the sample (381 acres) is over two and one-half times that of the average farm size for Pennsylvania (146 acres) (U.S. Dept. of Commerce, 1978) while 73.7% of the sample growers operate farms larger than the state average. In terms of

Table 3. Selected Demographic Characteristics of Growers

Demographic Characteristics	Percent of growers (n=19)
Age of the grower	
33 - 44	36.8
45 - 54	31.6
55 & older	31.6
mean=48 years	
Education level attained by grower	
less than college graduate	21.1
college graduate	52.6
post graduate study	26.3
Years grower involved in farming	
9 - 19	26.3
20 - 29	21.1
30 & over	52.6
mean=26.9 years	
Prior grower experience with computers	
none	26.3
little	10.5
some	36.8
extensive	26.3

Table 4. Selected Structural Characteristics of Apple Operations

Structural Characteristics	Percent of growers (n=19)
Total acres in operation	
1 - 129	15.8
130 - 264	21.1
265 - 419	21.1
420 - 549	15.8
550-1000	26.3
mean =381 acres	
Total apple acreage	
1 - 39	15.8
40 - 49	10.5
50 - 89	31.6
90-299	15.8
300-600	26.3
mean=157 acres	
Type of farm ownership	
single family	42.1
incorporation	57.9
Pesticide costs per acre ($)	
25 - 129	25.0
130 - 169	18.8
170 - 249	25.0
250 - 400	31.2
mean=$192/acre	
Average apple yield per acre (bu.)	
275 - 449	22.2
450 - 524	38.9
525 -1000	38.9
mean=520 bu./ acre	

apple production the average orchard in the sample is 157 acres, while the average size commerical orchard in the state is 42 acres (USDA/PDA, 1987). Here, 78.9% of the growers in the sample operate orchards larger than the state average. These data suggest that the farms in the sample are overwhelmingly large-scale operations relative to Pennsylvania.

The average apple yield per acre produced by the growers is indicative of technological and production sophistication associated with large-scale operations as well. The average yield within the sample is 520 bushels per acre, while the state average is 460 bushels per acre. Only one-third of the growers in the sample reported production less than the state average, with one grower reporting a non-bearing orchard at present.

The average cost of pesticide application per acre was $192 per acre. While state averages are not available, Pennsylvania tree fruit extension specialists estimated the average cost to be approximately $200 per acre (Travis, 1989; Rajotte, 1989). A significant disparity exists among the sample growers with 25.0% spending less than $130 per acre on pesticides and 31.2% spending $250-400 per acre. This may be the result of the different pest complexes and climatic zones found in different parts of the state.

The type of farm ownership most prevelant in the sample is incorporation (57.9%), as opposed to single family ownership. The incorporation category includes partnerships and family corporations. In Pennsylvania, fully 90% of farms are owned by single farm families (Sachs, 1982). The very high rate of incorporation among the sample would seem to generally indicate large-scale, business firm oriented, farm organization among the

Distributions associated with all the structural characteristic variables indicate that the growers in the sample are primarily large-scale, business oriented operations when compared with all farms and orchards in Pennsylvania. This is significant with regard to the model proposed by Audirac and Beaulieu. Their theory holds that farms exhibiting characteristics of larger, more firm-oriented operations will be most likely to adopt microcomputer based technologies.

Grower Attitudinal Characteristics Toward Farming, Environment, Pesticides, Human Health, and Expert Systems

Table 5 displays the grower scores derived from the attitudinal questions on the baseline survey. For the group of questions concerned with the environmental impact of farming, 42.1% scored the maximum of 20 while the average score was 17. A score of 15 indicates that a grower felt that each farming/environmental issue was at least "important." Fully 73.7% scored at least 15. From an attitudinal standpoint, these data would indicate that the majority of growers would be interested in exploring methods of reducing the impact of farming on the environment such as offered by the ApplES expert system.

The group of questions concerned with the health effects of pesticide use has a fairly even distribution among the score categories as shown in Table 5. The maximum score of 16 was reached by 36.8% of the growers. A score of 12 indicates that a grower was at least "concerned" about each issue. 31.6% of the growers scored less than 12. Slightly more than two-thirds of the growers (68.4%) are concerned about pesticide use at the farm and societal levels, implying an interest in methods of reducing pesticide applications.

The group of questions pertaining to the environmental impact of pesticide use measures the degree to which growers agree or disagree that pesticides are or are not hazardous to the environment as well as whether they favor changes in policy and/or practice to ameliorate negative impacts. A score of 30 or more indicates at least general support for reducing pesticide use and impacts. In Table 5 we see that a majority (52.6%) scored between 30 and the maximum score of 45. However, 31.6% scored 25 or less, indicative of at least general disagreement with the idea that pesticide use has negative impacts on the environment. Significant numbers of growers indicate a need to change practices as well as public policy in order to reduce pesticide impacts on the environment. However, a significant number also feel that there is little need to implement change in pesticide use practices.

The fourth set of questions asked growers to rate specific characteristics of expert systems technologies as not important, important, very important, or no opinion. Of a possible 39 only 15.8% scored 30 or more. 15.8% of the growers scored 20 or less, indicating a definite lack of familiarity with expert systems of more than one-third of the sample. This was expected as the survey was administered prior to most growers having used the system.

Relationships of Demographic, Structural, and Attitudinal Variables to Dependent Variables

This section will discuss the results of the bivariate analysis of the selected demographic, structural, and attitudinal variables with the two dependent variables of adoption, "actual system use" and "change in production practices." Tables 6-18 are constructed such that each of the four dependent variables are tabulated with a single independent variable in one table. In each case for "Total Times Accessed" growers who have accessed the system less than an average of two times per month or a total of less than 16 times will be classified as "low" users and those accessing 16 total times or more will be classified as "high" users. Similiarly, for "Total Hours Used," less than an average of one

Table 5. Selected Attitudinal Characteristics of Growers

Attitudinal Characteristics	Percent of growers (n=19)
Environmental impact of farming	
score	
11 - 15	31.6
16 - 19	26.3
20	42.1
possible range 9-20 mean=17	
Health risk of pesticide use in agriculture	
score	
4 - 11	31.6
12 - 14	31.6
15 - 16	36.8
possible range 4-16 mean=12	
Environmental impact of pesticide use	
score	
18 - 25	31.6
26 - 29	15.8
30 - 45	52.6
possible range 9-45 mean=28	
Attitude toward expert systems	
score	
0 - 20	15.9
21 - 30	68.2
31 - 39	15.9
possible range 0-39 mean=25	

hour per month or a total of less than eight hours is classified as "low" use and eight or more hours as "high" use. These two variables will be referred to collectively as Use in this section.

In each table the variable "Change in Practices" represents a summed score which is classified 0-1 as "low" change and 2 or more classified as "high" change; and the variable "Closer Monitoring" represents a summed score which is classified 0-2 as "low" monitoring and 3 or more as "high" monitoring. These two variables will be referred to collectively as Change in this section.

Demographic Variables

As seen in Table 6, the age of the grower is related differently to Use than it is to Change. The age categories were created with the mean age (48) serving as the division point. This closely approximates the average farmer age in Pennsylvania (49.3). Although the majority of both young and older growers are in the low use category for both "total times accessed" and "total hours used," older growers are more likely to be high users than younger growers for both use categories. The difference is slight in "total times accessed" (40.0-44.4%) and much more pronounced in "total hours used" (20.0-44.4%). These relationships are reversed in Change with younger growers much more likely to score higher than older in both "change in practices" (50.0-33.3%) and "closer monitoring" (70.0-44.4%).

Table 6. AGE OF GROWER

		Total Times Accessed		Total Hours Used	
		Low	High	Low	High
Age of grower	33 - 48	60.0	40.0	80.0	20.0
	49 +	55.6	44.4	55.6	44.4
		N=19		N=19	

		Change in Practices		Closer Monitoring	
		Low	High	Low	High
Age grower	33 - 48	50.0	50.0	30.0	70.0
	49+	66.7	33.3	55.6	44.4
		N=19		N=19	

The number of years which an apple grower has been involved in farming is related to age and may be indicative of many things including the physical maturity of her/his orchard, scale of operation, age, net worth, and resistance to changing practices. As shown in Table 7, this variable seems to be unrelated to Use but appears to have some relationship to Change. Growers with 20 or more years experience are somewhat more likely to be high users with regard to "total times accessed" (46.1- 33.3%) but slightly less likely with regard to "total hours used" (30.8-33.3%). More importantly, both categories of experience are more likely to be low users in both Use categories. The situation is quite different in Change. While less experienced growers score somewhat higher in "change in practices" (50.0-38.5%), they score significantly higher in "closer monitoring" than do more experienced growers (83.3-46.1%) (significant at the .15 level).

Educational level is thought to be a very important variable in predicting adoption of agricultural technologies. This is even more the case with computer based technologies. While the present sample as a whole has a high degree of education (79% college graduates) there appears to be little relationship between educational level attained and three of the dependent variables, as can be seen in Table 8. With regard to "total times accessed," growers without college degrees are somewhat more likely to be high users (50-40%). However, with regard to "total hours used" 100% of the non-college graduates are low users, while 40% of the college graduates remain high users. As mentioned previously, the number of times accessed is an important variable in that it

Table 7. YEARS GROWER INVOLVED IN FARMING

		Total Times Accessed		Total Hours Used	
		Low	High	Low	High
Years in farming	less than 20 years	66.7	33.3	66.7	33.3
	more than 20 years	53.9	46.1	69.2	30.8
		N=19		N=19	

		Change in Practices		Closer Monitoring *	
		Low	High	Low	High
Years in farming	less than 20 years	50.0	50.0	16.7	83.3
	more than 20 years	61.5	38.5	53.9	46.1
		N=19		N=19	

* $p < .15$
** $p < .10$
*** $p < .05$

Table 8. EDUCATION LEVEL ATTAINED BY GROWER

		Total Times Accessed		Total Hours Used*	
		Low	High	Low	High
Education level	less than college graduate	50.0	50.0	100.0	0.0
	college graduate +	60.0	40.0	60.0	40.0
		N=19		N=19	

		Change in Practices		Closer Monitoring	
		Low	High	Low	High
Education level	less than college graduate	50.0	50.0	50.0	50.0
	college graduate +	60.0	40.0	40.0	60.0
		N=19		N=19	

* $p < .15$
** $p < .10$
*** $p < .05$

shows how frequently the system is being used. However, the actual amount of time spent using the system may be a more significant indicator of adoption of the innovation. Some growers reported using the system primarily as a quick validation of their own knowledge regarding a decision, hence a relatively high number of accesses and a low number of hours used. On the other hand, the growers reporting high numbers of hours using the system are presumably more fully engaging the system even with lower rates of total times accessed.

Among Change very little difference appears to exist between college graduates and non-college graduates. In "change in practices" 50% of the non-college graduates score high, while 40% of college graduates do. In "closer monitoring" more college graduates score high than do non-college graduates (60-50%). With the exception of "total hours used," this difference may be unrelated to Use and Change. This relationship was found to be statistically significant at the .15 level.

Previous experience using computers on the part of the grower is thought to be a very significant variable in terms of predicting adoption of a computer based technology such as expert systems (Audirac and Beaulieu, 1986). This variable is also likely related to education since those with higher levels of education are more likely to have been exposed to computers. Table 9 bears this theory out somewhat. Across all four dependent variables growers in the little or no previous computer experience category are overwhelmingly low users, 71.4% in each case. At least 50% of the growers in the higher computer experience category ranked high in all but "total hours used" (33.3%). The most significant difference between the experience categories occurs in "closer monitoring" where 71.4% of the low computer experience growers score low and 75.0% of the high computer experience growers score high. This relationship was found to be significant at the .05 level.

For the selected demographic variables it is in general the case that the younger, lesser educated, least experienced farmers, and least experienced computer operators are lower users of the expert system in terms of both "total times accessed" and "total hours used." It must also be pointed out, however, that in none of these relationships are there more high users than low users. The situation is reversed when the Change variables are considered. With the exception of previous computer use it is precisely the younger, lesser educated, and least experienced growers which score higher in each "change in practices" and "closer monitoring" relationship. As well, high scorers are a majority in over half of these Change relationships.

The age and education composition of the group may potentially provide an explanation for high system use patterns that exist as younger people with higher levels of education are more likely to be associated with higher degrees of computer experience. The ability to effectively utilize microcomputers is a requisite condition of access to this technology. To this end, the high level of computer expertise within the sample may also be significant in explaining system use variation among growers.

Structural Variables

Total acreage and total apple acreage are important theoretical variables in that size is a indicator of the scale of an operation. Larger size and thus larger scale are often

Table 9. PREVIOUS COMPUTER EXPERIENCE OF GROWER

		Total Times Accessed		Total Hours Used	
		Low	High	Low	High
Previous computer experience	little to none	71.4	28.6	71.4	28.6
	some to extensive	50.0	50.0	66.7	33.3
		N=19		N=19	

		Change in Practices		Closer Monitoring ***	
		Low	High	Low	High
Previous computer experience	little to none	71.4	28.6	71.4	28.6
	some to extensive	50.0	50.0	25.0	75.0
		N=19		N=19	

* $p < .15$
** $p < .10$
*** $p < .05$

associated with more sophisticated production technologies, higher productivity, higher income, higher education levels, etc. Table 10 shows the relationships between the total acres of an operation and the dependent variables. Table 11 shows the relationships between the total apple acres of an operation and the dependent variables. These acreage variables are considered separately because for some larger growers, apple production may not be the primary crop grown. Growers whose main crop is apples may differ in terms of Use and Change than growers for whom apples are one of many crops.

However, Tables 10 and 11 are being discussed together because the relationships between the dependent variables and the small and large acreage categories are almost identical for both tables. In every case for both tables growers with smaller farms and with smaller apple acreages rank higher than larger growers with respect to Use and Change. In terms of "total time accessed," the differences are small (44.4-40.0% and 45.4-37.5%). In all "total hours used," "change in practices," and "closer monitoring" relationships the differences are much more pronounced, with roughly 30% separating small growers from large growers in each case.

In Table 10 the relationships between total acres and "change in practices" and total acres and "closer monitoring" are both significant at the .10 level. In Table 11 significance occurs at the .15 level for total apple acres and "total hours used" and total apple acres and "closer monitoring."

