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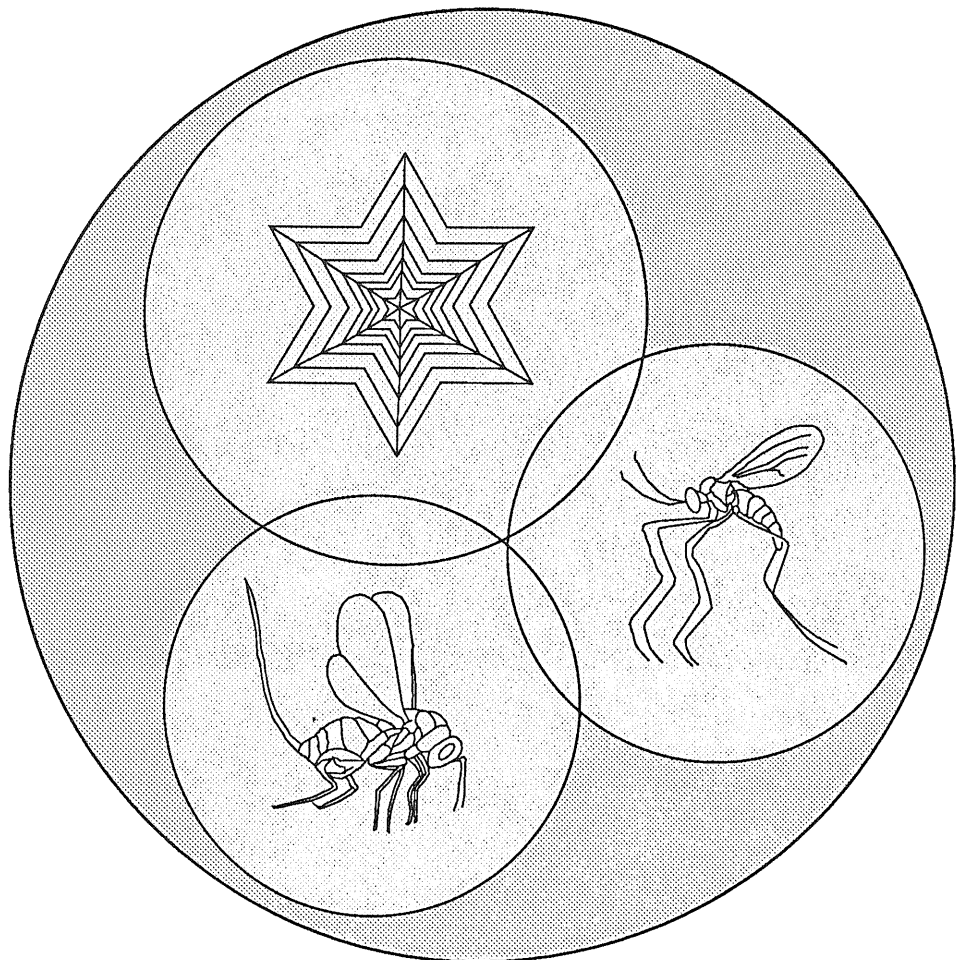
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Pest Management in Douglas-fir Seed Orchards: A Microcomputer Decision Method

James B. Hoy

Michael I. Haverty



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The computer program described provides a Douglas-fir seed orchard manager (user) with a quantitative method for making insect pest management decisions on a desk-top computer. The decision system uses site-specific information such as estimates of seed crop size, insect attack rates, insecticide efficacy and application costs, weather, and crop value. At sites where information on insect attack is not available, regional attack rates within the program may be used. The heart of the decision system is a payoff analysis. It evaluates alternative management actions and identifies the best action under the best or worst conditions, and the action that minimizes the opportunity cost. Tutorial help is included in the program as well as utility programs for entering local weather data.

Retrieval Terms: Douglas-fir, seed orchard, pest management, pest control decision method, payoff analysis, frost damage probability estimation

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Since 1960 many Douglas-fir seed orchards have been established along the Pacific Coast region of the United States and in British Columbia, Canada (Bordelon and others 1987, Hanson 1986). Additional orchards have been established in the "Inland Empire" region of the Rocky Mountains. Many orchards are approaching the truly productive phase of their lifetimes. However, Douglas-fir seed production varies greatly among years, sites and genetic stocks, even under the most careful management, due to natural variation in male and female cone production, frost related cone mortality,

and destruction by insects. A recent survey of seed orchard managers found that they want and need an objective method of making decisions for managing insect pests.

This report describes a method and computer program, with which a seed orchard manager can combine economic and biological factors to help make pest management decisions. This report provides instructions for using the microcomputer program that determines the dollar payoff of alternative insect pest control strategies in seed orchards.

Introduction

The most serious insect pests in coastal Douglas-fir seed orchards are the Douglas-fir cone gall midge (*Contarinia oregonensis* Foote) and the Douglas-fir seed chalcid (*Megastigmus spermotrophus* Wachtl) (Schowalter and others 1985).¹ Several species of moths, primarily the Douglas-fir cone moth (*Barbara colfaxiana* [Kearfott]) and cone worms (*Dioryctria* spp.), also feed on cone and seed tissue, and can on occasion be serious pests (Hedlin and others 1980). Other miscellaneous pests, such as the seed bug (*Leptoglossus occidentalis* Heidemann), occur so rarely or so sporadically that control strategies are not well developed (Schowalter and others 1985). The cone gall midge and the cone moth have relatively short oviposition periods that are roughly synchronized with flowering. Insecticide treatments aimed at the more destructive midge will probably reduce losses to the moth as well. Furthermore, cone samples taken to monitor midge populations can provide information about cone moth populations (Miller 1986). Thus far, there is no effective method for monitoring seed chalcid to aid control decisions for this destructive wasp.

Seed production in orchards is promoted by a variety of cultural practices, including pest

control. Insect pest populations are sometimes reduced by two methods, i.e., sanitation of the seed orchard by removal of infested, unharvested cones or insecticide applications or both.² Insecticides are usually applied from the ground and are currently used in about 60 percent of the producing orchards. As orchards mature, more insecticide applications are likely, at least until overproduction of seed occurs. Dimethoate (Cygon) is the most commonly used insecticide in Douglas-fir seed orchards in the United States, and the only insecticide used in Canada.³ However, many managers express concern that dimethoate may damage vegetative growth and flowers, and recent laboratory experiments show that dimethoate may reduce pollen germination (Sutherland and others 1984). Without field confirmation of seed loss from phytotoxicity, we must leave it to the user to consider that this may be a factor. The portion of the program that calculates yields can easily include such, if losses are quantified. Alternative insecticide treatments are being evaluated in the United States (Stein and Markin 1986) and Canada (Summers and Miller 1986).

Biological Background

¹Unpublished data on file, Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

²This report neither recommends the pesticide uses reported, nor implies that they have been registered by the appropriate government agencies.

³Trade names or products are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

Pest Management Background

An objective decision system for pest management requires information on value of the crop, cost and efficacy of control methods, reliable estimates of the sizes of the crop and pest populations, and estimates of losses other than those to pests, e.g., frost damage or phytotoxicity of insecticides. The value of the seed is related to demand and availability of seed and, as production increases, could be expected to go down. Methods for estimating crop size range from optimistic intuition to the precise, but expensive, tree-by-tree sampling method developed in Canada (Miller 1986). Extensive, reliable survey data on the pests are available (Schowalter and others 1985, Haverty and others [in preparation]).

Efficacy of insecticide treatments is quite variable and difficult to accurately project, though cost of treatments is relatively easy to calculate. Estimates of seed losses to causes other than insects are limited to optional estimates of frost damage and phytotoxicity of insecticides in this program.

Pest management decisions characteristically are made in the face of uncertainty, by managers with various degrees of willingness to take risks to increase net payoff. A payoff analysis can help clarify when insecticide application is uneconomical, and more importantly, which of various control actions can be expected to provide the greatest economic gain.

Payoff Analysis (Options 1, 2, 3)

The payoff analysis evaluates alternative management actions under mutually exclusive environmental conditions and identifies the best action under the best conditions (the maximax), the best action under the worst conditions (the maximin), and the action that minimizes the difference between the greatest and least payoff (the minimax regret). Finally, the expected payoff for each action (a weighted average using the probability of occurrence of each condition) is found by this analysis (Poole 1981).

Pest attack rates and weather conditions result in variable seed production, which is further affected by pest control actions. The interaction of natural conditions and control actions can best be presented in a table of all possible payoffs. Beyond such an inclusive table, the **expected payoff for each alternative control action** can be calculated, allowing for the probability of occurrence of each combination of conditions at a given site. Three decision criteria are then applied. For the risk-averse manager the action giving best payoff under the worst condition is identified (the maximin). For the risk-prone manager the action giving best possible payoff is identified (the maximax). For the managers who expect their supervisor to evaluate them with hindsight, the cost of lost opportunity or regret table (the difference between the payoff from the ideal action and the action taken) may be of use.

The user of this program may either accept assumptions that are built into the program or must estimate (intuitively or objectively) up to seven factors to allow calculation of the payoff table and expected payoff for each action. The factors are these: (1) filled seeds per tree, (2) insect attack rates, (3) insecticide efficacy, (4) control action cost, (5) probability of frost damage, (6) losses due to phytotoxicity of insecticide, and (7) value of seed.

Estimates of these factors may be based on published data, current data from on-site surveys, or theoretical models. The user is given the option of using values provided by the program system, or values drawn from "help" utilities that are a part of the system, or the user's own estimates. Three "help" utilities have been provided to estimate: (1) insecticide application costs, (2) flowering date (Thomson and Moncrieff 1982), and (3) probability of frost damage (Timmis 1977). Losses due to phytotoxicity must be superimposed by the manager after all other analyses have been completed. Seed value is set after accepting or rejecting a suggested value.

