The Russell WGR Plantation

Introduction Spring 1981

Radiata pine (Pinus radiata D. Don.) has become an important species for many purposes (commercial forests, parks, windbreaks, urban and amenity plantings, Christmas trees) in many Mediterranean-climate regions of the world. Western gall-rust (Endocronartium harknessii (Moore) Hiratsuka) is a wide-spread pathogen on many species of hard (diploxylon) pines over much of northern and western North America. It occurs on radiata pine in three of its five native populations, and commonly on planted radiata pine in much of California and Oregon. Damage to radiata pine is variable, but can be severe. Western gall-rust (WGR) has not yet been reported outside of North America. Because of its wide host-range within Pinus, and its ability to spread from pine to pine without an intermediate stage on an alternate host, there is concern that it may spread rapidly and cause serious damage if and when it does establish in other pine regions.

Radiata pines at the University of California's Russell Reservation have been infected by WGR for over two decades, and there the disease has been at epidemic levels on young radiata pine since about 1974. Repeated observations on its occurrence and spread have been made in radiata pine plantations installed at Russell Reservation for other purposes since 1969, and on a small clonal plantation designed specifically to test the relationship of WGR susceptibility to radiata pine's maturation state since 1979. Based on these early observations, it appears that there is substantial and perhaps usable variation in susceptibility to WGR among populations, among clones, and among maturation states of radiata pine. In late 1980, a proposal was discussed for a cooperative project including CSIRO (Australia), UC Berkeley, and perhaps others. An important and early part of this broader proposal is a plantation at Russell, called the Russell Reservation Western Gall Rust Susceptibility Test for Populations, Open-pollinated Families, Hybrids and Select Families of Radiata Pine, abbreviated as "The Russell WGR Plantation." It objectives are listed below.

Objectives of The Russell WGR Study

1. Assess and rank the 5 native populations re susceptibility to WGR (and, opportunistically, to other biotic and physical events that may occur).
2. Assess the susceptibility of 20 available between-population F1 hybrids.
3. Assess and rank susceptibility of 30 select full-sib families.
4. Assess patterns of infection within and between replications and locations, using 4 standard clones and 900 candidate seedlings that will also be cloned.
5. Investigate possibility of genotype-site or genotype-year interactions.
6. Make early selections of useful clones for further testing and possible release for wide-spread planting.
7. Test a subset of these clones over a greater variety of sites.
8. Test a subset of these clones for reliability of greenhouse inoculation tests with local WGR.
9. Test a subset of these clones with WGR from other areas of N. America, using greenhouse inoculation techniques.
10. Investigate inheritance of susceptibility to WGR using interpopulation hybrids.

Materials and Methods

The 5 population-samples shall each consist of 5 seedlings from each of 20 families collected from a variety of sites in each population. In 14 cases, a full-sib control-cross among two trees from that population is used, and the remaining 86 families are open-pollinated collections (Appendix Ia and Ib).

The 20 between-population hybrids shall each be a control-pollinated full-sib family. Each possible between-population cross will be represented by at least one full-sib family. The majority of crosses included in this plantation will have a tree from the Guadalupe population, the population which early observations indicate is least susceptible to WGR. Many of the rest will have a Cedros tree as one parent. Each such family will contribute 5 full-sib seedlings. In seven of these, the between-population hybrid is paired with 2 of the 14 within-population full-sib families, each with one parent in common with the hybrid family (Appendix II).

The 4 standard clones are drawn from a larger sample of New Zealand select family 55x19 (Z5, Z6) or a random sample from the Monterey population (MM6, MM10). Z5 and MM6 give promise of being good timber trees in absence of WGR. Z6 is an outstanding prospect as a Christmas tree. MM10 is a generally poor tree. All are highly susceptible to WGR.

The 30 full-sib select families are a fair sample of the families being produced in Australia's (and New Zealand's) radiata breeding programs (Appendix III). Each will contribute 10 full-sib seedlings, and should be capable of providing additional seeds for later expanded testing.

