

Table 3. — *P. pringlei* terpene phenotypes.

Chemical	$\alpha$ -pinene phenotype		$\Delta$ -3-carene phenotype	
	Mean %	Range %	Mean %	Range %
$\alpha$ -pinene	62.64	42.97-83.15	13.35	4.27-28.55
$\beta$ -pinene	12.07	0.63-44.17	16.76	0.88-38.34
$\Delta$ -3-carene	0.06	0.00-0.81	48.73	27.16-64.69
longifolene	9.18	0.00-24.06	8.87	2.37-19.56

Table 4. — MIROV's (1961) *P. pringlei* data.

Chemical	Mean %
$\alpha$ -pinene	73
$\beta$ -pinene	2
$\Delta$ -3-carene	11
terpinolene	1
methyl chavicol	2.5
longifolene	6

Representative data covering the entire natural ranges of *P. greggii* and *P. pringlei* are now required to determine the extent of inter- and intra-provenance variation. Full comparisons could then be made with other closed cone pines already studied in depth.

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#### References

ANDREWS, D. F.: Plots of high-dimensional data. *Biometrics* 28: 125-126 (1972). — BARNES, R. D. and STYLES, B. T.: The closed-cone pines of Mexico and Central America. *Commonw. For. Rev.*

62 (2): 81-84 (1983). — BURLEY, J. and GREEN, C. L.: Variation of gum turpentine between provenances of *Pinus caribaea* MORFLET and *P. oocarpa* SCHIEDE in Central America. In: Symposium on Forest Tree Biochemistry. European Communities, Rept. Eur. 5885, Brussels pp. 73-108. (Eds. D. T. SEALS *et al.*) (1977). — COPPEN, J. J. W., ROBINSON, J. M. and MULLIN, L. J.: Composition of xylem resin from five Mexican and Central American *Pinus* species growing in Zimbabwe. *Phytochem.* 27 (6): 1731-1734 (1988). — CRITCHFIELD, W. B. and LITTLE, E. L.: Geographic distribution of pines of the World. USDA For. Serv. Misc. Publ. 991 (1966). — EGUILUZ PIEDRA, T.: Taxonomic relationships of *Pinus tecunumanii* from Guatemala. *Commonw. For. Rev.* 65 (4): 303-313 (1986). — ILOFF, P. M. and MIROV, N. T.: Composition of gum turpentines of pines XVI. A report on *Pinus oocarpa* and *P. pseudostrobus* var. *oaxacana* from Chiapas and *P. cooperi* from Durango. J. of the American Pharmaceutical Ass. Scientific Ed. XLII (1): 46-49 (1953). — LOCKHART, L. A.: Investigation of tropical pine resin terpenes. University of Oxford, MSc thesis (1985). — LOCKHART, L. A.: The intensive study of tropical pine gene resources. In: Proc. Internat. Workshop on Biochemical Markers in the Population Genetics of Forest trees. (Eds. H. H. HATTEMER and S. FINESCHI). pp 113-119 (1990a). — LOCKHART, L. A.: Chemotaxonomic relationships within the Central American Closedcone pines. *Silvae Genetica* 39 (5-6): 173-184 (1990b). — LOYTTYNIEMI, K., LOYTTYNIEMI, R., HILTUNEN, R. and RAISANEN, S.: Monoterpene composition of needle oil of *Pinus oocarpa* and *Pinus caribaea*. *Silva Fennica* 16 (4): 351-355 (1982). — McCARTER, P. S. and BIRKS, J. S.: *Pinus patula* subspecies *tecunumanii*. The application of numerical techniques to some problems of its taxonomy. *Commonw. For. Rev.* 64 (2): 117-132 (1985). — MARTINEZ, M.: Una nueva especie de *Pinus* mexicano. *Madrona* 7: 4-8 (1943). — MIROV, N. T.: Composition of gum turpentines of pines. USDA For. Serv. Tech. Bull. No. 1239: 159 pp (1961). — STYLES, B. T.: The identity of SCHWERDT-FEGER's Central American Pine. *Forest Genetic Resources Bulletin*, FAO No 13: 47-51 (1985).

## Variation in Susceptibility of *Pinus muricata* and *Pinus radiata* to Two Species of Aphidoidea

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#### Summary

In two provenance trials in north-eastern New South Wales, Australia, it was found that the closely related species *Pinus radiata* and *P. muricata* differed markedly in relative susceptibility to two species of aphid.

