DEVELOPMENT OF A COMPUTERIZED SEED ORCHARD INVENTORY-MONITORING SYSTEM AND ANALYSIS OF SEED ORCHARD PRODUCTIVITY VARIABLES

by

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Dissertation submitted to the Graduate Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Forestry and Forest Products

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August, 1982
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ACKNOWLEDGEMENTS

I would like to express my most sincere appreciation to everyone who has contributed to the successful completion of this dissertation. I am especially grateful to Dr. Peter P. Feret for his patience and wealth of ideas.

I would also like to thank the other members of my committee: Dr. Klaus Hinkelmann and Dr. Richard Oderwald who were never too busy to help with my statistical problems, Dr. Robert L. McElwee who put his years of experience with seed orchards at my disposal and, and Dr. David L. Bramlett, who got me involved in the IMS project and instructed me in the intricacies of cone analysis.

Other individuals to whom I am indebted are Donald Queijo, who spent many nights on the IMS computer programs and Ron Campbell, who, as manager of Weyerhaeuser's Magnolia seed orchard, supplied much of the data for the project. Other Weyerhaeuser personnel who aided me in the development of the Computerized IMS were Dr. Michael Greenwood, Steven Duke, Mary Winslow and Daryl Stogner.

Lastly, I want to thank my parents, who have always supported my endeavors to obtain an education and my wife, Roberta, whose love and support made my task a light one.

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INTRODUCTION

Genetically-improved seeds produced by southern pine seed orchards hold promise of producing trees exhibiting improved growth, wood quality and pest resistance. However, the capital investment in seed orchard establishment and equipment and the costs of orchard maintenance, protection and cone harvesting are considerable. Thus, efficient seed orchard management is imperative. Orchard management and consequently seed production could greatly benefit from the introduction of a system that would forecast annual cone and seed crops and monitor production efficiency. Such a system, named the Inventory-Monitoring System (IMS), has been recently developed (Bramlett and Godbee, 1982) but has not been implemented in operational seed orchards because economically-realistic sampling procedures have not yet been developed. An accurate yield prediction system must track many variables at multiple levels to produce reliable cone and seed yield estimates, yet the seed orchard manager has only a limited amount of manpower and equipment to invest in such a system. In addition, the record-keeping and mathematical calculations associated with the IMS are formidable enough to make computerization of the system mandatory. With these problems in mind, the current study was undertaken with the following objectives:

1. To establish and make operational a user-oriented computer program for use with the southern pine seed orchard Inventory-Monitoring System (IMS).
2. To execute the Computerized IMS in an operational loblolly pine seed orchard in order to determine its accuracy and reliability in predicting cone and seed yields and its utility in monitoring orchard productivity.
3. To characterize the variation (among-clones, within-clones and among-years) in important seed orchard production and productivity variables, deriving variance estimates and broad-sense heritability estimates for each character and to employ this information to recommend sample sizes and sampling strategies for use with the IMS.
4. To survey within-crown variation in cone and seed characters that may have an impact on the accuracy of the IMS or on how sampling should be conducted.
5. To use statistical analysis of cone analysis-derived variables to recommend modifications in the cone analysis procedure in order to reduce the man-hours invested in cone analysis for the IMS.

LITERATURE REVIEW

Early Efforts at Cone Crop Prediction

There has long been an interest in the prediction of cone and seed production for the southern pines. In the years prior to the establishment of southern pine seed orchards, estimation of seed crop parameters concentrated on two areas: selection of trees to be left as seed trees in reproduction cuttings and prediction of seed crops for seed production areas. Researchers attempted to estimate pine seed crop sizes by visual sampling methods and to ascertain easily-measured parameters useful in predicting the seed-producing potential of individual trees. Wenger (1953) and VanHaverbeke and Barber (1964) and Hoekstra (1960) applied binocular counts of cones to estimate cone crops of standing loblolly pine (*Pinus taeda*) trees. Thorbjornsen (1960), however, found that errors stemming from ground binocular counts of loblolly pine cones on the North Carolina coastal plain made it impossible to develop reliable correlations between fecundity levels and estimates of cone production.

Other researchers further developed techniques for estimation of cone and seed crops by attempting to predict months or even years in advance of seedfall. Varnell (1976a) found previous fecundity of individual slash pines (Pinus elliottii) in north central Florida to be the best indicator for predicting conelet, cone and seed production. Wenger (1957) believed that an existing loblolly pine seed crop could be judged as good, average, or poor during seed collections. Then, with rainfall records for the preceding May to July period, this information could be used to predict the seed crop two years later. Wenger's finding that loblolly pine seed crops influence future productivity was supported by Grano (1973). Grano, however, disputed Wenger's claim that good seed crops in one year necessarily portend inadequate crops two years later, since three plentiful seed years immediately followed a bumper year in his study. Trousdell (1950) found evidence that a prediction of crop failures and bumper crops for a loblolly pine stand could be made six months in advance, based on a sound-plus-missing cone ratio of the existing crop to the previous year's crop. He cautioned that the size of a change in seed production as estimated by this ratio would overestimate sound seed as total production rises. This is because the greater the total seed production, the higher the percentage of sound seed and the smaller the total seed production, the lower the percentage of sound seed.

Rietveld (1978), working with ponderosa pine (*P. ponderosa*), reported that flower counts made in July estimated the potential cone crop for the following year 15 months in advance, while a conelet count estimated the progress of the current year's cone crop 3 months in advance of cone maturity.

Factors Affecting Fruitfulness

In an effort to understand the factors making cone and seed crops more or less predictable, researchers have produced results that relate potential cone and seed production to a number of endogenous and environmental factors, including crown size and density (Grano, 1957), diameter-at breast-height and volume (Thorbjornsen, 1960), rainfall (Grano, 1973, Lamb et al., 1973, Varnell, 1976) and temperature (Maguire, 1956, Lester, 1967). Several authors have reported that the ability to produce large (or small) cone and seed crops appears to be a heritable characteristic (VanHaverbeke and Hunt, 1964, Varnell, 1976a, Brown, 1971, Grano, 1973, Bramlett, 1968, Shoulders, 1967). Varnell et al. (1967) determined broad-sense heritabilities of 0.50 and 0.49 for fruitfulness in slash pine from cone yields in 14- to 17-year old rooted cuttings and from flower production in 4- to 6-year old air-layered propagules, respectively. A narrow-sense heritability of 0.13 was calculated from mature cone yield in 16-year old progeny. The narrow-sense heritability estimate indicated a low additive genetic component for this character.

Within-Tree Variation in Cone and Seed Production

Besides genetic and environmental variation in cone and seed production, a number of studies have attempted to analyze the variation found within individual trees. Sarvas (1962) found that Scotch pine (*P. sylvestris*) cones from the upper third of the crown had a significantly higher number of fertile scales and a significantly lower percentage of empty seed than cones from the lower two-thirds of the crown. He attributed the difference in empty seed percentages to the lower probability of self-pollination in the upper crown. Todhunter and Polk (1981) reported that while seed potential and total seed per cone were not affected by crown location in jack pine (*P. banksiana*) clones, the upper crowns produced cones with significantly higher numbers and percent of sound seed. Lyons (1956) reported similar results for red pine (*P. resinosa*), and further indicated that there was a strong relationship between cone characters and the order of the branch on which the cone was borne. Scale number and seed capacity (the number of ovules normally developed at the time of pollination) were higher in the upper part of the crown, and within each crown level, were highest for cones on first order branches and lowest for cones on third order branches. First-year ovule abortion was lowest among cones on primary branches from the upper third of the crown and highest among cones on third order branches from the lowest third of the crown. Dickman and Kozlowski (1971) also observed that secondary lateral branches consistently produced larger cones than did tertiary branches of red pine, but found that the middle third of the crown produced the largest cones, although not consistently. Lyons (1956) cautioned that the variability among cones within a tree raises the possibility of typifying a tree incorrectly by sampling cones without careful regard for their location in the crown.

Many researchers have concentrated on the problem of defining the factors determining the within-crown distribution of cones. Hard (1964) found a significant correlation between cone production and branch size (length multiplied by base diameter) in red pine. He indicated cones of individual trees were concentrated in the middle third of the crown. Mattson (1979) reported cones per branch decreased from top to bottom of the crown in red pine. In his study, numbers of month-old female strobili per branch increased with branch length and insolation. Branches on the south side of the crown invariably had more cones than other branches. Thorbjornsen (1960), working with loblolly pine, calculated that 28 percent of the cones were located on the tips of the main (primary) branches and that main side (secondary) branches supported 59 percent. Only 15 percent of the total cones per tree were located in the lower half of the crown, while 35 percent were located in the top quarter and 50 percent were in the next lower quarter. Debarr et al. (1975) found 76 to 87 percent of the total cone crop was located in the upper half of the tree crowns of slash pine in their study, and that the east and south quadrants of the crown supported significantly larger crops than the north and west quadrants. They also reported that significantly greater numbers and percentages of cones in the upper crown were infested with coneworms (Dioryctria spp.). Smith and Stanley (1969) observed a predominance of female cones on the east crowns of open-grown slash pines and conjectured that the distribution of cones was affected by morning insolation during the summer cone initiation period. The authors also discovered that branches were longer and the stem radial increment was greatest on the side of the crown where the most flowers occurred. However, the number of branches was higher on the side of the crown with the least cones. Smith and Stanley (1969) also noted the following relationship between annual growth increment and flower distribution: during cone initiation, the northwest stem (the side of fewest cones) formed more latewood, while energy on the other side was presumably diverted into cones.

Smith and Stanley's (1969) conclusions regarding the role of insolation as the prime external factor inducing the reproductive pathway in apex development have been disputed by the results of Kosinski and Giertych's (1979) study of floral initiation in Scotch pine. They discovered that more female strobili were induced in buds on the side of the shoot apex furtherest away from the trunk than in those located closer to the trunk, regardless of crown quadrant. The tendency for female flowers to form as far as possible on the outside of the crown, stated the authors, was evidence that direct insolation could not have been the primary factor determining floral induction, since even on the northern side of the tree, there were more strobili on the distal side of the north-facing shoots. Instead, gravimorphism and differential nutitional supply were suggested as determinants of this pattern of floral induction. Kosinsky and Giertych also observed that on the terminal shoots there was a decline in flowering with altitude, while on the whorl shoots, the reverse was true. The common observation that there are more cones toward the top of the crown was attributed to the fact that lateral shoots are much more numerous than terminals, so that their pattern of vertical differentiation in flowering dominates.

In some cases, relationships have been established between certain branch characteristics and the production of female strobili in pine species. Varnell (1970), working with slash pine, found that the average overall length and average diameter at the base of cone-bearing primary and secondary branches were greater than for non-bearing branches. He cited this as evidence that the vigor of vegetative branches and the initiation of reproductive structures are related. In a parallel study with longleaf pine (P. palustris), Varnell (1976b) reported similar results and went on to state that the relationship between vegetative shoot development was somewhat stronger for secondary than for primary branches. Furthermore, for secondary branches a highly significant association was noted between the absence of conelets in the current year and the nonproduction of female strobili the following year.

Cone and Seed Losses During the Developmental Cycle

Throughout the literature there has been repeated an important message concerning the considerable difference between the potential cone and seed crops (represented by the female flower crop) and the actual cone and seed crops. Trousdell (1950) emphasized that throughout the period from female bud formation to final viable seed, many factors are at work increasing or decreasing the ultimate quantity and quality of seed. Rietveld (1978) and Roeser (1941) also made this point. Wenger (1957) apparently did not stress the importance of these factors strongly enough in describing annual variation of loblolly pine seed crops, prompting criticism from Zobel and Maki (1958). As Grano (1973) explained, abundant flowering is a prerequisite for a plentiful cone crop, but does not necessarily assure it.

The gap between potential and actual seed production is an area which assumes maximum importance in southern pine seed orchards. If the demand for genetically improved seed is to be met economically, it is important that each orchard produce seeds efficiently (Bramlett, 1977). Thus the establishment of southern pine seed orchards has not only created a more intense need for estimating cone and seed crops, but has made it imperative to identify the factors acting to reduce cone and seed yields. For managerial reasons it is also important that the time and extent of the impact of these factors be delineated in order to maximize actual production.

Factors that are known or suspected to influence cone and seed yields once flowers are present in pine species are many. Some affect cone yields, some affect seed yields per cone and some play a major role at both levels.

Several authors have stated that competition exists among first-year conelets and vegetative shoots for nutrients or carbohydrates (Sweet and Bollman, 1970, Brown, 1973, Grano, 1973). The competitive disadvantage of first-year cones has been discussed as a possible reason for abscission (Lester, 1967, Maguire, 1956). Bramlett (1972) believed that growth regulators were involved in cone abscission in shortleaf pine (P. echinata).

The role of inadequate pollination in the loss of conelets is ill-defined. Sarvas (1962) reported that when the female strobilus of Scotch pine is poorly pollinated, it deteriorates and in most cases drops during the first growing season or at the beginning of the second. He attributed 80 percent of conelet abscission in Scotch pine to inadequate pollination. Boyer (1974) found longleaf pine cone production to be influenced by the density of air-borne pollen. Brown's (1971) results showed that the total seed yield per mature cone (an index of pollen supplied to the cone) was correlated with the degree of cone drop in grafted clones of Scotch pine. In a later study Brown (1973) found conelet abscission on some Scotch pine clones was insensitive to changes in pollen concentration. He also reported no relationship between cone loss and seed yield per cone and concluded that any correlations that exist between seed yield per cone and loss of cones do not indicate a causal interrelation, but that similar influences affect both the development of cones and the development of seeds. Varnell (1979) found no correlation between cone production and number of seed per cone in slash pine. Kormanik (1974) reported that the chances of conelet abscission from failure of pollination in the southeastern United States appear small and that seedbug feeding may cause much of the conelet abortion in southern pine seed orchards.

Impact of Insects on Cone and Seed Production

In recent years a significant literature has developed describing the impact of insects on both cone and seed production in the southern pines. Any predictive system for seed orchard yields must certainly take this factor into account. In the southern pines insects acting to reduce seed yields may be divided into three groups: those that damage flowers and conelets, those that damage cones and those that damage seed. Flower- and conelet-damaging insects of southern pines include the pine conelet looper, *Nepytia semiclusaria* (Ebel and Debarr, 1973), slash pine flower thrips, *Gnophothrips fuscus* (Ebel, 1961, Debarr, 1969), Nantucket pine tip moth, *Rhyacionia frustrana* (Yates and Ebel, 1972) and Virginia pine sawfly, *Neodiprion pratti pratti* (Bramlett and Hutchinson, 1965). Although known primarily for their damage to cones, the following insects damage flowers and conelets as well: southern pine coneworm, *Dioryctria amatella*, loblolly pine coneworm, *D. merkeli*, blister coneworm, *D. clarioralis*, south coastal coneworm, *D. ebeli* and cone-feeding midges of the family cecidomyiidae. (Hedlin et al., 1980). Other southern pine cone-damaging insects are the webbing coneworm, *D. disclusa*, and the shortleaf pine coneborer, *Eucosma cocana* (Ebel and Yates, 1974).

Seed-damaging insects of southern pines include slash pine seedworm, *Laspeyresia anaranjada* (Merkel, 1967), longleaf pine seedworm, *L. ingens* (Coyne, 1968), eastern pine seedworm, *L. toreuta* (Ciesla and Bell, 1966, Ebel, 1971), shieldback pine seedbug, *Tetyra bipunctata* (Debarr, 1967, 1970, 1974, Debarr and Ebel, 1973), and leaffooted pine seedbug, Leptoglossus corculus (Debarr, 1967, 1970, 1974, Debarr and Ebel, 1973), which has also been shown to have a role in conelet abortion (Debarr and Ebel, 1974, Debarr and Kormanik, 1975). Ebel et al. (1975) provided a guide to insects that limit seed production in the southern pines, including descriptions of each species of insect and the type of damage associated with it.

Evidence exists showing inherent resistance or susceptibility to infestation by cone- and seed-damaging insects of slash pine, including coneworms, seedworms, thrips and seedbugs (Merkel, 1967, Merkel et al., 1965, Debarr et al., 1972). It is also now known that fungi damage both seeds and flowers of southern pines (Miller and Bramlett, 1975, 1979, Miller, 1976). Miller and Bramlett (1979) demonstrated that at least two plant pathogenic fungi, Diplodia gossypina and Fusarium moniliforme var. subglutinans, are present in certain seedlots of slash pine and that both fungi can damage cones and seeds of that species.

Categories of Seed Losses

Damaged ovules and seeds of southern pines generally fall into one of three classes: (1) first-year aborted ovules, (2) second-year aborted ovules or (3) empty seeds. First-year aborted ovules are potential seeds that abort during the first growing season, appearing in mature cones as "wings without seeds" (Bramlett, 1977). The two major known causes of first-year abortions are pollination failure (Sarvas, 1962, McWilliam, 1959, Brown, 1971, Bramlett, 1974) and feeding by seedbugs, particularly L. corculus (Debarr and Ebel, 1973, 1974). Second-year aborted ovules survive the first year of development, but abort the second year before formation of a mature seed coat. These ovules often appear in mature cones as collapsed and resinous. The major cause of second-year aborted ovules is seedbug feeding on the developing cones (Debarr, 1967, Krugman and Koerber, 1969, Bramlett and Moyer, 1973). Empty seeds result from damage appearing in late summer of the second growing season, following the development of the seedcoat to the point that embryo abortion does not cause it to collapse (Bramlett, 1974). Empty seeds are known to be caused by seedbug feeding (Debarr, 1970, 1974, Debarr and Ebel, 1974, Bramlett and Moyer, 1973) and embryonic lethals (Sarvas, 1962, Bramlett and Popham, 1971, Bramlett and Pepper, 1974).

Other types of developed seed losses not classified as empty seeds are those due to seedworm (Laspeyresia spp.) damage, fungal infection and malformed seeds. The malformed seed category includes seeds with incomplete gametophyte tissue and abnormal seeds with distorted or missing embryos. Incomplete gametophytes are apparently due to retarded development or inadequate nutrition. Malformed seeds usually account for less than 10 percent of the developed seeds from a seed orchard (Bramlett et al., 1977).

Life Table Approach to Seed Orchard Cone Mortality

Since southern pine seed orchards are vulnerable to losses at two levels--the yield of cones and the yield of sound seed per cone, it is necessary to trace production and losses at both levels to evaluate overall production and productivity. At the cone yield level, several authors have recommended or applied a life table approach to follow strobilus losses from the time of flower initiation to cone maturity. Bramlett (1972) traced cone crop development for 6 years in shortleaf pine and found that cone production was seriously reduced by high mortality of both flowers and cones. Ebel and Yates (1974) and Yates and Ebel (1978) were able to attribute conelet and cone losses to the action of insect pests during specific periods of development by monitoring strobilus losses over the developmental cycle for shortleaf pine and loblolly pine.

Goyer and Nachod (1976), studying conelet, cone and seed losses in a Louisiana loblolly pine seed orchard, reported that conelets were damaged by insects during the first few months of development. The authors recommended periodic surveys to pinpoint losses from the time of flowering until cone harvest and suggested that these surveys should be concentrated during those periods when damage is most prevalent, mainly May through July.

Fatzinger et al. (1980) also applied a life table analysis to survey the survival of female strobili on five species of pine in 6 pine seed orchards over 4 years. This method allowed them to determine that the majority of female strobili losses occurred during spring of the first year of strobilus development. The authors concluded that because of differences in the causes and rates of strobilus mortality among pine species, orchard locations and years, strobilus mortality should be monitored in each orchard to determine which management practices should be applied to maximize seed yields.

Debarr and Barber (1975) observed that the life table approach has many advantages for the analysis of pest management problems in seed orchards. The application of life tables allows determination of the time periods in which the most significant conelet or cone mortality occurs, provides a direct accounting of seed losses and as it is a multifactor approach, it supplies data for studying mutual competition for the same host. Furthermore, the authors stated the life table approach permits the seed orchard manager to appraise each mortality factor by the dollar value of the seed loss.

Cone Efficiency

Bramlett (1977) and Godbee et al. (1977) introduced the concept of cone efficiency as a means of evaluating cone development for a given flower crop in the seed orchard. Cone efficiency is the ratio of the number of harvested cones to the number of flowers originally present. As Bramlett (1977) observed, the concept of cone efficiency has certain limitations. For example, although the calculated value of cone efficiency represents the overall survival of the flower crop, it does not identify specific causes of cone mortality. Another problem reported by Bramlett is that the number of flowers originally present strongly influences cone efficiency. As the size of the flower crop increases, a constant cone efficiency represents a greater number of aborted cones. If the number of aborted cones remains constant, the cone efficiency decreases as the flower crop grows smaller and increases as the crop grows larger. A further complication noted by Bramlett (1977) arises when the size of the previous year's cone crop influences the cone efficiency of the present crop, due to its impact on the size of cone insect populations. As Mattson (1971) and Lester (1963) reported from work with red pine, the number of insect-attacked cones tends to increase annually unless limited by cone abundance. Small cone crops drastically reduce cone insect populations, resulting in only limited damage the following year. Large crops can have the opposite effect. Thus cone efficiency seems to be regulated by a negative feedback principle: the larger the current flower crop, the lower the cone efficency of the succeeding year's crop.

Seed Potential and Seed Efficiency

To be of value in prediction of seed orchard seed yields, a cone efficiency monitoring system must be accompanied by additional information, including the capacity of harvested cones to produce seed, and the degree to which the cones meet their potential in terms of actual sound seed produced.

To describe the potential of cones to produce seed, the term "seed production capacity" was introduced by Lyons (1956) and defined as as the number of ovules in a cone that are capable of becoming seeds by virtue of being normally developed at the time of pollination. Bramlett (1974) similarly described "seed potential" as the maximum number of seeds a cone is capable of producing. However, he gave the term the more utilitarian definition of two times the number of fertile cone scales, since each fertile scale is capable of bearing two seeds.

Although seed potential establishes the upper biological limit for seed production for a given cone, the actual yield of filled seeds is the only product of value from the orchard (Bramlett, 1977). Therefore a value for seed potential is only important when it is compared with actual yield (Bramlett, 1974). "Seed production efficiency" (Lyons, 1956) or simply "seed efficiency" (Bramlett, 1974) is defined as the ratio of filled seeds produced by a cone to the cone's seed potential. Thus productivity can be expressed in terms of seed efficiency and it is this seed efficiency value that is reduced by seed or ovule losses occurring during development.

The values of seed potential and seed efficiency for a given cone can be determined by "cone analysis," developed by Bramlett et al. (1977). In this procedure, all loose seeds and aborted ovules are extracted from the cone by normal procedures. Then the cone scales are systematically removed and all the remaining ovules and seeds are collected. Scales are classified as fertile or infertile. Fertile scales can be identified by their wider bases and by the depressions left by developing ovules (Karrfalt and Belcher, 1977). Infertile scales may have wings associated with rudimentary ovules, but they can be distinguished by their narrow bases (Bramlett et al., 1977). The number of scales classed as fertile is used to calculate the seed potential of the cone. Ovules and seeds extracted and dissected from the cone are then classified on the basis of their external appearance, as first-year aborted ovules, second-year aborted ovules or developed seeds. The characteristics by which seeds or ovules of the different classes can be distinguished are well-documented (Bramlett et al., 1977, Bramlett, 1974, 1977).

Seeds classified as fully-developed by their external appearance are further categorized on the basis of radiographic examination as filled, malformed, insect-damaged, fungal-damaged or empty. The number of filled seeds from each cone, as determined by this analysis, is taken as a percentage of the cone's seed potential to calculate its seed efficiency.

Extraction Efficiency and Germination Efficiency

Cone analysis is also used to determine the values of other variables useful in describing seed orchard productivity. One of these characters, "extraction efficiency," measures the ease with which developed seeds are removed from the cone. It is defined as the percentage of total developed seeds in the cone extracted by kiln- or air- drying the cones (Bramlett et al., 1977). The primary factor determining extraction efficiency is the degree of cone opening after heating in the extraction kiln. Poor cone opening may be associated with cones harvested too early, fungal damage, insect damage or case-hardening during storage (Bramlett, 1977). Poor extraction technique may also be responsible for low extraction efficiencies, which should be above 90 percent for mature, well-opened cones (Bramlett et al., 1977).

A fourth value is calculated for each cone when its seeds are germinated. This is the percentage of filled seeds from the cone that germinate normally during a specified test period and is called the "germination efficiency" or "germination percentage" (Bramlett, 1977). This value usually averages above 90 percent (Bramlett et al., 1977).

Seedling Efficiency

The product of three of the four values derived by cone analysis (seed efficiency, extraction efficiency and germination efficiency) gives the proportion of the seed potentially capable of producing seedlings. This value is called the "seedling efficiency" (Karrfalt and Belcher, 1977). Bramlett et al. (1977) believed that a maximum realistic goal for production seed orchards is a seedling efficiency of about 55 percent.

SOSET Procedures

An alternative method of analyzing seed yields and quality of orchard clones is employed in the Seed Orchard Evaluation Testing (SOSET) program. The procedures used in SOSET were introduced in the Seed Orchard Survey (SOS) program (Belcher and Hitt, 1973). The SOSET procedure differs from the cone analysis procedure mainly in that it does not analyze each cone as an individual unit, giving a less complete evaluation of seed production. In SOSET, cone samples (10 to 20 cones per clone) are bulked by clone and only the extractable seeds are analyzed. Seed yields are evaluated relative to the yields of other clones, instead of comparing the yield of an individual cone to its production capacity, and categories of seed losses are incompletely determined (Karrfalt, 1977). Although the SOSET procedure supplies less information than cone analysis, it is also less time-consuming.

Seed Orchard-to-Nursery Efficiency

When the information derived from cone analysis is combined with a system monitoring cone efficiency, an evaluation of the overall ability of a given flower crop to produce seedlings becomes possible. This performance can be evaluated by calculating a value named "seed orchard-to-nursery efficiency" (SO-NE). SO-NE is the product of three efficiency values generated by cone analysis and one generated by a cone survival monitoring system: seed efficiency, extraction efficiency, germination efficiency and cone efficiency respectively (Bramlett, 1977). The SO-NE value obtained by multiplying these four efficiency scores compares the cumulative efficiency to the biological reproductive potential for the orchard (Godbee et al., 1977).

Godbee et al. (1977) employed SO-NE to evaluate the effectiveness of an insecticide spray program in a slash pine seed orchard. In their study, the primary seed losses were attributed to pre-harvest mortality of flowers and conelets (apparently due to seedbug feeding) and to the abortion of ovules before seed maturity. SO-NE was computed to be 17 percent for plots sprayed with insecticide, compared to only 6 percent for the control (unsprayed) plots. Thus the calculation of SO-NE allowed a cost-benefit analysis.

With additional data, the above efficiency values make possible the calculation of a large number of predicted values valuable to the seed orchard manager. For example, the number of cones produced by a particular clone in the seed orchard may be predicted by multiplying the predicted cone efficiency for that clone by the number of ramets of that clone in the orchard and multiplying the resulting product by an average number of flowers per ramet. The number of seedlings produced by a clone in the orchard may be predicted by multiplying the predicted clonal SC-NE by the predicted clonal seed potential, then multiplying the resulting product by the product of the number of ramets of that clone in the orchard and the average number of flowers per ramet.

Inventory-Monitoring Systems

It appears that it is not only desirable but feasible to devise a system that can monitor the seed production efficiency of the clones in a seed orchard, and provide a running inventory of the annual cone and seed crops expected to be harvested at cone maturity. With the proper catalog of data, the expected quantities of cones, seeds and seedlings could be estimated as much as 18 months prior to harvest. In addition, the SO-NE values provided by an inventory-monitoring system would allow the seed orchard manager to identify the critical times and probable causes of seed losses, as was shown by Godbee et al. (1977). This information and the comparison of SO-NE values to management production goals could then be applied as a basis for decisions regarding the application of management practices to reduce seed losses. The economic advantages or disadvantages of additional management inputs could be determined by weighing the increased seed production against the costs of the management practices applied to achieve that gain (Godbee et al., 1977, Bramlett and Godbee, 1982).

Godbee et al. (1977) applied a prototype of an inventory-monitoring system in a 35-acre slash pine seed orchard in order to evaluate the efficacy of an insect control program. They randomly sampled two ramets each of three clones per plot (with four plots per block and four blocks in the orchard) for a total of 96 sample trees. Initial whole tree counts of female strobili were made for each tree. Then by subsampling 10 tagged branches per tree periodically throughout the developmental cycle of the cones, the authors were able to trace cone losses and identify the critical periods and probable causes of these losses.

Only recently have guidelines for the establishment such a system been published by Bramlett and Godbee (1982). In their report, several sampling procedures for the installation of inventory-monitoring systems in southern pine seed orchards were described. In all of these, as in Godbee et al. (1977), total flower counts of selected sample trees are used to estimate the potential cone crop in a seed orchard. Periodic examination of sample branches within each sample tree is used to measure the survival of the initial flower crop and to predict expected cone and seed yields at cone maturity. The different sampling strategies involve the selection of sample trees according to the objectives of the seed orchard manager, available personnel, the equipment needed to conduct the counts and the variability within the orchard. Godbee et al. (1977) suggested different strategies for estimating orchard productivity, estimating orchard and clone productivity, estimating productivity of sample clones and estimating productivity of stratified clones.

The practical application of the guidelines established by Bramlett and Godbee (1982) has yet to be tested in an operational seed orchard. Thus, it is still unknown whether or not the twin goals of accuracy and economic efficiency can be met with any sampling strategy. The operation of an inventory-monitoring system requires a considerable investment in manpower and equipment. A significant amount of time is required just to make the initial total flower count on each sample tree. The seed orchard manager can only be expected to invest the personnel and equipment needed to complete the sampling for limited periods of time. On the other hand, in the case of an individual seed orchard, there may be little feel for the intensity of sampling needed to obtain accurate predictions, due to a lack of knowledge of within-orchard variability, which can be caused by annual climatic effects, clonal effects, age of the ramets (within clones), site effects and cultural practices. On a broader level, the lack of information on variability among orchards may hamper the general application of an inventory-monitoring system. Thus the number of trees sampled and how many times they are sampled will have their upper limits determined by the amount of manpower and equipment the seed orchard manager is willing to invest. The lower sampling limit will be the lowest level at which cone and seed production estimates can be made within acceptable confidence intervals. In order for inventory-monitoring systems to be put into service in operational seed orchards, the levels of sampling necessary to satisfy both limits must be defined. That is, sampling must be economically realistic yet produce results accurate enough to be useful.

Additionally, an inventory-monitoring system must include some procedure for determining the ability of the cones of the sample trees to produce germinable seeds, such as the cone analysis procedure or the procedure employed in SOSET. The cone analysis procedure, as described earlier, involves a large investment in time per cone analyzed. The number of cones per clone needed for analysis in order to accurately characterize the clone is another value that has not been precisely defined. Karrfalt and Belcher (1977) reported that a sample of two cones per clone was not adequate to accurately estimate seed efficiency, because of within-clone variation. They recommended a sample size of 20 to 25 cones per clone in order to provide seed efficiency estimates accurate within 10 to 15 percent. The authors found seed potential to be a far less variable trait than seed efficiency, making accurate clonal estimations of seed potential possible with smaller samples of cones. The procedure employed in SOSET is far less time-consuming than cone analysis but provides no basis for computing a cone's seed yield relative to its production capacity. Therefore, it cannot be of use in calculating seed orchard-to-nursery efficiency. Thus with the establishment of an inventory-monitoring system, there is a need not only to characterize the variation in the values provided by cone analysis, but also, as with the number of trees to be sampled, to use this information to determine economically-realistic levels of cone sampling that produce adequately accurate estimates.

The problem of cone sampling for cone analysis is further complicated by within-crown variability in cone and seed characters which has been found in many studies noted earlier. The problems associated with cone analysis and the data derived from it will certainly have to be dealt with in an operational inventory-monitoring system.

Finally, the huge amounts of data generated by an inventory-monitoring system and the mathematical calculations necessary to interpret this data make the computerization of such a system mandatory. Computer programs designed to handle data from an inventory-monitoring system must be sophisticated enough to calculate and update efficiency values and predict seed yields, yet they must also be designed so that they are accessible to the seed orchard manager and oriented towards his needs.

Clearly, the information provided by an accurate inventory-monitoring system would be valuable to the seed orchard manager. With the guidelines for the establishment of such a system now available (Bramlett and Godbee, 1982), the next logical steps involve a characterization of those variables that will have an impact on the reliability and usefulness of an operational inventory-monitoring system and the adjustment of the system to suit the needs and limitations of the seed orchard manager. Only by actually applying some version of the system to an operational seed orchard can its usefulness and accuracy be tested and the areas requiring modification be identified.

MATERIALS AND METHODS

Computerized IMS Development

The original version of the Inventory Monitoring System (IMS) computer program was obtained from the Weyerhaeuser Company in September, 1979 and placed on disk storage at the Virginia Tech Computing Center. The program was modified to Fortran G in order to be compiled by the Fortran G compiler on Virginia Tech's IBM 370 computer. All subroutines were traced by hand, using sample data to find and correct errors in the code and to write new blocks of code. The program was judged to be executing correctly when it consistently produced output that agreed with calculations performed by hand. Once at this stage, a number of modifications were initiated to improve the efficiency and usefulness of the program, which is currently named IMSYS. These modifications included:

1. Insertion of documentation into IMSYS to generally describe the operations accomplished by each subroutine, and to give line by line definitions of variable names and functions of statements used in the code.

2. Expansion of the number of flower, conelet and cone count observations that could be handled by the program during the cone cycle from 5 to 7.
3. Insertion of the latest predicted cone efficiency updating equations based on strobilus life table curves from Bramlett and Godbee (1982).
4. Rewriting of averaging calculations used by the program, so that clonal cone efficiency calculations would only be based on trees that actually bore flowers.
5. Creation of a new routine named AVGACTS to calculate clonal averages for efficiency values from actual cone analysis data and sample tree flower and harvested cone data. New data file formats were required for this routine.
6. Creation of a new routine named NEWOBV to use the clonal averages computed by AVGACTS to generate the basis for a new user input file, giving the system year-to-year continuity.
7. Creation of a CMS exec file named GOIMS to make the programs run interactively and to aid the user in coordinating his data files with the proper programs.[1]

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[1] With the creation of AVGACTS, NEWOBV and GOIMS, the IMS computer program (IMSYS) was in effect expanded into a computer package, made up of four files, and referred to hereafter as the Computerized IMS.

In addition to the modifications made directly to the program and the creation of new routines, a user's guide was written to accompany the program package (Appendix A). The main purpose of the user's guide was to demonstrate how to organize data collected under the guidelines established by Bramlett and Godbee (1982) and Bramlett et al. (1977) so that the Computerized IMS could be used to generate the desired predictive and monitoring information.

Computerized IMS Testing

In March, 1979, the framework for a cone and seed yield Inventory-Monitoring System was installed in Weyerhaeuser's Magnolia, Arkansas southern loblolly pine seed orchard. This system provided both the flower and cone counts and the cone analysis results that became the data base to be utilized in testing the computer programs of the IMS computer package. The design of the system for the most part followed guidelines established by Bramlett and Godbee (1982) for estimating orchard and clone productivity. Initially, 6 sample trees were randomly chosen from each of the 41 clones in the 3000-ramet orchard, for a total of 246 inventory trees. Six trees per clone was regarded as the upper economic limit for the number of inventory trees, since the seed orchard manager had limited manpower and equipment to allocate for IMS data collection. Since many of the clones in the orchard included ramets grafted in different years, sampling was stratified by age class.

At the time of flowering in March, 1979, total female flower counts were conducted on the sample ramets. Counts included all dead flowers and undeveloped buds. Also at flowering, 6 sample branches were selected from within the cone-bearing portion of the crown of each sample tree, permanently tagged with a metal tag and marked with flagging. The selected sample branches were systematically located in the tree crown so that only one setting of the hydraulic lift truck was required to visit all sample branches. All flowers (including dead flowers and undeveloped buds) on the sample branches of each sample tree were counted initially. Then, the number of live flowers on the sample branches was counted and recorded as the March, 1979 "update." Live flower counts on the sample branches were again updated in June and October, 1979, and in March, June and October, 1980, when the cone crop was harvested. Also in October, 1980, the total live cones produced by each sample ramet were recorded. In March, 1980, the tags on some of the lowest sample branches were moved to branches higher up in the crown in order to ensure that sample branches remained in the cone-bearing portion of the crown.

Then, as in the previous year, total-tree counts of female flowers were conducted, followed by sample branch counts. Updates of surviving flower counts on the sample branches were conducted in March and June, 1980 and in June, 1981. In October, 1981 the total live cones produced by each inventory tree were recorded. It should be noted that during summer, 1980, several clones were rogued from the seed orchard and several inventory ramets of the remaining clones were removed in a thinning operation, decreasing the population of inventory trees from 241 in March, 1980 to 197 in October, 1980. Furthermore, at the time of the 1981 harvest, operational manpower and equipment constraints made it possible only to count the live cones on inventory trees of the 15 clones that were harvested operationally. Consequently, much data was lost for both the 1980 and 1981 cone crops.

Following the 1980 and 1981 harvests, clonal cone yields predicted by the Computerized IMS were compared to operational harvest tallies made by the seed orchard manager, in order to evaluate the accuracy and reliability of the Computerized IMS in predicting cone yields.

The other portion of the data base needed to develop and test the computer programs was cone analysis-derived data for each of the clones being monitored. At the time of cone harvest in 1979, 1980 and 1981, three ramets were randomly chosen from the 6 inventory ramets of each clone for annual sampling. Of the total healthy cones harvested from each of these trees, 3 were randomly sampled for cone analysis. Cone analysis was conducted according to the guidelines established by Bramlett et al. (1977). Cone analysis data along with sample tree flower- and cone-count data was used to create and update estimates for seed potential (SP), seed efficiency (SE), extraction efficiency (EE), germination efficiency (GE) and cone efficiency (CE) to be used by the Computerized IMS.

