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NATIONAL INSTITUTE FOR FOREST PRODUCTS INNOVATION

Developing more productive plantation trees better adapted to changing environments

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National Institute for Forest Products Innovation

Mount Gambier

by

T.A. McRae, M. Ivkovic, D.C. McKersie, D.J. Pilbeam, G.W. Dutkowski, R.J. Kerr, J. Klapste, D. Stackpole

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Researcher/s:
T.A. McRae, M. Ivkovic, D.C. McKersie, D.J. Pilbeam, G.W. Dutkowski, R.J. Kerr, J. Klapste
Tree Breeding Australia Limited
PO BOX 1811 Mount Gambier, SA

D. Stackpole
OneFortyOne Plantations Pty Ltd.
152 Jubilee Highway East, PO Box 1383, Mount Gambier SA 5290

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Executive Summary

The purpose of genetic improvement programs is to breed and select trees with improved productivity, product quality and plant health attributes. There is a need to expand the range of site types for testing genetic material given the potential risks associated with climate change and acknowledging there is limited suitable land available in the traditional production areas to enable industry expansion. The project is a part of a pre-emptive strategy for climate adaptation of the plantation industry. The aim was to establish genetic resources in a network of field trials suitable for screening material under a broad range of potential production environments.

Two series of trials have been established in the 2023 and 2024 planting seasons (in total 16 trials for radiata pine and 7 trials for blue gum). The radiata pine trials include advanced generation families, unimproved provenance families and seed lots, and hybrid families among new selections from the five native provenances (Monterey, Año Nuevo, Cambria, Guadalupe Is. and Cedros Is.) crossed to elite commercial male parents. The trials also include cuttings of elite families (containerised and bare rooted), commercial seed lots and controls. The trials are about 4 to 6 ha in size (each containing from 4000 to 9000 trees) and have strong genetic connectedness.

The blue gum trials include progeny of advanced generation families and control seed lots. They are about 1.5 to 4.5 ha in size (each containing some 1400 to 5179 trees). The trials included some other eucalypt species (*Corymbia maculata*, *E. cladocalyx*, *E. bicostata*, *E. maidenii*, *E. cideroxylon*, *E_dunnii*, *E_nitens* and *E_smithii*) – but survival and growth in the nursery was generally poor.

Genetic material was tested under a broad range of environments and site types in SA, the GT and other plantation regions, to increase accuracy of prediction and selection intensity. The trials span high-medium, medium-low, and low-marginal productivity site types. Strong genetic linkage among treatments across trials will enable data sets to be used to quantify the importance of genotype × environment interactions. This will enable the collection of performance data and selection of better adapted genotypes for use in deployment and breeding. The outcome will be more productive and resilient plantations.

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Introduction

Developing the best strategies for *E. globulus* and *P. radiata* plantations under climate change were studied as part of FWPA project PNC228-1011 (Pinkard *et al*. 2014). Forecast changes in the frequency and intensity of droughts, bushfires, and emergent tree diseases and pests threaten where plantation managers can plant with the confidence of getting a healthy tree crop in the future, and how they should look after their trees. The authors modelled predictions of plantation productivity for 2030 and 2050 under a range of likely climate scenarios. Data was considered from five key Australian forestry regions: southern WA; the Green Triangle in SA and Victoria; eastern Victoria and southern NSW; and northern NSW for both *E. globulus* and *P. radiata* (only *P. radiata* in northern NSW). The importance of site-level assessments was highlighted, because of the complex interactions between site conditions, climate changes and hazards such as pests.

The modelling suggested productivity for plantations currently in well performing areas may be only slightly affected, with little change by 2030 or even 2050. However, plantations growing in the drier areas of existing plantation regions are considered vulnerable to reduced productivity and increasing mortality, and in the worst instances may be highly likely to fail. Pinkard *et al*. (2014) developed a set of regional reports to help industry understand and mitigate potential hazards that might exist in the next 15 years, no matter which climate pattern ultimately occurs. They also suggested up to 2030, good silvicultural management has the potential to mitigate the negative impacts of climate change for both *P. radiata* and *E. globulus* within the core of the plantation estate.

Bush *et al.* (2018) synthesised the current state of knowledge about species for changing climates and opportunities for Australian dryland forestry. One approach to selecting species for dryland forestry is to work with existing species and try to breed for traits that will result in better adaptation to drier climates. A strategy for *P. radiata* was outlined by Matheson *et al.* (2007) who advocated screening and selection of material from the Mexican island populations that are from sites that are significantly hotter and drier than the US mainland provenances sites, Monterey and Año Nuevo, on which both the Australian and New Zealand breeding populations are largely based. Guadalupe Island provenance has shown some promise and this material is being integrated into the TBA's breeding base population, but further testing on marginal sites is required (Gapare *et al.* 2012).