Following stratification, 8 seeds (15 for the Australian and New Zealand selects) will be germinated per family, to produce 5 (or 10) seedlings for planting during late winter 1982. They will be grown in the Gill Tract greenhouse and lathhouse, as weather dictates, in individual galvanized tubes in Davis potting mix, watered and fertilized as appropriate. Lower branches will donate cuttings prior to outplanting.

Cuttings from juvenile hedged donors sufficient to produce 25 plantable ramets per clone will also be rooted for the 4 standard clones during 1981.

The Russell site will be cleared during Spring 1981, and will lie fallow prior to planting. Deer will be excluded by fencing at Russell. This plantation will consist of 5 replications, laid out as indicated on the map (Appendix IV). Planting will be at 2-meter square spacing. Replications 1 and 2 are adjacent to a heavily-infected radiata pine WGR test (including clones Z5, Z6, MM6 and MM10), which will serve as a source of nearby inoculum. The effect of rain-splash infection may be evident in replications 1 and 2. Replications 3, 4, and 5 will occupy the western and northern parts of the plantation away from the current infection, and will monitor longer-distance wind-borne infection.

The 1000 locations available at Russell will be allocated as follows: 500 to samples of the 5 native populations; 100 to between-population crosses, 100 to 4 standard clones; 300 to full-sib select families.

Each replication will consist of 200 trees, as follows: one seedling from each of the population-sample o-p families (=100 trees); one seedling from each of the hybrid families (=20 trees); five ramets of each of the standard clones (=20 trees); and two seedlings from each of the select families (=60 trees).

The 200 trees in each replication will be organized in twenty 10-tree plots, each consisting of 2 rows and 5 columns as follows: one seedling from each native population (=5 trees); one hybrid seedling; 1 ramet of one of the standard clones; and 3 seedlings from 3 different select families. These 10-tree plots may be combined into larger plots for analyses.

Data will be taken as indicated in the Timetable (Appendix V).

Hedge-orchards, consisting of 2 ramets/clone, will be established from the cuttings taken in 1981, at a location to be determined.

Details of later experiments will be developed during 1981.

Natural infection will be used. If little infection is evident by the third year, then additional inoculum will be provided using cut branches with sporulating galls.

Analyses of The Russell WGR Plantation

1. A qualitative judgment on the importance of observed damage will be subjective. Trees killed by WGR-associated damage, or trees with severely deformed boles due to stem galls, are clearly unacceptable.

2. Statistical comparison and ranking of the 5 populations will be done by two methods: (a) a parametric analysis such as ANOVA,using numbers of galls per tree within and between replications; (b) a non-parametric analysis using rank or sign ($\pm$ average) of the single representative of each population within each 10-tree plot.

3. The seedlings of each hybrid family will be compared to the nearest (probably in the same 10-tree plot) members of its two parent populations in parametric (paired t-test) and non-parametric (sign test) analyses.

4. Variation between full-sib families and between o-p families from the population samples will be analysed by ANOVA, comparing within-family variance to between-family variance. Unusually susceptible and unusually resistant families may be identified for possible further testing.

5. Variation between full-sib select families will be analysed by ANOVA, estimating between-replication, within-replication, and between-family variation.

6. Full-sib select families will be ranked, relative to each other, and relative to the 5 population-samples. Unusually susceptible and unusually resistant families will be identified for further testing.

7. Patterns of infection with respect to site variation and, in particular, with respect to distance and direction from infection sources, will be investigated using plot means, replication means, and observations on each of the 4 standard clones.

Discussion

These experiments will allow us to follow up on the observation that seedlings from different populations have substantially different susceptibility to WGR, and that adjacent individual trees, both in plantations and in natural stands, sometimes are sharply contrasting in their levels of infection.

We will also be able to investigate differences between o-p families and between full-sib random and select families, and to compare hybrids to their two populations of origins. In 7 cases, the hybrids can be compared to full-sib families from the population of origin with parents common to both the between- and within-population families.

It will give (particularly) the Australians and New Zealanders an early warning on possible severity of WGR in their plantations, should the disease invade their forests. If there is variability in WGR susceptibility among their select families, that will allow them to develop breeding and plantation strategies in advance of such invasion. If the select families prove to be mostly susceptible, but usable variation exists in the native stands, then breeding strategies may be adjusted accordingly.