The user who is able to provide precise information, such as insect attack rates and cone crop, will get more precise answers than one who must provide "armchair" estimates. For managers who cannot do extensive insect sampling or cone counts, this program may nevertheless be of use by formalizing consideration of the many factors that combine to

combine to affect the size of the seed harvest and economic payoff.

In the future if there is a surplus of seed production and fixed costs do not go down, payoff analysis will become increasingly useful. Orchard managers with an eye to the future now have the time to collect pest abundance and weather data for use when production costs and seed prices converge.

Copies of the program may be obtained by sending an initialized disk for an Apple II or

an IBM PC compatible microcomputer to the authors, along with an acknowledgment that the program has not been field tested, and that only backup copies of the program will be made.

The instructions that follow are arranged parallel to what is presented on the computer monitor as the program is used. Wherever the user is given a choice of optional activities, all options are presented as subsections of the guide before going on to the next section.

We provide three aids to understanding the use and structure of this program: *figure 1*, *figure 2*, and *table 1*. The user decision tree (*fig. 1*) shows the alternative routes through the program. Next is the master program flow chart (*fig. 2*), which is a more technical illustration of the major decision points and components of the program, with program line numbers included. *Table 1* itemizes, by

line number, the sections of the program and also provides cross references to *appendixes A-K*, which show detailed flowcharts of each program section. The decision tree will be useful regardless of the degree of experience of the user. We provide the latter two aids for experienced programmers who may wish to modify the program for their own special needs.

Computer Program Background

For the Apple II version, put the diskette in the disk drive and turn on the power, or give a command that will boot the disk, or type RUN PACK, (Return). For the IBM PC version, boot your system, place a disk with

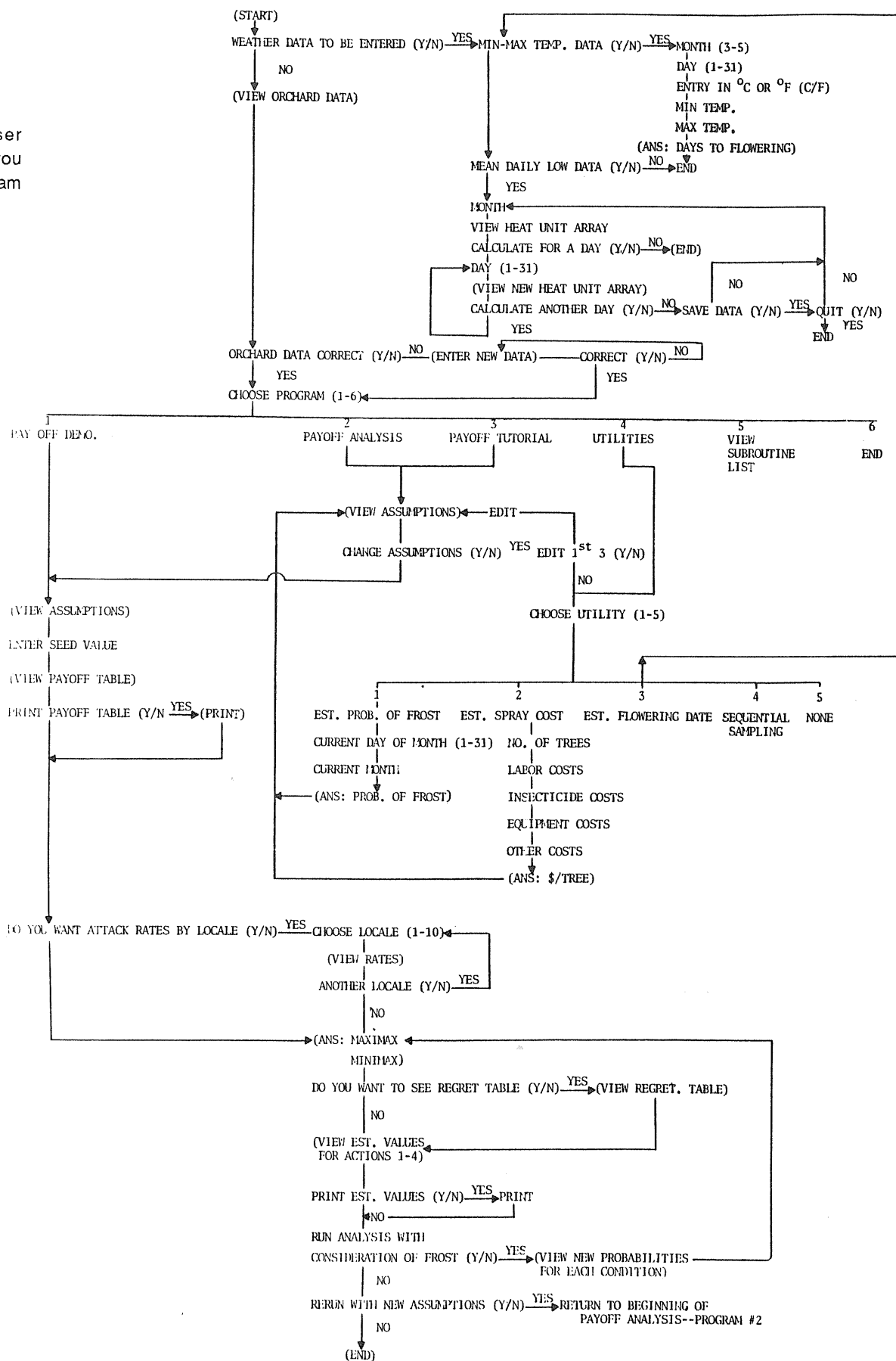
BASICA and the program in drive A, and type BASICA PACK (Return). Following a display of the program title and credits, you are given the opportunity to enter weather data.

Program Use

Line numbers	Section	Appendix
1000-2999	Payoff analysis	K
3000-3500	Utility selection	D
5000-5490	Spray cost estimation	G
5500-6085	Flowering date estimation	H
9000-9990	Orchard data	C
11000-11599	Locale attack probability	J
12000-12500	Current assumptions	E
15000-15340	Frost damage probability estimation	F
18000-19990	Weather data entry	B
20000-20130	Payoff table display	I
31000-31930	Initialization	A

Table 1—Program sections by line numbers

Figure 1—This user decision tree helps you choose which program sections to use.



