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Annual Variation in the Seed Crops Of Loblolly Pine

Karl F. Wenger
Southeastern Forest Experiment Station,
Forest Service,
U. S. Department of Agriculture

ALTHOUGH CONE CROPS of loblolly pine fluctuate widely from year to year, they are more or less uniform over extensive territories in any one year. This uniformity gives rise to the familiar term "seed year." If seed years could be predicted well in advance, the information would be extremely useful in planning cone collections and regeneration measures. Prediction, however, requires an understanding of the basic causes of cone-crop fluctuation, which have received little study because quantitative data are difficult to obtain.

Seed-trapping records in the Bigwoods Experimental Forest[1] from 1946 to 1953 provided sufficient data for studying these causes. Only the records from mature, undisturbed stands were used, because these most clearly reflect the factors affecting size of seed crops. In immature stands, the year-to-year variation of seed crops is modified by the stand's yearly progress toward maturity; in partially cut stands by the effect of release; and in isolated trees by the probability of inadequate pollination. Stands must also be in stable and sympathetic ownership so that they can be withheld from cutting long enough to yield a sufficient number of observations.

Factors Affecting Seed Crops

Seed-crop records were obtained over a period of eight years in the Bigwoods from three stands that satisfied these requirements (Fig. 1). They were well-stocked, although they differed in density, age, origin, and the soils in which they grew. One was an old-field stand of 95 years growing on sandy loam of the Kalmia series. The other two were forest grown, 145 years old, on Craven and Lenoir silt loams. The effects of these stand differences were eliminated from the data by expressing the seed production of each stand as a proportion of the bumper 1947 crop.

Inspection of the data suggested that a large crop in one year was followed by a small crop two years later, and vice versa. The resulting pattern is two good seed years followed by two poor seed years. Regression analysis showed that this relation was highly significant.

This relation suggested that internal physiological factors were a major cause of the annual fluctuations of seed crops. The flower buds formed during one growing season blossom the following spring and produce mature cones and seed two growing seasons later. The cones remain quite small until fertilization occurs in the spring of their second year. Then they develop rapidly, reaching full size in a few months. Thus, a heavy crop in its final season apparently retarded floral differentiation strongly, the inference being that nutrient supplies were used by the maturing crop faster than they could be replenished.

On the other hand, the more or less uniform fluctuation throughout extensive localities suggests weather also as a major factor. In Europe, heavy production of beech mast occurred when the summer of the preceding year was drier and warmer than normal (*1*). In southeastern Virginia, measures to stimulate cone production of loblolly pine must be applied before late June to affect the buds formed during that growing season. (*7*). Consequently, rainfall between the beginning of the growing season and midsummer is more likely to influence fruiting than rainfall at

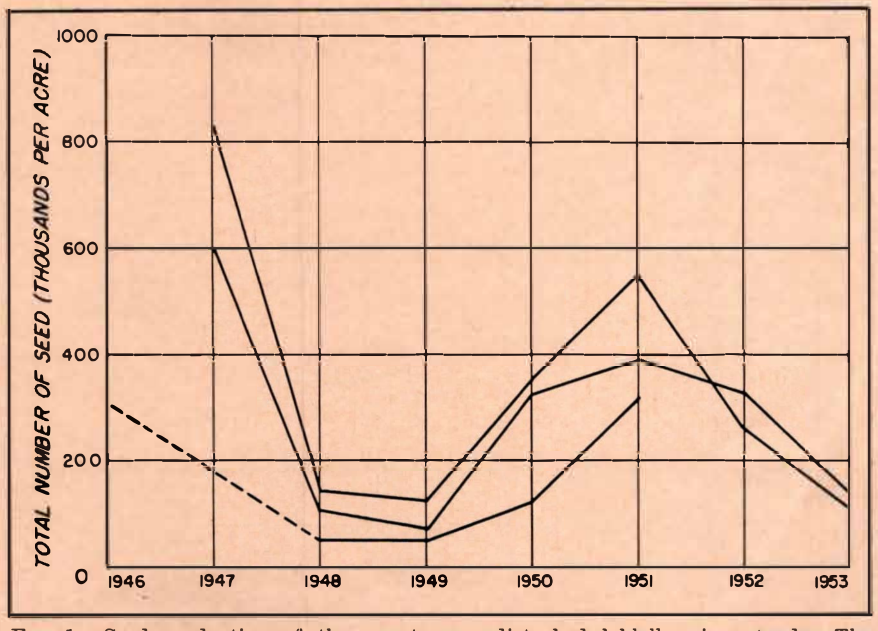

FIG. 1.—Seed production of three mature, undisturbed loblolly pine stands. The lines connect the values for the same stand in succeeding years. No observation was made in one stand in 1947; the dashed line connects the values for 1946 and 1948.