*P. radiata* was more susceptible than *P. muricata* to the woolly aphid, *Pineus pini*. A putative intervarietal hybrid, *P. radiata* var. *binata* x *P. radiata* var. *radiata*, was the most susceptible, *P. radiata* var. *radiata* was less suscep-

tible and *P. muricata* the least susceptible. There were also differences in susceptibility between five local seedlots of *P. radiata* var. *radiata* from New South Wales plantations. The four seed orchard lots were less susceptible than a seedlot collected from unimproved plantations. This is possibly due to an indirect response to selection for growth rate in plantations where *Pineus pini* has been present for many years.

In contrast, *Pinus muricata* was more susceptible to the needle aphid, *Eulachnus thunbergii*, than was *Pinus radiata*. There appears to be clinal variation in the natural populations of *P. muricata*, with the northern provenances being the most susceptible and the southernmost provenance sampled, Monterey, being no more susceptible than *P. radiata*.

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**Key words:** *Pineus*, *Eulachnus*, *Pinus radiata*, *Pinus muricata*, infestation, susceptibility, *Oocarpae*.

### Introduction

Seven species of aphid have been reported occurring on *Pinus radiata* D. DON in its natural range in California but none is regarded as being an important pest (OHMART, 1981). Nor are aphids considered important on *Pinus muricata* D. DON in its natural range (FURNISS and CAROLIN, 1977). However, in Australia (TANTON and ALDER, 1977), New Zealand (ZONTAG, 1977) and southern Africa (ODERA, 1974; BARNES *et al.*, 1976; ODENDAAL, 1980) aphids, especially *Pineus pini* L. and *Eulachnus rileyi* WILLIAMS are important pests of *Pinus* species including *P. radiata*.

Two species of aphid were observed infesting trees in provenance trials of *P. muricata* and *P. radiata* on the northern tablelands of New South Wales, Australia. One species was identified as *Eulachnus thunbergii* WILSON (Aphidoidea: Aphididae). This east Asian species had previously been recorded in Australia from two collections made in 1958 on *P. taeda* L. on the coastal plain of northern New South Wales (EASTOP, 1966) and one collection in 1986 on *P. luchuensis* MAYR on the central tablelands of New South Wales (J. A. SIMPSON, unpubl. data). The other species was identified as *Pineus pini* (Aphidoidea: Adelgidae), a species widespread in Australia (MINKO, 1961; MOORE, 1963) and known to suppress growth of *P. radiata* (TANTON and ALDER, 1977). The taxonomy of *Pineus* species is not clear (BARNES *et al.*, 1976; McCLURE, 1982). We have chosen to follow ODERA (1974) and EASTOP (in BARNES *et al.*, 1976) and use the name *P. pini* for the aphid commonly known as *P. laevis* MASKILL in Australia and New Zealand (e. g. ZONTAG, 1977, 1982; TANTON and ALDER, 1977).

This paper reports variation in susceptibility of provenances of *P. radiata* and *P. muricata* to *P. pini* and *E. thunbergii* in two field trials in New South Wales, Australia.

### Methods

The two provenance trials in which incidence was assessed are located three km apart in Nundle State Forest (lat 31° 25'S long. 151° 12'E.), on the southern edge of the Northern Tableland region of New South Wales. The trial at site one, planted in 1980, is at 1200 m altitude on a

soil derived from Paleozoic sediments. It consists of a 3 x 3 lattice square with four replicates of nine seedlots and each plot is 25 trees. The trial at site two was planted two years later at an altitude of 1300 m on Tertiary basalt. It is a 3 x 4 rectangular lattice design with six replicates of 12 seedlots and each plot is 49 trees.

The seedlots of *P. radiata* and *P. muricata* in these trials are shown in Table 1. Seed of all eight *P. muricata* provenances was collected in natural stands in California and details of the collection are given by ELDRIGE (1978, 1979). Of the *P. radiata* provenances, the CG seedlot ('Canberra-Guadalupe') was wind pollinated seed collected from a small number of trees of Guadalupe Island provenance growing in a radiata pine plantation in the Australian Capital Territory. Therefore it probably consists mainly of the inter-varietal hybrid, *P. radiata* var. *binata* x *P. radiata* var. *radiata*, between the Guadalupe and the surrounding local population which is thought to have been derived from Monterey, Ano Nuevo, or a mixture of both provenances of *P. radiata* var. *radiata* (MORAN and BELL, 1987). Seedlot FF was collected at final felling of mature plantations in southern New South Wales. The other four *P. radiata* lots are all from New South Wales seed orchards. Seedlots TSOSEL and VSOSEL were collected from restricted numbers of clones in the Tallaganda and Vulcan seed orchards and TSO and VSO were from all clones in the same orchards. The selected clones at Tallaganda were chosen for apparent resistance to *Dothistroma* needle blight and those at Vulcan for superior form on very fertile soils derived from basalt.