MASTER PROGRAM FLOW

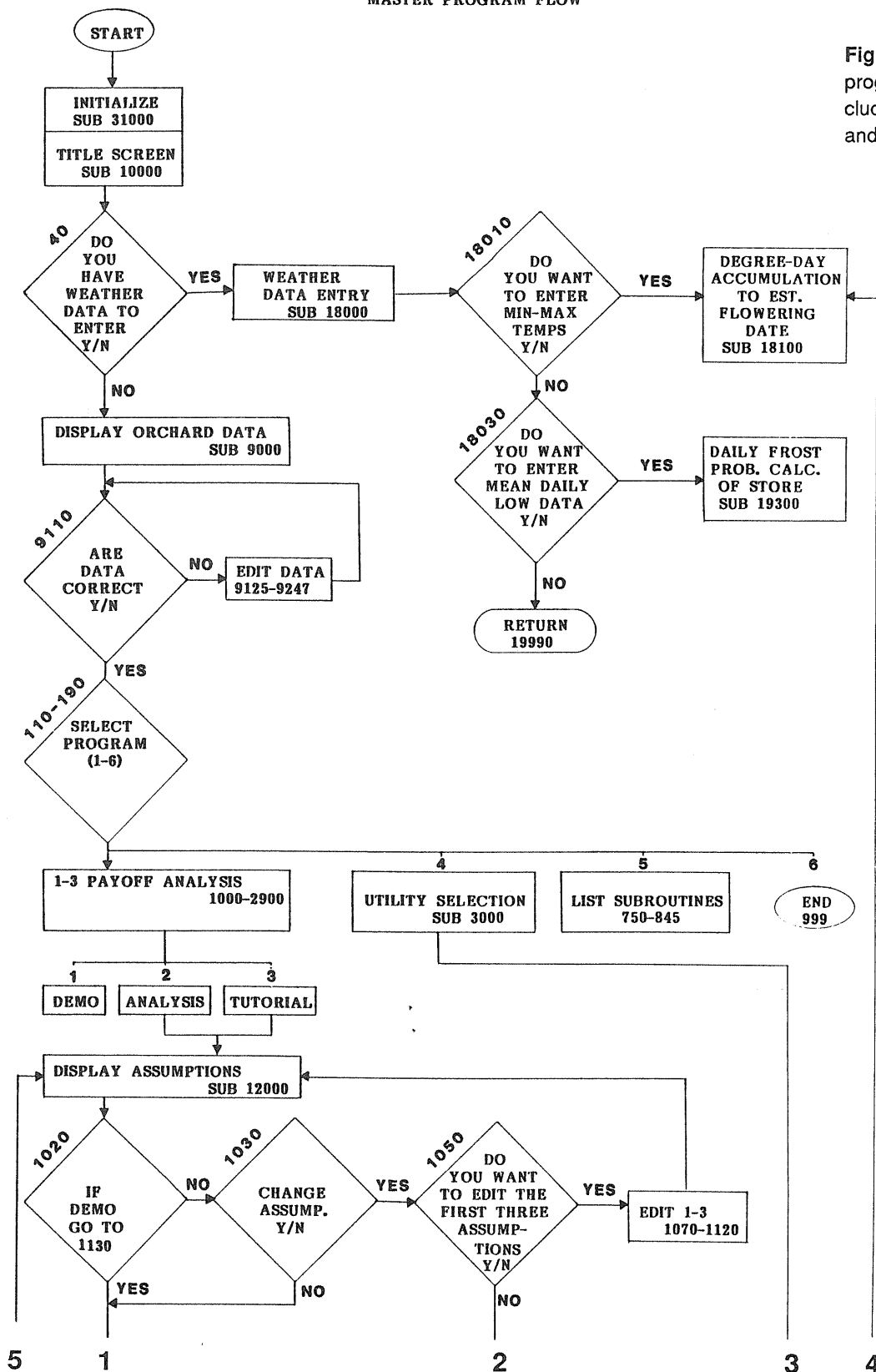
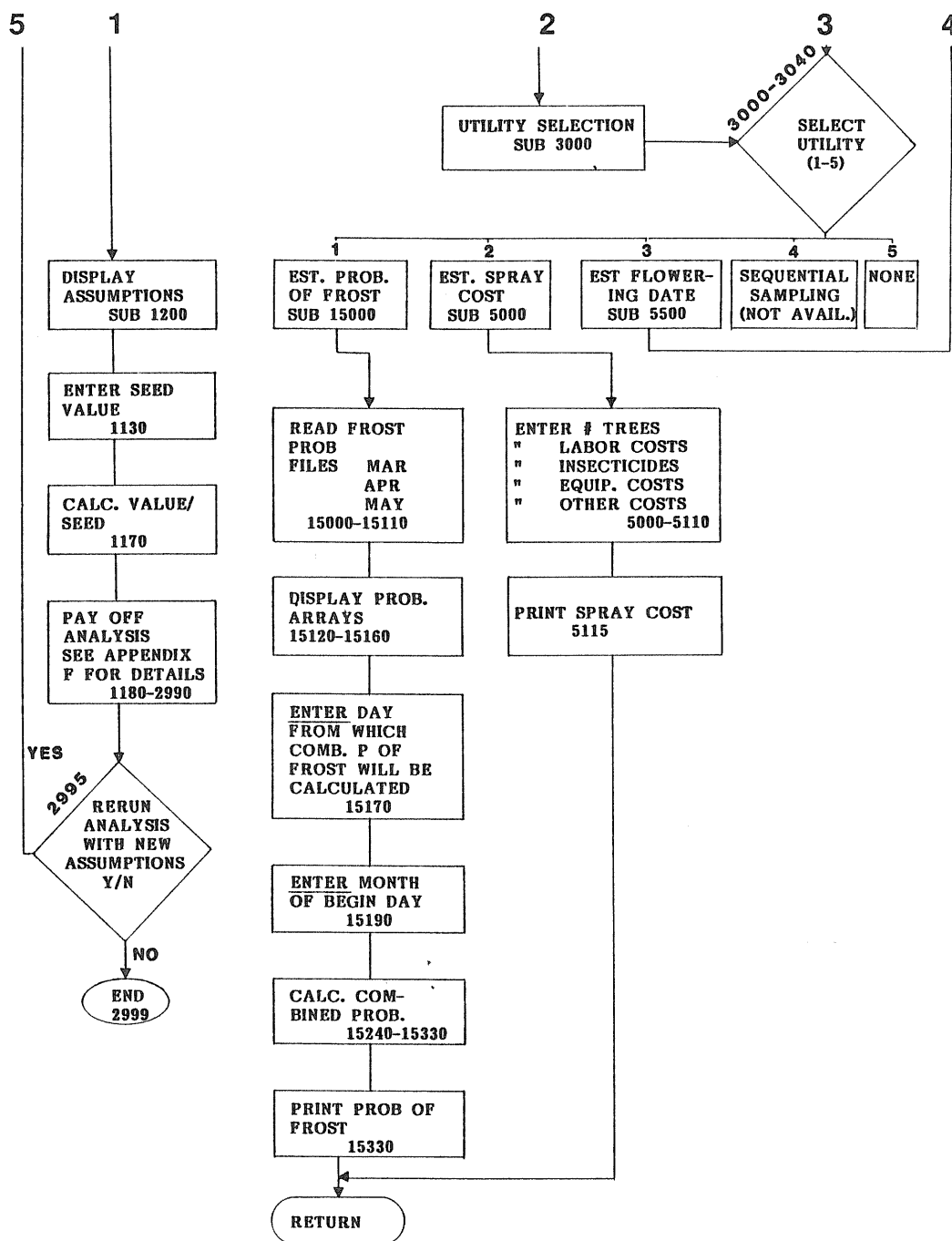


Figure 2—This master program flow chart includes program prompts and line numbers.

Figure 2—This master program flowchart includes program prompts and line numbers.



This portion of the program allows daily entry of maximum and minimum temperatures for use in calculating the accumulated degree-days for prediction of flowering date (and the associated attacks of gall midge and cone moth). See the section on Flowering Date Estimation under Utility List (Option 4) for how to calculate the flowering date. The purpose of this utility program is to help plan sampling for the midge or scheduling of control operations, or both. Although flowering dates vary from one clone or family to another, the general model should be useful, particularly after several comparisons of the model's predictions and actual flowering of the trees in the user's orchard.

The program asks for current observed daily minimum and maximum temperatures at the orchard, calculates the number of accumulated heat units for the day, stores that amount in a file on the disk, and totals the heat units to date. Then the program compares the total with the theoretical amount needed for flowering, and gives an approximation of the number of days until flowering may be expected. The model is based on data for vegetative flushing in British Columbia, with an adjustment for local differences in opening of flower and vegetative buds. The program is intended as a conservative estimate of when to expect flowering. It is not based on field observations of flowering.

Weather Data Entry

Daily Minimum and Maximum Temperature Data

Daily Mean Low Temperature Data is a utility program for filling the data files called MAR, APR, and MAY. The files contain the probabilities of frost for each day of March, April, and May. For a given orchard the files only need to be filled once, using the best available weather data. Enter the mean daily low and the standard deviation of the mean for each date. Means based on at least 20 to 30 years of data are desirable if available.

When you choose this data entry option, the following displays and entries are required:

- Enter the month for which daily probability of frost is to be calculated.

- After display of the probabilities already calculated, enter the day of the month for which you want to calculate the probability of frost.
- Enter the mean daily low and standard deviation.
- After calculation and display of the frost probability and the probability array for the month, you may select another day of the month or you may save the array and continue after selecting an appropriate month.
- If you decide to stop entering data, a message will be displayed explaining what has been done.

Daily Mean Low Temperature Data

Orchard data is the beginning of the main program. It provides a display of historical information (*fig. 3*) about the orchard that is under management. The information is stored in a file called LOCAL INFO. If you manage more than one orchard, you should use a separate program disk for each orchard. Only the displayed probabilities of insect attack are required for use of the program. Even those are optional in that attack probabilities by phytogeographic province (locale) are provided in the PROB OF ATTACK file,

which may be recalled from this file during the payoff analysis. If you accept the displayed information as correct, the program goes on to display a choice of options. If local attack rates are not available, you may either assign equal probabilities of occurrence by typing .3333 for low, moderate, and high rates, or by using the locale probabilities just mentioned. We recommend using locale probabilities, as called from the PROB OF ATTACK file.

Orchard Data Entry and Editing

Activity Selection

Payoff Analysis (Options 1, 2, 3)

You may wish to have a streamlined demonstration of the payoff analysis (option 1) or a detailed tutorial with information that complements this user's manual (option 3). If you are an experienced user, choose the routine payoff analysis (option 2). The utility list (option 4) allows you to go directly to programs that estimate spray cost, probability of frost damage, or flowering date. Displays of the major subroutines of the program (option 5) are provided to aid expansion or revision of the package of programs.

Payoff Demonstration (Option 1)

The demonstration option sends you through the use of payoff analysis without changing the initial assumptions except having a choice of the probabilities of insect attack rates. *Figure 4* defines low, moderate, and high attack rates for midge plus moth and seed wasp. Payoffs are calculated on the basis of the **probabilities** of nine combinations of insect attack. The probability of each combination is initially assumed to be equal and the basic payoff table is displayed. Then known or estimated local (or provincial) attack rate probabilities are superimposed on the initial table. However, you enter the value of the seed. Seed value may be set at whatever you believe is realistic. In the absence of any other amount we have used the only published value—\$77.00/lb (Miller 1983).

Initially payoff is calculated under the assumption of nine conditions of insect attack, each with an equal probability of occurrence. The nine conditions are these:

- Low attack by gall midge and cone moth, and low attack by seed wasp.
- Low attack by gall midge and cone moth, and moderate attack by seed wasp.
- Low attack by gall midge and cone moth, and high attack by seed wasp.
- Moderate attack by gall midge and cone moth, and low attack by seed wasp.
- Moderate attack by gall midge and cone moth, and moderate attack by seed wasp.
- Moderate attack by gall midge and cone moth, and high attack by seed wasp.
- High attack by gall midge and cone moth, and low attack by seed wasp.

- High attack by gall midge and cone moth, and moderate attack by seed wasp.
- High attack by gall midge and cone moth, and high attack by seed wasp.

Figure 4 provides the assumptions and *figures 5-7* the output for a hypothetical example. The payoff (*fig. 5*), **in dollars worth of seed per tree**, is presented as a table according to four alternative management choices: (1) an early spray to control losses to midges and cone moths, (2) a late spray to control seed wasps, (3) both an early and late spray to control losses to midges, moths, and wasps, or (4) no spray at all.

You may select the probability of attack based on local data or from the PROB OF ATTACK file at this point (*fig. 6, table 1*). *Appendix L* gives the basis for our estimates for attack rates in various phytogeographic provinces (Schowalter and others 1985), and subsequently derived probabilities of low, moderate, or high attack (*fig. 4*). The last locale (province) selected provides the probabilities for further analysis if the user chooses other than local data as stored in the orchard (local) data file.

Next, probability of occurrence for each of the nine conditions is used to calculate payoff, and the expected results of the alternative management actions are calculated along with the best possible payoff (maximax), the best payoff under the worst conditions (maximin), and the maximum regret (maximax minus the result of action taken) for all combinations of conditions and management actions (*fig. 7*).

