Technology Transfer

A User-oriented Approach to the Design of a Knowledge-based System for Winter Freeze Protection of Peaches and Nectarines

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ADDITIONAL INDEX WORDS. *Prunus persica*, interview, mail survey, task analysis, task allocation, computers, bud hardiness, model

SUMMARY. The techniques of task analysis and task allocation were applied to the problem of decision support system development in tree fruit production. The task of midwinter freeze protection of peach and nectarine [*Prunus persica* (L.) Batsch] flower buds was chosen as the model system. Sixty-five tasks and subtasks were identified as necessary components of the freeze-protection activity at the testing and subsequent management activity levels. Of these, 45 were done exclusively in the orchard where we wished to focus our efforts to benefit the broadest group of growers. Of these 45 tasks or subtasks, 13 were judged suitable for computerization. These 13 tasks were prioritized in order

of importance to growers through a self-administered mail survey that asked how often they would use a computer to perform each task. Based on a 77% rate of return, peach and nectarine growers indicated that they were most likely to use a computer to monitor weather forecasts for general weather and freeze alerts, monitor real-time orchard temperatures, and estimate critical temperature ranges for flower-bud damage. This close interaction also produced additional design and use information for the proposed knowledge-based system, such as data presentation requirements, the presence of a variety of farming styles that often determined how the critical temperature data were produced and used, and the challenges of developing suitable validation data for the users.

Peaches and nectarines are grown on 1700 ha in central Washington and, while data are not available for nectarines, peach production on 1200 ha had an average yearly value of \$11,448,567 over the 5-year period ending in 1995 (Hasslen and McCall, 1995). Cold weather injury is the most serious cause of crop loss and can severely limit production (Proebsting, 1982). Because of the perennial risk of spring freeze damage, peach and nectarine growers traditionally have invested in freeze-protection technology (Reiger, 1979), particularly fossil fuel-burning orchard heaters and wind machines. Based on winter bud hardiness research initiated at Washington State Univ. in the late 1950s, growers realized that this technology also could be used to protect dormant peach and nectarine flower buds from freeze damage (Willett et al., 1994).

The relationship between temperature and fluctuations in dormant bud hardiness was quantified and a simulation was developed to predict peach bud hardiness (Proebsting et al., 1988). This simulation was coded in BASIC and made available to peach and nectarine growers. However, perhaps because growers were uncertain of its accuracy or because they were unfamiliar with using computers to obtain production information, the simulation is not in use. Additionally, because the simulation does not predict bud hardiness with equal validity during the entire late fall to early spring period, considerable expertise is required to interpret its output. If heuristic reasoning about the pattern of changes in hardiness of dormant peach and nectarine buds could be merged with the simulation software, a more useful tool might result.

During the past decade, interest has grown in using computer applications to help make agricultural management decisions. Computer programs that attempt to mimic human reasoning, referred to as knowledge-based systems (KBS), are receiving the most attention and currently are regarded as potentially the most effective computer-based method of delivering production information to farmers (Calvin and Rajotte, 1989). Winter freeze protection of peaches and nectarines appears to be a perfect candidate for KBS development, as it is a distinct task subset of cold-weather injury protection and has a well-established knowledge base consisting of documented and undocumented experience. It is an important task that could benefit from additional real-time information. Incorporating bud hardiness simulation into a computer-aided decision support system is logical because calculations made by the simulation are complex and can be done quickly by a computer.

The early years of agricultural KBS development pro-

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duced high expectations for these systems, including the possibility of raising the performance of an average worker to the level of an expert (McKinion and Lemmon, 1985). Recently, some of these early agricultural KBS developers have noted that few, if any, of the currently available KBS are in general use by agricultural producers (Thompson et al., 1992). This has been attributed in two reports (Goodell et al., 1993; Thompson et al., 1992) to limited attention given to the user of these systems during program development and to the assumption by the expert developers that the user is interested in system interpretations with which the expert is most familiar. Both of these reports recommend that the users become partners in the early design phase and that developers consult closely with users during development to truly understand users' needs.