Trial one was assessed in May 1988 and trial two assessed one month later. Only presence or absence was scored. Two observers scored each tree working from opposite sides. A tree was scored as infested by *P. pini* if any of the white waxy exudate produced by the pest was visible on the bark or at the bases of needle fascicles. *E. thunbergii* was scored present only if live aphids were found. No attempt was made to score severity of infestation.

### Results

The white wax secretions of *P. pini* were usually quite conspicuous on moderately to heavily infested trees. However, on lightly infested trees, most infestations

Table 1. — List of provenances.

Species	Code	Origin	Latitude(°N)
<i>P. muricata</i>	07	Monterey, Huckleberry Hill	36°35'
<i>P. muricata</i>	08-1	Sonoma County, coast	38°38'
<i>P. muricata</i>	08-2	Sonoma County, inland	38°38'
<i>P. muricata</i>	09-1	Mendocino County, south, coast	38°52'
<i>P. muricata</i>	09-2	Mendocino County, south, inland	38°51'
<i>P. muricata</i>	09-3	Mendocino County, north, coast	39°20'
<i>P. muricata</i>	09-4	Mendocino County, north, inland	39°15'
<i>P. muricata</i>	10	Humboldt County, Trinidad Head	41°06'
<i>P. radiata</i>	VSO	Vulcan seed orchard	
<i>P. radiata</i>	VSOSEL	Vulcan seed orchard, selected clones	
<i>P. radiata</i>	TSO	Tallaganda seed orchard	
<i>P. radiata</i>	TSOSEL	Tallaganda seed orchard, selected clones	
<i>P. radiata</i>	FF	Final crop from unimproved plantations	
<i>P. radiata</i>	CG	Guadalupe Island mother trees, wind-pollinated in plantations near Canberra	

Table 2. — Analyses of variance of *Eulachnus thunbergii* incidence.

Source of variation	Site 1				Site 2			
	DF	Mean square	F	Prob>F	DF	Mean square	F	Prob>F
Replicate	3	0.2444			5	0.0191		
Provenance	8	0.1964	2.44	0.043	11	0.0566	2.30	0.021
Error	24	0.0804			55	0.0246		

Table 3. — Analyses of variance of *Pineus pini* incidence.

Source of variation	Site 1				Site 2			
	DF	Mean square	F	Prob>F	DF	Mean square	F	Prob>F
Replicate	3	0.0265			5	0.0149		
Provenance	8	0.2459	11.45	0.000	11	0.1657	16.40	0.000
Error	24	0.0215			55	0.0101		

were inconspicuous, either under bark flakes or at the base of fascicle sheaths. Infested trees usually had a very distinctive appearance with unusually short shoots.

*E. thunbergii* was confined to the needles. These small, grey to black, mobile aphids were most abundant on the oldest age classes of needles. Infested trees often had the appearance of being infected by a needle cast disease as infested needles were a chlorotic pale yellow, or green with yellow spots. Sooty mould, growing on the sugars excreted by the aphids, was often present.

Analyses of variance for proportion of trees infested by *E. thunbergii* at both sites are presented in Table 2. The corresponding analyses for *P. pini* are presented in Table 3. Arcsine square root transformation was necessary to stabilise variance in the data. The lattice designs controlled little additional microsite variation so, for simplicity of presentation, both trials have been analysed as if they were randomised complete block designs.

The incidence of *E. thunbergii* infestation was much higher at site one than at site two. There were significant differences (probability of a larger value of F being less than 5%) between provenances at both sites. The provenance means and the least significant difference (prob = 5%) for comparison of mean transformed incidence are shown in Table 4. At both sites, Mendocino County *P. muricata* (09) was the most severely infested and *P. muricata* from central California (08 and 07) and the northernmost population (10) were intermediate. There are no significant differences between any of the *P. radiata* populations.

