Use of the Inventory-Monitoring System for Shortleaf and Eastern White Pine Cone and Seed Crops at the Beech Creek Seed Orchard

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Cone and seed crops of eastern white pine (Pinus strobus *L.) and shortleaf pine (*P. echinata *Mill.) seed orchard trees were monitored with an inventory-monitoring system. Survival curves for the crops were developed showing the cone efficiency and when losses were occurring in the orchard trees. Cones of one species were analyzed. Results of this study allow the seed orchard manager to evaluate orchard productivity and to develop more* cost-effective *pest management programs.* Tree Planters' Notes 39(4):23-29; 1988.

In June of 1981 at the Beech Creek Seed Orchard, Nantahala National Forest, USDA Forest Service, Murphy, NC, we began to use the inventory-monitoring system (IMS) developed by Bramlett and Godbee (1). This system involves periodic inspection of sample trees and branches to measure the survival of the initial cone crop and to predict expected cone and seed yields at maturity. The data collected allow the orchard manager to calculate the cone efficiency of the orchard and to determine when losses are occurring. At maturity, cone analysis of a sample of the cones in the IMS is used to evaluate the seed production efficiency of the sample trees. Collectively, the information can then be used to determine what corrective procedures need to be taken to bring cone and seed production efficiency levels up to an acceptable level.

Two species, each from a different geographical source, were monitored using the IMS. The methods used with each species shall be described separately.

Methods

Study I. The inventory-monitoring system was first used to study eastern white pines *(Pinus strobus* L.) from a North Carolina source. The stratified clone procedure was used to estimate the orchard productivity.

Clones were classified on the basis of cone production, that is, being either poor, moderate, or good cone producers. Then a proportion of the clones were randomly selected to represent each production class based on previous knowledge of the cone production of each clone. Thirty-nine sample trees (ramets) were selected representing 8 good, 5 moderate, and 3 poor cone producers. Ideally, three ramets would have been selected from each production class, but due to logistical problems a few clones were represented by only one or two ramets.

A total flower count was made on the sample trees as soon as possible after flowering was complete, and then sample branches were tagged. These sample branches were then counted periodically throughout the life-cycle from flower to mature cone. The branches were selected throughout the flower-bearing portions of the trees so as to be a good representative sample of the flower crop in all crown positions.

Subsequent counts were made of the sample branches only, and from this information inferences were made regarding the total flower and cone crops. Four to eight sample branches per sample tree were selected with 1 to 25 flowers per branch. This represented from approximately 28% of the total tree count for the good producers, to as high as 100% on the low producers.

Thus, there was a fairly large percentage of the total tree flowers represented by the sample branches. This would not have been possible in a year with a heavy flower crop.

The 39 sample trees were about 2.5% of the eastern white pines from the North Carolina source. This number of sample trees is not quite up to the recommended minimum of 48 trees, but because of the relatively poor flower crop of 1981, this number should be more than adequate.

Study II. The IMS technique was next used to study shortleaf pines from a Kentucky source. The stratified clone procedure was used to choose the sample trees.

Thirty-five sample trees were selected representing 6 good, 4 moderate, and 2 poor cone producers. All clones were represented by three ramets with the exception of 1 clone. Six to 8 sample branches were selected per sample tree, with each branch bearing 1 to 25 flowers. Nine to 100% of the total tree count was encompassed by the sample branch count.

The 35 sample trees represent about 2%, of the shortleaf pines from the Kentucky source.

Results and Discussion

Study I. The history of the 1981-82 flower/cone crop from the eastern white pines from the North Carolina source at the Beech Creek Seed Orchard is presented in figure 1 (all the sample trees studied) and figure 2 (random sample of 18 of the original 39 ramets used to calculate the data in figure 1). Both graphs differ very little except that an additional conelet count was made in July for figure 2.

