THE EASTERN WHITE PINE COOPERATIVE BLISTER-RUST RESISTANT DEVELOPMENT PROGRAM

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INTRODUCTION

Programs directed towards the development of eastern white pine trees (Pinus strobus L.) resistant to the blister-rust fungus (Cronartium ribicola J. C. Fischer ex. Rabh.) have been conducted since the late thirties. Perhaps the most intensive studies have been directed by Dr. R. R. Hirt (New York), Dr. C. Heimburger (Ontario, Canada) and Drs. A. J. Riker and R. F. Patton (Wisconsin). The development program described in this paper is actually a continuation of the Riker-Patton work; however, both plant materials and techniques developed by Hirt and Heimburger have been included.

In 1960, the research being conducted by Riker and Patton at the University of Wisconsin, and supported by the Wisconsin Conservation Department, was summarized. Their data collected over a twenty-three-year period showed 1) that resistance was in fact present in certain genotypes; 2) that resistance was apparently due to the additive effects of multiple gene factors; and 3) that certain genotypes could transmit resistance to blister rust to a useful percentage of their progeny. During 1963, Patton presented these facts to the Chief, United States Forest Service and suggested that a full-scale development program be initiated to produce rust-resistant white pine planting stock. A survey of the State Foresters in Michigan, Minnesota and Wisconsin and Region 9, USFS showed that approximately 14 million white pine seedlings would be planted annually if resistant stock were available. Based on these facts, the Chief directed Region 9, USFS to initiate a cooperative program.

A Memorandum of Understanding for the Development of Blister-Rust Resistant Eastern White Pine was prepared by State and Private Forestry, USFS and the Division of Timber Management, Region 9, USFS. This was approved by the following nine cooperators during the fall of 1965:

1. U.S. Forest Service, Region 9
2. Lake States Forest Exp. Station, USFS (now North Central Forest Exp. Sta.)
3. University of Wisconsin, Madison, Wisconsin
4. Michigan Conservation Dept. (now Dept. of Natural Resources)
5. Minnesota Conservation Dept. (now Dept. of Natural Resources)
6. Wisconsin Conservation Dept. (now Dept. of Natural Resources)
7. Michigan Dept. of Agriculture
8. Minnesota Dept. of Agriculture
9. Wisconsin Dept. of Agriculture

The duty assignments as outlined in the Memorandum are:

Departments of Agriculture - select rust-free phenotypes in the field. Departments of Natural Resources - collect scion material and perform controlled pollinations on selected trees. University of Wisconsin - provide technical guidance and supply records of their research. North Central Forest Experiment Station - provide technical guidance and conduct basic research on rust resistance in eastern white pine. Region 9, USFS - coordinate the overall program. Prepare plans and train Forest Service and State personnel in selecting rust-free phenotypes, scion collection, grafting and hybridization. Establish seed orchards and clonal breeding arboretum. Develop a technique for inoculating large numbers of seedling progenies. Provide technical guidance to cooperators on seed orchard establishment and management.

The time schedule for this development program is shown in Figure 1.