Finally, the analysis includes consideration of a 10th possible condition, i.e., loss of the crop to frost damage. We have chosen to use a varying probability of 100 percent frost damage, rather than a varying percentage of seed lost to frost, as a factor in payoff calculation. During the demonstration run the probability of frost damage (100 percent damage) is set at 0.5. The probabilities of all other conditions are adjusted accordingly and the payoff values are calculated and displayed. In practice, the probability of frost from the day of analysis through the remainder of the season must be calculated, using the frost probability estimation utility pro-

Geographic province	Gall midge and cone moth			Seed wasp		
	L (15pct)	M (35pct)	H (70pct)	L (5pct)	M (20pct)	H (50pct)
Olympic Peninsula	0.80	0.15	0.05	0.75	0.23	0.02
Puget Trough	0.90	0.09	0.01	0.60	0.35	0.05
Northern Cascades	0.33	0.34	0.33	0.90	0.09	0.01
Western Cascades	0.35	0.40	0.25	0.15	0.55	0.30
Willamette Valley	0.85	0.14	0.01	0.33	0.34	0.33
Coast Range	0.70	0.20	0.10	0.20	0.45	0.35
California Coast	0.95	0.04	0.01	0.01	0.29	0.70
Sierra Nevada	0.35	0.55	0.10	0.01	0.29	0.70

Table 2—Probabilities of low (L), medium (M), or high (H) attack rates (in pct) and resulting seed losses by Douglas-fir cone gall midge, Douglas-fir cone moth and Douglas-fir seed chalcid in Douglas-fir seed orchards in eight geographic provinces in the western United States. Probabilities are authors' estimates from data in *appendix L*.

```

CURRENT ORCHARD DATA
ORCHARD NAME: HYP0
INFO ENTRY DATE: 10 MAR 87
SANITATION DONE: Y
ADEQUATE POLLEN: Y
WILD D-F NEARBY: N
CROP LAST YEAR: N
MIDGES LAST YEAR: L
WASPS LAST YEAR: H
ANNUAL VARIATION IN FILLED SEED: M
PROB. MIDGE ATTACK RATE (L/M/H): .3333 .3333
.3334
PROB. WASP ATTACK RATE (L/M/H): .3333 .3334
.3333

```

Figure 3—The main program provides historical data about the seed orchard being managed, from a file called LOCAL INFO.

Figure 4—The Demonstration Option uses established assumptions, including three rates of attack--low, moderate, high--for midge plus moth and seed wasp, as shown in this figure.

THE INITIAL ASSUMPTIONS ARE:	
INSECTICIDE EFFICACY (% KILL/TREAT.)	80
AVERAGE CONES/TREE	400
AVERAGE FILLED SEED/CONE	26
TOT. SPRAY COST/TREE/TREAT.	\$3.00
MIDGE+MOTH ATTACK (% SEEDS):	LOW = 15
	MOD. = 35
	HIGH = 70
WASP ATTACK RATE:	LOW = 5
	MOD. = 20
	HIGH = 50
NO FROST DAMAGE OR PHYTOTOXICITY OCCURS	

Figure 5—The payoff, in tabular form, is displayed according to four management alternatives for spraying: early, late, both, or none.

PAYOFF FOR SPRAY EARLY,LATE,BOTH OR NONE					
-PROB. EQUAL FOR ALL POSSIBLE CONDITIONS					
MN= MIDGE-MOTH ATTACK, W=WASP ATTACK					
SEED \$77/LB EFFIC.80% CONES/TREE 400					
=====					
MN	W	EARLY	LATE	BOTH	NONE
L	L	16.09	14.44	13.90	16.73
L	M	13.08	13.91	13.30	14.09
L	H	7.05	12.05	12.09	8.80
M	L	15.31	10.33	13.08	12.79
M	M	12.42	9.93	12.50	10.70
M	H	6.63	9.12	11.34	6.73
H	L	13.93	3.15	11.64	5.90
H	M	11.25	2.96	11.11	4.97
H	H	5.91	2.59	10.04	3.10
DO YOU WANT THIS TABLE PRINTED (Y/N)					

LOCALE CHOICES

- 1)COAST RANGE
 - 2)N. CASCADES
 - 3)OLYMPIC PENINSULA
 - 4)PUGET TROUGH
 - 5)SIERRA NEVADA
 - 6)W. CASCADES
 - 7)WILLAMETTE VALLEY
 - 8)COASTAL B.C.
 - 9)INLAND B.C.
 - 10)LOCAL DATA
 - 11)NONE OF THE ABOVE
- TYPE THE NUMBER OF YOUR CHOICE (1-11)

Figure 6—The PROB OF ATTACK files, based on data from various locales, can be used to select the probability of insect attacks.

**MAXIMUM POSSIBLE PAYOFF OF \$16.73
FROM ACTION 4**

**MAXIMUM PAYOFF UNDER WORST
CONDITIONS
OF \$10.04 FROM ACTION 3**

**DO YOU WANT TO SEE THE REGRET
TABLE (Y/N)**

EXPECTED PAYOFFS/TREE ARE:

**FOR ACTION 1: 11.29
FOR ACTION 2: 8.80
FOR ACTION 3: 12.11
FOR ACTION 4: 9.31**

PRESS RETURN TO GO ON

Figure 7—Payoffs for various combinations of conditions and management actions are displayed following calculations, as shown in this figure.

gram before the last phase of the payoff analysis. Empirically we know that the percent damage due to frost is variable from location to location and from year to year. Our projection of a 50 percent chance of 100 percent loss due to frost is based on recent observations in Douglas-fir seed orchards of the western United States and on limited experimental studies (Timmis 1977). We suggest that seed orchard managers project site-specific estimates of the extent and probability of loss to frost and consider their capability to ameliorate losses to frost.

Following consideration of frost damage as a factor, the demonstration option allows the user to rerun the analysis with new assumptions. A rerun provides experience as the program might be routinely used, when various combinations of cones per tree, insecticide efficacy, etc. would be used for "arm-chair" analysis with a variety of assumptions.

Routine Analysis (Option 2)

All utility programs and editing of assumptions are available during the use of option 2, payoff analysis with assumption change available at the start of the analysis. This option is expected to be used on a routine

basis. The opportunity to change assumptions is given as soon as the initial assumptions are displayed, unlike the demonstration option (option 1) described in the preceding section.

Seed value is the central factor in determining which management action to choose. The suggested value of \$77 per pound is conservative. It is based on production cost data for seed (Miller 1983), adjusted for inflation and currency differential. One reviewer of this report suggested that \$500 per pound was a realistic value. We recommend that users set their own value for seed.

Payoff Tutorial (Option 3)

Option 3 is similar to option 2, except that at several times during the use of option 3, background information regarding the assumptions, analysis, or interpretation of the results are presented on the monitor screen. This option is a poor alternative to reading the user's manual. The tutorial is intended for users who are unfamiliar with payoff analysis but want to concentrate on just using the computer during the learning process. The tutorial is not intended as a short course in probability theory.

Utility List (Option 4) Option 4 gives you a choice of four utility programs: (1) estimation of frost damage probability, (2) estimation of spray cost per tree, (3) estimation of flowering date, and (4) sequential sampling guidelines, which are not currently available, except for the cone gall midge (Miller 1986). The first two programs may be used during payoff analysis and contribute the calculated values to the current set of assumptions. The third program is an aid in planning sampling or scheduling other efforts that must be coordinated with flowering or presumed, season-related insect emergence or attack.

Frost Damage Probability Estimation

A utility program calculates the combined probability of frost damage from a specified date through the remainder of the season. You provide the starting day and month. Mean daily lows and standard deviations for the orchard must have been previously en-

tered into data files MAR, APR, and MAY (see the section on Weather Data Entry above). In the absence of a frost model in either the scientific or commercial literature we offer this utility program.

Spray Cost Estimation

Another utility program asks for the number of trees to be treated and the various costs associated with spraying. The calculated cost per tree becomes the assumed spray cost during analysis.

Flowering Date Estimation

The relationship between development of plants and temperature is, in general, that the higher the average temperature for a day, the greater the growth. However, there is a threshold below which no growth occurs. By accumulating the amount of time during which the threshold was exceeded, an estimate of the progress in development may be

established. A utility program calculates the accumulated heat units above the development threshold temperature for a given day and adds that amount to the previously accumulated heat units for the season. Then the expected number of days until flowering is calculated by dividing the difference by either the expected units per day accumulated during warm weather or the expected units per day accumulated during cool weather. The concepts and formulas upon which this utility

is based are given elsewhere (Zalom and others 1983). The specific threshold temperature ($LT = 2.78$) and required heat units ($HU = 578$) for flowering are based on vegetative bud burst (see Thompson and Moncrieff 1982 for details). Our rough estimate that flowering occurs 3 weeks before vegetative bud burst studies is combined with the designated threshold and required heat units to produce our flowering date estimate.

Option 5 is for use by programmers as a convenient reference to the functional divisions of the entire package of programs.

Relatively simple program changes allow any subroutine to be used independently.