Table 10. TOTAL ACRES IN PRODUCTION

		Total Times Accessed		Total Hours Used	
		Low	High	Low	High
Total acres	1 - 270	55.6	44.4	55.6	44.4
	271 - 1000	60.0	40.0	80.0	20.0
		N=19		N=19	

		Change in Practices **		Closer Monitoring **	
		Low	High	Low	High
Total acres	1 - 270	33.3	66.7	22.2	77.8
	271 - 1000	80.0	20.0	60.0	40.0
		N=19		N=19	

* $p < .15$
** $p < .10$
*** $p < .05$

Table 11. TOTAL APPLE ACRES IN PRODUCTION

Total apple acres	Total Times Accessed: Low	Total Times Accessed: High	Total Hours Used *: Low	Total Hours Used *: High
1 - 75	54.6	45.4	54.6	45.4
76 - 600	62.5	37.5	87.5	12.5
	N=19		N=19	

Total apple acres	Change in Practices: Low	Change in Practices: High	Closer Monitoring *: Low	Closer Monitoring *: High
1 - 75	45.4	54.6	27.3	72.7
76 - 600	75.0	25.0	62.5	37.5
	N=19		N=19	

* $p < .15$
** $p < .10$
*** $p < .05$

While these results were not expected based on the model, a feasible explanation does exist. The larger growers clearly have more acres to manage and may be more diversified in terms of number of different crops, in both cases limiting time for actually using an expert system, particularly one devoted to one crop. It is also the case that larger apple growers are less flexible in their spray schedules due to the number of acres which they must cover. It might also be presumed that larger size is an indication of a grower's success as a production manager, which may indicate resistance to changing successful practices. As well, smaller growers focussing on apples as their main crop may have more of a vested interest in becoming as efficient and productive as possible on that one crop.

No distinct patterns are found for type of farm ownership as shown in Table 12. A grower running an incorporated operation is somewhat more likely to be a higher user with regard to "total times accessed" than a single family operator (45.4-37.5%). However, a greater percentage of single family operators are higher users (50.0%) in terms of "total hours used" and are significantly higher users than incorporations (18.2%) (significant at the .15 level). The single family operator is more likely to change practices in "change in practices" (50.0-36.4%) and is also more likely to be stimulated to "closer monitoring" (62.5-54.6%).

Interestingly, high users are a minority for both ownership categories in "change in practices," but high users are a majority for both in "closer monitoring." In general, it would appear that single family operators are somewhat higher users than incorporated operators, and more likely to make changes in practices.

Table 12. TYPE OF FARM OWNERSHIP

Type of ownership		Total Times Accessed		Total Hours Used *	
		Low	High	Low	High
	single family	62.5	37.5	50.0	50.0
	incorporation	54.6	45.4	81.8	18.2
		N=19		N=19	

Type of ownership		Change in Practices		Closer Monitoring	
		Low	High	Low	High
	single family	50.0	50.0	37.5	62.5
	incorporation	63.6	36.4	45.4	54.6
		N=19		N=19	

* $p < .15$
** $p < .10$
*** $p < .05$

Table 13 looks at the average dollar amounts spent on pesticide applications per acre. This variable attempts to categorize a grower's disposition to spraying pesticides. Growers in the lower category may be more technically efficient in their spray applications or they may be personally disposed towards using less chemicals or are more willing to risk damaged fruit. In either case these growers may be more likely to use a technology which reduces pesticide inputs. Growers in the high category may be less efficient or less concerned about excessive chemical use. They may be, however, more willing to change practices if viable alternatives are offered.

As may be seen in Table 13 neither category of grower is exceptionally disposed to high use of the expert system. With regard to "total time accessed," growers spraying less are much more likely to be high users (50.0-16.7%), but are somewhat less likely in terms of "total hours used" (20.0-33.3%). There is no difference between low spray and high spray growers with regard to "change in practices" (50.0%), while high spray growers are a little more likely to be stimulated to "closer monitoring" (66.7-60.0%). For both categories of growers the expert systems appears to have more impact on Change, with a majority of low spray and high spray growers indicating some changes. A lower N was obtained due to a lack of appropriate records on the part of three growers.

Yield data can give some indication of the level of efficiency and technological sophistication employed by a grower on her/his operation. Growers obtaining higher average yields are more likely to be using the most up-to-date production techniques and may be more likely to use the expert system. This theory is somewhat upheld by the results in Table 14. In terms of Use, high-yielding growers are higher users, slightly so in "total times accessed" (42.9-36.4%) and more pronouncedly in "total hours used" (42.9-18.2%). High-yielding growers are decidedly less likely to change practices (45.4-

28.6%), but are slightly more likely to be stimulated to "closer monitoring" (57.1-54.6%). The fact that high-yielding growers are higher on all counts but "change in practices" is not necessarily inconsistent. The fact that high-yielding growers are higher users indicates that they perceive some value in using the system. However, as measured by their high yields, they are presently successful managers of their operations and may thus be less likely to need or want to change practices. It appears that these growers do recognise a value for their operation in additional pest scouting. The lower N in this table is attributed to one grower wishing not to report her or his yield data.

In general, for the selected structural variables, it is the growers whose operations tend to not be the higher, more "firm-oriented" levels of structure who are using the system and changing production practices. This is most surprisingly the case in terms of total acreages, however alternative explanations for this have been discussed. Perhaps as surprising is the type of farm ownership, where incorporation would be expected to tend more toward a business firm orientation and adoption of expert systems, as discussed in the model. Only the results for the yield data occurred as expected, however, it is not known how high yield relates to other structural characteristics.

A relatively high level of farming experience among the group also exists, with over half (52.6%) having more than 30 years of farm experience. This may translate into resistance to adoption of the technology in the Change categories as many growers may be reluctant to alter a successful production system which they have developed over their entire farming lifetime. It may also point to a relative inflexibility of decision-making on the part of the larger growers due to their size, which may signify that the technology is most suited for smaller growers, at least with regard to apple production.

Table 13. AVERAGE PESTICIDE COSTS PER ACRE

		Total Times Accessed		Total Hours Used	
		Low	High	Low	High
Avg.pesticide cost/acre	Less than $200 per acre	50.0	50.0	80.0	20.0
	More than $200 per acre	83.3	16.7	66.7	33.3
		N=16		N=16	

		Change in Practices		Closer Monitoring	
		Low	High	Low	High
Avg.pesticide cost /acre	Less than $200 per acre	50.0	50.0	40.0	60.0
	More than $200 per acre	50.0	50.0	33.3	66.7
		N=16		N=16	

Table 14. AVERAGE YIELD PER ACRE IN BUSHELS

Average per acre (in bu.)	Total Times Accessed: Low	Total Times Accessed: High	Total Hours Used: Low	Total Hours Used: High
275 - 520	63.6	36.4	81.8	18.2
521 - 1000	57.1	42.9	57.1	42.9
	N=18		N=18	

Average per acre (in bu.)	Change in Practices: Low	Change in Practices: High	Closer Monitoring: Low	Closer Monitoring: High
275 - 520	54.6	45.4	45.4	54.6
521 - 1000	71.4	28.6	42.9	57.1
	N=18		N=18	

Attitudinal Variables

The variable "Grower attitudes toward the impact of farming on the environment" is represented by a summated score from a series of questions which attempt to discern the level of importance each grower places on protecting various aspects of the environment from detrimental farming activities. Growers with low concern would be expected to rank lower in use than growers with high concern. As may be seen in Table 15, this is the case with regard to both "total times accessed" and "total hours used" where only 22.2% of growers with low concern are high users. Growers with high concern are much more likely to be high users with 60.0% in "total times accessed" and 40.0% in "total hours used." A significant relationship at the .10 level exists for "total times accessed."

With regard to Change, attitude is less clearly related. Growers with low concern are less likely to change their practices (50.0 -33.3%) but more likely to be stimulated to monitor more closely (66.7-50.0%) than are growers with high concern. However, growers with high concern are equally likely to be low or high with regard to both "change in practices" and "closer monitoring."

In general, it does not appear that this attitudinal variable serves as a good indicator of expert system adoption. Growers with high concern are higher in terms of the two Use categories and in one of the Change categories. However, there is little consistency of Use and Change within grower categories.

The variable "Grower attitudes toward health risk of agricultural chemical use" as shown in Table 16 provides slightly more consistency with regard to those growers who exhibit low concern, but their relation to growers with high concern changes both in Use and Change. In terms of "total times accessed" low concern growers are much less likely

Table 15. GROWER ATTITUDES TOWARD IMPACT OF FARMING ON THE ENVIRONMENT

Attitude score		Total Times Accessed ** Low	Total Times Accessed ** High	Total Hours Used Low	Total Hours Used High
	low concern (10 - 17)	77.8	22.2	77.8	22.2
	high concern (18 - 20)	40.0	60.0	60.0	40.0
		N=19		N=19	

Attitude score		Change in Practices Low	Change in Practices High	Closer Monitoring Low	Closer Monitoring High
	low concern (10 - 17)	66.7	33.3	33.3	66.7
	high concern (18 - 20)	50.0	50.0	50.0	50.0
		N=19		N=19	

* $p < .15$
** $p < .10$
*** $p < .05$

to be high users than growers with high concern (50.0-33.3%). However, in terms of "total hours used" those with low concern are slightly more likely to be high users (33.3-30.0%). However, in "change in practices" low concern growers are much more likely to change practices (55.6-30.0%) than high concern growers, but slightly less likely to be stimulated to "closer monitoring."

As with the previous attitudinal variable, it does not appear that "attitudes toward health risk" serves as a good indicator of expert system adoption as the relationships are not clearly discernible.

Knowing a grower's attitude about the impact of pesticides on the environment might reveal something about how or why that grower uses the expert system. A grower with little concern that pesticides harm the environment might be oriented toward using the expert system only as an economic tool, to reduce inputs only when s/he perceives the ability to save money. On the other hand, a grower with high concern might be more interested in using the system for a variety of reasons. As may be seen in Table 17, the variable "Grower attitudes towards impact of pesticides on the environment" does not differentiate between high and low grower Use or Change particularly well.

With regard to "total times accessed," low concern growers are clearly less likely to use the expert system than are high concern growers (58.3-14.3%). However, in the other Use category, "total hours used," there is only a slight difference between the two categories of growers, with high concern growers more likely to use the system (33.3-28.6%). In terms of Change, the patterns reverse. In "change in practices" there is virtually no difference between the two growers. Low concern growers rank 42.9% and high concern growers rank 41.7%. In "closer monitoring" low concern growers are much more likely to be stimulated to closer monitoring (71.4-50.0%). It should be noted that the

Table 16. GROWER ATTITUDES TOWARD HEALTH RISK OF AGRICULTURAL CHEMICAL USE

		Total Times Accessed		Total Hours Used	
		Low	High	Low	High
Attitude score	low concern (4 - 12)	66.7	33.3	66.7	33.3
	high concern (13 - 16)	50.0	50.0	70.0	30.0
		N=19		N=19	

		Change in Practices		Closer Monitoring	
		Low	High	Low	High
Attitude score	low concern (4 - 12)	44.4	55.6	44.4	55.6
	high concern (13 - 16)	70.0	30.0	40.0	60.0
		N=19		N=19	

Table 17. GROWER ATTITUDES TOWARDS IMPACT OF PESTICIDES ON THE ENVIRONMENT

		Total Times Accessed **		Total Hours Used	
		Low	High	Low	High
Attitude score	low concern (9 - 26)	85.7	14.3	71.4	28.6
	high concern (27 - 45)	41.7	58.3	66.7	33.3
		N=19		N=19	

		Change in Practices		Closer Monitoring	
		Low	High	Low	High
Attitude score	low concern (9 - 26)	57.1	42.9	28.6	71.4
	high concern (27 - 45)	58.3	41.7	50.0	50.0
		N=19		N=19	

* $p < .15$
** $p < .10$
*** $p < .05$

only relationship with statistical significance is "total times accessed" (at the .10 level), which is also the only relationship which produced expected results.

Familiarity with the capabilities of expert systems would likely increase a grower's confidence in the systems ability to provide significant help to her/him in the operation of her/his orchard. Differentiating between growers opinions indicating low or high confidence in the capabilities of expert systems may enable some prediction about useage patterns and changes in production. Growers with high confidence would be expected to be higher users. As Table 18 shows, this theory may not hold. In each case, growers with a lower confidence rating use the system more or change practices more.

With regard to Use, the differences are slight. In "total times accessed" low confidence growers are 4.4% more likely (44.4-40.0%) and in "total hours used" they are 3.3% more likely (33.3-30.0%). With regard to Change, lower confidence growers are only slightly more likely to have "change in practices" (44.4-40.0%) and much more likely to be stimulated to "closer monitoring" (66.7-50.0%).

In general, the attitudinal variables analyzed do not appear to offer reliably consistent relationships with which predictions of Use and Change may be confidently made. Attitudes and beliefs about the environment, health risks associated with pesticides, agrichemical pollution, and expert systems, that are conceptually related to the capabilities and intentions of the ApplES do not seem to differentiate between who uses the system or changes practices because of that use very consistently.

Table 18. GROWER ATTITUDES TOWARD EXPERT SYSTEMS

Attitude score		Total Times Accessed		Total Hours Used	
		Low	High	Low	High
	low confidence (0 - 25)	55.6	44.4	66.7	33.3
	high confidence (26 - 39)	60.0	40.0	70.0	30.0
		N=19		N=19	

Attitude score		Change in Practices		Closer Monitoring	
		Low	High	Low	High
	low confidence (0 -25)	55.6	44.4	33.3	66.7
	high confidence (26 -39)	60.0	40.0	50.0	50.0
		N=19		N=19	

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This research has looked at an ongoing pilot field test of an expert system known as ApplES in order to explore which apple growers will adopt and use this technology and with what consequences for the genereation of more sustainable production systems through reduction in pesticide use. By allowing more efficient and rapid data management and scenario sorting, the expert system enabled some farmers to more readily adopt IPM-oriented practices which reduce dependence upon pesticides.

This study has sought to answer several questions surrounding the diffusion and adoption of this technology: Which farmers will be inclined to adopt such a technology? which farmers will be able to effectively adopt this computer based technology? What structural, demographic, or addititonal factors may be related to effective adoption of the technology? What actual impact would widespread adoption have on the implementation of IPM programs which may result in pesticide use reduction?

According to Audirac and Beaulieu, the access conditions of a given technology are important variables to consider in the process of diffusion. These access conditions result from (1) research and development of technological innovations, (2) the intrinsic characteristics of the technology, and (3) the distributional characteristics of the innovation.

Consequently they feel that the characteristics of a farming operation as business firm provide more reliable indicators of microcomputer adoption. Potential adopters are more likely to respond to these access conditions than to personal characteristics, attitudes, or beliefs. Audirac and Beaulieu hypothesize that, since diffusion is a structural process, adopters will be those people whose structural and related demographic characteristics mesh with the access conditions inherent to the technology.

