The collection, cleaning, drying and storage of enough tree seeds for reforestation in California is increasingly important in today's forest management. A prime factor inhibiting seed production is insect damage. Many insect pests are not externally visible, and empty seeds or deformed or diseased embryos cannot be discovered except by seed dissection. A new high-speed X-ray technique for the rapid analysis of the proportion of sound seed is discussed in this report.

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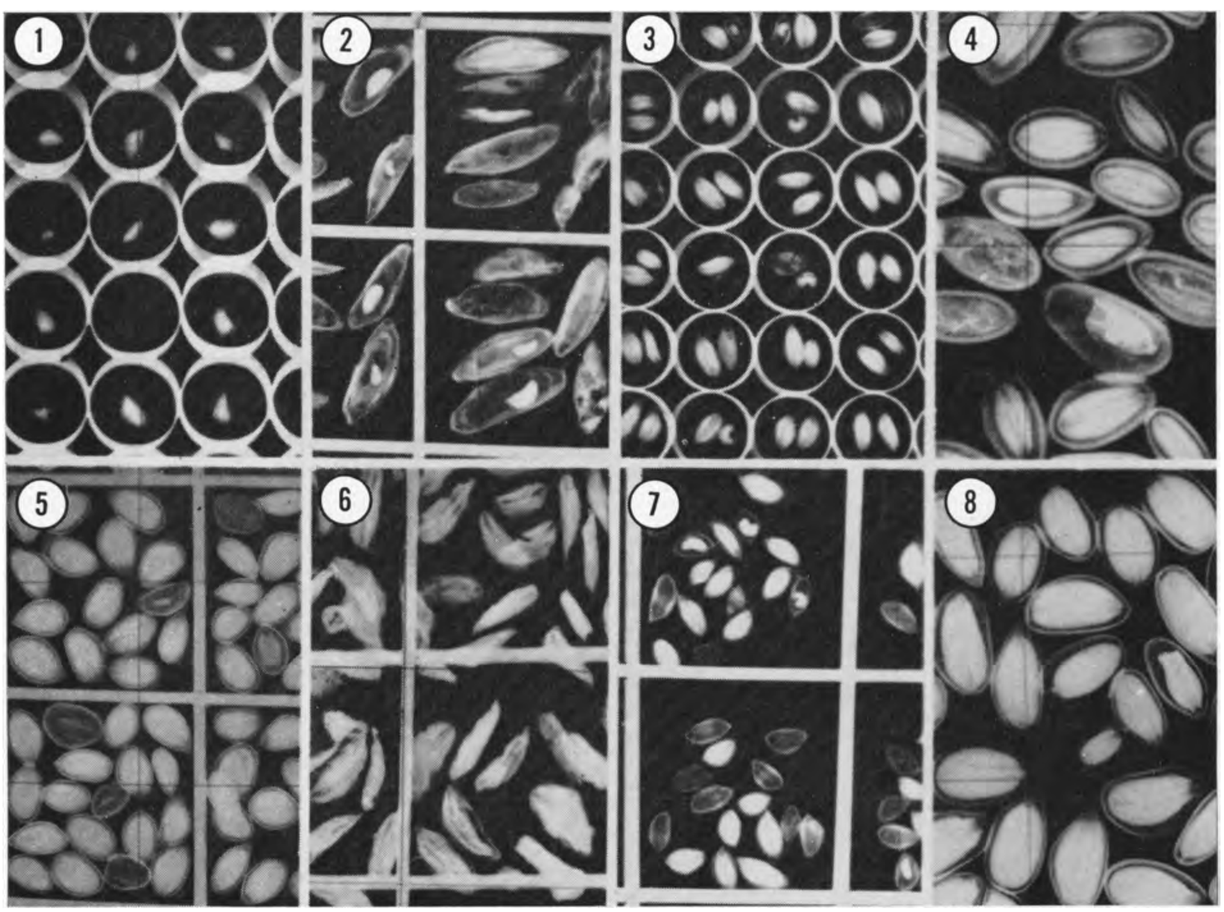
X-ray inspection technique aids
FOREST TREE SEED PRODUCTION

OVER FOUR MILLION acres of California designated as forest land are inadequately stocked with trees. Each year additional forest acreage is cut, burned or depleted by insects, disease and animals. Trees lost in the forest are not always replaced by natural reforestation. The sporadic nature of seed crops of forest trees and many hazards during seed formation and seedling establishment, limit natural regeneration. Failure to establish a good supply of seedlings results in reduced stocking, poor forest growth, and conversion of forest land to brush—adversely affecting commercial forestry. Reforestation failure also can affect aesthetic values of national and state parks and reduce the water-holding capacity of watersheds.

Collection of forest tree seeds and the supplying of seedlings to the forest industry, the farmer, and for reforestation of public lands is a responsibility of the California Division of Forestry. Each year its four forest nurseries in the northern part of the State produce more than four million seedlings. Of the 25 species grown, six or seven make up the bulk of production—including Douglas-fir, white and red fir, and ponderosa, Jeffrey and Monterey pine. The nurseries require about 4,000 pounds of seed annually to fill production requirements. Unfortunately, good seed-producing cone crops

Radiographs below show: (1) Degrees of viability, redwood; (2) Red fir, badly infested; (3) and (7) Douglas fir showing two methods of separating samples for counting and study; (4) Sugar pine, none infested but several blanks; (5) Ponderosa pine, empty seed, malformed embryos show clearly; (6) White fir, generally poor seed; (8) Coulter pine, several ill-formed embryos.



occur only about once in every five to seven years. This makes it necessary to collect large quantities when crops are good. Such a large crop occurred in the fall of 1962 and the Division of Forestry collected about 235 tons of cones, from which an estimated 18,800 pounds of clean seed may be obtained.