The genetic base of *E. globulus* could also be further explored with the aim of creating a breed that is more resistant to drought. The species has performed well on a wide range of sites and demonstrated significant sub-race, provenance and family variation to drought damage (Dutkowski and Potts 2012). It would be possible to re-test material from the other subspecies for suitability to site types outside the current estate.

Bush *et al.* (2018) and Dieters (2007) also suggested that, for inland sites, some alternative species are inherently better adapted to low rainfall conditions. There is an existing suite of both softwood and hardwood dryland species for which further testing and development is now warranted. However, the alternative pine species are regarded as only of peripheral interest for plantation forestry, which currently is primarily restricted to traditional, higher-rainfall sites. As a result, there is a risk that genetic material of these and other pine species currently in Australia will be lost or eroded in the short to medium term. A gene conservation strategy was recommended and implemented for *P. radiata* as part of FWPA project PNC135-0809 (Active genetic conservation and utilisation of native radiata pine germplasm).

It is now very difficult to import either seed or vegetative material of any *Pinus* species into Australia due to the risk of pine pitch canker. Therefore, pine germplasm existing within Australia will need to provide the genetic diversity to support the long-term viability of the softwood plantation industry. Similarly, expansion of pine plantations into marginal, low-rainfall environments will need to utilise genetic diversity (both within and between species) extant within Australia.

Industry has flagged its intention to substantially grow the estate in the GT region (GTFIH) in the next decade – expanding into new areas. New and improved varieties of trees underpin productivity improvements and the resilience of our plantation estates. This is increasingly important as the demand for wood fibre products increases and we face new challenges associated with changing climates, fires, drought, and new pests and disease threats.

This project focused on extending the range for plantation species (radiata pine and blue gum) by developing genetic material better adapted to more marginal and challenging environments. It has also considered other potential species as alternatives, but this approach may prove more difficult to achieve a successful outcome in the medium term. The plantation forestry and timber processing sectors need to be economically and financially sustainable. Tree survival alone will not be sufficient to sustain a commercially viable industry - harvest yields need to be at a level and scale to achieve cost efficiencies and generate competitive financial returns.

Tree Breeding Australia manages national tree improvement programs for radiata pine and blue gum, the premier species grown in SA and the GT region. The project addresses long term supply issues facing the forest products industries in SA, the GT and other regions by enabling industry expansion and lifting productivity and resource quality in softwood and hardwood plantations. Tree improvement research (breeding and phenotyping) is being scaled up to double the current rate of genetic gain in pine and eucalypt breeding programs and bring forward productivity increases.

The project objectives

Develop and test advanced generation genetic material for radiata pine and blue gum under a broader range of environments, specifically targeting more challenging ones likely to be experienced with climate change or industry expansion in SA and the GT region.

Improve our understanding of the importance of genotype by environment interactions for tree survival, productivity, tree form, wood quality, plant health attributes and other traits of commercial importance.

Identify selections which are more productive and better adapted to changing and more marginal site types for use in breeding and deployment.

The project is part of a national program, with a focus on SA and the Green Triangle region.

Methodology

Trial Establishment

Two series of trials have been established in the 2023 (Series III) and 2024 (Series IV) planting seasons (in total 16 trials for radiata pine and 7 trials for blue gum). These trials complement trials established in recent years, particularly in the 2021 and 2022 seasons.

The radiata pine trials include advanced generation families, pure provenance Guadalupe families, and hybrid families among new selections from the five provenances (Monterey, Año Nuevo, Cambria, Guadalupe Is. and Cedros Is.) which were crossed to elite commercial male parents. The trials also include cuttings of elite CP families, deployment family cuttings (containerised and bare rooted), commercial seedlings and control treatments. Genetic linkage among treatments in different trials will enable data sets to be used to quantify the importance of genotype x environment interactions.

The blue gum trials include advanced generation CP and OP families (150+), commercial seed lots (OP and MSP) and controls.

The trials utilise experimental designs with large plots (100 trees) embedded within replicates. The large plots contain families and treatments of similar growth potential to minimise the confounding effects of competition among neighbouring trees. These designs are effective in demonstrating realised gains based on predicted breeding values. Each controlled pollinated CP family is represented by up to 20 full sibs per site. Some trials may be highly unbalanced due to the viability of seed and plants varying for different families and treatments.