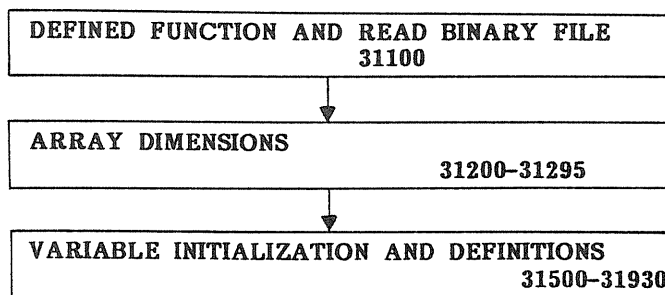
Subroutine List (Option 5)

Appendixes

APPENDIX A

INITIALIZATION (DEFINED FUNCTION, ARRAY DIMENSIONS, VARIABLE INITIALIZATION AND DEFINITIONS)

(LINES 31000-31930)



VARIABLES SET: A

CF

CN

CP

D\$

D3

D4

I

IE

N

PI

SC

SP

MY = SP * CP

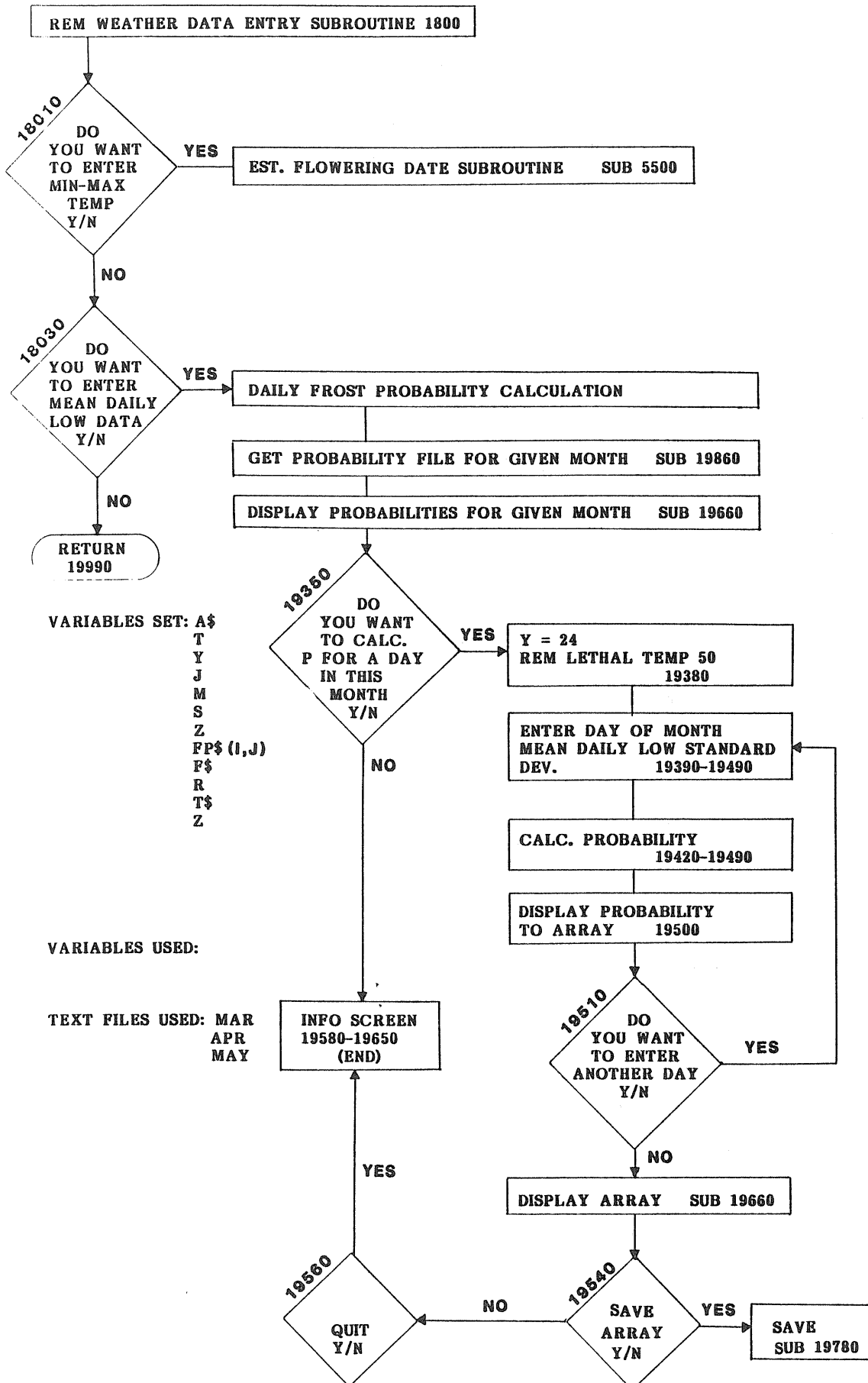
VARIABLES USED: SP

CP

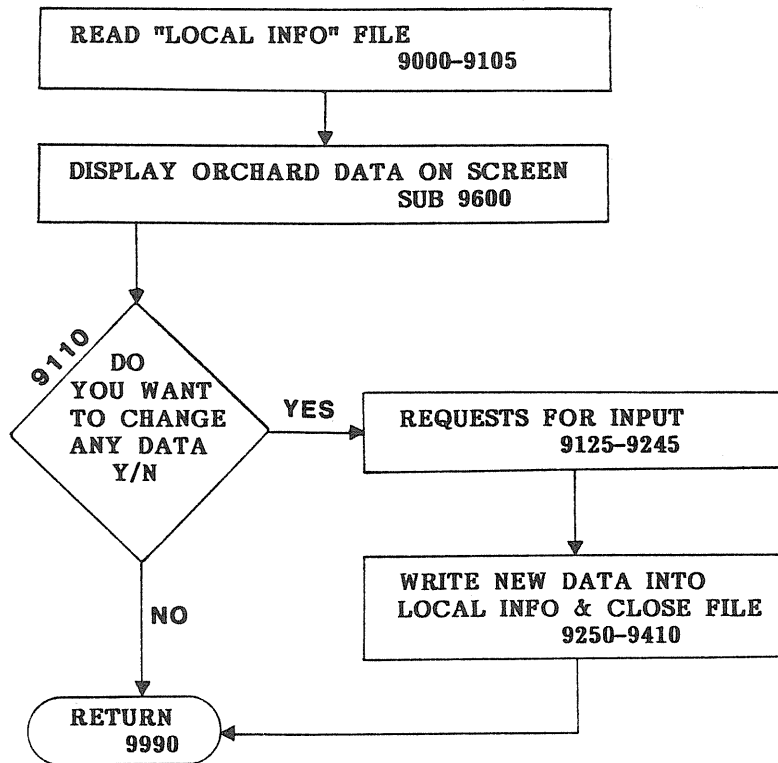
TEXT FILES USED: NONE

APPENDIX B

WEATHER DATA ENTRY (LINES 18000-19990)



APPENDIX C
ORCHARD DATA
(LINES 9000-9990)



VARIABLES SET: A\$
AO\$ THROUGH A7\$
L\$
L0\$ THROUGH L7\$
L8\$
L9\$
MM (10,1) THROUGH MM (10,3)
W (10,1) THROUGH W (10,3)

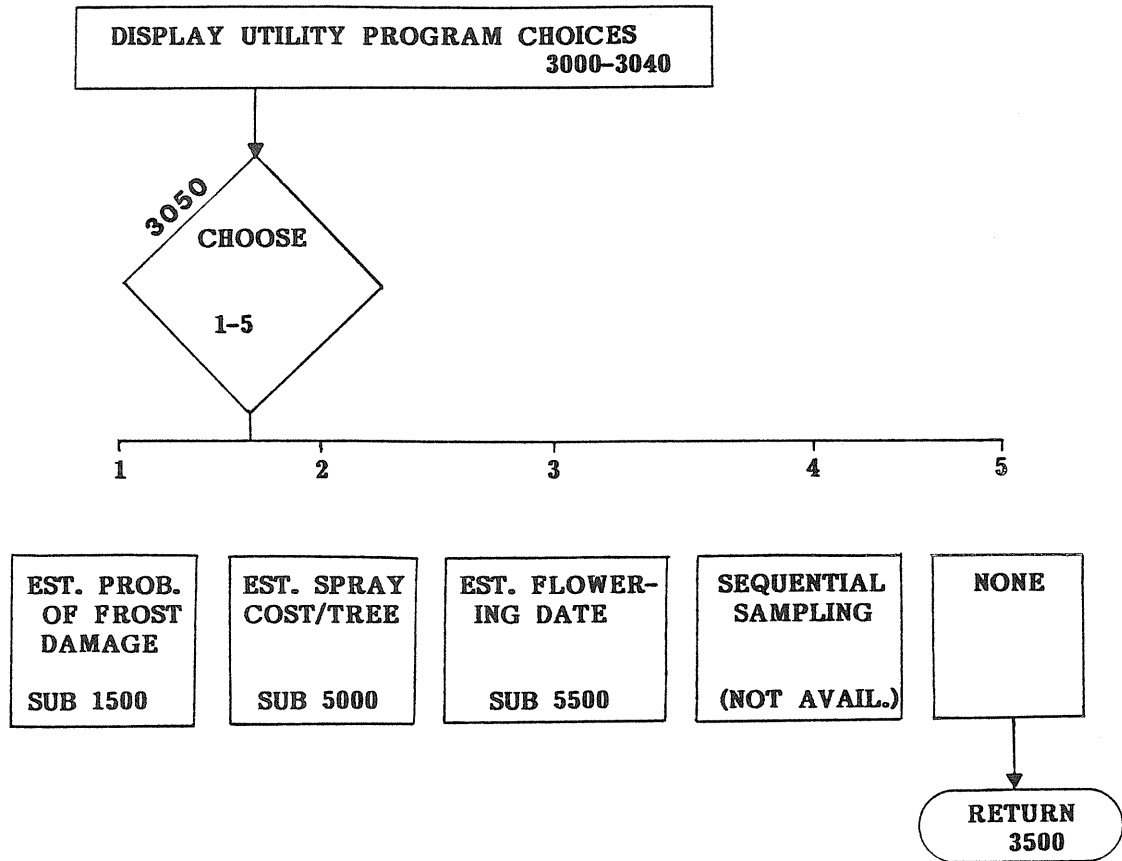
VARIABLES USED: X

TEXT FILES USED: LOCAL INFO

APPENDIX D

UTILITY SELECTION

(LINES 3000-3500)