Several observations can be made from the data. This group of eastern white pines had a low to moderate amount of flowers initially. Many flowers aborted between flowering in May and

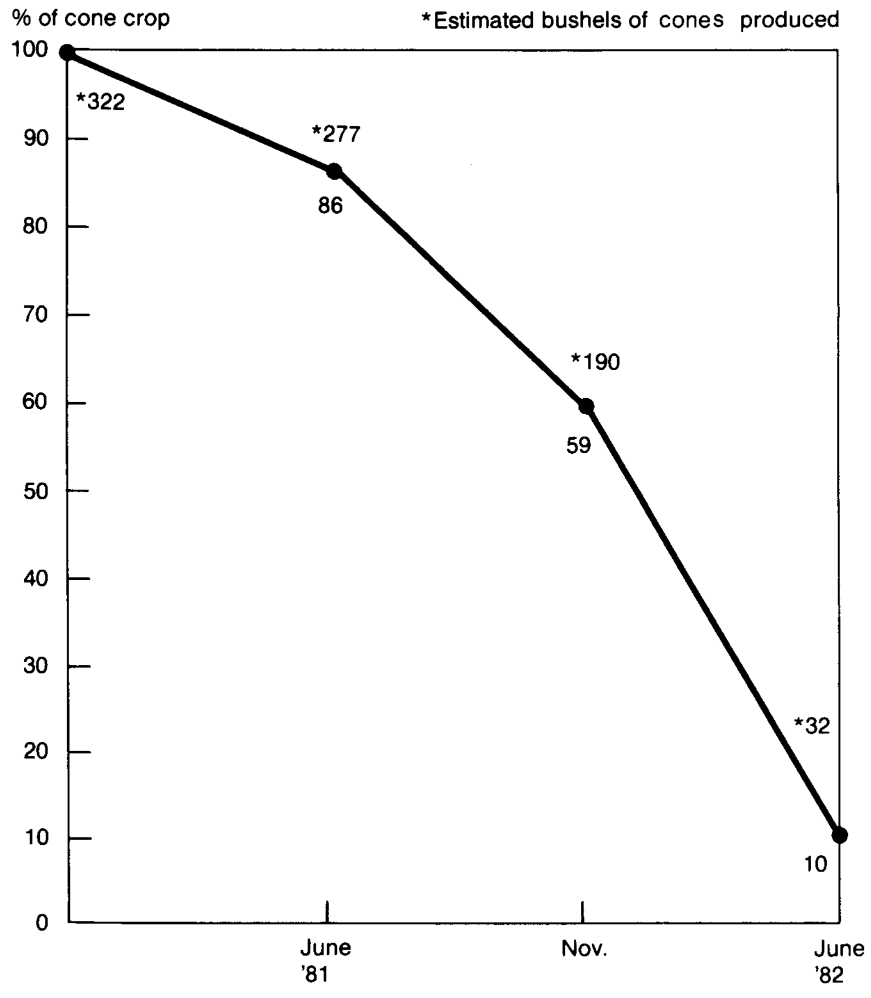

Figure 1—*Cone efficiency and estimated bushels of eastern white pine cones at the Beech Creek Seed Orchard (1981–82 cone crop; all sample trees).*

the count made in July (about 30`%, see fig. 2). This may have been due to the poor pollen crop, but the only way to substantiate that claim would be to count pollen grains per ovule, which was beyond the scope of this study.