In contrast, *P. radiata* was more severely infested by *P. pini* than was *P. muricata* and there was much greater differentiation between the *P. radiata* populations (Table 5). The Guadalupe hybrid seedlot (CG) was significantly more severely infested than any other at site one. At site two, Guadalupe was not represented and the final fellings (FF)

Table 4. — Proportion of trees infested by *Eulachnus thunbergii*.

Site 1			Site 2		
Provenance	Mean transformed score	Actual score* %	Provenance	Mean transformed score	Actual score* %
<i>P. muricata</i>			<i>P. muricata</i>		
09-4	1.24	85	09-1	0.24	7
09-3	1.19	83	09-2	0.23	8
09-1	1.18	82	09-4	0.20	11
09-2	1.17	85	09-3	0.17	8
10	1.01	67	08-1	0.08	2
08-1	0.96	62	10	0.08	2
07	0.74	46	08-2	0.04	1
<i>P. radiata</i>			<i>P. radiata</i>		
CG	0.71	44	VSOSEL	0.00	0
TSO	0.70	43	FF	0.00	0
			VSO	0.00	0
			TSOSEL	0.00	0
			TSO	0.00	0
LSD(Prob=.05) 0.41			0.19		

\*) Order of actual means may differ from that of mean transformed value.

Table 5. — Proportion of trees infested by *Pineus pini*.

Site 1			Site 2		
Provenance	Mean transformed score	Actual score* %	Provenance	Mean transformed score	Actual score* %
<i>P. radiata</i>			<i>P. radiata</i>		
CG	0.81	52	FF	0.50	23
TSO	0.42	19	TSOSEL	0.42	18
			VSO	0.40	16
			TSO	0.37	13
			VSOSEL	0.36	13
<i>P. muricata</i>			<i>P. muricata</i>		
09-4	0.23	7	08-1	0.14	2
10	0.22	7	09-2	0.14	2
09-2	0.21	6	08-2	0.12	2
09-1	0.13	3	09-1	0.10	2
07	0.06	1	09-4	0.09	2
08-1	0.06	1	09-3	0.06	1
09-3	0.00	0	10	0.05	2
LSD(Prob=.05) 0.21			0.12		

\*) Order of actual means may differ from that of mean transformed value.

seedlot was the most severely infested, being significantly more susceptible than two of the seed orchard lots. Also at site two, all the *P. muricata* lots were significantly less infested than all of the *P. radiata* provenances and there was little variation among the *P. muricata* provenances. All were resistant with *P. pini* infestation on site one being 7% or less and on site two 2% or less.

#### Discussion

Neither pest is native to North America where both species of pine naturally occur but *P. pini* has been present in Australia for many years (FROGATT, 1923) and is common in plantations of *P. radiata*. However, the related species, *Pineus borneri* ANNAND, has been recorded on *P. radiata* in California but is apparently uncommon (FURNISS and CAROLIN, 1977; OHMART, 1981). *E. thunbergii* has not been reported previously on *P. radiata*. Because of its extreme isolation it is highly unlikely that the natural population on Guadalupe Island, from which the seed parents of the CG seedlot originated, has ever been subject to attack by *P. pini*. The pollen parents of CG and the other *P. radiata* seedlots would have undergone natural selection for resistance to *P. pini* to varying degrees in Australia. The clones in the seed orchards have not been directly selected for resistance to *P. pini* but they have been intensively selected for growth rate. Attack by *P. pini* has been shown to reduce growth rate in *P. radiata* (TANTON and ALDER, 1977), therefore selection for growth rate may have indirectly selected for resistance. This may be the reason for the slightly lower infestation in the seed orchard lots than in the seedlot collected from unimproved plantations.

*P. muricata* has a discontinuous distribution along the coast of California and Baja California and has been divided into a number of forms or varieties (MILLAR, 1986), at least two of which are included in these trials. There is an abrupt transition in continuous stands in northern Sonoma County from a northern form with distinctly

bluish needles to a southern form with more typically green needles. Provenances 10 and 09 are 'blue' forms and 08 and 07 'green' forms. There is no grouping of the *P. muricata* provenances by geographic origin for *P. pini* incidence at site one and at site two the incidence is effectively zero for all the *P. muricata* provenances. There is, however, a general clinal trend in susceptibility to *E. thunbergii*. The southernmost 'green' population (07) is the least susceptible, almost identical to *P. radiata*, the northern 'green' population (08) is more susceptible and the southern 'blue' (09) is the most susceptible. The exception to the pattern is the northernmost 'blue' (10) which is grouped with Sonoma County 'green' (08) on both sites. MILLAR *et al.* (1988) concluded, on the basis of allozymes, that the Mendocino population (09) was more similar to the Sonoma 'green' (08) than to the Trinidad Head 'blue' (10) and that divergence in *P. muricata* had occurred as the species had migrated northwards.

