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Estimating Cone and Seed Production and Monitoring Pest Damage in Southern Pine Seed Orchards

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Contents

Abstract

Field sampling procedures and computer programs are described for monitoring seed production and pest damage in southern pine seed orchards. The system estimates total orchard yields of female strobili and seeds, quantifies pest damage, determines times of year when losses occur, and produces life tables for female strobili. An example is included to illustrate the sampling procedures and the operation of user-friendly computer programs.

Keywords: Cone and seed insects, cone and seed diseases, sampling, seed orchard production, survey.

Estimating Cone and Seed Production and Monitoring Pest Damage in Southern Pine Seed Orchards

Managers of southern pine seed orchards need periodic estimates of the number and condition of the first- and second-year crops of cones concurrently present on southern pines. Female strobili are subject to damage by insects, diseases, and other factors throughout the period of some 20 months required for development from flowers to mature cones.

A sampling method was developed to provide periodic estimates of pest damage and strobilus productivity in southern orchards. Because of the wide variation in strobilus production and mortality between orchards, clones, and years, the sampling system was designed for individual seed orchards (Fatzinger 1984). This paper describes the field sampling procedures and computer programs developed from 1982 to 1986 by the Integrated Forest Pest Management Cooperative (U.S. Department of Agriculture, Forest Service, and the University of Florida). The objectives were to estimate orchard yields of female strobili and seeds, to quantify pest damage, to determine the times of year when losses occur, and to develop life tables for female strobili. An example of a hypothetical orchard is included to illustrate the sampling procedures and the operation of user-friendly computer programs that have been developed (Appendix I). Copies of the computer programs and analyses for the hypothetical seed orchard can be obtained from the Project Manager, Integrated Forest Pest Management Cooperative, Department of Forestry, University of Florida, Gainesville, FL 32611.

Orchard Sampling Procedures

The sampling system includes four steps: (1) selecting sample trees within an orchard, (2) sampling female strobili in different portions of the crowns of sample trees, (3) making periodic observations, and (4) collecting seed samples (Appendix I, fig. 1). For each step, we have developed a basic method, which will be described first. Other available options, such as random selection of sample trees, and whole-crown sampling, are discussed in later sections of this Paper.

Selection of Sample Trees

The basic method calls for selection of 42 sample trees per orchard. Fourteen sample clones are chosen, with the probability of selection proportional to the relative strobilus production (size) of each clone within the orchard (Appendix I). When records of strobilus production are not available, the number of ramets per clone is used as the criterion of size. Clones are selected with replacement; i.e., selection of a clone more than once is permitted. When this occurs, the total number of sample trees remains the same, but the number of clones sampled is decreased by one. Ramets are considered to be primary sampling units, and three are randomly selected as sample trees within each sample clone.

Selection of Sample Strobili

Clusters of female strobili are used as secondary sampling units because they are more convenient to count than individual strobili on sample trees. All clusters of first-year female strobili are counted on each sample tree when the system is installed. The counts should be made as accurately as possible because they serve as a basis for estimating orchard productivity and for determining total losses of strobili. The accuracy of these total-tree counts is improved by dividing the crowns into four directional quadrants. Plastic flagging placed at midcrown height on the north, south, east, and west sides of the trees serves this purpose.

The initial counts should be made shortly after the female flowers have emerged through the bud scales (stage 3 to stage 4 of development, Bramlett and O'Gwynn 1980) when they are easily distinguished from vegetative buds. If desired, a separate sample can be made of the second-year strobili present on the same sample trees, but only first-year strobili should be counted on the same trees during subsequent years.

A 10-percent random sample of the flower clusters in the southeast-crown quadrant is selected for subsequent observations. Each of the sample clusters is identified by consecutively numbered tags attached to the branch immediately below the cluster. First-year strobili should not bear the same tag numbers as the second-year strobili.

In practice, we make an initial count of the total number of clusters in each of the four quadrants and total these for the tree count. We then begin recounting clusters from the top of the southeast quadrant and tag those clusters whose count corresponds with the numbers in a table of random numbers produced by computer program A, which is described later.

It may be necessary to include a few extra randomly selected clusters to assure a representative spread of sample clusters from the top to the bottom of the crown. A 10-percent sample of the clusters on young trees bearing few strobili could result in samples too small for reliable use in estimating yields. Therefore, a minimum of 10 clusters is tagged or all of the clusters are tagged when there are less than 10 clusters present in a quadrant.

Periodic Observations on Sample Clusters

Two types of observations are taken on the sample clusters. The first type, referred to as a "general sample," is taken three times a year on all sample trees to estimate the numbers and conditions of female strobili present in sample clones and in the entire orchard. The times of these observations and the corresponding stages of development of first- and second-year female strobili are: (1) late winter (first-year flowers and early second-year conelets), (2) late spring (early first-year conelets and second-year green cones), and (3) fall (late first-year conelets and second-year mature cones). The second type of observation, referred to as an "intensive subsample," is made to meet local needs. One of the three sample ramets in each sample clone is randomly selected and observed at monthly, or more frequent, intervals during periods when major losses are typically known to occur (Fatzinger and others 1980). The intensive subsamples are taken to record pest damage before the affected strobili die and fall from the trees. The data also provide interim summaries of the proportions of strobili killed or injured by different pests on the subsample of 14 trees. When estimates of clonal and orchard productivity are desired, the general sampling procedure can be substituted for some or all of the intensive subsamples.

Field Data Forms

Records of first- and second-year strobili are kept on separate data forms. The "initial data sheets" are used only when the female strobili are tagged at the beginning of sampling (Appendix II). Data forms for subsequent observations on the tagged clusters are generated by the program, which is described in detail in a later section of this paper. The program lists each sample cluster and updates the form with the numbers of strobili remaining per cluster and the conditions and causes of damage observed during the previous observation period. This feature facilitates the use of strobilus clusters as observational units for determining causes of damage to strobili. The program also identifies inconsistencies in the numbers of strobili recorded for individual clusters during previous observations.

Sample trees are numbered consecutively from 1 to 42, regardless of their clonal identity, and are identified individually by these sample tree numbers. The clonal information, seed source data, numbers of initial flower clusters present, and other identification listed on the initial data forms are stored in a computer file for use when needed. The orchard name, tree species, sample tree number, date of previous sampling, and year of flowering are printed on the subsequent field data sheets for reference, so this information need not be entered a second time.

Cone Collection and Seed Analysis

A sample of six apparently healthy cones is collected from each sample tree at cone harvest. The 252 sample cones (42 sample trees x 6 cones per tree) are selected from the tagged clusters in the southeast-crown quadrant by randomly marking six clusters on the field data forms. One healthy cone is selected as a sample from each of the six marked sample clusters or from the nearest tagged or untagged cluster if no healthy cones remain in a selected cluster. Each sample cone is placed in an

individual paper bag labeled with the orchard name, tree number, and cluster tag number. The cones are stored until their scales begin to open in a room with sufficient ventilation to prevent mold formation. The cone scales of slash and loblolly pines can then be opened further by drying the cones in kilns or forced-air ovens for 24 hours at 49 °C (120 °F).

Most of the seeds are extracted by forcibly tapping the dried cones until seeds no longer fall from them. The remaining seeds must be removed from the cones by dissection to increase the accuracy of estimates of seed quality. This can be accomplished by the procedures described by Bramlett and others (1977). All seeds extracted from each cone are placed in a paper envelope for radiography. Radiographs can be interpreted by criteria described by DeBarr (1970), Ebel and others (1975), and Bramlett and others (1977). The radiographed seeds are germinated following the procedures described by Fatzinger and others (1980). Seed data are recorded on the standardized form illustrated in Appendix II and used to estimate the average number of seeds per cone, the proportion of seeds damaged, causes of damage, and the proportion of seeds viable at harvest.

Optional Sampling Methods

Random selection of sample trees. Simple random selection of sample trees is appropriate when clonal identities of trees cannot be determined, such as in seedling seed orchards. In that case, the 42 sample trees are selected at random (fig. 1). The intensive subsample is taken on a random selection of 14 sample trees.

Whole-crown sampling. The sampling system and its programs can be used with data collected from sample clusters located throughout the whole crown. Initial numbers of clusters present in different quadrants of the crowns of sample trees must be counted and recorded separately. If desired, separate records of the numbers of clusters found specifically in the upper and lower height levels of the southeast- and southwest-crown quadrants also may be maintained.