[1]Maintained in Hertford County, North Carolina, by the U. S. Forest Service in cooperation with the Camp Division, Union Bag-Camp Paper Corporation, Franklin, Virginia.

other times of the year. Daily records of rainfall within 3 miles of the Bigwoods Experimental Forest have been kept since March 1949. Records of rainfall before 1949 were available from a weather station at Holland, Virginia, about 20 miles from the experimental forest.

Graphic methods were used to determine the time between April and August when rainfall was most likely to affect fruiting two years later. Differences between the observed seed crops and estimates made by the cyclical relation already found were computed. These were plotted over the rainfall for each month from April to August of two years before, and over every likely 2-, 3-, and 4-month combination of the same five months. The lack of any relation was clear in most cases but seed production seemed to be closely related to June-to-July and May-to-July rainfall. Therefore, each of these values was used in turn in the regression analysis, together with the seed crop of the same year and the interaction between them as the independent variables. Slightly but not significantly more of the variation in seed production was accounted for by the May-to-July rainfall than by the June-to-July rainfall.

The final analysis showed that May-to-July rainfall and its interaction with the seed crop of the same year each accounted for a highly significant portion of the variation in the seed crop two years later. The earlier seed crop by itself did not significantly affect the seed crop two years later after the effects of the two more important variables had been accounted for. The final relation was as follows:

$$Y = -17.9008 + 4.590(b) - 0.0256(bc)$$

in which Y = current seed crop
b = May-to-July rainfall two years earlier
c = seed crop two years earlier

Thus, seed production varied directly with the May-to-July rainfall and inversely with the seed crop of two years earlier (Fig. 2).

The multiple correlation coefficient derived from the data was 0.89, showing that the relations were very close. One of these relations is well supported by observation made in the Duke Forest near Durham, North Carolina (*3*), which show the same negative correlation of seed crops in a 2-year cycle as the Bigwoods observations.

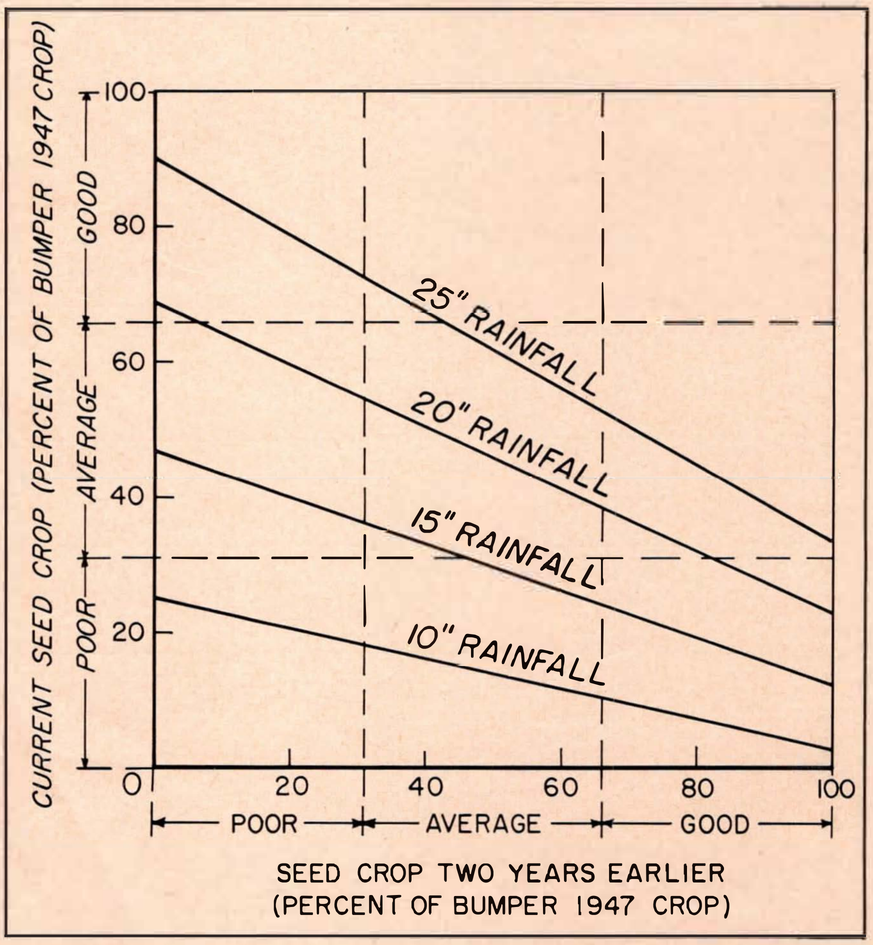

FIG. 2.—Relation between the size of the current seed crop, the May-to-July rainfall two years earlier, and the seed crop two years earlier.