A human-factors approach to expert system development has been proposed to ensure optimization of the human/computer interaction (Amell et al., 1991; Gordon et al., 1987; Madni, 1988; Sjöflot, 1986). A human-factors approach is the design and evaluation of a system or equipment for the optimization of human performance and, therefore, optimizes total system performance (Gordon et al., 1987). They note that, while the goals of optimization may mean increasing accuracy, safety, efficiency, and/or

speed of performance, another important goal may be to improve user satisfaction.

Computer-based decision-aid developers must understand the type of questions as well as the depth and breadth of the answers needed by the user and have a complete understanding of the type of work done by the user (Castore et al., 1988). Two well-established human-factors design techniques can be used to fulfill the latter requirement. Task analysis consists of identifying all of the physical and psychological tasks and the associated subtasks that must be completed by either the human or machine to meet the various system-performance requirements and constraints. Task allocation is a process of determining which of the identified tasks or subtasks are best performed by the human and which are best performed by the machine. This process of allocation is an ongoing part of the design process. While it can be systematized, it is essentially a creative process that cannot be done entirely by formula (Price, 1985).

There are few real-world examples that describe the use of task analysis in expert-system software development. Suh and Suh (1993) proposed using specific human-factors guidelines to improve the acceptance of expert-system technology and its greater inclusion into management information systems, and Frascina and Steele (1992) applied a human-factors approach to create a user-centered design process for a hospital information support system. Amell et al. (1991) provided the first example of applying human-factors techniques to KBS development in natural resource management, focusing on identification of potential KBS applications in the relatively broad and complex task of forest stand-level analysis. They offered suggestions on using human-factors techniques to create a KBS more compatible with user needs. We used Amell's work as a conceptual framework on which to develop an example of a user-driven design process for KBS development in horticultural management, with a goal of developing a prototype peach and nectarine freeze protection KBS for use by central Washington orchardists.

Materials and methods

To understand fully the task of winter freeze protection, the literature on stone fruit freeze protection was reviewed thoroughly. This information is important to understanding the type of work done by the people making commercial stone fruit bud hardiness determinations, because their activities are based on this information. Key personnel at three peach and nectarine growing, packing, and sales organizations in the Yakima Valley (the largest peach and nectarine growing area in the Pacific Northwest) who currently operate freeze chambers to make and disseminate stone fruit bud hardiness determinations, were asked to participate

Table 1. Likert-type scale survey asking peach and nectarine growers about the potential usefulness of some computer-based applications. Only a portion of the table is shown as an illustration.

Next we would like to ask you some questions about decisions and actions which are important for winter freeze protection.

Q-6 From previous research, we have identified the following tasks which could possibly be computerized. For

each task listed below, indicate how often you would use a reliable computer-based decision support system to do the task. If you think a task does not apply to your job select NA (Circle one choice for each task).

If you had a reliable computer-based decision support system, how often would you use it to do this task for you?

1. Monitor National

Weather Service

forecasts for general

weather..... ALWAYS OFTEN SOMETIMES RARELY NEVER NA

2. Monitor National

Weather Service

forecasts for freeze

alerts..... ALWAYS OFTEN SOMETIMES RARELY NEVER NA

3. Based on weather

forecast make a

preliminary estimate of

freeze

risk..... ALWAYS OFTEN SOMETIMES RARELY NEVER NA

Table 2. Results of task analysis for winter freeze protection of peaches and nectarines.