Computer programs for analysis of whole-crown samples were retained in the system for estimating damage of pests that may be nonuniformly distributed among crown quadrants. The whole-crown sampling procedure requires different types of initial data forms than those used for the southeast-crown quadrant sampling procedure (Appendix II).

General sample data only. The inclusion of intensive subsample data in the sampling system is optional and need be taken only when detailed information on the causes of strobilus mortality is desired.

Computer Programs, Statistical and Analytical Methods

Five computer programs utilizing procedures in the Statistical Analysis System (SAS Institute 1985a, 1985b) were developed for the seed orchard sampling system. One program produces random number tables for use in selecting random samples of strobilus clusters in tree crowns. A second program provides field data sheets updated with information on the numbers and conditions of sample strobili observed during the previous sample. Two other programs are used to summarize the field data and to compute periodic estimates of orchard productivity and pest damage. The fifth program summarizes information on seed quality and quantity on a clonal basis. An example of the use of these programs and a guide for their use are given in Appendixes I and III. All programs are currently operated under an IBM interactive system Time-Sharing Option (TSO) at the Northeast Regional Data Center (NERDC) of the University of Florida. They can be installed on other computers supporting SAS and TSO.

Datasets

A set of data consists of all observations taken during one general sample, one intensive subsample, or a seed analysis for one crop of cones. At least six datasets are accumulated over the period of strobilus development from flowers to mature cones. The first general sample recorded on the initial data form is referred to as the "Initial Dataset"; subsequent observations on the same strobilus clusters are referred to as "Follow-Up Datasets."

Naming datasets. Each dataset is given a qualified name in the format required by NERDC, which consists of alpha-numeric fields separated by decimal points; for example:

```
'UF.A#######.EX8601.GEN86'
```

The qualified name begins and ends with a single quotation mark and can consist of up to 17 fields. Each field must begin with an alphabetic character and end with a period. A field can contain up to 8 alpha-numeric characters. In the above example of the format for a qualified name, the first field, UF, is a prefix required by NERDC. The second field, A#######, is the user's account number with the first numeral replaced by its alphabetic equivalent; e.g., 1 = A, 2 = B, . . ., 9 = I. The third field, EX8601, identifies the dataset. The first two characters identify the orchard (EX = example), and the last four characters identify the year (86 = 1986) and month (01 = January) during which the sample was taken. The last field, GEN86, identifies the type of sample taken (GEN = general sample) and the year of flowering (86) for the strobili sampled. Other abbreviations used for the type of sample are INIT for an initial dataset, INT for intensive subsample data, and SEED for seed samples, for example:

```
'UF.A#######.EX8601.INIT86'
'UF.A#######.EX8601.INT86'
'UF.A#######.EX8601.GEN86'
'UF.A#######.EX8601.SEED87'
```

The dataset for the initial observation ('UF.A#######. EX8601.INIT86') was obtained by taking a general sample, and the abbreviation "INIT" is used instead of "GEN" to identify the sample as the first one taken.

Operation of the Programs

The programs are written to be self-explanatory and user friendly. An operator is guided by messages or "prompts" displayed on a terminal screen. Each program consists of a control list and a control program. The control list (CLIST) provides prompts for the input of information necessary to initialize the control programs. Once initialized, the control programs run automatically to analyze data and to print forms or random number tables. The control lists are individually called up for execution by one of the following commands:

```
EXEC 'UF.A#######.RANDOM.CLIST'
EXEC 'UF.A#######.FORMS.CLIST'
EXEC 'UF.A#######.YIELD.CLIST'
EXEC 'UF.A#######.DAMGINT.CLIST'
EXEC 'UF.A#######.SEED.CLIST'
```

Examples of the "prompts" for the five programs are given in Appendix III. If a mistake is made while typing a response to a "prompt," it can be corrected before it is entered into the computer by backspacing and typing over the mistake with the correct information. Once a mistake has been entered into the computer with the "return" key, the program must be terminated and begun over. The program can be terminated by striking the "break" key, and typing END,N.

Random numbers (Program A). This program is used to generate up to 43 tables of random numbers for selecting a 10-percent random sample of clusters. The tables are titled with different numbers representing the total numbers of clusters within a quadrant from which a sample is to be drawn. Each table contains 30 sets of random numbers, and the length of each set is equal to the number of clusters to be included in the 10-percent sample. A set of random numbers in a table is used only once. The table with the next highest number of total clusters is used when the total cluster count falls between two of the tables.

The program is divided into three subprograms, which produce random numbers for different sizes of strobilus crops on sample trees. The first subprogram produces 8 tables (3 pages per table) of random numbers for trees with 11 to 25 clusters per-crown quadrant in steps of 2 clusters; i.e., 11 clusters, 13 clusters, etc.; the second subprogram produces 14 tables (3 pages per table) for trees with 25 to 95 clusters in steps of 5 clusters, and the third produces 21 tables (1 page per table) for trees with 95 to 200 clusters per quadrant in steps of 5. Since one of the subprograms usually provides a sufficient span of numbers for a given orchard, it is not necessary to print all 43 tables.

Field data forms (Program B). The "data forms" program is run after the initial or follow-up datasets are on file. The

program produces 42 sets of forms for a general sample and 14 sets for an intensive subsample. The forms are printed on 9.5-by 11-inch continuous form paper and are updated with information on the numbers and conditions of strobili remaining in each of the initial sample clusters. In addition, inconsistencies in counts of strobili remaining in individual clusters from one sampling period to the next are marked with an asterisk.

Orchard productivity (Program C). Program C summarizes the field data and provides estimates of the numbers of sound and damaged strobili present in sample clones and the entire orchard after each sampling. A "Clone Dataset" must be on file when using the PPS (probability proportional to size) sampling method. It is a list of all clones present in the orchard and includes measures of the size (numbers of ramets per clone or records of previous yields) for each clone. An example of a "Clone Dataset" named 'UF.A#######.EX.CLONE86' is given in Appendix I. When a simple random sample has been taken, program C requires only the total number of trees present in an orchard. The program output includes the following:

Orchard size and sample tree data:

(1) Numbers of ramets per clone in orchard.
(2) Numbers of total and sample clusters.
(3) Initial numbers of strobili in sample clusters.
(4) Current numbers of total and sound strobili sampled.

Estimates for sample clones:

(1) Initial mean numbers of strobili per tree.
(2) Current mean numbers of total and sound strobili per tree and per sample clone.

Estimates for entire orchard:

(1) Initial number of strobili.
(2) Current numbers of total and sound strobili.
(3) Variance, standard deviation, coefficient of variation, upper and lower limits for 95-percent confidence limits of the estimates.
(4) Percent sound strobili.

Orchard productivity is estimated as follows. First, for each sample ramet, the average initial number of strobili, the current average number of strobili, and the current average number of healthy (sound) strobili are estimated on a per-cluster basis. Second, these results, together with the initial total cluster count for the sample ramet, are used to estimate the average initial total strobilus count, the current total strobilus count, and the current total sound strobilus count for each sample ramet. Third, estimates for the individual sample ramet are averaged within each sample clone, and these averages are multiplied by the number of ramets within the clone to estimate the corresponding clonal totals.

Fourth, each estimated clonal total is divided by the associated clonal PPS sampling fraction to estimate the orchard total. Therefore, orchard totals for initial strobilus count, current strobilus count, and current sound strobilus count are estimated from corresponding values for sample clones. Associated standard errors are computed for the estimates pertaining to total strobilus count and total sound strobilus count.

Damage estimates (Program D). Program D can be run on either the general sample data (42 sample trees) or the intensive subsample data (14 sample trees). Summaries containing the information shown below can be obtained for each cause of damage and for all causes combined:

(1) Initial number of strobili.
(2) Number and percent of strobili lost since start of sampling (by date and clone).
(3) Number of strobili at time of last sample.
(4) Number and percent of strobili lost or injured since last sample.
(5) Strobilus mortality curves.

The purpose of the damage estimates program is to track specific factors causing damaged and missing strobili by clone over time. To this end, rates of damage and destruction of strobili are summarized for each clone-cause combination by sample period. Changes occurring in any sample period are carried across subsequent sample periods to facilitate cumulative analyses over time. Analyses for individual sample periods are based on the number of strobili available from the previous sample period. Cumulative percentages are based on initial strobilus counts. Output includes both counts and percentages reflecting current and cumulative changes, by sample period, for each clone-cause combination.