Seed Orchard Variation

In order to gain an understanding of the magnitude and design of sampling needed for the IMS to produce accurate predictive and monitoring information for the Magnolia loblolly pine seed orchard, characterization of the variation in several productivity variables employed by the IMS was undertaken. These variables were primarily cone analysis-derived variables, including seed potential (SP), seed efficiency (SE), extraction efficiency (EE) and germination efficiency (GE). Two other variables vital to the operation of the IMS, cone efficiency (CE) and flowers-per-tree, were also investigated. The sources of variation analyzed for these characters included among-clone, age-class (within-clone), ramet (within-age-class, within-clone), annual, orchard location and within-crown effects.

Among-Clone and Within-Clone Variation

In October, 1979, fifteen clones were chosen from the seed orchard population to study among-clone and within-clone variation in the variables of interest. Five (in some cases 6) inventory trees were selected from each of these clones and 5 cones were randomly sampled from the total healthy cones produced by each ramet. Data from cone analysis of these cones was used in a nested analysis of variance procedure to check for significance of clonal, age-class (within-clone) and ramet (within-age-class, within-clone) effects on the variables of interest. In addition, the proportion of variation in cone and seed characters due to the different components of variance were calculated and broad-sense heritability estimates were computed for each character. Finally, the data from this sampling procedure were used to suggest sample sizes (number of ramets and number of cones per ramet) that would be necessary to estimate clonal mean values for the variables of interest with specified levels of accuracy and confidence. The method employed to project sample sizes was that outlined by

Snedecor and Cochran (1967) for sampling in two stages, using estimates of variance components and standard error.

In order to further elucidate the variation in SP, SE, EE and GE existing among ramets of an individual clone in the Magnolia seed orchard, three clones were chosen for extensive within-clone sampling during the 1981 cone harvest. From each of these clones, 10 ramets were randomly selected and 5 healthy cones were randomly sampled from each ramet for cone analysis. It should be noted that it was necessary to go outside the population of inventory trees in the orchard to obtain enough sampling units for this part of the study. Analysis of variance was employed to obtain variance estimates for these variables.

Data for analysis of variance of CE and flowers-per-tree were obtained from the inventory tree flower counts conducted in March, 1979 and March, 1980 and the inventory tree live cone counts made during the 1980 and 1981 harvests for use with the Computerized IMS. Procedures for conducting these counts are described under Computerized IMS Testing. Recommended sample sizes (number of ramets) for accurate clonal mean CE estimation were projected using the method outlined by Snedecor and Cochran (1967) for projecting size of sample using standard deviation.

Annual Variation

Annual variation in cone analysis-derived variables (SP, SE, EE, GE) was investigated using the 1979, 1980 and 1981 cone analysis data collected for use in the development of the computer programs. As noted earlier (see Computerized IMS Testing), each year, 3 healthy cones were randomly sampled from each of 3 randomly selected inventory ramets of each clone in the orchard to generate cone analysis data for use with the programs. This same data base was analyzed on a clone by clone basis to characterize annual variation. It should be noted that due to very low cone production and roguing in 1980 and operational harvesting constraints in 1981, cone analysis data for all three years of the study was only available for 18 of the 41 clones originally sampled in 1979.

Cone efficiency (CE) data for the inventory trees was also analyzed to characterize variation between the 1980 and 1981 crops for this variable. Again, low cone production and operational harvesting constraints limited the number of clones for which there was sufficient 1980 and 1981 CE data to 9.

Orchard Location Effects

Since the most extensive cone analysis-derived data set available was that obtained from the 1979 crop, this data set was further utilized to visualize broad orchard location effects on cone analysis-derived variables (SP, SE, EE, GE). Cone efficiency (CE) and flowers-per-tree were also analyzed for orchard location effects. By using row and column location of the sample trees as independent variables in a multiple regression model, predicted values for these variables were generated and plotted over the orchard layout.

Within-Crown Variation

In October, 1979, five trees, each representing a different clone, were selected in order to examine the variation in cone and seed characters within their crowns. These trees were selected mainly on the criterion of having cones well-distributed throughout their crowns. The crown of each tree was partitioned into three elevation levels by measuring the length of the live crown and dividing it into three equal zones: top, middle and bottom. Each height zone was subdivided onto north, south, east and west quadrants (Figure 4). The numbers of healthy, damaged and dead cones counted in each of the 12 resulting crown sectors were recorded. Then, from each crown sector, 3 cones were sampled, where possible, providing a total of 36 cones per tree. As each cone was sampled, data describing the cone's location in the crown and characteristics of the branch on which it was borne were recorded (Table 1). Correlation analysis was used to examine the relationships between crown variables and cone and seed varables derived by cone analysis of the sampled cones (including SP, SE, EE and GE). Variation in cone numbers and in cone analysis-derived variables among quadrants and height zones was investigated using analysis of variance, Duncan's multiple range test, and t-test comparisons of quadrant and height zone least square means.

Cone Analysis Modification

The mass of cone analysis data collected over the three years of the study was further analyzed in an effort to relate easy-to-measure cone characteristics, such as clonal mean cone length and clonal mean cone width, to variables which are more time-consuming to measure. The more time-consuming measurements, such as clonal mean seed potential (SP) and clonal mean seed efficiency (SE), are needed for the Computerized IMS to compute seed yield predictions. Regression equations were developed to delineate the relationships between the two sets of variables.

Statistical Analysis

All statistical analyses were conducted using the SAS computer package (Barr et al., 1979). A number of statistical models were used to analyze variation in cone analysis-derived variables (SP, SE, EE, GE), cone efficiency (CE) and flowers-per-tree.

For analysis of among-clone and within-clone variation in cone analysis-derived variables, the model employed was:

$$X_{ijkl} = \mu + \alpha_i + \beta_{ij} + \gamma_{ijk} + \varepsilon_{ijkl}$$

Where: X_{ijkl}=observation for the variable of interest on the (ijkl)th cone.

μ=overall mean for the variable of interest.

α_i=effect due to the ith clone.

β_{ij}=effect due to the jth age-class within the ith clone.

γ_{ijk}=effect due to the kth ramet within the jth age-class within the ith clone.

ε_{ijkl}=residual effect of the (ijkl)th observation.

All effects in the above model were assumed to be random. The models for among-clone and within-clone variation in CE and flowers-per-tree were the same as above, with the exception that since the observations corresponded to ramets instead of cones, the ramet effect became the residual effect, resulting in the following model:

$$X_{ijk} = \mu + \alpha_i + \beta_{ij} + \varepsilon_{ijk}$$

Where: X_{ijk}=observation for the variable of interest on the (ijk)th ramet.

μ=overall mean for the variable of interest.

α_i=effect due to the ith clone.

β_{ij}=effect due to the jth age-class within the ith clone.

ε_{ijk}=residual effect of the (ijk)th observation.

Again, all effects were assumed to be random. For analysis of annual variation in SP, SE, EE and GE, the model employed was:

$$X_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

Where: X_{ijk}=observation for the variable of interest on the (ijk)th cone.

μ=overall mean for the variable of interest.

α_i=effect due to the ith clone.

β_j=effect due to the jth year.

$(\alpha\beta)_{ij}$=effect due to the interaction between the ith clone and the jth year.

ε_{ijk}=residual effect of the (ijk)th observation.

For analysis of within-crown variation in SP, SE, EE and GE, the model employed was:

$$X_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik}$$
$$+ (\beta\gamma)_{jk} + (\alpha\beta\gamma)_{ijk} + \varepsilon_{ijkl}$$

Where: X_{ijkl}=observation for the variable of interest on the (ijkl)th cone.

μ=overall mean for the variable of interest.

α_i=effect due to the ith clone.

β_j=effect due to the jth crown height zone.

γ_k=effect due to the kth crown quadrant.

$(\alpha\beta)_{ij}$=effect due to the interaction between the ith clone and the jth height zone.

$(\alpha\beta)_{ik}$=effect due to the interaction between the ith clone and the kth quadrant.

$(\beta\gamma)_{jk}$=effect due to the interaction between the jth height zone and the kth quadrant.

$(\alpha\beta\gamma)_{ijk}$=effect due to the interaction among the ith clone, the jth height zone and the kth quadrant.

ε_{ijkl}=residual effect of the (ijkl)th observation.

Quadrant, height zone and quadrant-height zone interaction were assumed to be fixed effects while all other effects were assumed to be random.

RESULTS

Computerized IMS Development

The most recent version of the Computerized IMS available at this time is currently on disk file at Virginia Tech's computing center. Programs of the package can be found in Appendix A. The programs have been executed several times using multiple data sets to ensure that they operate as designed. Sample data files used by the programs and sample output generated by the program are included in Appendix A.

User-orientation of the Computerized IMS has been handled with the following devices: (1) A CMS exec file forms the interactive part of the system to help the user coordinate his data files with the proper program and obtain output from program runs. (2) A user's guide for the Computerized IMS has been written and made available, containing column-by-column instructions for creating data files to be used with the programs and examples of these files (Appendix A).

Computerized IMS Testing

The Computerized IMS was executed using data from the inventory trees selected in Weyerhaeuser's loblolly pine seed orchard at Magnolia, Arkansas. For the 1980 crop, predictive runs were completed using strobilus count data collected in March, June and October, 1979 and March and June, 1980 for a total of one "Initial" run and 6 "Update" runs. Table 2 compares the clonal and overall orchard predictions for bushels of harvested cones to the totals actually harvested operationally in 1980. It should be noted that the predictions listed in Table 2 were based on a generalized cone efficiency estimate of 70 percent, which was used for all clones. The highest correlation obtained between clonal predictions and clonal harvests was for the "Initial" prediction (r=.4333) while the lowest such correlation was for the "Second June" prediction (r=.3220). The closest overall orchard prediction to the actual orchard harvest was the "Second March" prediction, which exceeded the actual harvest by 23.59 bushels or 56 percent.

Table 3 includes the same comparisons as Table 2, but instead of a generalized cone efficiency estimate, the program runs which generated the predictions listed in Table 3 used clonal cone efficiency estimates obtained from the 1981 crop. Though this procedure was somewhat artificial, and some clones had to be dropped since there was no 1981 crop cone efficiency data for them, it at least provided the program with actual cone efficiency estimates. The highest correlation obtained between 1980 crop clonal predictions and clonal harvests using this method was for the "First October" prediction (r=.5040) while the lowest such correlation was for the "First March" predicton (r=.3581). The closest overall orchard prediction to the actual orchard harvest was the "Second March" prediction, which exceeded the actual harvest by 6.84 bushels or 16 percent.

For the 1981 crop, predictive runs were completed using strobilus count data collected in March and June, 1980 and in June, 1981 for a total of one "Initial" run and 3 "Update" runs. Clonal cone efficiency estimates obtained from the 1980 crop were used by the program for these predictive runs. The clonal and overall orchard predictions for bushels of harvested cones computed by each run are compared to the totals actually harvested operationally in Table 4. The highest correlation obtained between clonal predictions and clonal harvests was for the "First June" prediction (r=.9400), while the lowest such correlation ws for the "Second June" prediction (r=.7895). The closest overall orchard prediction to the actual orchard harvest was the "Initial" prediction which underestimated the actual harvest by 10.82 bushels or 4.6 percent.

Tables 5 and 6 contain clonal averages for CE, SE, EE, GE and seed orchard-to-nursery efficiency (SO-NE) generated by the Computerized IMS for the 1980 and 1981 crops, using actual sample tree flower and cone totals and cone analysis data for those crops. The 1980 and 1981 plots of overall SO-NE as a product of CE x SE x EE x GE (Figures 1 and 2) indicate that the largest detractors from the orchard's producing potential in both years were losses reflected in low cone efficiency and low seed efficiency. Overall SO-NE was 22 percent for the 1980 crop and 24 percent for the 1981 crop.

Seed Orchard Variation

Among-Clone and Within-Clone Variation

Cone Analysis-Derived Variables.

Nested analysis of variance of the intensive within-clone cone analysis data collected for 15 clones in 1979 revealed that clonal effects, age-class (within-clone) effects and ramet (within-age-class, within-clone) effects were all highly significant for seed potential (SP), seed efficiency (SE) and germination efficiency (GE). Clonal effects and age-class effects were highly significant for extraction efficiency (EE), while ramet effects were not significant (Table 7).

The very low p-values for clonal effects on these variables warranted the calculation of broad-sense heritability (clonal repeatability=R) estimates as indices of genetic control over these characters. The heritability estimates indicated strong genetic control of germination efficiency (R=.6419) and seed potential (R=.4315), and much weaker, but still notable genetic control of seed efficiency (R=.3353) and extraction efficiency (R=.1965). Table 7 lists the variance components computed for each character.

The high proportion of error variance for each of these 4 variables (SP, SE, EE, GE) indicated a large part of the variation was due not to variation among ramets within a clone, but to variation among cones from a single ramet.

In order to define the scope of sampling required to estimate clonal mean values for SP, SE, EE and GE with useful levels of accuracy and confidence, variance was analyzed on a clone-by-clone basis for each of the 15 intensively-sampled clones from the 1979 crop. The standard error of each clonal mean was calculated and the sample sizes (number of ramets of each clone and number of cones per ramet) necessary to obtain estimates within plus or minus 10 percent of the true clonal means with 90 percent confidence were projected. These projected sample sizes are listed in Table 8. Recommended sample sizes varied from 4 cones to 9 cones per clone for estimation of clonal mean SP and from 6 cones to 28 cones per clone for estimation of clonal mean SE.

Results of analysis of extensive within-clone cone analysis-derived data acquired for 3 clones at the 1981 harvest are summarized in Table 9. In contrast to the 1979 crop sample, clonal effects were not significant for SE and age-class (within-clone) effects were only significant for SE in this sample. However, it should be noted that only 3 clones were used for this part of the study. In the case of each clone, examination of the variance components for SP, SE, EE and GE revealed that one-half or more of the variation in these characters was due to within-tree effects. However, for SE, ramet (within-clone) effects accounted for almost 40 percent of the variation. Thus, of the four characters studied here (SP, SE, EE, GE), the one shown to be under the least genetic control (SE) seems to be the character most likely to be affected by the environmental conditions (i.e. microsite, slope, aspect, etc.) associated with the different ramets of a clone at different locations in the orchard.

Sample sizes necessary to obtain estimates within plus or minus 10 percent of the true clonal mean values for SP, SE, EE, and GE with 90 percent confidence were computed from the extensive within-clone data for the 3 clones sampled in 1981 (Table 10). The recommended sample sizes differed very little from the sample size reccommendations obtained from the less extensive 1979 cone analysis data, with the exception of the sample sizes needed for clonal mean SE estimation. For example, recommended sample sizes for clonal mean SP remained at 5 or 6 cones per clone. In the case of clonal mean SE estimation, the sample sizes necessary to obtain the desired levels of accuracy and confidence were found to be much larger (50 or 70 cones per clone) due to the very high among-ramet variability revealed in the 1981 seed efficiency data.

Cone Efficiency.

For the 20 clones sampled during the 1980 cone crop with sufficient data, cone efficiency (CE) was found to vary significantly among clones but not among age-classes within clones (Table 11). A broad-sense heritability (clonal repeatability=R) estimate for CE derived from 1980 crop data indicated weak genetic control of this character (R=.1702). A parallel analysis of CE was conducted for 14 of the clones harvested in 1981. For this sample, clone was found to have a highly significant effect on CE, while age-class effects were again not significant (Table 11). A broad-sense heritability estimate for cone efficiency calculated from the 1981 data indicated a much higher degree of genetic control over this character (R=.3204) than did the 1980 crop heritability estimate.

Clonal standard deviations for cone efficiency were used to project the number of ramets from each clone that would have to be sampled in order to obtain estimates for clonal mean cone efficiency accurate within plus or minus 10 percent with 90 percent confidence. Wide variability in cone efficiency among ramets of some clones was contrasted with low variability among ramets of other clones sampled, resulting in a range of sample size recommendations. Under the 6-ramets-per-clone economic limit for the IMS in the Magnolia orchard, very few of the clones were adequately sampled to obtain reliable estimates for 1980 crop clonal mean cone efficiencies. However, for the 1981 crop, which had much lower within-clone variation in cone efficiency for many clones, several of the clones could be adequately represented by 6 sample trees (Table 12).

Flowers-per-Tree.

A final variable of great importance to the operation of the IMS is the clonal average number of flowers per sample tree, which is used to represent all ramets of a clone in the orchard. To verify that flowers-per-tree was a variable that had a significant relationship with clone, analysis of variance was conducted on the 1980 and 1981 data for this variable. For both cone crops, flowers-per-tree was found to be significantly affected by clone and by age-class.

Broad-sense heritability estimates computed for this variable for the 1980 and 1981 cone crops indicated a degree of genetic control in both years comparable to that found for cone efficiency (R=.1105 and R=.2026 for 1980 and 1981 respectively). Table 13 displays variance components computed for this character for the 1980 and 1981 crops. The very high coefficients of variation for this variable found for the majority of the clones indicated that very large sample sizes would be needed to obtain reliable estimates for clonal mean flowers-per-tree (Table 14).

Annual Variation

Annual variation was investigated for cone analysis-derived variables (SP, SE, EE, GE) and cone efficiency (CE), since the IMS employs running clonal averages for all of these variables over successive cone crops in computing its predictions. Variation among years was tested both by analysis of variance and by converting the clonal efficiency estimates to ranks in order to determine the stability of clonal ranks among years.

Cone Analysis-Derived Variables.

Analysis of annual variation of cone analysis-derived variables using 18 clones for which there was data for all three cone crops (1979, 1980 and 1981) revealed that clone, cone year and clone-cone year interaction all had highly significant effects on SP, SE, EE and GE (Table 15). By ranking, it was found that clones with high SP averages in 1979 maintained relatively high SP averages in successive years while clones with low 1979 SP averages maintained relatively low averages for this variable over all three years of the study. The relative rankings did not hold as well over three years for SE or GE, and held very poorly for EE (Table 16). Pairwise correlations among the three cone crops for SP, SE, EE and GE clonal ranks are presented in Table 17. Clonal ranks for SP displayed the highest correlation between years, averaging around .80.

Annual variation in clonal SP, SE, EE and GE was analyzed over 3 years on a clone-by-clone basis for the same 18 clones. Table 18 summarizes the numbers of clones found to have significant annual variation for each character. As could be expected from the broad-sense heritability estimates noted earlier, SE displayed significant annual variation, while GE showed little significant annual variation.

Cone Efficiency.

Of the 9 clones for which there was sufficient cone efficiency (CE) data to compare the 1980 and 1981 crops, 8 had higher mean CE values for the 1981 crop than for the

1980 crop and all 9 clones had lower standard deviations for 1981 crop CE than for 1980 crop CE. However, only 2 of the clonal CE averages were significantly different between the two crops (Table 19). Paired t-tests conducted on the clonal mean CE values for the two cone crops indicated that the 1981 crop had significantly higher clonal mean CE values than the 1980 crop (Table 19). Ranking of these 9 clones by their CE averages for 1980 and 1981 indicated approximately the same amount of year-to-year stability in rank as was found for seed efficiency (SE). The correlation between the 1980 and 1981 cone crop CE ranks was .4833 (Table 20).

Orchard Location Effects

In order to further demonstrate the pattern and degree of variation within the seed orchard for the variables of interest, an attempt to visualize broad variation in these characters with orchard location was made using contour plotting techniques. Assuming that (1) each ramet of each clone was located randomly within the orchard and (2) the sample ramets were chosen from each clone in a random manner, then a plot of SP, SE, EE, GE, CE or flowers-per-tree over the orchard layout should reflect broad orchard location effects on that variable independent of clonal effects. For each of these variables, a regression model relating row and column location of each sample tree in the orchard to the variable was used to create and plot predicted values for a full row and column matrix simulating the Magnolia seed orchard.

Significant linear patterns of variation could not be established for SP, SE, GE, CE, or flowers-per-tree for any of the sampled cone crops. Significant linear patterns of variation with row, column or row-column "interaction" were found in the 1979 crop for extraction efficiency (EE). (Table 21). The very low R-square value for this regression model indicated that very little of the variation in EE was accounted for by the model. This was to be expected since it has already been shown that clonal and within-tree effects accounted for large portions of the variance in EE However, broad environmental gradients having an impact on EE could be visualized by plotting the values predicted by the regression. In the contour plot displayed in Figure 3, predicted EE appears to decrease towards the northeast and southwest corners of the orchard and increase towards the southeast and northwest corners.

Within-Crown Variation

Cone Distribution.

Analysis of variance of cone totals from crown quadrants and crown height zones of the 5 sample trees chosen indicated that height zones and quadrants differed significantly in numbers of mature cones present at harvest in October, 1979. Clone-height zone interaction effects on this variable were also highly significant (Table 22). Duncan's multiple range test showed that the middle one-third of the crown had significantly more cones than the bottom one-third, which had significantly more cones than the top one-third (Figure 5). Clone-height zone interaction did not cause this general relationship to vary among the clones sampled. Duncan's multiple range test also indicated that the west quadrant had significantly fewer cones than the north or south quadrants (Figure 5).

Cone Analysis-Derived Variables.

Seed potential (SP) was not significantly affected by crown quadrant, crown height zone or any interaction of these effects with clone or with each other (Table 23). Seed efficiency (SE) was found to be significantly affected by quadrant and by height zone. However, clone-height zone interaction was also significant, making it difficult to draw conclusions about the effect of height zone on this variable (Table 23). Extraction efficiency (EE) and germination efficiency (GE) were also significantly affected by quadrant and height zone, but clone-quadrant and clone-height zone interactions again made conclusions concerning the effects of height zone and quadrant unreliable. Analysis of variance also indicated that percent empty seeds per cone was significantly affected by quadrant, height zone, clone-quadrant interaction and clone-height zone interaction. Percent first-year aborted ovules per cone and percent second-year aborted ovules per cone were affected by clone-height zone interaction and quadrant-height zone interaction respectively (Table 23).

The results of t-tests comparing least square means revealed that SE values for cones from the north quadrant were significantly lower than those for cones from any other quadrant (Figure 6). Empty seed percentage was found to be significantly higher for cones from the north quadrant than for cones from any other quadrant (Figure 6). Clone-quadrant interaction did not cause this general relationship to vary among clones.

Correlation analysis revealed no significant correlations between the crown "environment" variables listed in Table 1 and SE or GE. However, EE was negatively correlated with branch diameters one-half inch above and one-half inch below the point of cone attachment (r=-.4731 and r=-.4580 respectively), and positively correlated (r=.3460) with branch order (Table 24). The opposite relationship was indicated between the same crown variables and SP, which was positively correlated with branch diameters one-half inch above and one-half inch below the point of cone attachment (r=.2924 and r=.3368 respectively) and negatively correlated (r=-.2657) with branch order (Table 24).

Cone Analysis Modification

The sizable amounts of genetic control over some of the variables of interest (notably, seed potential) and the fact the sampled clones maintained their relative rankings for some of these variables from year to year (again, especially true for seed potential) encouraged the development of regression equations to be used in estimating clonal means for these variables, currently derived through the time-consuming process of cone analysis. Clonal mean values for seed potential (SP), seed efficiency (SE), extraction efficiency (EE) and germination efficiency (GE) are used by the Computerized IMS in predicting seed yields, making short-cuts in their estimation highly desirable for the IMS user. Some independent variables of possible value for such regression equations and requiring minimal man hours to obtain include clonal mean values for SP, SE, EE and GE from previous cone crops. Correlation analysis of cone analysis-derived variables (Table 25) also suggested that clonal mean values for cone length, cone width, extracted seed per cone and extracted filled seed per cone from the current cone crop would be useful as independent variables.

The independent variables which accounted for the most variation in the 1980 crop's clonal mean SP (R-squared=.80) were the 1979 crop's clonal mean SP and the 1980 crop's clonal mean cone length (Table 26). Addition of the 1980 crop's clonal mean cone length and clonal mean extracted seed number improved the model only slightly.

The independent variables which accounted for the most variation in the 1980 crop's clonal mean SE (R-squared=.88) were the 1979 crop's clonal mean SE, 1980 crop's clonal mean cone width and 1980 crop's clonal mean number of extracted filled seed per cone (Table 26).

Compared to the models for clonal mean SP and clonal mean SE, only relatively poor models could be developed for clonal mean EE and GE (Table 26). The low R-squared values for these models (.62 and .42 for clonal mean EE and clonal mean GE respectively) were probably due to the lack of annual stability for clonal mean EE and low variation among clonal mean GE values among clones.

DISCUSSION

The results of the current study have implications not only for the use of the IMS, but for other aspects of southern pine seed orchard operation. The types and amounts of variation found in the seed orchard used for this study may affect how the IMS is implemented in operational seed orchards and call into question many of the assumptions on which the IMS is based.

Computerized IMS Testing

The performance of the Computerized IMS in predicting clonal production of cones indicates that the system may require a great deal of fine tuning before the predictions become reliable at a 90 percent level of confidence. The poor performance of the system in predicting the 1980 crop clonal harvests (Tables 2 and 3) can be related to a number of factors. The chief of these was the fact that since the 1980 crop was the first cone crop to be predicted by the system, there was no real data base from previous cone crops on which the system could base its estimates (e.g. for cone efficiency). Since the IMS is dependent on the accumulation of data from previous crops to make its predictions, inaccurate predictions could be expected. The improvement of the 1980 crop predictions with the replacement of generalized cone efficiency estimates by actual 1981 crop cone efficiency data shows that at least some of the inaccuracy was due to the generalized estimates. The performance of the system in predicting clonal cone production for the 1981 crop (Table 4) was much more encouraging, which was to be expected, since 1981 crop predictions could be based on actual cone efficiency data obtained from the 1980 crop. However, it is disappointing to note that the best prediction for total cones from the orchard was that computed on the "Initial" run. Theoretically, prediction accuracy should have increased as the surviving cone counts were updated, so that the "Second June" run should have produced the most accurate predictions.

A number of "fine tuning" procedures could aid the accuracy of the IMS for the Magnolia orchard once the system has been in operation for a number of years. The reasons to expect improvement in the accuracy of prediction with time are many: (1) After a number of years, a large data base can be built up for each clone in the orchard. The more data available to the IMS concerning the past productivity of a clone, the more accurately the system will be able to predict its future performance. If cycles of productivity for each clone are established over the years, these cycles could easily be built into the system. (2) For the first two cone crops predicted by the IMS, a generalized seed orchard cone mortality curve was used by the program as a basis for its predictive equations. Once a few cone crops are completely monitored for an orchard, a mortality curve could be plotted specifically for that orchard, replacing the generalized curve and resulting in more accurate predictive equations. (3) In order for the IMS to produce reliable predictions, counting of the strobili on the sample trees must be completed accurately. As those employed to count strobili flowers, conelets and cones become more experienced, their accuracy should improve, increasing the accuracy of the predictions. (4) As orchard management practices improve, the genetic component should account for more of the observed variation in seed orchards, making clonal estimates for variables used by the IMS more reliable. Examples of management practices which may decrease non-clonal variation are improved insect control and supplemental mass pollination.

The 1980 and 1981 plots of seed orchard-to-nursery efficiency (SO-NE) (Figures 1 and 2) resembled the idealized plot presented by Bramlett and Godbee (1982), except that both SO-NE values for the Magnolia orchard were approximately 20 percent lower than Bramlett and Godbee's (1982) idealized plot. The lower SO-NE values for the Magnolia orchard were mainly due to relatively low cone efficiency (CE) and seed efficiency (SE) values, resulting in much sharper drops from the orchard potential than those represented in the idealized plot. Bramlett and Godbee's (1982) values represent a realistic goal for orchard managers, but were not achieved in the Magnolia orchard. Seed yields in the Magnolia orchard could be increased by 100 percent if a SO-NE value of 45 percent could be achieved.

Seed Orchard Variation

Among-Clone and Within-Clone Variation

The finding that many of the variables used by the Computerized IMS are under substantial genetic control has favorable implications for the use of the system, since the program package was established to monitor orchards on a clonal basis. Also, the confirmation of the theory that age of the ramet (within-clone) has a significant impact on such variables as seed potential (SP), seed efficiency (SE), extraction efficiency (EE), germination efficiency (GE) and flowers-per-tree justifies the precautions taken in the predictive program to take age-class into account. The program is designed to compute clonal predictions for each age-class within a clone, then compute the clonal prediction as a weighted average of the age-class predictions, with the weighting based in the number of ramets of the clone in each age-class.

The fact that clones were found to have differing amounts of within-clone variation for such variables as seed efficiency (SE) and cone efficiency (CE), as indicated in Tables 8 and 12, leads to two general conclusions: (1) Even for a given orchard, it is probably impossible to make a blanket recommendation concerning the number of trees per clone to be sampled for 90 percent reliable clonal cone efficiency estimates or for the number of cones per clone to be sampled for 90 per cent reliable clonal cone analysis-derived values. Some clones appeared to contain so much variability that sample sizes necessary for reliable estimates of clonal means became economically unrealistic. Other clones could be adequately represented by a relatively low number of sampling units. Sample size recommendations appeared to be especially troublesome for estimating clonal SE, for which ramet and within-ramet components of variance were both substantial, compared to clonal and age-class components (Tables 7 and 9). It should be noted that even though the within-ramet variance component is much greater than the among-ramet component for most cone analysis-derived variables (SP, EE, GE) it is more cost effective to sample a single cone from each of a number of ramets than to sample many cones from each of a few ramets. This is because it is much less costly to visit a tree in order to sample a single cone than to complete cone analysis on a cone. In other words, subsampling would not be cost-effective. (2) The directions given by Bramlett and Godbee (1982) stating that the number of sample trees selected for use with the IMS should be in proportion to the number of ramets per clone in the orchard may not be sound. A better option might be to base clonal sample sizes on the results of a preliminary survey of within-clone variation for each clone in the orchard. Clones displaying higher variability would be sampled more intensively than clones with lower variability.

The reliability of clonal estimates for CE also suffered from a problem already discussed by Bramlett (1977). He noted that the number of flowers originally present on a tree strongly influenced its CE value. In a young orchard, such as the one used in the current study, some sample trees had only a few flowers to begin with. If these flowers were lost, which could occur by chance with such small numbers, the CE for that tree would be zero percent. Another tree of the same clone with only a few flowers may retain them to maturity, resulting in a CE of 100 percent. Finally, a sample tree which initiates no flowers for a given crop contributes no data for CE at all, since there are no flowers from which to obtain survival data. Such occurrences make clonal cone efficiency estimates and consequently clonal cone and seed production estimates for young orchards highly questionable, especially in years of low flower production. This could have been one of the reasons that the predictive accuracy of the Computerized IMS was so much better for the 1981 crop, which was a large one, than for the 1980 crop, which was relatively small. In older orchards with larger numbers of flowers initiated per tree, clonal cone efficiency estimates should become more reliable.

Probably the worst implications of the study concerning the IMS as currently designed are for the use by the system of clonal average flowers-per-tree values as a basis for predicting clonal cone harvests. Even though the predictive program takes into account the effects of age-class on this variable, the very large variation among ramets within clones for both years sampled (Table 14) may make it impossible to obtain reliable clonal estimates for this variable. However, it should be noted that the coefficients of variation listed in Table 14 were computed for clones containing relatively young trees with their flower-producing capacity limited by their relatively small crowns. As in the case of cone efficiency, as the orchard ages and the trees produce larger cone crops, the variation in flowers-per-tree within clones may become less of a problem.

One possible alternative to the present sample tree system would be to conduct total tree flower counts on a large number of trees per clone (for the purpose of estimating average number of flowers-per-tree) while conducting sample branch flower counts on a smaller number of trees per clone (for the purpose of updating cone efficiency estimates).

The adverse impact of low sample tree flower and cone totals on the reliability of clonal CE and average-flowers-per-tree estimates suggests a second option of sampling only those clones with large flower counts for the purpose of estimating total orchard producton. By dropping the low-producing clones from the system, sampling could be greatly reduced without much loss of accuracy for estimation of overall orchard production.

Annual Variation

Annual variation in cone analysis-derived variables indicated that clonal estimates for most of these variables should be estimated by sampling cones for cone analysis from every crop. This is especially true for seed efficiency (SE) and extraction efficiency (EE), for which high annual variation was indicated, both by analysis of variance (Table 18) and clonal rank variation among years (Tables 16 and 17). Such variation is to be expected for EE, since in a given year, it is very dependent on how the cones are handled by seed orchard personnel. Cones that are harvested too early or dried improperly are subject to case-hardening and may not open properly, resulting in lowered EE values. A given crop's clonal estimates for seed potential (SP), which displayed the lowest annual variability, could apparently be used for a number of successive cone crops without a serious loss in accuracy.

It is difficult to make conclusions concerning annual variation in clonal cone efficiency (CE) estimates due to the problem noted earlier with low flower numbers per sample tree in young orchards. However, the apparent low annual stability in clonal CE ranks has at least one serious consequence: it advises against the option of estimating productivity of stratified clones described by Bramlett and

Godbee (1982). In this procedure, clones are classified on the basis of productivity. Then a proportion of the clones is randomly selected to represent each production class. However, the low annual stability for clonal CE ranks between the two successive cone crops studied here indicates that a clone in the top productivity class for one crop may be in the bottom class for the following crop. Thus, based on observation of these two cone crops, estimating productivity of a stratum based on such a clone could be very unreliable.

Orchard Location Effects

Other sources of variation within the orchard not fully investigated in this study could have a large impact on the accuracy of the IMS as well as other aspects of orchard operation. The effect of orchard location on such variables as cone efficiency (CE) and seed efficiency (SE) was only investigated in a broad linear fashion. The finding that only extraction efficiency (EE) showed a linear relationship with row and column location in the orchard (Table 22 and Figure 3) does not rule out the possibility of microsite effects on this and other variables within the orchard. For example, nonlinear relationships due to the rolling nature of the orchard topography could be present. The indication of a trend toward lower EE values in some areas of the orchard used in this study suggests that caution should be used in using the results of cone flotation tests as indicators of readiness for harvest for whole clones. The failure to recognize that orchard location can have an impact on cone ripeness could lead to the premature harvest of some cones, resulting in case-hardened cones that will not open properly and causing low EE values.

Within-Crown Variation

The substantial amounts of within-ramet variance for cone analysis-derived variables (SP, SE, EE, GE) made the investigation of within-crown variation an important objective, since this type of variation could have consequences both for the operation of the IMS and for cone harvesting practices.

The concentration of cones in the middle one-third of the crown for the 5 trees sampled (Figure 5) supported results obtained by Hard (1964) with red pine and Thorbjornsen (1960) with loblolly pine. Low cone totals for the west quadrant (Figure 5) did not contradict reports by Debarr et al. (1975) or Smith and Stanley (1969). Since Todhunter and Polk (1981) only divided the crowns of their jack pine sample trees into top and bottom height zones and north and south halves, it was not posible to compare their results with those reported here.

Among cone analysis-derived variables, results of the current study agreed well with some previous studies and contradicted others. The absence of crown location effects on seed potential (SP) reported here (Table 23) was also reported by Todhunter and Polk (1981), although Sarvas (1962) and Lyons (1956) reported higher numbers of fertile scales for cones from the upper crowns of scotch pine and red pine respectively. Results concerning seed efficiency (SE) were not as well-defined in this study as in other studies. Due to clone-height zone interaction for SE and empty seed percentage (Table 23), conclusions could not be drawn regarding the effect of height zone on these variables. Other studies (Sarvas, 1962, Lyons, 1956, Todhunter and Polk, 1981) reported highest SE values and lowest empty seed percentages for cones from the upper crown. The relatively small size of the trees used in this study may have prevented well-defined crown height zone effects from being expressed for these variables. It should be noted here that because only one tree per clone was employed in this study, clonal effects could not be separated from effects associated with individual ramets (such as orchard location, site, slope and aspect).

Therefore effects attributed here to clone-height zone interaction or clone-quadrant interaction may actually be ramet-height zone or ramet-quadrant interaction effects. Site-crown interacton effects were reported to be significant for SE by Todhunter and Polk (1981).

The finding that cones from the north quadrant had lower SE values than cones from other quadrants was attributed to their higher percentages of empty seeds (Figure 6), since other major categories of lost seeds, including percent first-year aborted ovules and percent second-year aborted ovules did not differ significantly among quadrants. The higher empty seed percentages noted for cones from the north quadrant could have been due to any of a number of factors: (1) Since empty seeds are known to be a product of embryonic lethal alleles, which could become homozygous with self-pollination, it is possible that prevailing winds from the south during pollination resulted in a higher frequency of selfing in the north quadrant, causing higher empty seed percentages there. (2) It is also possible, as suggested by Todhunter and Polk (1981), that within-crown microclimatic effects could have played a role in empty seed production, possibly by having an impact on within-crown insect population distribution, since seedbug feeding is known to be a major cause of empty seeds.

The positive correlation of seed potential (SP) with branch diameter and the negative correlation of this variable with increasing branch order (Table 24) indicated that cones borne on larger, older branches tend to have more fertile scales. This finding agreed well with results obtained by Lyons (1956) with red pine. The negative correlation of extraction efficiency (EE) with increasing branch diameter and the positive correlation of this variable with increasing branch order indicated that seeds were easier to extract from cones borne on younger, more slender branches than those borne on older, thicker branches. Since the primary determinant of EE for a given cone is the degree of cone opening, it appeared that cones from thicker branches did not open as well upon drying as cone from more slender branches, and that this influence continued even after the cones were removed from the tree. The extreme case of this relationship was that of cones borne on the main stem (trunk) of these trees, which all opened very poorly. It is possible that in orchards where cones are picked by hand operationally, harvesters should not even bother to pick the few cones borne on the trunk, since few seed will be extracted from them by conventional extractors.

The within-crown variation described here certainly supports Lyons' (1956) contention that cone sampling without regard for crown location could result in erroneous conclusions concerning a tree's productivity. However, the random sampling of single cones from multiple ramets of a clone recommended earlier for clonal SP, SE, EE and GE estimates for use with the IMS should be an adequate precaution against such errors.