Task and description	
1	Monitor weather. Monitor National Weather Service Forecasts for general weather. ^z Monitor National Weather Service Forecasts for freeze alerts. ^z
2	Make preliminary estimates of freeze damage risk. ^z Estimate risk based on previous season tree vigor. Estimate risk based on time of year. Estimate risk based on previous days temperatures and seasonal trends. Integrate all factors.
3	Protect flower buds and woody parts of the tree if (wood may be less hardy than buds): Time of year is before November 15 Previous days temperatures have been warm (>5C) and Predicted temperature is -10C to -20C or less.
4	Initiate protection planning for dormant flower buds if (wood is hardier than buds). Time of year is after November 15 and Predicted temperature is -15C to -20C or Time of year is after January 31 and Warm temperatures (>5C) occur, dehardening specific varieties which may have completed endodormancy, based on previous season's bud tests.
5	Determine regions and varieties at risk of freeze damage. Identify geographical areas at risk of bud damage based on regionally temperature forecasts. ^y Identify varieties to be tested, choosing most tender varieties and/or those most extensively planted. ^z Randomly collect shoots of those varieties from those areas taking care to collect wood which would be retained after pruning. Keep shoots at ambient air temperatures during collection and transport. Protect from thawing and get into the freeze chamber as soon as possible. Start freeze chamber. Set freeze chamber to at or below outside ambient temperature. Estimate critical freezing range based on previous experience or previous test results, trying to include minimum predicted temperature. ^z Estimate flower bud kill at temperatures above and below selected critical range. ^z Select uniform size and vigor shoots for placement in freeze chamber allotting 30 to 70 buds per test temperature, depending on species. Loosely bundle each sample. Select one bundle as an unfrozen control to determine preexisting damage. Place bundles singly in freeze chamber or bundle with others to be removed at specific test temperature. Allow samples to equilibrate for 20-30 minutes in chamber. Lower temperature in freeze chamber at the rate of 1-2 degrees per half hour to desired test temperatures. Hold chamber at desired test temperatures for 25-30 minutes. Remove sample and place at room temperature to allow injured tissue to initiate browning reaction. After 45-60 minutes cut diagonally through flower buds with a single edged razor. Examine cut buds with or without the aid of magnification looking for a brown discoloration of the pistil or receptacle tissue. Ignore buds killed previously, identified by dry, brown damaged tissue. Record number of fresh, dead (discolored) buds for each variety, location and test temperature. Convert to per cent kill and record. Summarize tests and report to growers. Growers, in consultation with field staff, determine allowable per cent kill and critical temperatures. ^z
6	Once tests are completed, continually monitor National Weather Service forecasts for expected minimum temperatures, dewpoint, wind speed and direction.
7	Prepare for protection. Install thermometers and frost alarms accurate to expected minimums. If necessary clear snow from orchard heaters and plow roads to wind machines. Fuel orchard heaters. Run wind machines for 30 to 60 minutes during afternoon. Set frost alarm for 2 to 5 degrees above critical temperatures depending on dewpoint and allowing for any differences between frost alarm location and coldest areas and amount of protection which needs to be activated. ^z Develop a written plan to start protection at specific temperatures to avoid confusion later. Go to bed early. Monitor orchard temperatures. ^z If frost alarm is triggered, waken, dress, jump in pickup and check on-site thermometers in the coldest areas which may need protection. Continue checking temperatures in traditional cold spots. Start and idle wind machines if temperatures drop to 0-5 F. ^z
8	Protect stone fruit orchards. Engage wind machines if temperatures drop within about 2 F of predetermined critical temperatures depending on amount of equipment to be started and rate of temperature fall. Continue checking orchard temperatures. Light supplemental heaters if temperatures drop to or below critical temperatures with wind machines running. Continue protection until ambient air temperature outside protected area is well above critical in the orchard. Extinguish supplemental heaters as soon as possible Stop wind machines. ^z
9	Assess damage. Estimate bud losses based on actual minimums. ^z Collect sample of flower buds from protected orchards. Allow to warm to room temperature to complete browning reaction. Cut diagonally through flower buds to expose pistil and receptacle tissue. Observe number of damaged buds to determine effectiveness of protection.

^zTasks allocated to computerization.^yn = 113.