If a more ambitious California research program is supported, including clonal outplantings at several sites and greenhouse inoculation with non-local populations of WGR, the early-warning information will be more complete, and usful selections may be identified. New techniques in tissue culture may soon allow such selected clones to be moved safely to countries free of the disease.

W.J. Libby
K. Old
A. Power

Spring 1981

APPENDIX Ia

CONTROLLED CROSSES, AND O-P FAMILIES OF THE 1978 COLLECTION USED AS POPULATION SAMPLES IN THE RUSSELL WGR PLANTATION.

The seeds used in this experiment have two sources: 1978 mainland and island collections; and controlled crosses completed at Russell Reservation and Gill Tract during 1977-81.

Identifying codes of the trees from the 1978 o-p collection in the three mainland populations have the form XX-Y-ZZ: XX indicates the population (01= Año Nuevo; 02= Monterey; 03= Cambria), Y indicates the stand and ZZ the tree number. On the other hand, controlled-cross parents have the form XYZ: X indicates the population (A= Año Nuevo; C= Cambria; M= Monterey), Y and Z are stands and tree but not necessarily the same stand and tree given the same number in the 1978 collection. Open-pollinated 1978 collections from Cedros and Guadalupe Islands have designations in the form XZZ or XZZZ: X indicates the population (L= Guadalupe; T= Cedros), ZZ or ZZZ indicates tree number. Island trees in the 0-99 series donated cones in the earlier 1964 collection of Libby, Linhart and Bannister. An "X" following such a number means the 1978 collection may have been from the same tree sampled in 1964, or may have been from a nearby tree. No "X" implies certainty that the same tree donated seeds in 1964 and 1978. Numbers 100 or greater are for 1978 seed-donors that are not close to a specific 1964 donor. A letter "a" or "b" following the Guadalupe and Cedros tree I.D. indicates that the seedlings are o-p sibs from the same cone (e.g. L01a and L01b, both from mother tree L01).

The information in this Appendix was compiled from an internal report of the C.S.I.R.O. (Refreshing the Genetic Resources of radiata pine plantations, Eldridge 1978) and from Libby's files at UC Berkeley on the native population collections and subsequent controlled crosses.

o-p: open-pollinated family collected in native stand.
fs : full-sib family of two trees from the same native stand. These are related to the interpopulation hybrids (Appendix II).

AÑO NUEVO POPULATION (01), (5 stands; 14 o-p families, 6 fs families).

Año Nuevo coast (1).

op 01-1-1
op 01-1-20
op 01-1-36
op 01-1-60

Big Basin State Park.(5)

fs A02 x A04

Last Chance Road and jeep trail (2).

op 01-2-36
op 01-2-45

fs A63 x A61
fs A66 x A67
fs A49 x A47

Swanton (3).

op 01-3-3
op 01-3-6
op 01-3-16
op 01-3-24
op 01-3-37

Steele's and Bradley's (4).

op 01-4-5
op 01-4-18
op 01-4-22

fs A17 x A19
fs A33 x A31

MONTEREY POPULATION (02), (6 stands: 19 o-p families, 1 f.s. family).

Monterey coastal sand dunes (1).

op 02-1-1
op 02-1-16
op 02-1-90

Town area (2).

op 02-2-51
op 02-2-91
op 02-2-97

Huckleberry Hill (3).

op 02-3-1
op 02-3-20
op 02-3-35

Jacks Peak (4).

op 02-4-15
op 02-4-65
op 02-4-75

Point Lobos (5).
Ken Old failed to detect signs of WGR in this stand. At his request, 5 families from this stand are included.

op 02-5-4
op 02-5-7
op 02-5-13
op 02-5-19

fs M03 x M02

Carmel Highlands (6).

op 02-6-9
op 02-6-12
op 02-6-94

CAMBRIA POPULATION (03), (3 stands: 20 o-p families).

Pico Creek (1).

op 03-1-1
op 03-1-5
op 03-1-6
op 03-1-83
op 03-1-84
op 03-1-95

CAMBRIA POPULATION (cont.).