ACCOMPLISHMENTS

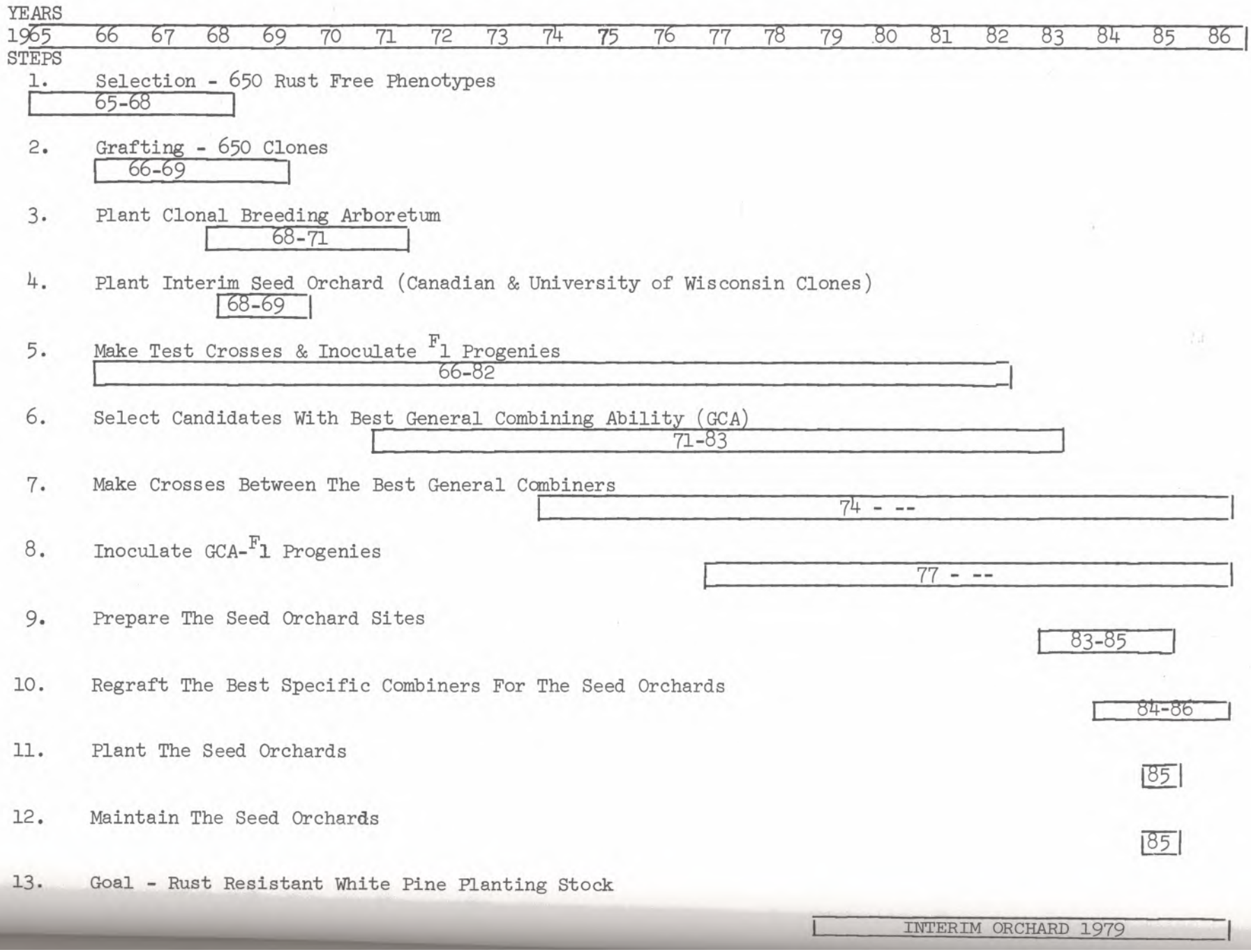
Selection.--Beginning in the fall of 1965, an intensive search was made throughout the "high hazard blister-rust zone" in Michigan, Minnesota, and Wisconsin to locate rust-free phenotypes. To be selected, the candidate had to meet the following criteria: 1) it was a good target for blister rust spores throughout most of its life; 2) it showed no signs of previous or current blister-rust infection; 3) white pine trees adjacent to candidate were infected with blister rust; 4) it was between 20 and 60 years of age; 5) it showed evidence of flowering.

A total of 947 candidates were selected and reported by the various cooperators. Each of these candidates were rechecked using binoculars and by actually climbing to check suspicious branches for rust infections. Seven hundred and five selections were accepted following the second screening. The number of accepted selections are shown for each cooperator in Table 1.

Table 1.--Number of clones included in the eastern white pine blister-rust resistant development program.

National Forest or Cooperator	Number of clones P. strobus	Number of clones Exotic
Chequamegon N.F.	41	
Chippewa N.F.	31	
Hiawatha N.F.	32	
Nicolet N.F.	49	
Ottawa N.F.	38	
Superior N.F.	47	
Michigan	147	
Minnesota	158	
Wisconsin	157	
Univ. of Wisconsin	5	
	705	
Mt. Rose Plantation (N.Y.)	10	
Hurlin Plantation (N.H.)	19	
Ontario, Canada	42	
		1 (P. cembra)
		2 (P. peuce)
		2 (P. koraiensis)
		14 (P. griffithii)
Ohio		1 (P. flexilis)
		1 (P. koraiensis)
	71	21
Total Rust-Free Clones	776	
New York	30 (weevil resistant)	
Grand Total	806	21

Figure 1.--Time schedule for blister-rust-resistant eastern white pine development program.



Vegetative Propagation.--Each of the 705 rust-free selections were grafted using the side veneer graft technique. Scion material was collected during February of 1966, 67, 68, and 69 by the various cooperators, and hand carried to the J. W. Tourney Nursery, Watersmeet, Michigan, where greenhouse facilities were available. The grafts were removed from the greenhouse in mid-June and lined out in a nursery bed for two growing seasons. The grafts were then lifted and transported to the Oconto River Seed Orchards located near Langlade, Wisconsin, where they were planted in the clonal breeding arboretum or the interim seed orchard.