Fig. 1. Decisions made and actions taken during the risk estimation phase of winter freeze protection of peaches and nectarines. Numbers and letters in the body of this and the following figures refer to the position of the task on the task list.

in the project. As growers themselves, these individuals indicated an interest in a computer-based decision aid, although none of them was a regular computer user.

Each individual's opinions and ideas were solicited at least five times during the task analysis and allocation procedure. An initial interview introduced the project to each cooperator and allowed us to become more familiar with all participants and their objectives when making bud hardiness determinations. Two subsequent interviews with each cooperator were structured using question probes (Gordon and Gill, 1989) to map the declarative knowledge of subjects before they began the problem-solving task. This method consists of using an extensive and systematic set of questions to interview each person. Interviews lasted about 1 hour and were recorded and transcribed for analysis. After the second interview with each cooperator, responses were compiled into a composite task list. Two additional interviews were conducted with each subject to confirm that the task list was complete, accurate, and in the

proper order. A new composite task list was developed after each round of reviews. On-site visits also were made during bud-hardiness testing and freeze protection activities to observe and understand more fully the tasks associated with this process.

The task lists then were organized into decision/action diagrams (Meister, 1985). These are referenced also as information flow charts and are used to show the flow of required system data in terms of decisions and actions performed. These diagrams are used to provide an easily understood graphic representation of the system and allow easy translation of the information into flow charts for computerized sections of the system. Cooperators were consulted as necessary during this process for additional clarification. Using rules provided by Price (1985), specific

Fig. 2. The process of conducting winter bud hardiness freeze tests as conducted by packinghouses in estimating critical temperatures for protection.

Fig. 3. The physical actions and decisions associated with preparation for freeze protection in peach and nectarine orchards.

tasks then were allocated to either the machine or human components of the system.

Following task allocation, a mail survey using the total design method (Dillman, 1978) was conducted between 12

Apr. and 29 June 1994. The mailing list was developed from a database of Washington orchardists who had identified themselves as growing peaches or nectarines on subscription renewal surveys conducted by the *Good Fruit Grower* magazine. All fruit growers in Washington automatically receive this periodical. A grower who is identified as a peach and nectarine grower on this list may have horticultural interest in peaches and nectarines but may not have commercial quantities of these fruit. The 1992 Census of Agriculture identified 352 peach growers in the 8 counties of central Washington by requesting responses if the farmer had as few as 20 trees for home use as well as those maintained for sale of production (U.S. Dept. of Commerce, 1994). The *Good Fruit Grower* list had more than 600 names in the same geographic area. To avoid the expense of sending surveys to many individuals who had minor economic interests in peach and nectarine production, extensive modifications were made to this mailing list in consultation with knowledgeable industry representatives who had close ties to the packing and marketing of stone fruit. In doing this, we identified 158 peach and nectarine growers in Washington who produced 10 t of fruit or more each year. Ten tons is the sales volume threshold at which fruit inspection by the Washington State Dept. of Agriculture is mandatory. All of the growers were asked how often they would use a computer to do each of the 13 tasks that were allocated to computerization. Responses were organized on a Likert-type scale from always to not applicable (NA) (Table 1). Once the survey was complete, the Likert-type scale responses were converted to numerical values (1–6) for analysis. The NA response was retained in the analysis and interpreted to mean never-ever or impossible. There could have been many reasons for this response, ranging from a lack of a computer to those respondents who never use freeze protection.

A nonparametric test, Friedman's two-way analysis for block designs (Conover, 1980), was used. For this test, each respondent was considered a block and each of the tasks allocated for possible computerization was considered a treatment. Grower responses were ranked from 1 to 13 within blocks across the treatments (Number Cruncher Statistical System, Kaysville, Utah), with ties given the mean value of the corresponding ranks. These ranks were then subjected to a main effects analysis of variance (PROC GLM; SAS Institute, Cary, N.C.). Friedman rank sums were obtained as the product of each treatment's mean rank and the total number of responses for this question ($n = 113$). Differences between the Friedman rank sums were examined by subjecting them to the nonparametric, distribution-free multiple comparison procedure described by Hollander and Wolfe (1973).