Seed analyses (Program E). This program summarizes the quantity and quality of seeds extracted from the 252 sample cones collected at harvest. The seed-data analysis provides estimates for each sample clone and for all sample clones combined. Each set of analyses includes summary statistics per cone and per clone. Pooled summaries give percentages of: (1) germination, (2) full seeds, (3) empty seeds, (4) seed bug damage, (5) fungus damage, (6) seedworm damage, (7) unknown damage, and (8) processing damage. Values provided include:

(1) Total number of cones examined, seeds extracted and seeds germinated.
(2) Mean numbers of total seeds per cone, germinated seeds per cone, percent of seed germinated, and standard deviations.
(3) Numbers and percentages of seeds classified as full, empty, and damaged by seed bugs, seedworms, fungi, or unknown factors.

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Appendix I

Hypothetical Example of Sampling Procedures and User-Friendly Computer Programs

A hypothetical seed orchard illustrates the sampling procedure and operation of the computer programs. The orchard contains 860 trees of 30 clones with 2 to 98 ramets per clone (table 1). The example demonstrates the use of program A for generating tables of random numbers and programs C, D, and E for analyzing data simulated for two general samples, two intensive subsamples, and a seed sample. A complete listing of the programs and printouts of the results of analyses for this example can be obtained from the Project Manager, Integrated Forest Pest Management Cooperative, Department of Forestry, University of Florida, Gainesville, FL 32611. Other examples of analyses of data collected in southern pine seed orchards were given by Fatzinger and others.[1]

Southeast Quadrant Sampling

Selection of sample trees. Fourteen sample clones were selected with the probability of selection proportional to their relative sizes in the hypothetical orchard. Size was based on the number of ramets per clone (table 1). The size variable was then accumulated and the range of the accumulated sizes was listed for each of the ranked clones. Fourteen three-digit numbers less than or equal to the sum of the size variables (= 860) were selected from a table of random numbers. The first 14 random numbers selected were 823, 463, 719, 375, 155, 295, 783, 500, 653, 416, 300, 600, 571, and 028. Clones selected for sampling were those whose size range included one or more of these 14 numbers. In the example, clone number 9 was selected twice, resulting in a total of 13 sample clones for the orchard with 6 sample ramets in clone 9.

Selection of sample strobili. Random number tables were generated with program A to facilitate the selection of sample clusters in the southeast-crown quadrants of sample trees (table 2). The control list of program A was initiated under TSO with the command:

```
EXEC 'UF.A#######.RANDOM.CLIST'
```

The program responded with the "prompt":

```
ENTER CODE FOR TOTAL NUMBER OF CLUSTERS
   IN THE SOUTHEAST QUADRANT
      IF LESS THAN 25 THEN ENTER  A
      IF 25 TO 95 THEN ENTER  B
      IF MORE THAN 95 THEN ENTER  C
```

---

[1] Fatzinger, Carl W.; Muse, H. David; Miller, Thomas [and others]. Survey and pest monitoring system for southern pine seed orchards. Southern Journal of Applied Forestry [in preparation].

The numbers of simulated clusters in the southeast-crown quadrants of the sample trees in the hypothetical orchard ranged from 20 to 98. Program A was therefore run three times to enter each of the responses (A, B, and C) to produce random number tables encompassing from 20 to 98 clusters per quadrant.

Field data forms and dataset names. Examples of filled-in field data forms are illustrated in figures 1 through 4. The following fully qualified dataset names were assigned to the simulated datasets:

'UF.A#######.EX8602.INIT86' = first general sample (initial dataset) taken at beginning of sampling (Feb. 1986)

'UF.A#######.EX8603.INT86' = first intensive subsample (Mar. 1986)

'UF.A#######.EX8604.INT86' = second intensive subsample (Apr. 1986)

'UF.A#######.EX8606.GEN86' = second and last general sample (June 1986)

'UF.A#######.EX.SEED86' = seed collected for analysis (Sep. 1987)

Operation of Computer Programs

Clone dataset. A "clone dataset" was constructed, named 'UF.A#######.EX.CLONE86', and placed on file (table 3). Data were entered into the clone dataset in list format with at least one space between variables. The first variable (EX) is the two-letter code used to identify the orchard. The second variable is the clone identification number (1 to 30 in the example). The third and fourth variables in each line of data represent the relative sizes of clones within the orchard. The third variable is the number of ramets present in the clone, and the fourth variable is a measure of previous strobilus production (numbers of flowers or mature cones) of the clone. Only one of these last two variables is required but, if one is not used, it must be represented in the dataset by a zero or a decimal point.

Yield and damage estimates. Programs C and D provided estimates of orchard productivity and pest damage using the data for the first general sample. The operation of these programs is illustrated by the following lists of "prompts" generated by the control lists. Responses to the "prompts" are underlined and contained within brackets in each of the examples.

Program C was initiated with the command:

```
EXEC 'UF.A#######.YIELD.CLIST'
```

The user-friendly "prompts" generated by program C were:

```
ENTER THE PINE SPECIES FOR WHICH ANALYSIS IS DESIRED.
USE ONE WORD  [SLASH]

ENTER THE FULLY QUALIFIED DATASET NAME FOR INITIAL DATA
   ['UF.A#######.EX8602.INIT86']

IS THERE A FOLLOW-UP DATASET TO BE ANALYZED?
   IF YES ENTER Y
   IF NO ENTER N  [N]

ENTER SIZE MEASURE TO BE USED IN DEVELOPING ESTIMATES
   IF MEASURE IS PREVIOUS YIELD THEN ENTER PY

   IF MEASURE IS NUMBER OF RAMETS PER CLONE THEN ENTER NR
      OTHERWISE ENTER SR  [NR]

ENTER THE FULLY QUALIFIED DATASET NAME FOR CLONE DATA
   ['UF.A#######.EX.CLONE86']

ENTER 2 DIGIT FLOWER YEAR FOR WHICH YIELDS ARE TO BE
   ESTIMATED [86]

ENTER 2 CHARACTER ORCHARD CODE USED IN DATA  [EX]

ENTER COMPANY TITLE.  USE UP TO THREE WORDS WITH A HYPHEN
   BETWEEN WORDS  [HYPOTHETICAL-ORCHARD-EXAMPLE]

ENTER LOCATION OF CROWN SAMPLED
   IF WHOLE CROWN THEN ENTER WC
   IF SE QUADRANT THAN ENTER SE  [SE]

ENTER TYPE ANALYSIS DESIRED.  CHOICES ARE:
   YIELDL, YIELDM, AND YIELDS.  FOR A STANDARD ANALYSIS
   ENTER YIELDS  [YIELDS]
```

Program D was executed to estimate damage caused by specific pests and other factors observed during the initial sampling:

```
EXEC 'UF.A#######.DAMGINT.CLIST'
```

The program "prompts" were:

```
ENTER PINE SPECIES FOR WHICH ANALYSIS IS DESIRED.
USE ONE WORD  [SLASH]

ENTER THE FULLY QUALIFIED DATASET NAME FOR INITIAL DATA
   ['UF.A#######.EX8602.INIT86']

ENTER THE NUMBER OF FOLLOW-UP DATASETS TO BE USED IN
THIS  ANALYSIS.  MINIMUM NUMBER IS 0 AND MAXIMUM NUMBER
IS 12  [0]
```

```
ENTER 2 DIGIT FLOWER YEAR FOR WHICH ANALYSIS IS DESIRED
[86]

ENTER 2 CHARACTER ORCHARD CODE USED IN DATA  [EX]

ENTER COMPANY TITLE.  USE UP TO THREE WORDS WITH A
HYPHEN BETWEEN WORDS  [HYPOTHETICAL-ORCHARD-EXAMPLE]

ENTER LOCATION OF CROWN SAMPLED
   IF WHOLE CROWN THEN ENTER WC
   IF SE QUADRANT THAN ENTER SE  [SE]
```

Program D also was used to estimate pest damage for the two intensive subsamples simulated for March and April. Responses to the control list were identical to those listed above for the initial sample with the exception of the response to the third "prompt." This response was changed from [0] to [1] for the first intensive subsample and to [2] for the second subsample. The control list program then requested names for the follow-up datasets; i.e., 'UF.A#######.EX8603.INT86' for the March observation, and 'UF.A#######.EX8604.INT86' for the April observation.