Cone Analysis Modification

Regression equations developed to reduce the man-hours spent on cone analysis necessary to operate the IMS appear to be more promising for some cone analysis-derived variables than for others. Seed potential (SP), which is under relatively strong genetic control and for which clonal estimates displayed the highest annual stability, probably offers the best opportunity for estimation using a regression equation (Table 26). Extraction efficiency (EE), under minimal genetic control, and for which clonal estimates displayed very low annual stability, depends heavily on handling of the cones by orchard personnel in a given year. Thus, clonal EE values may never be predictable (Table 26).

Improved orchard management (e.g. insect control) may increase the annual stability for some of these variables, especially clonal estimates for seed efficiency (SE), resulting in improved prediction capability. It is also possible that for a given orchard (or even a given clone) cycles of high and low productivity may be established after observing a number of crops, allowing development of regression equations based on these cycles. In any case, some source of clonal SP, SE, EE and GE estimates must be available for the IMS to function. Only by using productivity variables such as SE, which compare yields of cones to their production capacities, can the IMS make its seed yield predictions.

SUMMARY AND CONCLUSIONS

The Inventory-Monitoring System (IMS) as designed by Bramlett and Godbee (1982) and the computerized version of the IMS tested in the current study offer the seed orchard manager a systematic method of monitoring his orchard's productivity and predicting cone and seed yields up to 18 months prior to harvest. The pilot test completed here indicated that the IMS has the potential to accurately predict crops if supplied with the proper data. However, those planning to install such a system must be aware of its limitations and the factors which may hinder the usefulness of the system in an operational orchard

Not the least of the problems in using the IMS is the cost of obtaining the necessary data. Large amounts of variation were revealed in the seed orchard used in this study for production and productivity variables such as cone efficiency, seed efficiency and flowers-per-tree. Since the sources of this variation included annual, clonal, age-class, ramet and within-crown effects, all of these factors must be taken into account when planning the sampling necessary to operate the IMS. In some cases, the sampling required to produce reliable estimates with 90 percent confidence is economically unrealistic.

However, there is reason to believe that for a given orchard, the twin goals of prediction accuracy and economy can be met given enough time. With the accumulation of data from a number of cone crops and the decrease in non-clonal sources of variation expected from improved management, required sample sizes should decrease to manageable levels. On the other hand, certain sampling procedures for the IMS will probably remain mandatory for as long as the orchard is being monitored. For example, whole-tree strobilus counts at the time of flowering will have to be conducted for each crop, even though this process is one of the most time-consuming tasks associated with the IMS. Otherwise, there is no basis for the clonal average flowers-per-tree estimates used by the predictive program. Although flowers-per-tree varies widely within clones, it is still the only realistic value to use in estimating total potential cones. Hopefully, within-clone variation both for this variable and cone efficiency will be lower in older orchards. Another sampling procedure for which realistic alternatives are unlikely is that of sampling ramets from all clones in the orchard for which harvesting is planned. The variation noted in the present study both among clones within a given crop and within-clones among crops makes such a scheme the most sound, even though it is more expensive than other schemes suggested by Bramlett and Godbee (1982). The option does exist, however, to drop low-producing clones from the system for the purpose of overall orchard production estimation, since they tend to add little to total orchard production while exacerbating sampling problems due to their high within-clone variation in cone efficiency and flowers-per-ramet.

It is relevant to point out that with the adoption of more intensive plantation management in the South, which is likely to include such techniques as family-block plantings for specific sites, clone-by-clone monitoring of seed orchard seed yields will become increasingly desirable. Thus, an accurate Inventory-Monitoring System could be a valuable part of this new intensive management.

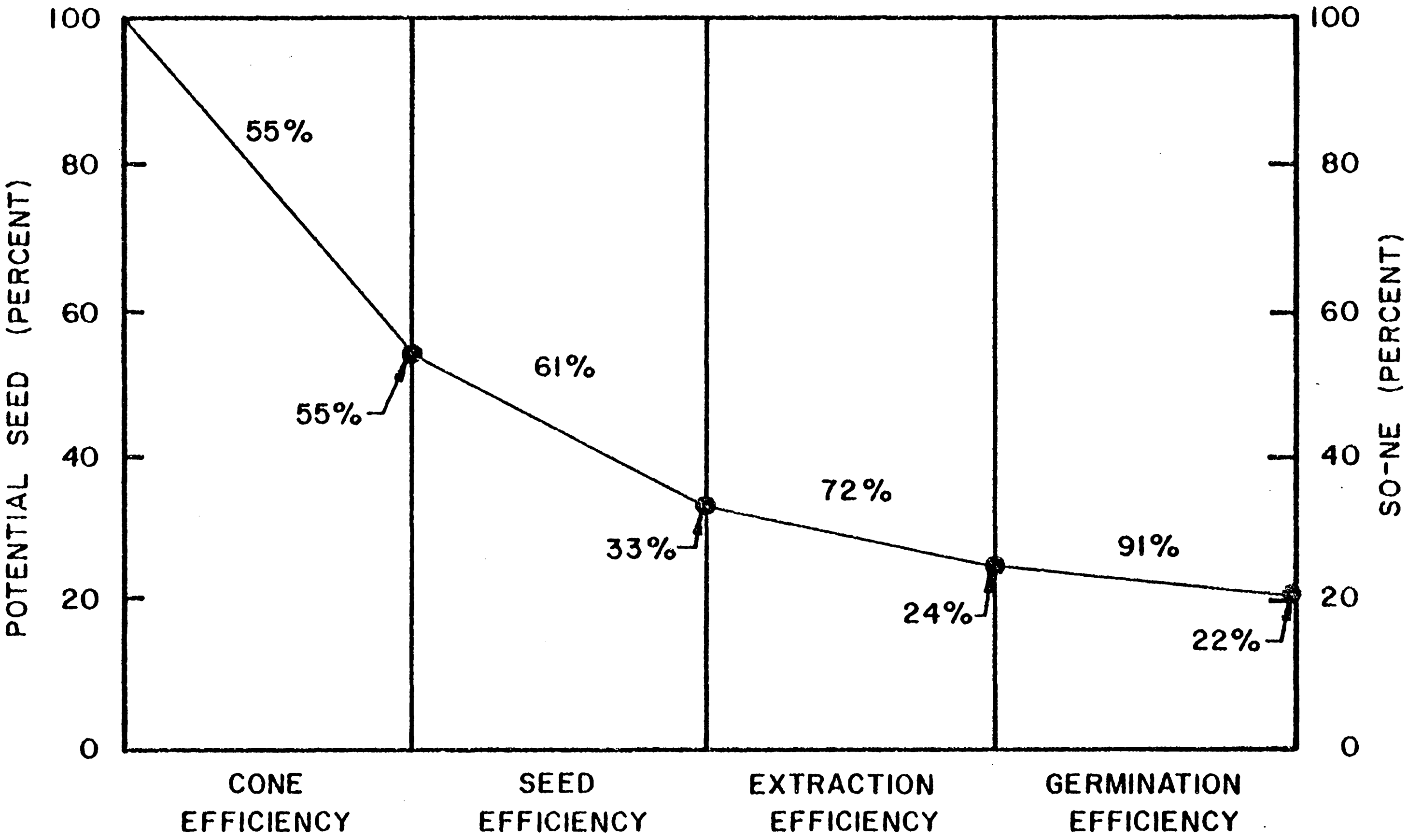

Figure 1. Overall seed orchard-to-nursery efficiency (SO-NE) for Magnolia southern loblolly orchard, 1980 crop.

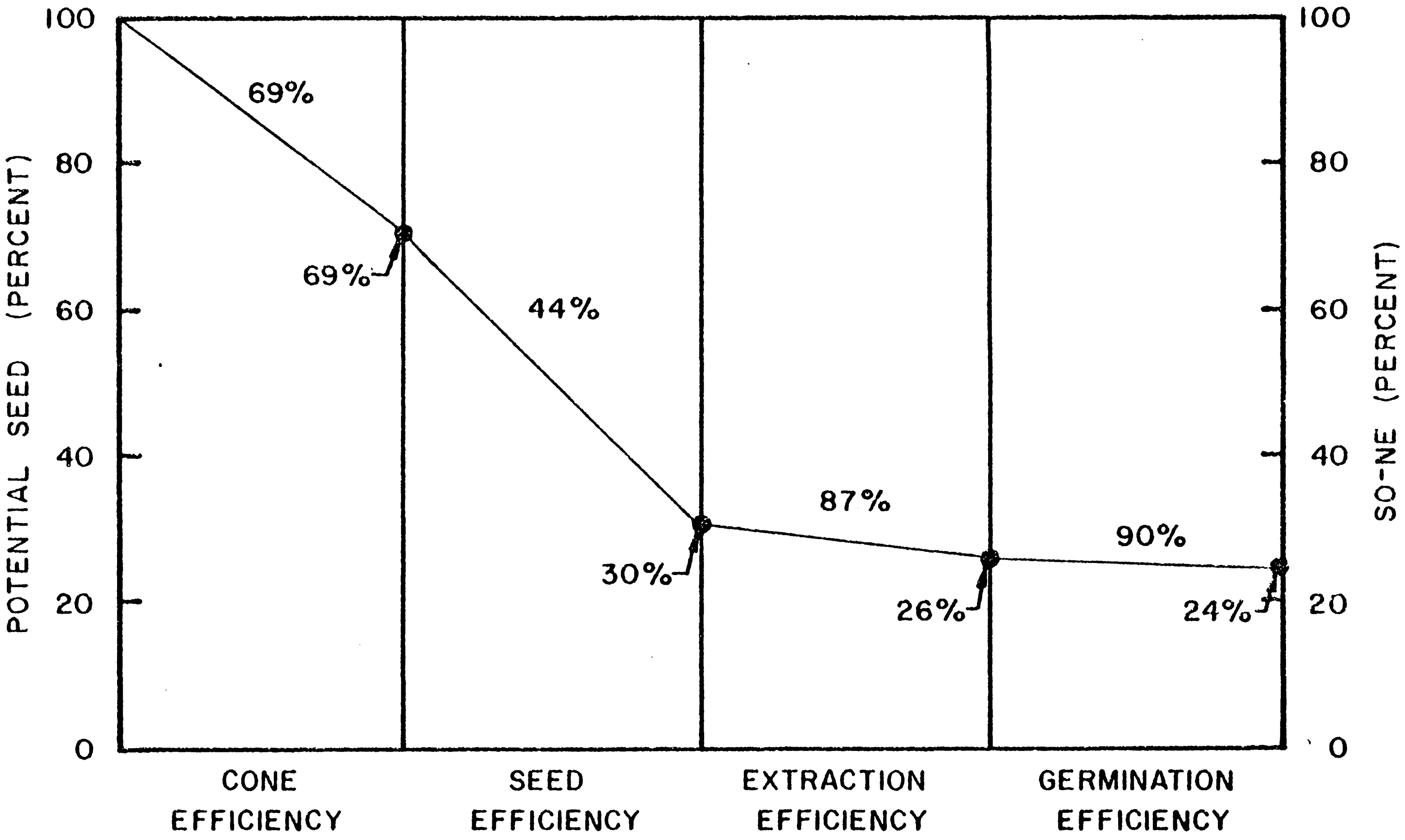

Figure 2. Overall seed orchard-to-nursery efficiency (SO-NE) for Magnolia southern loblolly orchard, 1981 crop.

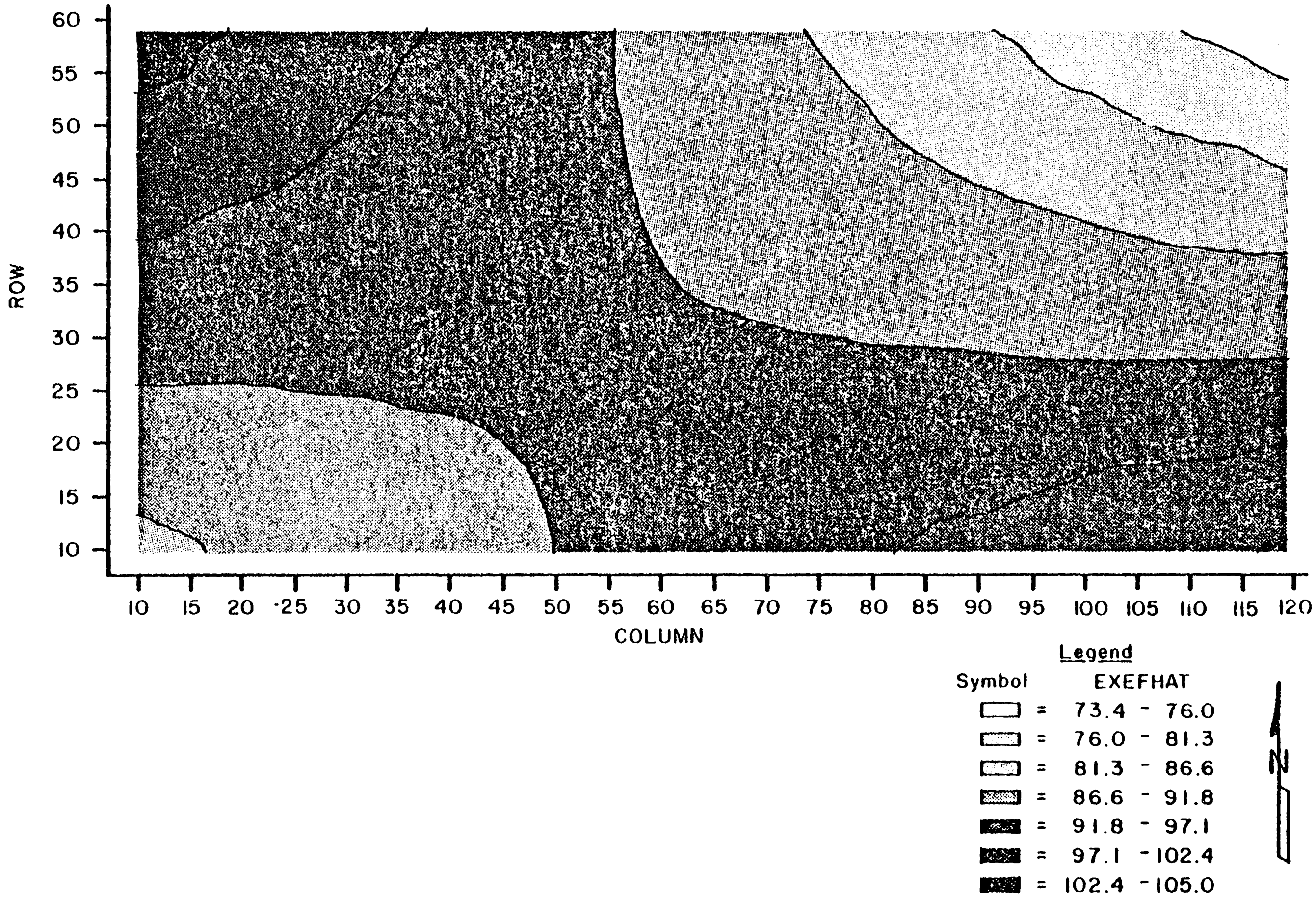

Figure 3. Contour plot of predicted extraction efficiency (EXEFHAT) over seed orchard row and column location, 1979 crop.

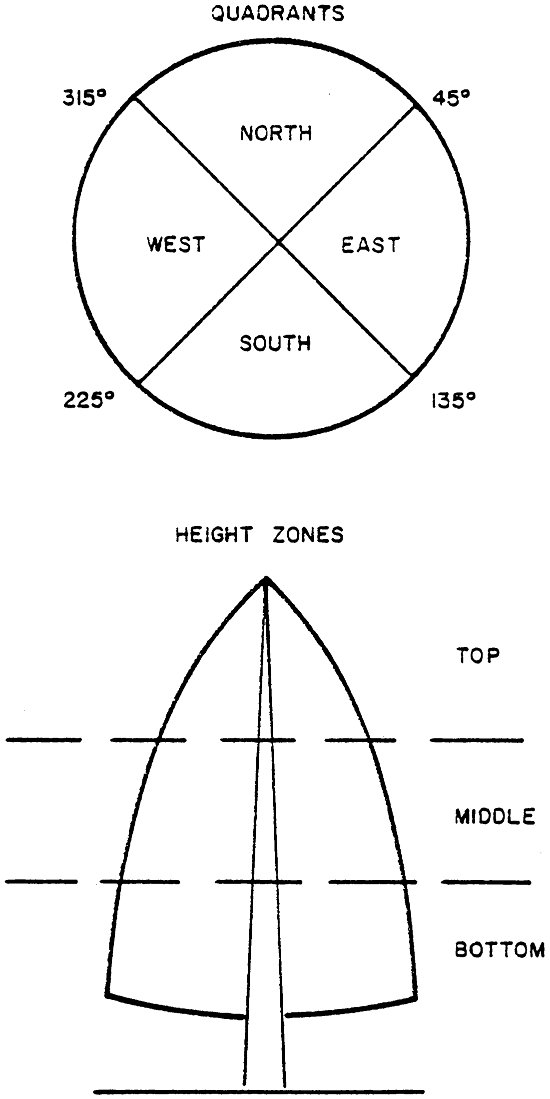

Figure 4. Crown sampling sectors for study of within-crown variation.

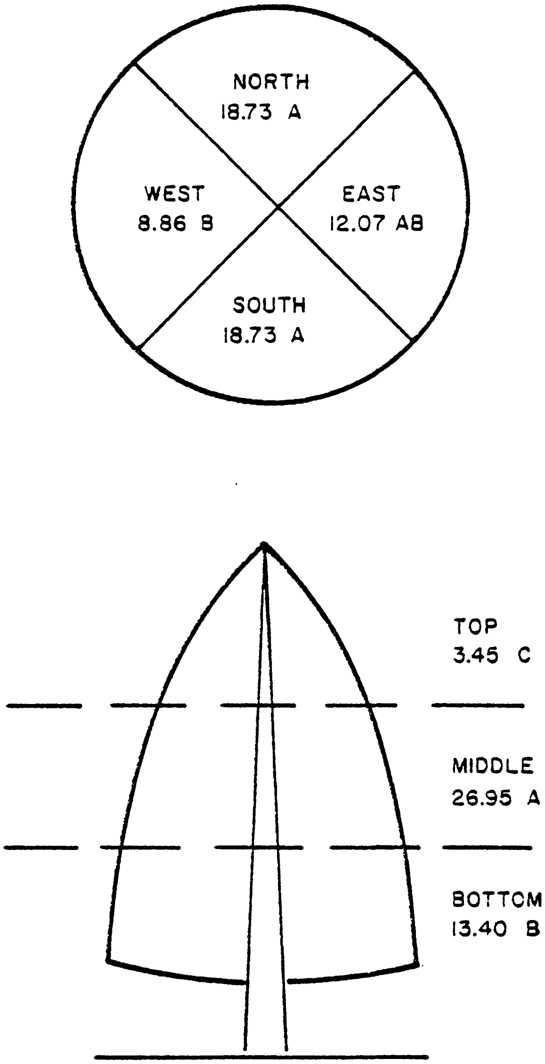

Figure 5. Crown quadrant and height zone means and Duncan's multiple range test results for total number of cones. Means with the same letter are not significantly different at the .05 level.

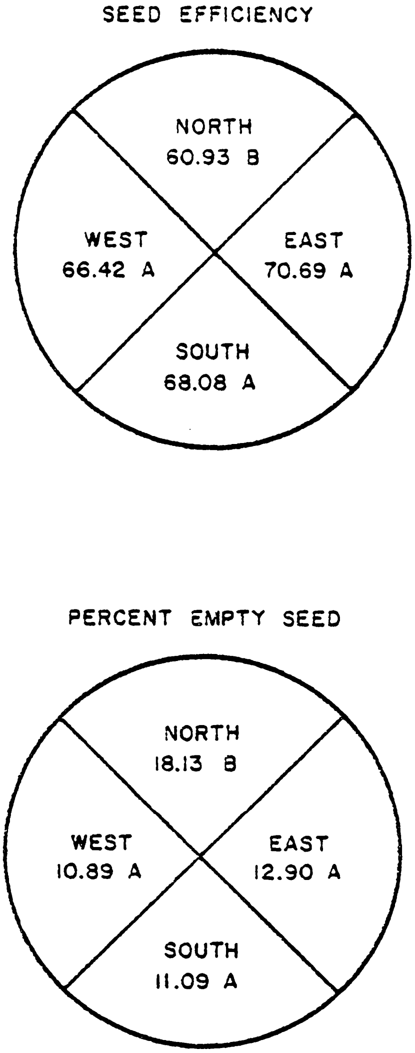

Figure 6. Crown quadrant least square means and T-test results for seed efficiency and percent empty seed. Means with the same letter are not significantly different at the .05 level.

Table 1. Variables considered in within-crown study for each cone.

Independent variables

Clone
Horizontal distance to trunk
Vertical distance to ground (height zone)
Number of cones in cluster
Branch length
Distance from cone to branch tip
Branch diameter 1/2-inch above point of cone attachment
Branch diameter 1/2-inch below point of cone attachment
Branch order
Azimuth (quadrant)

Dependent variables

Seed potential
Seed efficiency
Extraction efficiency
Germination efficiency
Percent empty seed
Percent first-year aborted ovules
Percent second-year aborted ovules

Table 2. Predicted and harvested cones (in bushels) from Magnolia southern loblolly orchard, 1980 crop.

Clone	Predictions						Actual
	Initial (1979)	1st March (1979)	1st June (1979)	1st October (1979)	2nd March (1980)	2nd June (1980)	Harvested
DF1158	2.08	1.73	1.77	1.95	2.06	2.01	1.25
DF3551	0.77	0.17	0.17	0.19	0.22	0.26	0.12
DF3559	2.44	0.96	1.11	1.11	1.14	1.20	2.00
DF3624	10.35	8.28	7.40	7.81	8.05	7.72	5.00
H18	6.24	5.05	5.28	5.32	5.10	5.13	2.25
H19	5.57	5.79	6.34	4.82	4.57	4.65	2.00
H21	7.79	4.92	5.17	6.21	5.32	5.43	12.50
S4PT6	7.13	6.87	7.79	7.70	7.27	7.10	1.00
SH11	31.38	20.33	12.05	12.06	12.31	13.80	7.25
SH15	7.20	6.41	6.19	5.81	5.41	6.06	5.50
WMAPT7	16.19	13.68	11.45	12.68	13.00	15.29	2.25
WSHPT6	3.17	1.89	2.04	2.09	1.79	1.81	2.00
WWOPT1	3.86	3.26	3.64	3.73	3.47	2.62	3.00
Total	104.17	79.34	70.40	71.48	69.71	73.08	46.12
Correlation coefficient with actual	.4333	.3693	.3413	.3877	.3413	.3220	
P-value	.1392	.2169	.2538	.1905	.2537	.2832	

Table 3. Predicted and harvested cones (in bushels) from Magnolia southern loblolly orchard, 1980 crop, using clonal cone efficiency estimates from 1981 crop.

Clone	Predictions						Actuals
	Initial (1979)	1st March (1979)	1st June (1979)	1st October (1979)	2nd March (1980)	2nd June (1980)	Harvested
DF3551	0.64	0.12	0.14	0.15	0.16	0.20	0.12
DF3559	2.71	1.15	1.29	1.30	1.32	1.39	2.00
DF3624	3.25	1.40	1.53	1.69	1.71	1.57	5.00
H18	5.89	4.69	4.92	4.96	4.81	4.84	2.25
H19	5.96	6.19	6.74	5.22	4.96	5.04	2.00
H21	4.56	2.31	2.59	3.95	3.06	3.23	12.50
S4PT6	6.83	6.56	7.49	7.39	6.97	6.84	1.00
SH11	32.28	21.22	12.64	12.65	12.91	14.69	7.25
SH15	9.67	8.88	8.65	8.28	7.88	8.53	5.50
WSHPT6	3.03	1.78	1.93	1.98	1.68	1.72	2.00
WWOPT1	4.47	3.86	4.25	4.32	4.00	3.10	3.00
Total	79.29	58.16	52.17	51.89	49.46	51.15	42.62
Correlation coefficient with actual	.3588	.3581	.3784	.5040	.4894	.4782	
P-value	.2786	.2796	.2512	.1140	.1266	.1368	

Table 4. Predicted and harvested cones (in bushels) from Magnolia southern loblolly orchard, 1981 crop.

Clone	Predictions				Actual
	Initial (1980)	1st March (1980)	1st June (1980)	2nd June (1981)	Harvested
28LOBI	1.03	1.03	1.01	1.13	0.75
C18B	2.70	2.58	2.41	1.62	1.00
C25A	1.22	0.55	0.51	1.36	2.00
DF3551	0.50	0.35	0.45	0.55	0.50
DF3559	6.27	6.70	7.51	7.60	9.25
DF3624	16.88	15.71	10.07	6.22	3.75
H18	22.30	22.21	20.12	20.71	15.00
H19	30.98	27.65	30.43	30.55	38.00
H21	19.59	17.87	16.30	9.62	40.00
H30	5.58	4.57	4.10	2.65	5.00
S4PT6	10.67	9.66	9.73	5.10	9.00
SH11	70.32	65.36	47.04	26.19	73.65
SH15	8.51	8.82	10.05	3.31	17.00
SH8	6.78	5.73	2.42	6.71	5.50
WSHPT6	15.79	12.43	10.92	7.80	11.50
WWOPT1	2.96	2.02	2.07	2.24	1.00
Total	222.08	203.24	175.14	133.36	232.90
Correlation coefficient with actual	.9317	.9301	.9400	.7895	
P-value	.0001	.0001	.0001	.0003	

Table 5. Clonal averages for cone efficiency, cone analysis-derived variables and seed orchard-to-nursery efficiency, 1980 crop.

Clone	Cone efficiency (%)	Seed efficiency (%)	Extraction efficiency (%)	Germination efficiency (%)	Seed orchard-to-nursery efficiency (%)
1420	80	46	1	89	0
22LOBI	35	71	47	78	9
28LOBI	61	28	82	99	14
C18B	91	70	99	100	63
C25A	26	20	99	93	5
DF1146	32	79	35	96	9
DF1158	79	35	90	96	24
DF3252	32	72	84	97	19
DF3551	23	87	95	96	18
DF3556	70	81	36	97	20
DF3559	49	65	96	95	29
DF3624	48	76	35	89	11
DF3636	13	81	99	99	10
DF3660	72	58	95	99	40
H18	36	56	59	96	11
H19	56	71	59	91	21
H21	50	60	97	98	28
H30	83	37	53	93	15
S4PT6	55	61	32	99	11
S4PT8	67	63	98	100	41
SH11	33	47	96	91	14
SH15	62	79	100	100	49
SH8	23	54	87	99	11
WHAPT3	90	64	98	87	49
WMAPT1	71	36	65	88	14
WMAPT7	55	63	50	79	14
WNAPT6	65	87	99	98	55
WR1PT2	79	57	93	97	40
WSHPT6	66	48	62	97	19
WWOPT1	47	85	92	98	36
Orchard average	55	61	72	91	22

Table 6. Clonal averages for cone efficiency, cone analysis-derived variables and seed orchard-to-nursery efficiency, 1981 crop.

Clone	Cone efficiency (%)	Seed efficiency (%)	Extraction efficiency (%)	Germination efficiency (%)	Seed orchard-to-nursery efficiency (%)
28LOBI	77	26	84	89	15
C18B	86	50	83	87	31
C25A	98	13	85	96	11
DF3551	56	49	86	100	24
DF3559	78	35	98	100	27
DF3624	22	37	75	90	5
H18	66	41	68	92	17
H19	75	49	85	93	29
H21	41	59	88	88	19
H30	97	20	95	94	18
S4PT6	67	44	54	88	14
S4PT8	47	53	100	98	24
SH11	72	48	97	43	14
SH15	94	80	93	92	64
SH8	49	38	97	94	17
WSHPT6	67	39	99	95	25
WWOPT1	81	72	100	93	54
Orchard average	69	44	87	90	24

Table 7. Nested analysis of variance summary for cone analysis-derived variables, 1979 crop.

		Seed Potential				Seed Efficiency			
Source	df	Mean square	F	P-value	% variance	Mean square	F	P-value	% variance
Clone	14	5986.8	43.88	.0001	43.15	3405.9	23.04	.0001	33.53
Age-class	19	768.8	5.63	.0001	14.50	447.2	3.03	.0001	0.00
Ramet	48	299.0	2.19	.0001	8.15	505.6	3.42	.0001	21.68
Residual	328	136.4			34.20	147.8			44.79
Broad-sense heritability estimate (R)			.4315				.3353		

Table 7. (Continued)

		Extraction Efficiency				Germination Efficiency			
Source	df	Mean square	F	P-value	% variance	Mean square	F	P-value	% variance
Clone	14	1596.0	16.53	.0001	19.65	10550.0	67.85	.0001	64.19
Age-class	19	350.5	3.63	.0001	22.92	468.4	3.01	.0001	4.91
Ramet	48	37.6	0.39	1.000	0.00	244.8	1.57	.0124	3.18
Residual	328	96.5			57.43	155.5			27.72
Broad-sense heritability estimate (R)			.1965				.6419		

Table 8. Sample sizes needed for clonal mean estimation for cone analysis-derived variables, 1979 crop.*

Clone	Seed Potential			Seed Efficiency			Extraction Efficiency			Germination Efficiency		
	Mean	Standard error	Sample size	Mean (%)	Standard error (%)	Sample size	Mean (%)	Standard error (%)	Sample size	Mean (%)	Standard error (%)	Sample size
DF1146	141.3	3.2	5	84.1	3.7	8	71.7	3.3	24	94.6	1.0	4
DF1158	121.9	1.6	4	42.1	1.2	8	98.9	0.3	2	98.9	0.3	2
DF3252	167.0	4.7	6	81.6	2.7	6	98.1	1.0	3	98.9	0.2	2
DF3335	146.9	8.4	9	76.0	5.3	13	97.1	1.5	3	98.0	0.2	2
DF3559	146.3	6.6	7	78.3	5.6	15	92.9	4.1	7	82.7	7.2	25
DF3660	142.4	2.9	4	64.1	4.6	20	93.9	2.2	6	97.4	5.0	20
SH11	125.9	3.0	5	69.9	4.5	20	95.5	9.4	6	94.6	2.5	11
SH15	130.6	3.2	5	83.7	2.9	8	99.2	0.1	2	99.1	0.3	2
SH18	155.5	0.6	4	66.7	1.2	12	84.8	4.1	30	86.1	4.0	25
S2PT16	157.0	3.1	4	79.6	2.9	9	97.7	0.4	3	98.6	0.3	2
WHAPT3	158.9	2.8	4	73.0	5.0	18	96.5	1.3	3	24.9	5.1	50
WNAPT6	125.4	5.7	8	82.4	5.8	15	97.6	0.8	3	96.2	1.5	4
WRIPT2	120.1	2.2	4	63.4	3.1	28	99.6	0.1	2	96.8	0.6	3
WSHPT4	141.5	2.7	4	75.0	6.5	20	99.4	0.1	2	95.4	1.8	4
WSHPT6	126.4	2.5	4	59.6	1.9	7	99.0	0.3	2	92.4	4.4	9

*Sample sizes required for accuracy within ± 10% of true clonal mean with 90% confidence; sample size = number of ramets with 1 cone subsampled per ramet.

Table 9. Nested analysis of variance summary for cone analysis-derived variables, 1981 crop.

		Seed Potential				Seed Efficiency			
Source	df	Mean square	F	P-value	% variance	Mean square	F	P-value	% variance
Clone	2	5336.4	25.68	.0001	31.22	27.7	0.12	.8862	0.00
Age-class	6	121.8	0.61	.7246	0.00	1458.3	6.36	.0001	7.47
Ramet	21	418.7	2.09	.0071	12.27	1068.1	4.66	.0001	39.09
Residual	120	200.7			56.51	229.4			53.44

Table 9. (Continued)

		Extraction Efficiency				Germination Efficiency			
Source	df	Mean square	F	P-value	% variance	Mean square	F	P-value	% variance
Clone	2	3142.8	15.19	.0001	18.33	1857.3	13.48	.0001	17.25
Age-class	6	381.0	1.84	.0965	0.00	134.1	0.97	.4464	0.00
Ramet	21	424.3	2.05	.0083	14.19	436.2	3.17	.0001	25.02
Residual	120	206.8			67.48	137.7			57.73

Table 10. Sample sizes needed for clonal mean estimation for cone analysis-derived variables, 1981 crop.

Clone	Seed Potential			Seed Efficiency			Extraction Efficiency			Germination Efficiency		
	Mean	Standard error	Sample size	Mean	Standard error	Sample size	Mean	Standard error	Sample size	Mean	Standard error	Sample size
				(%)	(%)		(%)	(%)		(%)	(%)	
DF1146	137.8	3.1	6	47.0	5.4	50	80.2	3.8	21	94.3	4.0	5
DF3559	130.4	2.1	6	47.4	3.4	50	93.5	3.0	10	97.0	1.6	6
WHAPT3	150.8	2.9	5	46.0	5.3	70	94.3	1.0	3	85.4	4.1	15

*Sample sizes required for accuracy within ± 10% of true clonal mean with 90% confidence; sample size = number of ramets with 1 cone subsampled per ramet.

Table 11. Nested analysis of variance summary for cone efficiency, 1980 and 1981 crops.

Source	df	Mean square	F	P-value	% variance
		1980 Crop			
Clone	28	.147	1.68	.0437	17.02
Age-class	27	.080	0.92	.5852	0.69
Residual	66	.087			82.29
Broad-sense heritability estimate (R)		.1702			
		1981 Crop			
Clone	16	1369.28	5.34	.0003	32.04
Age-class	19	382.50	1.69	.1161	24.92
Residual	28	282.14			43.05
Broad-sense heritability estimate (R)		.3204			

Table 12. Clonal mean cone efficiencies (mean CE) and sample sizes needed for clonal mean estimation for cone efficiency, 1980 and 1981 crops.*

	1980			1981		
Clone	Mean CE (%)	Standard deviation (%)	Sample size	Mean CE (%)	Standard deviation (%)	Sample size
DF1146	24.9	17.1	8			
DF1158	63.7	38.0	39			
DF3252	27.0	20.0	11			
DF3551	28.8	47.6	62	59.9	35.1	34
DF3556	74.3	20.7	12			
DF3559	46.8	24.8	17	80.8	12.0	4
DF3624				33.1	17.0	8
DF3660	59.0	47.3	61			
H19	55.9	22.9	15	75.5	8.6	2
H21	55.7	32.8	29	41.8	23.7	16
SH11	34.3	29.5	24	64.7	11.4	4
S4PT6	67.4	26.4	19	71.3	17.9	9
WHAPT3	92.2	1.1	2			
WMAPT1	68.2	16.8	8			
WNAPT6	72.7	18.8	10			
WRIPT2	79.6	32.0	28			
WSHPT6	59.2	35.3	34	66.2	13.2	5
WWOPT1	65.2	22.0	14	79.8	16.9	8
22LOBI	27.8	24.8	17			
28LOBI	59.8	29.9	24	81.4	12.7	5
C18B				84.9	14.9	6

*Sample sizes required for accuracy within ±10% of true clonal mean with 90% confidence; sample size = number of ramets.

Table 13. Nested analysis of variance summary for flowers-per-tree, 1980 and 1981 crops.

Source	df	Mean square	F	P-value	% variance
		1980 Crop			
Clone	31	5204.9	2.68	.0001	11.05
Age-class	36	4000.2	2.06	.0027	35.37
Residual	100	1943.9			53.59
Broad-sense heritability estimate (R)		.1105			
		1981 Crop			
Clone	31	56888.8	5.61	.0001	20.26
Age-class	36	41231.3	4.06	.0001	52.36
Residual	100	10144.3			27.38
Broad-sense heritability estimate (R)		.2026			

Table 14. Clonal means and coefficients of variation (C.V.) for flowers-per-tree, 1980 and 1981 crops.

	1980		1981	
Clone	Mean	C.V. (%)	Mean	C.V. (%)
C18B	1.6	129.6	20.8	46.8
C25A	3.8	171.8	26.0	112.5
DF1146	14.8	100.8	35.6	143.9
DF1158	22.5	136.3	73.7	66.8
DF3252	128.8	128.4	218.5	113.7
DF3551	8.5	107.0	13.2	74.0
DF3556	29.0	58.5	88.8	54.3
DF3559	43.2	72.7	172.5	79.1
DF3624	55.7	57.9	122.2	90.4
DF3636	3.0	81.6	4.0	128.7
DF3660	6.7	103.8	135.0	173.1
H18	22.4	187.2	138.0	163.0
H19	21.2	86.3	156.4	74.2
H21	34.3	43.8	117.0	37.8
SH11	155.5	104.0	665.2	61.4
SH15	40.3	44.9	56.3	122.0
S4PT6	23.8	126.0	56.7	67.6
S4PT8	0.6	149.1	2.8	122.2
WHAPT3	90.8	49.8	276.6	36.1
WMAPT1	116.5	49.6	384.8	29.2
WMAPT7	92.5	75.1	160.0	59.7
WNAPT6	76.0	121.0	286.2	73.6
WRIPT2	15.2	43.2	215.0	20.4
WSHPT6	55.8	90.0	331.3	80.9
WWOPT1	19.5	115.0	15.7	69.6
14-20	1.0	173.2	1.8	223.6
22LOBI	3.8	93.9	2.0	151.6
28LOBI	13.6	99.0	12.6	68.4

Table 15. Analysis of variance summary for cone analysis-derived variables over 3 years.

		Seed Potential			Seed Efficiency			Extraction Efficiency			Germination Efficiency		
Source	df	Mean square	F	P-value	Mean square	F	P-value	Mean square	F	P-value	Mean square	F	P-value
Clone	17	7702.2	39.16	.0001	6462.1	29.80	.0001	4483.9	8.84	.0001	1582.0	12.11	.0001
Year	2	5417.7	27.55	.0001	17781.8	82.00	.0001	8808.9	17.36	.0001	1305.9	10.00	.0001
Clone × year	34	442.7	2.25	.0001	953.8	4.40	.0001	1799.2	3.55	.0001	1156.4	8.85	.0001
Residual	413	196.7			216.8			507.4			130.6		

Table 16. Ranks of clonal least square means for cone analysis-derived variables over 3 years.