The differences between the provenances and species may have been partly obscured as trees were scored as being infested with *E. thunbergii* only if live aphids were observed, and no attempt was made to score severity of damage. At site one, the population of *E. thunbergii* was very high on the more susceptible blue provenances of *P. muricata* and had caused considerable damage to the foliage. Aphids could be found on the adjacent *P. radiata*, so those trees were also scored as infested, but infestation was slight and there was little, if any, apparent damage. The trial at site two was assessed one month later than the first trial and the numbers of *E. thunbergii* appeared to have fallen greatly in the intervening period. Many trees of the susceptible provenances were clearly severely damaged by *E. thunbergii*, but as no live aphids could be found, these trees were scored as uninfested.

One possible cause of the variation in susceptibility between the species and provenances might be differences in the monoterpene composition of their needle resins (LEVIN, 1976; GATES and ALEXANDER, 1982; MATSON and HAIN,

1985), but if this is the case, then the relationship is not straightforward. The monoterpenes of all the *P. radiata* provenances are similar, being composed mainly of  $\alpha$ -pinene and  $\beta$ -pinene (BANNISTER and McDONALD, 1983). In *P. muricata* there is wide variation in monoterpene composition. Oleoresin of the Trinidad Head population is largely  $\alpha$ -pinene. For the other northern populations it is mainly 3-carene, while for the southern populations, mainly sabinene (MIROV *et al.*, 1966). This variation is not related to susceptibility to either aphid species in any simple way.

It is more likely that resistance involves various active resistance responses (ROHFRIE, 1988) as well as anatomical, chemical and nutritional characteristics of the host (HANOVER, 1975) and if so would be polygenetically inherited. BARNES *et al.* (1976) reported genetic variation in susceptibility to *P. pini* in several *Pinus* species in Zimbabwe (then Rhodesia) and estimated narrow sense heritability as 0.65 for severity of infestation of *P. elliottii*. They also suggested that maladaptation to the planting site was an important factor predisposing trees to attack. This could explain why their local population of *Pinus patula* was less susceptible to *P. pini* than provenances from natural populations in Mexico, even though the pest had only recently been introduced to southern Africa and there could have been no direct selection for resistance.

In the trials reported here, the rankings of the provenances for susceptibility to both species of aphid were stable over both sites, suggesting that there is minimal genotype  $\times$  site interaction, even though the soils had very different nutritional status. However, infestation of *P. muricata* by *E. thunbergii* was much greater at site one, the less fertile site which is deficient in nitrogen, phosphorus, calcium and magnesium (SIMPSON and ADES, unpubl. data), suggesting that physiological stress may increase susceptibility to that species also.

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#### References

BANNISTER, M. H. and McDONALD, I. R. C.: Turpentine composition of the pines of Guadalupe and Cedros Islands, Baja California. *New Zealand J. Botany* 21: 373–377 (1983). — BARNES, R. D., JARVIS, R. F., SCHWEPENHAUSER, M. A. and MULLIN, L. J.: Intro-