Town area (2).

op 03-2-1
op 03-2-4
op 03-2-67
op 03-2-73
op 03-2-80
op 03-2-84
op 03-2-87
op 03-2-90

Inland from Scott Rock (3).

op 03-3-6
op 03-3-85
op 03-3-89
op 03-3-91
op 03-3-93
op 03-3-98

GUADALUPE ISLAND POPULATION (L)
(3 subdivisions: 15 o-p families, 5 f.s. families).

Upper population.

op L55
op L57X
op L103
op L107

fs L08a x L02b

Middle-elevation population.

op L65X
op L141

fs L66a x L65a
fs L14a x L15b
fs L33b x L31b
fs L28a x L29b

Low-middle-elevation population.

op L70X
op L72X
op L78X
op L143
op L146
op L147
op L169
op L174
op L176

CEDROS ISLAND POPULATION (T), (2 major populations, each with 2 subdivisions: 18 o-p families, 2 f.s. families).

Southern Part of South Population.

op T131
op T132
op T19X

fs T30b x T80b
fs T77a x T78b

Northern Part of South Population

op T08X
op T124
op T126
op T152 (outlier)

Southern part of North Population.

op T41
op T89X
op T110X
op T113X
op T117

Northern part of North Population.

op T34X
op T36X
op T101X
op T102X
op T103X
op T104X

APPENDIX I b DESCRIPTION AND GEOGRAPHICAL LOCATION OF THE NATIVE STANDS.

POPULATION Stand or Controlled cross.	ELEVATION (meters)	LATITUDE (approx.)	LONGITUDE (approx.)	STAND DESCRIPTION
ANO NUEVO POPULATION (01 or A)				
01-1	15-61	37°05'-37°07.5'	122°16'-122°18.5'	Año Nuevo coastal stands along Hwy 1 from Greyhound Rock to approx. 1 km N. of Coastways Ranch. West aspect.
A02xA04	229	37°07.5'	122°17'	Big Basin State Park.
01-2	122-329	37°05.5'-37°07'	122°15'-122°17'	Along Last Chance Road and on jeep trail running N. out of Rancho del Oso.
A49xA47	229	37°06'	122°17'	Central part of 01-2
A63xA61 A66xA67	122	37°05'	122°16'	Lower part of 01-2
01-3	61-244	37°04-37°05'	122°13'-122°14.5'	Interior valley and ridges E. of Swanton Rd. between Winter Creek and Mill Creek. Includes McCrary's Big Creek Ranch. Aspect mainly West.
01-4	61-213	37°07'-37°08.5'	122°17.5'-122°18.5	S. Steele's ranch and along trail behind Bradley's home at Coastways Ranch. Northermost stands. Aspect mainly west.
A17xA19	229-259	37°08'	122°18'	Upper N.E. edges of 01-4
A31xA33	91	37°07'	122°18'	SW part of 01-4
MONTEREY POPULATION (02 or M).				
02-1	6-61	36°35'-36°38'	121°55.5'-121°58'	Coastal sand dunes strip from Cypress Pt. Golf Course (at Fan Shell Beach) North to Pt. Pinos Lighthouse grounds. West aspect, exposed.
02-2	24-61	36°34.5'-36°36.5'	121°50.5'-121°54'	Monterey town area from the civilian airport, NW through residential districts to the lower edge of the Presidio. Southern boundary is marked by Del Monte Shopping Center and the South edge of Old Del Monte Golf Course.
02-3	61-213	36°34'-36°36'	121°54.5'-121°56.5'	The area boundary follows the eastern edge of Huckleberry Hill north to the back of the Presidio, and extends SW past the Del Monte Corp. quarry to the edge of Forest Lake residential area.

Appendix Ib (cont.)