	Seed Potential			Seed Efficiency			Extraction Efficiency			Germination Efficiency		
Clone	1979	1980	1981	1979	1980	1981	1979	1980	1981	1979	1980	1981
C18B	15.5	16	15	3	7	4	9	3	11	3	2	14
C25A	18	18	18	18	18	18	7	2	14	10	14	13
DF1146	9	6	4	5	3	8	18	17	15	14	11	9
DF3551	2	3	2	1	1	6	16	8	10	1	9	1
DF3559	5	10	10	2	8	15	12	5	3	9	12	2
DF3624	1	1	1	7	5	14	15	16	16	13	17	11
H18	6	8.5	11	14	12	11	5	13	17	7	10	12
H19	4	2	6	10	6	5	13	14	12	15	15	10
H21	17	8.5	17	12	11	3	8	7	9	12	6	17
H30	7	7	9	17	16	17	11	15	7	8	13	6
SH11	14	13	12	9	15	7	1	6	5	16	16	18
SH15	11	11	13	6	4	1	2	1	8	2	1	8
SH8	10	14	5	15	13	13	14	10	6	6	4	5
S4PT6	12	15	13.5	4	10	9	3	18	18	4	3	16
WHAPT3	3	5	3	8	9	10	10	4	4	18	18	4
WSHPT6	13	12	8	11	14	12	6	12	2	17	8	3
WWOPT1	8	4	7	13	2	2	4	9	1	11	7	7
28LOBI	15.5	17	16	16	17	16	17	11	13	5	5	15

Table 17. Spearman's correlation coefficients and P-values for clonal least square means for cone analysis-derived variables between years.

		1979	1980	1981
			Seed Potential	
	1979			
Seed Potential	1980	.8275 .0001		
	1981	.8499 .0001	.7690 .0001	
			Seed Efficiency	
	1979			
Seed Efficiency	1980	.6966 .0013		
	1981	.4303 .0746	.6532 .0033	
			Extraction Efficiency	
	1979			
Extraction Efficiency	1980	.3210 .1941		
	1981	.2157 .3900	.4407 .0672	
			Germination Efficiency	
	1979			
Germination Efficiency	1980	.7028 .0011		
	1981	-.0114 .9643	-.1269 .6157	

Table 18. Summary of analysis of variance results for cone analysis-derived variables over 3 years, conducted by clone.

Variable	Number of clones showing:	
	Significant variation over 3 years: (at .05 level)	Nonsignificant variation over 3 years: (at .05 level)
Seed potential	9	9
Seed efficiency	15	3
Extraction efficiency	9	9
Germination efficiency	6	12

Table 19. T-test results summary for cone efficiency over 2 years.

Clone	1980 Mean (%) Standard deviation (%)	1981 Mean (%) Standard deviation (%)	T	P-value
DF3551	28.8 47.6	59.9 35.1	-1.05	0.33
DF3559	46.8 24.8	80.8 12.0	-2.79	0.02
H19	55.9 22.9	75.5 8.6	-1.60	0.16
H21	55.7 32.8	41.8 23.7	0.84	0.42
SH11	34.3 29.5	64.7 11.4	-2.33	0.04
S4PT6	67.4 26.4	71.3 17.9	-0.25	0.81
WSHPT6	59.2 35.3	66.2 13.2	-0.46	0.66
WWOPT1	65.2 22.0	79.8 17.0	-1.18	0.27
28LOBI	59.8 29.9	81.4 12.7	-1.48	0.18
Paired T-test of clonal means:			-3.18	0.01

Table 20. Ranks of clonal least square means for cone efficiency over 2 years.

Clone	1980	1981
DF3551	9	8
DF3559	7	2
H19	5	4
H21	6	9
SH11	8	7
S4PT6	1	5
WSHPT6	4	6
WWOPT1	2	3
28LOBI	3	1

Spearman's correlation coefficient: 0.4833

P-value 0.1875

Table 21. Regression model for orchard location effects on extraction efficiency, 1979 crop.

Dependent variable	Independent variables	Estimate	T	P-value	R-squared
Extraction Efficiency, 1979 crop	Intercept	79.09	8.25	.0001	.0329
	Row	0.49	1.54	.1254	
	Column	0.25	1.53	.1271	
	Row × column	-0.01	-1.94	.0544	

Table 22. Analysis of variance summary for within-crown variation in cone numbers.

Source	df	Mean square	F	P-value
Clone	4	2322.39	37.24	.0001
Height zone	2	2782.85	44.63	.0001
Quadrant	3	367.29	5.89	.0037
Quadrant × height zone	6	125.54	2.01	.1033
Clone × height zone	8	450.14	7.22	.0001
Clone × quadrant	12	102.86	1.65	.1433
Residual	24	62.35		

Table 23. Analysis of variance summary for within-crown variation in cone analysis-derived variables.

Source	df	Seed Potential			Seed Efficiency		
		Mean square	F	P-value	Mean square	F	P-value
Clone	3	13607.12	88.71	.0001	6657.08	63.18	.0001
Height zone	2	21.92	0.14	.8670	388.00	3.65	.0300
Quadrant	3	280.84	1.83	.1451	506.71	4.84	.0037
Height zone × quadrant	6	113.68	0.74	.6178	60.08	0.57	.7503
Clone × height zone	6	280.25	1.83	.1019	1295.11	12.25	.0001
Clone × quadrant	9	93.10	0.61	.7894	106.02	0.99	.4507
Clone × height zone × quadrant	18	172.42	1.12	.3420	169.80	1.60	.0752
Residual	95	153.38			105.03		

Table 23. (Continued)

		Extraction Efficiency			Germination Efficiency		
Source	df	Mean square	F	P-value	Mean square	F	P-value
Clone	3	3925.23	48.60	.0001	682.92	16.18	.0001
Height zone	2	3683.90	45.62	.0001	458.34	10.86	.0001
Quadrant	3	402.13	4.98	.0031	242.32	5.74	.0013
Height zone × quadrant	6	286.90	3.55	.0032	376.18	8.91	.0001
Clone × height zone	6	3487.95	43.19	.0001	815.78	19.32	.0001
Clone × quadrant	9	216.13	2.68	.0082	401.55	9.51	.0001
Clone × height zone × quadrant	18	207.98	2.58	.0016	256.79	6.08	.0001
Residual	95	80.76			42.22		

Table 23. (Continued)

Source	df	Percent Empty Seed Mean square	F	P-value	Percent First-Year Aborted Ovules Mean square	F	P-value	Percent Second-Year Aborted Ovules Mean square	F	P-value
Clone	3	1241.95	41.01	.0001	3412.08	40.91	.0001	0.70	4.92	.0033
Height zone	2	104.68	3.46	.0357	58.11	0.70	.5008	0.14	0.96	.3877
Quadrant	3	341.94	11.29	.0001	185.41	2.22	.0891	0.23	1.66	.1804
Height zone × quadrant	6	70.31	2.32	.0394	39.76	0.48	.8241	0.33	2.36	.0363
Clone × height zone	6	227.74	7.52	.0001	259.90	3.12	.0079	0.26	1.88	.0923
Clone × quadrant	9	61.88	2.04	.0430	139.70	1.67	.1052	0.22	1.53	.1471
Clone × height zone × quadrant	18	34.51	1.14	.3290	119.48	1.43	.1344	0.22	1.55	.0912
Residual	95	30.28			83.41			0.14		

Table 24. Correlation of extraction efficiency and seed potential with branch characteristics.

		Extraction efficiency	Seed potential
Branch diameter 1/2-inch above point of cone attachment	Correlation coefficient	-0.4731	.2924
	P-value	0.0001	.0001
Branch diameter 1/2-inch below point of cone attachment	Correlation coefficient	-0.4580	.3368
	P-value	0.0001	.0001
Branch order	Correlation coefficient	0.3460	-.2657
	P-value	0.0001	.0004

Table 25. Correlation coefficients and P-values for some cone analysis-derived variables.

	Seed potential	Seed efficiency	Extraction efficiency	Germination efficiency
Cone length	.4408 .0001	.2976 .0001	.0050 .9387	.0102 .8770
Cone width	.4218 .0001	.3515 .0001	.0107 .7852	.0612 .1189
Extracted seed	.5146 .0001	.6190 .0001	.5684 .0001	.2600 .0001
Extracted filled seed	.5135 .0001	.7788 .0001	.4339 .0001	.2548 .0001
Extracted germinated seed	.4906 .0001	.7772 .0001	.4524 .0001	.3091 .0001

Table 26. Regression models for clonal means of cone analysis-derived variables.

Dependent variable	Independent variables	Estimate	R-squared
1980 clonal mean seed potential	1. Intercept	-6.46	0.80
	2. 1979 clonal mean seed potential	0.72	
	3. 1980 clonal mean cone length	0.47	
1980 clonal mean seed efficiency	1. Intercept	-22.02	0.88
	2. 1979 clonal mean seed efficiency	0.52	
	3. 1980 clonal mean cone width	0.81	
	4. 1980 clonal mean extracted filled seed	0.23	
1980 clonal mean extraction efficiency	1. Intercept	54.62	0.62
	2. 1979 clonal mean extraction efficiency	0.37	
	3. 1980 clonal mean extracted seed	0.48	
	4. 1980 clonal mean cone width	-1.33	
1980 clonal mean germination efficiency	1. Intercept	62.74	0.40
	2. 1979 clonal mean germination efficiency	0.28	
	3. 1980 clonal mean extracted seed	0.06	

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APPENDIX A

A COMPUTER PROGRAM PACKAGE
FOR USE WITH THE
SOUTHERN PINE SEED ORCHARD INVENTORY-MONITORING SYSTEM

by
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Publication No. FWS-2-82
School of Forestry and Wildlife Resources
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061
1982

ACKNOWLEDGEMENTS

The development of the Computerized Inventory-Monitoring System was funded by the U.S.D.A. Forest Service, Southeastern Forest Experiment Station.

The authors wish to acknowledge the Weyerhaeuser Company for its assistance with the development of the computerized IMS. Individual thanks are due to Mary Winslow, Ron Campbell, Michael Greenwood and Steven Duke.

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PROGRAM AVAILABILITY

The IMS computer package is currently on file at the Virginia Tech Computing Center. Those desiring tape copies of the package should send a nonlabeled, 1600 BPI tape to:

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228 Cheatham Hall
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INTRODUCTION

Southern pine seed orchards covering more than 10,000 acres currently produce over 160,000 pounds of improved seed having a potential of 1 billion seedlings annually. By the year 2000, annual seed production is expected to reach 500,000 pounds. Seed orchards not only represent potential for improved growth, wood quality and pest resistance, but they also represent a large capital investment in orchard establishment and equipment and the significant annual costs of orchard maintenance, protection and harvesting. Since the immediate goal of the seed orchard investment is the annual production of cones and seed, the task of the seed orchard manager could be greatly lightened by a system that will forecast annual cone and seed crops and monitor production efficiency. Such a system has been developed by Bramlett and Godbee (1982). In the Inventory- Monitoring System (IMS) a set of sample trees are chosen from the seed orchard population. Then, based on the survival of cones on tagged sample branches in each sample tree, the expected number of cones and seed from the orchard can be predicted as early as 18 months prior to cone harvest. Bramlett and Godbee (1982) detailed various procedures for the selection of sample trees as well as methods for choosing sample branches and conducting flower, conelet and cone counts. Besides providing guidelines for data collection in the orchard, the authors also defined the variables used in the calculation of predicted cone and seed yields, including cone efficiency, seed potential, seed efficiency, extraction efficiency and germination efficiency. They showed how to compute (or update) the values of these variables and how to apply them in models to calculate predicted bushels of cones, predicted pounds of seed, predicted number of seedlings and other predicted values for the orchard. In addition to these predicted values, Bramlett and Godbee (1982) also demonstrated how the IMS can be used by the orchard manager to evaluate orchard productivity, identify the factors reducing yields, and formulate corrective action, including fertilization and pest management.

Because a great deal of record-keeping and repetitive mathematical operations are involved in the IMS, it is ideally suited to computerization. A computerized version of the IMS not only has the advantage of efficient data storage and manipulation, but it also makes possible the application of more sophisticated mathematical models as they become available, and facilitates the utilization of productivity data accumulated from year to year to improve the accuracy of the system.

The computerized IMS is an interactive package designed to be used by the seed orchard manager. It is currently accessed by CMS on the IBM 370 mainframe at Virginia Tech, but can be modified for use on other computers. To use the IMS package, the user collects data from seed orchard sample trees under the guidelines specified by Bramlett and Godbee (1982). It should be noted that the programs are set up to handle the sampling design described in that paper for "Estimating Orchard and Clone Productivity." The user employs the CMS editor to enter the data into formatted data files which are stored on the CMS disk. The IMS programs then access these files, as directed by the user, to compute the predicted and actual values for the variables noted above (e.g. for cone efficiency, seed efficiency) for each clone and for the whole orchard. These values are written by the programs to the user's CMS disk from which the user can access them.

Although this publication contains printed copies of the programs that make up the IMS package, it is primarily a user's guide and therefore describes the system at the user level, with little detail concerning the mechanics of the programs. In the user's guide are short descriptins of each of the programs of the IMS package and more detailed descriptions of the user-created data files utilized by the IMS programs and the output generated by the IMS programs. In the part of the user's guide which is concerned with creation of the data files, column by column data entry instructions are provided.

Also included in the user's guide are a user's flow chart of the IMS programs and files, and samples of each of the user-created data files and program-generated output files.

The printed copies of the IMS components contained in this publication include one CMS exec file and 3 Fortran programs. The Fortran programs are fully documented within the code, with a block of comments at the head of each subroutine describing its mechanics.

USER'S GUIDE FOR THE COMPUTERIZED INVENTORY-MONITORING SYSTEM

PROGRAMS WITHIN THE COMPUTERIZED INVENTORY-MONITORING SYSTEM

GOIMS

GOIMS is a CMS exec file which forms the major interactive part of the system. It asks the user questions concerning what kind of program run he desires to make ("Predictions" or "Actuals") and which data files he wants the program to employ in making these runs ("Observations," " Actual Flowers and Cones" or "Actual Cone Analysis"). It also tells the user under what file names he can find the results of a run on the project disk and gives him the option of having the system help him create new data files. The GOIMS exec accesses the various programs within the system as needed. It is initiated by typing "GOIMS."

IMSYS

IMSYS, the main program of the computerized IMS, is written in Fortran and is accessed by the GOIMS exec when the user requests a "Predictions" run. It utilizes strobilus survival data from sample trees and clonal estimates for seed efficiency, extraction efficiency, etc., supplied by the user in an "Observations" data file, to compute clonal cone and seed yield predictions and to update these predictions throughout the cone cycle. IMSYS automatically puts these predicted values on the CMS disk from which the user can access them.

AVGACTS

AVGACTS is a Fortran program accessed by the GOIMS exec when needed for an "Actuals" run. AVGACTS utilizes actual cone analysis data and actual flower-and cone-count data from sample trees, supplied by the user in specified data files, to compute "Actual" (not "Predictions") clonal averages for efficiency values, such as cone efficiency and seed efficiency. AVGACTS automatically puts these clonal average values on the CMS disk from which the user can access them.

NEWOBV

NEWOBV is a Fortran program accessed by the GOIMS exec when the user requests the system to help him create the basis for a new user "Observations" data file to eventually be used by IMSYS. NEWOBV utilizes, as specified by the user, a clonal averages file created by AVGACTS and an existing "Observations" file already on the CMS disk to construct the skeleton for a new user "Observations" file which the user can simply fill in with sample tree flower count data as they are obtained.

USER-CREATED DATA FILES UTILIZED BY THE COMPUTERIZED INVENTORY-MONITORING SYSTEM

Files used by IMSYS

IMSYS makes use of three user-created data files, CLONTAB, SYSTAT and DATA__ to make the "Predictions" runs referred to in the GOIMS exec.

CLONTAB (FN FT FM[1] = CLONTAB DATA A)

This data file contains one line of data for each clone. It can be used by IMSYS for multiple cone crops--it doesn't have to be created for each cone crop. CLONTAB once created is automatically accessed by IMSYS when needed. It should contain the following information for each clone:

Column	
1-4	Orchard name (alphanumeric, left-justified).
5-19	Clone name (alphanumeric, left-justified).
20-21	Index number assigned to clone. Any integer can be assigned to any clone from 1 up to the number of clones in the table (right-justified).
22-25	Estimated clonal cones-per-bushel (right-justified).
26-30	Estimated clonal seed-per-pound (right-justified).

Figure 1 is a sample CLONTAB data set.

---

[1] FN FT FM = Filename Filetype Filemode as used in CMS.

SYSTAT (FN FT FM = SYSTAT DATA A)

This data file contains only one line of data. It needs to be reset before makng any INITIAL run for a cone crop. SYSTAT, like CLONTAB, is automatically accessed by IMSYS when needed. It should contain the following information (all right-justified):

Column	
1-3	Number of clone means in CLONTAB.
4-6	Zero (0) (for any INITIAL run).
7-9	Highest index number in CLONTAB.
10-12	Zero (0) (For an INITIAL run for an even cone year).
13-15	Zero (0) (For an INITIAL run for an odd cone year).
16-18	Last two digits of 1st observation year for the cone crop (Flowering Year).
19-21	Last two digits of 2nd observation year for the cone crop (Cone Harvest Year).

The zeros placed in this file by the user in columns 6, 12, and 15 are simply place-holders. As the program (IMSYS) executes, it will use these spaces to count the number of records it processes on an INITIAL run. Therefore, whenever an INITIAL run is made for an even-year cone crop (e.g. the 1980 crop) the counter in columns 10-12 will have to be reset to 0, and whenever an INITIAL run is made for an odd-year cone crop (e.g. 1981) the counter in columns 16-18 will have to be reset to 0.

Figure 2 is a sample SYSTAT file.

DATA__ (FN FT FM = DATA__ DATA A)

The actual name of this file depends on the harvest year for the cone crop being monitored. Thus for the 1980 cone crop, this file would be called DATA80, for the 1981 crop, DATA81, etc. DATA__ is the "Observations" data file referred to in the GOIMS exec. It contains one line of data for each sample tree. For the first two cone crops to be processed by the system, it must be completely created by the user. All data in this data set should be sorted by clone, so that all sample ramets of one clone appear together, and so that the clone names appear in the same order as they do in CLONTAB. It should be noted that the format of this file is similar to but <u>not</u> identical to the sample tree data sheet (Figure 1) in Bramlett and Godbee (1982). Sample tree data to be used by the program must be entered according to the following format. In DATA__ the following information is entered for <u>each sample tree</u>:

<u>Column</u>	
1-2	Last 2 digits of cone year
3-6	Orchard name (alphanumeric, left-justified).
7-19	Clone name (alphanumeric, left-justified).
	All entries from this point are right-justified.
20-21	Row number of sample tree location.
22-24	Column number of sample tree location.
25-26	Last 2 digits of year sample tree was grafted.
27-29	Number of ramets of the same clone AND same age as the sample tree. If there is a clone with more age classes than there are sample trees, or if for some other reason all age classes are not represented by the sample trees, unrepresented trees should be grouped into the nearest age class, so that the total number of ramets in the clone is represented.
30-33	Total number of female strobili that emerge on the sample tree at anthesis.
34-36	Total number of female strobili that emerge on the sample branches of the sample tree at anthesis (this will be called the INITIAL observation).
37-39	Number of surviving female strobili counted on the sample branches at the time of the first count (called the FIRST MARCH OBSERVATION).
40-42	Number of surviving female strobili counted on the sample branches at the time of the second count (called the FIRST JUNE observation).
43-45	Number of surviving female strobili counted on the sample branches at the time of the third count (called the FIRST OCTOBER observation).
46-48	Number of surviving female strobili counted on the

	sample branches at the time of fourth count (called the SECOND MARCH observation).
49-51	Number of surviving female strobili counted on the sample branches at the time of the fifth count (called the SECOND JUNE observation).
52-54	Number of surviving cones counted on the sample branches at harvest time (called the FINAL observation).
55-57	Estimated clonal seed potential
58-59	Estimated clonal cone efficiency.
60-61	Estimated clonal seed efficiency.
62-63	Estimated clonal extraction efficiency.
64-65	Estimated clonal germination efficiency.

DATA__ has a size limit of 255 records (255 sample trees). Selection of the sample trees to be used for this data file should be conducted according to Bramlett and Godbee's (1982) instructions for "Estimating Orchard and Clone Productivity." Likewise the sample (female strobili) counts and periodic sample branch counts should be conducted as detailed by Bramlett and Godbee (1982). Estimates for clonal seed potential, seed efficiency, extraction efficiency and germination efficiency should be supplied by the user from the most recent cone analysis data available. Bramlett et al. (1977) detailed the cone analysis procedure employed to obtain these data. If no cone analysis data is available, best available estimates for these values should be used. The same can be done for estimated clonal cone efficiency.

DATA__ is ready to be used by IMSYS for an INITIAL "Predictions" run when columns 1 through 36 and columns 55 through 65 are filled-in with values for each sample tree. An INITIAL run must be made before "Predictions" runs using any of the other strobili counts can be made. However, once an INITIAL run has been made, runs using the other strobili counts to update the predictions can be made in any order. For example, once SECOND MARCH strobili counts are placed in columns 40-42, a SECOND MARCH "Predictions" run can be made without making any of the preceding "Predictions" runs (FIRST MARCH, FIRST JUNE, FIRST OCTOBER) or even having values in those columns in DATA__. Thus the user has the option of making any of the six strobili counts following INITIAL that he wants to, in order to have IMSYS update the predictions.

See Files Created by NEWOBV for information on how the system can aid in the creation of DATA__ files for subsequent cone crops.

Figure 3 is a sample DATA__ data set called DATA82, since it is for a 1982 cone crop.

Files used by AVGACTS

Following the end of the first cycle (harvest of first monitored crop) the user has the option of employing two additional programs that will make information gained from the analysis of one cone and seed crop automatically available for use in predicting subsequent cone and seed crops. These programs are named AVGACTS and NEWOBV. AVGACTS makes use of two user-created data files, ACTFLC__ and ACTCAS__, to make the "Actuals" run referred to in the GOIMS exec.

ACTFLC__ (FN FT FM = ACTFLC__ DATA A)

This is the "actual flowers and cones" data set referred to in the GOIMS exec. As with DATA__, the full name of this file depends on the harvest year being monitored. Thus for the 1980 cone crop, the file would be called ACTFLC80, for the 1981 crop, ACTFLC81, etc. AVGACTS uses the data in ACTFLC__ to calculate the average actual cone efficiency for each sample clone. Data in this data set should be sorted by clone such that the clone names appear in the same order as they did in the DATA__ file for the same cone year. ACTFLC__ should contain the following data for each sample tree:

Column	
1-2	Last 2 digits of cone year.
3-10	Clone name (left-justified).
11	Blank

All entries from this point on are right-justified.

12-13	Row location of sample tree.
14	Blank
15-17	Column location of sample tree.
18	Blank
19-22	Total number of female strobili counted on the sample tree at anthesis.
23	Blank
24-27	Total number of living cones harvested from sample tree.

NOTE: If it is impossible or undesirable to count the total number of cones harvested from a sample tree, the following alternative values can be substituted for the whole tree counts, and will be used by the program to estimate "Actual" clonal cone efficiencies:

Column	
19-10	Total number of female strobili counted on the sample branches of the sample tree at anthesis (same as the INITIAL observation in DATA__).
24-27	Total number surviving cones counted on the sample branches of the sample tree at harvest time (same as the FINAL observation in DATA__).

Figure 4 is a sample ACTFLC__ data set.

ACTCAS__ (FN FT FM = ACTCAS__ DATA A)

This is the "actual cone analysis" data set referred to in the GOIMS exec. As with ACTFLC__, the full name of this file depends on the harvest year for the cone crop being monitored (ACTCAS80, ACTCAS81 etc.). Data obtained from cone analysis of sample cones from each clone will be put in this data set. AVGACTS will use it to compute an average seed potential, seed efficiency, etc. for each clone. Data in this data file should be sorted by clone such that the clone names appear in the same order as they did in ACTFLC__ file for the same cone year. Bramlett et al. (1977) details the cone analysis procedure employed to obtain the data to be entered in this file.

IMPORTANT NOTE: If there is no cone analysis data for a particular clone (possibly because the clone produced no cones to analyze), the clone name should still be entered into this data file, at least once, and zeros should be filled in for number of fertile scales, number of extracted seed, etc. This procedure is necessary in order to keep a one-to-one correspondence between the clone names in ACTFLC__ and ACTCAS__.

ACTCAS__ should contain the following data for each sample cone:

Column	
1-2	Last 2 digits of cone year.
3-10	Clone Name (left-justified).
11	Blank
	All entries from this point on are right-justified.
12-13	Row location of sample trees that cone came from.
14	Blank
15-17	Column location of sample tree that cone came from.
18-20	Blank
21-22	Cone identification number (1, 2, 3, etc.) if more than one cone comes from a sample tree.
23	Blank
24-26	Number of fertile scales counted on cone.
27	Blank
28-30	Number of extracted seed from cone.
31	Blank
32-34	Total number of seed in cone (extracted + dissected)
35	Blank
36-38	Total number of filled seed from cone.
39	Blank
40-42	Total number of germinated seed from cone.

Figure 5 is a sample ACTCAS__ data set.

Files used by NEWOBV

NEWOBV uses two additional data files but neither has to be specially created by the user for NEWOBV to use. See "Files Created by NEWOBV" for information on these two files.

OUTPUT GENERATED BY THE COMPUTERIZED INVENTORY-MONITORING SYSTEM

Files created by IMSYS

IMSYS generates two output files that are written to the project disk for the user to access: OUTPUT and CONPROD.

OUTPUT (FN FT FM = OUTPUT DATA A)

This file contains, for any "Predictions" run requested of the system (INITIAL, FIRST MARCH, FIRST JUNE, FIRST OCTOBER, SECOND MARCH, SECOND JUNE or FINAL), all the predictive information generated by IMSYS for each clone, including : Predicted values for cone efficiency, seed potential, seed efficiency, extraction efficiency, germination efficiency, total seed, extracted seed, bushels of cones, total cones, pounds extracted seed, number of seedlings, and seed orchard-to-nursery efficiency. It also contains overall seed orchard predictions for these values.

Figures 6 and 7 are sample OUTPUT files.

CONPROD (FN FT FM = CONPROD GUIDE A)

This file is a shortened version of OUTPUT, containing only the following information for each clone for a given run (INITIAL, FIRST MARCH, etc.): Predicted bushels of cones, predicted number of cones, and number of ramets of the clone in the orchard.

Figure 8 shows two sample CONPROD files.

Files created by AVGACTS

CLNAVGS (FN FT FM = CLNAVGS DATA A)

AVGACTS generates one output file named CLNAVGS that is written to the project disk for the user to access. It contains output from the "Actuals" run performed by AVGACTS, including "Actual" clonal averages for seed potential, seed efficiency, extraction efficiency, germination efficiency, cone efficiency, and seed orchard-to-nursery efficiency.

Figure 9 is a sample CLNAVGS file.

Files created by NEWOBV

DATA__ (FN FT FM = DATA__ DATA A)

NEWOBV generates one data file that is both named and, to a certain extent, designed by the user.[2] This file is the basis for a new user "Observations" file DATA__, a file discussed earlier under the "User-Created Data Files" section. With the use of NEWOBV, the user no longer has to completely type the DATA__ file for each new cone crop. Instead, NEWOBV will create a skeleton of a DATA__ file for the user

---

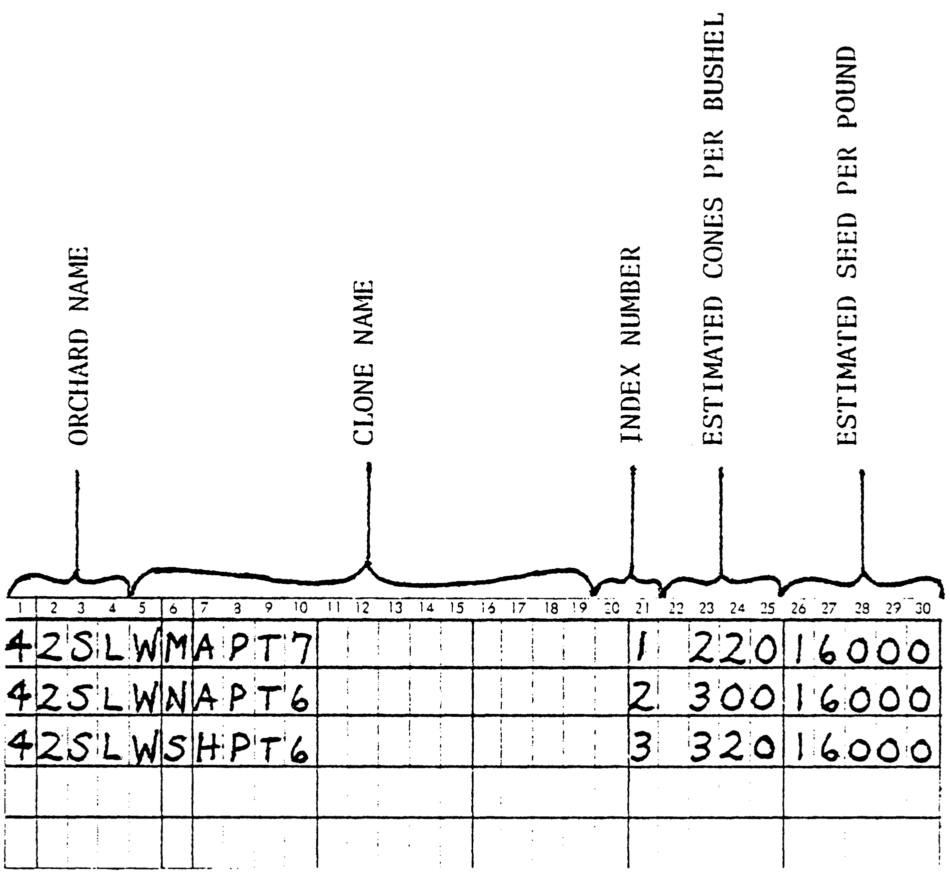
[2] Note on naming files: Any of the user-created data files described in the user's guide except CLONTAB and SYSTAT can be named by the user. DATA82, ACTFLC82 and ACTCAS82 were used in the guide as recommended file names for systems that only need to monitor a single orchard. If, for example, two "Observations" files were needed for a system monitoring the 1982 cone crops in both a slash pine seed orchard and a loblolly pine seed orchard, they might be named SLASH82 and LOB82.

already containing most of the data of a complete DATA__ file except the flower count observations, which the user can simply fill in as he obtains the data. NEWOBV uses a DATA__ file from a previous crop specified by the user as the source for the data that will appear in columns 3-29 of the new DATA__ file (orchard, clone name, row, column, year grafted, number of ramets in same age class). Then, NEWOBV uses the clonal averages for seed potential, seed efficiency, etc. created by the latest run of AVGACTS (and stored on the CMS disk as CLNAVGS) to create updated clonal estimates for these values by averaging them with the estimates found in the old DATA__ file. These updated clonal estimates are then inserted into columns 55-65 of the new DATA__ file. This leaves columns 30-54 ready to be filled-in with flower-count observations by the user as he obtains them.

Cone year (columns 1-2) for the newly-created DATA__ file is automatically incremented by 2 by NEWOBV. This is because we have made the assumption that the actual cone analysis data from a given cone crop (say 1981) will not be available in the time to be of much use in predicting the next year's crop (1982) but should be ready just in time to coincide with the first flower counts for the following year's crop (1983). In other words, we assume that DATA81 and "Actual" data from the 1981 crop will be used to create the DATA83 file, DATA82 and "Actual" data from the 1982 crop will be used to create the DATA84 file, etc.

Figure 10 is a sample NEWOBV-created DATA__ file called DATA84.

EXAMPLES OF USER-CREATED FILES



ORCHARD NAME	CLONE NAME	INDEX NUMBER	ESTIMATED CONES PER BUSHEL	ESTIMATED SEED PER POUND
42SLW	MAPT7	1	220	16000
42SLW	NAPT6	2	300	16000
42SLW	SHPT6	3	320	16000

Figure 1. Sample CLONTAB. In this sample clone table there are three clones, all in the same orchard, assigned index numbers 1, 2 and 3.

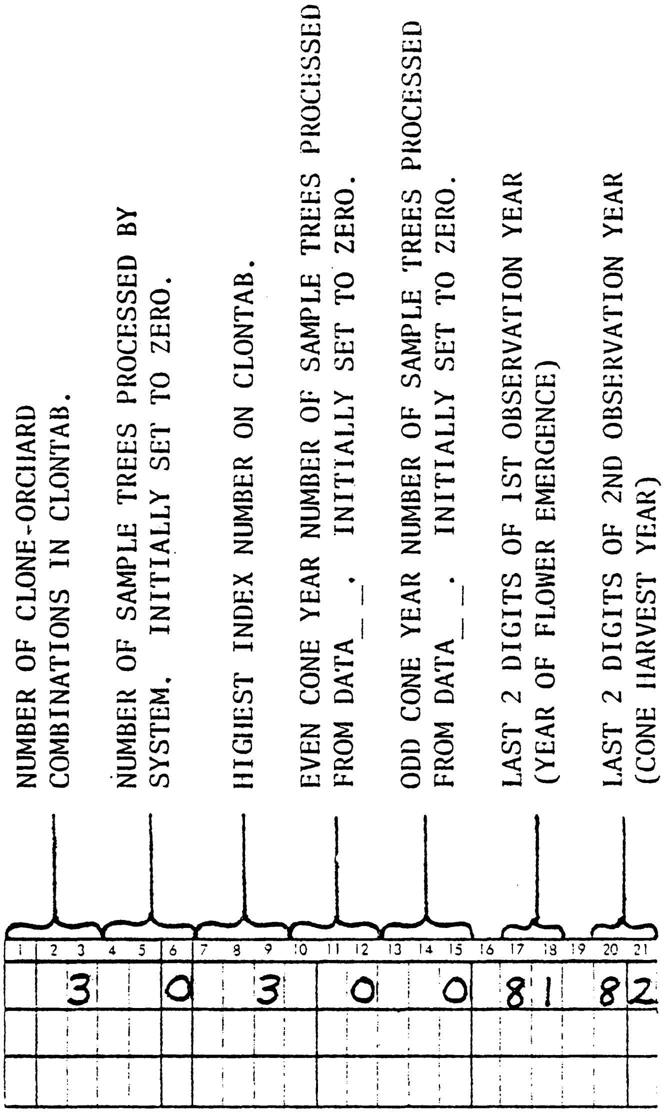
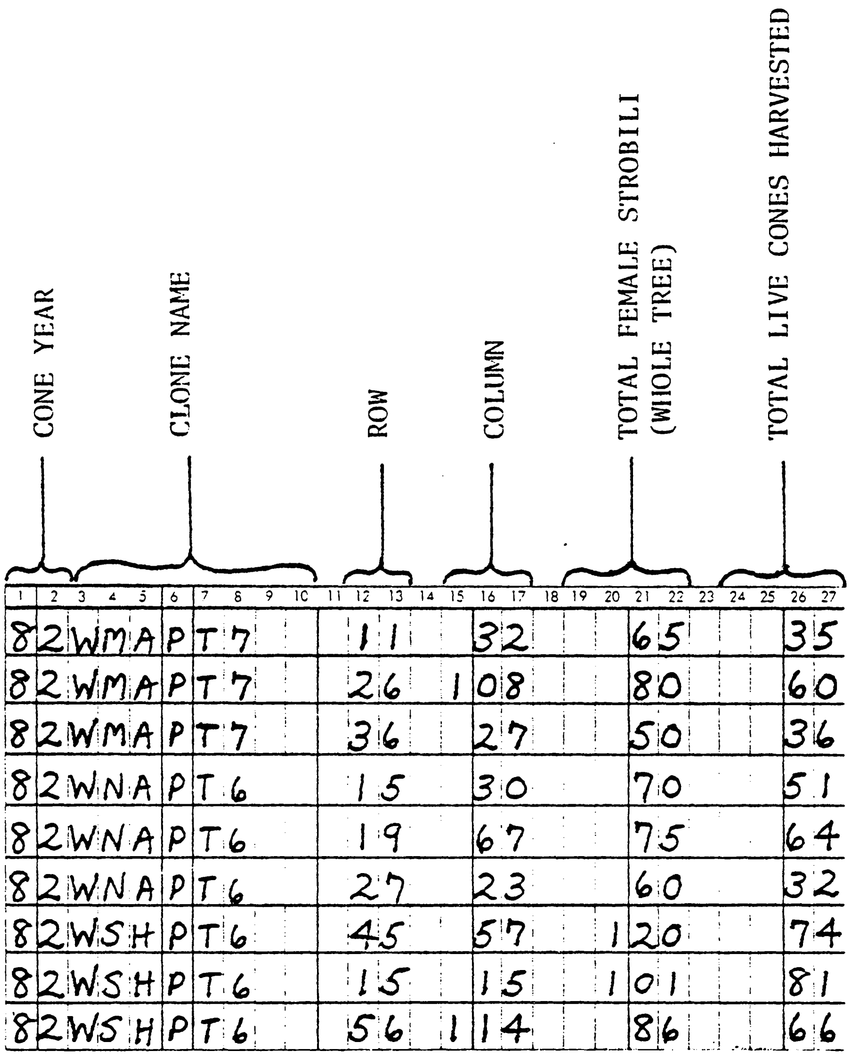


Figure 2. Sample SYSTAT. In this sample system status record, note that all the "counters" have been zeroed-out and that the year columns are set to process the 1982 cone crop.