This study created variables from survey data that best represented 1) the kinds of structural/demographic characteristics most associated with the access conditions of the microcomputer-based technology, ApplES; and 2) the grower attitudes and beliefs most relevant to qualities inherent to ApplES. These variables were then analyzed with dependent variables representing adoption of the system (system use and practice change) in order to test the Audirac and Beaulieu hypothesis.

Extending from the model proposed by Audirac and Beaulieu we would expect that the adopters of the ApplES expert system, as measured by this study, would be the growers with more education, more farm experience, more experience with computers, who operated larger farms, with operations incorporated as a business firm, and who were managing inputs and generating outputs most efficiently.

The results of this study do not conclusively support the model as constructed by Audirac and Beaulieu. This study found a plurality of relationships, some of which support the model, some of which do not. In general, among demographic characteristics as they were related to both Use variables, the structural variable "yield," and all attitudinal variables, the results would support the predictive orientation of the model.

With respect to the demographic variables, the older, better educated, more experienced growers and computer operators were the higher users. This is consistent with the model as these personal traits are related to the access conditions of this particular technology. Growers producing the highest yields were also high users as well as more likely to be stimulated to closer monitoring. However, relationships across the Change variables of the demographic characteristics generally found that the younger, less educated, least experienced growers were changing practices and monitoring more closely as a result of using the system. Similar results were obtained from the structural variables, where growers whose operations were less "firm-oriented" in structure were the higher users as well as the most likely to change practices.

While these are important departures from the model, there may be external reasons influencing the results which need to be considered and incorporated into the model. With reference to the demographics, growers with lower age, education, experience are in fact using the system less but changing practices more. It may be that even though these growers' use is less, the impact on those who do use it is greater. Changes suggested or stimulated by the system may be more readily accepted by growers who are still learning and evolving as apple production managers, as compared to their counterparts in the study. More experienced, better educated growers, and presumably more successful, may be understandably more reluctant to make changes in their production systems.

Similar possibilities exist for the structural variables. With respect to the Use variable, as was noted earlier, the larger growers have more acres to manage and may be more diversified, in both cases limiting time for actually using an expert system, particularly for one crop. It might also be the case that larger, more "firm-oriented" growers have less flexibility or perceived need to make the same incremental changes which smaller growers are able to make. It might also be presumed that larger size is an indication of a grower's success as a production manager, which again, may indicate resistance to changing successful practices. As well, smaller apple growers may have more need for becoming the most efficient apple producer possible, as proportionately more of their income depends upon the yield per acre.

The results of analysis of the attitudinal variables generally support Audirac and Beaulieu's position that personal, behavioral, and attitudinal orientations are not reliable indicators of agricultural microcomputer technology adoption. In general, the attitudinal variables analyzed did not show consistently reliable relationships between attitudes toward the environment, pesticide use, or health issues and Use or Change. Adoption of the system does not appear to be related to a growers attitudes about environmental or health issues, or pesticide use.

While the results of this study do not reveal adequate evidence to vigorously support the Audirac and Beaulieu thesis, they do indicate that the model is developing in the appropriate direction and that the need for further refinement and conceptualization is warranted. While it would be well, in the interpretation of these results, to keep in mind the experimental nature of the study and the small sample size, it would appear that the model stands justifiably on its claim to dismiss attitudes as indicators of adoption. The results surrounding the relationship between the demographic variables and Use may indicate some validity to the model.

Given the experimental nature of the present research, the relatively unexamined phenomena of microcomputers in agriculture from a long-term sociological perspective, and that the present findings are at least partially congruent with the Audirac and Beaulieu model, I feel that it is reasonable to conclude that this model should be given further consideration in future diffusion research. This is underscored by the fact that a review of the research found no evidence of other agriculture-oriented expert systems ever having been field tested, making comparative analysis impossible.

Evidence from the this study does support the Audirac and Beaulieu thesis that the access conditions of a technology need to be condsidered in the diffusion process. Those access conditions of the expert system derived from its technological development as well as its intrinsic characteristics are important variables in the diffusion process. In particular, two characteristics seem noteworthy based on the results of this study.

The ApplES expert system is foremost an information technology. While it contains database production information, it also requires the input of reliable, site-specific information in order to formulate decision support recommendations for the user. The information needed as well as the resultant recommendations require the apple producer to form questions and to look at problems in a different manner than have previous information delivery systems used in apple production. That this transition will not occur automatically is reflected by the fact that the test group exhibited varying levels of use and that almost none of the changes in practices occurred until growers had sufficient time to delvelop an understanding of the system's logic. Some growers indicated that they still do not "trust" the system to make decisions for them. This would appear to be one case where the access conditions are likely to not be met by the farming operation, thus inhibiting adoption. The expert system is an information technology that is intrinsically different than most information technologies previously utilized by apple producers. The kinds of practical and educational experience a grower/user has may effect how well the system is understood and thus, adopted.

Secondly, the expert system is a technology inherently connnected to microcomputers. In order for a grower to make use of the decision support capabilities of ApplES they must: a) have access to a microcomputer capable of running the system; b) be able to operate the computer proficiently. While the ApplES program was designed and developed to be used by people with little or no computer experience, results of the study indicate that growers with the least amounts of computer experience also had the lowest rates of system use. This would appear to be another good example of the access conditions of the technology not being met by the farming operation. The technology is inherently computer-based and a farming operation must have access to a computer and a person who can operate it before the technology will be adopted.

By substituting information for inputs the ApplES expert system has the potential to contribute to the generation of more sustainable apple production systems in the Northeast. This can occur through the introduction of more information intensive, IPM oriented practices into the production system. This study has provided some preliminary evidence that changes in usual production practices occur as grower/users substitute information for purchased inputs, in this case, pesticides. It was also demonstrated that the substitution of information for inputs was stimulated by the expert system, which enabled the grower/user to rapidly collect, integrate and interpret the information.

However, based on other evidence produced by the study, it appears that the potential for sustainable agriculture which this technology holds will be diminished without some attention to better linking the access conditions of the technology to the farming operation. This conclusion raises a host of questions needing further exploration concerning the potential of expert systems as a tool for sustainable agriculture.

First, do the unique access conditions inherent in this information technology present insurmontable barriers to the widespread adoption of the technology, thus limiting its usefulness as a tool for sustainable agriculture? Or will educational programs implemented with the general introduction of this technology serve to match the access conditions with the general apple producing operation?

A concern is here raised as to who will be able to adopt this technology and the purposes for which it will be used? Will only larger scale operations be able to afford the hardware necessary to operate the expert system? If so, what impact would this have on the structure of the apple industry, particularly, would it increase concentration and encourage expansion of operations? If the technology proved to be readily accessible to all scales of operations, what advantages might it generate for smaller producers?

Further articulation of the relationship between adoption and and scale needs to occur. The use patterns of large scale users pointed out by this study are significant in the context of how the expert system will be primarily utilized. What ramifications will these use patterns have for sustainable agriculture? Will the expert system be viewed merely as an electronic version of printed production guides and utilized primarily as an economic consultant?

Lastly, if the widespread adoption of expert systems occurs how will it alter existing information delivery systems? Will expert systems replace traditional forms of extension publications, consultants, or the grower's own knowledge altogether or will use of these various sources become more closely integrated? What will be the consequences to the structure of agriculture for either scenario?

Based on the evidence provided by this study, without additional attention to the areas of concern outlined above, expert systems for agriculture will not reach its potential as an effective tool for sustainable agriculture. Without new educational programs aimed at basic computer use and at the transition to information driven, whole farm systems decision-making, expert systems will likely be used sporadically throughout the farming population, and then primarily as an economic consultant, rather than as the integrated, systems oriented tool as it was intended.

Recommendations

Although few expected relationships were obtained with respect to the structural variables in particular, the results, coupled with alternative explanations posed do indicate that further work in this direction may be fruitful. It may be necessary to modify the model for some agricultural microcomputer technologies, particularly commodity specific technologies such as ApplES. Perhaps further conceptual clarity and definition of what are the most appropriate structural variables for analysis, at what levels, and for which commodities/technologies, rather than discussing "structural variables" in a homogeneous fashion would elicit the results intended by Audirac and Beaulieu's model.

The results from this research seem to indicate that there may be additional considerations that must be taken into account. For instance, even though a grower and her/his operation may have structural/demographic characteristics which match the access conditions of a given technology, it is possible that precisely these characteristics will be limiting factors of adoption, when viewed from the broad parameters of the existing model. The results of this study suggest this with regard to apple production. For instance, the model would predict that larger scale operations, with more characteristics of a business firm, would be more likely to adopt the technology. However, the study revealed some evidence that larger growers may not have the flexibility to implement the recommendations of the expert system on a regular basis. This may or may not be an issue with regard to corn or vegetable production. More inquiry is necessary on this point as well as others which may prove to be exceptions to the model. In the future it may be necessary to take the generalized model and modify it for specific commodities once the particular production, structural, and demographic characteristics unique to that commodity have been identified and understood. In this way rather than being, a generalized conceptualization for what constitute access conditions to microcomputer based information technologies, the access conditions would become specific to the crop and type of production system.

The results of this study also seem to indicate that, with regard to the ApplES expert system, some work will need to be done at the first stage of the diffusion process outlined by Audirac and Beaulieu if ApplES is to become an effective tool for sustainable agriculture. This first stage concerns the set of activities which provide for the "...establishment of diffusion agencies or a network of outlets from which the innovation is distributed to potential adopters" (Audirac and Beaulieu, 1986:63).

In the present case, it is planned that this diffusion network will be the traditional cooperative extension service network of university and county extension offices and personnel. In addition to acting as the distributive agent for this innovation, this network will have to also provide new educational training programs in two areas identified by this research if the effective adoption of this innovation and its potential for sustainable agriculture are to be realized. As discussed earlier, some growers are not using the system very much and others are not being stimulated to change production practices based on their use of the system. In either case, effective adoption is not occurring and the potential to reduce the amount of pesticide inputs being used is diminished.

In order to correct this situation when the system is offered to the general public, it is recommended that the diffusion agency provide new educational programming in the following areas: 1) training and basic orientation to computer use for farming operations and agricultural expert systems in particular. These training sessions should be held on a very localized basis and taught by a person(s) familiar both with expert systems software operation and the cropping system being discussed; 2) training which provides an overview of the gradual modification of existing production systems to incorporate reduced-input methods. This training should focus on the societal level needs and responsibilities for reducing pesticide use as well as the long-term farm level benefits for doing so; 3) establishment of "local experts" to provide a resource for growers experiencing difficulties in the computer or expert system; 4) continuing updating of system capabilities so that recommendations remain current and appropriate; and 5) training extension specialists and agents to familiarize them with the possibilities of the system.

It may also be necessary to begin the process of delineating the criteria and goals for sustainable agriculture attainable with the expert systems as a tool. In this way scientists will be better able to begin to design production systems for large scale agricultural operations that provide more flexibility in responding to dynamic production conditions, thus enabling the time and spatially specific recommendations of the expert system to be better implemented. In the long run, this may be the greatest contribution of agricultural expert systems development toward a more sustainable system of global agriculture.

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APPENDIX 1

PERIODIC SURVEY OF EXPERT SYSTEMS USERS
ApplES - Expert Systems for Orchard Management

PENNSYLVANIA PILOT PROGRAM
MONTHLY TELEPHONE GROWER SURVEY

01 GROWER ______________________ 02 DATE __________

03 HOW MANY TIMES HAS THE SYSTEM BEEN ACCESSED IN THE LAST MONTH? ____________

04 WHAT IS THE APPROXIMATE TOTAL AMOUNT OF TIME THE SYSTEM HAS BEEN USED? ____________ (in hours and/or minutes)

04.1 WHAT TIME OF THE DAY DO YOU USUALLY USE THE SYSTEM? ____________

04.2 WHAT DETERMINES WHEN YOU ACCESS THE SYSTEM (ie. problem, routine, weather, slow period, etc.)?
____

05 WHAT WOULD STIMULATE YOU TO USE THE SYSTEM MORE THAN YOU ARE PRESENTLY? (ie. more time, time of year, if system addressed different problems)

____

____

____

WHO IS ACCESSING THE SYSTEM?

		FREQUENTLY	OCCASIONALLY	NEVER
06	grower	_____	_____	_____
07	manager	_____	_____	_____
08	other family ______________	_____	_____	_____
09	worker	_____	_____	_____
10	other ______________	_____	_____	_____

HOW MANY TIMES HAS THE SYSTEM BEEN ACCESSED FOR THE FOLLOWING?

11 SOLVING ACTUAL FIELD PROBLEMS _____
12 SOLVING HYPOTHETICAL SITUATIONS _____
13 LEARNING ABOUT THE SYSTEM _____

WE WOULD LIKE TO KNOW WHAT MODULES YOU HAVE ACCESSED IN THE PAST TWO WEEKS.