A fifth analysis was run for the general sample of data simulated for the June observation. Program C was again run to produce estimates of orchard productivity using dataset 'UF.A#######.EX8606.GEN86' as a follow-up dataset.

Simulated data for a seed extraction were the last data analyzed for the example. Program E was used for these analyses as follows:

```
EXEC 'UF.A#######.SEED.CLIST'
```

The program responded with the following "prompts":

```
ENTER THE FULLY QUALIFIED DATASET NAME FOR SEED DATA
   ['UF.A#######.EX.SEED86']

ENTER THE FULLY QUALIFIED DATASET NAME FOR INITIAL DATA
   ['UF.A#######.EX8602.INIT86']

ENTER THE 2 CHARACTER ORCHARD CODE USED IN THE DATA  [EX]

ENTER THE COMPANY TITLE.  USE UP TO THREE WORDS WITH
A HYPHEN BETWEEN WORDS  [HYPOTHETICAL-ORCHARD-EXAMPLE]

ENTER 2 DIGIT FLOWER YEAR FOR WHICH ANALYSIS IS DESIRED
   [87]

ENTER SPECIES FOR WHICH ANALYSIS IS DESIRED  [SLASH]
```

Table 1.--Example of procedure used for selecting sample clones from a hypothetical 30 clone seed orchard with probability proportional to size

Size (No. ramets)	Clone	Accumulated size (No. ramets)	Size range (No. ramets)	Random numbers	Clones selected
98	26	98	1- 98	28	26
96	3	194	99-194	155	3
78	15	272	195-272		
62	9	334	273-334	295, 300	9
60	7	394	335-394	375	7
58	6	452	395-452	416	6
43	4	495	453-495	463	4
36	30	531	496-531	500	30
34	17	565	532-565		
27	28	592	566-592	571	28
26	29	618	593-618	600	29
25	10	643	619-643		
24	5	667	644-667	653	5
20	11	687	668-687		
19	14	706	688-706		
19	2	725	707-725	719	2
17	12	742	726-742		
16	23	758	743-758		
16	18	774	759-774		
12	13	786	775-786	783	13
12	20	798	787-798		
12	19	810	799-810		
9	27	819	811-819		
9	21	828	820-828	823	21
8	22	836	829-836		
8	24	844	837-844		
6	1	850	845-850		
4	25	854	851-854		
4	16	858	855-858		
2	8	860	859-860		

Table 2.--Example of a random number table generated with Program A for selection of sample clusters in the southeast-crown quadrant of sample tree number 4 in the example

RANDOM NUMBERS FOR A TOTAL OF 50 CLUSTERS	
SET 1	1 6 19 24 33 37 38 41 46 49
SET 2	4 10 13 16 22 26 27 38 41 44
SET 3	1 2 4 14 26 27 28 29 43 46
SET 4	3 6 7 14 25 27 34 40 43 44
SET 5	4 6 14 18 25 30 33 34 41 46
SET 6	3 7 14 18 21 22 23 25 34 49
SET 7	3 12 20 22 23 29 31 33 40 48
SET 8	1 11 14 23 26 27 31 36 38 46
SET 9	2 12 16 23 29 33 36 43 48 49
SET 10	6 11 12 21 22 25 26 28 31 43
.	.
.	.
.	.
SET 30	7 16 23 24 30 33 37 41 42 46

Table 3.--Example of the clone dataset ('UF.A#######.EX.CLONE86') used for the hypothetical orchard in this Paper

EX	1	6	0
EX	2	19	0
EX	3	96	0
EX	4	43	0
EX	5	24	0
EX	6	58	0
EX	7	60	0
EX	8	2	0
EX	9	62	0
EX	10	25	0
EX	11	20	0
EX	12	17	0
EX	13	12	0
EX	14	19	0
EX	15	78	0
EX	16	4	0
EX	17	34	0
EX	18	16	0
EX	19	12	0
EX	20	12	0
EX	21	9	0
EX	22	8	0
EX	23	16	0
EX	24	8	0
EX	25	4	0
EX	26	98	0
EX	27	9	0
EX	28	27	0
EX	29	26	0
EX	30	36	0

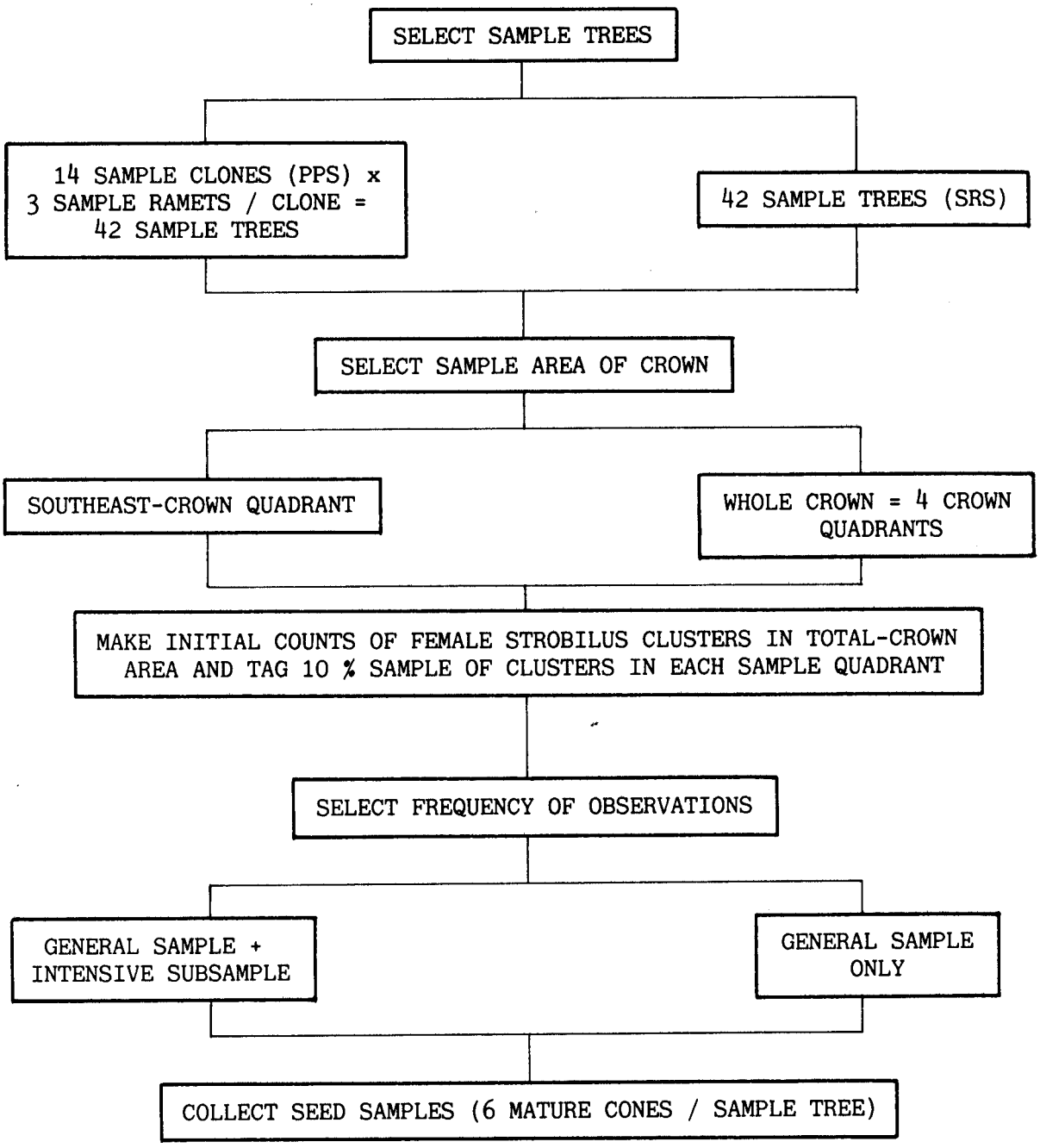
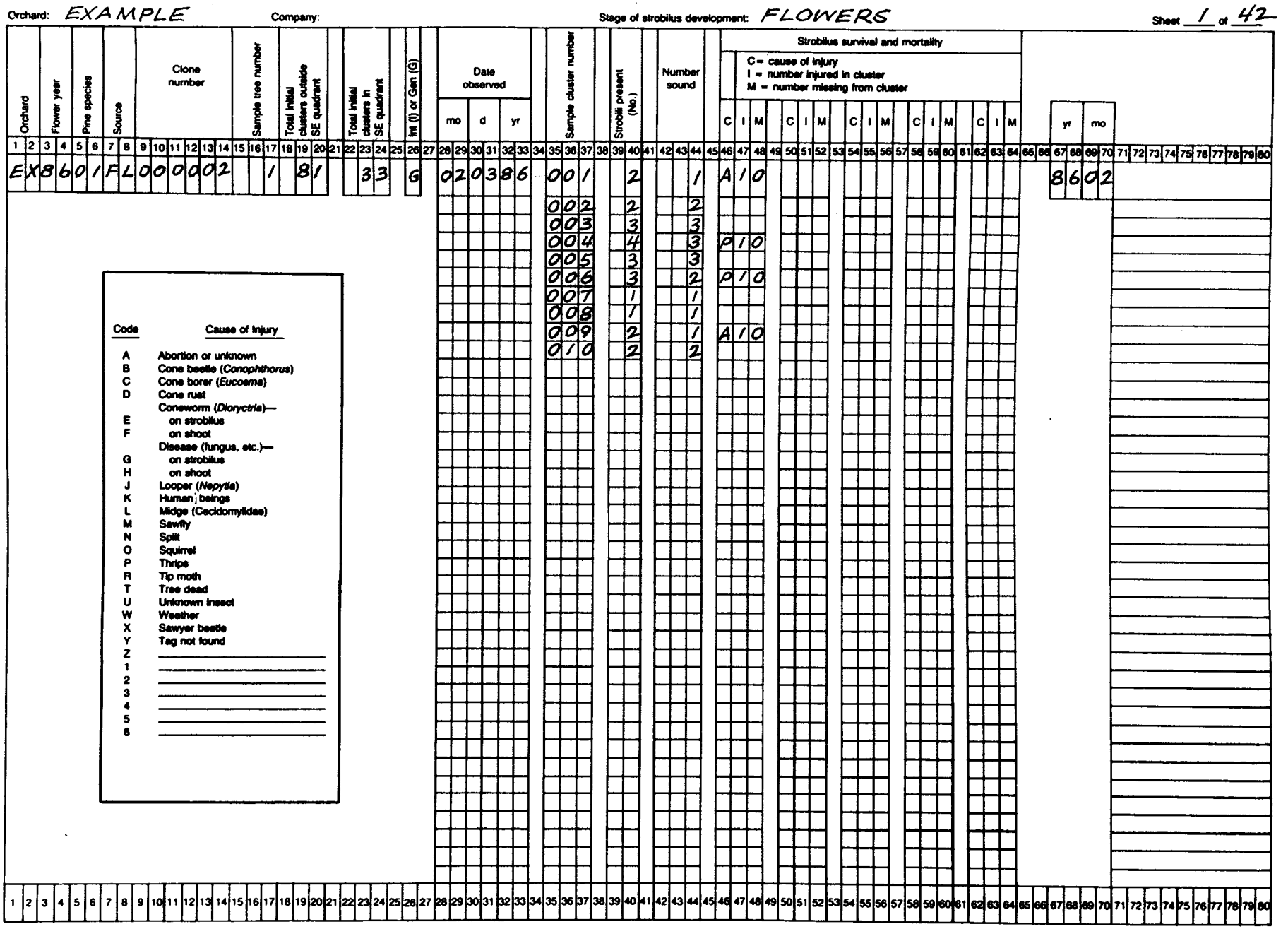


