New Trends in Breeding Trees for Disease and Insect Resistance

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For many generations silviculturists have been using various means at their disposal to reduce damage caused by diseases and insects to forest trees. The production and use of more resistant varieties is a relatively new way of reaching this objective. Most tree breeding programs that are aiming for improved resistance are still in their infancy. My purpose in this brief review is to point out some examples of recent developments in resistance breeding in order to illustrate the type of work that is underway. Several more comprehensive or specialized reviews are listed after the literature citations.

Sources of Resistance

Opportunities for discovering heritable sources of resistance that can be utilized for tree improvement have increased tremendously in recent years. The ever growing number of provenance and progeny test plantings provides many situations where the latent genetic diversity in resistance may be uncovered and measured after suitable exposure to an insect or pathogen. Accumulating evidence about fusiform rust resistance illustrates this trend. Reports by Wells and Wakeley (1966) and by Wells (1966) enlarge on earlier information, pointing toward geographic regions where selection for resistance should be most rewarding. Studies at North Carolina State (1966) indicate the usefulness of progeny tests for detecting fusiform rust resistance; "...it now appears that perhaps the greatest immediate gain from the Cooperative Tree Improvement Program may be in disease resistance."

Similar types of information about other diseases and insects may contribute to changing the emphasis in existing programs, or to the establishment of new ones. The test plantings provide additional alternatives in the search for resistance, which formerly depended more on heavy infestations and epidemics in natural stands or plantations. I expect a considerable expansion in efforts to produce varieties with built-in resistance, especially in view of the public's growing concern about all types of pollution, including pesticides, in our environment.

Effectiveness of Selection

The methods used in finding and testing resistance are becoming much more complex. The sophisticated techniques that are commonly employed have diverse influences on a breeding project. They may include dignifying research plans, attracting support for research while adding to the cost, and glamorizing publications. 'Hopefully, they also help us to gain a deeper understanding of the complicated host-pest-environment relationships, and improve the selection process.

Although the selection of supposedly resistant phenotypes in the forest is beset with uncertainties, certain of these can be reduced. Van Arsdell (1965 a and b), for example, has greatly refined the knowledge of the microclimate and epidemiology of white pine blister rust. Silver iodide tracers, wind tunnels, and tagged spores are to be used in further studies. Patton and Riker (1966) have taken advantage of this information about blister rust distribution patterns in making their recent selections.

The use of artificial inoculations for making comparisons of disease resistance has become nearly a standard practice, at least in progeny testing. It has been employed with fusiform rust (Driver et al 1966, Goddard & Arnold 1966, Jewell & Mallett 1964), Fomes Annosus (Driver & Ginns 1966), littleleaf disease of shortleaf pine (Bryan 1965), white pine blister rust (Hoff 1966), Dutch elm disease (Ouellet 1964), and others. Some procedures simulate conditions that could occur in nature, while others are quite different. In the littleleaf work, for instance, two-to six-week-old seedlings were employed in separate test tubes that were plugged with cotton. Although techniques vary, they generally tend to employ small trees in large numbers, uniform and sometimes repeated inoculations, and a dosage that permits optimum discrimination of resistance levels.

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Problems may arise in attempting to obtain uniform and repeatable results. Information about spore distribution and germination has been obtained by using phosphorus - 32 (Pomerleau & Mehran 1966) or fluorescent dye (Patton 1967). Changes in soil moisture partly explain seasonal variations in susceptibility to Dutch elm disease. (Smalley & Kais 1966). Studies such as these help to define optimum conditions and to improve the reliability of testing.

Selection for insect resistance involves further complications, introduced through variations in insect behavior. In the case of the Douglas fir beetle (Atkins 1966), changes were noted in a population as the season progressed and from year to year due to both innate and environmental factors; host-positive females behaved differently from those that tended to fly away.

It is especially desirable to have a thorough understanding of insect behavior when artificial infestations are employed to screen for resistance, in order to avoid the possibility of deviations in the effectiveness of testing. The rather large variability in natural insect attacks is one of the main reasons why artificial exposures are so useful. We have been able to find differences in susceptibility to white pine weevil attack among white pine provenances by exposing seedlings in cages, even though there were only ten trees per provenance, and' these were shorter than trees ordinarily attacked in nature (Soles and Gerhold 1967). Results from older white pine provenance experiments had been much less revealing.