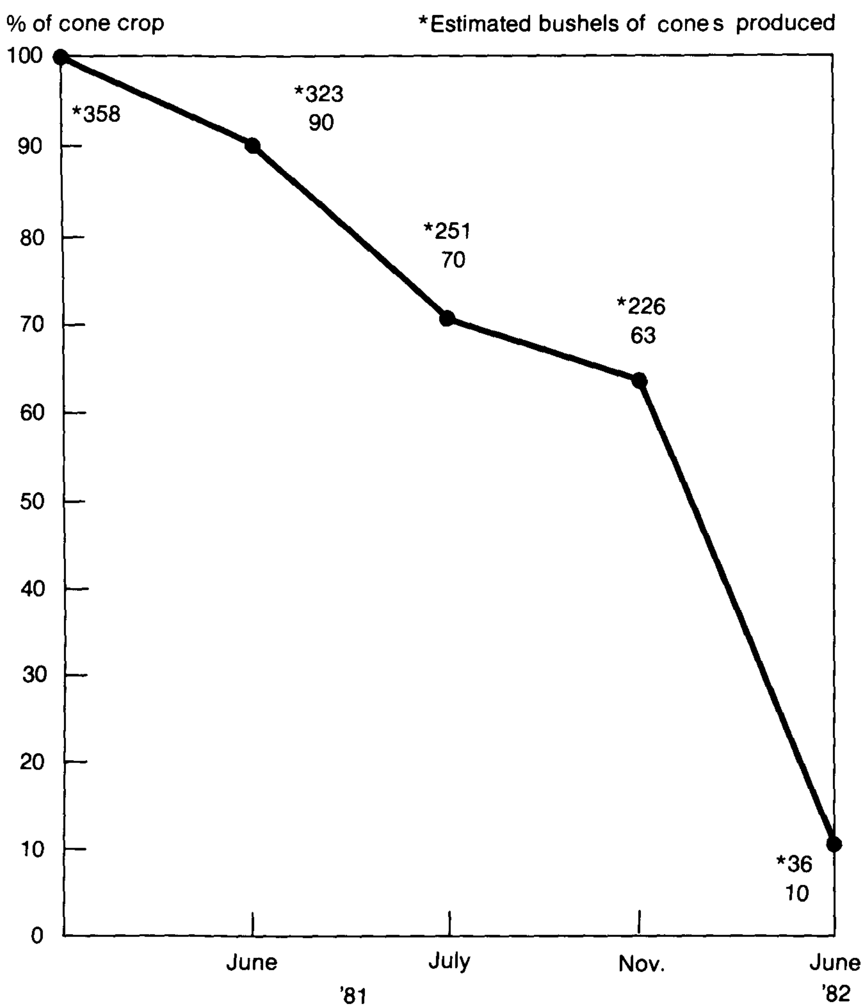

Figure 2—*Cone efficiency and estimated bushels of eastern white pine cones at the Beech Creek Seed Orchard (1981–82 cone crop; random sample, 18 of 39 ramets).*

The trees retained about 60% of their conelets into the winter. This cone efficiency value is quite acceptable considering that no effort was made to protect the conelets from insect attack during this period.

The curves for November 1981 to June 1982 (figs. 1 and 2) show a gradual loss in cones until April, when the curves drop off drastically. These curves are only approximations because there was not time to do a cone count in early April. It is known from past history and from the life cycle of one of the major cone-attacking insects—the white pine cone beetle, *Conophthorus coniperda (Schwartz)*—that the majority of cone loss during this period occurs during the spring and early summer.

Because the cone crop was so poor, no pesticide was applied to protect the cones from the white pine cone beetle. The results of no protection is dramatic (fig. 1 and 2). At this point the study was terminated because 90% of the cone crop was gone and little valuable information could be realized between June and the maturation of the cones in August.

Study II. The cone efficiency of the 1982-83 flower/cone crop from shortleaf pines from a Kentucky source was excellent (figure 3). Losses were minor throughout the crop's life cycle. Cone efficiency values above 60%, are generally acceptable in southern pine seed orchards. The 89% survival we obtained is probably near or at the peak efficiency that could be expected.

One of the primary reasons for using the IMS is to estimate cone and seed yields. Figure 3 shows the estimated number of bushels one could expect to harvest from this shortleaf pine orchard. With the IMS data, there were 510 bushels of cones predicted. In actual field harvest, this source yielded 517 bushels. Needless to say, we were quite pleased with the estimate derived from the IMS data. The small crop of white pine cones in study I was not harvested, and therefore the comparison between field results and predicted values could not be made.

Cone analysis of a small sample of the cones collected from the IMS at maturity yielded the data presented in figure 4. Due to economic restraints it was not possible to perform complete cone analysis on all cones, and only one cone per clone was used in the IMS. Thus the seed efficiency values are derived from a rather small sample. The value of 69% seed efficiency is quite high considering that the biological maximum is thought to be around 90%. Values above 55% indicate good management practices are being used at the seed orchard (2).