Figure 1.--Schematic of sampling procedure identifying several options available in the system: (1) methods for selection of sample trees with the selection proportional to size (PPS) or simple random sampling (SRS) techniques, (2) whole-crown and southeast-crown quadrant methods for sampling tree crowns, and (3) modification in frequency of sampling.

Figure 2.--Example of an initial field data form for the southeast-crown quadrant of sample tree number 1 of the hypothetical seed orchard.



General Sample Data
(IFPM Coop.)

Orchard = IFPM Coop. example
Previous date =
Observations marked by *
contain one or more mistakes

Species = Slash
Sample tree = 8

Flower year = 86

Orchard	Species	Tree	Date			Tag number	Number left	Current condition						Previous condition				
			mo	d	yr			Sound	CIM	CIM	CIM	CIM	CIM	Sound	CI	CI	CI	CI
EX	01	8				001	2	0	F02					2				
EX	01	8				002	5	5						5				
EX	01	8				003	4	2	P01	A01				3	P1			
EX	01	8				004	4	3	P01					3	P1			
EX	01	8				005	3	1	P01	A01				2	P1			
EX	01	8				006	5	5						5				
EX	01	8				007	4	4						4				
EX	01	8				008	6	4	P01	A01				5	P1			
EX	01	8				009	3	0	A03					3				
EX	01	8				010	2	2						2				

Figure 3.--Example of the follow-up data forms generated by program B for the second observation period in the hypothetical seed orchard.

EXAMPLE

Sheet _____ of _____

Orchard	Flower year	Species	Tree number	Quadrant	Level	Tag number	Seed analysis: X-ray interpretation: Full (No.)	Empty (No.)	Seedbug (No.)	Fungus (No.)	Seedworm (No.)	Unknown (No.)	Processing damage (No.)	Germinates (No.)
EX	86	01	1	SEU		4	100	2	0	1	0	0	0	83
				SEU		1	79	5	0	0	0	0	0	38
				SEL		2	73	3	0	0	0	0	0	21
				SEU		3	112	7	0	0	0	0	0	58
				SEU		7	55	3	0	1	0	0	0	31
				SEU		9	38	0	0	0	0	0	0	30
			2	SEU		4	38	0	2	0	0	0	0	38
				SEU		2	26	0	0	0	0	0	0	6
				SEU		8	52	6	0	0	1	0	0	28
				SEU		10	63	6	0	0	2	0	0	20
				SEL		1	22	16	0	0	0	0	0	12
				SEU		3	20	1	0	0	0	0	0	0
			3	SEU		9	132	6	0	0	1	0	0	117
				SEL		10	72	33	2	0	0	0	0	0
				SEL		7	38	41	1	0	0	0	0	2

Figure 4.--Example of the data form for seed analyses used to record results of seed extraction, radiographic analyses, and germination tests.

Appendix II

Field Data Forms

Initial Data Forms

The two types of initial data forms are illustrated in, and can be copied directly from, this Appendix (figs. 5 and 6). All data entries must be right-justified within the columns.

Information used to identify the orchard, the sample tree, the type and size of sample, and the observation date (cols. 1-33 and 67-70) is entered only once in the first row of each initial data form (figs. 2 and 7). Changes in the information listed in columns 19 to 33 of the form for whole-crown sampling (fig. 7) or columns 28-33 of the form for southeast-crown quadrant sampling (fig. 2) are made only once in the row where the change occurs. The information listed in columns 1 to 33 and 67 to 70, however, must be duplicated by the keypunch operator for each row of data on the form that follows the entry before it is filed as a dataset.

Different types of information are entered in columns 18 to 26 of the initial forms for the southeast-crown quadrant and whole-crown sampling procedures. The quadrant and height level sampled, the type of sample (general or intensive subsample), and the total number of clusters present in the quadrant are listed in columns 19 to 26 of the form for whole-crown samples. Columns 18 to 26 of the form for southeast-crown quadrant samples are used to record the numbers of total clusters outside and inside the southeast quadrant, and the type of sample taken.

Columns 1 through 17 and 27 through 80 of both forms are identical. A two-digit code used to identify the species of pine sampled is entered in columns 5 and 6:

Slash pine	01
Loblolly pine	02
Longleaf pine	03
Shortleaf pine	04
Virginia pine	05
Sand pine	06

Columns 9 to 14 (clone number) and columns 35 to 37 (cluster number) must contain zeros instead of blanks in unused spaces. The cluster numbers (tag numbers) and numbers of female strobili present in the sample clusters are recorded in columns 35 to 40.