INSECT MANAGEMENT (DEVELOPMENTAL)

14 DID YOU USE THE INSECT MANAGEMENT MODULE?
1) yes _____ 2) no ____ (IF NO, GO TO WEED MODULE)

15 IF YES, APPROXIMATELY HOW MANY TIMES? ______

16 DID YOU GET THE INFORMATION YOU WERE LOOKING FOR?
1) yes _____ 2) no _____ (IF NO ASK FOR EXPLANATION)

17 DID YOU FOLLOW THE RECOMMENDATIONS:
1) completely _____
2) partially _____
3) not at all _____
18 IF NOT, why? _____ (ie. hypothetical, learning, didn't like)

19 HOW SATISFIED WERE YOU WITH THE RESULTS OF THE RECOMMENDATIONS?
1) very satisfied _____
2) somewhat satisfied _____
3) neutral _____
4) somewhat dissatisfied _____
5) very dissatisfied _____

WEED CONTROL (HORTICULTURE)

20 DID YOU USE THE WEED CONTROL MODULE?
1) yes _____ 2) no ____ (IF NO, GO TO DISEASE DIAGNOSIS MODULE)

21 IF YES, APPROXIMATELY HOW MANY TIMES? ______

22 DID YOU GET THE INFORMATION YOU WERE LOOKING FOR?
1) yes _____ 2) no _____ (IF NO ASK FOR EXPLANATION)

23 DID YOU FOLLOW THE RECOMMENDATIONS:
1) completely _____

2) partially _____
3) not at all _____
24 IF NOT, why? _____ (ie. hypothetical, learning, didn't like)

25 HOW SATISFIED WERE YOU WITH THE RESULTS OF THE RECOMMENDATIONS?
1) very satisfied _____
2) somewhat satisfied _____
3) neutral _____
4) somewhat dissatisfied _____
5) very dissatisfied _____

DISEASE DIAGNOSIS (DIAGNOSIS)

26 DID YOU USE THE DISEASE DIAGNOSIS MODULE?
1) yes _____ 2) no ____ (IF NO, GO TO NUTRIENT DEF MODULE)

27 IF YES, APPROXIMATELY HOW MANY TIMES? ______

28 DID YOU GET THE INFORMATION YOU WERE LOOKING FOR?
1) yes _____ 2) no _____ (IF NO ASK FOR EXPLANATION)

29 DID YOU FOLLOW THE RECOMMENDATIONS:
1) completely _____
2) partially _____
3) not at all _____
30 IF NOT, why? _____ (ie. hypothetical, learning, didn't like)

31 HOW SATISFIED WERE YOU WITH THE RESULTS OF THE RECOMMENDATIONS?
1) very satisfied _____
2) somewhat satisfied _____
3) neutral _____
4) somewhat dissatisfied _____
5) very dissatisfied _____

NUTRIENT DEFICIENCY (DIAGNOSIS)

32 DID YOU USE THE NUTRIENT DEFICIENCY MODULE?
1) yes _____ 2) no ____ (IF NO, GO TO LEAF ANALYSIS MODULE)

33 IF YES, APPROXIMATELY HOW MANY TIMES? ______

34 DID YOU GET THE INFORMATION YOU WERE LOOKING FOR?
1) yes _____ 2) no _____ (IF NO ASK FOR EXPLANATION)

35 DID YOU FOLLOW THE RECOMMENDATIONS:
1) completely _____
2) partially _____
3) not at all _____

36 IF NOT, why? _____ (ie. hypothetical, learning, didn't like)

37 HOW SATISFIED WERE YOU WITH THE RESULTS OF THE RECOMMENDATIONS?

1) very satisfied _____
2) somewhat satisfied _____
3) neutral _____
4) somewhat dissatisfied _____
5) very dissatisfied _____

LEAF ANALYSIS (DIAGNOSIS)

38 DID YOU USE THE LEAF ANALYSIS MODULE?

1) yes _____ 2) no ____ (IF NO, GO TO TREE SPACING MODULE)

39 IF YES, APPROXIMATELY HOW MANY TIMES? ______

40 DID YOU GET THE INFORMATION YOU WERE LOOKING FOR?

1) yes _____ 2) no _____ (IF NO ASK FOR EXPLANATION)

41 DID YOU FOLLOW THE RECOMMENDATIONS:

1) completely _____
2) partially _____
3) not at all _____

42 IF NOT, why? _____ (ie. hypothetical, learning, didn't like)

43 HOW SATISFIED WERE YOU WITH THE RESULTS OF THE RECOMMENDATIONS?

1) very satisfied _____
2) somewhat satisfied _____
3) neutral _____
4) somewhat dissatisfied _____
5) very dissatisfied _____

TREE SPACING (HORTICULTURAL)

44 DID YOU USE THE TREE SPACING MODULE?

1) yes _____ 2) no ____ (IF NO, GO TO NEXT PAGE)

45 IF YES, APPROXIMATELY HOW MANY TIMES? ______

46 DID YOU GET THE INFORMATION YOU WERE LOOKING FOR?

1) yes _____ 2) no _____ (IF NO ASK FOR EXPLANATION)

47 DID YOU FOLLOW THE RECOMMENDATIONS:
1) completely _____
2) partially _____
3) not at all _____

48 IF NOT, why? _____ (ie. hypothetical, learning, didn't like)

49 HOW SATISFIED WERE YOU WITH THE RESULTS OF THE RECOMMENDATIONS?
1) very satisfied _____
2) somewhat satisfied _____
3) neutral _____
4) somewhat dissatisfied _____
5) very dissatisfied _____

---

50 HAS THE USE OF THE SYSTEM CHANGED YOUR SPRAY PRACTICES OR OTHER PRACTICES IN THE PAST MONTH? (IN OTHER WORDS DID THE SYSTEM PERSUADE YOU TO DO SOMETHING YOU WOULDN'T NORMALLY HAVE DONE?)
1) no change _____ 2) some change _____ 3) great change _____
PLEASE EXPLAIN

51 DID THE SYSTEM STIMULATE YOU TO MORE CLOSELY MONITOR YOUR CROP? FOR EXAMPLE DID YOU COUNT MITES AND STETHORUS OR LOOK FOR LEAF NUTRIENT DEFICIENCY SYMPTOMS?
1) yes _____ 2) no _____
PLEASE EXPLAIN

52 (IF YES), DID YOU MORE CLOSELY MONITOR BECAUSE:

1) THE SYSTEM REQUIRED THIS INFORMATION OR

2) YOU RECOGNISE THE ADDITIONAL VALUE IN MONITORING

53 DO YOU SHARE INFORMATION GAINED FROM THE SYSTEM WITH OTHER GROWERS?
1) yes _____ 2) no _____
IF YES, WITH WHOM?

WHAT OTHER SOURCES OF INFORMATION HAVE YOU UTILIZED THE PAST MONTH?

54 AG CHEMICAL DEALER _____
55 EXTENSION PERSONNEL _____
56 CONSULTANT _____
57 OTHER FARMER _____
58 TREE FRUIT PROD GUIDE _____
59 FRUIT TIMES NEWSLETTER _____
60 OTHER_______________________

61 SINCE YOU RECEIVED THE EXPERT SYSTEM HAS YOUR USE OF THESE SOURCES BEEN:

1) much less 2) less 3) same 4) more 5) much more

62 HAVE YOU HAD ANY PROBLEMS WITH THE MACHINE OR THE SOFTWARE DURING THE PAST MONTH?
1) yes _____ 2) no _____
IF YES, PLEASE EXPLAIN.

63 DID YOU TALK WITH ANYONE AT PENN STATE REGARDING THE PROBLEM? 1) yes _____ 2) no _____
WITH WHOM? _________________

64 HOW SATISFIED WERE YOU WITH THE HELP YOU RECEIVED?

1) VERY SATISFIED
2) SATISFIED
3) INDIFFERENT
4) UNSATISFIED
5) VERY UNSATISFIED

65 AT THIS POINT, DO YOU HAVE ANY SUGGESTIONS FOR IMPROVING THE SYSTEM?

APPENDIX 2

Baseline Farm Data Survey of Apple Growers

We would like some information about your operation for this year (1988)

Farm size

1 How many total acres do you operate ____
2 acres owned _____
3 acres rented _____

Crops

4 How many acres of apples _____ acres
5 How many acres of grapes _____ acres

	What other crops do you grow				change in acreage from 1987		crop is % of gr 1988 in
6	___________	_____ acres		7	________	8	______
9	___________	_____ acres		10	________	11	______
12	___________	_____ acres		13	________	14	______
15	___________	_____ acres		16	________	17	______
18	___________	_____ acres		19	________	20	______
21	___________	_____ acres		22	________	23	______

Do you raise any livestock

24 dairy _____ cows
25 beef _____ head
26 sheep _____ ewes
27 hogs _____ head
28 horses _____
29 broilers _____ birds
30 layers _____ birds

Farm operator characteristics

31 Is your farm enterprise :

1 single family operation
2 partnership
3 family-owned corporation
4 non-family owned corporation

To what extent are the following people involved in the day-to-day decision-making of your operation. Please answer:

		very involved	somewhat involved	not involved
32	Husband	1	2	3
33	Wife	1	2	3
34	Son	1	2	3
35	Daughter	1	2	3
36	Brother/Sister	1	2	3
37	Farm manager	1	2	3
38	Other employees	1	2	3

39 Of these people who is the principal decision-maker?

____

40 What is the age of the principal decison-maker ______

(ask only if unclear)

41 What is the sex of the principal decision-maker M F

42 What level of formal education have you completed: **(READ CHOICE**

___ some high school (or less)
___ high school graduate
___ vocational school
___ some college
___ college graduate
___ post-graduate study

Next we would like to know about any off-farm employment in 1987. Were you employed off the farm:

			spouse
43	_____ not at all	45	_____ not at all
	_____ full time		_____ full time
	_____ part time		_____ part time
	if part time were you employed		
44	_____ regularl	46	_____ regularly
	_____ seasonally		_____ seasonally

47 Occupation __________________ 48 Occupation ____________

Labor hired in 1987 (do not include immediate family)

		# of full-time workers		# of part-time workers
49	year around	_____	50	_____
51	growing season only	_____	52	_____
53	harvest only	_____	54	_____

55 How many years have you farmed _____

How many years have you grown

56 apples _____

57 grapes _____

We would like to know what sources of information you use to decide how much fertilizer to apply? Do you use:

		always	frequently	sometimes	never
58	university soil testing	1	2	3	4
59	extension recommendation	1	2	3	4
60	commercial lab recommend	1	2	3	4
61	dealer recommend	1	2	3	4
62	my own knowledge	1	2	3	4
63	other (please describe)	1	2	3	4

____

64 How often do you test your soil for fertility needs? **(READ ALL ANSWERS)**

___annually
___ every 2 years
___ every 3 years
___ every 4 or more
___ don't test soil

How would you rate the importance of each of the following information sources for knowing when and how to apply pesticides, please answer: **(READ CHOICES, THEN READ LIST)**

		not important	somewhat important	very important	extremel importan·
65	follow directions on label	1	2	3	4
66	county extension agent	1	2	3	4
67	Penn State fruit specialist	1	2	3	4
68	my own knowledge	1	2	3	4
69	extension educational mtgs	1	2	3	4
70	agri-business fieldperson	1	2	3	4
71	private consulting fieldperson	1	2	3	4
72	agri-business counterperson (Agway)	1	2	3	4
73	other farmer	1	2	3	4
74	other	1	2	3	4

(please describe ____________________)

75 How often do you talk to your county extension agent? **(READ CHO**

___ once per week or more often
___ every two weeks
___ once per month
___ every six months
___ less than every six months
___ never

76 How often do you talk with a Penn State fruit specialist? **(READ)**

___ once per week or more often
___ every two weeks
___ once per month
___ every six months
___ less than every six months
___ never

APPLES This set of questions pertain to your apple production practices

77-79 On what do you base your first scab spray : **(READ CHOICES, check any)**

1 Same calendar date each year

2 Presence of green leaf tissue
3 Maturity of scab spores
4 Published extension alerts such as newsletters
5 Other ____________________

80-82 After petal fall, how do you most often decide on your first miticide application: **(READ CHOICES, check all that apply)**

1 Same calendar date each year
2 Automatically in one of the cover sprays
3 Mite counts are greater than 3 per leaf
4 Published extension alerts such as newsletters
5 Other ____________________

83 Do you routinely scout for insects and diseases in your orchard?
Yes _____ No _____

84 **IF YES,** who scouts for pests in your orchard?
farmer _____
farm employee _____
private consultant _____
industry consultant _____

85 **IF YES,** do you keep written records of pest levels in your orchard?
Yes _____ No _____

86 When do you normally stop spraying for mites: **(READ CHOICES)**

1 At harvest
2 Between the 6th and 8th cover
3 When stethorus populations are high enough
4 When mites are below economic threshold

87-88 What kind of weather monitoring equipment do you utilize?
1 thermometer/ rain gauge
2 hydrothermograph
3 an automatic weather station such as Reuter-Stoke
4 television
5 other ____________________________
6 none

89 Do you keep day-by-day records of the weather?

Yes ____ No _____

90 On average, how many times did you enter your orchard to spray during each of the last three years? (include all herbicide, fungicide,insecticide, rodent)

____________ complete sprays
____________ aternate row middles

91 As a yearly average over the last three years, approximately how much did you spend per acre for pesticides in apples (including miticides, insecticides, fungicides, and additives such as calcium chloride but excluding application costs such as gasoline for tractor and labor)? $_________

92 What percentage of your acreage has been fertilized in the past 3 y

___________ acres

93 Approximately how much did you spend on fertilizer per acre during the past 3 years?

$_____________

94 As a yearly average over the last three years, approximately how many bushels of apples per acre did you produce?

___________ bushels

95 Can you tell us approximately what percentage of your apple production is sold fresh?

_____ don't sell fresh apples
_____10% or less
_____ 11 to 25%
_____ 26 to 50%
_____ 51 to 75%
_____ 76 to 99%
_____ 100%

96 As a yearly average, over the last three years, approximately what net price (after deducting any packing, storage, and selling costs) per bushel did you receive for your **fresh** apple crop?

$ ____________

97 As a yearly average, over the last three years, approximately what net price (after deducting any packing, storage, and selling costs) did you receive for your **processing** apple crop?

$ ____________

Next I would like to ask your opinion about several issues of concern to Pennsylvanians. How important is each issue to you? Please respond:

		not important	of some importance	important	very important	no opinion
114	Profitability in agriculture	1	2	3	4	0
115	Protecting water quality	1	2	3	4	0
116	Conserving soil from erosion	1	2	3	4	0
117	Immigration laws	1	2	3	4	0
118	Effect of pesticides on wildlife and pets	1	2	3	4	0
119	Effects of pesticides on workers	1	2	3	4	0
120	Drift of ag chemical sprays	1	2	3	4	0

Now I would like to ask your opinion concerning the use of agricultural chemicals (fertilizers and pesticides)

Are you concerned that the use of agricultural chemicals pose a health risk:

Please respond:

		not at all concerned	somewhat concerned	concerned	very concerned	not sure
121	In the nation	1	2	3	4	5
122	In Pennsylvania	1	2	3	4	5
123	In your county	1	2	3	4	5
124	On your own farm	1	2	3	4	5

I am going to read a list of statements and would like you to indica the extent to which you agree or disagree with each.

	strongly disagree	somewhat disagree	undecided	somewhat agree	strongly agree
125 I am confident that agricultural pesticides, if used as directed, are not a threat to the environment.	1	2	3	4	5
126 We cannot be too careful when it comes to putting new pesticides on the market.	1	2	3	4	5
127 Should ground water supplies become contaminated I'm confident scientists will develop ways to purify them.	1	2	3	4	5
128 We already have too much regulation on the use of agricultural pesticides.	1	2	3	4	5
129 So little pesticide residue ever enters the ground water, it could never pose a health risk for humans.	1	2	3	4	5
130 Instead of worrying about the effects of pesticideswe should spend more effort in solving other problems in farming.	1	2	3	4	5
131 Although some farmers could reduce fertilizer and pesticide expenses by more precise applications, for me these savings probably would not justify the added time, cost, and effort.	1	2	3	4	5
132 Pollution control requirements have gone too far; they already cost more than they are worth.	1	2	3	4	5
133 Protecting the environment is so important that the requirements cannot be too high, and continuing improvements must be made regardless of cost.	1	2	3	4	5
134 I would consider modifying my pesticide practices but I am not sure that I know enough to make the changess.	1	2	3	4	5
135 I can usually find the solutions to problems on my farm quickly.	1	2	3	4	5
136 Considering the availability of Penn State specialists, chemical company fieldpeople, and my own knowledge, there probably isn't any problem on my farm that I cannot find a solution for.	1	2	3	4	5

From what you know now about expert systems, if you were given the job of recruiting other farmers for participation in an Expert Systems program, how would you rate the following selling points, please respond:

Expert systems:	not importnant	important	very important	no opinion
137 helps me select the best chemicals for the pest problem	1	2	3	4
138 always available to give a recommendation	1	2	3	4
139 recommendations are specific to my situation	1	2	3	4
140 system is easy to use	1	2	3	4
141 it gives reliable recommendations, based on the best information available	1	2	3	4
142 it provides a range of alternatives to any given problem	1	2	3	4
143 helps control yield & quality loss	1	2	3	4
144 increases farm profits.	1	2	3	4
145 involves reduced use of pesticides	1	2	3	4
146 reduces environmental damage.	1	2	3	4
147 gives an unbiased opinion of pest problems.	1	2	3	4
148 frees you to use your management skills elsewhere.	1	2	3	4
149 reduces chances of low yields and profits	1	2	3	4

150 Prior to this project, how much experience had you had with computers?

1 none
2 very little
3 some
4 extensive use

151 Have you ever worked with any of the following computer systems?

1 wordprocessing
2 bookkeeping
3 electronic spreadsheets
4 data management

152 Do you own a computer?

Yes _____ No _____

153 If yes, what type
____ Apple Macintosh
_____ IBM/PC or other computer that uses IBM software

154 Do you use a computer in your fruit growing business?
Yes ____ No ____

If yes, for which purpose(s)? (check all that apply)

155 _____ Bookkeeping
157 _____ Electronic Mail
158 _____ Weather Monitoring
159 _____ Printing advertising and marketing brochures
160 _____ Printing bills and receipts
161 _____ Maintaining mailing lists
162 _____ Other uses (please specify) ______________________
____
____

Now I'd like to ask a few questions about farm income. Please remember that your answers will be absolutely confidential and will never appear alone, only as an total average for the project.