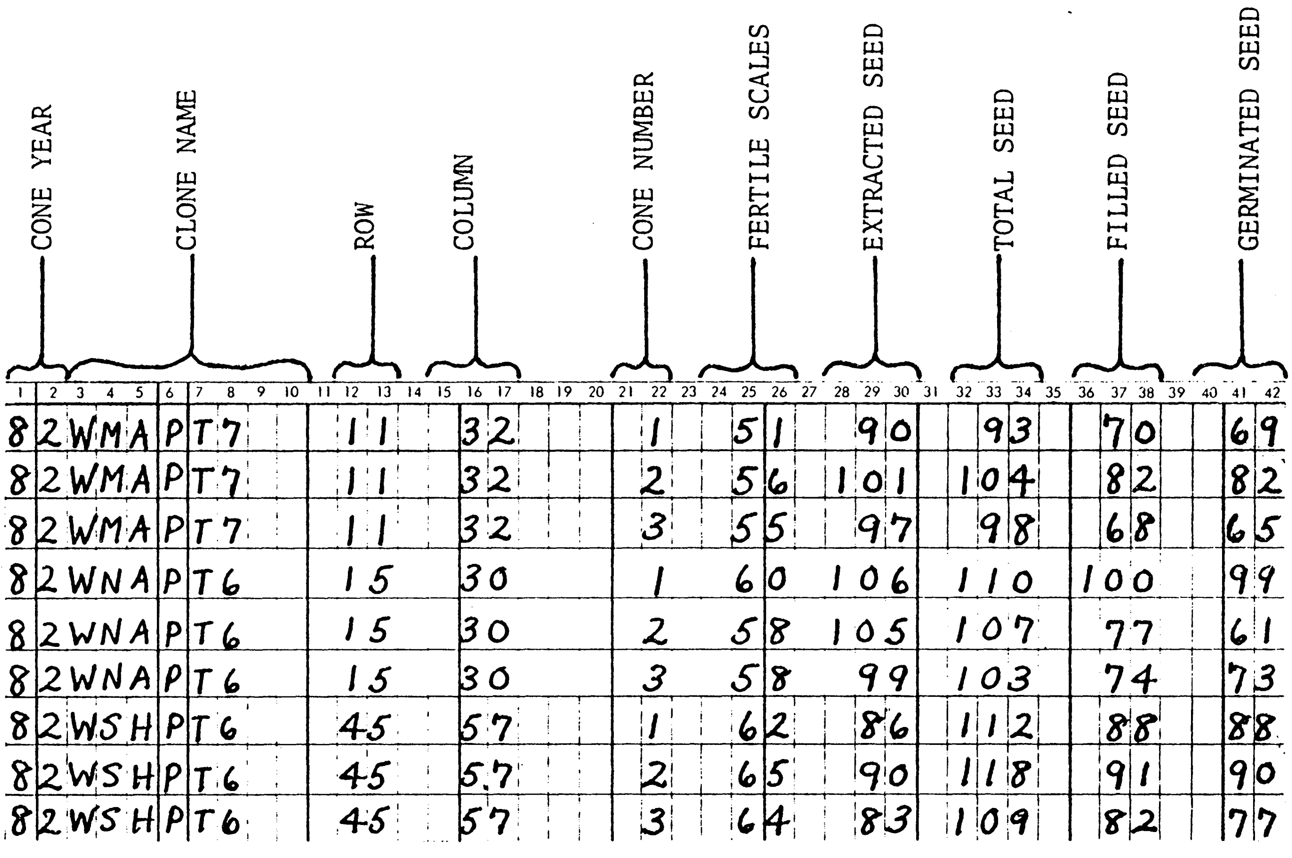
CONE YEAR (1–2)	ORCHARD NAME (3–6)	CLONE NAME (7–19)	ROW (20–21)	COLUMN (22–24)	YEAR GRAFTED (25–26)	NUMBER OF RAMETS IN SAME AGE CLASS (27–29)	TOTAL FEMALE STROBILI (WHOLE TREE) (30–33)	INITIAL = TOTAL FEMALE STROBILI (SAMPLE BRANCHES) (34–36)	1ST MARCH = TOTAL SURVIVING FEMALE STROBILI (SAMPLE BRANCHES) (37–39)	1ST JUNE (40–42)	1ST OCTOBER (43–45)	2ND MARCH (46–48)	2ND JUNE (49–51)	FINAL (52–54)	ESTIMATED SEED POTENTIAL (55–57)	ESTIMATED CONE EFFICIENCY (58–59)	ESTIMATED SEED EFFICIENCY (60–61)	ESTIMATED EXTRACTION EFFICIENCY (62–63)	ESTIMATED GERMINATION EFFICIENCY (64–65)
82	425L	WMAPT7	11	32	73	12	65	25	22	20	20				110	60	70	90	95
82	425L	WMAPT7	26	108	73	12	80	40	38	37	30				110	60	70	90	95
82	425L	WMAPT7	36	27	75	10	50	32	32	30	25				110	60	70	90	95
82	425L	WNAPT6	15	30	75	17	70	35	30	28	25				130	60	70	90	95
82	425L	WNAPT6	19	67	75	17	75	40	38	35	35				130	60	70	90	95
82	425L	WNAPT6	27	23	75	17	60	30	30	18	15				130	60	70	90	95
82	425L	WSHPT6	45	57	73	15	120	94	90	87	82				120	60	70	90	95
82	425L	WSHPT6	15	15	73	15	101	87	80	80	71				120	60	70	90	95
82	425L	WSHPT6	56	114	73	15	86	39	29	29	28				120	60	70	90	95

Figure 3. Sample DATA_ _ (DATA82). In this sample user "Observations"data set for a 1982 cone crop there are three clones, each represented by three sample trees. Note that clone WMAPT7 has sample trees representing two age classes. This sample DATA82 has sample branch flower count data through the "FIRST OCTOBER" observation, with the rest of the flower counts yet to be filled in. The efficiency estimates are just general estimates, not obtained from actual cone analysis data.



CONE YEAR	CLONE NAME	ROW	COLUMN	TOTAL FEMALE STROBILI (WHOLE TREE)	TOTAL LIVE CONES HARVESTED
82	WMAPT7	11	32	65	35
82	WMAPT7	26	108	80	60
82	WMAPT7	36	27	50	36
82	WNAPT6	15	30	70	51
82	WNAPT6	19	67	75	64
82	WNAPT6	27	23	60	32
82	WSHPT6	45	57	120	74
82	WSHPT6	15	15	101	81
82	WSHPT6	56	114	86	66

Figure 4. Sample ACTFLC_ _ (ACTFLC82) This "actual flowers and cones" data set contains the same nine sample trees as the sample DATA_ _ data set, DATA82. Note that the "Total Female Strobili (Whole Tree)" counts are the same on ACTFLC82 and DATA82.



CONE YEAR	CLONE NAME	ROW	COLUMN	CONE NUMBER	FERTILE SCALES	EXTRACTED SEED	TOTAL SEED	FILLED SEED	GERMINATED SEED
82	WMAPT7	11	32	1	51	90	93	70	69
82	WMAPT7	11	32	2	56	101	104	82	82
82	WMAPT7	11	32	3	55	97	98	68	65
82	WNAPT6	15	30	1	60	106	110	100	99
82	WNAPT6	15	30	2	58	105	107	77	61
82	WNAPT6	15	30	3	58	99	103	74	73
82	WSHPT6	45	57	1	62	86	112	88	88
82	WSHPT6	45	57	2	65	90	118	91	90
82	WSHPT6	45	57	3	64	83	109	82	77

Figure 5. Sample ACTCAS_ _ (ACTCAS82). This sample "actual cone analysis" data set has cone analysis data for three clones, each represented by three cones sampled from one tree of each clone.

EXAMPLES OF COMPUTERIZED IMS OUTPUT

```
 INITIAL RUN FOR CONE YR. 82 ACTUAL YR. 81
======================================
 RESULTS FOR CLONE WMAPT7        ORCHARD 42SL YEAR 82
  CONE EFF. (PCE)=  0.60     SEED EFF. (PSE)=  0.70
  SEED POT. (PSP)=  110.0     EXT. EFF. (PEE)=  0.90
  GERM. EFF. (PGE)=  0.95    NO. RAMETS (NR)= 22
  AVG. FEM. FLOWERS/RAMET (NF)=   62.27
  CONES PER BU.=     220     SEED PER LB.= 16000
 PREDICTED SEED (PTS=NR*NF*PCE*PSP*PSE)                     63293.96
 PREDICTED NO. EXT. SEED (PES=PTS*PEE)                      56964.53
 PREDICTED BUSHELS OF CONES (PBU=(NR*NF*PCE)/CONBU)             3.74
 PREDICTED CONES (PCO=(NR*NF*PCE))                            822.00
 PREDICTED LBS EXTRACTED SEED (PLB=(PTS*PEE)/SEED               3.56
 PREDICTED NO. SEEDLINGS (PVS=PES*PGE)                     54116.28
.PREDICTED ORCH. TO NURS. EFF.                                 35.91 %
======================================
 RESULTS FOR CLONE WNAPT6        ORCHARD 42SL YEAR 82
  CONE EFF. (PCE)=  0.60     SEED EFF. (PSE)=  0.70
  SEED POT. (PSP)=  130.0     EXT. EFF. (PEE)=  0.90
  GERM. EFF. (PGE)=  0.95    NO. RAMETS (NR)= 17
  AVG. FEM. FLOWERS/RAMET (NF)=   68.33
  CONES PER BU.=     323     SEED PER LB.= 16000
 PREDICTED SEED (PTS=NR*NF*PCE*PSP*PSE)                     63426.89
 PREDICTED NO. EXT. SEED (PES=PTS*PEE)                      57084.18
 PREDICTED BUSHELS OF CONES (PBU=(NR*NF*PCE)/CONBU)             2.16
 PREDICTED CONES (PCO=(NR*NF*PCE))                            697.00
 PREDICTED LBS EXTRACTED SEED (PLB=(PTS*PEE)/SEED               3.57
 PREDICTED NO. SEEDLINGS (PVS=PES*PGE)                     54229.95
 PREDICTED ORCH. TO NURS. EFF.                                 35.91 %
======================================
 RESULTS FOR CLONE WSHPT6        ORCHARD 42SL YEAR 82
  CONE EFF. (PCE)=  0.60     SEED EFF. (PSE)=  0.70
  SEED POT. (PSP)=  120.0     EXT. EFF. (PEE)=  0.90
  GERM. EFF. (PGE)=  0.95    NO. RAMETS (NR)= 15
  AVG. FEM. FLOWERS/RAMET (NF)=  102.33
  CONES PER BU.=     416     SEED PER LB.= 16000
 PREDICTED SEED (PTS=NR*NF*PCE*PSP*PSE)                     77363.87
 PREDICTED NO. EXT. SEED (PES=PTS*PEE)                      69627.44
 PREDICTED BUSHELS OF CONES (PBU=(NR*NF*PCE)/CONBU)             2.21
 PREDICTED CONES (PCO=(NR*NF*PCE))                            921.00
 PREDICTED LBS EXTRACTED SEED (PLB=(PTS*PEE)/SEED               4.35
 PREDICTED NO. SEEDLINGS (PVS=PES*PGE)                     66146.00
 PREDICTED ORCH. TO NURS. EFF.                                 35.91 %
======================================
======================================
======================================
 RESULTS FOR ORCHARD 42SL
 PREDICTED ORCHARD SEED PRODUCTION (SUM PTS)      204084.7
 PREDICTED NO. OF BUSHELS OF CONES (SUM PBU)           8.1
 PREDICTED NO. OF CONES (SUM PCO)                   2440.0
 PREDICTED NO. OF SEEDLINGS (SUM PVS)             174492.2
 PREDICTED LBS. OF SEED (SUM PLB)                     11.5
 PREDICTED ORCH. TO NURS. EFF.                                 35.91 %
```

Figure 6. Sample OUTPUT from INITIAL run. The results printed on this sample OUTPUT file were computed by IMSYS in an INITIAL "Predictions" run, using the INITIAL flower counts on DATA82.

```
 RESULTS FOR OCTOBER CONE YR. 82 ACTUAL YR. 81
====================================
 RESULTS FOR CLONE WMAPT7        ORCHARD 42SL YEAR 82
  CONE EFF. (PCE)=  0.38     SEED EFF. (PSE)=  0.70
  SEED POT. (PSP)=  110.0     EXT. EFF. (PEE)=  0.90
  GERM. EFF. (PGE)=  0.95    NO. RAMETS (NR)= 22
  AVG. FEM. FLOWERS/RAMET (NF)=   62.27
  CONES PER BU.=    220     SEED PER LB.= 16000
 PREDICTED SEED (PTS=NR*NF*PCE*PSP*PSE)                   40437.78
 PREDICTED NO. EXT. SEED (PES=PTS*PEE)                    36393.98
 PREDICTED BUSHELS OF CONES (PBU=(NR*NF*PCE)/CONBU)           2.39
 PREDICTED CONES (PCO=(NR*NF*PCE))                          525.17
 PREDICTED LBS EXTRACTED SEED (PLB=(PTS*PEE)/SEED             2.27
 PREDICTED NO. SEEDLINGS (PVS=PES*PGE)                   34574.27
 PREDICTED ORCH. TO NURS. EFF.                               22.94 %
====================================
 RESULTS FOR CLONE WNAPT6        ORCHARD 42SL YEAR 82
  CONE EFF. (PCE)=  0.50     SEED EFF. (PSE)=  0.70
  SEED POT. (PSP)=  130.0     EXT. EFF. (PEE)=  0.90
  GERM. EFF. (PGE)=  0.95    NO. RAMETS (NR)= 17
  AVG. FEM. FLOWERS/RAMET (NF)=   68.33
  CONES PER BU.= .  323     SEED PER LB.= 16000
 PREDICTED SEED (PTS=NR*NF*PCE*PSP*PSE)                   52478.17
 PREDICTED NO. EXT. SEED (PES=PTS*PEE)                    47230.33
 PREDICTED BUSHELS OF CONES (PBU=(NR*NF*PCE)/CONBU)           1.79
 PREDICTED CONES (PCO=(NR*NF*PCE))                          576.68
 PREDICTED LBS EXTRACTED SEED (PLB=(PTS*PEE)/SEED             2.95
 PREDICTED NO. SEEDLINGS (PVS=PES*PGE)                   44868.79
 PREDICTED ORCH. TO NURS. EFF.                               29.71 %
====================================
 RESULTS FOR CLONE WSHPT6        ORCHARD 42SL YEAR 82
  CONE EFF. (PCE)=  0.60     SEED EFF. (PSE)=  0.70
  SEED POT. (PSP)=  120.0     EXT. EFF. (PEE)=  0.90
  GERM. EFF. (PGE)=  0.95    NO. RAMETS (NR)= 15
  AVG. FEM. FLOWERS/RAMET (NF)=  102.33
  CONES PER BU.=    416     SEED PER LB.= 16000
 PREDICTED SEED (PTS=NR*NF*PCE*PSP*PSE)                   77638.12
 PREDICTED NO. EXT. SEED (PES=PTS*PEE)                    69874.25
 PREDICTED BUSHELS OF CONES (PBU=(NR*NF*PCE)/CONBU)           2.22
 PREDICTED CONES (PCO=(NR*NF*PCE))                          924.26
 PREDICTED LBS EXTRACTED SEED (PLB=(PTS*PEE)/SEED             4.37
 PREDICTED NO. SEEDLINGS (PVS=PES*PGE)                   66380.50
 PREDICTED ORCH. TO NURS. EFF.                               36.04 %
====================================
====================================
====================================
 RESULTS FOR ORCHARD 42SL
 PREDICTED ORCHARD SEED PRODUCTION (SUM PTS)     170554.1
 PREDICTED NO. OF BUSHELS OF CONES (SUM PBU)          6.4
 PREDICTED NO. OF CONES (SUM PCO)                  2026.1
 PREDICTED NO. OF SEEDLINGS (SUM PVS)            145823.5
 PREDICTED LBS. OF SEED (SUM PLB)                     9.6
 PREDICTED ORCH. TO NURS. EFF.                               29.56 %
```

Figure 7. Sample OUTPUT from FIRST OCTOBER run. The results printed on this sample OUTPUT file were computed by IMSYS in a FIRST OCTOBER "Predictions" run, using the FIRST OCTOBER flower counts on DATA82.

```
CONE PRODUCTION GUIDE ----- INITIAL    CONE YR. 82 ACTUAL YR. 81

   CLONE ID         BUSHELS OF CONES    TOTAL CONES     RAMETS
   --------         ----------------    -----------     ------
   WMAPT7                       3.74         822.00         22
   WNAPT6                       2.16         697.00         17
   WSHPT6                       2.21         921.00         15
```

```
CONE PRODUCTION GUIDE ----- OCTOBER    CONE YR. 82 ACTUAL YR. 81

   CLONE ID         BUSHELS OF CONES    TOTAL CONES     RAMETS
   --------         ----------------    -----------     ------
   WMAPT7                       2.39         525.17         22
   WNAPT6                       1.79         576.68         17
   WSHPT6                       2.22         924.26         15
```

Figure 8. Sample CONPROD from INITIAL and FIRST OCTOBER runs. The results printed on these sample cone production reports are simply abbreviated versions of the results printed on OUTPUT for the INITIAL and FIRST OCTOBER runs.

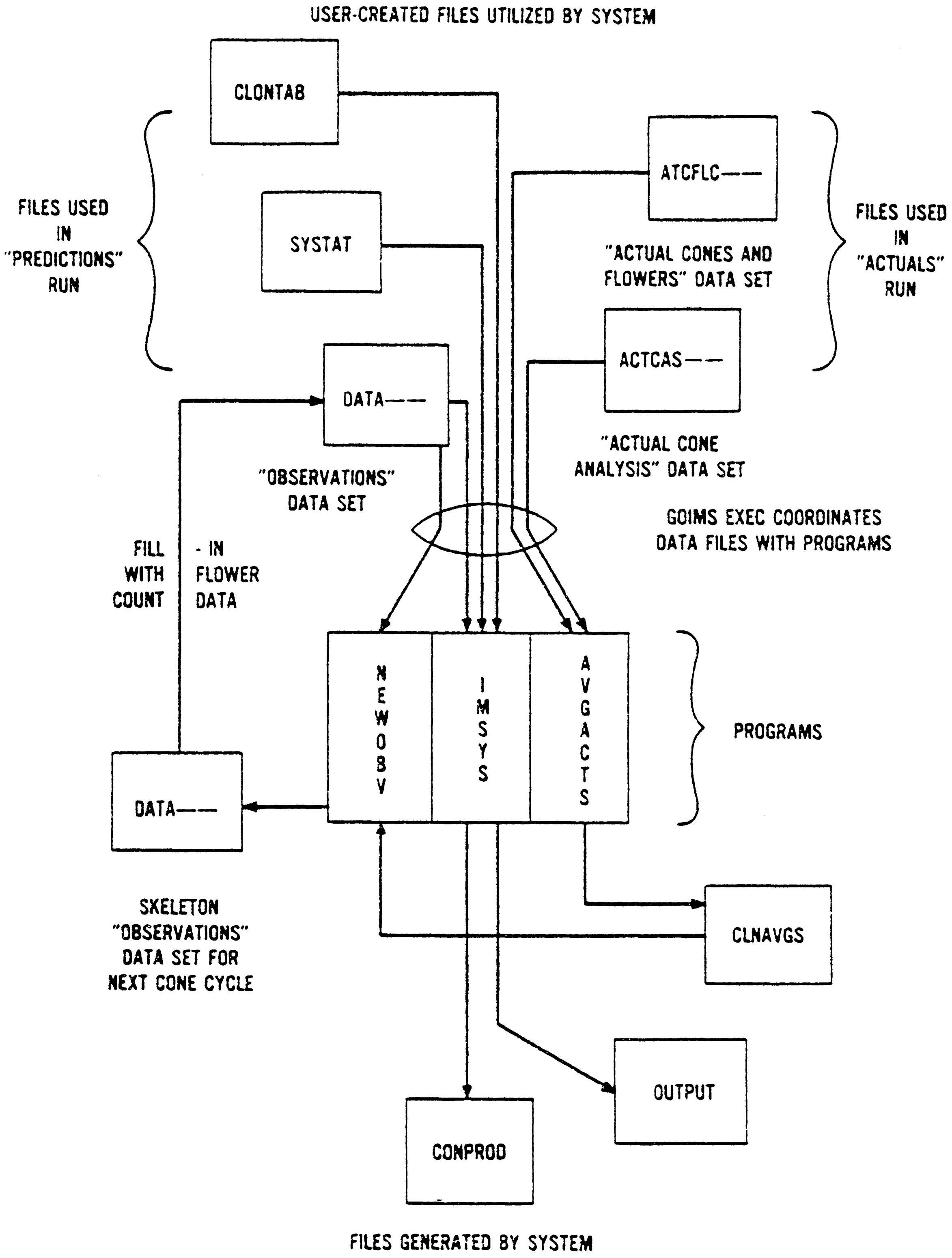
```
                ****CLONAL AVERAGES****
 CLONE        SP       CE     SE     EE     GE    SONE
 -----       ----     ----   ----   ----   ----   ----
WMAPT7     108.00   0.67   0.68   0.98   0.98   0.44
WNAPT6     117.33   0.72   0.71   0.97   0.93   0.46
WSHPT6     127.33   0.72   0.68   0.76   0.98   0.37
```

Figure 9. Sample CLNAVGS. The clonal averages for seed potential, cone efficiency, seed efficiency, extraction efficiency, germination efficiency and seed orchard-to-nursery efficiency were computed by AVGACTS in an "Actuals" run.

```
8442SLWMAPT7        11 3273 12                              10963699496
8442SLWMAPT7        2610873 12                              10963699496
8442SLWMAPT7        36 2775 10                              10963699496
8442SLWNAPT6        15 3075 17                              12366709394
8442SLWNAPT6        19 6775 17                              12366709394
8442SLWNAPT6        27 2375 17                              12366709394
8442SLWSHPT6        45 5773 15                              12366698396
8442SLWSHPT6        15 1573 15                              12366698396
8442SLWSHPT6        5611473 15                              12366698396
```

Figure 10. Sample DATA_ _ (DATA84). This sample DATA_ _ file resembles the user-created DATA82 file shown in Figure 3. DATA84, however, was created by NEWOBV, using DATA82 and CLNAVGS (see Figure 9). Note that the efficiency estimates in DATA84 have been updated by averaging the old efficiency estimates in DATA82 with the actual clonal averages for these efficiency values from CLNAVGS. NEWOBV leaves the spaces in the center of DATA84 blank for the user to fill in with flower count data as they become available.

USER'S FLOW CHART FOR COMPUTERIZED INVENTORY-MONITORING SYSTEM



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Bramlett, D. L. and J. F. Godbee, Jr. 1982. Inventory-monitoring systems for southern pine seed orchards. Georgia Forest Research Paper No. 28. Georgia Forestry Commission, Macon, GA. 11 p.

Bramlett, D. L., E. W. Belcher Jr., G. L. Debarr, G. D. Hertel, R. P. Karrfalt, C. W. Lantz, T. Miller, K. D. Ware, and H. O. Yates III. 1977. Cone analysis of southern pines, a guidebook. USDA Forest Service General Technical Report SE-13. Southeastern Forest Expriment Station, Asheville NC, and Southeastern Area, State and Private Forestry, Atlanta, GA. 28 p.

IMS PROGRAMS

GOIMS

```
&CONTROL ERROR
GLOBAL TXTLIB FORTXLIB
*GLOBAL MACLIB WATLIB
CP TERMINAL LINESIZE 132
FILEDEF 04 TERMINAL
FILEDEF 06 TERMINAL
FILEDEF 19 TERMINAL
-MSG
&BEGTYPE


WELCOME TO THE "INVENTORY MONITORING SYSTEM."  WHEN READY TO BEGIN
YOUR SESSION, ENTER A NULL LINE.
&END
&READ ARGS
&IF &INDEX EQ 0 &SKIP 1
&GOTO -MSG
-PRED?
&BEGTYPE


DO YOU INTEND TO MAKE A "PREDICTIONS" RUN DURING THIS SESSION? (YES|NO)


&END
&READ ARGS
&IF &INDEX EQ 0 &1 = NO
&IF &1 EQ NO &GOTO -ACTS?
&IF &1 EQ N &GOTO -ACTS?
&IF &1 EQ YES &GOTO -PRO1
&IF &1 EQ Y &GOTO -PRO1
&TYPE *** ERROR *** INVALID RESPONSE. TRY AGAIN!
&GOTO -PRED?
-PRO1
&BEGTYPE
ENTER "OBSERVATIONS" DATA SET NAME. ENTER (FN FT FM)
&END
-LABEL1
&READ ARGS
&IF &INDEX EQ 3 &SKIP 3
&TYPE *** ERROR *** WRONG FORMAT.
&TYPE               SHOULD BE: FN FT FM, PLEASE REENTER.
&GOTO -LABEL1
&UDFN = &1
&UDFT = &2
&UDFM = &3
FI 03 DISK &UDFN &UDFT &UDFM ( PERM LRECL 80 BLKSIZE 800 RECFM FB )
FI 08 DISK SYSTAT DATA A1 ( LRECL 80 BLOCK 80 RECFM F
FI 01 DISK CLONTAB DATA A1 ( PERM LRECL 40 BLKSIZE 400 RECFM FB )
FI 02 DISK PCETAB DATA A1 ( LRECL 130 BLOCK 130 RECFM F )
FI 12 DISK ORCHDAT1 DATA A ( LRECL 130 BLOCK 130 RECFM FB )
FI 09 DISK ORCHDAT2 DATA A1 (LRECL 130 BLOCK 130 RECFM FB)
FI 11 DISK CONPROD GUIDE A1 ( LRECL 80 BLOCK 80 RECFM FB )
FI 10 DISK OUTPUT DATA A1 ( LRECL 80 BLOCK 80 RECFM FB )
LOAD IMSYS ( CLEAR NOMAP START )
*WATFIV MAIN
&BEGTYPE
          PREDICTIONS CALCULATED.

    PREDICTIVE REPORT EXISTS ON DISK FILE "OUTPUT DATA A1".
    CONE PRODUCTION GUIDE EXISTS ON DISK FILE "CONPROD GUIDE A1".
```

```
&END
-ACTS?
&BEGTYPE


DO YOU INTEND TO MAKE AN "ACTUALS" RUN DURING THIS SESSION ? (YES|NO)
&END
&READ ARGS
&IF &INDEX EQ 0 &1 = NO
&IF &1 EQ NO &GOTO -DONE
&IF &1 EQ N &GOTO -DONE
&IF &1 EQ YES &GOTO -PRO2
&IF &1 EQ Y &GOTO -PRO2
&TYPE *** ERROR *** INVALID RESPONSE. TRY AGAIN!
&GOTO -ACTS?
-PRO2
&BEGTYPE


ENTER "ACTUAL FLOWERS AND CONES" DATA SET NAME (FN FT FM).
&END
-LABEL2
&READ ARGS
&IF &INDEX EQ 3 &SKIP 3
&TYPE *ERROR* WRONG FORMAT.
&TYPE SHOULD BE FN FT FM, REENTER
&GOTO -LABEL2
&CRFN = &1
&CRFT = &2
&CRFM = &3
FI 11 DISK &CRFN &CRFT &CRFM (LRECL 80 BLOCK 80 RECFM FB)
&BEGTYPE


ENTER "ACTUAL CONE ANALYSIS" DATA SET NAME (FN FT FM).
&END
-LABEL3
&READ ARGS
&IF &INDEX EQ 3 &SKIP 3
&TYPE *ERROR* WRONG FORMAT.
&TYPE SHOULD BE FN FT FM, REENTER.
&GOTO -LABEL3
&CAFN = &1
&CAFT = &2
&CAFM = &3
FI 13 DISK &CAFN &CAFT &CAFM ( LRECL 80 BLOCK 80 RECFM FB)
FI 18 DISK CLNAVGS DATA A1 ( LRECL 80 BLOCK 80 RECFM FB )
FI 08 DISK SLAVE DATA A1 (LRECL 80 BLOCK 80 RECFM FB )
&BEGTYPE

            CALCULATING CLONAL AVERAGES FROM ACTUAL CONE ANALYSIS DATA.


&END
LOAD AVGACTS ( CLEAR NOMAP START )
&BEGTYPE


            CLONAL AVERAGES COMPUTED --- REPORT OF RESULTS EXISTS
            ON DISK FILE "CLNAVGS DATA A1".
```

```
&END
-NEWOBV
&BEGTYPE


DO YOU WISH TO USE THE CALCULATED CLONAL AVERAGES AS A BASIS
FOR A NEW USER "OBSERVATIONS" DATA SET? (YES|NO)
&END
&READ ARGS
&IF &INDEX EQ 0 &1 = NO
&IF &1 EQ NO &GOTO -DONE
&IF &1 EQ N &GOTO -DONE
&IF &1 EQ YES &GOTO -PRO3
&IF &1 EQ Y &GOTO -PRO3
&TYPE *** ERROR *** INVALID RESPONSE. TRY AGAIN!
&GOTO -NEWOBV
-PRO3
&BEGTYPE


WHICH EXISTING "OBSERVATIONS" DATA SET DO YOU WISH IT MODELED
AFTER? (ENTER FN FT FM)
&END
-LABEL4
&READ ARGS
&IF &INDEX EQ 3 &SKIP 3
&TYPE *** ERROR *** WRONG FORMAT.
&TYPE               SHOULD BE: FN FT FM, PLEASE REENTER.
&GOTO -LABEL4
&ODFN = &1
&ODFT = &2
&ODFM = &3
FI 03 DISK &ODFN &ODFT &ODFM (PERM LRECL 80 BLKSIZE 800 RECFM FB )
&BEGTYPE


WHAT DO YOU WISH TO CALL THE NEWLY CREATED "OBSERVATIONS"
DATA SET ? (ENTER FILENAME ONLY)
&END
-LABEL5
&READ ARGS
&IF &INDEX EQ 1 &SKIP 3
&TYPE *** ERROR *** WRONG FORMAT.
&TYPE               PLEASE REENTER, "FILENAME" ONLY.
&GOTO -LABEL5
&NDFN = &1
FI 10 DISK &1 DATA A1 ( LRECL 80 BLOCK 800 RECFM FB )
FI 18 DISK CLNAVGS DATA A1 (LRECL 80 BLOCK 80 RECFM FB )
&BEGTYPE

            CREATING NEW USER "OBSERVATIONS" DATA SET.


&END
LOAD NEWOBV ( CLEAR NOMAP START )
&BEGTYPE


             NEW "OBSERVATIONS" DATA SET CREATED AND STORED ON
             DISK UNDER THE FILENAME YOU SPECIFIED ABOVE.
&END
```

```
-DONE
&BEGTYPE

            THE SESSION IS OVER --- RETURNING USER TO CMS.

&END
&EXIT
```