Smith (1966) is developing a method of forcing attacks of western pine beetles to test the resistance of pines, which appears to be influenced by resin composition. The beetles can be restricted to individual trees by cages, or an indigenous population can be attracted by hanging freshly infested ponderosa pine bolts just below the crown. If these field tests confirm the laboratory findings which suggest that certain resin components confer resistance by the lethal effect of vapors on attacking insects, the breeding of resistant varieties will be facilitated. The resin of a phenotypically re sistant•tree can be analyzed quickly by gas chromatography, in order to classify it for a mating design. We are using similar techniques to study the olfactory reactions of weevils to the terpenes of white pines.

Other studies are uncovering additional effects on insects related to chemicals in their hosts. A volatile principle from oak leaves is prerequisite for the, release of sex pheromone by the. female Polyphemus moth, which is necessary for the sexual activation of males (Riddiford and Williams 1967). A compound isolated from balsam fir prevents hemipteran nymphs from becoming sexually mature (Bowers et al 1966). Three terpene alcohols isolated from the frass of male bark beetles have been identified as the sex attractants responsible for the mass attack following initial boring activity (Silverstein et al 1966).

In view of so many fascinating possibilities for research, it is well to keep in mind that not all of them will contribute directly to progress in improving trees. If a diversion of resources into a tangential line of research is contemplated, its potential contribution to improvement objectives should be assessed carefully.

Useful Life of Resistant Varieties

There continues to be concern about the possibility of pathogens and insects overcoming improvements in the resistance of trees. Some limited evidence has been accumulating that pests are capable of adapting to new hosts, and of course agricultural breeders are well aware of the problem. Holmes (1965) has discovered differences in virulence among several cultures of the Dutch elm fungus; both virulence and resistance apparently invole polygenic inheritance. Different forms of **Cronartium fusiforme** have been reported (Kais 1966), though I do not know that they differ in virulence.

The genetic variation that is prerequisite for adaptation to a new or more resistant host could be introduced through hybridization. The white pine weevil is capable of crossing with related weevils (Manna and Smith 1959, Drouin et al 1963, Godwin and Odell 1966), and this could provide one possible explanation of how it was able to adapt to red pine in Michigan (Graham and Satterlund 1956). Lewontin and Birch (1966) have described a situation in Australia in which hybridization apparently provided the variation that enabled an insect to extend its adaptation to new hosts and environments.

The experience of wheat breeders in Mexico could lead us to make pessimistic predictions, if an analagous situation existed in forestry. Six different stem rust races have occurred in 20 years, so that a useful lifetime of only 4 years is expected for a pure-line wheat variety. In temperate zones, where ecological conditions are less favorable for the rust, the useful lifetime is three times as long (Borlaug 1965). Fortunately, most tree species are much more heterozygous. In addition, a variety of measures can be taken to make it more difficult for a pest to overcome resistance. Further research is essential so that we will know which of these measures may need to be taken.

Personnel and Communications

Few, if any, resistance breeding projects have adequate personnel and resources for the development and production of tree varieties with improved disease or insect resistance. In view of this situation, collaboration and communication among those having common interests is especially important. Considerable efficiency can be gained by exchanging information and ideas, sharing biological materials, and possibly joining forces or dividing responsibilities to accomplish certain phases of the work. For some years tree improvement conferences, workshops, regional research committee meetings, and various other regional, national, and international meetings have been successful in improving communications.

The need for more direct contacts among geneticists, pathologists, entomologists, and physiologists has been felt by many individuals. Resolutions to this effect were passed at the World Consultation on Forest Genetics at Stockholm in 1963 and at an Advanced Study Institute on Genetic Improvement for Disease and Insect Resistance of Forest Trees in 1964 at the Pennsylvania State University. As a result, the International Union of Forest Research Organizations has organized a Working Group to deal with this subject. It is open to all interested members, and will be organized more formally at the 13th Congress in Munich this year. The main objective will he to facilitate cooperation among those persons who are working on resistance to particular diseases or insects, by improving communications among indivudials, and by organizing specialized symposia.

Conclusion

In looking toward the future, I see many opportunities for practical improvements in disease and insect resistance. We have fairly good knowledge of the complexities involved in selection, and we are developing workable techniques to cope with them. We still have much to learn about breeding systems that will produce the improved varieties. This is one of our most urgent needs.

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