Planting zones

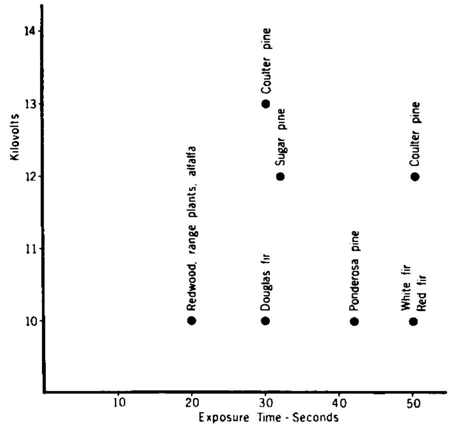
The State is divided into thirteen zones to check area suitability of planting stock grown in the nurseries. In considering annual cone collection quotas, planting requirements in each zone must be considered. Douglas-fir seedlings, for example, that have been grown from seed collected in the Douglas-fir belt of the North Coast (Zone XI) are not adaptable for planting in high elevations of the Northern Sierra (Zone III). One complication in cone collection is that good crops of cones are not produced in all zones at the same times, and production may be very spotty within zones. Another complication occurs when demand for seedlings is heaviest in a zone where crops may be lightest.

Cones are collected from mid-August to early December and most of them are shipped to the Division's seed processing plant near Davis, Yolo County. Here they are spread on cement slabs to open in the sun. After opening, cones are fed through a mechanical shaker to remove the seeds. The product from the shaker is termed rough-clean seed. Some field stations also have facilities for opening cones and the extracted, rough-clean seed is sent to Davis for further processing.

Seed processing

The pine and Douglas-fir seeds have wings that must be removed before they can be used in the nursery. A drum containing revolving rubber vanes is used to gently rub off the wings. Cleaning and up-grading processes, which are similar to those used in cleaning and up-grading agricultural seeds, follow dewinging. A mechanical cleaner employing a combination of forced air and grading screens produces the most viable seed possible. Wings are not removed from white fir because rubbing injures the seed. After cleaning, all seed is tested and placed in refrigeration, the pines at 38°F., the Douglas-fir and true firs at 0°F. Slightly below freezing temperatures would be better for pine seed, but equipment presently used was not designed for lower temperatures.

Most conifer species exhibit an internal dormancy which must be overcome before germination takes place. This requires a pre-chill or vernalization process. Seeds are placed in a moisture-retaining medium and held in a refrigerator at just above freezing for 30 to 90 days (depending on species). Germination tests are then run for about 30 days at a constant temperature of 72°F—to provide nursery managers with information on the number of seeds needed per square foot of seed bed. Optimum density for one- and two-year well-developed seedlings is 30 to the square foot. Germination varies considerably among species and from lot to lot within species. Maximum germination for white fir is about 60 per cent and many lots may be much poorer.



Approximate exposure guide for radiographing tree seeds.

A number of factors, such as weather and insects, may affect the quality of seed in a cone crop. The poorer the cone crop, usually the more intense are insect attacks—and the poorer the quality of seed. Some cones exhibit such poor quality seed that they are not worth collecting.

Attacking insects may include caterpillars, beetles, borers and many kinds of sucking insects. Damage caused by most of the cone destroyers is visible externally and such defective cones can be screened out before processing the seed. Many of the insects which feed on seed can be easily detected but there are several which develop within the seed itself and are discovered only by dissection or other means. These include species of flies and wasps which are capable of destroying 85% or more of seed crops by themselves.

One of the major problems with these pests is that they cannot be removed by the current methods of cleaning and sorting seeds. Therefore, the stocks of seed upon which the foresters rely may be much less than is estimated on a volume or weight basis. In 1961, the University of California and the California Division of Forestry instituted studies of "bad seed" detection methods based on European use of X rays in seed examination.

X-ray photos

This method is based on the fact that it is possible to obtain excellent radiographs (X-ray photos) of the internal structures of seeds using low kilovolt radiography—similar to that used by dentists and dermatologists. The structure and condition of the plant embryo is readily seen and the presence of any foreign body (insect, disease or other defect) shows up clearly. With the appropriate X-ray unit (0 to 35 kilovolts at 10 milliamperes), seeds of almost any size can be radiographed and pictures of high quality obtained. The main factor affecting exposure time was size and thickness of the seed coat, as indicated on the graph. These voltage and exposure guides were developed to give the best resolution of detail.

Data obtained in these studies show the value of the technique in determining relative productivity of seed collection zones, degree of insect infestation, value of cleaning seed, relative proportions of hollow or inviable seeds and relative losses in tree species as indicated in the composite photo. Future studies will include a more precise program of X-raying samples of seed lots before cleaning and after cleaning, prior to storage—with the following objectives:

1. Provide information on the tree species affected, the location of centers of greatest insect activity and, if continued each year, some estimate of insect trends.
2. Furnish biological material for determination of insect species involved and their biologies.
3. Permit appraisal of the viability of seed according to the appearances of the embryo and endoplasm. This would be of value in determining: (a) efficiency of the cleaning and extraction process; (b) evaluation of the relative merits of seed from various sources; (c) failure of seeds to develop or lack of pollination according to tree species and sources; (d) viability in one day rather than two to four months for conventional methods.

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