IMSYS

```
C$JOB WATFIV,FREE
C
C                             PROGRAM "IMSYS"
C
C----------------------------------------------------------------------C
C                             ROUTINE "MAIN"                           C
C     ROUTINE "MAIN" DIRECTS EXECUTION OF THE SUBROUTINES WHICH        C
C     ACCOMPLISH THE VARIOUS TASKS REQUIRED OF THE SYSTEM. A GENERAL   C
C     OUTLINE OF THESE TASKS FOLLOWS:                                  C
C        1.) QUERY USER FOR OBSERVATION YEAR AND MONTH.                C
C        2.) ACCESS SYSTAT FILE(08) TO INITIALIZE SYSTEM COUNTERS.     C
C        3.) READ LAST RUN'S PREDICTED CONE EFFICIENCY TABLE (STORED   C
C            ON DISK FILE 02 (PCETAB)) INTO CURRENT RUN'S PREDICTED    C
C            CONE EFFICIENCY TABLE IF OTHER THAN INITIAL RUN.          C
C        4.) CALL SUBROUTINE "SPDAT" TO INPUT CURRENT MONTH'S          C
C            OBSERVATIONS.                                             C
C        5.) CALL SUBROUTINE DAVER TO PERFORM THE REQUIRED             C
C            CALCULATIONS.                                             C
C        6.) SAVE THE PCETAB TABLE BY WRITING ITS CONTENTS TO DISK     C
C            FILE 02.                                                  C
C        7.) STOP                                                      C
C----------------------------------------------------------------------C

      INTEGER DESC(6),CLONE(3)
      COMMON CLONE,LOC,ICONYR,IYR,INDEX,ICONBU,ISEDLB,NORM,I1ST,I2ND
      COMMON INDEX2(255),ICOL2(255),IROW2(255),ASUM2(255,16),
     1CSUM2(255,4),DSUM2(255,4),NFR2(255),IYRGF2(255)
      DIMENSION IREP(4)
      DATA IREP/'Y','N'/

C
C------->QUERY USER FOR CONE HARVEST YEAR(EVEN OR ODD) AND OBSERVATION
C------->MONTH(1,2,3,4,5,6,OR 7).
C
      WRITE(19,1000)
1000  FORMAT(' ENTER WHETHER CONE HARVEST YEAR EVEN OR ODD.              '/
     1'        ENTER:      "1" FOR "ODD YEAR"                           '/
     2'               OR   "2" FOR "EVEN YEAR"  ')
      READ(04,11) IYRT
      IYR=IYRT

10    WRITE(19,2000)
2000  FORMAT(' ENTER CODE OF CURRENT OBSERVATION MONTH:                  '/
     1'          1  =  INITIAL OBSERVATION                             '/
     2'          2  =  1ST MARCH OBSERVATION                           '/
     3'          3  =  1ST JUNE OBSERVATION                            '/
     4'          4  =  OCTOBER OBSERVATION                             '/
     5'          5  =  2ND MARCH OBSERVATION                           '/
     6'          6  =  2ND JUNE OBSERVATION                            '/
     7'          7  =  FINAL OBSERVATION    ')
      READ(04,11) IMON
11    FORMAT(I1)
      IF(IMON.LT.1.OR.IMON.GT.7) GO TO 12
      GO TO 14
12    WRITE(04,13)
13    FORMAT(' INVALID OBSERVATION MONTH --- REENTER.')
      GO TO 10
C

C------->READ SYSTEM STATUS RECORD FROM UNIT 08(SYSTAT)
C---------> NOC  = NO. OF CLONE-ORCH. COMBINATIONS ON 01(CLONTAB)
```

```
C----------> NORM = NO. OF ROW-COLUMNS WRITTEN TO 02(PCETAB) BY SYSTEM
C----------> IND  = HIGHEST INDEX ON FILE 01(CLONTAB)
C----------> NOE  = EVEN YR. NO. OF ROW COLUMNS FROM USER INPUT(03)
C----------> NOD  = ODD YR. NO. OF ROW-COLUMNS FROM USER INPUT(03)
C----------> I1ST-->I2ND = OBSERVATION YEARS INCLUDED IN THE STUDY
C
14    CONTINUE
      REWIND 08
      READ(08,200) NOC,NORM,IND,NOE,NOD,I1ST,I2ND
200   FORMAT(8I3)
C

C-------->SET "NOO7" TO THE NUMBER OF RECORDS TO BE PROCESSED IN
C-------->ORCHDAT1 (FILE 12) FOR ODD CONE YEAR OR ORCHDAT2 (FILE 09)
C-------->FOR EVEN CONE YEAR AS DETERMINED BY THE SYSTEM DURING INPUT
C-------->OF USERS OBSERVATION DATA ( A ONE TO ONE CORRESPONDENCE
C-------->EXISTS). SET NOO7=NOD FOR ODD CONE YEAR OR NOO7=NOE FOR EVEN
C-------->CONE YEAR.
C
      IF(IYRT-1) 50,60,50
60    NOO7=NOD
      GO TO 70
50    NOO7=NOE

C
C-------->READ LAST RUN'S PREDICTED CONE EFFICIENCY TABLE INTO CURRENT
C-------->RUN'S PREDICTED CONE EFFICIENCY TABLE IF OTHER THAN INITIAL
C-------->RUN.
C
70    IF (IMON-1) 9005,83,80
80    REWIND 02
      DO 100 I=1,NORM
      READ(02,205) INDEX2(I),IROW2(I),ICOL2(I),NFR2(I),IYRGF2(I)
      READ(02,206) (ASUM2(I,J),J=1,16)
      READ(02,206) (CSUM2(I,J),J=1,4),(DSUM2(I,J),J=1,4)
100   CONTINUE
205   FORMAT(I5,2I3,2I4)
206   FORMAT(16F8.2)
83    CONTINUE

81    ISTP=0

C
C-------->CALL SPDAT TO INPUT AND VERIFY USER INPUT DATA
C
      CALL SPDAT(IMON,ISTP,IYRT,NOO7,NOC,IND,NOE,NOD)
      IF(ISTP) 9004,9004,9005
9004  WRITE(19,9034)
      WRITE(19,9033)
      WRITE(19,9034)
9033  FORMAT(' USER DATA UPDATE COMPLETE --- CALCULATIONS BEGIN. ')
9034  FORMAT( // )

C
C-------->CALL DAVER TO PERFORM CALCULATIONS ON INPUT DATA
C
      CALL DAVER(IMON,NOO7)

C
C-------->SAVE CONTENTS OF PCETAB TABLE BY WRITING TO DISK 02(PCETAB)
C
```

```
      REWIND 02
      DO 300 I=1,NORM
      WRITE(02,205)INDEX2(I),IROW2(I),ICOL2(I),NFR2(I),IYRGF2(I)
      WRITE(02,206) (ASUM2(I,J),J=1,16)
      WRITE(02,206)(CSUM2(I,J),J=1,4),(DSUM2(I,J),J=1,4)
300   CONTINUE
C
C------->GIVE USER THE CHANCE TO EXECUTE THE SYSTEM AGAIN
C
      WRITE(19,9034)
365   WRITE(19,375)
375   FORMAT(' ARE THERE ADDITIONAL OBSERVATIONS ON YOUR INPUT FILE  '/
     1' YOU WISH TO PROCESS? (Y/N) ')
      READ(04,376) IANS
      WRITE(19,9034)
376   FORMAT(A1)
      IF(IANS.EQ.IREP(1)) GO TO 10
      IF(IANS.NE.IREP(2)) GO TO 365
9005  CONTINUE
      STOP
      END
C-------------------------------------------------------------------C
C                           SUBROUTINE "SPDAT"                      C
C                                                                   C
C     SUBROUTINE "SPDAT" IS CALLED BY ROUTINE "MAIN" TO INPUT THE   C
C     USER'S CURRENT OBSERVATION DATA FROM DISK FILE 03 , BUILD AND C
C     UPDATE THE ORCHARD DATA TABLE AND INITIATE CONSTRUCTION OF THE C
C     INITIAL PREDICTED CONE EFFICIENCY TABLE.                      C
C-------------------------------------------------------------------C
      SUBROUTINE SPDAT(IMON,ISTP,IYRT,NOO7,NOPC,INDL,NOE,NOD)
      INTEGER CLONE(3)
      COMMON CLONE,LOC,ICONYR,IYR,INDEX,ICONBU,ISSED,NORM,I1ST,I2ND
      COMMON INDEX2(255),ICOL2(255),IROW2(255),ASUM2(255,16),
     1CSUM2(255,4),DSUM2(255,4),NFR2(255),IYRGF2(255)
      DIMENSION ICYRR7(255),LOCC7(255),ICLCC1(255),ICLCC2(255),
     1ICLCC3(255),IRW7(255),ICL7(255),IYRGF7(255),NRAMT7(255),NF7(255),
     2IBRCT7(255),IMAR1(255),IJUN1(255),IOCT(255),IMAR2(255),
     3IJUN2(255),IFINAL(255),IESP(255),IECE(255),IESE(255),IEEE(255),
     4IEGE(255),IASP(255),IASE(255),IAEE(255),IAGE(255)
      DIMENSION IREST(17),IZERO(6)
      INTEGER LOCC,CLCC(3)
      REWIND 03
      IK7=0
      NORMH=NORM
      NEW8=0
      DO 9060 IKL=1,6
9060  IZERO(IKL)=0
      IF(IMON-1) 1000,1000,2000
C
C------->INPUT INITIAL OBSERVATION DATA
C
C------->READ INITIAL OBSERVATION DATA. BUILD STARTING ORCHARD DATA
C------->TABLE AND WRITE IT TO DISK FILE 12 (ORCHDAT1) FOR ODD CONE
C------->YEAR OR DISK FILE 09 (ORCHDAT2) FOR EVEN CONE YEAR. BUILD
C------->STARTING PREDICTED CONE EFFICIENCY TABLE BY CALLING SUBROUTINE
C------->"FINDRO". UPDATE SYSTEM STATUS RECORD (DISK FILE 08 (SYSTAT))
C------->TO REFLECT THE NUMBER OF RECORDS READ FROM FILE 03 (NOD OR NOE)
C------->AND NUMBER OF RECORDS WRITTEN TO PCETAB (NORM).
C
1000  READ(03,1002,END=5005) ICONYR,LOC,(CLONE(K),K=1,3),IROW,ICOL,
     1IYRGRF,NRAMET,NF,IBRCNT,IESTSP,IESTCE,IESTSE,IESTEE,IESTGE
```

```
1002  FORMAT(I2,A4,3A4,2I3,I2,I3,I4,I3,18X,I3,4I2)
C------->CALL SUBROUTINE "FNDCL" TO CHECK CLONE VALIDITY
      CALL FNDCL(IFND,NOPC,ISTP)
C------->IFND=0 MEANS CLONE NOT IN CLONE FILE
C------->IFND=1 MEANS CLONE WAS FOUND AT THE LOC AND SO PROCEED
      IF(IFND) 1000,1000,1113
1113  CALL FINDRO(IROW,ICOL,NEW8,NORMH,NRAMET,IYRGRF)
      IK7=IK7+1
      IF(IYR.EQ.2) GO TO 1114
      WRITE(12,1003) ICONYR,LOC,(CLONE(I),I=1,3),IROW,ICOL,IYRGRF,
     1NRAMET,NF,IBRCNT,(IZERO(K),K=1,6),IESTSP,IESTCE,IESTSE,IESTEE,
     2IESTGE,(IZERO(K),K=1,4)
1003  FORMAT(I2,4A4,21I4)
      GO TO 1000
1114  WRITE(09,1003) ICONYR,LOC,(CLONE(I),I=1,3),IROW,ICOL,IYRGRF,
     1NRAMET,NF,IBRCNT,(IZERO(K),K=1,6),IESTSP,IESTCE,IESTSE,IESTEE,
     2IESTGE,(IZERO(K),K=1,4)
      GO TO 1000

C------->UPDATE THE SYSTEM STATUS RECORD ( DISK FILE 08 (SYSTAT)).
5005  NOO7=IK7
      IF(NOO7) 9077,9076,9077
9077  IF(IYRT-1) 9074,9075,9074
C------->WRITE NEW SYSTEM STATUS RECORD FOR ODD YEAR
9075  REWIND 08
      WRITE(08,200) NOPC,NORM,INDL,NOE,NOO7,I1ST,I2ND
9076  RETURN
C------->WRITE NEW SYSTEM STATUS RECORD FOR EVEN YEAR
9074  REWIND 08
      WRITE(08,200) NOPC,NORM,INDL,NOO7,NOD,I1ST,I2ND
      RETURN

C------->IF OBV. MONTH OUT OF RANGE PRINT ERROR MSG. AND ABORT RUN
2000  IF(IMON-7) 2003,2003,2004
2004  WRITE(19,2005)
2005  FORMAT(' ERROR ON MONTH --- RUN IS TERMINATED.')
200   FORMAT(8I3)
      STOP

C------->FOR OBSERVATIONS 2 - 7 READ THE VALUES OF THE LAST PROGRAM
C------->RUN'S ORCHARD DATA TABLE ( STORED AUTOMATICALLY ON DISK FILE
C------->12 (ORCHDAT1) FOR ODD CONE YEAR OR DISK FILE 09 (ORCHDAT2) FOR
C------->EVEN CONE YEAR AFTER EACH OBSERVATION MONTH'S USER DATA UPDATE)
C------->INTO THE CURRENT RUN'S ORCHARD DATA TABLE AND THEN BRANCH TO
C------->THE CURRENT MONTH'S USER INPUT MODULE.
C
2003  IF(IYR.EQ.2) GO TO 2006
      REWIND 12
      DO 2100 I=1,NOO7
      READ(12,1003) ICYRR7(I),LOCC7(I),ICLCC1(I),ICLCC2(I),ICLCC3(I),
     1IRW7(I),ICL7(I),IYRGF7(I),NRAMT7(I),NF7(I),IBRCT7(I),IMAR1(I),
     2IJUN1(I),IOCT(I),IMAR2(I),IJUN2(I),IFINAL(I),IESP(I),IECE(I),
     3IESE(I),IEEE(I),IEGE(I),IASP(I),IASE(I),IAEE(I),IAGE(I)
2100  CONTINUE
      GO TO 2999
2006  REWIND 09
      DO 2200 I=1,NOO7
      READ(09,1003) ICYRR7(I),LOCC7(I),ICLCC1(I),ICLCC2(I),ICLCC3(I),
     1IRW7(I),ICL7(I),IYRGF7(I),NRAMT7(I),NF7(I),IBRCT7(I),IMAR1(I),
     2IJUN1(I),IOCT(I),IMAR2(I),IJUN2(I),IFINAL(I),IESP(I),IECE(I),
     3IESE(I),IEEE(I),IEGE(I),IASP(I),IASE(I),IAEE(I),IAGE(I)
```

```
2200  CONTINUE
C
C------->FOR OBSERVATIONS 2-7 BRANCH TO THE APPROPRIATE MODULE TO INPUT
C------->THE USER'S CURRENT OBSERVATION DATA AND ENTER EACH NEW OBSER-
C------->VATION VALUE INTO THE ORCHARD DATA TABLE.
C

2999  INON=IMON-1
      GO TO (3000,4000,5000,6000,7000,8000),INON

C
C------->INPUT 1ST MARCH OBSERVATION DATA
C
3000  READ(03,3002,END=9000) ICONYR,LOC,(CLONE(K),K=1,3),IROW,ICOL,MOBV
3002  FORMAT(I2,A4,3A4,2I3,12X,I3)
      CALL FNDCL(IFND,NOPC,ISTP)
      IF(IFND) 3000,3000,3013
3013  DO 4050 KK=1,NOO7
      IF(ICONYR-ICYRR7(KK)) 4050,4052,4050
4052  IF(LOCC7(KK).NE.LOC) GO TO 4050
      IF(CLONE(1).NE.ICLCC1(KK).OR.CLONE(2).NE.ICLCC2(KK).OR.CLONE(3)
     1.NE.ICLCC3(KK)) GO TO 4050
      IF(IROW-IRW7(KK)) 4050,4055,4050
4055  IF(ICOL-ICL7(KK)) 4050,4056,4050
4056  IMAR1(KK)=MOBV
      GO TO 3000
4050  CONTINUE
      WRITE(19,4051) (CLONE(I),I=1,3),LOC,IROW,ICOL
4051  FORMAT(' ROW AND COL. MISSING: CLONE',3A4,' LOC',A4,' ROW',I4,
     1' COL',I4)
      ISTP=1
      GO TO 3000
C
C------->INPUT 1ST JUNE OBSERVATION DATA
C
4000  READ(03,4002,END=9000) ICONYR,LOC,(CLONE(K),K=1,3),IROW,ICOL,MOBV
4002  FORMAT(I2,A4,3A4,2I3,15X,I3)
      CALL FNDCL(IFND,NOPC,ISTP)
      IF(IFND) 4000,4000,4013
4013  DO 4150 KK=1,NOO7
      IF(ICONYR-ICYRR7(KK)) 4150,4152,4150
4152  IF(LOCC7(KK).NE.LOC) GO TO 4150
      IF(CLONE(1).NE.ICLCC1(KK).OR.CLONE(2).NE.ICLCC2(KK).OR.CLONE(3)
     1.NE.ICLCC3(KK)) GO TO 4150
      IF(IROW-IRW7(KK)) 4150,4155,4150
4155  IF(ICOL-ICL7(KK)) 4150,4156,4150
4156  IJUN1(KK)=MOBV
      GO TO 4000
4150  CONTINUE
      WRITE(19,4051) (CLONE(I),I=1,3),LOC,IROW,ICOL
      ISTP=1
      GO TO 4000
C
C------->INPUT OCTOBER OBSERVATION DATA
C
5000  READ(03,5002,END=9000) ICONYR,LOC,(CLONE(K),K=1,3),IROW,ICOL,MOBV
5002  FORMAT(I2,A4,3A4,2I3,18X,I3)
      CALL FNDCL(IFND,NOPC,ISTP)
      IF(IFND) 5000,5000,5013
5013  DO 4250 KK=1,NOO7
      IF(ICONYR-ICYRR7(KK)) 4250,4252,4250
```

```
 4252 IF(LOCC7(KK).NE.LOC) GO TO 4250
      IF(CLONE(1).NE.ICLCC1(KK).OR.CLONE(2).NE.ICLCC2(KK).OR.CLONE(3)
     1.NE.ICLCC3(KK)) GO TO 4250
      IF(IROW-IRW7(KK)) 4250,4255,4250
 4255 IF(ICOL-ICL7(KK)) 4250,4256,4250
 4256 IOCT(KK)=MOBV
      GO TO 5000
 4250 CONTINUE
      WRITE(19,4051) (CLONE(I),I=1,3),LOC,IROW,ICOL
      ISTP=1
      GO TO 5000
C
C------->INPUT 2ND MARCH OBSERVATION DATA
C
 6000 READ(03,6002,END=9000) ICONYR,LOC,(CLONE(K),K=1,3),IROW,ICOL,MOBV
 6002 FORMAT(I2,A4,3A4,2I3,21X,I3)
      CALL FNDCL(IFND,NOPC,ISTP)
      IF(IFND) 6000,6000,6013
 6013 DO 4350 KK=1,NOO7
      IF(ICONYR-ICYRR7(KK)) 4350,4352,4350
 4352 IF(LOCC7(KK).NE.LOC) GO TO 4350
      IF(CLONE(1).NE.ICLCC1(KK).OR.CLONE(2).NE.ICLCC2(KK).OR.CLONE(3)
     1.NE.ICLCC3(KK)) GO TO 4350
      IF(IROW-IRW7(KK)) 4350,4355,4350
 4355 IF(ICOL-ICL7(KK)) 4350,4356,4350
 4356 IMAR2(KK)=MOBV
      GO TO 6000
 4350 CONTINUE
      WRITE(19,4051) (CLONE(I),I=1,3),LOC,IROW,ICOL
      ISTP=1
      GO TO 6000
C
C------->INPUT 2ND JUNE OBSERVATION DATA
C
 7000 READ(03,7002,END=9000) ICONYR,LOC,(CLONE(K),K=1,3),IROW,ICOL,MOBV
 7002 FORMAT(I2,A4,3A4,2I3,24X,I3)
      CALL FNDCL(IFND,NOPC,ISTP)
      IF(IFND) 7000,7000,7013
 7013 DO 4450 KK=1,NOO7
      IF(ICONYR-ICYRR7(KK)) 4450,4452,4450
 4452 IF(LOCC7(KK).NE.LOC) GO TO 4450
      IF(CLONE(1).NE.ICLCC1(KK).OR.CLONE(2).NE.ICLCC2(KK).OR.CLONE(3)
     1.NE.ICLCC3(KK)) GO TO 4450
      IF(IROW-IRW7(KK)) 4450,4455,4450
 4455 IF(ICOL-ICL7(KK)) 4450,4456,4450
 4456 IJUN2(KK)=MOBV
      GO TO 7000
 4450 CONTINUE
      WRITE(19,4051) (CLONE(I),I=1,3),LOC,IROW,ICOL
      ISTP=1
      GO TO 7000
C
C------->INPUT FINAL OBSERVATION DATA
C
 8000 READ(03,8002,END=9000) ICONYR,LOC,(CLONE(K),K=1,3),IROW,ICOL,MOBV
 8002 FORMAT(I2,A4,3A4,2I3,27X,I3)
      CALL FNDCL(IFND,NOPC,ISTP)
      IF(IFND) 8000,8000,8013
 8013 DO 4550 KK=1,NOO7
      IF(ICONYR-ICYRR7(KK)) 4550,4552,4550
 4552 IF(LOCC7(KK).NE.LOC) GO TO 4550
```

```
      IF(CLONE(1).NE.ICLCC1(KK).OR.CLONE(2).NE.ICLCC2(KK).OR.CLONE(3)
     1.NE.ICLCC3(KK)) GO TO 4550
      IF(IROW-IRW7(KK)) 4550,4555,4550
4555  IF(ICOL-ICL7(KK)) 4550,4556,4550
4556  IFINAL(KK)=MOBV
      GO TO 8000
4550  CONTINUE
      WRITE(19,4051) (CLONE(I),I=1,3),LOC,IROW,ICOL
      ISTP=1
      GO TO 8000

C------->OUTPUT A COPY OF THE CURRENT ORCHARD DATA TABLE TO DISK FILE 12
C------->(ORCHDAT1) FOR ODD CONE YEAR OR DISK FILE 09 (ORCHDAT2) FOR
C------->EVEN CONE YEAR FOR IMMEDIATE PROCESSING BY SUBROUTINE "DAVER"
C------->AND ACCESS BY FUTURE SYSTEM RUNS.
9000  IF(IYR.EQ.2) GO TO 9100
      REWIND 12
      DO 9006 I=1,NOO7
      WRITE(12,1003) ICYRR7(I),LOCC7(I),ICLCC1(I),ICLCC2(I),
     1ICLCC3(I),IRW7(I),ICL7(I),IYRGF7(I),NRAMT7(I),NF7(I),
     2IBRCT7(I),IMAR1(I),IJUN1(I),IOCT(I),IMAR2(I),IJUN2(I),IFINAL(I)
     3,IESP(I),IECE(I),IESE(I),IEEE(I),IEGE(I),
     4IASP(I),IASE(I),IAEE(I),IAGE(I)
9006  CONTINUE
      RETURN
9100  REWIND 09
      DO 9106 I=1,NOO7
      WRITE(09,1003) ICYRR7(I),LOCC7(I),ICLCC1(I),ICLCC2(I),
     1ICLCC3(I),IRW7(I),ICL7(I),IYRGF7(I),NRAMT7(I),NF7(I),
     2IBRCT7(I),IMAR1(I),IJUN1(I),IOCT(I),IMAR2(I),IJUN2(I),IFINAL(I)
     3,IESP(I),IECE(I),IESE(I),IEEE(I),IEGE(I),
     4IASP(I),IASE(I),IAEE(I),IAGE(I)
9106  CONTINUE
      RETURN
      END
C-------------------------------------------------------------------------C
C                            SUBROUTINE "FNDCL"                           C
C                                                                         C
C     SUBROUTINE "FNDCL" IS CALLED BY SUBROUTINE "SPDAT" TO               C
C     VERIFY THAT EACH CLONE ENCOUNTERED IN THE USER'S INPUT DATA         C
C     IS A VALID CLONE, INCLUDED IN A PREVIOUSLY DEFINED OBSERVATION      C
C     GROUP. THE VALID CLONES COMPRISING THE OBSERVATION GROUP ARE        C
C     DEFINED BY THE USER'S ENTRIES IN DISK FILE 01 ( CLONTAB ).          C
C-------------------------------------------------------------------------C

      SUBROUTINE FNDCL(IFND,NOPC,ISTP)
      INTEGER CLONE(3)
      COMMON CLONE,LOC,ICONYR,IYR,INDEX,ICONBU,ISEED,NORM,I1ST,I2ND
      COMMON INDEX2(255),ICOL2(255),IROW2(255),ASUM2(255,16),
     1CSUM2(255,4),DSUM2(255,4),NFR2(255),IYRGF2(255)
      INTEGER CLONT(3),LOCT
C------->SET IFND=1 IF CLONE THERE; OTHERWISE SET IFND=0
      IFND=0
      REWIND 01
      DO 10 I=1,NOPC
      READ(01,500) LOCT,(CLONT(K),K=1,3),IND,ICONBU,ISEDLB
 500  FORMAT(A4,3A4,I5,I4,I5)
      IF(LOCT.NE.LOC) GO TO 10
      IF(CLONT(1).NE.CLONE(1).OR.CLONT(2).NE.CLONE(2).OR.CLONT(3)
     1.NE.CLONE(3)) GO TO 10
      IFND=1
```

```
      INDEX=IND
      RETURN
10    CONTINUE
      WRITE(19,600) LOC,(CLONE(I),I=1,3)
600   FORMAT(' NEED TO ADD LOC ',A4,' CLONE ',3A4)
      ISTP=1
      RETURN
      END
C----------------------------------------------------------------------C
C                         SUBROUTINE "FINDRO"                          C
C                                                                      C
C     SUBROUTINE "FINDRO" IS CALLED BY SUBROUTINE "SPDAT" TO BUILD     C
C     THE STARTING PREDICTED CONE EFFICIENCY TABLE SEGMENT FOR EACH    C
C     NEW CLONE ENCOUNTERED IN THE USER'S INPUT DATA (INIT. RUN ONLY). C
C----------------------------------------------------------------------C

      SUBROUTINE FINDRO(IROW,ICOL,NEW8,NORMH,NFR,IYRGRF)
      INTEGER CLONE(3)
      COMMON CLONE,LOC,ICONYR,IYR,INDEX,ICONBU,ISEED,NORM,I1ST,I2ND
      COMMON INDEX2(255),ICOL2(255),IROW2(255),ASUM2(255,16),
     1CSUM2(255,4),DSUM2(255,4),NFR2(255),IYRGF2(255)
      DIMENSION IFR(2),AR(16),CR(4),DR(4),ASUM(16),
     1CSUM(4),DSUM(4),NOCL(10),ITOT(10),ITTOT(10)
      IKT=0
      REWIND 15
C-------->INITIALIZE ARRAY ASUM(16) TO 0.
      DO 3000 K=1,16
      ASUM(K)=0.
3000  CONTINUE
C-------->INITIALIZE ARRAYS CSUM(4) AND DSUM(4) TO 0.
      DO 3002 K=1,4
      CSUM(K)=0.
3002  DSUM(K)=0.
      IF(NORM) 999,985,999
999   DO 10 I=1,NORM
      IF(INDEX2(I)-INDEX) 10,12,10
12    IF(I-NORMH) 2012,2012,1000
2012  IKT=IKT+1
1000  IF(IROW2(I)-IROW) 10,13,10
13    IF(ICOL2(I)-ICOL) 10,14,10
10    CONTINUE
      IF(IKT) 985,985,993
993   CALL FBNDRO(IROW,ICOL,NEW8,NORMH,NFR,IYRGRF,IKT)
      GO TO 14
985   NORM=NORM+1
      NEW8=1
      INDEX2(NORM)=INDEX
      IROW2(NORM)=IROW
      ICOL2(NORM)=ICOL
      DO 100 I=1,16
100   ASUM2(NORM,I)=ASUM(I)
      DO 202 I=1,4
      CSUM2(NORM,I)=CSUM(I)
      DSUM2(NORM,I)=DSUM(I)
202   CONTINUE
      NFR2(NORM)=NFR
      IYRGF2(NORM)=IYRGRF
      WRITE(10,800) INDEX,IROW,ICOL
800   FORMAT(' NEW ROW AND COL. FOR CLONE NO. ',I4,' ROW',I4,' COL',I4)
14    CONTINUE
      RETURN
```

```
      END
C-----------------------------------------------------------------------C
C                           SUBROUTINE "FBNDRO"                         C
C                                                                       C
C     SUBROUTINE "FBNDRO" IS CALLED BY SUBROUTINE "FINDRO" TO ADD       C
C     ALL OBSERVATIONS WITHIN A GIVEN CLONE ID TO THE PREDICTED         C
C     CONE EFFICIENCY TABLE.                                            C
C-----------------------------------------------------------------------C

      SUBROUTINE FBNDRO(IROW,ICOL,NEW8,NORMH,NFR,IYRGRF,IKT)
      INTEGER CLONE(3)
      COMMON CLONE,LOC,ICONYR,IYR,INDEX,ICONBU,ISEED,NORM,I1ST,I2ND
      COMMON INDEX2(255),ICOL2(255),IROW2(255),ASUM2(255,16),
     1CSUM2(255,4),DSUM2(255,4),NFR2(255),IYRGF2(255)
      DIMENSION IFR(2),AR(16),CR(4),DR(4)
     1,ASUM(16),CSUM(4),DSUM(4),AS(10,16)
     2,CS(10,4),NOCL(10),DS(10,4),ITOT(10),ITTOT(10)
C------->SET NEW8=1 IF ROW AND COL ADDED
      REWIND 15
      IFST=1
      KLAS=1
      DO 4000 I=1,10
      DO 4000 K=1,16
      AS(I,K)=0.
4000  CONTINUE
      DO 4001 I=1,10
      DO 4001 K=1,4
      CS(I,K)=0.
      DS(I,K)=0.
4001  CONTINUE
      DO 4002 I=1,10
      ITTOT(I)=0
      ITOT(I)=0
4002  CONTINUE
      IGTOT=0
      DO 3000 K=1,16
      ASUM(K)=0.
3000  CONTINUE
      DO 3002 K=1,4
      CSUM(K)=0.
3002  DSUM(K)=0.
      ITOT2=0
999   DO 10 I=1,IKT
      IFR2=IYRGF2(I)
      IFR(2)=NFR2(I)
      DO 940 K=1,12
940   AR(K)=ASUM2(I,K)
      DO 941 K=1,4
      CR(K)=CSUM2(I,K)
      DR(K)=DSUM2(I,K)
941   CONTINUE
2012  IF(IFST-1) 1301,1301,1302
1301  IFST=2
      JJ=1
      NOCL(KLAS)=IFR(2)
      ITTOT(1)=IFR(1)
      IGTOT=IFR(1)
      GO TO 1303
1302  DO 1304 JJ=1,KLAS
      IF(IFR(2)-NOCL(JJ)) 1304,1303,1304
1304  CONTINUE
```

```
      KLAS=KLAS+1
      JJ=KLAS
      NOCL(KLAS)=IFR(2)
      ITTOT(KLAS)=IFR(1)
      IGTOT=IGTOT+IFR(1)
1303  ITOT(JJ)=ITOT(JJ)+1
      DO 1012 K=1,16
      AS(JJ,K)=AS(JJ,K)+AR(K)
1012  CONTINUE
      DO 1011 K=1,4
      CS(JJ,K)=CS(JJ,K)+CR(K)
1011  DS(JJ,K)=DS(JJ,K)+DR(K)
10    CONTINUE
985   NORM=NORM+1
      NEW8=1
      IF(IKT) 2010,2000,2010
2010  DO 20 J=1,KLAS
      DO 20 JJ=1,4
      DS(J,JJ)=DS(J,JJ)/ITOT(J)
20    CS(J,JJ)=CS(J,JJ)/ITOT(J)
      DO 26 J=1,KLAS
      DO 26 JJ=1,16
26    AS(J,JJ)=AS(J,JJ)/ITOT(J)
      DO 22 I=1,4
      DO 22 IKMM=1,KLAS
      CSUM(I)=CSUM(I)+CS(IKMM,I)*ITTOT(IKMM)
22    DSUM(I)=DSUM(I)+DS(IKMM,I)*ITTOT(IKMM)
      DO 23 I=1,16
      DO 23 IKMM=1,KLAS
      ASUM(I)=ASUM(I)+AS(IKMM,I)*ITTOT(IKMM)
23    CONTINUE
      DO 24 I=1,16
      ASUM(I)=ASUM(I)/IGTOT
24    CONTINUE
      DO 25 I=1,4
      CSUM(I)=CSUM(I)/IGTOT
25    DSUM(I)=DSUM(I)/IGTOT
2000  INDEX2(NORM)=INDEX
      IROW2(NORM)=IROW
      ICOL2(NORM)=ICOL
      DO 100 I=1,16
100   ASUM2(NORM,I)=ASUM(I)
      DO 200 I=1,4
      CSUM2(NORM,I)=CSUM(I)
200   DSUM2(NORM,I)=DSUM(I)
      NFR2(NORM)=NFR
      IYRGF2(NORM)=IYRGRF
      WRITE(10,222) INDEX,IROW,ICOL
222   FORMAT(' NEW ROW AND COL. FOR CLONE NO. ',I4,' ROW',I4,' COL',I4)
14    RETURN
      END
C-------------------------------------------------------------------------C
C                          SUBROUTINE "DAVER"                             C
C                                                                         C
C     SUBROUTINE "DAVER" IS CALLED BY ROUTINE "MAIN"TO CALCULATE THE      C
C     AVERAGE NUMBER OF FLOWERS PER SAMPLE TREE FOR EACH CLONE.           C
C     "DAVER" ALSO CALLS SUBROUTINE "PCESTR" ON THE INITIAL RUN AND       C
C     SUBROUTINE "PCEMON" ON SUBSEQUENT RUNS TO OBTAIN INDIVIDUAL         C
C     SAMPLE TREE VALUES FOR PREDICTED SEED POTENTIAL, CONE               C
C     EFFICIENCY, SEED EFFICIENCY, EXTRACTION EFFICIENCY AND              C
C     GERMINATION EFFICIENCY, AND TRANSFORMS THESE INTO CLONAL AND        C
```

```
C     OVERALL ORCHARD ESTIMATES FOR THESE VARIABLES.  "DAVER" ALSO     C
C     USES THESE EFFICIENCY VALUES TO COMPUTE CLONAL AND OVERALL       C
C     ORCHARD VALUES FOR PREDICTED TOTAL SEED, EXTRACTED SEED, BUSHELS C
C     OF CONES, TOTAL CONES, POUNDS EXTRACTED SEED, TOTAL SEEDLINGS    C
C     AND SEED ORCHARD TO NURSERY EFFICIENCY.  FINALLY, "DAVER" SENDS  C
C     THESE RESULTS AS OUTPUT TO TWO DISK FILES.  ONE OF THESE         C
C     ("OUTPUT") CONTAINS ALL COMPUTED RESULTS.  THE OTHER ("CONPROD") C
C     IS A SIMPLIFIED CONE PRODUCTION REPORT.                          C
C----------------------------------------------------------------------C

      SUBROUTINE DAVER(IMON,NOO7)
      INTEGER HCLON(3),HLOC,HCONYR,HESTCE
      COMMON HCLON,HLOC,HCONYR,IYR,INDEX,ICONBU,ISEDLB,NORM,I1ST,I2ND
      COMMON INDEX2(255),ICOL2(255),IROW2(255),ASUM2(255,16),
     1CSUM2(255,4),DSUM2(255,4),NFR2(255),IYRGF2(255)
      DIMENSION IAGE(10),NORAM(10),MONTO(6),SUMT(4),IBR(10),INF(10)
     1,IRO(10),ICO(10),ESTSE(10),ESTCE(10),ESTSP(10),ESTEE(10),ESTGE(10)
     2,AAGE(10),ACTCE(10),ACTSE(10),ACTSP(10),ACTEE(10),ACTGE(10)
     3,AMONTO(10),QCEU(10),QSEU(10),QSPU(10),QSEE(10),BAGE(10),ITTOT(10)
     4,ITOT(10),QSUM(10),NFF(10),QSGE(10),ITOTCE(10),ITTOTX(10)
      INTEGER LOC,CLONE(3),AGECL,PTREES,RAMETS,GTOTCE
      REAL ACTCE,ACTSE,ACTSP,ACTEE,ACTGE
      REAL DUM
      OPC1=0.
      OPC2=0.
      OPC3=0.
      OPC4=0.
      ADDCL=0.
      ADDC1=0.
      OPES=0.
      OPTS=0.
      OPBU=0.
      PCOS=0.
      OPVS=0.
      OPLB=0.
      INON2=0
      ANONE=0.
      ONONE=0.
      PCEU=0.
      PSEU=0.
      PSPU=0.
      PSEE=0.
      PSGE=0.

C------->INITIALIZE COUNTER "IK7" TO COUNT RECORDS READ FROM ORCHDAT1
C------->(FILE 12) OR ORCHDAT2 (FILE 09).
      IK7=1

      IF(IK7-NOO7) 8188,8188,500
8188  IF(IYR.EQ.2) GO TO 8288
C------->REWIND ORCHDAT1 (FILE 12) TO PREPARE FOR PROCESSING.
      REWIND 12
C------->READ 1ST RECORD FROM ORCHDAT1 (FILE 12) AND COMPUTE REQUIRED
C------->OUTPUT HEADER INFORMATION.
      READ(12,833) ICONYR,LOC,(CLONE(K),K=1,3),IROW,ICOL,IYRGRF,NRAMET,
     1NF,IBRCNT,(MONTO(K),K=1,5),IOBV7,IESTSP,IESTCE,IESTSE,IESTEE,
     2IESTGE
833   FORMAT(I2,4A4,17I4)
      GO TO 8289
C------->REWIND ORCHDAT2 (FILE 09) FOR PROCESSING.
8288  REWIND 09
```

```
C------->READ 1ST RECORD FROM ORCHDAT2 (FILE 09) AND COMPUTE REQUIRED
C------->OUTPUT HEADER INFORMATION.
      READ(09,833) ICONYR,LOC,(CLONE(K),K=1,3),IROW,ICOL,IYRGRF,NRAMET,
     1NF,IBRCNT,(MONTO(K),K=1,5),IOBV7,IESTSP,IESTCE,IESTSE,IESTEE,
     2IESTGE
8289  IACTYR=ICONYR-1
      ITOT2=NRAMET

C-------> PROVIDE SPACING BETWEEN CONSECUTIVE RUN REPORTS
      WRITE(10,1199)
      WRITE(10,1199)
      WRITE(11,1199)
      WRITE(11,1199)


C
C------->PRINT OUTPUT HEADERS FOR CURRENT OBSERVATION MONTH
C
      GO TO (9001,9002,9003,9004,9005,9006,9007),IMON

C------->HEADER FOR 1ST MARCH OBSERVATION RESULTS
9002  WRITE(10,9052) ICONYR,IACTYR
9052  FORMAT(' RESULTS FOR 1ST MAR. CONE YR. ',I2,' ACTUAL YR. ',I2)
      WRITE(11,9152) ICONYR,IACTYR
9152  FORMAT(' CONE PRODUCTION GUIDE ----- 1ST MARCH  CONE YR. ',I2,' AC
     1TUAL YR. ',I2)
      GO TO 9060

C------->HEADER FOR 1ST JUNE OBSERVATION RESULTS
9003  WRITE(10,9053) ICONYR,IACTYR
9053  FORMAT(' RESULTS FOR 1ST JUNE CONE YR. ',I2,' ACTUAL YR. ',I2)
      WRITE(11,9153) ICONYR,IACTYR
9153  FORMAT(' CONE PRODUCTION GUIDE ----- 1ST JUNE   CONE YR. ',I2,' AC
     1TUAL YR. ',I2)
      GO TO 9060

C------->HEADER FOR OCTOBER OBSERVATION RESULTS
9004  WRITE(10,9054) ICONYR,IACTYR
9054  FORMAT(' RESULTS FOR OCTOBER CONE YR. ',I2,' ACTUAL YR. ',I2)
      WRITE(11,9154) ICONYR,IACTYR
9154  FORMAT(' CONE PRODUCTION GUIDE ----- OCTOBER    CONE YR. ',I2,' AC
     1TUAL YR. ',I2)
      GO TO 9060

C------->HEADER FOR 2ND MARCH OBSERVATION RESULTS
9005  WRITE(10,9055) ICONYR,ICONYR
9055  FORMAT(' RESULTS FOR 2ND MARCH CONE YR. ',I2,' ACTUAL YR. ',I2)
      WRITE(11,9155) ICONYR,ICONYR
9155  FORMAT(' CONE PRODUCTION GUIDE ----- 2ND MARCH  CONE YR. ',I2,' AC
     1TUAL YR. ',I2)
      GO TO 9060

C------->HEADER FOR 2ND JUNE OBSERVATION RESULTS
9006  WRITE(10,9056) ICONYR,ICONYR
9056  FORMAT(' RESULTS FOR 2ND JUNE   CONE YR. ',I2,' ACTUAL YR.',I2)
      WRITE(11,9156) ICONYR,ICONYR
9156  FORMAT(' CONE PRODUCTION GUIDE ----- 2ND JUNE   CONE YR. ',I2,' AC
     1TUAL YR. ',I2)
      GO TO 9060

C------->HEADER FOR FINAL OBSERVATION RESULTS
```

```
9007  WRITE(10,9057) ICONYR,ICONYR
9057  FORMAT(' FINAL RESULTS FOR CONE YR. ',I2, 'ACTUAL YR. ',I2)
      WRITE(11,9157) ICONYR,ICONYR
9157  FORMAT(' CONE PRODUCTION GUIDE ----- FINAL      CONE YR. ',I2,' AC
     1TUAL YR. ',I2)
      GO TO 9060

C------->HEADER FOR INITIAL OBSERVATION RESULTS
9001  WRITE(10,9051) ICONYR,IACTYR
9051  FORMAT(' INITIAL RUN FOR CONE YR. ',I2,' ACTUAL YR. ',I2)
      WRITE(11,9151) ICONYR,IACTYR
9151  FORMAT(' CONE PRODUCTION GUIDE ----- INITIAL    CONE YR. ',I2,' AC
     1TUAL YR. ',I2)
9060  WRITE(11,1199)
1199  FORMAT( ' ' )
      WRITE(11,1200)
1200  FORMAT('    CLONE ID       BUSHELS OF CONES     TOTAL CONES     RA
     1METS')
      WRITE(11,1201)
1201  FORMAT('    --------       ----------------     -----------     --
     1----')


C
C------->BEGIN CALCULATIONS ON CURRENT MONTHS OBSERVATION DATA
C
      NORAM(1)=NRAMET
      ISET2=0
      ISET=0
C------->KTC COUNTS THE NUMBER OF RECORDS READ FOR EACH CLONE ID
      KTC=1
C-------> AAGE = AGE OF RAMET
C-------> IBR = INITIAL SAMPLE BRANCH COUNT
C-------> NF = TOTAL NUMBER OF FLOWERS ON SAMPLE TREE
      AAGE(1)=ICONYR-IYRGRF
      IBR(KTC)=IBRCNT
      INF(KTC)=NF
      IRO(KTC)=IROW
      ICO(KTC)=ICOL
      NFF(KTC)=NF
      ESTSE(KTC)=IESTSE/100.
      ESTCE(KTC)=IESTCE/100.
      ESTSP(KTC)=IESTSP
      ESTEE(KTC)=IESTEE/100.
      ESTGE(KTC)=IESTGE/100.

      IF(IMON-1) 2040,2040,2041

C
C------->FOR OBSERVATIONS 2 - 7
C
C-------> AMONTO = THE NUMBER OF FLOWERS COUNTED ON THE SAMPLE BRANCHES
C-------> OF A SAMPLE RAMET IN AN OBSERVATION MONTH
2041  IF(IMON-7) 5039,5038,5038
5038  AMONTO(KTC)=IOBV7
      GO TO 5040
5039  AMONTO(KTC)=MONTO(IMON-1)
5040  IF(IBRCNT) 1050,1050,1052
C------->FOR ZERO BRANCH COUNT
1050  AMONTO(KTC)=0.
      GO TO 2040
```

```
C-------->FOR POSITIVE BRANCH COUNT
C--------> AMONTO NOW BECOMES THE PERCENTAGE OF FLOWERS SURVIVING
C--------> TILL THE CURRENT OBSERVATION MONTH
1052  AMONTO(KTC)=(AMONTO(KTC)/IBR(KTC))


C
C-------->FOR ALL OBSERVATION MONTHS
C
2040  HCLON(1)=CLONE(1)
      HCLON(2)=CLONE(2)
      HCLON(3)=CLONE(3)
      HLOC=LOC
      HCONYR=ICONYR
      CALL FINDCL

C
C-------->INCREMENT RECORDS READ COUNTER(IK7) AND BEGIN A LOOP TO PROCESS
C-------->ALL REMAINING RECORDS EXISTING ON DISK FILE 12 (ORCHDAT1) OR
C-------->DISK FILE 09 (ORCHDAT2). WHEN IK7>NOO7 ALL RECORDS CONTAINED IN
C-------->ORCHDAT1 OR ORCHDAT2 HAVE BEEN INITIALLY PROCESSED AND THE
C-------->LOOP IS EXITED.
C

10     IK7=IK7+1
       IF(IK7-NOO7) 8189,8189,500
8189   IF(IYR.EQ.2) GO TO 8190
       READ(12,833) ICONYR,LOC,(CLONE(K),K=1,3),IROW,ICOL,IYRGRF,
      1NRAMET,NF,IBRCNT,(MONTO(K),K=1,5),IOBV7,IESTSP,IESTCE,IESTSE,
      2IESTEE,IESTGE
       GO TO 8199
8190   READ(09,833) ICONYR,LOC,(CLONE(K),K=1,3),IROW,ICOL,IYRGRF,
      1NRAMET,NF,IBRCNT,(MONTO(K),K=1,5),IOBV7,IESTSP,IESTCE,IESTSE,
      2IESTEE,IESTGE
C-------->SET STATUS FLAGS ISET AND ISET2 TO ZERO
C-------->ISET2 IS SET TO 1 WHEN  ALL RECORDS OF A GIVEN CLONE HAVE BEEN
C-------->PROCESSED.
C-------->ISET IS SET TO 1 WHEN ALL RECORDS IN FILE 12 (ORCHDAT1) OR FILE
C-------->09 (ORCHDAT2) HAVE BEEN PROCESSED.
C-------->HAVE BEEN PROCESSED.
8199   ISET2=0
       ISET=0
C
C-------->IF CURRENT CLONE NAME(CLONE) AND LOCATION(LOC) ARE THE SAME
C-------->AS LAST READ CLONE NAME(HCLON) AND LOCATION(HLOC) CONTINUE
C-------->BUILDING TABLE WITH DATA CONTAINED ON THE CURRENT RECORD.
C-------->IF NAME AND/OR LOCATION DIFFER GO SUM LAST CLONE ENTRIES BY
C-------->AGE CLASS.
C
       IF(CLONE(1).NE.HCLON(1).OR.CLONE(2).NE.HCLON(2).OR.CLONE(3).NE.
      1HCLON(3)) GO TO 200
       IF(LOC.NE.HLOC) GO TO 200
       ITOT2=ITOT2+NRAMET
       IF(IMON-1) 110,110,120
 120   KTC=KTC+1

       IF(IMON-7) 5020,1063,1063

 C------>FOR OBSERVATIONS 2 - 7
 5020  IF(IMON-7) 5022,5021,1063
 C--------> AMONTO = THE NUMBER OF FLOWERS COUNTED ON THE SAMPLE BRANCHES
```

```
C-------> OF A SAMPLE RAMET IN AN OBSERVATION MONTH
5022  AMONTO(KTC)=MONTO(IMON-1)
      GO TO 5033
5021  AMONTO(KTC)=IOBV7
5033  IF(IBRCNT) 1060,1060,1062
C------->FOR ZERO BRANCH COUNT
1060  AMONTO(KTC)=0.
      GO TO 1063
C------->FOR POSITIVE BRANCH COUNT
C------->AMONTO NOW BECOMES THE PERCENTAGE OF FLOWERS SURVIVING UNTIL
C------->THE CURRENT OBSERVATION MONTH
1062  AMONTO(KTC)=(AMONTO(KTC)/IBRCNT)

C
C------->FOR OBSERVATIONS 2 - 7
C
C-------> NF = TOTAL NUMBER OF FLOWERS ON SAMPLE RAMET
C-------> IBR = INITIAL SAMPLE BRANCH COUNT
C-------> AAGE = AGE OF RAMET=CONE YEAR-YEAR GRAFTED
1063  NFF(KTC)=NF
      INF(KTC)=NF
      IBR(KTC)=IBRCNT
      IRO(KTC)=IROW
      ICO(KTC)=ICOL
      NORAM(KTC)=NRAMET
      AAGE(KTC)=ICONYR-IYRGRF
      GO TO 10


C
C------->FOR INITIAL OBSERVATION ONLY
C
C-------> KTC IS INCREMENTED TO COUNT THE NUMBER OF RECORDS READ
C-------> FOR THE CURRENT CLONE
110   KTC=KTC+1
      IBR(KTC)=IBRCNT
      INF(KTC)=NF
      IRO(KTC)=IROW
      ICO(KTC)=ICOL
      ESTCE(KTC)=IESTCE/100.
      ESTSE(KTC)=IESTSE/100.
      ESTSP(KTC)=IESTSP
      ESTEE(KTC)=IESTEE/100.
      ESTGE(KTC)=IESTGE/100.
      NFF(KTC)=NF
      NORAM(KTC)=NRAMET
      AAGE(KTC)=(ICONYR-IYRGRF)
      GO TO 10
C
C-------> CODE FOR ZERO INITIAL BRANCH COUNT CASE FOR CONE EFFICIENCY
C-------> GTOTCE = TOTAL NUMBER OF RAMETS TO BE USED AS A DIVISOR
C-------> AGECL = AGE CLASS
C-------> PTREES = NUMBER OF SAMPLE TREES IN AGE CLASS
C-------> KTC = NUMBER OF SAMPLE TREES IN CURRENT CLONE
200   GTOTCE=0
      AGECL=1
      PTREES=1
      IF(IBR(1).EQ.0) PTREES=0
      RAMETS=NORAM(1)
      IF(IBR(1).EQ.0) RAMETS=0
      MKAGE=IAGE(1)
```

```
      DO 501 I=2,KTC
      IF(MKAGE.NE.IAGE(I)) GO TO 100
      IF(MKAGE.EQ.IAGE(I).AND.IBR(I).EQ.0) GO TO 501
      PTREES=PTREES+1
      RAMETS=NORAM(I)
      GO TO 501
100   ITOTCE(AGECL)=PTREES
      ITTOTX(AGECL)=RAMETS
      GTOTCE=GTOTCE+RAMETS
      PTREES=1
      IF(IBR(I).EQ.0) PTREES=0
      RAMETS=NORAM(I)
      IF(IBR(I).EQ.0) RAMETS=0
      MKAGE=IAGE(I)
      AGECL=AGECL+1
501   CONTINUE
      ITOTCE(AGECL)=PTREES
      ITTOTX(AGECL)=RAMETS
      GTOTCE=GTOTCE+RAMETS


C
C------->BEGIN SUMMING PROCESS FOR THE CURRENT CLONE
C
C------->IF IMON=1(INITIAL OBV.), WRITE INIT. SUM INFO. TO HEADER
      IF(IMON-1) 201,201,202
201   IF(ISET-1) 2030,2031,2030
C------->ISET2=1 MEANS BEEN THRU SUMMING PROCESS
2031  IF(ISET2-1) 2030,285,2030
C
C------->BEGIN SUMMING PROCESS FOR INITIAL OBSERVATION DATA
C
2030  ISET2=1
C-------> NOCLAS = COUNTER FOR NUMBER OF AGE CLASSES IN CURRENT CLONE
      NOCLAS=1
      I=1
C-------> ITOT = COUNTER FOR NUMBER OF SAMPLE TREES IN AN AGE CLASS
      ITOT(NOCLAS)=1
C-------> ITTOT = NUMBER OF RAMETS IN AN AGE CLASS
      ITTOT(NOCLAS)=NORAM(1)
C-------> GTOT = NUMBER OF RAMETS IN THE CURRENT CLONE
      GTOT=NORAM(1)
      BAGE(NOCLAS)=AAGE(1)
      IF(KTC-1) 9670,9660,9670
9670  IL=I+1
      DO 9620 L=IL,KTC
      DO 9622 KK=1,NOCLAS
      IF(AAGE(L).EQ.BAGE(KK)) GO TO 9623
9622  CONTINUE
      NOCLAS=NOCLAS+1
      ITOT(NOCLAS)=1
      ITTOT(NOCLAS)=NORAM(L)
      BAGE(NOCLAS)=AAGE(L)
C-------> GTOT = THE TOTAL NUMBER OF RAMETS OF CURRENT CLONE OF ALL AGES
      GTOT=GTOT+NORAM(L)
      GO TO 9620
9623  ITOT(NOCLAS)=ITOT(NOCLAS)+1
9620  CONTINUE
9660  TOTAGE=0.
      DO 9624 K=1,NOCLAS
9624  TOTAGE=TOTAGE+BAGE(K)*ITTOT(K)
```

```
C-------> AGE = AVERAGE AGE OF RAMETS WITHIN CURRENT CLONE GROUP
C-------> WEIGHTED BY THE NUMBER OF RAMETS IN EACH AGE CLASS
      AGE=TOTAGE/GTOT
      ITOTR=GTOT+.0001
      DO 9735 IKM=1,NOCLAS
      QSUM(IKM)=0.
9735  CONTINUE
      DO 5502 IKM=1,KTC
      DO 9731 IKMM=1,NOCLAS
      IF(AAGE(IKM).EQ.BAGE(IKMM)) GO TO 9732
9731  CONTINUE
      GO TO 5502
C-------> QSUM = TOTAL NUMBER OF FLOWERS ON SAMPLE RAMETS OF ONE AGE
C-------> CLASS
9732  QSUM(IKMM)=QSUM(IKMM)+NFF(IKM)
5502  CONTINUE
      DO 9733 IKMM=1,NOCLAS
C-------> NOW,QSUM = AVERAGE NUMBER OF FLOWERS PER RAMET IN AN
C-------> AGE CLASS
      QSUM(IKMM)=QSUM(IKMM)/ITOT(IKMM)
9733  CONTINUE
      SUMNF=0.
      DO 9734 IKMM=1,NOCLAS
C-------> SUMNF = NUMBER OF FLOWERS FOR THE CLONE WITHIN THE ORCHARD
      SUMNF=SUMNF+QSUM(IKMM)*ITTOT(IKMM)
9734  CONTINUE
C-------> CALCULATE AVERAGE NUMBER OF FLOWERS PER RAMET ACROSS ALL AGE
C-------> CLASSES FOR THE CURRENT CLONE=SUMNF
      SUMNF=SUMNF/GTOT
      DO 9705 IKM=1,NOCLAS
      QCEU(IKM)=0.
      QSEU(IKM)=0.
      QSPU(IKM)=0.
      QSEE(IKM)=0.
      QSGE(IKM)=0.
9705  CONTINUE
      DO 5002 IKM=1,KTC
      DO 9701 IKMM=1,NOCLAS
      IF(AAGE(IKM).EQ.BAGE(IKMM)) GO TO 9702
9701  CONTINUE
      GO TO 5002
C
C-------> SEND ESTIMATES FOR CONE EFFICIENCY, SEED EFFICIENCY,
C-------> SEED POTENTIAL, EXTRACTION EFFICIENCY AND
C-------> GERMINATION EFFICIENCY TO SUBROUTINE PCESTR.
C-------> PCESTR CALCULATES AND RETURNS PREDICTED (UPDATED)
C-------> CONE EFFICIENCY, SEED EFFICIENCY, SEED POTENTIAL,
C-------> EXTRACTION EFFICIENCY AND GERMINATION EFFICIENCY.
C
9702  CALL PCESTR(IRO(IKM),ICO(IKM),ESTCE(IKM),ESTSE(IKM),
     1ESTSP(IKM),ESTEE(IKM),ESTGE(IKM),AAGE(IKM),QCEU,QSEU,QSPU,QSGE,
     2QSEE,IKMM)
5002  CONTINUE
C
C-------> COMPUTE AGE CLASS (WITHIN-CLONE) AVERAGES FOR PREDICTED
C-------> CONE EFFICIENCY, SEED EFFICIENCY, SEED POTENTIAL,
C-------> EXTRACTION EFFICIENCY AND GERMINATION EFFICIENCY.
C
      DO 9703 IKMM=1,NOCLAS
      QCEU(IKMM)=QCEU(IKMM)/ITOT(IKMM)
      QSEU(IKMM)=QSEU(IKMM)/ITOT(IKMM)
```

```
      QSPU(IKMM)=QSPU(IKMM)/ITOT(IKMM)
      QSEE(IKMM)=QSEE(IKMM)/ITOT(IKMM)
9703  QSGE(IKMM)=QSGE(IKMM)/ITOT(IKMM)
      PCEU=0.
      PSEU=0.
      PSPU=0.
      PSEE=0.
      PSGE=0.
      DO 9704 IKMM=1,NOCLAS
      PCEU=PCEU+QCEU(IKMM)*ITTOT(IKMM)
      PSEU=PSEU+QSEU(IKMM)*ITTOT(IKMM)
      PSPU=PSPU+QSPU(IKMM)*ITTOT(IKMM)
      PSEE=PSEE+QSEE(IKMM)*ITTOT(IKMM)
9704  PSGE=PSGE+QSGE(IKMM)*ITTOT(IKMM)
C
C-------> COMPUTE CLONAL AVERAGES FOR PREDICTED CONE
C-------> EFFICIENCY, SEED EFFICIENCY, SEED POTENTIAL,
C-------> EXTRACTION EFFICIENCY AND GERMINATION
C-------> EFFICIENCY.
C
      PCEU=PCEU/GTOT
      PSEU=PSEU/GTOT
      PSPU=PSPU/GTOT
      PSEE=PSEE/GTOT
      PSGE=PSGE/GTOT
      GO TO 304

C
C------->BEGIN SUMMING PROCESS FOR FOR OBSERVATIONS 2 - FINAL(7)
C

202   IF(ISET-1) 2032,2033,2032
2033  IF(ISET2-1) 2032,285,2032
2032  ISET2=1
C-------> NOCLAS = THE NUMBER OF DIFFERENT AGE CLASSES ENCOUNTERED
C-------> WITHIN THE CURRENT CLONE ID
      NOCLAS=1
      I=1
C-------> ITOT = COUNTER FOR NUMBER OF SAMPLE TREES IN AN AGE CLASS
C-------> ITTOT = NUMBER OF RAMETS IN AN AGE CLASS FOR CURRENT CLONE
C-------> GTOT = NUMBER OF RAMETS IN CURRENT CLONE
      ITOT(NOCLAS)=1
      ITTOT(NOCLAS)=NORAM(1)
      GTOT=NORAM(1)
      BAGE(NOCLAS)=AAGE(1)
      IF(KTC-1) 2052,2051,2052
2052  IL=I+1
      DO 2053 L=IL,KTC
      DO 2054 KK=1,NOCLAS
      IF(AAGE(L).EQ.BAGE(KK)) GO TO 2055
2054  CONTINUE
      NOCLAS=NOCLAS+1
      ITOT(NOCLAS)=1
      ITTOT(NOCLAS)=NORAM(L)
      BAGE(NOCLAS)=AAGE(L)
      GTOT=GTOT+NORAM(L)
      GO TO 2053
C-------> INCREMENT NUMBER OF SAMPLE RAMETS IN THE AGE CLASS BY ONE
2055  ITOT(NOCLAS)=ITOT(NOCLAS)+1
2053  CONTINUE
C-------> CALCULATE TOTAL AGE AND THEN AVERAGE AGE FOR CLONE
```

```
2051   TOTAGE=0.
       DO 2057 K=1,NOCLAS
2057   TOTAGE=TOTAGE+BAGE(K)*ITTOT(K)
       AGE=TOTAGE/GTOT
       ITOTR=GTOT+.0001
       DO 9635 IKM=1,NOCLAS
       QSUM(IKM)=0.
9635   CONTINUE
       DO 5602 IKM=1,KTC
       DO 9631 IKMM=1,NOCLAS
       IF(AAGE(IKM).EQ.BAGE(IKMM)) GO TO 9632
9631   CONTINUE
       GO TO 5602
9632   QSUM(IKMM)=QSUM(IKMM)+NFF(IKM)
5602   CONTINUE
C-------> CALCULATE QSUM FOR EACH AGE CLASS. QSUM(IKMM) = TOTAL
C-------> NUMBER OF FLOWERS FOR RAMETS OF EACH AGE CLASS IN
C-------> CURRENT CLONE ID
       DO 9633 IKMM=1,NOCLAS
C-------> NOW, QSUM = AVERAGE NUMBER OF FLOWERS PER SAMPLE RAMET
C-------> IN AN AGE CLASS
       QSUM(IKMM)=QSUM(IKMM)/ITOT(IKMM)
9633   CONTINUE
       SUMNF=0.
       DO 9634 IKMM=1,NOCLAS
C-------> SUMNF = NUMBER OF FLOWERS FOR THE WHOLE CURRENT CLONE
       SUMNF=SUMNF+QSUM(IKMM)*ITTOT(IKMM)
9634   CONTINUE
C-------> NOW, SUMNF = AVERAGE NUMBER OF FLOWERS PER RAMET FOR THE
C-------> CURRENT CLONE
       SUMNF=SUMNF/GTOT


C
C------->FOR OBSERVATION MONTHS 2 - 7
C
600    DO 9605 IKM=1,NOCLAS
       QCEU(IKM)=0.
       QSEU(IKM)=0.
       QSPU(IKM)=0.
       QSEE(IKM)=0.
       QSGE(IKM)=0.
9605   CONTINUE
       DO 5005 IKM=1,KTC
       DO 9601 IKMM=1,NOCLAS
       IF(AAGE(IKM).EQ.BAGE(IKMM)) GO TO 9602
9601   CONTINUE
C
C-------> CALL PCEMON TO CALCULATE UPDATED PREDICTED CONE EFFICIENCY,
C-------> SEED EFFICIENCY, SEED POTENTIAL, EXTRACTION EFFICIENCY AND
C-------> GERMINATION EFFICIENCY FOR EACH RECORD (RAMET). DAVER SENDS
C-------> PCEMON AMONTO=CURRENT MONTH'S OBSERVED CONE EFFICIENCY FOR
C-------> EACH SAMPLE RAMET. AMONTO WILL BE RECEIVED BY PCEMON AS OBCE.
C
9602   CALL PCEMON(IRO(IKM);ICO(IKM),IMON,QCEU,AMONTO(IKM),
      1QSEU,QSPU,QSEE,QSGE,IKMM)
5005   CONTINUE
C
C-------> COMPUTE AGE CLASS (WITHIN-CLONE) AVERAGES FOR PREDICTED
C-------> CONE EFFICIENCY, SEED EFFICIENCY, SEED POTENTIAL,
C-------> EXTRACTION EFFICIENCY AND GERMINATION EFFICIENCY.
```

```
C
      DO 9603 IKMM=1,NOCLAS
      IF(ITOTCE(IKMM).EQ.0) GO TO 9617
      QCEU(IKMM)=QCEU(IKMM)/ITOTCE(IKMM)
9617  QSEU(IKMM)=QSEU(IKMM)/ITOT(IKMM)
      QSPU(IKMM)=QSPU(IKMM)/ITOT(IKMM)
      QSEE(IKMM)=QSEE(IKMM)/ITOT(IKMM)
9603  QSGE(IKMM)=QSGE(IKMM)/ITOT(IKMM)
      PCEU=0.
      PSEU=0.
      PSPU=0.
      PSEE=0.
      PSGE=0.
      DO 9604 IKMM=1,NOCLAS
      IF(ITTOTX(IKMM).EQ.0) GO TO 9618
      PCEU=PCEU+QCEU(IKMM)*ITTOTX(IKMM)
9618  PSEU=PSEU+QSEU(IKMM)*ITTOT(IKMM)
      PSPU=PSPU+QSPU(IKMM)*ITTOT(IKMM)
      PSEE=PSEE+QSEE(IKMM)*ITTOT(IKMM)
9604  PSGE=PSGE+QSGE(IKMM)*ITTOT(IKMM)
      IF(GTOTCE.EQ.0) GO TO 9700
      PCEU=PCEU/GTOTCE
      GO TO 9707
9700  PCEU=0
C
C-------> COMPUTE CLONAL AVERAGES FOR PREDICTED CONE
C-------> EFFICIENCY, SEED EFFICIENCY, SEED POTENTIAL,
C-------> EXTRACTION EFFICIENCY AND GERMINATION
C-------> EFFICIENCY.
C
9707  PSEU=PSEU/GTOT
      PSPU=PSPU/GTOT
      PSEE=PSEE/GTOT
      PSGE=PSGE/GTOT
      GO TO 304


C
C------->COMPUTE  FINAL OUTPUT VALUES FOR THE CURRENT CLONE
C
C-------> PTS = PREDICTED TOTAL SEED
C-------> PES = PREDICTED EXTRACTED SEED
C-------> PCO = PREDICTED NUMBER OF CONES
C-------> PBU = PREDICTED BUSHELS OF CONES
C-------> PLB = PREDICTED POUNDS OF SEED
C-------> PVS = PREDICTED VIABLE SEED (PREDICTED NUMBER OF SEEDLINGS)
C-------> ANONE = PREDICTED ORCHARD-TO-NURSERY EFFICIENCY
C-------> OPC1 = ORCHARD SUM PREDICTED CONE EFFICIENCY
C-------> OPC2 = ORCHARD SUM PREDICTED SEED EFFICIENCY
C-------> OPC3 = ORCHARD SUM PREDICTED EXTRACTION EFFICIENCY
C-------> OPC4 = ORCHARD SUM PREDICTED GERMINATION EFFICIENCY
C-------> OPES = ORCHARD SUM PREDICTED EXTRACTED SEED
C-------> OPTS = ORCHARD SUM PREDICTED TOTAL SEED
C-------> OPBU = ORCHARD SUM PREDICTED BUSHELS OF CONES
C-------> PCOS = ORCHARD SUM PREDICTED TOTAL CONES
C-------> OPVS = ORCHARD SUM PREDICTED VIABLE SEED (NUMBER OF SEEDLINGS)
C-------> OPLB = ORCHARD SUM PREDICTED POUNDS OF SEED
304   PTS=PCEU*ITOTR*SUMNF*PSEU*PSPU
      PES=PTS*PSEE
      PCO=ITOTR*SUMNF*PCEU
      PBU=PCO/ICONBU
```

```
      PLB=(PTS*PSEE)/ISEDLB
      PVS=PES*PSGE
      ANONE=(PCEU*PSEU*PSGE*PSEE)*100.
      OPC1=OPC1+PCEU
      OPC2=OPC2+PSEU
      OPC3=OPC3+PSGE
      OPC4=OPC4+PSEE
C-------> ADDCL COUNTS NUMBER OF CLONES
C-------> ADDC1 COUNTS NUMBER OF CLONES WITH NONZERO
C-------> FLOWER COUNTS.
      IF(SUMNF.EQ.0) GO TO 305
      ADDC1=ADDC1+1
305   ADDCL=ADDCL+1
      OPES=OPES+PES
      OPTS=OPTS+PTS
      OPBU=OPBU+PBU
      PCOS=PCOS+PCO
      OPVS=OPVS+PVS
      OPLB=OPLB+PLB


C
C-------> WRITE A CONE PRODUCTION REPORT RECORD
C
      WRITE(11,1202) HCLON(1),HCLON(2),HCLON(3),PBU,PCO,ITOTR
1202  FORMAT(4X,3A4,6X,F12.2,6X,F12.2,6X,I3)
C
C------->OUTPUT CALCULATED RESULTS FOR CURRENT CLONE
C
      WRITE(10,1357)
      WRITE(10,1361) HCLON(1),HCLON(2),HCLON(3),LOC,HCONYR
1361  FORMAT(' RESULTS FOR CLONE ',3A4,' ORCHARD ',A4,' YEAR ',I2)
      IF(SUMNF.EQ.0) GO TO 1608
      WRITE(10,1637) PCEU,PSEU
1637  FORMAT('  CONE EFF. (PCE)=',F6.2,4X,' SEED EFF. (PSE)=',F6.2)
      GO TO 1610
1608  WRITE(10,1609) PSEU
1609  FORMAT('  CONE EFF. (PCE)=  NO DATA',2X,' SEED EFF. (PSE)=',F6.2)
1610  WRITE(10,9637) PSPU,PSEE
9637  FORMAT('  SEED POT. (PSP)=',F7.1,4X,' EXT. EFF. (PEE)=',F6.2)
      WRITE(10,1639) PSGE,ITOTR
1639  FORMAT('  GERM. EFF. (PGE)=',F6.2,4X,'NO. RAMETS (NR)=',I3)
      WRITE(10,9638) SUMNF
      WRITE(10,1638) ICONBU,ISEDLB
9638  FORMAT('  AVG. FEM. FLOWERS/RAMET (NF)=',F8.2)
1638  FORMAT('  CONES PER BU.= ',I6,4X,' SEED PER LB.=',I6)

C
C------->OUTPUT ESTIMATED VALUES FOR:
C------->PREDICTED SEED, EXTRACTED SEED, BUSHELS OF CONES, CONES,
C------->LBS. EXTRACTED SEED AND NUMBER OF SEEDLINGS.
C
      WRITE(10,1362) PTS
1362  FORMAT(' PREDICTED SEED (PTS=NR*NF*PCE*PSP*PSE)',10X,F15.2)
      WRITE(10,1363) PES
1363  FORMAT(' PREDICTED NO. EXT. SEED (PES=PTS*PEE)',11X,F15.2)
      WRITE(10,1364) PBU
      WRITE(10,9987) PCO
1364  FORMAT(' PREDICTED BUSHELS OF CONES (PBU=(NR*NF*PCE)/CONBU)
     1,F12.2)
9987  FORMAT(' PREDICTED CONES (PCO=(NR*NF*PCE)) ',17X,F12.2)
```

```
      WRITE(10,1365) PLB
1365  FORMAT(' PREDICTED LBS EXTRACTED SEED (PLB=(PTS*PEE)/SEED
     1F12.2)
      WRITE(10,1366) PVS
      IF(SUMNF.EQ.0) GO TO 9555
      WRITE(10,9561) ANONE
      GO TO 1380
9555  WRITE(10,9562)
1366  FORMAT(' PREDICTED NO. SEEDLINGS (PVS=PES*PGE)',10X,F15.2)


C
C------->IF ISET=1, ALL CLONES HAVE BEEN PROCESSED AND THE OVERALL
C------->ORCHARD RESULTS WILL NEXT BE OUTPUT. IF ISET=0 GO PROCESS THE
C------->NEXT CLONE.
C
1380  IF(ISET) 1383,1383,1384
1383  IF(HLOC.EQ.LOC) GO TO 205
1384  WRITE(10,1357)
      WRITE(10,1357)
      WRITE(10,1357)
1357  FORMAT('=======================================')
      WRITE(10,1359) LOC
1359  FORMAT(' RESULTS FOR ORCHARD ',A4)
      WRITE(10,1391) OPTS
      WRITE(10,1392) OPBU
      WRITE(10,9985) PCOS
      WRITE(10,1393) OPVS
      WRITE(10,1394) OPLB
C-------> OPC1 = ORCHARD AVERAGE PREDICTED CONE EFFICIENCY
C-------> OPC2 = ORCHARD AVERAGE PREDICTED SEED EFFICIENCY
C-------> OPC3 = ORCHARD AVERAGE PREDICTED EXTRACTION EFFICIENCY
C-------> OPC4 = ORCHARD AVERAGE PREDICTED GERMINATION EFFICIECY
      OPC1=OPC1/ADDC1
      OPC2=OPC2/ADDCL
      OPC3=OPC3/ADDCL
      OPC4=OPC4/ADDCL
C-------> ONONE = AVERAGE ORCHARD SEED ORCHARD-TO-NURSERY EFFICIENCY
      ONONE=(OPC1*OPC2*OPC3*OPC4)*100.
      WRITE(10,9561) ONONE
      ONONE=0.
      OPES=0.
      OPTS=0.
      OPBU=0.
      OPVS=0.
      PCOS=0.
      ADDCL=0.
      ADDC1=0.
      OPC1=0.
      OPC2=0.
      OPC3=0.
      OPC4=0.

205   IF(ISET) 280,280,285
1391  FORMAT(' PREDICTED ORCHARD SEED PRODUCTION (SUM PTS) ',F12.1)
1392  FORMAT(' PREDICTED NO. OF BUSHELS OF CONES (SUM PBU) ',F12.1)
9985  FORMAT(' PREDICTED NO. OF CONES (SUM PCO) ',11X,F12.1)
1393  FORMAT(' PREDICTED NO. OF SEEDLINGS (SUM PVS)',8X,F12.1)
1394  FORMAT(' PREDICTED LBS. OF SEED (SUM PLB)',12X,F12.1)
9561  FORMAT(' PREDICTED ORCH. TO NURS. EFF.',26X,F8.2,' %')
9562  FORMAT(' PREDICTED ORCH. TO NURS. EFF.',26X,' NO DATA')
```

```
280   IF(IMON-1) 210,210,220
220   SUMT(IMON)=0
      KTC=0.
      SUMNF=0.
      ITOTR=0
      TOTAGE=0.
      ITOT2=0
      HCONYR=ICONYR
      HCLON(1)=CLONE(1)
      HCLON(2)=CLONE(2)
      HCLON(3)=CLONE(3)
      HLOC=LOC
      HESTCE=IESTCE
      CALL FINDCL
      GO TO 120
210   SUMNF=0
      ITOTR=0
      TOTAGE=0.
      ITOT2=0
      KTC=0
      HCONYR=ICONYR
      HCLON(1)=CLONE(1)
      HCLON(2)=CLONE(2)
      HCLON(3)=CLONE(3)
      HLOC=LOC
      CALL FINDCL
      GO TO 110

500   ISET=1
      GO TO 200

285   RETURN
      END
C---------------------------------------------------------------------C
C                           SUBROUTINE "PCESTR"                       C
C                                                                     C
C     SUBROUTINE "PCESTR" IS CALLED BY SUBROUTINE "DAVER" ON THE      C
C     INITIAL RUN TO COMPUTE PREDICTED CONE EFFICIENCY, SEED          C
C     POTENTIAL, SEED EFFICIENCY, EXTRACTION EFFICIENCY, AND          C
C     GERMINATION EFFICIENCY VALUES FOR EACH SAMPLE FROM THE USER'S   C
C     OBSERVATIONS FILE.  THESE VALUES ARE BOTH STORED IN THE "PCETAB" C
C     TABLE AND RETURNED TO "DAVER."                                  C
C---------------------------------------------------------------------C

      SUBROUTINE PCESTR(IRO,ICOL,EST,ESTSE,ESTSP,ESTEE,ESTGE,AGE,PCE1,
     1PSEU1,PSP1,PSG1,PSE1,IKMM)
      INTEGER CLONE(3)
      COMMON CLONE,LOC,ICONYR,IYR,INDEX,ICONBU,ISEDLB,NORMM,I1ST,I2ND
      COMMON INDEX2(255),ICOL2(255),IROW2(255),ASUM2(255,16),
     1CSUM2(255,4),DSUM2(255,4),NFR2(255),IYRGF2(255)
      DIMENSION PSEU1(10),PCE1(10),PSP1(10),PSG1(10),PSE1(10)
      REAL DUM

      IF(ICONYR-I1ST) 10,20,40
10    WRITE(19,12)
12    FORMAT(' ERROR ON YEAR --- RUN IS TERMINATED. ')
      STOP

40    IF(ICONYR-I2ND) 10,20,10
```

```
20    IF(EST.EQ.0.) GO TO 700
      PCE=EST
      GO TO 702
700   PCE=0.
702   PCE1(IKMM)=PCE1(IKMM)+PCE
      IF(ESTSE.EQ.0.) GO TO 704
      PSEU=ESTSE
      GO TO 705
704   PSEU=0.
705   PSEU1(IKMM)=PSEU1(IKMM)+PSEU
      PSP=ESTSP
      PSP1(IKMM)=PSP1(IKMM)+PSP
      PSG=ESTGE
      PSE=ESTEE
      PSG1(IKMM)=PSG1(IKMM)+PSG
      PSE1(IKMM)=PSE1(IKMM)+PSE

70    IF(MOD(IYR,2)) 17,18,17
C------->STORE INITIAL PCE FOR ODD YEAR
17    CALL PCETAB(IRO,ICOL,PCE,DUM,1,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM
     1,DUM,DUM,DUM)
C------->STORE INITIAL PSEU AND PSP
      CALL PCETAB(IRO,ICOL,PSEU,PSP,19,PSE,PSG,DUM,DUM,DUM,DUM,DUM,DUM,D
     1UM,DUM,DUM,DUM)
      RETURN

C------->STORE INITIAL PCE FOR EVEN YR.
18    CALL PCETAB(IRO,ICOL,PCE,DUM,6,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM
     1,DUM,DUM,DUM)
C------->STORE INITIAL PSEU,PSP FOR EVEN YR.
      CALL PCETAB(IRO,ICOL,PSEU,PSP,21,PSE,PSG,DUM,DUM,DUM,DUM,DUM,DUM,D
     1UM,DUM,DUM,DUM)
      RETURN
      END

C----------------------------------------------------------------------C
C                             SUBROUTINE "PCEMON"                      C
C                                                                      C
C     SUBROUTINE "PCEMON" IS CALLED BY SUBROUTINE "DAVER" ON ALL       C
C     RUNS EXCEPT THE INITIAL RUN TO COMPUTE A PREDICTED CONE          C
C     EFFICIENCY UPDATE FOR EACH SAMPLE TREE BASED ON THE OBSERVED     C
C     CONE EFFICIENCY VALUE SENT BY "DAVER" FOR A SPECIFIC OBSERVATION C
C     MONTH (1ST MARCH, 1ST JUNE, 1ST OCTOBER, 2ND MARCH, 2ND JUNE OR  C
C     FINAL).  FOR A GIVEN OBSERVATION MONTH, "PCEMON" PLUGS THE       C
C     OBSERVED CONE EFFICIENCY VALUE INTO AN EQUATION BASED ON A       C
C     GENERALIZED CONE MORTALITY CURVE, TO CREATE A PREDICTED CONE     C
C     EFFICIENCY UPDATE FOR EACH SAMPLE TREE.  THIS VALUE AND VALUES   C
C     FOR PREDICTED SEED POTENTIAL, SEED EFFICIENCY, EXTRACTION        C
C     EFFICIENCY AND GERMINATION EFFICIENCY RETRIEVED FROM THE         C
C     "PCETAB" TABLE ARE RETURNED TO "DAVER."  THE VALUE FOR           C
C     PREDICTED CONE EFFICIENCY UPDATE IS ALSO STORED IN THE "PCETAB"  C
C     TABLE.                                                           C
C----------------------------------------------------------------------C

      SUBROUTINE PCEMON(IRO,ICOL,IMON,PCEU1,OBCE,PSEU1,PSPU1,PSEE1,PSGE1
     1,IKMM)
      INTEGER CLONE(3)
      COMMON CLONE,LOC,ICONYR,IYR,INDEX,ICONBU,ISEDLB,NORMM,I1ST,I2ND
      COMMON INDEX2(255),ICOL2(255),IROW2(255),ASUM2(255,16),
     1CSUM2(255,4),DSUM2(255,4),NFR2(255),IYRGF2(255)
      DIMENSION PSPU1(10),PCEU1(10),PSEU1(10),PSEE1(10),PSGE1(10)
```

```
      REAL DUM

C------->GET INITIAL PCE FOR EVEN OR ODD YEAR
      IF(MOD(IYR,2)) 22,23,22
22    CALL PCETAB(IRO,ICOL,PCE,DUM,3,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM
     1,DUM,DUM,DUM)
      GO TO 24
C------->GET INITIAL PCE FOR EVEN YEAR
23    CALL PCETAB(IRO,ICOL,PCE,DUM,10,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM)

C------->CHECK TO BE SURE A VALID OBSERVATION MONTH HAS BEEN PASSED
C------->OBSERVATIONS 2 - 7 ARE VALID.
24    IF(IMON-1) 10,10,20
20    IF(IMON-7) 25,25,10
10    WRITE(19,12)
12    FORMAT(' ERROR IN MONTH --- RUN IS TERMINATED. ')
      STOP

C------->BRANCH TO THE MODULE FOR THE CURRENT OBSERVATION MONTH
25    INON=IMON-1
      GO TO (100,200,300,400,500,600),INON

C
C------->CALCULATE AND ENTER PCEU FOR 1ST MARCH OBSERVATION
C
100   IF(OBCE.LE.0.) GO TO 701
      IF(PCE.EQ.0.) GO TO 701
      GO TO 702
701   PCEU=0.0
      GO TO 703
C-------> THIS EQUATION USES THE ORCHARD'S GENERALIZED CONE MORTALITY
C-------> CURVE TO CONVERT THE OBSERVED CONE EFFICIENCY (OBCE SENT FROM
C-------> DAVER) TO UPDATED PREDICTED CONE EFFICIENCY FOR THE FIRST
702   PCEU=PCE+.05-(1.00-OBCE)
      IF(PCEU.GT.1.00) PCEU=1.00
      IF(PCEU.LT.0.00) PCEU=0.00
703   PCEU1(IKMM)=PCEU1(IKMM)+PCEU

      IF(MOD(IYR,2)) 102,103,102
C------->STORE FOR MONTH 1, PCEU (ODD)
102   CALL PCETAB(IRO,ICOL,PCEU,DUM,4,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM)
C------->GET THE STORED PSEU AND PSP (ODD)
      CALL PCETAB(IRO,ICOL,PSEU,PSPU,20,PSEE,PSGE,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM,DUM)
      PSPU1(IKMM)=PSPU1(IKMM)+PSPU
      PSEU1(IKMM)=PSEU1(IKMM)+PSEU
      PSEE1(IKMM)=PSEE1(IKMM)+PSEE
      PSGE1(IKMM)=PSGE1(IKMM)+PSGE
      RETURN

103   CALL PCETAB(IRO,ICOL,PCEU,DUM,11,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,D
     1UM,DUM,DUM,DUM)
      CALL PCETAB(IRO,ICOL,PSEU,PSPU,22,PSEE,PSGE,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM,DUM)
      PSPU1(IKMM)=PSPU1(IKMM)+PSPU
      PSEU1(IKMM)=PSEU1(IKMM)+PSEU
      PSEE1(IKMM)=PSEE1(IKMM)+PSEE
      PSGE1(IKMM)=PSGE1(IKMM)+PSGE
      RETURN
```

```
C
C------->CALCULATE AND ENTER VALUES FOR 1ST JUNE OBSERVATION
C
200   IF(OBCE.LE.0.) GO TO 704
      IF(PCE.EQ.0.) GO TO 704
      GO TO 705
704   PCEU=0.0
      GO TO 706
C-------> THIS EQUATION USES THE ORCHARD'S GENERALIZED CONE MORTALITY
C-------> CURVE TO CONVERT THE OBSERVED CONE EFFICIENCY (OBCE) TO
C-------> UPDATED PREDICTED CONE EFFICIENCY FOR THE FIRST JUNE
C-------> OBSERVATION IN THE CONE CYCLE.
705   PCEU=PCE+.15-(1.00-OBCE)
      IF(PCEU.GT.1.00) PCEU=1.00
      IF(PCEU.LT.0.00) PCEU=0.00
706   PCEU1(IKMM)=PCEU1(IKMM)+PCEU

      IF(MOD(IYR,2)) 202,203,202
203   CALL PCETAB(IRO,ICOL,PCEU,DUM,12,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,D
     1UM,DUM,DUM,DUM)
      CALL PCETAB(IRO,ICOL,PSEU,PSPU,22,PSEE,PSGE,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM,DUM)
      PSPU1(IKMM)=PSPU1(IKMM)+PSPU
      PSEU1(IKMM)=PSEU1(IKMM)+PSEU
      PSEE1(IKMM)=PSEE1(IKMM)+PSEE
      PSGE1(IKMM)=PSGE1(IKMM)+PSGE
      RETURN

202   CALL PCETAB(IRO,ICOL,PCEU,DUM,7,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM)
      CALL PCETAB(IRO,ICOL,PSEU,PSPU,20,PSEE,PSGE,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM,DUM)
      PSPU1(IKMM)=PSPU1(IKMM)+PSPU
      PSEU1(IKMM)=PSEU1(IKMM)+PSEU
      PSEE1(IKMM)=PSEE1(IKMM)+PSEE
      PSGE1(IKMM)=PSGE1(IKMM)+PSGE
      RETURN

C
C------->CALCULATE AND INPUT VALUES FOR OCTOBER OBSERVATION MONTH
C
300   IF(OBCE.LE.0.) GO TO 707
      IF(PCE.EQ.0.) GO TO 707
      GO TO 708
707   PCEU=0.0
      GO TO 709
C-------> THIS EQUATION USES THE ORCHARD'S GENERALIZED CONE MORTALITY
C-------> CURVE TO CONVERT THE OBSERVED CONE EFFICIENCY (OBCE) TO
C-------> UPDATED PREDICTED CONE EFFICIENCY FOR THE OCTOBER OBSERVATION
C-------> IN THE CONE CYCLE.
708   PCEU=PCE+.20-(1.00-OBCE)
      IF(PCEU.GT.1.00) PCEU=1.00
      IF(PCEU.LT.0.00) PCEU=0.00
709   PCEU1(IKMM)=PCEU1(IKMM)+PCEU

      IF(MOD(IYR,2)) 302,303,302
303   CALL PCETAB(IRO,ICOL,PCEU,DUM,13,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,D
     1UM,DUM,DUM,DUM)
      CALL PCETAB(IRO,ICOL,PSEU,PSPU,22,PSEE,PSGE,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM,DUM)
```

```
      PSPU1(IKMM)=PSPU1(IKMM)+PSPU
      PSEU1(IKMM)=PSEU1(IKMM)+PSEU
      PSEE1(IKMM)=PSEE1(IKMM)+PSEE
      PSGE1(IKMM)=PSGE1(IKMM)+PSGE
      RETURN

302   CALL PCETAB(IRO,ICOL,PCEU,DUM,8,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM)
      CALL PCETAB(IRO,ICOL,PSEU,PSPU,20,PSEE,PSGE,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM,DUM)
      PSPU1(IKMM)=PSPU1(IKMM)+PSPU
      PSEU1(IKMM)=PSEU1(IKMM)+PSEU
      PSEE1(IKMM)=PSEE1(IKMM)+PSEE
      PSGE1(IKMM)=PSGE1(IKMM)+PSGE
      RETURN

C
C-------->CALCULATE AND INPUT VALUES FOR 2ND MARCH OBSERVATION MONTH
C
400   IF(OBCE.LE.0.) GO TO 710
      IF(PCE.EQ.0.) GO TO 710
      GO TO 711
710   PCEU=0.0
      GO TO 712
C--------> THIS EQUATION USES THE ORCHARD'S GENERALIZED CONE MORTALITY
C--------> CURVE TO CONVERT THE OBSERVED CONE EFFICIENCY (OBCE) TO
C--------> UPDATED PREDICTED CONE EFFICIENCY FOR THE SECOND MARCH
C--------> OBSERVATION IN THE CONE CYCLE.
711   PCEU=PCE+.25-(1.00-OBCE)
      IF(PCEU.GT.1.00) PCEU=1.00
      IF(PCEU.LT.0.00) PCEU=0.00
712   PCEU1(IKMM)=PCEU1(IKMM)+PCEU
      IF(MOD(IYR,2)) 402,403,402
403   CALL PCETAB(IRO,ICOL,PCEU,DUM,14,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,D
     1UM,DUM,DUM,DUM)
      CALL PCETAB(IRO,ICOL,PSEU,PSPU,22,PSEE,PSGE,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM,DUM)
      PSPU1(IKMM)=PSPU1(IKMM)+PSPU
      PSEU1(IKMM)=PSEU1(IKMM)+PSEU
      PSEE1(IKMM)=PSEE1(IKMM)+PSEE
      PSGE1(IKMM)=PSGE1(IKMM)+PSGE
      RETURN

402   CALL PCETAB(IRO,ICOL,PCEU,DUM,9,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM)
      CALL PCETAB(IRO,ICOL,PSEU,PSPU,20,PSEE,PSGE,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM,DUM)
      PSPU1(IKMM)=PSPU1(IKMM)+PSPU
      PSEU1(IKMM)=PSEU1(IKMM)+PSEU
      PSEE1(IKMM)=PSEE1(IKMM)+PSEE
      PSGE1(IKMM)=PSGE1(IKMM)+PSGE
      RETURN

C
C-------->CALCULATE AND INPUT VALUES FOR 2ND JUNE OBSERVATION MONTH
C
500   IF(OBCE.LE.0.) GO TO 713
      IF(PCE.EQ.0.) GO TO 713
      GO TO 714
713   PCEU=0.0
      GO TO 715
```

```
C-------> THIS EQUATION USES THE ORCHARD'S GENERALIZED MORTALITY
C-------> CURVE TO CONVERT THE OBSERVED CONE EFFICIENCY (OBCE) TO
C-------> UPDATED PREDICTED CONE EFFICIENCY FOR THE SECOND JUNE
C-------> OBSERVATION IN THE CONE CYCLE.
714   PCEU=PCE+.30-(1.00-OBCE)
      IF(PCEU.GT.1.00) PCEU=1.00
      IF(PCEU.LT.0.00) PCEU=0.00
715   PCEU1(IKMM)=PCEU1(IKMM)+PCEU

      IF(MOD(IYR,2)) 502,503,502
503   CALL PCETAB(IRO,ICOL,PCEU,DUM,17,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,D
     1UM,DUM,DUM,DUM)
      CALL PCETAB(IRO,ICOL,PSEU,PSPU,22,PSEE,PSGE,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM,DUM)
      PSPU1(IKMM)=PSPU1(IKMM)+PSPU
      PSEU1(IKMM)=PSEU1(IKMM)+PSEU
      PSEE1(IKMM)=PSEE1(IKMM)+PSEE
      PSGE1(IKMM)=PSGE1(IKMM)+PSGE
      RETURN

502   CALL PCETAB(IRO,ICOL,PCEU,DUM,15,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,D
     1UM,DUM,DUM,DUM)
      CALL PCETAB(IRO,ICOL,PSEU,PSPU,20,PSEE,PSGE,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM,DUM)
      PSPU1(IKMM)=PSPU1(IKMM)+PSPU
      PSEU1(IKMM)=PSEU1(IKMM)+PSEU
      PSEE1(IKMM)=PSEE1(IKMM)+PSEE
      PSGE1(IKMM)=PSGE1(IKMM)+PSGE
      RETURN

C
C-------> CALCULATE AND INPUT VALUES FOR FINAL OBSERVATION MONTH
C
600   IF(OBCE.LE.0.) GO TO 813
      IF(PCE.EQ.0.) GO TO 813
      GO TO 814
813   PCEU=0.0
      GO TO 815
C-------> THIS EQUATION USES THE ORCHARD'S GENERALIZED CONE MORTALITY
C-------> CURVE TO CONVERT THE OBSERVED CONE EFFICIENCY (OBCE) TO
C-------> UPDATED PREDICTED CONE EFFICIENCY FOR THE FINAL OBSERVATION
C-------> IN THE CONE CYCLE.
814   PCEU=PCE+.45-(1.00-OBCE)
      IF(PCEU.GT.1.00) PCEU=1.00
      IF(PCEU.LT.0.00) PCEU=0.00
815   PCEU1(IKMM)=PCEU1(IKMM)+PCEU

      IF(MOD(IYR,2)) 603,602,603
603   CALL PCETAB(IRO,ICOL,PCEU,DUM,16,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,D
     1UM,DUM,DUM,DUM)
      CALL PCETAB(IRO,ICOL,PSEU,PSPU,20,PSEE,PSGE,DUM,DUM,DUM,DUM,DUM,DU
     1M,DUM,DUM,DUM,DUM)
      PSPU1(IKMM)=PSPU1(IKMM)+PSPU
      PSEU1(IKMM)=PSEU1(IKMM)+PSEU
      PSEE1(IKMM)=PSEE1(IKMM)+PSEE
      PSGE1(IKMM)=PSGE1(IKMM)+PSGE
      RETURN

602   CALL PCETAB(IRO,ICOL,PCEU,DUM,18,DUM,DUM,DUM,DUM,DUM,DUM,DUM,DUM,D
     1UM,DUM,DUM,DUM)
      CALL PCETAB(IRO,ICOL,PSEU,PSPU,22,PSEE,PSGE,DUM,DUM,DUM,DUM,DUM,DU
```

```
     1M,DUM,DUM,DUM,DUM)
      PSPU1(IKMM)=PSPU1(IKMM)+PSPU
      PSEU1(IKMM)=PSEU1(IKMM)+PSEU
      PSEE1(IKMM)=PSEE1(IKMM)+PSEE
      PSGE1(IKMM)=PSGE1(IKMM)+PSGE
      RETURN
      END
C----------------------------------------------------------------------C
C                         SUBROUTINE "PCETAB"                          C
C                                                                      C
C     SUBROUTINE "PCETAB" IS CALLED BY SUBROUTINES "PCESTR" AND
C     "PCEMON" TO STORE DATA IN, AND RETRIEVE DATA FROM THE            C
C     PREDICTED CONE EFFICIENCY TABLE.                                 C
C     SUBROUTINE "PCETAB" IS CALLED BY SUBROUTINE "PCESTR" TO          C
C     STORE STARTING VALUES IN THE PCETAB TABLE WHICH CONTAINS,        C
C     FOR EACH SAMPLE TREE, INITIAL ESTIMATES FOR PREDICTED CONE       C
C     EFFICIENCY, SEED POTENTIAL,SEED EFFICIENCY, EXTRACTION           C
C     EFFICIENCY AND GERMINATION EFFICIENCY.  "PCETAB" IS ALSO         C
C     CALLED BY SUBROUTINE "PCEMON" TO RETRIEVE THESE VALUES FOR       C
C     "PCEMON" TO USE IN ITS CALCULATIONS AND "PCETAB" IS CALLED       C
C     BY "PCEMON" TO STORE THE PREDICTED CONE EFFICIENCY UPDATES       C
C     THAT IT COMPUTES FOR EACH SAMPLE TREE IN THE "PCETAB" TABLE.     C
C----------------------------------------------------------------------C

      SUBROUTINE PCETAB(IRO,ICOL,PCESUM,C2,ICOD,PCSSUM,CS2,PCPSUM,CP2,
     1PEESUM,CE2,PGSUM,CG2,ASE,ASP,AEE,AGG)
      INTEGER CLONE(3)
      COMMON CLONE,LOC,ICONYR,IYR,INDEX,ICONBU,ISEDLB,NORM,I1ST,I2ND
      COMMON INDEX2(255),ICOL2(255),IROW2(255),ASUM2(255,16),
     1CSUM2(255,4),DSUM2(255,4),NFR2(255),IYRGF2(255)
C-------->ASUM2 IS FOR INIT CE OF ODD AND EVEN YR. AND FOR
C-------->CE UPDATES FOR 1ST MARCH, 1ST JUNE, 1ST OCTOBER,
C-------->2ND MARCH, 2ND JUNE AND FINAL OF ODD AND EVEN YR.
C-------->CSUM2 IS FOR INIT SP AND SE OF ODD AND EVEN YR.
C-------->DSUM2 IS FOR INIT EE AND GE OF ODD AND EVEN YR.

C-------->IF AN INVALID CODE HAS BEEN PASSED TO "PCETAB" PRINT
C-------->A MESSAGE AND ABORT THE RUN.
      IF(ICOD-1) 10,40,20
20    IF(ICOD-24) 40,40,10
10    WRITE(19,111)
111   FORMAT(' ILLEGAL CODE IN PCETAB ROUTINE --- RUN IS TERMINATED. ')
      STOP

C-------->CALL FINDPO TO FIND THE POSITION OF THE CURRENT CLONE
C-------->IN THE PCETAB TABLE (FILE 02).  FINDPO IS SENT INDEX,
C-------->IRO AND ICOL. FINDPO RETURNS I.
40    CALL FINDPO(IRO,ICOL,I,INDL)

C-------->GO TO THE MODULE INDICATED BY THE OPERATION CODE (ICOD)

      GO TO (41,80,43,44,80,41,47,48,49,43,44,47,48,49,50,51,50,51,701,
     1702,701,702,80,80),ICOD

C-------->CODE  1  -- STORE INITIAL PCE FOR ODD YEAR
C-------->CODE  6  -- STORE INITIAL PCE FOR EVEN YEAR
41    IF(ICOD-1) 456,456,457
456   ASUM2(I,1)=PCESUM
      RETURN
457   ASUM2(I,2)=PCESUM
      RETURN
```

```
C-------->CODE  3 -- RETRIEVE INITIAL PCE FOR ODD YEAR
C-------->CODE 10 -- RETRIEVE INITIAL PCE FOR EVEN YEAR
43    IF(ICOD-3) 576,576,577
576   PCESUM=ASUM2(I,1)
      RETURN
577   PCESUM=ASUM2(I,2)
      RETURN

C-------->CODE  4 -- STORE PCEU FOR 1ST MARCH OBV., ODD YEAR
C-------->CODE 11 -- STORE PCEU FOR 1ST MARCH OBV., EVEN YEAR
44    IF(ICOD-4) 586,586,587
586   ASUM2(I,5)=PCESUM
      RETURN
587   ASUM2(I,11)=PCESUM
      RETURN

C-------->CODE  7 -- STORE PCEU FOR 1ST JUNE OBV., ODD YEAR
C-------->CODE 12 -- STORE PCEU FOR 1ST JUNE OBV., EVEN YEAR
47    IF(ICOD-7) 596,596,597
596   ASUM2(I,6)=PCESUM
      RETURN
597   ASUM2(I,12)=PCESUM
      RETURN

C-------->CODE  8 -- STORE PCEU FOR OCTOBER OBV., ODD YEAR
C-------->CODE 13 -- STORE PCEU FOR OCTOBER OBV., EVEN YEAR
48    IF(ICOD-8) 606,606,607
606   ASUM2(I,7)=PCESUM
      RETURN
607   ASUM2(I,13)=PCESUM
      RETURN

C-------->CODE  9 -- STORE PCEU FOR 2ND MARCH OBV., ODD YEAR
C-------->CODE 14 -- STORE PCEU FOR 2ND MARCH OBV., EVEN YEAR
49    IF(ICOD-9) 616,616,617
616   ASUM2(I,8)=PCESUM
      RETURN
617   ASUM2(I,14)=PCESUM
      RETURN

C-------->CODE 15 -- STORE PCEU FOR 2ND JUNE OBV., ODD YEAR
C-------->CODE 17 -- STORE PCEU FOR 2ND JUNE OBV., EVEN YEAR
50    IF(ICOD-15) 626,626,627
626   ASUM2(I,9)=PCESUM
      RETURN
627   ASUM2(I,15)=PCESUM
      RETURN

C-------->CODE 16 -- STORE PCEU FOR FINAL OBV., ODD YEAR
C-------->CODE 18 -- STORE PCEU FOR FINAL OBV., EVEN YEAR
51    IF(ICOD-16) 636,636,637
636   ASUM2(I,10)=PCESUM
      RETURN
637   ASUM2(I,16)=PCESUM
      RETURN


C-------->CODE 19 -- STORE INITIAL PSEU AND PSP FOR ODD YEAR
C-------->CODE 21 -- STORE INITIAL PSEU AND PSP FOR EVEN YEAR
```

```
701   IF(ICOD-19) 757,757,758
C------->STORE FOR ODD YR., INITIAL PSEU AND PSP
757   CSUM2(I,1)=PCESUM
      CSUM2(I,2)=C2
      DSUM2(I,1)=PCSSUM
      DSUM2(I,2)=CS2
      RETURN
C------->STORE FOR EVEN YR., INITIAL PSEU AND PSP AND PSE,PSG
758   CSUM2(I,3)=PCESUM
      CSUM2(I,4)=C2
      DSUM2(I,3)=PCSSUM
      DSUM2(I,4)=CS2
      RETURN

C------->CODE 20 --- GET STORED PSEU AND PSP FOR ODD YEAR
C------->CODE 22 --- GET STORED PSEU AND PSP FOR EVEN YEAR
702   IF(ICOD-20) 767,767,768
767   PCESUM=CSUM2(I,1)
      C2=CSUM2(I,2)
      PCSSUM=DSUM2(I,1)
      CS2=DSUM2(I,2)
      RETURN
768   PCESUM=CSUM2(I,3)
      C2=CSUM2(I,4)
      PCSSUM=DSUM2(I,3)
      CS2=DSUM2(I,4)
      RETURN
80    CONTINUE
      END
C---------------------------------------------------------------------C
C                         SUBROUTINE "FINDCL"                         C
C                                                                     C
C     SUBROUTINE "FINDCL" IS CALLED BY SUBROUTINE "DAVER" TO          C
C     DETERMINE IF A PARTICULAR CLONE NAME ENCOUNTERED IN THE USER'S  C
C     "OBSERVATION" DATA IS A VALID CLONE CONTAINED IN THE STUDY GROUP C
C     DEFINED BY THE ENTRIES ON DISK FILE CLONTAB. IF FOUND THE INDEX C
C     INTO CLONTAB IS RETURNED ALONG WITH VALUES FOR CONES PER BUSHEL C
C     AND SEED PER LB. FOR THE PARTICULAR CLONE ID. IF NOT FOUND, AN  C
C     ERROR MSG. IS OUTPUT AND THE RUN TERMINATED.                    C
C---------------------------------------------------------------------C

      SUBROUTINE FINDCL
      INTEGER CLONE(3)
      COMMON CLONE,LOC,ICONYR,IYR,INDEX,ICONBU,ISEDLB,NORM,I1ST,I2ND
      COMMON INDEX2(255),ICOL2(255),IROW2(255),ASUM2(255,16),
     1CSUM2(255,4),DSUM2(255,4),NFR2(255),IYRGF2(255)
      INTEGER ALOC,ACLON(3)
      REWIND 01
10    READ(01,500,END=25) ALOC,(ACLON(K),K=1,3),IND,ICONBU,ISEDLB
      IF(ALOC.NE.LOC) GO TO 10
      IF(ACLON(1).NE.CLONE(1).OR.ACLON(2).NE.CLONE(2).OR.ACLON(3)
     1.NE.CLONE(3)) GO TO 10
      INDEX=IND
      RETURN
25    WRITE(19,26) CLONE,LOC
26    FORMAT(' CLONE ',3A4,' AT LOC ',I4,' MISSING --- RUN IS TERMINATED
     1. ')
500   FORMAT(A4,3A4,I5,I4,I5)
      STOP
      END
C---------------------------------------------------------------------C
```

```
C                          SUBROUTINE "FINDPO"                             C
C                                                                          C
C     SUBROUTINE "FINDPO " IS CALLED BY SUBROUTINE "PCETAB" TO FIND        C
C     THE POSITION OF THE CURRENT CLONE BEING PROCESSED WITHIN THE         C
C     PREDICTED CONE EFFICIENCY TABLE. IF FOUND THE INDEX INTO THE         C
C     TABLE IS RETURNED. IF NOT FOUND AN ERROR MSG IS OUTPUT AND THE       C
C     RUN TERMINATED.                                                      C
C--------------------------------------------------------------------------C

      SUBROUTINE FINDPO(IROW,ICOL,J,INDL)
      INTEGER CLONE(3)
      COMMON CLONE,LOC,ICONYR,IYR,INDEX,ICONBU,ISEDLB,NORM,I1ST,I2ND
      COMMON INDEX2(255),ICOL2(255),IROW2(255),ASUM2(255,16),
     1CSUM2(255,4),DSUM2(255,4),NFR2(255),IYRGF2(255)
C------->TO FIND POSITION; RETURN J; SENT INDEX,IROW,ICOL
      DO 55 J=1,NORM
      IF(INDEX2(J)-INDEX) 55,56,55
56    IF(IROW2(J)-IROW) 55,57,55
57    IF(ICOL2(J)-ICOL) 55,58,55
55    CONTINUE
555   WRITE(19,556)
556   FORMAT(' INDEX ON ROW AND COL. NOT ON FILE 02 --- RUN IS TERMINATE
     1D. ')
      STOP
58    INDL=INDEX2(J)
      RETURN
      END
C$ENTRY
```