The extraction efficiency average of 73% was obtained from a much larger sample (10 cones per clone), but the results may be less representative than

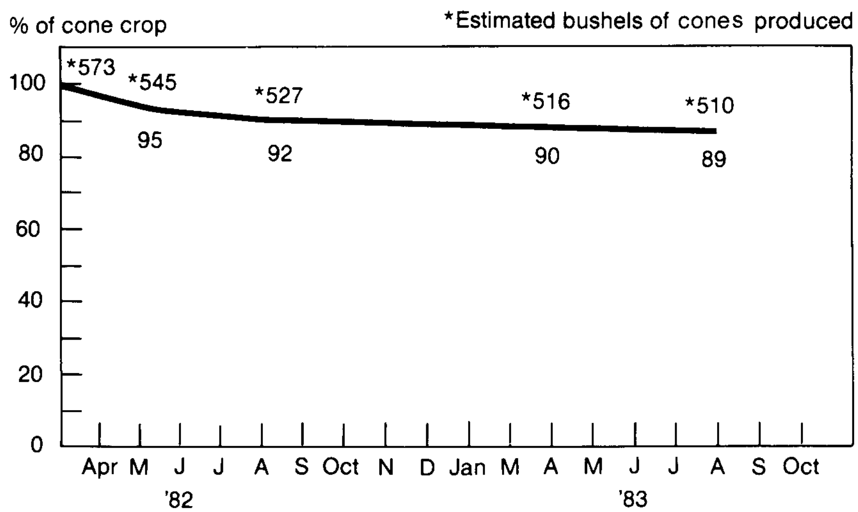

Figure 3—*Cone efficiency and estimated bushels of the shortleaf pine cone crop at the Beech Creek Seed Orchard (1982–83 cone crop).*

expected extractory efficiencies for several reasons. First of all, the cones were collected 1 week earlier than normal in order to avoid interfering with production cone collections. Thus the IMS sample cones were not quite mature and subject to case hardening.

Secondly, shipment of the cones was delayed, restricting natural cone opening prior to receipt at the cone analysis service. Actual field results from the bulk cone collections in this shortleaf source yielded nearly 1 pound of seed per bushel of cones. This figure indicated a more acceptable extraction efficiency than was predicted with the IMS sample cones.

Germination was not tested by the cone analysis service, but the general orchard collections from this shortleaf source yielded seed that showed 80% germination (fig. 4).

From closer analysis of the cone analysis data (table 1), several observations can be made:

1. An average of 79 developed seed per cone were extracted.
2. The average seed potential for this shortleaf seed orchard was 101, which is

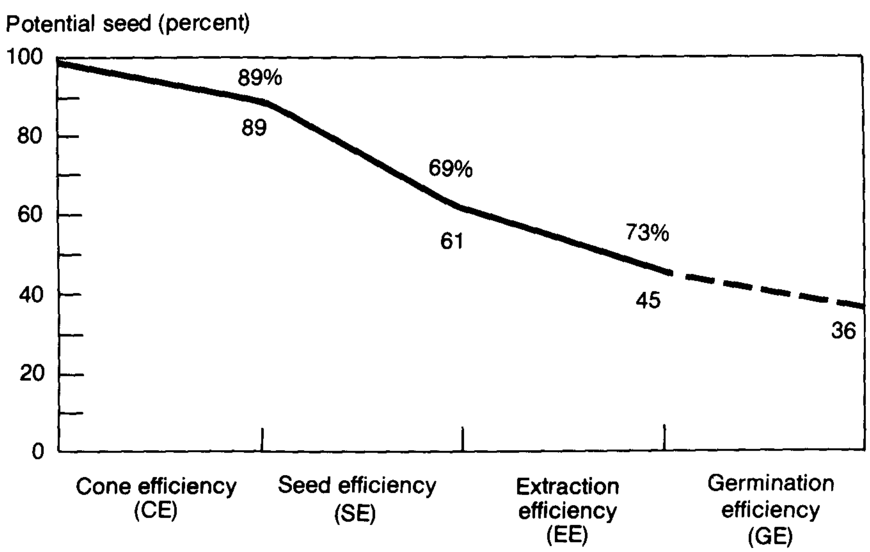

Figure 4—*Seed orchard-to-nursery efficiency of the 1982–83 shortleaf pine seed crop.*

slightly higher than the expected average of 88 to 90. The range was from 80 to 148, possibly indicating that those clones in the upper end of the range have some loblolly parents in their pedigree. Clone 42 in particular has longer needles and produces much larger cones than those normally characteristic of a shortleaf pine. It has also been suggested that the seed orchard environment, with the cultural regimes practiced there—for example, fertilization, thinning, subsoiling, etc.—may increase seed potential much like these practices increase flowering potential.