Results and discussion

Although the task of winter freeze protection represents a very small portion of orchard manage-

Fig. 4. Decisions/actions necessary to protect peach and nectarine orchards from winter freeze damage.

ment decisionmaking, through the process of task analysis we identified 65 tasks and subtasks associated with midwinter freeze protection in peaches and nectarines (Table 2). These tasks fell into five general categories: risk estimation, hardiness testing, preparation for freeze protection, protection, and damage assessment. Some of these are physical tasks and others are cognitive tasks. Of the 65 tasks, 20 were performed by packinghouse employees who were directly involved in operating freeze chambers to determine critical temperatures. The remaining 45 tasks were performed at the orchard level. Of these 45, 13 were allocated to computerization (Table 2).

The decision/action diagrams (Figs. 1–5) illustrate a more-realistic information flow than could be represented in the task list and allowed us to develop a more detailed conceptual model of the process. These flow charts provide insight into which portions of the decision process are well understood and which could benefit from additional expertise when considering freeze protection action. For example, it became clear that we needed to know more about the period before late November when wood damage may occur at higher temperatures than bud damage. Also, growers are aware that significant changes in the hardening/dehardening process occur in the late winter once endodormancy requirements are fulfilled, but their understanding of how these processes change is incomplete. The existing bud-hardiness simulation is inaccurate in estimating bud hardiness at this time of year and additional expertise about the limits of reliability of this portion of the simulation is needed. The decision/action diagrams were also useful in structuring and guiding the knowledge acquisition portion of the project.

The mail survey of 158 peach and nectarine growers in the state resulted in a 77% response rate to all or most of the survey. In the section in which we asked respondents to rate their willingness to use a computer in each of 13 tasks, there were 113 usable responses for a 71% response rate. The tasks surrounding weather forecasting and estimating critical temperatures were ranked highest for potential computerization by Washington peach and nectarine growers (Table 3). Damage assessment and using a computer to start and stop wind machines were ranked lower. These differences may be due to a grower's reluctance to rely on nonhuman assistants to perform such critical tasks as turning the wind machines on and off or for complicated tasks, such as estimating flower bud kill in an orchard, that may affect subsequent deci-

sions to invest in protection on future cold nights. Only 45% of the growers had practiced winter freeze protection during the previous three winters. Of the respondents, 74% reported owning a computer.

Apart from the quantitative measures, task analysis also provides a means of producing a specification requirement that ensures that critical components are included but it also can 1) constrain development so as not to add superfluous tasks, 2) provide a hypothetical model of the process, and 3) provide a set of benchmark tests against which the computer system design can be tested (Johnson, 1992). It is inevitable that the types of focused discussions occurring during a task analysis also lead to greater knowledge about potential user attitudes and needs.

For example, the results of research-based peach bud hardiness testing are usually presented as the temperature at which 50% bud kill will occur (T50). The prototype bud hardiness simulation that we are currently validating in on-farm trials also reports bud hardiness in terms of T50. However, since peach growers developed the concept of critical temperatures for winter freeze protection from their experiences with spring frost protection, a time of year when even 10% kill is to be avoided, being provided only with a prediction of a 50% kill temperature is not perceived as sufficient management information. Ironically, the cooperators interviewed for this study noted that as much as 60% bud loss could be sustained without significant crop loss and higher losses could be tolerated with an adjustment in pruning. To be acceptable, the simulation must provide output that estimates bud kill at a range of percentages from near 0% to 50% or higher. As a result of the information learned in the task analysis interviews, it seems appropriate to modify any future simulation output to provide a range of critical temperatures from 0% to 100% bud kill. This would allow growers greater flexibility in their use of the output of the simulation.