AVGACTS

```
C----------------------------------------------------------------------C
C                            ROUTINE "AVGACTS"                         C
C                                                                      C
C     THE FOLLOWING PROGRAM USES TWO USER DEFINED INPUT FILES TO       C
C     TO CALCULATE A CLONAL AVERAGE FOR ACTUAL SEED POTENTIAL, SEED    C
C     EFFICIENCY, EXTRACTION EFFICIENCY, GERMINATION EFFICIENCY,       C
C     AND CONE EFFICIENCY FOR EACH CLONE IN THE USERS OBSERVATION      C
C     GROUP.                                                           C
C                                                                      C
C     INPUT TO THE PROGRAM:                                            C
C        1. ACTUAL FLOWERS AND CONES DATA (DISK FILE 11)               C
C        2. ACTUAL CONE ANALYSIS DATA (DISK FILE 13)                   C
C                                                                      C
C     OUTPUT:                                                          C
C        A DISK FILE CONTAINING THE CLONAL AVERAGES, ONE RECORD        C
C        PER CLONE. (DISK FILE 18 (CLNAVGS))                           C
C                                                                      C
C----------------------------------------------------------------------C
      INTEGER CLN1,CLN2,CUR1,CUR2,YR,ROW,COL,CURROW,CURCOL
      INTEGER FERT,EXTRAC,TOTSD,FILL,GERM
      INTEGER ENDCLN,EOF,TOTFL,TOTCO,DONE,PTREES
      REAL ASP,ASE,AEE,AGE,CNT
      REAL TFERT,TEXTS,TTOTSD,TFILL,TGERM
      REAL XACTCE,GTOTCO,GTOTFL
      GTOTFL=0.0
      GTOTCO=0.0
      PTREES=0
      XACTCE=0.0
      DONE=0
C
C-------> AVERAGE THE FLOWERS AND CONES DATA BY CLONE DELETING ZERO
C-------> FLOWER COUNTS.
C-------> COMPUTE THE ACTUAL CONE EFFICIENCY FOR EACH CLONE ID
C-------> ENCOUNTERED IN THE USERS FLOWERS AND CONES DATA SET AND
C-------> WRITE A RECORD CONTAINING YR., CLONE ID, ROW, COL AND
C-------> ACTUAL CONE EFFICIENCY FOR EACH ON TEMPORARY DISK 08.
C
      READ(11,100,END=500) YR,CLN1,CLN2,ROW,COL,TOTFL,TOTCO
100   FORMAT(I2,2A4,1X,I2,1X,I3,1X,I4,1X,I4)
      CUR1=CLN1
      CUR2=CLN2
      IF(TOTFL.EQ.0) GO TO 200
      GTOTFL=GTOTFL+TOTFL
      GTOTCO=GTOTCO+TOTCO
      PTREES=PTREES+1
200   READ(11,100,END=500) YR,CLN1,CLN2,ROW,COL,TOTFL,TOTCO
      IF(CLN1.EQ.CUR1.AND.CLN2.EQ.CUR2) GO TO 400
210   IF(GTOTFL.EQ.0.0) GO TO 225
220   XACTCE=(GTOTCO/GTOTFL)
      IF(XACTCE.GT.1.00) XACTCE=1.00
      GO TO 230
225   XACTCE=2.0
C-------> WRITE A RECORD CONTAINING CURRENT CLONES ACTUAL CONE EFF.
230   WRITE(08,240) YR,CUR1,CUR2,ROW,COL,XACTCE
240   FORMAT(I2,2A4,I2,I3,F6.2)
      IF(DONE.EQ.1) GO TO 777
      PTREES=0
      GTOTFL=0.0
      GTOTCO=0.0
      CUR1=CLN1
      CUR2=CLN2
```

```
400   IF( TOTFL.EQ.0 ) GO TO 200
      GTOTFL=GTOTFL+TOTFL
      GTOTCO=GTOTCO+TOTCO
      PTREES=PTREES+1
      GO TO 200
500   DONE=1
      GO TO 210
C------->
C------->COMPUTE CLONAL AVERAGES FOR ACTUAL: SEED POTENTIAL, SEED
C------->EFFICIENCY, EXTRACTION EFFICIENCY, AND GERMINATION EFFICIENCY.
C------->READ THE PREVIOUSLY CALCULATED VALUE FOR ACTUAL CONE EFFICIENCY
C------->FROM DISK FILE 08(FOR THE CURRENT CLONE ID) AND WRITE A RECORD
C------->TO DISK FILE 18 CONTAINING THE CLONE ID AND ALL CORRESPONDING
C------->CLONAL AVERAGES.
C------->
777   REWIND 08
C------->OUTPUT HEADER FOR CLONAL AVERAGES FILE.
      WRITE(18,887)
      WRITE(18,888)
      WRITE(18,889)
887   FORMAT('            **** CLONAL AVERAGES ****')
888   FORMAT(' CLONE      SP      CE     SE     EE     GE    SONE ')
889   FORMAT(' -----     ----   ----   ----   ----   ----   ---- ')
      EOF=0
      ASP=0.0
      ASE=0.0
      AEE=0.0
      AGE=0.0
C-------> READ AN ACTUAL CONE ANALYSIS RECORD AND INITIALIZE AVERAGING
      READ(13,1000) YR,CLN1,CLN2,ROW,COL,FERT,EXTRAC,TOTSD,FILL,GERM
1000  FORMAT(I2,2A4,1X,I2,1X,I3,5X,5I4)
1100  CNT=1.0
      CUR1=CLN1
      CUR2=CLN2
C-------> INCREMENT WITHIN CLONE TOTALS FOR FERTILE SCALES, EXTRACTED
C-------> SEED, TOTAL SEED, FILLED SEED AND GERMINATED SEED.
      TFERT=FERT
      TEXTS=EXTRAC
      TTOTSD=TOTSD
      TFILL=FILL
      TGERM=GERM
C-------> READ ANOTHER ACTUAL CONE ANALYSIS RECORD AND CONTINUE
C-------> AVERAGING UNTIL CLONE ID CHANGES.
1500  READ(13,1000,END=1750) YR,CLN1,CLN2,ROW,COL,FERT,EXTRAC,TOTSD,FILL
     1,GERM
      IF(CLN1.NE.CUR1.OR.CLN2.NE.CUR2) GO TO 2200
      CNT=CNT+1
      TFERT=TFERT+FERT
      TEXTS=TEXTS+EXTRAC
      TTOTSD=TTOTSD+TOTSD
      TFILL=TFILL+FILL
      TGERM=TGERM+GERM
      GO TO 1500
1750  EOF=1
C-------> IF TOTAL FERTILE SCALES = ZERO OUTPUT ZEROS AND "NO DATA" MSG.
C-------> IF TOTAL FERTILE SCALES > ZERO CALCULATE THE CLONAL AVERAGES
C-------> AND OUTPUT THEM.
2200  IF(TFERT.EQ.0.0) GO TO 4500
C-------> ASP=CLONAL AVERAGE SEED POTENTIAL
C-------> ASE=CLONAL AVERAGE SEED EFFICIENCY
C-------> AEE=CLONAL AVERAGE EXTRACTION EFFICIENCY
```

```
C-------> AGE=CLONAL AVERAGE GERMINATION EFFICIENCY
      ASP=((2*TFERT)/CNT)
      ASE=((TFILL/ASP)/CNT)
      AEE=TEXTS/TTOTSD
      AGE=TGERM/TFILL
      TFERT=0.0
      TEXTS=0.0
      TTOTSD=0.0
      TFILL=0.0
      TGERM=0.0
C-------> GET THE AVERAGED ACTUAL CONE EFFICIENCY FOR CURRENT CLONE
4500  READ(08,4600) ACE
4600  FORMAT(15X,F6.2)
C------> WRITE THE CLONAL AVGS. OF CURRENT CLONE TO DISK
C------> FOR ZERO CONE EFF. WRITE ALL ZEROS AND "NO DATA" MESSAGE
      IF(ACE.EQ.2.0) GO TO 4780
      IF(ACE.EQ.0.0) GO TO 4790
      WRITE(18,4750) CUR1,CUR2,ASP,ASE,AEE,AGE,ACE
4750  FORMAT(2A4,2X,5F6.2)
      GO TO 4800
4780  WRITE(18,4781) CUR1,CUR2
4781  FORMAT(2A4,'     0.0     0.0     0.0     0.0     0.0 **NOTE** NO DATA - ZER
     1O FLOWERS PRODUCED')
      GO TO 4800
4790  WRITE(18,4791) CUR1,CUR2
4791  FORMAT(2A4,'     0.0     0.0     0.0     0.0     0.0 **NOTE** NO CAS DATA -
     1 NO CONES PRODUCED')
4800  IF(EOF.EQ.1) GO TO 5000
C------->ZERO OUT CLONAL ACCUMULATORS
      ASP=0.0
      ASE=0.0
      AEE=0.0
      AGE=0.0
      TFERT=0.0
      TEXTS=0.0
      TTOTSD=0.0
      TFILL=0.0
      TGERM=0.0
      GO TO 1100
5000  CONTINUE
      END
```