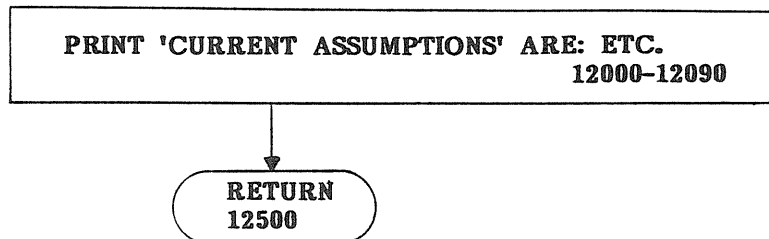
VARIABLES SET: A\$

TEXT FILES USED: NONE

APPENDIX E

CURRENT ASSUMPTIONS

(LINES 12000-12500)



VARIABLES SET: NONE

VARIABLES USED: IE

CP

SP

L\$ (10)

L\$ (1)

MM (1,1)

MM (1,2)

MM (1,3)

W (1,1)

W (1,2)

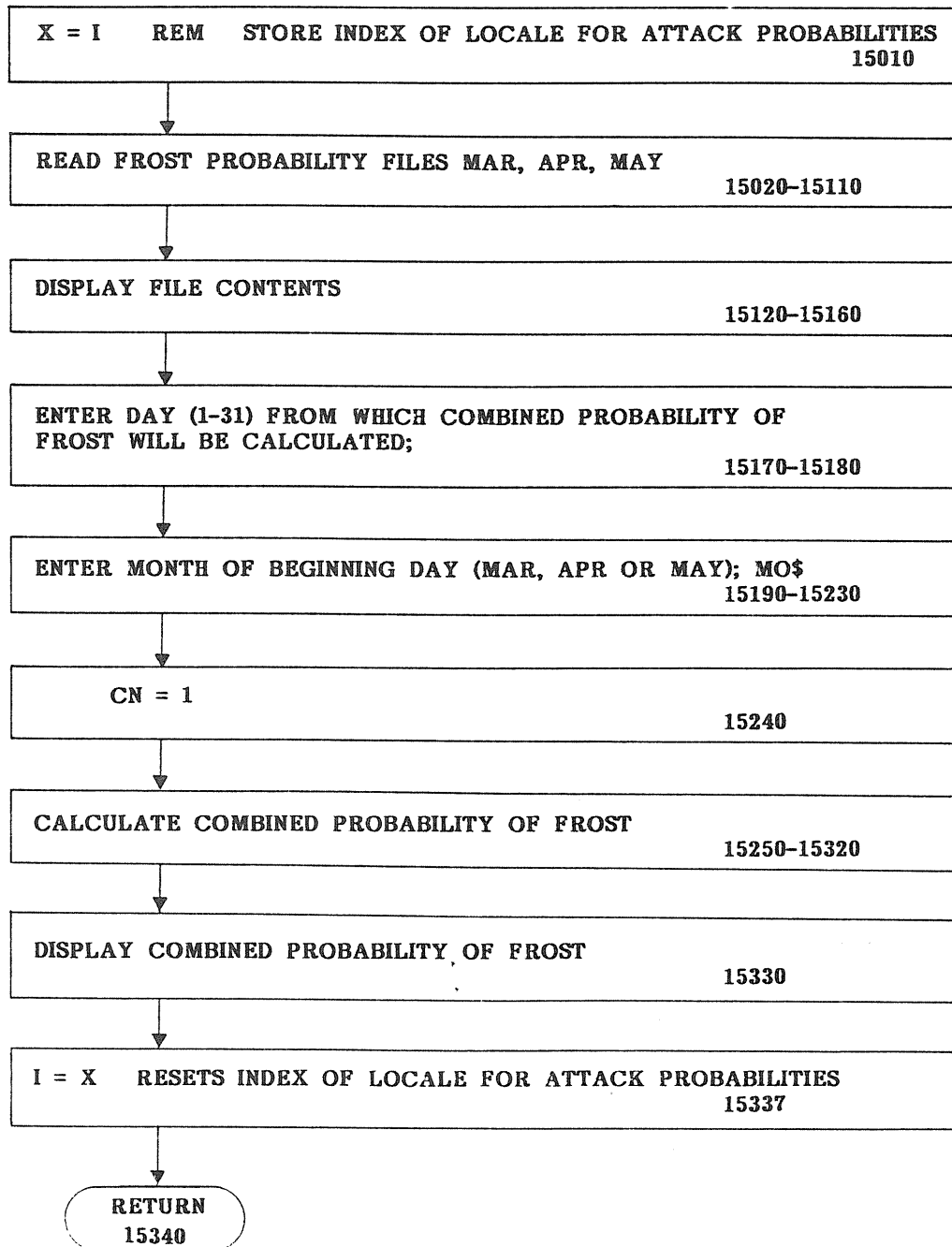
W (1,3)

CF

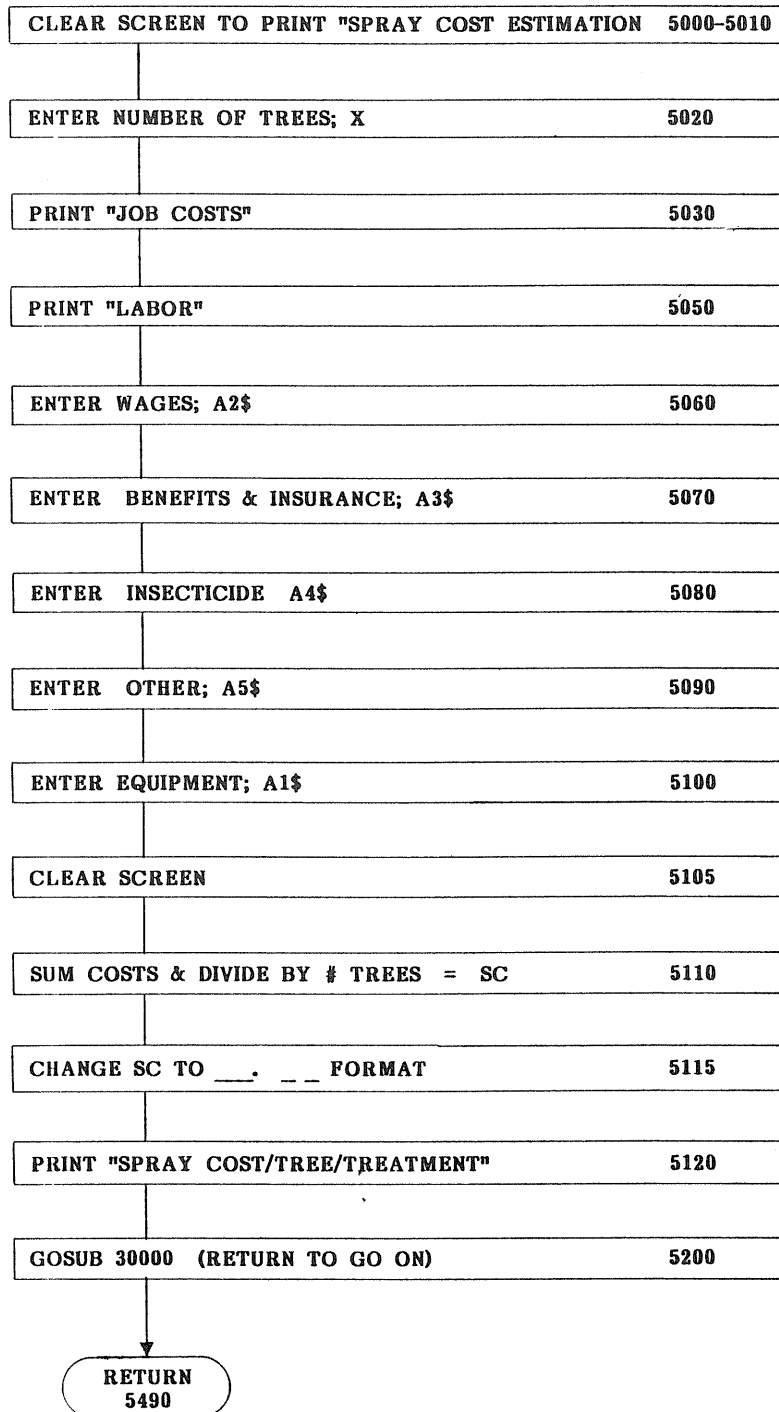
PP

TEXT FILES USED: NONE

APPENDIX F
ESTIMATION OF PROBABILITY OF FROST DAMAGE
(LINES 15000-15340)



APPENDIX G
ESTIMATION OF SPRAY COST
(LINES 5000-5490)