Although we believed that it was logical to use a computer to aid in the stone fruit freeze protection decision process, we first attempted to learn how the decision to freeze protect (or not) actually was made. We learned, among other things, that this decision, although implemented on a farm-by-farm basis, was really made as a community process. The five stone fruit packing houses that freeze buds routinely share information on the results of their freeze tests with each other as well as other growers in the community. Among winter freeze-protection practitioners who returned the mail survey, 74% agreed with the statement, "I try to compare freeze test results from two or more packing houses to help me set critical temperatures." Because there are no visible changes in bud appearance to help growers track bud hardiness, the process is relatively uncertain and growers welcome additional information.

In this study, three areas emerged in which the simulation could be helpful. The first is to help freeze-chamber operators determine the temperature range at which to conduct freeze tests. Some operators use the forecasted minimums as a guideline in setting the test range, but if the forecasted minimums will not result in bud kill, the test will not provide information on critical temperatures. Second, since freeze tests usually are not conducted daily, changes in hardiness in the days following a freeze test must be estimated. An accurate KBS could eliminate some of that guesswork. Third, the KBS must be able to predict hardiness

Fig. 5. Estimating damage following a critical or near critical freezing night.

Table 3. Results of multiple comparisons based on Friedman rank sums including the proportion of respondents who would always or often use a reliable computer-based decision aid to do the task.

Task no. and description	Rank sum ^a	Proportion ranked always or often ^y
6 Determine critical temperature range	611.33 d	0.72
2 Monitor National Weather Service forecasts for freeze alerts	614.72 d	0.73
3 Based on weather forecast make a preliminary estimate of flower bud freeze risk	713.03 dc	0.69
4 Calculate flower bud kill at temperatures above and below the critical temperature range	718.68 dc	0.62
5 Monitor National Weather Service forecasts for general weather	736.76 dc	0.64
Identify specific varieties at greatest risk of bud damage.	744.67 dc	0.65
Monitor orchard temperatures	750.32 dc	0.61
Set frost alarm	751.45 c	10.59
8 Determine acceptable flower bud loss and set temperatures to initiate protection	752.58 d	0.63
Based on regional forecasts identify growing districts at risk of freeze damage	836.20 cb	0.56
Estimate post-freeze bud kill based on actual orchard temperatures	858.80 b	0.53
Start wind machines	995.53 ba	0.38
Stop wind machines	1054.29 a	0.32

^aFriedman rank sum separation as described by Hollander and Wolfe (1973) at $P \leq 0.05$.

based on weather forecasts. Growers need lead time to prepare for freeze protection (Willett et al., 1994). Current National Weather Service forecasts for the succeeding 3 to 5 days are becoming much more accurate, with temperature the most reliable parameter that could, in turn, result in a fairly high quality prediction of bud hardiness.

Irrespective of how we, as developers, view its value, a KBS developed for winter freeze protection may never be used in the specific manner envisioned. For example, in spite of using the same technology and the same procedures to conduct freeze tests, some packing houses arrive at critical temperatures substantially higher than other packing houses. This study did not directly assess the reasons for these differences, but they were clear. It is important to develop a KBS that, in the end, helps growers organize information to make better decisions. Presently, we know that many peach and nectarine growers want to know when damaging temperatures might occur and how hardy the buds might be. How they use this information may depend on the relationships they have with other people in the freeze protection community.

Task analysis also provided considerable insight into some basic educational needs regarding the use of simulation data in comparison to the data collected by growers in their own freeze tests. While considerable variability exists in the amount of bud kill across the critical temperature range on any given winter day in a peach orchard, growers conducting freeze tests rarely gather sufficiently large samples to completely describe that variation. In assessing the accuracy of the peach bud hardiness simulation, growers have compared the mean bud kill from their own tests with that derived from the simulation at the same temperature. Given the variability that exists in freeze testing, these two means may be numerically but not significantly different. Past experience with grower validation of simulation models only required that the growers perceive that the expected result was obtained, not whether the simulation matched their own technical assessments. To assess the simulation's accuracy better, the validation process will need to provide growers with a better conceptual understanding of biological variability and its description.