163 Considering all sources of income, what was the net income of your household in 1987, before income taxes?

$ 0 - 10,000	______
10,000 - 20,000	______
20,000 - 30,000	______
30,000 - 50,000	______
50,000 -100,000	______
100,000-250,000	______
over $250,000	______

164 What was your off-farm income in 1987?
$ ___________

165 For statistical analysis, we are interested in getting some idea of your operation's asset to debt ratio. First estimate your assets which include everything owned, including land, machinery, cash, stocks, livestock, etc. Now estimate your debt, which would include loans secured by mortgages, unsecured loans, and accounts due to surplus. Are your operation's:

debts twice as large as assets	______
assets equal to debts	______
assets less than 2 times as large as debts	______
assets 2 times larger than debts	______
assets 3 times larger than debts	______
assets 4 times larger than debts	______
assets 5 times larger than debts	______

APPENDIX 3

Staff Paper No. 188 August 1990

Economic Evaluation of An Expert System for Apples

Andrew Laughland, Wesley N. Musser,
Timothy Bowser, and Edwin G. Rajotte

Paper prepared for a poster session at the joint annual meetings of the AAEA, WAEA, CAEFMS, and AERE in Vancouver, British Columbia, August 4-8, 1990. Jim Travis, William Kleiner, Caroline Sachs and numerous cooperating growers made helpful suggestions in formulating this research. Brooke Smokelin assisted in data coding and entry on this research. Partial support for this research was furnished by the U. S. Department of Agriculture Cooperative Agreement No. 89-03-01.

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Economic Evaluation of An Expert System for Apples

Production decisions for many agricultural commodities are becoming increasingly more complex. In apples and other horticultural commodities, obsolescence and removal from the market of pesticides combined with consumer demands for reduction in pesticides are causing producers to constantly consider new pest management methods. Increasing use of scouting, beneficial pests, selective pesticides, and other components of integrated pest management complicates these management decisions. Unlike earlier calendar pest control recommendations, general recommendations must be adapted to the specific environmental conditions and previous management decisions of the grower. At the same time, reductions in extension funding are causing assistance from agricultural production specialists to become more scarce.

Expert systems are a potential method to alleviate such management problems in agriculture. Expert systems are a class of electronic decision support systems designed to simulate the combined problem-solving capabilities of a number of persons who are experts in specialized disciplines or domains. Expert systems are able to draw and store inferences from information and are thus often called knowledge-based systems. A form of artificial intelligence, expert systems are capable of integrating and delivering quantitative information, much of which has been developed through basic and applied research, as well as heuristics (experientially based "rules of thumb") to interpret quantitatively derived values, or for use when quantitative values do not exist (Denning, Coulson and Saunders). Unlike many industrial applications, most expert systems for agricultural production management are still in the developmental and testing phases (Schmisseur and Doluschitz).

This paper reports on an economic evaluation of an extensive field testing of an expert system for apple production decisions in Pennsylvania. Profits of users of the expert system in 1989 were contrasted with profits of a control group of non-users. Profits were estimated with partial budgets for both groups. Sample statistics of economic variables were calculated for both groups and also analyzed in several econometric models. The analysis also gives some evidence on the effect of the expert system on risk.

Background to the Economic Evaluation

This evaluation concerned the Penn State Apple Orchard Consultant (PSAOC) which has been developed to assist apple growers on decisions about apple production. Rajotte, et al. and Rajotte and Bowser describe the expert system and its development in more detail. This section largely summarizes their discussion.

PSAOC has modules on insect control, disease control, and various aspects of horticultural management. While the goal of PSAOC is integrated, holistic decision-making, its modules were largely developed independently. Currently, the insect and disease modules have been integrated. Production recommendations are derived from three sources of information--state of the art scientific information on apple production, orchard production characteristics, and weather reports. Users input the latter two categories to obtain expert advice consistent with their specific orchard characteristics, past decisions, and current weather and production conditions.

PSAOC is now available for general distribution after four years of development and testing. The initial development of the computer programs took two years. The last two years involved field testing and revision of the programs. The field testing of PSAOC involved an interdisciplinary team of production scientists, rural sociologists, and agricultural economists. In 1988-1989, sociological evaluation was emphasized. Bowser presents the rural sociological analysis. In addition, data were collected for the economic analysis in 1989.

Information was collected with several methods. A baseline survey was used to collect basic information about the grower and the orchard. Monthly surveys during the growing season were used to monitor use of PSAOC and its impact on pest control decisions. Meetings were held with the grower participants in winter 1989 and 1990. The 1989 meeting provided crucial feedback on PSAOC design and was also used to formulate the economic evaluation. Sources of data for the economic evaluation are discussed in more detail in the next section.

Participants in the field testing were selected from a list of volunteers who were identified in regular apple extension educational meetings in 1988. Of the 140 volunteers, 26 were selected as the pilot test group. These growers were chosen to represent the spectrum of apple production characteristics in Pennsylvania, including farm size, geographical location, and experience with computers. These pilot test participants met with the study organizers for a day and were given instructional training and software in 1988. Fourteen growers who did not own computers, were loaned Macintosh computers. A control group was chosen in 1989 to provide economic and other data. These growers were chosen to have similar characteristics to the test group to allow a quasi-experimental analysis of the effects of the expert system.

Methods for Economic Evaluation

Many farm-level economic evaluations of pest management methods occur after the adoption process is largely completed. Adopters are then contrasted with non-adopters. However, adopters likely differ on management ability and perhaps other resources from the non-adopters. Thus, the impact of the innovation can be confounded with the beginning resource endowments (Wetzstein, et al.). Alternatively, bio-physical simulation models are used to evaluate innovations in a constant resource environment (Reichelderfer and Bender; Boggers, Cardelli, and Barfield). However, these models may assume management that is beyond field-level capability. Thus, the selection of field test and control groups from a relatively homogenous group of grower volunteers is quite unique for economic evaluation.

The basic premise of PSAOC is that management decisions must consider the apple production system rather than specific production decisions which are the responsibilities of traditional academic disciplines. During the design phase of the economic evaluation, the initial plans were to collect complete input-output data to allow a complete enterprise budgeting analysis of the operations. However, growers in the testing program after the 1988 season reported that they believed that largely pest control decisions would be impacted by using PSAOC. Thus, pest control inputs were assumed separable from other inputs to limit data requirements, and the decision variable was returns above pest control costs (R_p).

In discussing the components of R_p, explicit consideration about the hypothesized impact of the PSAOC is helpful. It was expected that expert system use would benefit growers by educating them about state of the art practices and helping them process specific information about their farm. Anticipated changes in behavior from expert system use included more efficient monitoring for pests and more efficient use of pesticides. In terms of impact on R_p, increases in yield or quality for the same level of inputs, and/or decreases in pesticide quantities are expected. However, management time associated with monitoring and expert system use could increase. If all of these changes are beneficial for expert system use, pest control costs should decrease, revenue should increase and R_p increase.

With these concepts outlined, R_p is defined for the k^{th} case as:

$$(1)\ R_{pk} = \sum_i P_{ik}Q_{ik} - \sum_j w_{jk}X_{jk} - VC_{Mk} - w_{sk}t_{sk} - w_{xk}t_{xk}$$

where P_{ik} = price received for i^{th} grade and variety of apple,

Q_{ik} = quantity produced for i^{th} grade and variety of apple,

w_{jk} = price for j^{th} pesticide input,

X_{jk} = quantity used of j^{th} pesticide,

VC_{Mk} = total variable cost of machinery used in pesticide application,

W_{sk} = per unit value of time for monitoring pests

t_{sk} = time used for monitoring

w_{xk} = per unit value of time used for operating expert system, and

t_{xk} = time used for operating expert system

The first term of R_p is total revenue and total pest control costs is the negative value of the remainder of R_p. The next sector discusses sources of data for these components of R_p.

Economic Data

Data were collected from the growers with a series of mail and telephone surveys. Before the production season began, each grower was asked to select two orchard blocks for the 1989 growing season. One was to be a fresh market variety, preferably Red Delicious, and the other was to be a processing variety, preferably York Imperial. This procedure was designed to further standardize the analysis between user and control groups. All of the data collected were related to the two blocks. Each block is one observation for most of the analysis in this paper. Information about the size, spacing, cultural practices, equipment used, and mix of varieties was collected for each block. After harvest, yields, average prices received and grading information was collected. All these data were converted to per acre figures for each block.

The spring survey also collected data on value of time used for monitoring pests, operating the PSAOC, and machine applications of pesticides. Given that these activities may occur at different times and be conducted by different individuals, separate values were elicited for each of these activities. An adaptation of contingent valuation methods used in natural resource economics (Mitchell and Carson) was utilized to obtain these values. The introduction to the time value question was:

> Please indicate the wage rate, including benefits, of the person performing each of the following production tasks. If the person is not paid a wage (such as a family member), determine the wage rate by estimating how much a person would be paid if hired for that task.

The remainder of the data for R_p were obtained from three sources. Values for t_{sk} and t_{xk} were obtained from weekly surveys during the 28 week growing season. Pesticide use were obtained from copies of pesticide logs that growers maintain for processors and other marketing firms. Finally, VC_{Mk} were calculated with the Mississippi State Budget Generator (Spurlock and Laughlin) using machinery data for each block, the value of time, and number of pesticide applications.

Initially, 60 orchard blocks were identified for data collection. Because of the extensive data requirements, complete data were available only on 35 blocks, 21 for the users and 14 for the control groups. Selected orchard characteristics of the two groups are presented in Table 1. Using standard Student's t tests for differences in the means, tree density and age of trees were not significantly different. The sample selection therefore controlled for differences in these variables impacting apple production. However, the block sizes and especially total apple acreages were significantly larger for the user groups. The sampling procedure largely focused on geographical distribution and unfortunately did not control for size of orchards.

Results

Sample statistics for several important variables are presented in Table 2. The t statistic is the standard test of differences between means and the F statistic for differences among variances. The magnitudes of the means are all consistent with the hypothesized level. Pesticide materials are less, scouting time is more, yields are higher, revenues are more, and returns above pest control are more for expert systems users than the control group. Using one-tailed rejection regions because of hypothesized magnitudes, only scouting time and yields are significantly different. The standard deviations of the two groups indicate the variations in these variables among group members. Since these statistics are from cross-sectional data, they may reflect heterogeneity in the groups rather than risk. However, it is interesting that returns, total revenues, and pesticide materials have smaller standard deviations for the users with the later being significant at the five percent level. These results are consistent with the common perception of improved information reducing risk (Hey).

Table 1. Selected Orchard Characteristics for Expert User and Control Samples[a]

Variable	Unit	Means User	Means Control
Block Size*	Acres	10.11 (1.54)	5.72 (1.47)
Tree Density	Trees/Acre	129.70 (17.99)	183.13 (40.52)
Age of Block[b]	Years	19.79 (2.21)	14.82 (2.56)
Total Apple Enterprise**	Acres	230.19 (41.00)	42.71 (12.86)

[a] Standard error of the mean in parentheses.
[b] Only 19 user blocks were available for this variable.

*Significantly different at 5% level
**Significantly different at 1% level

Table 2. Sample Means and Standard Deviations for Per Acre Economic Variables for Users and Control Groups.

Variable	Units	Means Control	Means User	t-statistic[a]	Standard Deviation Control	Standard Deviation User	F-Statistic[a]
Costs							
Pesticide Materials	dollars	337.14	329.24	0.15	177.02	103.95	52.90**
Scouting Time	dollars	48.5	70.24	-1.91**	29.72	37.43	1.59
Expert System Time	dollars	--	51.38	--	--	30.24	--
Yields	pounds	11,125.76	15,710.16	-1.38*	11,690.59	11,323.58	1.07
Revenues							
Fresh Market	dollars	1,127.32	1,569.27	-0.92	1,569.48	1,677.47	1.14
Processing	dollars	492.75	494.99	-0.01	163.63	110.06	2.61**
Total	dollars	1,765.13	2,058.76	-0.46	1,886.39	1,764.42	1.14
Returns Above pest Control	dollars	1,379.48	1,607.90	-0.36	1,872.56	1,763.65	1.13

[a] *indicates significant at 0.10 level, and **significant at .05 level

Regression models were also estimated for the key economic variables. These models allowed further evaluation of the impact of the expert system while holding some other variables constant which may vary between groups. Two regional dummies were included with the Southeast being the deleted region. Density, which is expected to be positive and a dummy for Red Delicious is included. Percent of revenue from processing was included because this outlet is less profitable than fresh market production. Percent of acreage in apples was included to measure specialization--this variable was expected to be positively related to revenue, returns and yields. Total apple acreage was included as a scale measure. Its effect on economic variables is uncertain as both economies and diseconomies of scale could be operational--gains from specialization versus problems of managerial control as acreage increases. Finally, a dummy variable was included for users.