The plants were be grown in commercial nurseries to ensure plants meet specification. Subject to moisture availability the trials were planted in the winter months. Plant spacing (stocking rate) is consistent with commercial operations. Tree survival and plant health was assessed at 3 months and 9 months of age. Trees will be further assessed at various intervals over the rotation for survival, growth (DBH and HT), wood quality (combination of RESI density and MoE, ST300 acoustic wave velocity), tree form (branch size and stem straightness), and plant health (pest and disease damage).

Needle samples have also been taken from several of the radiata pine trials for DNA assay as part of other research projects (NIF163-2122 and VNC580-2122). For some trials, this was done in the nursery to generate efficiencies.

Assessment of established trials

Trials included in early age assessments in SA and the GT region including those established as part of FWPA project PNC547-2021 were: BRGT1501 (Johnsons Lane, an OFO site), BRGT1701 (Dicksons, OFO), BRGT1701 (Dorodong, TPPL), BR1804 (Noolook, OFO), BRGT1901 (Mount Crawford, FSA), BRGT1902 (Lowan Lane, OFO), BRGT1903 (Kentbruck, GTFP), BRGT2001 (Mount Burr, OFO), BRGT2002 (Rennick, HVP), BRGT2101 (Muellers, FSA), BRGT2102 (Windigi, TPPL), BRGT2103 (South Patchells, TPPL), BRGT2104 (Powers Creek, AKD), BRGT2203 (Elfin South, AKD), BRGT2204 (Myora, OFO) and BRGT2201 (South Penola, TPPL). Data from these 16 targeted trials (up to 107,660 trees) will complement early age measurement data to be collected from 20 other sites (110,010 trees) established since 2015 across the broader radiata pine estate.

The data for radiata pine and blue gum will be deposited in the national DATAPLAN database and used in single-step TREEPLAN evaluations to generate breeding and deployment values for the different site types in the GT and other plantation regions. The data will be used to quantify the importance of genotype by environment interactions. Genetic parameters (heritabilities and correlations) will be estimated using ASReml or similar software. A high genetic correlation across site types indicates G×E is not strong and testing and selection on either site type will deliver genetic gain, subject to the accuracy of breeding values.

Results

Radiata pine trials

The radiata pine trials series III and IV (Table 1) were established in the 2023 and 2024 planting seasons. Additional trials in previous Series I and II were established in the 2021 and 2022 planting seasons as part of FWPA project PNC547-2021.

Radiata pine trial series III

The radiata pine trials included advanced generation control pollinated families (444 F), pure species Guadalupe Island provenance families (24 F), and hybrid families (109 F) among selections from the five provenances (Monterey, Año Nuevo, Cambria, and Guadalupe and Cedros Islands) which were crossed to elite commercial male parents. The trials also included some cuttings of seedlings (1210 genotypes with up to 5 clonal copies) from some 40 elite breeding families, commercial seed lots (6) and controls (4). Commercial cuttings from about 48 deployment CP families were also included. The total number of trees in the radiata pine trials was 33,500 – the trials were about 3.5 to 5 ha in size (each containing some 4500 to 7200 trees). The seedlings were grown at Mount Gambier (Gildera Forestry Services) nursery. Family cuttings were propagated at the Colac (ArborGen) and Maryvale research (HVP) nurseries.

These trials have good genetic linkage (through common parents) among other trials in Series III, but also with previous (including series I and II) and subsequent trials (Series IV) to enable TREEPLAN evaluations and benchmarking of different treatments across time (years) and space (sites).

Radiata pine trials series IV

The 2024 radiata trials (Series IV) are now all established (see Table 1) – this included 10 trials (spread across WA, SA, Victoria, NSW, Tasmania and NZ) with 60,800 plants. The plants were grown in nurseries at Manjimup (FPC), Mount Gambier (Gildera), Colac (ArborGen), Gelliondale (HVP), Somerset (Forico) and Te Teko (Arborgen NZ). Germination percentage and plant growth was good at all nurseries. There was some variation in growth among plant types (seedlings and cuttings) – but this was not unexpected.