Literature cited

- Amell, L.A., M.W. Stock, and S.E. Gordon. 1991. Expert systems for silviculture: A task analysis. *AI Applications* 5(1):23-32.
- Calvin, D.D. and E.G. Rajotte. 1989. Approaches to the development and implementation of knowledge-based systems in agriculture and natural resources. *AI Applications* 3(3):57-58.
- Castore, C.H., P.D. Wadwa, S.V. Karau, and J.R. Barrett. 1988. User acceptance of decision support software. Presented at the 1988 Annual Meeting of the Amer. Soc. Agr. Eng., microfiche collection; fiche no. 88-7540.
- Conover, W.J. 1980. *Practical nonparametric statistics*. 2nd ed. Wiley, New York.
- Dillman, D.A. 1978. *Mail and telephone surveys: A total design method*. Wiley, New York.
- Fraschina, T. and R.A. Steele. 1992. The integration of hospital information systems through user centered design. *MEDINFO* 92:1274-1279.
- Goodell, P.B., J.F. Strand, and M. Ostergard. 1993. Delivering expert systems to agriculture: Experiences with CALEX/Cotton. *AI Applications* 7(2&3):14-20.
- Gordon, S.E. and R.T. Gill. 1989. Question probes: A structured method for eliciting declarative knowledge. *AI Applications* 3(2):13-20.
- Gordon, S.E., R.T. Gill, and T.A. Dingus. 1987. Designing for the user: The role of human factors in expert system development. *AI Applications* 1(1):35-46.
- Hasslen, D.A. and J. McCall. 1993. *Washington fruit survey 1993*. Washington Agr. Stat. Serv., Olympia.
- Hollander, M. and D.A. Wolfe. 1973. *Nonparametric statistical analysis*. Wiley, New York.
- Johnson, P. 1992. *Human computer interaction: Psychology, task analysis and software engineering*. Maidenhead:McGraw-Hill, London.
- Madni, A.M. 1988. The role of human factors in expert systems design and acceptance. *Human Factors* 30(4):395-414.
- McKinion, J.M. and H.E. Lemmon. 1985. Expert systems for

agriculture. Computers Electronics Agr. 1:31-40.

Meister, D. 1985. Behavioral analysis and measurement methods. Wiley, New York.

Price, H.E. 1985. The allocation of functions in systems. Human Factors 27(1):33-45.

Proebsting, E.L. 1982. Cold resistance of stone fruit flower buds. Washington State Univ. Coop. Ext. PNW221.

Proebsting, E.L., P.K. Andrews, A. Swindeman-Murphy, and G. Reisenauer. 1988. Forecasting hardiness for winter cold protection in peach orchards, p. 159-163. In: P.H. Li (ed.). Low temperature stress physiology in crops. vol. 2. CRC Press, Boca Raton, Fla.

Reiger, M. 1979. Freeze protection for horticultural crops. Hort. Rev. 2:45-109.

Sjoflot, L. 1986. The human factor aspect in application of electronics and computers in agriculture, p. xvii:1-xvii:4. In: NJF Symp. Computers, Electronics and Control Engineering in Agriculture, Are, Sweden.

Suh, C.K. and E.H. Suh. 1993. Using human factor guidelines for developing expert systems. Expert Systems 10(3):151-156.

Thompson, T.L., J.R. Barrett, and D.D. Jones. 1992. Decision support systems for U.S. agriculture—A status report, p. 670-675. In: Proc. 4th Intl. Conf. Computers in Agricultural Extension Programs. Amer. Soc. Agr. Eng., St. Joseph, Mich.

Willett, M.J., E.L. Proebsting, and R.E. Redman III. 1994. Protecting stone fruit flower buds from winter freeze damage. HortTechnology 4:16-20.

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