NEWOBV

```
C---------------------------------------------------------------------C
C                          ROUTINE "NEWOBV"                           C
C                                                                     C
C     THE FOLLOWING PROGRAM ALLOWS THE USER TO CREATE THE BASIS       C
C     FOR A NEW "OBSERVATIONS" DATA SET USING AN EXISTING             C
C     "OBSERVATIONS" DATA SET. THE NEW DATA SET IS MODELED AFTER      C
C     THE CHOSEN "OBSERVATIONS" DATA SET, INCREMENTING CONE YEAR      C
C     BY TWO(2) YEARS AND AVERAGING THE CLONAL AVERAGES COMPUTED BY   C
C     ROUTINE "AVGACTS" WITH THE CHOSEN DATA SETS ESTIMATES,          C
C     RESULTING IN A NEW SET OF ESTIMATES FOR SEED POTENTIAL, SEED    C
C     EFFICIENCY, EXTRACTION EFFICIENCY, GERMINATION EFFICIENCY, AND  C
C     CONE EFFICIENCY. THE "OBSERVATION" ENTRIES ARE LEFT BLANK IN    C
C     IN THE NEW FILE, AND ARE TO BE ENTERED BY THE USER AS THEY      C
C     BECOME AVAILABLE.                                               C
C                                                                     C
C     INPUT:                                                          C
C        1. DISK FILE 03 --- THE DATA SET THAT THE NEW "OBSERVATIONS" C
C           DATA SET IS TO BE MODELED AFTER.                          C
C        2. DISK FILE 18 --- THE DATA SET CREATED BY ROUTINE          C
C           "AVGACTS" CONTAINING THE ACTUAL CLONAL AVERAGES OF THE    C
C           OBSERVATION GROUP.                                        C
C                                                                     C
C     OUTPUT:                                                         C
C        DISK FILE 10 --- THE NEW "OBSERVATIONS" DATA SET, MODELED    C
C        AFTER THE CHOSEN "OBSERVATIONS" DATA SET.                    C
C                                                                     C
C---------------------------------------------------------------------C
      INTEGER DIV,CLONE1,CLONE2,ASE,AEE,AGE,ACE,ASP
      REWIND 03
      REWIND 18
C------->STRIP HEADER INFO OFF OF CLONE AVERAGES FILE
      DO 75 I=1, 3
      READ(18,50)
50    FORMAT(1X)
75    CONTINUE
C------->READ A USER "OBSERVATIONS" RECORD (DISK FILE 13)
      READ(03,100,END=800) ICONYR,LOC,CLONE1,CLONE2,IROW,ICOL,IYRGRF,NRA
     1MET,IESTSP,IESTCE,IESTSE,IESTEE,IESTGE
100   FORMAT(I2,A4,2A4,4X,2I3,I2,I3,25X,I3,4I2)
      ICUR1=CLONE1
      ICUR2=CLONE2
C-------> READ A CLONAL AVERAGES RECORD (DISK FILE 18)
      READ(18,200) JCUR1,JCUR2,ASP,ASE,AEE,AGE,ACE
200   FORMAT(2A4,2X,I3,7X,I2,4X,I2,4X,I2,4X,I2)
C-------> AVERAGE CURRENT CLONES ACTUALS WITH OLD ESTIMATES
250   NCONYR=ICONYR+2
      IF(ASP.EQ.0) DIV=1
      IF(ASP.GT.0) DIV=2
      NESTSP=(IESTSP+ASP)/DIV
      NESTCE=(IESTCE+ACE)/DIV
      NESTSE=(IESTSE+ASE)/DIV
      NESTEE=(IESTEE+AEE)/DIV
      NESTGE=(IESTGE+AGE)/DIV
C-------> WRITE A NEW "OBSERVATIONS" DATA SET RECORD
      WRITE(10,100)NCONYR,LOC,CLONE1,CLONE2,IROW,ICOL,IYRGRF,NRAMET,NEST
     1SP,NESTCE,NESTSE,NESTEE,NESTGE
C-------> READ ANOTHER OLD "OBSERVATIONS" RECORD
400   READ(03,100,END=800)ICONYR,LOC,CLONE1,CLONE2,IROW,ICOL,IYRGRF,NRAM
     1ET,IESTSP,IESTCE,IESTSE,IESTEE,IESTGE
C-------> CONTINUE WRITING NEW "OBSERVATIONS" RECORDS UNTIL
C-------> NEW CLONE ID OCCURS.
```

```
      IF(CLONE1.NE.ICUR1.OR.CLONE2.NE.ICUR2) GO TO 500
      WRITE(10,100)NCONYR,LOC,CLONE1,CLONE2,IROW,ICOL,IYRGRF,NRAMET,NEST
     1SP,NESTCE,NESTSE,NESTEE,NESTGE
      GO TO 400
500   ICUR1=CLONE1
      ICUR2=CLONE2
C-------> READ ANOTHER CLONAL AVERAGES RECORD AND CONTINUE
C-------> PROCESSING.
      READ(18,200) JCUR1,JCUR2,ASP,ASE,AEE,AGE,ACE
      GO TO 250
800   CONTINUE
      END
```

DEVELOPMENT OF A COMPUTERIZED SEED ORCHARD INVENTORY-MONITORING SYSTEM AND ANALYSIS OF SEED ORCHARD PRODUCTIVITY VARIABLES

by

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(ABSTRACT)

A computer program package for use with the southern pine seed orchard Inventory-Monitoring System (IMS) was developed and tested using 1980 and 1981 cone crop data collected from Weyerhaeuser's loblolly pine seed orchard at Magnolia, Arkansas. The Computerized IMS, written in Fortran, is accompanied by a user's guide containing data entry instructions. The IMS package includes one predictive program and two programs designed to interpret actual harvest data and make it available for the computation of predictions for future crops. The predictive program utilizes strobilus survival data from sample trees and clonal estimates for cone analysis-derived variables to compute clonal cone and seed yield predictions. Cone yield predictions calculated by the Computerized IMS for the 1980 and 1981 crops indicated that it has the potential for producing useful production estimates. Investigations of variance within the seed orchard having an impact on IMS predictions centered on clonal, age-class (within-clone), annual, orchard location and within-crown effects on cone analysis-derived variables, cone efficiency and flowers-per-tree. Analysis of clonal variance indicated that seed potential and germination efficiency were under strong genetic control compared to the other characters. Annual clonal stability was high enough for clonal seed potential and seed efficiency to make useful regression models possible for estimating these variables without complete cone analysis. Clonal cone efficiencies displayed low annual stability, discouraging the use of stratified clones to estimate productivity, since clones could change productivity classes from year to year. Within-crown variation was not well-defined for most variables due to clone-crown sector interaction. However, cones were concentrated in the middle one-third of the crown and empty seed percentages were found to be highest in the north crown quadrant. The study indicated that clone-by-clone monitoring of seed orchard production, while the most expensive option, will produce the most reliable and useful yield predictions.