The radiata pine trials Series IV includes advanced generation control pollinated families (513 F), pure species Guadalupe Island provenance families and hybrid families (230 F) among selections from the five provenances (Monterey, Año Nuevo, Cambria, and Guadalupe and Cedros Islands) which were crossed to elite commercial male parents. The trials also included some cuttings of seedlings (about 1814 genotypes with up to 5 clonal copies) from some 70 elite breeding families, plus commercial lots and controls (4) for monitoring progress. The BRGT2403 and BRGT2407 also included 3500 plants (family cuttings and somatic embryogenesis (SE) derived plants sourced from the RPBC breeding program and grown at the ArborGen nursery at Colac. Late notification of their availability prevented these from being considered for other trials in the series as they had already been designed and plants labelled. FCNSW and TASWOOD were unable to accommodate a trial as part of the network of project trials.

The trials have good genetic linkage (through common parents) among other trials in Series IV, but also with previous trials (including Series I, II and III), to enable TREEPLAN evaluations and benchmarking of different treatments across time (years) and space (sites). The RPBC families will strengthen the linkage among the TBA and RPBC programs – facilitating future studies on genotype by environment (GE) interactions and enabling joint evaluations (subject to agreement).

Trial establishment for the 2024 trial series is completed and post plant survival assessments progressing. Timing of planting was disrupted by unseasonal dry conditions – with some companies cutting back or deferring planting programs due to a lack of rainfall (soil moisture). This has impacted post plant survival – but generally survival is excellent.

Table 1 The following radiata pine trials (Table 1) were established in the 2023 and 2024 planting season. Additional trials in previous Series I and II were established in the 2021 and 2022 planting seasons as part of FWPA project PNC547-2021.

	Trial ID	Trial Location	Site type	Trees in Trial	Status (post plant)
Series I		Seven trials established		44,760 Total trees in series	Survival assessments completed – some early age height data collected
Series II		Nine trials established		50,600 Total trees in series	Survival assessments done
Series III	BRGT2301	Mount Pleasant SA – Forestry SA	Predominantly sandy soil, 670 mm pa, Lower productivity site	5000	Survival excellent (98.6% plus with pedigreed refills)
	BRGT2302	Penola North SA – Penola Plantations (TPPL)	Sandy soil, 712 mm pa, Low-Med productivity	6000	Survival excellent initially but some losses (88.8%)
	BRGT2303	McGillivrays - Nangwarry SA – OFO Plantations	Sandy soil, 713 mm pa, Med – High productivity	4500	Survival excellent (99.7% plus with pedigreed refills)
	BRGT2304	Caroline Headquarters Mount Gambier SA – OFO Plantations	Sandy loam, 710 mm pa, High productivity	5400	Survival excellent (99.2% plus pedigreed refills)
	BRGT2305	Thorpedale VIC – HVP Plantations	Silty clay soil, 740 mm pa, Med productivity	5400	Survival excellent (99.9%) weed control to be updated
	BRGT2306	Sylvia Vale Bathurst NSW - AKD Softwoods	Granite to basalt clay loam soil, 714 mm pa, ex- pasture site, Low – Med productivity	7200	Survival (52.5%) compromised by severe frosts (minus 8 °C) – refills done all reps.
			Total trees Series III	**33,500**	
Series IV	BRGT2401	Dartmoor VIC - GTFP	Mounded – high site quality	9000	Dry conditions impacted – planted 10-11 July 2024 (97.3% post-plant survival – with pedigreed refills done)
	BRGT2402	Vause, Dorodong VIC – Cpt 41 - Penola Plantations (TPPL)	Mounded – medium productivity (SQ 3.4)	9000	Dry conditions impacted - planted 16 July 2024 (95.7% survival - with pedigreed refills done)
	BRGT2403	Rocky Camp, Mount Burr SA - OFO	Medium productivity (SQ 3-4), rainfall 715 mm	6000	Planted 12 July 2024 – post-plant survival excellent (99.5% with pedigreed refills done)
	BRGT2404	Dickers, Cromer SA - FSA	Mounded, rainfall 690 mm	5000	Planted 26 June 2024 (post-plant survival assessment pending)
	BRGT2405	Shelley Railway Cpt 18 VIC – HVP	Dothistroma prone site – High productivity – machine planted – rainfall 1220 mm	4000	Planted 31 Jul to 3 Aug 2024 – machine planted, post-plant survival about 84%
	BRGT2406	Shelley Railway Cpt 12 VIC - HVP	Dothistroma prone site – High productivity –	4000	Planted 26-30 July 2024 – machine