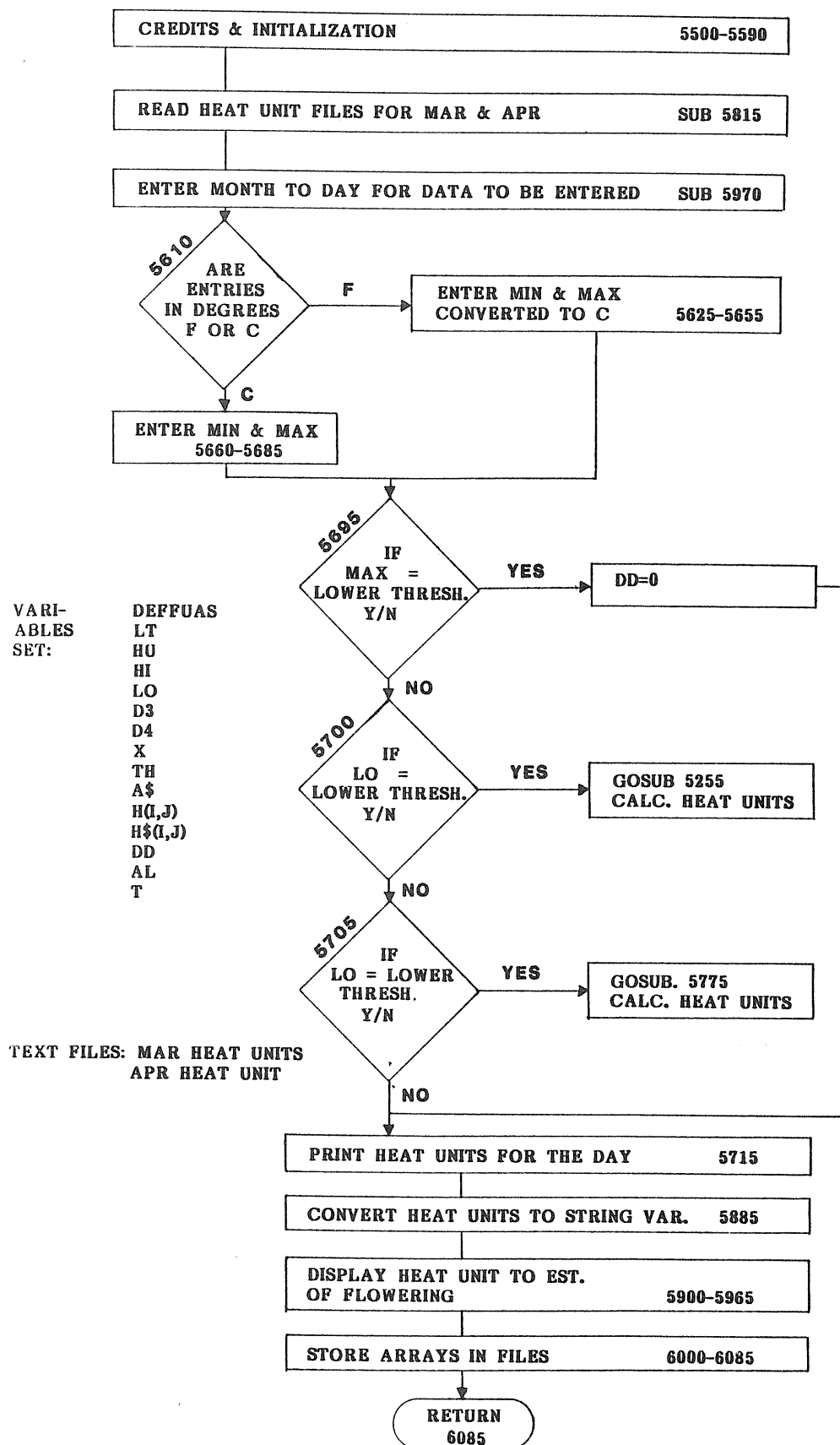


VARIABLES SET: X
A2\$
A3\$
A4\$
A5\$
A1\$
SC

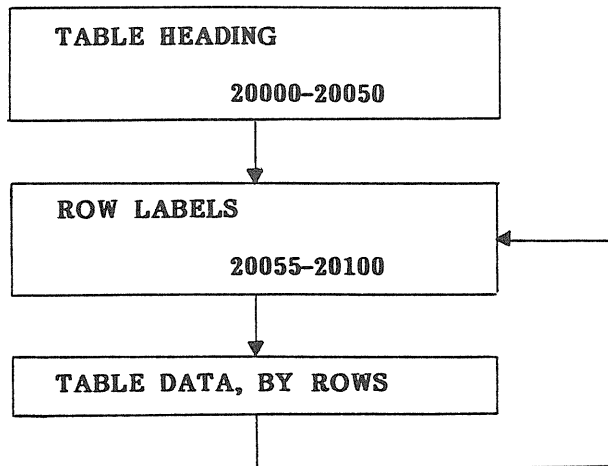
TEXT FILES USED: NONE

APPENDIX H

ESTIMATION OF FLOWERING DATE (LINES 5500-6085)



APPENDIX I
PAYOFF TABLE DISPLAY
(LINES 20000-20130)

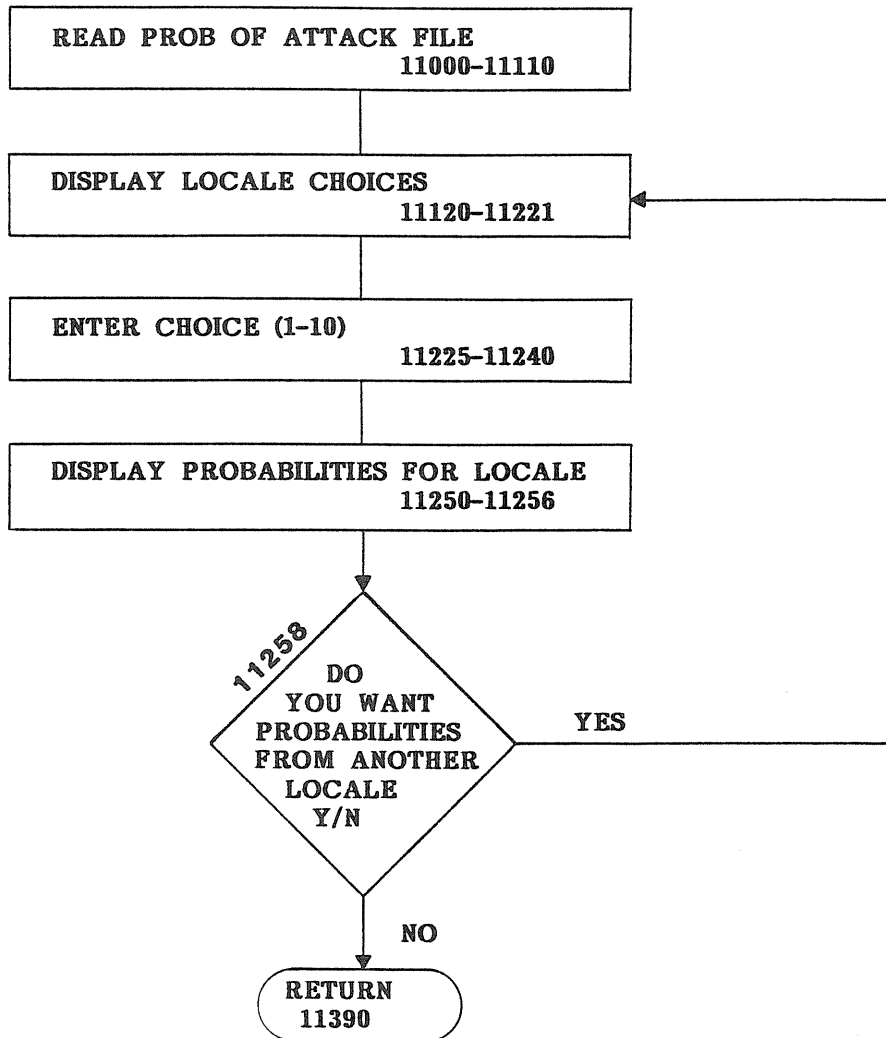


VARIABLES SET: I

VARIABLES USED: SP
V
IE
CP
MS\$
WS\$
S(1,I) - S(4,I)

TEXT FILES USED: NONE

APPENDIX J
LOCALE ATTACK PROBABILITY
(LINES 11000-11599)