Effects of Moisture on Fruiting

Since adequate soil moisture is required for the absorption of mineral nutrients and nitrogen, the annual fluctuations in loblolly pine seed crops may be caused by variations in the amounts of these substances absorbed. On the other hand, the findings of European workers indicate that carbohydrate reserves are the critical factor in floral initiation, flower buds instead of vegetative buds forming only when a surplus of carbohydrates is present. However, the formation of carbohydrates is affected by soil moisture, since the rate of photosynthesis varies with changes in soil moisture levels (*2*). The transformation and movement of materials within the plant are also influenced by the supply of moisture; consequently, moisture stress in the growing tips may be another factor affecting floral initiation. It seems probable, therefore, that the supply of moisture affects the rate and quantity of a number of processes and substances which are involved in the annual fluctuations of seed crops of loblolly pine.

The effect of rainfall observed in this study suggests that the larger seed crops produced by loblolly pine after crown release (*7*) are more likely a response to increased soil moisture than to increased light, since even dominant trees produce more cones after release. The reduction in transpiration following the removal of competing trees is probably equal to a substantial amount of rainfall.

The results of this study also suggest that irrigation might be very profitable in seed orchards. Whether the cycle of large and small crops could be overcome is problematical, but a heavy crop every third and fourth year might be virtually assured, provided no unusual flower or cone losses were caused by insects, diseases, or adverse weather.

Practical Applications

If further trials show that the relation presented above is reliable, seed crop forecasting is an obvious application. The size of the seed crops can be expressed in general terms, such as good, average, and poor, on the basis of a bumper crop in the locality (Fig. 2). A seed crop then could be judged during seed collections and, together with the rainfall for the preceding May-to-July period, used to predict the seed crop two years later.

The predicted crop would have to be examined at critical times between its initial prediction and its maturity, particularly when plans for individual tracts were based on the forecast, because any one of a variety of factors could destroy or substantially reduce a promising crop. Weather is especially critical during flowering, but extreme summer droughts have also reduced or destroyed seed crops (*5, 6*). Some opinion about insect damage could be formed or more detailed observations made during seed collections in the first autumn of the predicted crop. These agencies do not often destroy or seriously reduce a loblolly pine seed crop in the localities studied, as is shown by the consistent response of the species to partial or complete release (*7*) and by the relation of seed crops to rainfall and fruiting two years earlier.

Little need be said about the advantages of knowing the seed crop two years in advance in planning seed collections or regeneration measures such as seedbed preparation. Not so obvious is the use to which this method of seed crop forecasting can be put in planning seed-tree cuttings. The relation seems to give the most accurate forecast when the current seed crop is heavy. A heavy crop in one year apparently makes a poor crop two years later virtually certain because only an excessive amount of rainfall will increase the prospective crop to the average level (Fig. 2). Since a heavy crop can be predicted a year in advance by the cone-ratio method (*4*), a poor crop can be detected three years before it matures. If the released seed trees needed (*8*) were selected and treated during the winter following this first indication, their increased seed production would be available in the year of the poor crop.

When, on the other hand, the inspection a year in advance shows a poor crop on the trees, the crop three years later cannot be predicted with the same confidence because in that case rainfall has a much greater effect. However, the prospective crop is likely to be at least average, since only seriously deficient rainfall during the critical period will reduce it to the poor level. An average crop will usually result in a satisfactory amount of reproduction if seedbed preparation has been intensive (*8*). In a good seed year, the seedbed created by tractor logging is usually adequate. When the prospect of a good or average crop is not fulfilled because of severe drought or other calamities, which may occasionally happen, planting is the only recourse for promptly establishing a new stand.

Summary

The seed production of three mature, undisturbed stands of loblolly pine in northeastern North Carolina was found to vary inversely with the seed crop and directly with May-to-July rainfall of the second preceding year.

These results suggest that the larger seed crops produced by loblolly pine trees after crown release are a response to increased soil moisture rather than to increased light. They also suggest that irrigation may be very profitable in seed orchards.

If further testing shows them to be reliable, the relations found can be used to forecast seed crops in planning cone collections and regeneration measures. A poor crop can be detected three years in advance, ample time to select and release seed trees so that their increased seed production will be available in the poor seed year.

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