POPULATION	ELEVATION (meters)	LATITUDE (approx.)	LONGITUDE (approx.)	STAND DESCRIPTION
02-4	61-305	36°32.5'-36°34'	121°50'-121°53.5'	Jacks Peak Regional Park and ridges SE of Park. Also a few trees on north Park boundary in residential/pasture area.
02-5	15-61	36°29'-36°31.5'	121°56.5'-121°57.7'	Point Lobos State Reserve, along Hwy 1 north to Carmel River State Beach and south to Yankee Point area. Ken Old failed to find any WGR in his visit there. Flat aspect.
M03xM02	9	36°31'	121°57'	Sea-facing stand near western coast of Point Lobos Reserve.
02-6	76-579	36°29'-36°31'	121°54'-121°56'	Area East of Hwy 1 between San Jose Creek and Malpaso Creek. Includes residential areas of Carmel Highlands and Carmel Riviera; follows east along 3 parallel ridges. Aspect mainly west and north. Includes highest mainland trees, and some populations with associated redwood and douglas-fir.
CAMBRIA POPULATION (03)				
03-1	30-122	35°37'-35°38'	121°08.5'-121°09'	Pico Creek area on San Simeon estate. Aspect mainly west. An isolated stand.
03-2	30-122	35°32'-35°35.5'	121°04'-121°07'	Cambria town, main residential area; north to Leffingwell Creek; south to Airforce Station. All aspects, some flat.
03-3	61-183	35°34.5'-35°35.5'	121°03'-121°05'	Inland area north and east of Scott Rock. All aspects, some flat.
GUADALUPE ISLAND POPULATION (L).				
Upper	1120-1159	29°09'	118° 19'	
Mid-Elev.	747- 884	29°10'	118° 18'	
Low-Mid	579- 686	29°10'30''-29°10'50''	118° 17'	

APPENDIX Ib (cont).

POPULATION	ELEVATION (m)	LATITUDE	LONGITUDE
CEDROS ISLAND POPULATION. (T)			
North Population	290-579	28°13'	115°15'-
South Population	442-610	28°10'- 28°11'	115°14'+

APPENDIX II

INTERPOPULATION HYBRIDS AND INTRAPOPULATION CROSSES WITH COMMON PARENTS.

HYBRIDS ♀	♂	ASSOCIATED CROSS (see Appendix I) ♀	♂	♀	♂
A19	T80b	A17	A19	T30b	T80b
A33	L65a	A33	A31	L66a	L65a
A47	L15b	A49	A47	L14a	L15b
A67	L31b	A66	A67	L33b	L31b
M02	A02	M03	M02	A02	A04
L02b	T77a	L08a	L02b	T77a	T78b
L28a	A63	L28a	L29b	A63	A61

ADDITIONAL INTERPOPULATION HYBRIDS: ORIGIN OF PARENTS

	females			males		
♀ ♂	latitude	longitude	elevation (meters)	latitude	longitude	elevation (meters)
A43 x C43	37° 06'	122° 17'	229	35° 35'	121° 06'	91
A49 x T59b	37° 06'	122° 17'	229	28° 20'	115° 15'	610
A77 x L39b	37° 06'	122° 16'	274	29° 10'	118° 20'	747
M39 x C39	36° 29'	121° 56'	18	35° 34'	121° 05'	61
M04 x T33a	36° 31'	121° 57'	9	28° 22'	115° 15'	427
C21 x L01b	35° 35'	121° 07'	23	29° 09'	118° 20'	1143
C47 x L17b	35° 35'	121° 06'	91	29° 10'	118° 20'	747
L59 x T01a	29° 10'	118° 20'	747	28° 13'	115° 15'	457
L77b x C87	29° 10'	118° 20'	686-577	35° 32'	121° 03'	61
L83b x A97	29° 10'	118° 20'	686-577	37° 05'	122° 14'	137
L80a x M93*	29° 10'	118° 20'	686-577	36° 31'	121° 55'	280
T36a x M93*	28° 21'	115° 15'	503	36° 31'	121° 55'	280
T36a x C93*	28° 21'	115° 15'	503	35° 35'	121° 05'	122

* Note half-sib relationship of these hybrids.