duction, spread and control of pine woolly aphid, *P. pini* (L.), in Rhodesia. *South African Forestry Journal* 96: 1–11 (1976). — EASTOP, V. F.: A taxonomic study of Australian Aphidoidea (Homoptera). *Aust. J. Zool.* 14: 399–599 (1966). — ELDRIGE, K. G.: Seed collection in California. *Annual Report 1977 to 1978*, C. S. I. R. O., Division of Forest Research, pp 9–17 (1978). — ELDRIGE, K. G.: *P. muricata* seed collections, 1978. C. S. I. R. O., Division of Forest Research, Genetics Section Report No. 8, 55pp. (1979). — FROGGATT, W. W.: Forest insects of Australia. Forestry Commission of New South Wales, Sydney. 171pp. (1923). — FURNISS, R. L. and CAROLIN, W. W.: Western forest insects. USDA Forest Service Misc. Publ. No. 1339, 654 pp. (1977). — GATES, R. G. and ALEXANDER, H.: Host resistance and susceptibility. pp. 212–263. In: MILTON, J. B. and STURGEON, K. B. (eds.). Bark beetles in North American conifers. University of Texas Press, Austin (1982). — HANOVER, J. W.: Physiology of tree resistance to insects. *Ann. Rev. Entomol.* 20: 75–95 (1975). — LEVIN, D. A.: The chemical defenses of plants to pathogens and herbivores. *Annual Review of Ecology and Systematics* 7: 121–159 (1976). — MATSON, P. A. and HAIN, F. P.: Host conifer defense strategies: a hypothesis. pp. 33–42. In: SAFRANYIK, L. (ed.). The role of the host in the population dynamics of forest insects. Canadian Forest Service, Victoria (1985). — McCURE, M. S.: Distribution and damage of two *Pinus* species (Homoptera: Adelgidae) on red pine in New England. *Ann. Entomol. Soc. Amer.* 75: 150–157 (1982). — MILLAR, C. I.: The Californian closed-cone pines (Subsection *Oocarpae* LITTLE and CRITCHFIELD): a taxonomic history and review. *Taxon* 35: 657–670 (1986). — MILLAR, C. I., STRAUSS, S. H., CONKLE, M. T. and WESTFALL, R. D.: Allozyme differentiation and biosystematics of the Californian closed-cone pines (*Pinus* subsect. *Oocarpae*). *Systematic Botany* 13: 351–370 (1988). — MINKO, G.: Insects of *P. radiata* plantations in northeast Victoria. *Bull. No. 13*, Forests Commission of Victoria, Melbourne, (1961). — MIROV, N. T., ZAVARIN, E., SNAJBERK, K. and COSTELLO, K.: Further studies of terpene composition of *Pinus muricata* in relation to its taxonomy. *Phytochemistry* 5: 343–355 (1966). — MOORE, K. M.: Observations on some Australian forest insects. 14. A preliminary list of insects attacking *Pinus* spp. in New South Wales. *Australian Zoology* 13: 64–77 (1963). — MORAN, G. F. and BELL, J. C.: The origin and genetic diversity of *Pinus radiata* in Australia. *Theor. Appl. Genet.* 73: 616–622 (1987). — ODENDAAL, M.: *Eulachnus rileyi*: a new pest on pines in Zimbabwe. *South African Forestry J.* 115: 69–71 (1980). — ODERA, J. A.: Incidence and host trees of pine woolly aphid, *P. pini* in east Africa. *Commonwealth Forestry Review* 53: 128–136 (1974). — OHMART, C. P.: An annotated list of insects associated with *P. radiata* D. DON in California. CSIRO, Division of Forest Research, Divisional Report No. 8, 50pp. (1981). — ROHFRIE, O.: A resistance response of *Picea excelsa* to the aphid *Adelges abietis* (Homoptera: Aphidoidea). pp. 253–266. In: MATTSON, W. J., LEVIEUX, J. and BERNARD-DAGAN, C. (eds.). Mechanisms of woody plant defense against insects. Springer-Verlag, New York (1988). — TANTON, M. T. and ALDER, D.: The distribution and possible effects of the woolly aphid *Pinus* (Adelgidae: Homoptera) on *Pinus radiata* D. DON growing in the Australian Capital Territory. *Aust. For. Res.* 7: 253–263 (1977). — ZONDAG, R.: *Pinus laevis* (Homoptera: Adelgidae). *New Zealand Forest Research Institute, Forest and Timber insects in New Zealand* No. 25, 3pp. (1977). — ZONDAG, R.: Insects of exotic forests of the central North Island. *New Zealand Entomologist* 7: 276–280 (1982).

## Genetic Parameters and Predicted Selection Responses for Growth and Wood Properties in a Population of *Araucaria cunninghamii*

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#### Summary

Growth traits, stem straightness and wood properties were assessed in a hoop pine (*Araucaria cunninghamii*)

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progeny trial in south-eastern Queensland at 15 years of age. Estimates of narrow-sense heritability for height, diameter and straightness were 0.19, 0.22 and 0.61 respectively. For wood properties, the estimates for spiral grain angle, compression wood percentage and basic density were 0.33, 0.44 and 0.83 respectively. These estimates