Columns 42 through 64 are used to record observations on the survival of strobili and causes of damage within the sample clusters. The number of undamaged (sound) strobili is recorded in columns 42 to 44, and the causes of injury and numbers of injured or missing strobili are recorded under the five columns headed "CIM." Single letter or number codes for the causes of injuries are listed on the left side of the data sheet and are recorded under the columns headed "C." The numbers of strobili

injured but still present in the cluster are recorded under the "I" columns, and the numbers of strobili missing from the sample clusters are recorded under the "M" columns. For example, a "CIM" entry might be "P24" indicating that within one sample cluster, two strobili were injured by thrips and four strobili were killed by thrips. If more than 9 strobili within a sample cluster are affected by the same factor, the information can be recorded in more than one "CIM" column by repeating the cause code letter; e.g., "P21 P81" indicates that within the same cluster, 10 strobili (P2_ + P8_) were injured by thrips and 2 (P_1 + P_1) were killed by thrips. The last two digits of the year during which a sample was taken are entered in columns 67 to 68 and the two-digit number for the month of sampling is entered in columns 69 and 70.

Follow-Up Data Forms

Follow-up data forms are produced by program B for each observation after an initial dataset is on file (fig. 3). One set of forms is produced for each sample tree to be included in the next sample. These forms are headed with information identifying the orchard, year of flowering, sample tree number, and date of the most recent sample. Only the date of the current observation and the number and conditions of strobili in each sample cluster need to be entered on these forms. The date needs to be entered only once, in the first row of each data form, but must be duplicated by the keypunch operator for each row of data following the entry before it is filed as a dataset. Three-digit codes must be used for entries in the "CIM" columns. For example, an entry for two strobili missing with the cause of death unknown should be entered on the form as "A02" rather than "A2." Likewise, an entry for two strobili injured by thrips should be entered as "A20" rather than "A2."

Seed Data Forms

Information identifying the source of a seed sample is listed in columns 1 to 15, and the results of radiographic analyses and germination tests are recorded in columns 17 to 37 (fig. 8). Information in columns 1 to 9 needs to be entered only once, in the first row of each data form, but must be duplicated for each row of data following the entry before it is filed as a dataset. Changes in this information are made only once in the row where the change occurs.

Figure 5.--Initial data form for the southeast-crown quadrant sampling procedure (for example of data entries, see fig. 2).

Orchard: Company: Stage of strobilus development: Sheet _____ of _____

Orchard	Flower year	Pine species	Source	Clone number	Sample tree number	Total initial clusters outside SE quadrant	Total initial clusters in SE quadrant	Int (I) or Gen (G)	Date observed (mo, d, yr)	Sample cluster number	Strobili present (No.)	Number sound	Strobilus survival and mortality (C I M ×5)	yr	mo
1 2	3 4	5 6	7 8	9 10 11 12 13 14	15 16 17	18 19 20	21 22 23 24	25 26	27 28 29 30 31 32 33	34 35 36 37	38 39 40	41 42 43 44 45	46–65	66 67 68	69 70

Strobilus survival and mortality: C = cause of injury; I = number injured in cluster; M = number missing from cluster

Column numbers: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

Code	Cause of Injury
A	Abortion or unknown
B	Cone beetle (*Conophthorus*)
C	Cone borer (*Eucosma*)
D	Cone rust
	Coneworm (*Dioryctria*)—
E	on strobilus
F	on shoot
	Disease (fungus, etc.)—
G	on strobilus
H	on shoot
J	Looper (*Nepytia*)
K	Human beings
L	Midge (Cecidomyiidae)
M	Sawfly
N	Split
O	Squirrel
P	Thrips
R	Tip moth
T	Tree dead
U	Unknown insect
W	Weather
X	Sawyer beetle
Y	Tag not found
Z	______
1	______
2	______
3	______
4	______
5	______
6	______

Figure 6.--Initial data form for the whole-crown sampling procedure (for example of data entries, see fig. 7).

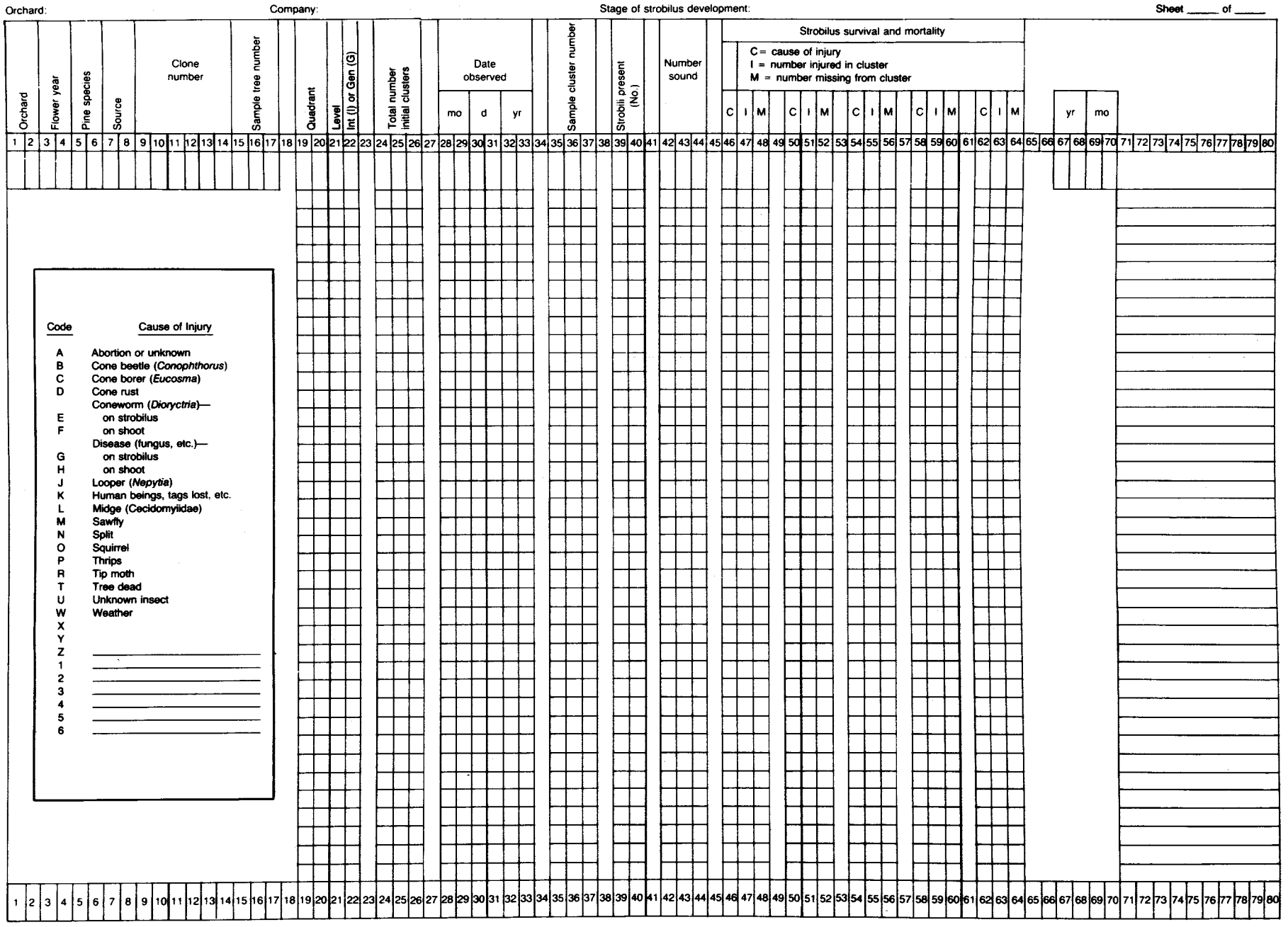
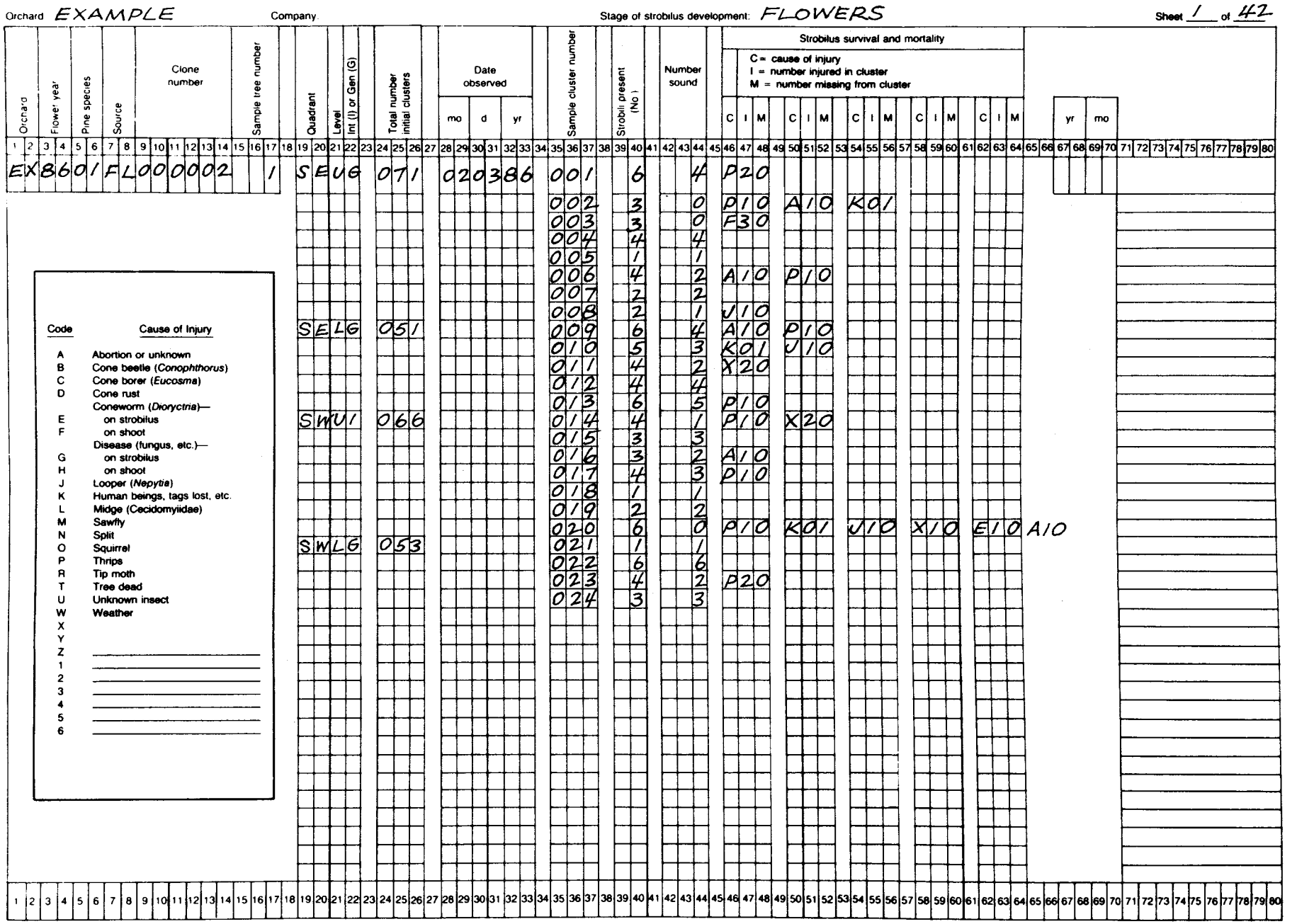