The results of regressing these variables on returns above pest costs, total revenue, pesticide material costs, and yields are reported in Table 3. The R^2 are good for cross-sectional regressions but do indicate that considerable unexplained variation exists. Density and Delicious were not significant in any of the regressions. However, regional dummies were significant in all but one case. Pesticide costs, yields, revenues and returns were all higher in the two regions with dummies than in the Southeast region. The specialization and scale variables were not significant. The sign of the scale variable supported the diseconomies argument except for the pesticide material costs variable. The specialization variables did not have the expected signs. The processing specialization variable did have the expected signs on returns and revenues with the later being significant at the 10% level.

Table 3. Estimated Regression Coefficients for Economic Outcomes for Expert Systems Evaluation[a]

Independent Variables	Returns Above Pest Control ($/acre)	Total Revenue ($/acre)	Pesticide Material Cost ($/acre)	Yield per Acre (lbs/acre)
Constant	2,279.06*	2,174.33*	105.97	4,998.96
	(1,287.48)	(1,244.33)	(97.16)	(7,863.09)
Orchard Density (trees/acre)	-1.59	-1.40	-0.16	-4.47
	(3.01)	(2.95)	(0.23)	(18.63)
Delicious Dummy (1 if predominant variety is Delicious)	-646.96	-810.86	83.50	-1,582.05
	(815.54)	(778.28)	(60.77)	(4,918.06)
Region 1 Dummy (South Central Pa.)	1,930.25*	1,619.76*	192.00**	6,282.72
	(1,054.01)	(923.40)	(72.10)	(5,835.09)
Region 2 Dummy (North & Western Pa.)	1,982.49**	1,722.86**	177.46***	12,176.20**
	(931.51)	(805.58)	(62.90)	(5,090.55)
Percent of Acreage in Apples	-7.02	-10.34	2.05	-29.43
	(17.18)	(16.18)	(1.26)	(102.25)
Percent of Revenue from Processing Sales	-15.43	-17.00*	0.66	7.59
	(9.82)	(9.56)	(0.75)	(60.43)
Total Apple Acreage	-4.32	-3.61	-0.40	-8.60
	(3.24)	(3.04)	(0.24)	(19.19)
Expert System User Dummy (1 if user)	1,245.84*	1,313.15*	6.36	9,891.87**
	(726.23)	(717.59)	(56.03)	(4,534.54)
Pesticide Material Cost ($/acre)	-2.63	---	---	---
	(2.54)	---	---	---
R^2	0.3958	0.3919	0.3509	0.3203

[a]Standard errors in parentheses.
*Indicates significant at 0.10 level, **at 0.05 level, and ***at 0.01 level.

The results on the user dummy are quite promising. Pesticide material cost does not have the expected sign but is not significant. However, yield has the correct sign and is significant at the five percent level, and returns and revenues have the correct sign and are significant at the ten percent level. The relative magnitudes of the coefficients are also consistent. A higher yield would suggest higher revenue unless quality and price has greatly diminished. Higher pest control costs would mean that returns would increase less than revenues. A case can be made for one-tailed tests of the user dummy variable because of prior expectations on the effect of the expert system. For these regression coefficients, B_{ij}, H_o: $B_{ij} \leq 0$ and H_1: $B_{ij} > 0$. Then, the t statistics of 1.715, 1.830, and 2.181 for returns, revenue, and yields, respectively are all greater than the five percent one-tail critical value of 1.706 for 26 degrees of freedom. Under this interpretation all the coefficients are significantly positive at the five percent level.

Conclusions

This paper reports on an economic evaluation of PSAOC, an apple expert system, developed at The Pennsylvania State University. While PSAOC also includes horticultural decision modules, co-operating growers argued that pest management decisions are the major use of PSOC so this evaluation focused on its impact on pest management and returns above pest control. Unlike most economic evaluations of pest control innovations, this research had a quasi-experimental design. Growers were chosen to field test the expert system from a list of volunteers obtained at extension education meetings. Economic data were collected from these growers during their second year of use. Similar data were collected from a group of growers matched to the user group on geography, size, and other variables. Data were collected on orchard blocks of standard varieties. Thus, more confidence can be placed in the results than most evaluations after the adoption process is largely complete.

The analysis in this paper is based on a data set of 35 blocks. Yields were significantly higher for the user group as was costs of monitoring time. Mean pesticide material costs were lower and mean revenues and returns were higher but not significant for users. In regression models of these economic variables, a dummy variable for expert system use was positive in yield, returns, and revenues, and all were significant at the five percent level in a one-tailed testing format. Despite the small sample, the analysis, therefore, supports the view that expert system use increases returns.

As in all evaluations of technology, the analysis perhaps did not control for all variables between the groups. The R^2 indicates that considerable variation is unexplained. Nevertheless, evaluating a pilot sample of users is more satisfactory in this regard than most pest control technology evaluations. The pilot testing procedure also provided useful feedback on improving the system and establishing a dissemination network (Rajotte and Bowser). Future use of this method should consider random assignment to groups to provide a more controlled experimental research and emphasize procedures for complete data collection so a larger sample is available for analysis.

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APPENDIX 4

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Appendix B

Expert Systems: An Aid to the Adoption of Sustainable Agriculture Systems

Edwin G. Rajotte and Timothy Bowser

Agricultural production has evolved into a complex business requiring the accumulation and integration of knowledge and information from many diverse sources, including marketing, horticulture, insect management, disease management, weed management, accounting, and tax laws. This is especially true of emerging sustainable practices that require even more information (to substitute for purchased inputs) for implementation. Very seldom do farm managers have all available information in a usable form at their disposal when major management decisions must be made. Increasingly, the modern grower must become expert in the acquisition of information for decision making to remain competitive. However, integration and interpretation of information from many sources may be beyond the means of individual growers, so they use the expertise of agricultural specialists. Unfortunately, agricultural specialist assistance is becoming relatively scarce at the same time that the complexity of agriculture is increasing. To alleviate this problem, it is essential that current information be structured and organized into a system for easy access by growers and agricultural specialists. No organized structure is currently available for information storage and retrieval; consequently, technical information, both experimental and experiential, is often lost or unavailable to potential users. One way to make this information readily available is through the use of electronic decision support systems.

The development of an electronic decision support system requires the combined efforts of specialists from many fields of agriculture and must be developed with the cooperation of the growers who will use them. Specialists tend to be trained in rather narrow domains and are best at solving

problems within that domain. However, there is a growing realization that the complex problems faced by growers go beyond the abilities of individual specialists. Interdisciplinary teams of specialists must work in unison to formulate solutions to agricultural problems. Agriculture must be viewed as a system of interacting parts where the perturbation of one part affects many others.

The acquisition and utilization of information can be considered a means of reducing the amount of uncertainty in a given decision problem (Hey, 1979). Because high-quality information has not been easily accessible to growers when they are faced with important management decisions, decision making on the farm has been surrounded by a high degree of uncertainty. To compensate for the large degree of uncertainty, farm managers have increased inputs of chemical pesticides and fertilizers in an effort to minimize the variability in yield and quality that can occur from year to year. The price of this strategy, however, is reduction in potentia profit and an increased threat to the environment because of the overuse o fertilizers and pesticides.

One way to alleviate these problems in agriculture is to substitute high quality interpreted information for purchased production inputs such a fertilizer, labor, and pesticides. By providing farm business managers wit up-to-date, interpreted information, the risk of decision making is reduced the application of unnecessary inputs is eliminated, and profits are increased The problem faced by land-grant colleges of agriculture and other provider of agricultural information has been how to deliver accurate information t farm managers rapidly in an integrated, interpreted fashion. Fortunately several technologies are now available that can help overcome thi problem: (1) data bases that include geographic information systems, (2 expert systems, (3) decision analysis tools, and (4) electronic communica tion through computer systems and telephone lines. A complication o this solution, however, is the fact that the adoption of computer technolog by growers is predicated on a linkage between a particular farm operatio and the access conditions of the particular technology (Audirac an Beaulieu, 1986). These access conditions are determined, in part, by th development of the technology and by private and public diffusion infra structures. The development of diffusion strategies that consider growers needs and capabilities relative to specific access conditions will accelerat the adoption of these new technologies.

DESCRIPTION OF EXPERT SYSTEMS

This discussion concentrates on defining expert systems, describing th development of an apple production expert system, and reporting some o the reactions of commercial apple growers to this new information deliver technology. An expert system(s) is a computer program designed to simulate the combined problem-solving capabilities of a number of people who are experts in specialized disciplines or domains (Coulson and Saunders, 1987; Denning, 1986). Expert systems are able to draw and store inferences from information and are thus often called knowledge-based systems. A form of artificial intelligence, expert systems are capable of integrating and delivering quantitative information, much of which has been developed through basic and applied research, as well as heuristics (experientially based rules of thumb) to interpret quantitatively derived values, or for use when quantitative values do not exist.

Expert systems technology can be used as a delivery mechanism in a larger decision support system. By computing sequences of symbols that represent different levels in the solution of a problem, the expert system attempts to represent a common problem-solving pattern: "if conditions, then consequences" (Denning, 1986; Rajotte, 1987). Moreover, because an expert system remembers its logical chain of reasoning, a user may query the system about why a particular recommendation was given.

In agriculture, expert systems can be used to integrate the perspectives of individual disciplines (e.g., agronomy, horticulture, entomology, ecology, and economics) in a fashion that addresses the day-to-day, ad hoc decision-making processes required of modern farmers. Developed correctly, expert systems can become a powerful tool for providing farmers with the readily accessible, highly integrated decision support they need to practice a sustainable system of farming.

Unlike many industrial applications, most expert systems for agricultural production management are still in the developmental and testing phases (Schmisseur and Doluschitz, 1987). This chapter describes the creation of an expert system for apple production and provides the results of the first widespread field testing of expert systems by growers. Unlike most studies, this research has implemented an evaluation plan simultaneously with the beginning of adoption of the system. Thus, some of the problems with earlier research, such as lack of baseline data and the potential confounding of management ability and adoption (Wetzstein et al., 1985) can be avoided. The purpose of this study is to document the socioeconomic impact of expert systems in terms of changes in knowledge, skills, attitudes, and practices.

DECISION MAKING FOR APPLE ORCHARDS

Apple orchards are highly diversified and complex ecological, economic, and social systems. Apple production is affected by a wide variety of insect, mite, disease, weed, and mammalian pests and is subject to the same economic and social constraints as any agricultural business enterprise. Moreover, orchardists are experiencing increased pressure from environmental and consumer groups to reduce their chemical use, particularly pesticides.

Apple producers have a need to utilize various sources of state-of-the-art agricultural knowledge as well as site-specific, on-farm information in a highly integrated fashion to reduce pesticide use and improve farm productivity and profitability. Alternative methods of pest management in apple production are needed in the face of increasing pesticide resistance and concerns about food safety and human health. The case for implementing integrated pest management (IPM) programs in apple production as one strategy to meet these requirements has been made previously (Rajotte et al., 1987).

However, the best means for effectively implementing IPM programs and other sustainable agriculture practices for widespread adoption are still being discovered. To overcome the initial complexities of converting to IPM, growers require more education, experience, and technical expertise. In addition, orchardists are confronted with an overwhelming amount of information that they need to assimilate in order to make decisions about production, harvesting, and the control of insects, diseases, and weeds. Traditional agricultural information and decision support delivery systems are discipline-oriented packages. Thus, growers must often integrate various disciplinary information and data for application to their own orchards (Rajotte et al., 1987). Rarely, if ever, do apple growers have the time or resources to compile and effectively assimilate all the required information involved in the daily decision-making process. An apple production expert system can provide an improved level of decision support in a timely and integrated fashion whenever and wherever growers require it.

THE PENN STATE APPLE ORCHARD CONSULTANT

An expert system known as the Penn State Apple Orchard Consultant (PSAOC) has been developed to help apple growers make better decisions about production and pest management. After 4 years of development and testing (including 2 years supported in part by a U.S. Department of Agriculture [USDA] low-input sustainable agriculture [LISA] grant), this system has recently been made available for sale to fruit growers in Pennsylvania through Penn State Cooperative Extension (Travis et al., 1990). The system integrates various facets of apple production. It gives the apple grower the information necessary to reduce some purchased inputs by substituting high-quality, integrated, information derived from three sources (state-of-the-art apple production and IPM knowledge;

site specific, farm level data; and weather records). A primary emphasis of the PSAOC expert system is to decrease the detrimental environmental impacts associated with pesticide and fertilizer use as well as input costs, thereby improving farm profitability and reducing economic risk.

PSAOC was designed to view the apple orchard from an ecological perspective as a complex and highly interdependent system where the alteration of one component results in changes in the entire system. The system mimics the way in which growers must approach problem-solving in their orchards. The goal is to consider the orchard as a whole organism, and to make management recommendations in a holistic fashion, rather than making individual recommendations based on independent components (Heinemann et al., 1989).

Two unique characteristics of the PSAOC program are (1) the relative user friendliness of the system, and (2) a built-in user feedback loop that facilitates the incorporation of grower and user suggestions for improving the system into updated versions of the program (Heinemann et al., 1989). The two versions of the PSAOC system, Macintosh (Apple Computers, currently available) and DOS (available in 1991), were designed so that a person who has never used a computer may operate it. Operation of the system can be accomplished without using the keyboard in the Macintosh version. Growers' use of the system is being continuously monitored and evaluated, which allows them to have direct input into how the system is being developed. The software shell being used (PennShell) allows modifications to be made quickly so that updated versions can be rapidly distributed to growers.

Developers of PSAOC felt that these two components (user friendliness and user feedback loop) were critical to attaining the goals (Bowser, 1990; Heinemann et al., 1989). These two components contribute prominently to the ability of growers to input into the system data specific to their own orchards as well as up-to-the-minute weather data. With these baseline data in the system, growers may query PSAOC about specific problems of pest management, soil fertility, and orchard planting. They may also request in-depth supplementary information (including pictures) about an individual insect, disease, or weed. The user may ask the system to explain the logic behind a given recommendation (Bowser, 1990; Crassweller et al., 1989; Heinemann et al., 1989).

Recommendations are usually given with a range of alternatives (where alternatives exist), thus allowing growers to combine their own preferences and experiences with the recommendation being offered by the system. This combined package of information is then used to support the decision-making process of the grower in planning a pest management or other strategy.