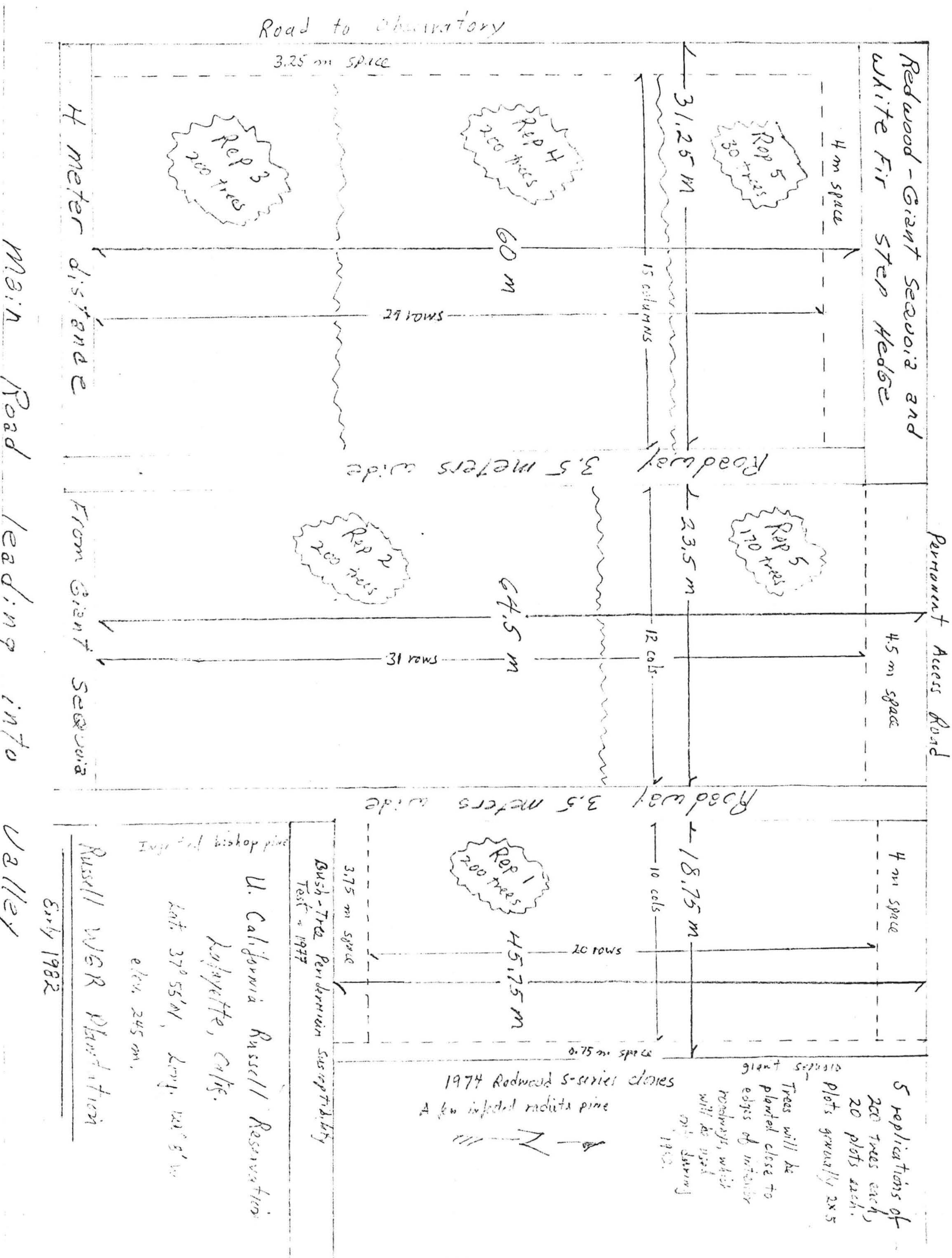
Appendix III

List and Data: Full-sib Select Families

Still to come from C.S.I.R.O.

Please add to this proposal later.