3. The average percentage of first-year aborted ovules was 21%, with over 80% of the clones having 16% or less first-year abortions. These abortions are caused mostly by a lack of viable pollen and/or by feeding by nymphs of the leaffooted pine seed bug—Leptoglossus corculus (Say) (2). These first-year abortions seldom fall below 10 to 15% in any given year.
4. The number of second-year ovule abortions was quite small, indicating that we had excellent control of the seed bugs early in the second growing season.
5. The average percentage of developed seed was 79%, with 87% of these developing into full seeds.
6. As already mentioned the average seed efficiency was 69%. This value is expressed as the ratio of filled to potential seed. The loss of 31% of the potential seed can be broken down as follows: 21 % of the loss was from first-year abortions and has already been discussed, 10% of the loss was from second year abortions acrd empty seeds with both of these conditions brought about primarily by seedbug feeding. Another cause of empty seeds may be embryo abortions brought about when recessive lethal genes combine (3, 4).

The pattern and general trends shown by these results can be closely correlated to the pest management program during the 1982-83 cone crop development, which is summarized here.

* The first pesticide application to this seed orchard was in February 1982, when carbofuran (Furadan 10-G) was applied at 4 ounces per inch dbh. Azinphosmethyl (Guthion 2L) applied at 3.5 gallons per 500 gallons of water) was sprayed on July 13 and monthly until September. The carbofuran should have protected the flower and conelet crop early in the growing season, yet there were moderate levels of first

Table 1—*Clonal and overall averages 1982–83 Kentucky shortleaf cone analysis summary*

Clone	TD	DS%	EE%	A1%	A2%	SEP	FL%	SE%
15	74	80	16	16	4	80	95	76
16	26	17	82	82	1	90	87	14
17	74	82	86	18	0	108	92	76
22	82	72	73	28	0	124	87	62
23	74	92	55	8	0	90	93	86
27	96	87	80	13	1	112	92	79
30	70	90	46	10	0	90	93	83
32	83	83	46	13	4	98	67	55
36	80	84	88	16	0	88	88	74
37	103	87	87	13	0	102	91	79
40	80	80	51	20	0	86	71	57
42	111	91	96	9	0	148	93	84
Overall averages	79*	79†	73*	21†	.75†	101†	87†	69†

* Average of 120 sample cones (12 clones).
† Average of 12 sample cones (1 cone clone).
TD = total developed seed, DS% = %developed seed, EE% = extraction efficiency, A1% = % first-year abortions, A2% = % second-year abortions, SEP = seed potential, FL% = % filled seed, SE% = seed efficiency %.

year ovule abortions. Possibly the carbofuran did give partial control, but its value may be questionable.

* Monthly spraying of azinphosmethyl (Guthion) after July 1982 and fenvalerate (Pydrin) beginning in midMay 1983 gave excellent control until the cones reached near full size in July 1983. Following a scale insect outbreak, entomologists recommended that we discontinue spraying with fenvalerate and use malathion instead. If the damage from seedbugs had occurred during the early summer, (during fenvalerate protection periods), then one would expect to have substantial numbers of second-year ovule abortions. Seedbug feeding on full-sized cones caused empty seeds rather than aborted ovules, thus one can assume the majority of the seedbug feeding occurred during July and beyond. Again empty seeds may not all be caused by seedbugs, but can also be caused by lethal gene combinations. Thus with 13% empty seed being extracted there was either a problem in late-season seedbug control, a problem with recessive genes, or a combination of these factors. However, 87% filled seed is very good seed yield, and it is doubtful that there is much opportunity for improvement.

Conclusion

it appears that the IMS is a valuable tool for seed orchard managers. If used on a continuing basis, orchard managers can evaluate both short and longterm changes in orchard productivity. When used in conjunction with cone analysis the manager can pinpoint when and where losses are occurring, and then determine if additional measures to protect the crop(s) are cost effective enough to justify the increased management costs.

As we build up several years of data, our ability to accurately predict seed yields will be greatly increased, as will our knowledge of the most crucial time periods in seed protection.

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