In addition, 71 rust-free eastern white pine selections from New York, New Hampshire, and Ontario, Canada; 30 weevil resistant white pine selections from New York; and 21 selections representing five exotic species have all been grafted (Table 1) and planted in the breeding arboretum or interim orchard.

Clonal Breeding Arboretum.--A clonal breeding arboretum including all rust-free selections, weevil resistant selections and exotic species except those planted in the interim seed orchard was established at the Oconto River Seed Orchards in 1969, with additional plantings made in 1970, 71 and 72. Five grafts of each clone were outplanted in the arboretum at, a 20 by 20 foot spacing. The area has been clean cultivated and a preemergent herbicide and sawdust mulch has been used to control the vegetation around each graft. A few of the grafts planted in 1969 produced flowers during the springs of 1971 and 72.

Interim Seed Orchard.--A 10-acre eastern white pine seed orchard was also established at the Oconto River Seed Orchards during 1969. The orchard includes grafts of 29 clones tested by Dr. Heimburger and 5 clones tested by Drs. Riker and Patton. Each clone is represented by approximately 25 ramets for a total of 865 grafts in the orchard. The planting design was generated by a computer program developed by Dr. G. Stairs, University of Wisconsin. The design provides for maximum cross pollination among clones, and minimum self-pollination within a clone. The grafts were planted at a 22 by 22 foot spacing, and the orchard has been managed using the same techniques as employed in the breeding arboretum (clean cultivation; herbicide and mulch). Limited amounts of flowering occurred in 1970, 71, and 72. The seed produced in this orchard will be included in the inoculation tests and will also be used to establish progeny tests to be evaluated for growth rate, form and resistance to blister rust under field conditions.

Hybridization.--The first controlled pollination work was performed in the spring of 1966 by Forest Service and State crews. This happened to be an excellent flowering year and strobili on 110 trees were isolated. Pollen was collected from the five trees selected by Dr. Patton for their ability to transmit rust-resistance to their offspring. The pollen collected from the three trees located in northern Minnesota was placed in one bulk lot, and that collected from the other two trees located in central Wisconsin was placed in a second bulk lot. These two bulked pollen lots were used to pollinate the receptive female strobili. Cones were collected from 96 of the 110 trees during the fall of 1967.

Additional field pollinations were made during the springs of 1967, 68, and 69. More than 225 trees had been included in the crossing program through 1969. Beginning in 1970 the pollination work was limited to the grafts growing in the clonal breeding arboretum and the interim seed orchard.

Testing.--An inoculation procedure has been developed to test large numbers of seedlings for resistance to blister rust. The first trial of this procedure was begun during the spring of 1970 when fourteen seed sources were sown in each of twenty large flats. The seedlings grew out-of-doors in these flats for two growing seasons. Towards the end of August in the second year, the flats containing the seedlings were moved into the warehouse where the humidity and temperature were partially controlled. Ribes cuttings containing at least three spore-bearing leaves were placed in the flats among the seedlings. After three days of high humidity and near optimum temperatures (60-75 °F.) the Ribes cuttings were removed, and the flats moved back outside. The seedlings will be scored for blister-rust infections during the summer of 1972 and again in 1973. If low infection rates are observed, the seedlings can be reinoculated. In any case, the surviving seedlings will be outplanted, and if they remain rust-free, will be used in future breeding work.

A second test was begun during the spring of 1970 using thirty seed sources. The seeds were started in the greenhouse in Jiffy-7 peat pots during March, and were outplanted into the flats during mid-June. These seedlings will be inoculated in August 1973.

Ribes nigrum cuttings initially supplied by Dr. Heimburger have been propagated by Dr. D. Lester, University of Wisconsin in cooperation with the Wisconsin Department of Natural Resources. Over 50,000 plants are now growing at the Oconto River Seed Orchards to supply inoculum for the inoculation program.

FUTURE

The first inoculation tests will be used to select the parents showing the best general combining ability for rust resistance in their offspring. These particular parents will be included in a partial diallel-crossing scheme, and the resulting progenies inoculated to determine the parents' specific combining ability. The parents showing the highest specific combining ability will be grafted and included in a new seed orchard for the production of seed capable of producing rust-resistant planting stock. Progenies resulting from this seed orchard will be progeny tested throughout the Lake States and evaluated for growth, form, and rust-resistance.

Hybridization, testing, and recurrent selection will be continued to increase the rust-resistance and growth potential of the white pine planting stock.