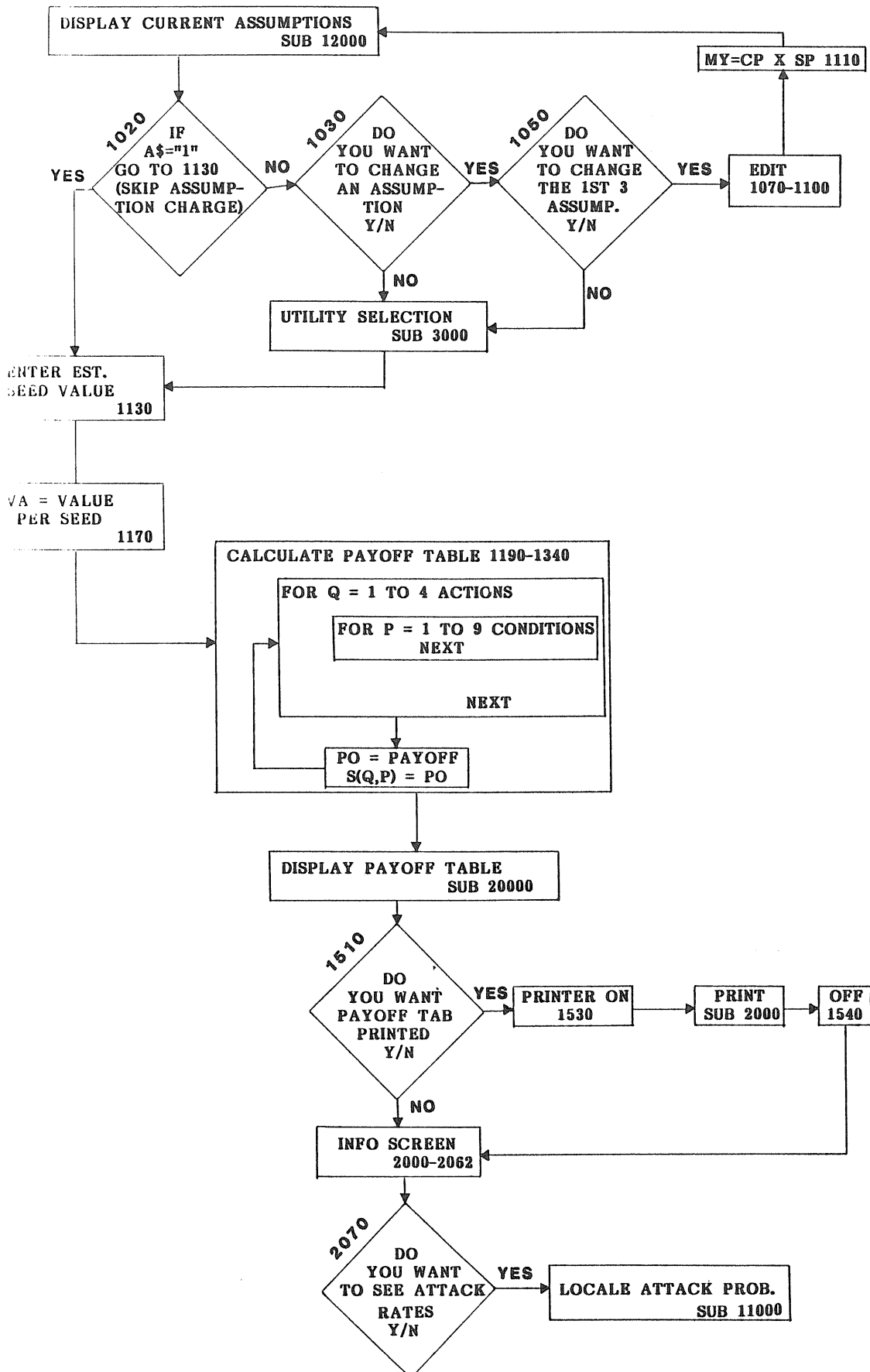


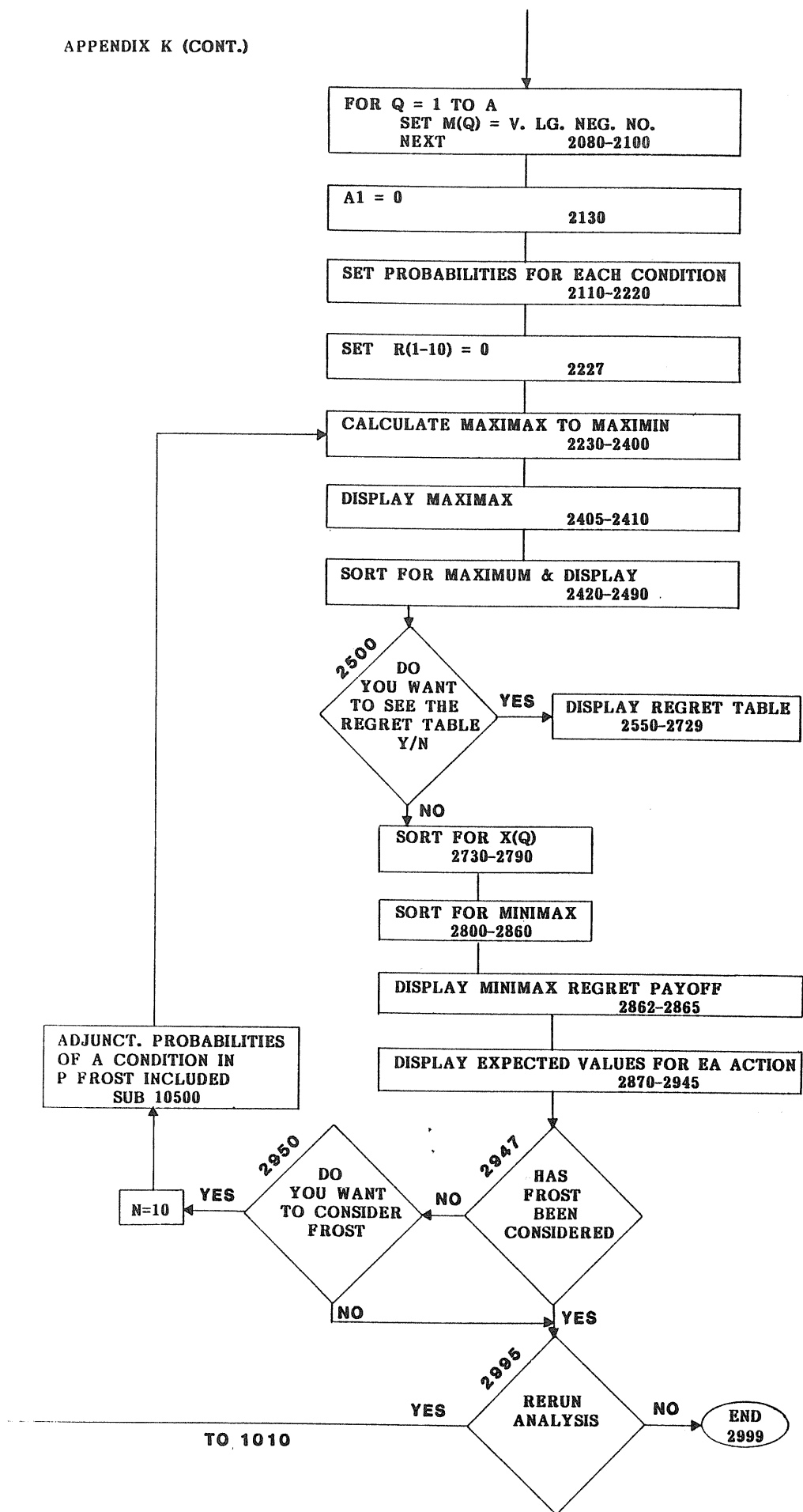
VARIABLES SET: I
J

VARIABLES USED: MM\$ (I,J)
MM (I,J)
W\$ (I,J)
W (I,J)
L\$ (1-10)

TEXT FILES USED: PROB OF ATTACK

APPENDIX K
PAYOFF ANALYSIS
(LINES 1000-2999)





APPENDIX K (CONT.)

VARIABLES SET

MM (10,1)
MM (10,2)
MM (10,3)

W (10,1)
W (10,2)
W (10,3)

CF = .5
A5
A1\$

VA

Q LOOP
P LOOP
EA
LA

PA PAYOFF

S(Q,P)

EL
LL
I
M (Q)
A1
P1 (10)
P1 (1-9)
R (1-10)
R (Q)

A3
A2
M (P)
R (P)
X (P)

VARIABLES USED: THOSE ABOVE PLUS

IE
CP
SP
MY
V
EL

TEXT FILES USED: NONE DIRECTLY

Appendix L

Basis For Estimated Attack Rates

Partitioning of insect impact to Douglas-fir seed by four insect species in 23 seed orchards from 1983 to 1985¹

Orchard	Year	Potential good seeds/ cone	Seed destroyed by...	
			Cone gall midge and cone moth	Seed wasp
Percent				
Olympic Peninsula				
Dennie Ahl	1983	37.2	33.7	6.4
Sequim	1983	8.3	9.4	16.2
Sequim	1984	26.3	3.7	1.6
Dennie Ahl	1985	19.9	17.6	5.6
Sequim	1985	24.2	5.7	0.8
Puget Trough				
Rochester	1983	25.3	18.2	0.8
South Sound	1983	24.7	20.3	23.2
Rochester	1984	14.8	10.8	30.4
DNR ²	1985	12.9	1.6	1.1
Fawn Lake	1985	22.0	2.2	0.0
Rochester	1985	19.2	0.4	0.0
South Sound	1985	26.4	10.3	5.5
Northern Cascades				
Captain Moses	1983	14.1	63.3	5.4
Captain Moses	1985	23.9	1.6	1.7
Western Cascades				
Horning	1983	14.1	59.4	28.3
Mason	1983	19.0	66.8	16.0
Mosby Creek	1983	19.2	43.7	43.3
Row River	1983	21.0	47.8	47.5
Mason	1984	16.5	17.3	22.7
Row River	1984	18.4	18.7	58.8
Horning	1985	30.5	3.3	1.1
Mason	1985	26.6	5.2	3.1
Mosby Creek	1985	22.3	11.7	11.1
Row River	1985	24.9	7.5	33.9

Orchard	Year	Potential good seeds/ cone	Seed destroyed by...	
			Cone gall midge and cone moth	Seed wasp
Percent				
Willamette Valley				
Eola Hills	1983	23.6	11.4	40.6
Research Center ³	1983	16.4	25.2	56.1
Schroeder	1983	14.6	8.5	61.3
Research Center	1984	17.2	6.9	34.2
Schroeder	1984	28.5	4.5	1.8
Turner	1984	24.2	4.5	2.5
Eola Hills	1985	36.4	1.5	0.5
Research Center	1985	22.6	18.1	7.5
Schroeder	1985	20.9	0.8	0.7
Turner	1985	26.7	2.4	0.6
Coast Range				
Beaver Creek	1983	15.9	48.7	41.5
McDonald	1983	18.9	47.2	47.8
Sixes	1983	16.6	53.6	32.4
Beaver Creek	1984	15.4	21.8	46.6
McDonald	1984	11.6	13.7	61.2
Sixes	1984	11.0	10.0	33.1
Beaver Creek	1985	27.8	2.6	4.4
Elk Creek	1985	23.7	5.4	6.8
McDonald	1985	18.5	2.6	7.2
Sixes	1985	14.3	5.0	5.2
California Coast				
Little River	1984	20.3	7.5	61.4
Little River	1985	19.6	6.0	29.7
Sierra Nevada				
Badger Hill	1983	8.8	36.8	44.0
Badger Hill	1984	18.6	9.4	26.8
Badger Hill	1985	3.5	24.3	57.8
¹ Information for seed losses derived from data in Schowalter and others (1985) and from Haverty and others (in prep.).				
² Department of Natural Resources, State of Washington.				
³ Weyerhaeuser Company.				

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