Figure 7.--Example of data recorded on initial data sheet for the whole-crown sampling procedure.



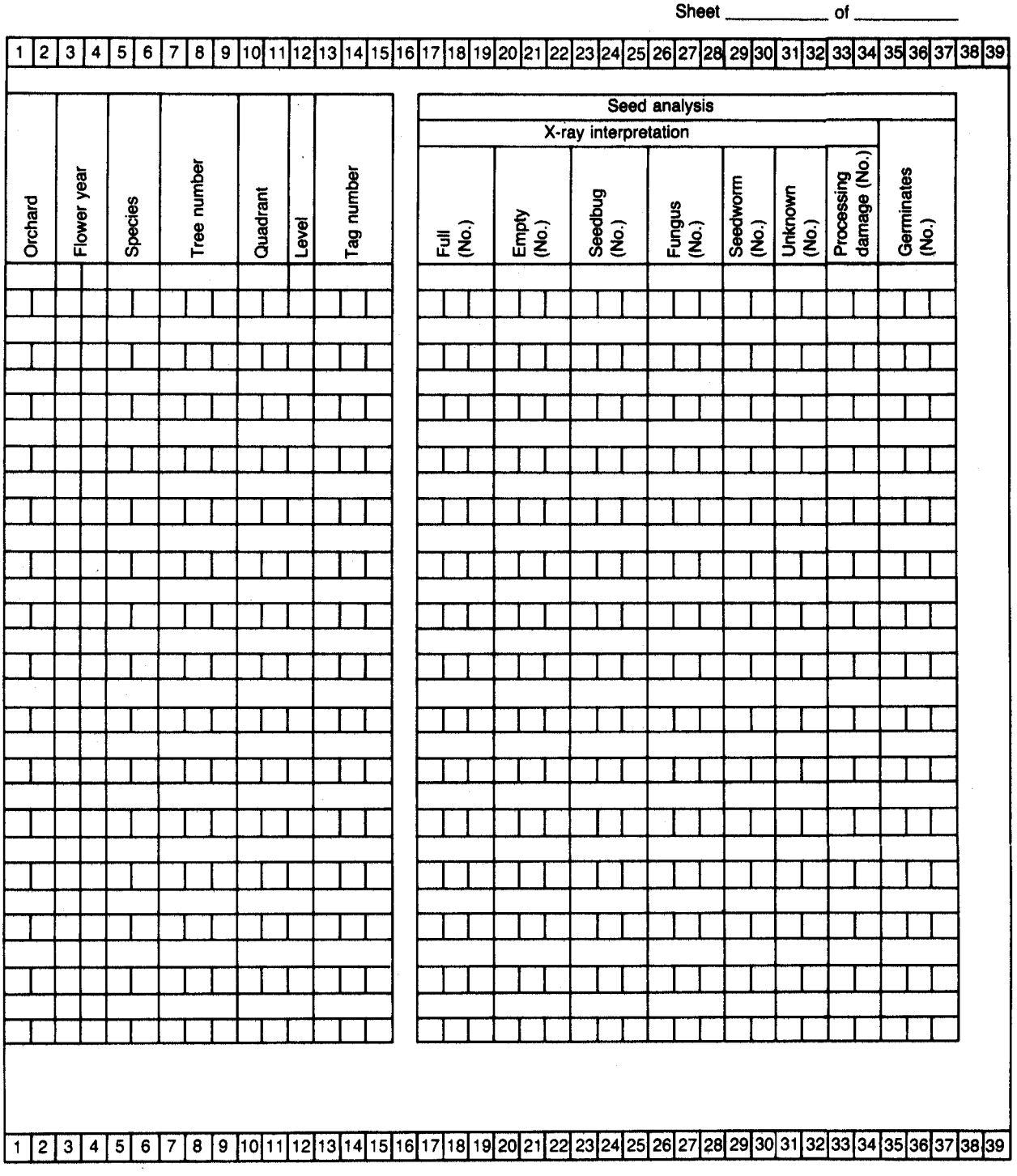


Figure 8.--Seed data form used to record results of seed extraction, radiographic analyses, and germination tests (for example of data entries, see fig. 4).