Appendix IV


Road to Observatory
3.25 m space
Redwood-Giant Sequoia and White Fir Step Hedge
31.25 m
Rep 5 30 trees
4 m space
Rep 4 200 trees
Rep 3 200 trees
4 meter distance from Giant Sequoia
60 m
15 columns
24 rows
Roadway 3.5 meters wide
Rep 2 200 trees
Rep 5 170 trees
23.5 m
Permanent Access Road
67.5 m
12 cols
31 rows
4.5 m space
Roadway 3.5 meters wide
Rep 1 200 trees
18.75 m
10 cols
20 rows
4 m space
45.75 m
3.75 m space
0.75 m space
Bush-Tree Ponderosa Susceptibility Test - 1977
Infected bishop pine
U. California Russell Reservation
Lafayette, Calif.
elev. 245 m.
Russell WGR Plantation
Early 1982
1974 Redwood S-series clones
A few infected radiata pine
N
giant sequoia
Trees will be planted close to edges of interior roadways, which will be used only during 1982.
5 replications of 200 trees each, 20 plots each. Plots generally 2x5
Main Road leading into Valley

Appendix V

Timetable for Russell WGR Plantation

Spring 1977.
a. Russell clonal planting installed.

Winter 1979
a. CSIRO 9-family trial planted at Navarro.

Spring 1979
a. Data on stem and branch galls taken on Russell clonal planting.

Spring 1980
a. Data on stem and branch galls taken on Russell clonal planting.
b. Maturation-state blocks planted at Russell and Navarro.

Fall 1980
a. Survival and heights on 1980 plantations of maturation-state blocks at Navarro and Russell.

Winter 1981
a. Formal proposal developed and submitted to CSIRO.
b. Native population seed requested from IFG seed bank, Placerville.
c. Site selected at Russell Reservation.
d. Manuscript on clonal planting prepared.

Spring 1981
a. Site visits by K. Old (CSIRO), W. Libby and F. Cobb (UC). Details of study developed further.
b. Trees removed from Russell site. Stumps pulled.
c. Seed of 30 select families requested from CSIRO, with New Zealand participation invited.
d. Final harvest of cones from controlled interpopulation crosses in Gill and Russell breeding-orchards. Seeds extracted and filled seeds counted and inventoried.
e. (Total inventory of seeds resulting from terminated radiata breeding project made available for allocation and distribution to CSIRO, NZ FRI, and others).
f. Clonal expansion of 4 "standard clones" begun.
g. Stratification of seed (particularly seeds of the Guadalupe population and its hybrids).
h. June - seeds set to germinate.
i. Cooperating sites for later full clonal replicates on Jackson State Forest, at Masonite Navarro site, and near the Ano Nuevo population proposed to potential cooperators.
j. Data taken on survival and disease incidence on CSIRO 9-family trial at Navarro (Old, Cobb).

Summer 1981
a. Seedlings and rooted cuttings raised at Gill Tract in folding cans.

b. Manuscript on clonal planting submitted for publication (Zagory, Libby).

Fall 1981

a. Plantation site plowed, disked.
b. Seek site(s) free of WGR for hedge-orchards.

Winter 1982

a. Data: Survival and heights of 1980 maturation-state blocks at Navarro and Russell.
b. Cuttings taken from lower branches of seedlings at Gill tract.
c. Plantation staked and flagged (2-meter square spacing).
d. Pre-emergence (Simazine) herbicide applied.
e. Seedlings and standard clones planted at Russell Reservation. Maps and indexes.
f. Deer fence (individual-tree or perimeter fence) installed.

Spring 1982

a. Assess frequency and distribution of sporulating galls on adjacent clonal planting at Russell.
b. Prepare one or more sites for clonal replication on cooperators' lands.
c. Raise cuttings for hedge-orchard(s) and clonal Replications at Gill.
d. Prepare hedge-orchard site(s), if necessary.
e. Data: Score Navarro 9-family trial for height, stem and branch galls.
f. Data: WGR incidence on Navarro and Russel maturation-state blocks.

Fall 1982

a. Hedge-orchard site(s) plowed, disked.
b. Data: Survival and heights of Russell WGR plantation.
c. Attend IUFRO radiata working group, Rotorua. Report progress to date. Adjust plans for current and planned research in consultation with US, NZ, CSIRO, and other involved cooperators at Rotorua meeting.