Structure of the Penn State Apple Orchard Consultant

When the PSAOC expert system was first introduced to growers in th field test it consisted of three main components: insects, diseases, an horticulture. Since each program fits onto one disk, a top level callin module provided a main menu to call each of the three main modules. I the most recent version, the insect and disease module were fully inte grated into an IPM module. PSAOC is further divided into profile (long- and short-term memory of an orchard block) and various decisi modules that utilize recent orchard observations.

Profiles

The apple producer's orchard management program is based o orchard blocks. A block is the largest unit of an orchard within whic consistent decisions are made (generically known as a management unit A typical orchard may consist of several blocks that are each manage differently. Information about the block is stored in two separate file called long-term and short-term profiles, and each block has its own pr files. The use of profiles eliminates the need for the grower to repea edly enter information about the orchard that changes infrequently. Th long-term profile consists of details about the orchard block that woul not change from day to day. For example, the location of the block wi not change at all. The tree varieties in each block, the ages of the trees, an the history of insect problems remain fixed for an entire growing seaso Projected harvest dates usually remain fixed until the end of the growin season, when they may be adjusted. The short-term profile contains infor mation that either needs updating on a more frequent basis or else has th potential for changing. For example, weather history data that need dail updating are kept in this profile. Crop load and market destination ma change because of a number of environmental factors that alter the quantit and quality of the crop.

Information (besides weather) that changes from hour to hour within day must be entered by the user at the beginning of a new session and is no stored in a profile. For instance, disease incidence and insect and mit population changes may be assessed as often as once a day.

The management program either can be initiated directly from the pro file, in which case all profile information will automatically be loaded int the program, or else the user will be asked if a profile should be loaded The user either can choose a previously defined profile or the user ca create a new one.

The Integrated Pest Management Module

The user has the option of requesting a recommendation about an individual pest problem or running the IPM module, which considers all the orchard and pest characteristics as an integrated system when the management of each component will affect other components.

By considering site characteristics, horticultural parameters, weather conditions, pest severity, and predator density, for example, the program determines whether the insect and mite populations are over thresholds that signal the need for action to control these pests. It then calls a pesticide management module to establish pesticide application priorities. With the help of the expert system, the user then builds a recommendation by considering pesticide efficacy and appropriateness, timing, days to harvest, and tank compatibility. For instance, if the mite population is over the threshold level and predators are not sufficient to control the mites, miticide rates are determined. These rates will vary depending on the severity of the problem. Insecticide rates are then determined for the primary insect over the threshold level (i.e., most damaging). If the primary insect control is effective for all secondary insects, no more insecticide compounds will be considered. Otherwise, the module will determine other compounds and rates to control the secondary insects. Steps similar to those described in the preceding paragraph are taken to determine the disease control recommendations.

The program has now determined an array of miticides, insecticides, and fungicides that will control the pest problems in the orchard block. The array of pesticides is then checked against the days-to-harvest rules. Certain pesticides cannot be applied within a certain period of time before harvest, and that period varies between materials. The program checks the current date and the estimated harvest date and then eliminates any materials that are illegal to use during that time. Most growers mix pesticides into a single tank application. The final filter for the pesticide array is to determine tank mix compatibility between pesticides. Any incompatible chemicals are removed from the array. The user is given a choice of selecting from a list of the remaining pesticides.

Rates for the chosen pesticides are displayed on the computer screen. The program generally recommends a tank mix of a fungicide to control diseases, a miticide to control mites, a primary insecticide to control the most damaging insects, and a secondary insecticide to control any insects that are over threshold but that are not controlled by the primary insecticide. After reviewing the pesticides and rates, the user has the option of asking for a different combination of pesticides for the same pest problems. This option is offered because there are many pesticide combinations that may be suitable.

PSAOC as a Tool for Sustainable Apple Production

Effective use of PSAOC provides growers with specific, IPM-oriente information that they may not have had in a usable form previously. Thi information may tell the grower that certain insect pests are present, b not at economically threatening levels that require application of a pesti cide, or that conditions for a disease infection period have not been me even though it is the proper season for disease infections. This infor mation is substituted for the routine spraying practices that might hav occurred without this knowledge. Thus, the ecosystem is spared the appli cation of unnecessary pesticides, while the grower realizes an economi savings derived from not applying pesticides. Moreover, the yield an quality of the crop is maintained because pest problems are manage with a profitability objective.

PSAOC is a potentially effective tool for sustainable apple productio for six reasons:

1. it delivers IPM-derived information and solutions to pest manage ment problems, the benefits of which are outlined above;
2. it provides this information in a very up-to-date and site-specifi fashion that is unattainable by traditional information delivery systems;
3. this information is always readily available to any grower with acces to a computer and the software, relieving dependence on the accessibility o literature or human experts, thus enabling the grower to make critical, timel decisions whenever necessary;
4. when used effectively, it provides the apple grower with the opportunity to reduce the usage of chemical pesticides, thus reducing the negative impacts of apple production on the ecosystem and human health;
5. it can increase grower profits; profitability is an essential condition for sustainable agriculture; and
6. as additional low-input sustainable methods of production are developed, these can be easily incorporated into PSAOC.

It remains to be seen whether apple producers will successfully adopt this new agricultural innovation on a widespread basis. To address this question, a field test and evaluation of the expert system was conducted during 8 months of the 1988 and 1989 growing seasons. Some of the results of this field research are presented below.

Field Testing the System

During regular extension educational meetings in 1988, apple growers were asked to volunteer for on-farm field testing of the expert system. Over 140 growers volunteered to participate in the first phase of the evaluation.

Of those volunteers, 26 apple growers were selected as a pilot test group. These growers were carefully selected to represent the spectrum of apple production characteristics in Pennsylvania, including farm size, geographic location, and experience with computers. These pilot test participants met with the study organizers for 1 day and were given instructional training and software. Fourteen growers who did not own computers were loaned Macintosh computers.

Growers agreed to use the system and to record their experiences with the system, suggestions for its improvement, and their usage patterns. A monthly telephone survey was used to collect the data being generated by the pilot group. Some results are discussed here. For a more complete discussion see Bowser (1990).

Grower Surveys: System Use and Practice Change

In this section grower usage of the PSAOC expert system is discussed, as are changes in farming practices resulting from this use of the system.

General System Usage Patterns

The number of times a grower uses the PSAOC expert system and the amount of time it is used during each session are indicators of the degree of adoption of the expert system. Table B-1 displays two measures of the

TABLE B-1 Penn State Apple Orchard Consultant Expert System Use Characteristics of Growers

System Use Characteristics	Percentage of Growers (n = 26)
Total no. of times system accessed by growers in 8 months	
0	7.7
1-9	19.2
10-15	34.6
16-29	15.4
30-110	23.1
Total no. of hours system used by growers in 8 months	
0	7.7
1-3	26.9
4-6	15.4
7-9	23.1
10-40	26.9

frequency of use of the expert system: the total number of times that individual growers accessed PSAOC, and the total number of hours they used the system. Both measures are summations of the data from an 8-month period in 1988 and 1989 during which the study data were collected.

The first measure, the number of times that the growers accessed the system, represents the number of times an individual grower actually turned on and used the system, regardless of the duration of the session. This measure shows that 7.7 percent of the growers did not use the system at all, 53.8 percent of the growers used the system less than 16 times in 8 months (2 times per month), and 23.1 percent used it 4 times or more each month.

The second measure in Table B-1 represents the total number of hours that the system was actually used by the growers during those 8 months. Again, 7.7 percent did not use the system at all, 42.3 percent of the growers used it for less than 6 hours, and 26.9 percent used it 10 hours or more.

Total use of the system varied widely by year and time of year. Figure B-1 shows the percentage of growers who accessed the system each month. This variation is explained in two ways. The growers did not receive the system for use until late July 1988. A very high percentage of growers accessed the system during August 1988 (73.3 percent) because they were trying it for the first time. Use of the system in August 1989 was 31.8 percent, which more accurately reflects the need for information a grower would have just prior to harvest. The percentage of growers who

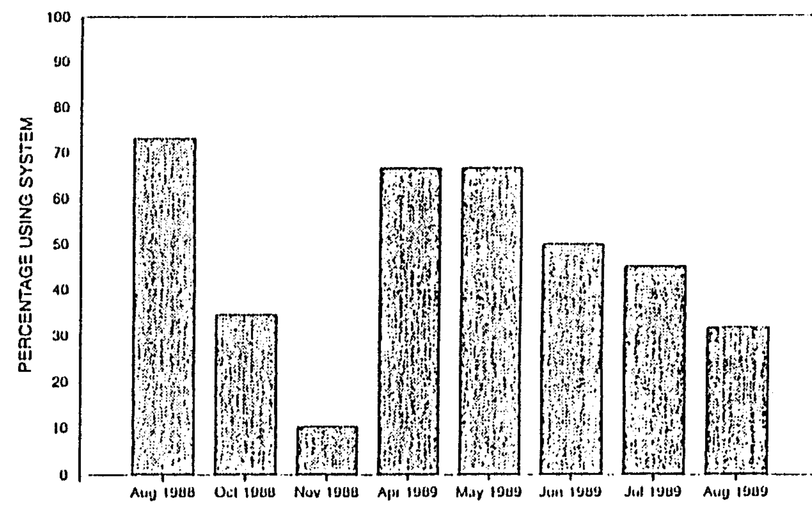

FIGURE B-1 Percentage of growers who accessed the Penn State Apple Orchard Consultant expert system each month.

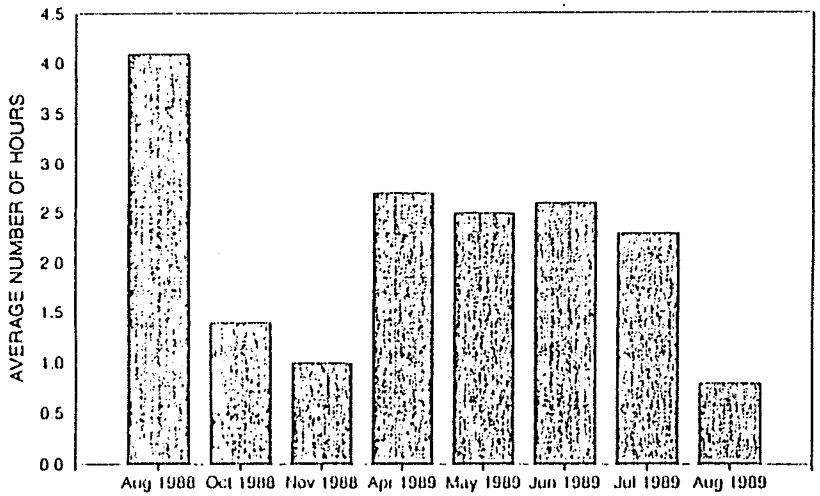

FIGURE B-2 Average number of hours per month the Penn State Apple Orchard Consultant expert system was accessed by growers.

used the system fell precipitously during October (31.8 percent) and November (10.3 percent) of 1988. During 1989, after the growers had the opportunity to review the system throughout the winter months, system use was high in the spring months. The spring is traditionally an intensive period of pest management because of favorable conditions for fungal and bacterial diseases caused by wet conditions. In addition, insect and mite populations begin to increase in the spring and are therefore more vulnerable to management actions. System use gradually decreases throughout the summer, as would be expected based on the declining informational needs of the growers.

Figure B-2 shows the average number of hours of use per month by growers who accessed the system. A pattern of variation similar to that described above occurred. On average, growers used the system fewer times but for longer durations earlier in the growing season than they did later in the growing season. This may be explained by the differences in types of information needed at different points in the growing season. Earlier in the season, growers were more involved in planning and scheduling for the season's work, which required more intensive and in-depth use of information sources. More importantly, pest problems (especially diseases) are much more complex in the spring than in the summer, requiring more time on the computer to extract a recommendation. During the summer months, growers are more involved in crop maintenance and

troubleshooting and may be doing more of the double checking of th own knowledge mentioned above.

These measures of system use taken together indicate one aspect adoption: use of the innovation. While the number of times that the PSAC system is accessed shows how frequently the system is being used, t actual amount of time spent using the system may be a more significa indicator of adoption of the innovation. Some growers reported that th used the system primarily as a quick validation of their own knowled regarding a decision. These growers reported a relatively high number accesses and a low number of hours used. Conversely, the growers w reported that they used the system for many hours were presumably mo fully engaging the logic of the system in their decision-making process.

General Practice Change Characteristics

The degree to which growers follow the recommendations presented l the expert system is a second aspect of adoption. Table B-2 displays tv measures of the frequencies of changes induced by use of the systei (1) any change in growers' production practices and (2) increased pe monitoring. Both measures were derived from the eight monthly surveys

The first measure is a sum of the number of times that growers indicat that use of the expert system stimulated some change in their producti practices. Over the course of the 8 survey months, 65.2 percent of tl growers indicated that they had changed standard production practices some way during at least 1 month. Of these growers, 17.4 percent indicat some change during 3 different months of the 8 survey months.

A significant number of those sampled (65.2 percent) engaged a ne and untried technology and were stimulated to change production practic as a result.

The second of the practice change characteristics displayed in Table B- is a sum of the number of times that a grower was stimulated by the expe system to go to the orchard and scout for a pest (monitoring). Pest monito ing is seminal to any IPM program. A large majority of growers (82 percent) reported that the system stimulated them to increase their monito ing at least once. A total of 30.3 percent of growers were stimulated t monitor their orchards four or more times. As the majority of pest monito ing occurs during April, May, and June, these numbers take on mo significance when viewed as a subset of the eight monthly observations.

Weekly Time Monitoring and Basic Economic Questionnaires

During the field test and evaluation process in the 1989 season, the ec nomic impact of the apple expert system on cooperators' operations and n

TABLE B-2 Penn State Apple Orchard Consultant Expert System Adoption Characteristics of Growers

Production Practice Change Characteristic	Percentage of Growers (n = 23)
No. of times growers reported some change in practices, per grower	
0	34.8
1	21.7
2	26.1
3	17.4
No. of times system stimulated increased pest monitoring, per grower	
0	17.4
1	26.0
2	4.4
3	21.7
4	21.7
6	4.4
7	4.4

income was estimated. Many growers already maintain pesticide logs that contain most of the data needed for development of an apple enterprise budget. A basic economic survey questionnaire was developed from the pesticide record and crop history logsheet of a major commercial apple processor to collect orchard characteristics, apple yields, and prices received. Additional information to aid in the comparison between expert systems users and a control group of nonusers was incorporated into the questionnaire. A weekly time monitoring survey was designed to gather information on the amount of time each grower spent scouting (monitoring) his or her orchard each week as well as what pest problem was being looked for. Pesticide application records were also collected to provide information on the chemicals and rates that the chemicals were applied to each orchard. The survey questionnaire was subjected to three reviews: first, by the research team; next, by all the county agents involved in the project; and finally, by selected growers who had expressed interest in its development. This feedback was particularly helpful for developing the yield and price components of the questionnaire, which was a two-part format that was collected in the spring and the fall.

