GAINS FROM RUST RESISTANT ORCHARDS ESTABLISHED WITH SEEDLINGS

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Abstract. Sixteen years of experience establishing seedling seed orchards with progeny that were disease-free after inoculation with the fusiform rust organism has provided a number of benefits not usually derived from clonal orchards. Some half-sib seedling seed orchard trees from resistant mother trees produce progeny with considerably greater resistance than that of the original mother tree. Seedlings derived from controlled crosses between some resistant families have produced some orchard trees with very highly resistant progeny. Families with superior growth characteristics, but with moderate to little rust resistance, have been improved by selecting orchard trees that have both good growth and high resistance. Families with unique sources of resistance, but inferior growth characteristics, have also been improved by selecting orchard trees with improved growth as well as unique rust resistance. The average level of rust resistance is higher in orchards established with seedlings than in those established with clones.

Keywords: *Cronartium quercuum* f. sp. *fusiforme*, loblolly pine, *Pinus taeda*, seedling seed orchard.

INTRODUCTION

Disease resistance offers the best means of limiting damage by fusiform rust (caused by *Cronartium quercuum* (Berk) Miyabe ex Shirai f. sp. *fusiforme*) in young southern pine plantations. Both clonal and seedling seed orchards (SSO) of rust-resistant loblolly pines (*Pinus taeda* L.) are being developed cooperatively by the USDA Forest Service and the Georgia Forestry Commission (USFS-GFC). One of the primary reasons for adopting the SSO approach was to increase heterogeneity in the rust resistant material. In the mid-1970's only a limited number of resistance sources had been identified.

METHODS

Powers and Kraus (1983) utilized a multi-step procedure for selecting crop trees for the SSO. First, loblolly pine seedlings were inoculated by the Concentrated Basidiospore Spray (CBS) system (Matthews and Rowan 1972). Our standard measure of familial resistance is the disease ratio (DR), which is computed by dividing the percent of seedlings with galls in the test family by that of the standard susceptible control. Test families with a DR > 0.70 are considered susceptible, those with a DR < 0.70 are resistant (Kuhlman and Powers

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1988). Susceptible families were discarded. In resistant families, seedlings with galls were culled. Healthy survivors from 14-16 resistant families were planted in orchard blocks at close spacings (1,418 trees per ha). All seedlings that became infected in the field were rogued. Additional roguing was needed to prevent crowding. Uninfected trees were rogued on the basis of poor growth or form. In an ongoing effort when an orchard tree produces seeds, its progeny are tested by the CBS system. Seed-producing trees are rogued by DR to a final density of no more than 119 trees per ha. In all, 92% of the original trees will be rogued.

This paper summarizes some of the positive results from the 16-year cooperative effort involved in the development of USFS-GFC loblolly pine SSO's.

Information presented in this paper is derived from seven SSO blocks established in 1975, 1976, and 1977. Second-generation progeny make up the SSO blocks. Those progeny were first screened in the CBS system and seedlings with galls were rogued. Rust-free survivors were used to establish the orchard blocks. Roguing in the orchard blocks has been done annually since the trees were 5 years old. Until the trees produced seeds, silvicultural characteristics were used to select residuals. Progeny of 429 trees from these seven blocks have been tested in the CBS system. Some results from those tests are presented here.

RESULTS AND DISCUSSION

Progeny from 429 trees from these seven loblolly SSO blocks have been screened in the CBS system, and 75% of these trees have produced resistant progeny according to the 0.70 DR. The statistical validity of the 0.70 DR as the criterion for separating resistant and susceptible families has been demonstrated in other studies (Kuhlman and Powers 1988, 1991).

The relative resistance of individual SSO trees, as indicated by the DR value, is helpful in deciding which trees to retain in the orchard and which ones to rogue. Three resistance categories were set up: susceptible with a DR > 0.70; resistant with DR > 0.30 to 0.70; and highly resistant with a DR < 0.30.

Trees with 10-5 or 29R as the maternal parent usually produced resistant progeny and less frequently had highly resistant or susceptible progeny (Table 1). Trees from controlled pollinations of 29R with 10-5 have 14 progeny rated highly resistant and 14 rated resistant. Evidence is mounting that resistance in 29R is of a different type than that in 10-5, since progeny of these sources vary in response to virulent, single-gall isolates (Kuhlman, 1989, 1992). SSO trees with highly resistant progeny probably have resistance genes from both parents. Therefore, identifying different types (mechanisms) of resistance should be beneficial for determining which crosses will combine different resistance types and thus provide highly resistant progeny.