Winter 1983

a. Hedge-orchard site(s) staked and flagged. Two replications of each of the 900 seedling-origin clones, plus four replications of each standard clone = 1816 locations (1-meter square spacing). Pre-emergence (Simazine) herbicide applied.
b. One or more coop sites staked and flagged (3-4 meter square spacing).
c. Hedge-orchard(s) planted, mapped, indexed.
d. Coop-site replication(s) planted, mapped, indexed. Deer fence probably not used, but judgment of cooperating foresters will be respected.
e. Cuttings taken for additional coop sites, if needed.

Spring 1983

a. Data: Height, stem and branch galls on CSIRO Navarro 9-family trial. Check for Dothistroma or other problems, with data if appropriate.
b. Data: Height, stem and branch galls, number of I^{o} and II^{o} branches on Navarro and Russell maturation-state blocks. Check for other problems, with data if appropriate.
c. Data: Height, diameter, stem-gall number, size and location, frequency and distribution of sporulating branch galls, on Russell clonal planting.
d. Data: WGR incidence on Russell WGR Plantation (inspection).
e. Cooperator site(s) prepared, if necessary.
f. Raise cuttings for coop site(s), if necessary.

Summer 1983

a. Fully analyse available data, to date. The maturation-block data should relate gall incidence to infection sites (i.e., number of elongating terminals at time of infection).
b. Raise cuttings at Gill for remaining coop clonal-replicate(s).

Fall 1983

a. Stake and flag remaining clonal-replicate coop site(s).
b. Data: Survival and height at Spring 1983 coop clonal-replicate planting(s).
c. Recruit forest pathology graduate student to investigate correlation of field-infection data to greenhouse-infection data of the same clones. Active research to begin in 1984, following late-spring analyses of infections at Russell WGR Plantation.

Winter 1984

a. Plant remaining coop clonal-replicate site(s), map, index.

Spring 1984

a. Data: Height, stem and branch galls, other morphological characteristics on maturation blocks at Navarro, Russell.
b. Data: Height, stem and branch galls at Russell WGR plantations.
c. Data: Incidence of WGR on 1983-planted coop clonal-replicates.

Summer 1984

a. Take cuttings from a diagnostic subset of The Russell WGR Plantation clones from hedge-orchard donors, for use in greenhouse-infection experiments. Root at Gill.

Later and general (detailed timetable updated at Rotorua meeting and periodically thereafter).

a. Survey for WGR incidence should be done in late spring, after one growing season.
b. Detailed assessment of stem and branch galls should be done in late spring, after 2 and 3 growing seasons.
c. Development of stem galls and their effect on survival, growth and form should be followed periodically from the 5th growing season on.

d. If variation in WGR susceptibility can be shown that is not only statistically significant, but also biologically and economically significant, then a series of additional studies are suggested. These include:

1. A greenhouse study should be done, inoculating rooted cuttings from a subset of the clones under test in the field. If such greenhouse tests can be shown to correlate well with field susceptibility of these clones, then a survey of susceptibility of these clones to strains of WGR collected from a variety of hosts from throughout N. America should be done. To minimize chances of spreading non-native strains of the pathogen, these inoculations should be done at a time when local trees are least susceptibile (perhaps mid-winter?) They should not be allowed to sporulate, but should be terminated after galls have been diagnosed.

2. A more detailed series of experiments in the field, using this same subset of diagnostic clones, could be installed on a greater number and variety of plantation sites.

3. Clones combining low suceptibility to WGR with other desirable characteristics could be selected and tested for use in California, and (if tissue-culture techniques allow safe transport of disease-free cultures) in other parts of the world.

4. Additional full-sib families from tree-breeding programs can be included in later tests, with a known set of clones or families from the first test for comparison.

5. Further investigations of the relationship of suceptibility to maturation state should be conducted, with at least three questions in mind. (a) Can we hold maturation state, and thus susceptibility, constant and juvenile for a set of diagnostic standard clones? (b) Does the change in susceptibility with increasing maturation state vary significantly among clones? (c) Can maturation-state changes in susceptibility be used in forest plantations at an operational level?