Results from the monitoring surveys are still being analyzed. While the findings reported here are preliminary and subject to change, they, too, indicate that the expert system is an effective teaching tool. In the past,

extension information has encouraged growers to monitor for mites at th time of bloom and thereafter (week 8 of the growing season). Both PSAO users and nonusers performed scouting at similar frequencies in the post bloom period. However, a new prebloom monitoring practice is recom mended by the expert system as an effective mite control strategy that ma reduce pesticide usage later in the season. The nonusers of PSAOC wer not as aware of this prebloom method. Figure B-3 shows that more PSAO system users tended to monitor for European red mites earlier in th season than did the comparison group of nonusers. Similar behavior ha been seen in PSAOC users who ended their monitoring processes soone than did the control group, thus making more efficient use of limited tim This constitutes direct evidence that use of an expert system can stimulat measurable changes in farming practices.

A preliminary comparison of the farm-gate economics of expert syste users versus those of expert system nonusers shows some trends. Eve though Pennsylvania suffered through a poor apple-growing season i 1989, the preliminary results of the survey show that yields of PSAO users and nonusers were roughly similar.

The cost of time spent monitoring the orchard for pests and using th expert system is also a component of the economic impact being examined Specifically, the team is looking to answer the question of whether saving

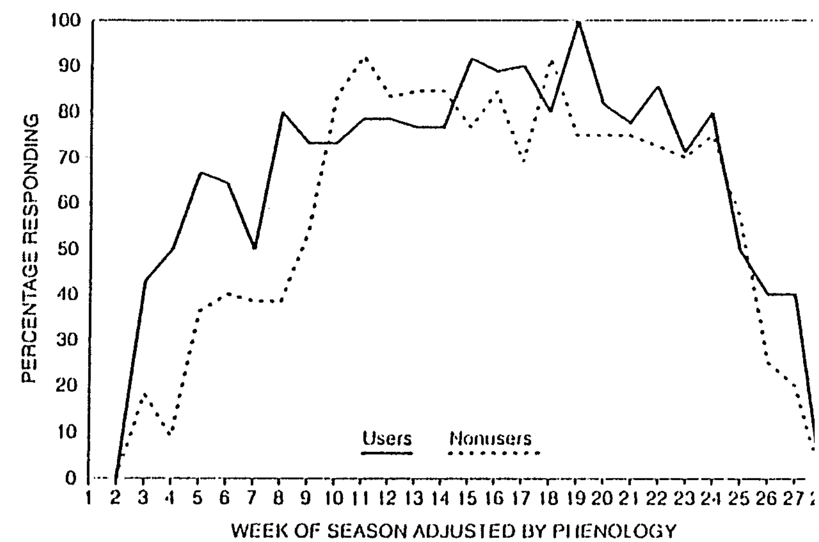

FIGURE B-3 Monitoring for European red mites (ERM) by users and nonusers of the Penn State Apple Orchard Consultant expert system.

on pesticide applications were being offset by greater costs in management. A weekly time-monitoring survey was developed that provides a checklist for most of the common items monitored. Primarily, it asks how much time was spent monitoring each block and using the expert system. This checklist went through the same review process the basic economics survey did.

No clear results have yet been obtained from the pesticide records analyzed thus far, but some interesting trends have been noted. There is some indication that system users may have applied lower amounts of some insecticides than nonusers did. Further analysis of this information may indicate whether or not the expert system is changing growers' practices regarding pesticide use and will provide the basis for partial budget analysis.

Further Mechanisms to Obtain Grower Evaluation, Feedback, and Training

Cooperators' Planning and Review Meetings

The experiences with the PSAOC expert system during the 1988 and 1989 growing seasons were summarized during facilitated meetings of cooperating growers, researchers, and extension personnel in February 1989 and March 1990, respectively. The primary purposes of the meetings were to review the system's performance over the year to date, provide the growers with an opportunity for in-depth input and discussion about improvements in the program, and collectively plan for the upcoming year. In addition, a major benefit was to bring growers from 13 counties in Pennsylvania and researchers and extension agents from three states together to interact for the first time.

The nominal group technique was employed during working sessions with the growers group to solicit any suggestions that they had for improving either the software itself or the field evaluation process. Recommendations were distilled and ranked by growers according to importance during a later session.

Growers and extension agents also strongly suggested the inclusion of more economic information into the PSAOC expert system. A session devoted to procedures for collecting relevant budget data yielded an additional step in the proposed analysis of farm-level economic impacts.

Researchers and extension specialists from The Pennsylvania State University (University Park), University of Massachusetts (Amherst), University of Vermont (Burlington), and the Rodale Research Center (Maxatawney, Pennsylvania) also met for 1.5 days to plan and coordinate the following year's program. Additional responsibilities for expert systems

development and evaluation were outlined for the second- and third-yea plans of work.

Midseason Grower Training Sessions

Based on feedback from growers as well as trends in the survey dat small-group training sessions were held at the Biglerville Fruit Laborator and the Berks County Agriculture Center during the summer of 198 It was determined that the newest version of PSAOC was not bein comprehended adequately and therefore was not being used to its fulle efficiency. These training sessions sought to correct this problem by fami iarizing the growers in-depth with the new aspects of the software.

Electronic Mail Network Among Growers and Researchers

Also in response to feedback from growers, an electronic mail use group was formed to improve communications between cooperating grow ers, researchers, and extension personnel. Using The Pennsylvania Sta University's PenMail system, the growers are able to communicate wi each other, with county extension agents, and with specialists on camp via electronic mail. This communications link has helped to make grow ers more comfortable with the computer and the information they receive.

The electronic mail system was set up in March 1989. Grower commu nications have included questions about insects, pest trapping, use of th computer, and information on the new version of PSAOC. The project' evaluation coordinator has sent out numerous informational and updat bulletins. The growers are also receiving their own copy of the state horti cultural newsletter by electronic mail. Half of the growers have accesse the system (for messages, responses, PenMail) roughly once a week, an the others have accessed the system about once a month. This system ha worked well so far, and it is expected that usage will continue to grow.

Site Visits to Cooperating Orchards

Visits to field test sites were made by evaluation staff at various point during the growing season, to observe orchard management and expert sys tems use by grower. These visits also provided more opportunity for th growers to give input into the development and improvement of PSAOC It was noted that the expert system was more often found in the busi ness office of the orchard, residing on the computer the grower used fo accounting.

Grower Panel at Professional Meetings

Three pilot study growers and the cooperating regional tree fruit exten sion agent presented a panel discussion on the Penn State Apple Orchard Consultant system to over 300 apple growers at a meeting of the Pennsylvania Horticultural Association in January 1990. Discussants provided insights into their experiences with testing of the system, citing both the problems and potentials of using the expert system in orchard management. Panelists were mostly supportive of the new technology, citing increased responsibility on the part of the grower to reduce environmental inputs and improve food safety while still maintaining profitability.

Involvement with Cooperative Extension Agents

Cooperative extension agents were directly involved in the organization and implementation of the project. In addition to consulting on the structure and content of the survey process, agents were primarily responsible for the selection of cooperating growers for the project.

County Extension Agents Survey on Expert Systems for Fruit Growers

A survey was distributed by electronic mail in January 1989 to measure the familiarity of county extension agents with fruit expert systems and to solicit feedback on the overall expert systems program. The survey was necessary for two reasons: (1) many extension personnel were not informed about expert systems development, thus indicating some training sessions were necessary; and (2) feedback was received that indicated agents in cooperating counties could be better served and utilized by the evaluation process.

The survey was sent by PenMail to agents with horticultural responsibilities in all 67 county extension offices in Pennsylvania. Additional questions were asked of agents in the counties where growers were cooperating in the pilot study to solicit feedback on improvements to the evaluation process.

A vast majority (84 percent) of county extension agents were at most only somewhat familiar with expert systems for fruit production. Seventy-six percent of agents indicated that they would attend an in-service training program on how to use this technology in their programs.

Extension Agent Expert System Training Session

In response to feedback from county extension agents, training sessions for county extension personnel were scheduled during the March extension in-service training programs at The Pennsylvania State University. Agents participated in a lecture and discussion of what expert systems are and how they work. In another session, participants received hands-on experience with expert systems in a computer laboratory. This training was provided

to help familiarize agents with expert systems and to lay the groundwor for the future diffusion of agricultural expert systems.

Local Experts Network

A proposal has been made to extension administration to initiate network of extension agents to serve as local experts to support expe systems users within a specified region. The local expert is a person wh learns a new technology quickly and is motivated to help others learn (Landy et al., 1987). Scharer (1983) suggests that the individual is centi to the ultimate success of the training effort. This process, which is ofte used in the diffusion of software technologies, provides a more rapid r sponse to user problems and educational needs than is currently availab through Cooperative Extension programs. It is expected that this netwo will facilitate a more efficient and effective adoption process.

CONCLUSIONS

The project reported here is the first in the literature of an agricultur oriented expert systems being tested in the field with comparisons of us and nonuser practices. Evidence from this study supports the thesis Audirac and Beaulieu (1986) that the access conditions of a technolog need to be considered in the diffusion process. Those access conditions the expert system derived from its technological development as well its intrinsic characteristics are important variables in the diffusion proces In particular, two characteristics seem noteworthy based on the resul of this study.

First, the Penn State Apple Orchard Consultant expert system is prima ily an information delivery technology. While it contains data bas production information (such as weather), it also requires the input of re able, site-specific information in order to formulate recommendations f the user. The information requested as well as the resultant recommend tions require the apple producer to form questions and to look at problen in a manner different from that of previous information delivery system used in apple production. That this transition will not occur automaticall is reflected by the fact that the test group exhibited various levels of us and that almost none of the changes in practices occurred until growe had sufficient time to develop some familiarity with the system's logi Some growers indicated that they still do not trust the system to mak decisions for them. This attitude is appropriate. PSAOC is not intended a substitute for good management but as a source of information to guid and enlighten growers' decisions. Distrust of the PSAOC expert syste could also be the result of incongruence between growers' perceptions the system versus those of their apple orchards. The expert system is an information technology that is intrinsically different from most information technologies that have previously been used by apple producers. The kinds of practical and educational experience a grower or user has may affect how well the system is understood and, thus, adopted.

Second, the expert system is a technology that is inherently connected to microcomputers. For a grower to make use of the decision support capabilities of PSAOC, they must (1) have access to a microcomputer capable of running the system and (2) be able to operate the computer proficiently. While the software was designed and developed to be used by people with little or no computer experience, results of the study indicate that growers with the least amounts of computer experience also had the lowest rates of system use. This would appear to be an example of the access conditions of the technology not being congruent with the farming operation. This technology is inherently computer based, and a farming operation must have access to a computer and a person who can operate it before the technology will be adopted.

By substituting information for some chemical inputs, the Penn State Apple Orchard Consultant expert system has the potential to contribute to the generation of more sustainable apple production systems in the northeastern United States. This trend can accelerate through the introduction of more information-intensive, low-input IPM practices into the farm production system. This study has provided some preliminary evidence that changes in usual production practices occur as growers and users substitute information for purchased inputs, in this case, pesticides. It was also demonstrated that the substitution of information for inputs was stimulated by the expert system, which enabled the grower or user to collect, integrate, and interpret the information rapidly. However, based on other evidence produced by the study, it appears that the potential for sustainable agriculture that this technology holds will be diminished without some attention to better linking of the access conditions of the technology to the farming operation.

RECOMMENDATIONS

More work will need to be done at the first stage of the diffusion process if the Penn State Apple Orchard Consultant is to become an effective tool for sustainable agriculture. This first stage concerns the set of activities which provide for the "establishment of diffusion agencies or a network of outlets from which the innovation is distributed to potential adopters" (Audirac and Beaulieu, 1986, p. 63).

In the present case, it is planned that this diffusion network will be the traditional Cooperative Extension Service network of university and county

extension offices and personnel. In addition to acting as the distributi agent for this innovation, this network must also provide new education training programs in key areas identified by this research, if the effecti adoption of this innovation and its potential for sustainable agricultu are to be realized. Some growers are not using the system very ofte and others are not being stimulated to change production practices bas on their use of the system. In some of these instances, perhaps no chan is necessary or advisable. In other instances, change would be high beneficial in terms of grower profits and reduced pesticide use. In the lat case, effective adoption is not occurring and the potential to reduce t amount of pesticide inputs being used is diminished.

To correct this situation when the system is offered for general u by growers, it is recommended that the diffusion agency provide n educational programming in the following areas:

1. training in and basic orientation to computer use for farming o erations in general and agricultural expert systems in particular; the training sessions should be held on a very localized basis and taught people who are familiar with expert systems software and the croppi system being discussed;
2. training that provides an overview of the gradual modification existing production systems to incorporate reduced-input methods; th training should focus on societal-level needs and responsibilities for redu ing pesticide use as well as the long-term farm-level benefits for doing s
3. establishment of a network of local experts to provide a resource f growers experiencing difficulties with the computer or expert system;
4. continual updating of system capabilities, so that recommendatio remain scientifically current and appropriate;
5. training of extension specialists and agents to familiarize them wi the possibilities and potentials of the system; and
6. beginning the process by delineating the criteria and goals for su tainable agriculture attainable with expert systems as a tool. In this wa scientists will be better able to begin to design production systems f agricultural operations of all sizes that provide more flexibility in respond ing to dynamic production conditions, thus enabling time and spatiall specific recommendations for the expert system to be better implemented In the long run this may be the greatest contribution of agricultural ex pert systems development toward a more sustainable system of globa agriculture.

ACKNOWLEDGMENTS

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E. Rajotte and L. Hull, Department of Entomology; R. Crassweller, Department of Horticulture; P. Heinemann, Department of Agricultural Engineering; and R. Bankert, V. Esh, J. Kelley, and C. Jung, Integrated Pest Management computer programmers. Program evaluation was conducted by J. McClure and T. Bowser, Department of Entomology; C. Sachs, W. Musser, and D. Laughland, Department of Agricultural Economics and Rural Sociology; and W. Kleiner, Pennsylvania State University Cooperative Extension. Cooperators from other institutions include L. Berkett, Department of Plant Pathology, University of Vermont; D. Cooley, Department of Plant Pathology, University of Massachusetts; and S. Wolfgang, orchard leader, Rodale Research Center. Partial support for this work was provided by LISA project LNE88-8, "Implementation of Electronic Decision Support System for Apple Production."

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