Progeny from 45 SSO trees with 11-20 as the maternal parent have been tested in the CBS system (Table 1). Six trees produced highly resistant progeny, 36 trees produced resistant progeny, and three produced susceptible progeny. Most trees infrequently had highly resistant progeny. Trees from families 10-6 and 29R x A (Arkansas) more frequently had susceptible progeny than did the other families.

Table 1. The relative resistance of seedling seed orchard trees from 10 families indicated by the average disease ratio (DR) of their progeny in CBS tests.

Family	Highly resistant (DR < 0.30)	Resistant (DR > 0.30 < 0.70)	Susceptible (DR > 0.70)
	No. of trees in category (average disease ratio)		
10-5 x W	7 (0.19)	52 (0.48)	3 (0.77)
29R x W	1 (0.26)	16 (0.58)	3 (0.85)
29R x 10-5	14 (0.20)	14 (0.55)	
11-20 x W	6 (0.20)	36 (0.49)	3 (1.09)
42R x W	1 (0.24)	21 (0.48)	
T601 x W		13 (0.52)	2 (0.74)
10-6 x W	1 (0.29)	15 (0.59)	10 (0.82)
29R x 42R	4 (0.23)	9 (0.47)	
29R x 4625-3	1 (0.26)	8 (0.52)	2 (0.80)
29R x 1495-35	1 (0.26)	15 (0.49)	9 (0.78)

Family 7-56 is widely known for its superior growth. Previously, Miller and Powers (1983) reported a 75% rust infection level in CBS tests, but 55% infections in the field. Some SSO trees from half-sib family 7-56 have retained the good growth of the family while having higher levels of resistance (Table 2)

Table 2. Rust susceptibility and relative growth of nine trees from half-sib family 7-56 in the seeding seed orchard.

Tree	Disease Ratio (DR) of progeny	Annual Diameter growth (cm.)[a]
153-517	0.30	2.49
155-042	0.35	2.22
155-148	0.39	2.39
158-569	0.38	2.41
158-625	0.40	2.69
154-192	0.42	2.02
154-208	0.45	2.30
154-290	0.46	2.29
157-234	0.59	2.48
7-56	0.87	

[a] dbh/age

Family 11-20 is a unique resistance source (Kuhlman 1992), but clones of 11-20 have been removed from some tree improvement programs because of poor growth characteristics. SSO trees from half-sib family 11-20 have yielded resistant progeny with a range of disease ratios (Table 3). These SSO trees have good growth rates that also should be passed on to their progeny. The SSO approach presents the opportunity to preserve the unique 11-20 resistance type by selecting trees with that resistance and with good growth.

Table 3. Rust susceptibility and relative growth of 12 trees from half-sib family 11-20 in the seedling seed orchard.

Tree	Disease ratio (DR) of progeny	Annual diameter growth (cm)
156-316	0.05	2.29
153-362	0.14	2.16
156-137	0.28	2.10
153-510	0.28	1.75
151-464	0.29	2.55
156-203	0.32	2.29
151-026	0.32	1.94
152-122	0.34	2.3o
151-654	0.37	1.26
152-196	0.41	2.38
152-329	0.43	2.49
151-620	0.47	2.24
11-20	0.40	

[a] dbh/age

Progeny from SSOs are more rust resistant in CBS tests than those from clonal orchards (Powers and Kraus 1986). Since we have expanded our clonal orchard with ramets from the SSO, these differences will probably soon disappear.

CONCLUSIONS

The SSO provide several advantages over the more traditional clonal orchard. Foremost is the chance to diversify the genetic base in the orchard with a heterogeneous seedling poulation. Second, we can identify highly resistant trees. Third, we can select trees with increased resistance that maintain the superior growth characteristics of their maternal parent. Fourth,unique resistance genes can be incorporated in trees with good silvicultural characteristics to save resistance genes that might otherwise be discarded. The major drawback to the SSO is that this method is labor intensive.

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