Appendix III

Guide for the Operation of Five Computer Programs for Producing Random Numbers, Field Data Forms, Orchard Productivity Estimates, Damage Estimates, and Seed Analyses

Random Numbers (Program A)

The control list is executed by the following command:

```
EXEC 'UF.A#######.RANDOM.CLIST'
```

Once executed, the "prompts" request information on the total numbers of strobilus clusters expected in the sampled quadrant:

```
ENTER CODE FOR TOTAL NUMBER OF CLUSTERS
IN THE SOUTHEAST QUADRANT
   IF LESS THAN 25 THEN ENTER  A
   IF 25 TO 95 THEN ENTER  B
   IF MORE THAN 95 THEN ENTER  C
```

Field Data Forms (Program B)

The program is executed with:

```
EXEC 'UF.A#######.FORMS.CLIST'
```

The following "prompts" are displayed requesting specific information on the orchard for which the field data forms are required:

```
ENTER TYPE OF SAMPLE FORM DESIRED
   IF GENERAL SAMPLE FORM THEN ENTER GEN
   IF INTENSIVE SAMPLE FORM THEN ENTER INT

ENTER LOCATION OF CROWN TO BE SAMPLED
   IF WHOLE CROWN THEN ENTER WC
   IF SE QUADRANT THEN ENTER SE

ENTER TWO DIGIT FLOWER YEAR

ENTER TWO CHARACTER ORCHARD CODE TO BE USED IN DATA

ENTER COMPANY TITLE.  USE UP TO THREE WORDS WITH
A HYPHEN BETWEEN WORDS

ENTER CODE TO INDICATE THE NUMBER OF INITIAL AND
FOLLOW-UP DATASETS
   IF 1 INITIAL FILE AND 0 FOLLOW-UP FILES THEN
      ENTER 1
   IF 1 INITIAL FILE AND 1 FOLLOW-UP FILE THEN ENTER
      2
   IF 2 INITIAL FILES AND 1 FOLLOW-UP FILE FOR ONLY
      ONE OF THE INITIAL FILES THEN ENTER 3
   IF 2 INITIAL FILES AND A FOLLOW-UP FILE FOR EACH
      INITIAL FILE THEN ENTER 4
```

Depending on the numbers entered, the following "prompts" will appear. Numbers to the left of statements refer to the numbers entered in the above step.

1,2 ENTER FULLY QUALIFIED DATASET NAME FOR THE INITIAL FILE

3 ENTER FULLY QUALIFIED DATASET NAME FOR THE INITIAL FILE WITH NO CORRESPONDING FOLLOW-UP FILE

3 ENTER FULLY QUALIFIED DATASET NAME FOR REMAINING INITIAL FILE

4 ENTER FULLY QUALIFIED DATASET NAME FOR FIRST INITIAL FILE

4 ENTER FULLY QUALIFIED DATASET NAME FOR SECOND INITIAL FILE

2,3,4 ENTER CODE TO INDICATE MOST RECENT GENERAL AND/OR INTENSIVE SAMPLES

- IF A GENERAL SAMPLE AND NO INTENSIVE SAMPLE THEN ENTER 1
- IF NO GENERAL SAMPLE AND AN INTENSIVE SAMPLE THEN ENTER 2
- IF A GENERAL SAMPLE AND AN INTENSIVE SAMPLE THEN ENTER 3

Numbers in parentheses to the left of the statements refer to the code numbers entered in the previous step.

(1,3) ENTER THE FULLY QUALIFIED DATASET NAME OF MOST RECENT GENERAL SAMPLE

(2,3) ENTER THE FULLY QUALIFIED DATASET NAME OF MOST RECENT INTENSIVE SAMPLE

Orchard Productivity (Program C)

The orchard productivity or "yield" program is initiated by the command:

```
EXEC 'UF.A#######.YIELD.CLIST'
```

The control list program responds with the following "prompts":

ENTER THE PINE SPECIES FOR WHICH ANALYSIS IS DESIRED. USE ONE WORD (e.g., SLASH)

ENTER THE FULLY QUALIFIED DATASET NAME FOR INITIAL DATA

IS THERE A FOLLOW-UP DATASET TO BE ANALYZED?

- IF YES ENTER Y
- IF NO ENTER N

If a Y is entered the program responds with:

ENTER THE FULLY QUALIFIED DATASET NAME FOR FOLLOW-UP DATA

ENTER SIZE MEASURE TO BE USED IN DEVELOPING ESTIMATES
IF MEASURE IS PREVIOUS YIELD THEN ENTER PY
IF MEASURE IS NUMBER OF RAMETS PER CLONE THEN ENTER NR OTHERWISE ENTER SR

If SR is entered the program responds with:

ENTER NUMBER OF TREES IN ORCHARD

ENTER THE FULLY QUALIFIED DATASET NAME FOR CLONE DATA

ENTER 2 DIGIT FLOWER YEAR FOR WHICH YIELDS ARE TO BE ESTIMATED

ENTER 2 CHARACTER ORCHARD CODE USED IN DATA

ENTER COMPANY TITLE. USE UP TO THREE WORDS WITH A HYPHEN BETWEEN WORDS

ENTER LOCATION OF CROWN SAMPLED
IF WHOLE CROWN THEN ENTER WC
IF SE QUADRANT THAN ENTER SE

ENTER TYPE ANALYSIS DESIRED. CHOICES ARE:
YIELDL, YIELDM, AND YIELDS. FOR A STANDARD ANALYSIS ENTER YIELDS

The program will produce three types of yield analyses. The L, M, and S suffixes to the word YIELD represent long, medium, and short analyses, respectively. The short analysis program (YIELDS) is the one generally selected and provides all estimates of strobilus productivity and survival. The medium analysis program (YIELDM) provides lists of factors used in estimating clonal and orchard yields in addition to the output of the YIELDS program. The long analysis program (YIELDL) is used to analyze data from four directional crown quadrants and two height levels.

Damage Estimates Program (D)

The damage estimate program is executed with:

EXEC 'UF.A#######.DAMGINT.CLIST'

The program responds with the following "prompts":

ENTER PINE SPECIES FOR WHICH ANALYSIS IS DESIRED. USE ONE WORD (e.g. "LOBLOLLY")

ENTER THE FULLY QUALIFIED DATASET NAME FOR INITIAL DATA

ENTER THE NUMBER OF FOLLOW-UP DATASETS TO BE USED IN THIS ANALYSIS. MINIMUM NUMBER IS 0 AND MAXIMUM NUMBER IS 12

Depending on the number entered in the above step, the program will step through a sequence of "prompts" to allow entry of dataset names for each follow-up dataset as follows:

ENTER THE FULLY QUALIFIED DATASET NAME FOR THE FIRST FOLLOW-UP DATASET

ENTER THE FULLY QUALIFIED DATASET NAME FOR THE NUMBER 2 FOLLOW-UP DATASET

ENTER THE FULLY QUALIFIED DATASET NAME FOR THE NUMBER 3 FOLLOW-UP DATASET

.
.
.
.

ENTER THE FULLY QUALIFIED DATASET NAME FOR THE NUMBER 12 FOLLOW-UP DATASET

The program then continues:

ENTER 2 DIGIT FLOWER YEAR FOR WHICH ANALYSIS IS DESIRED

ENTER 2 CHARACTER ORCHARD CODE USED IN DATA

ENTER COMPANY TITLE. USE UP TO THREE WORDS WITH A HYPHEN BETWEEN WORDS

ENTER LOCATION OF CROWN SAMPLED
IF WHOLE CROWN THEN ENTER WC
IF SE QUADRANT THAN ENTER SE

Seed Analyses (Program E)

This program is executed by entering:

EXEC 'UF.A#######.SEED.CLIST'

The program then responds:

ENTER THE FULLY QUALIFIED DATASET NAME FOR SEED DATA

ENTER THE FULLY QUALIFIED DATASET NAME FOR INITIAL DATA

ENTER THE 2 CHARACTER ORCHARD CODE USED IN THE DATA

ENTER THE COMPANY TITLE. USE UP TO THREE WORDS WITH A HYPHEN BETWEEN WORDS

ENTER 2 DIGIT FLOWER YEAR FOR WHICH ANALYSIS IS DESIRED

ENTER SPECIES FOR WHICH ANALYSIS IS DESIRED

Fatzinger, Carl W.; Muse, H. David; Miller, Thomas; Bhattacharyya, Helen T. 1988. Estimating cone and seed production and monitoring pest damage in southern pine seed orchards. Res. Pap. SE-271. Asheville, N.C.: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 30 pp.

Field sampling procedures and computer programs are described for monitoring seed production and pest damage in southern pine seed orchards. The system estimates total orchard yields of female strobili and seeds, quantifies pest damage, determines times of year when losses occur, and produces life tables for female strobili. An example is included to illustrate the sampling procedures and the operation of user-friendly computer programs.

Keywords: Cone and seed insects, cone and seed diseases, sampling, seed orchard production, survey.

Fatzinger, Carl W.; Muse, H. David; Miller, Thomas; Bhattacharyya, Helen T. 1988. Estimating cone and seed production and monitoring pest damage in southern pine seed orchards. Res. Pap. SE-271. Asheville, N.C.: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 30 pp.

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