	Trial ID	Trial Location	Site type	Trees in Trial	Status (post plant)
			machine planted – rainfall 1220 mm		planted, post-plant survival about 84%
	BRGT2407	Holloways, Tantanoola SA - OFO	High productivity (SQ1-2) – rainfall 715 mm	6000	Planted 18-19 July 2024 – post plant survival 99.4% with pedigreed refills done)
	BRGT2408	Wilga WA - FPC	Low-medium productivity, Deep gravel soil, 650 mm rainfall	7000	Planted 24 July 2024 – post-plant survival assessment pending
	BRGT2409	Levendale TAS – Lenah Estate	Gravel – rainfall 630 mm	6000	Planted 4 Sept 2024
	BRGT2410	Kinleith NZ – Timberlands Kaingaroa	High productivity – Dothistroma prone site – rainfall 1050 mm	4800	Planted 19-20 Aug 2024
		Established 2024 season	**Total trees Series IV**	**60,800**	

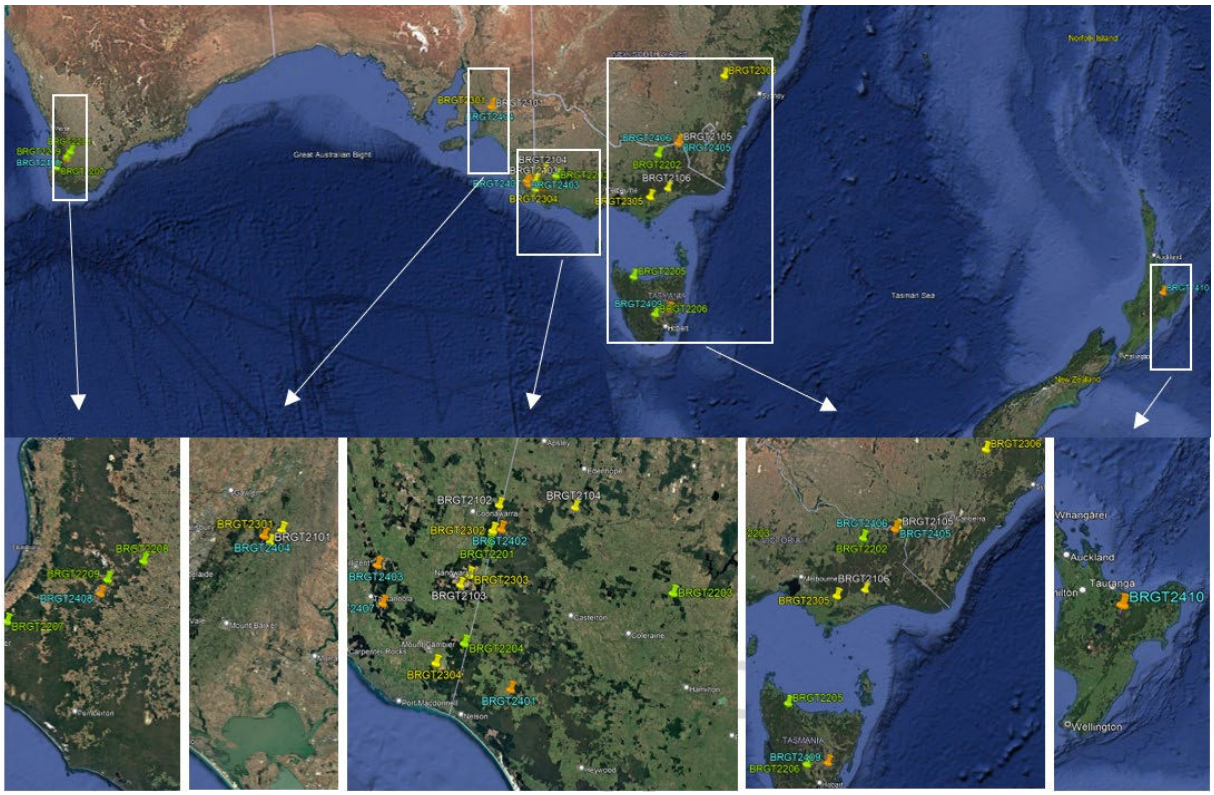

Figure 1 Locations of radiata pine trials planted in Series III 2023 and IV 2024.

There is a large network of field trials (current and historic) spread across the national plantation estate. Trees in these trials have been assessed for various growth, tree form, wood quality and health traits at various ages throughout the rotation cycles. The testing sites have usually been representative of the environmental conditions typical of plantation forestry in these established regions over time (Figure 2). The breeding and selection programs have very been successful in identifying trees with improved characteristics for use in deployment under these conditions.

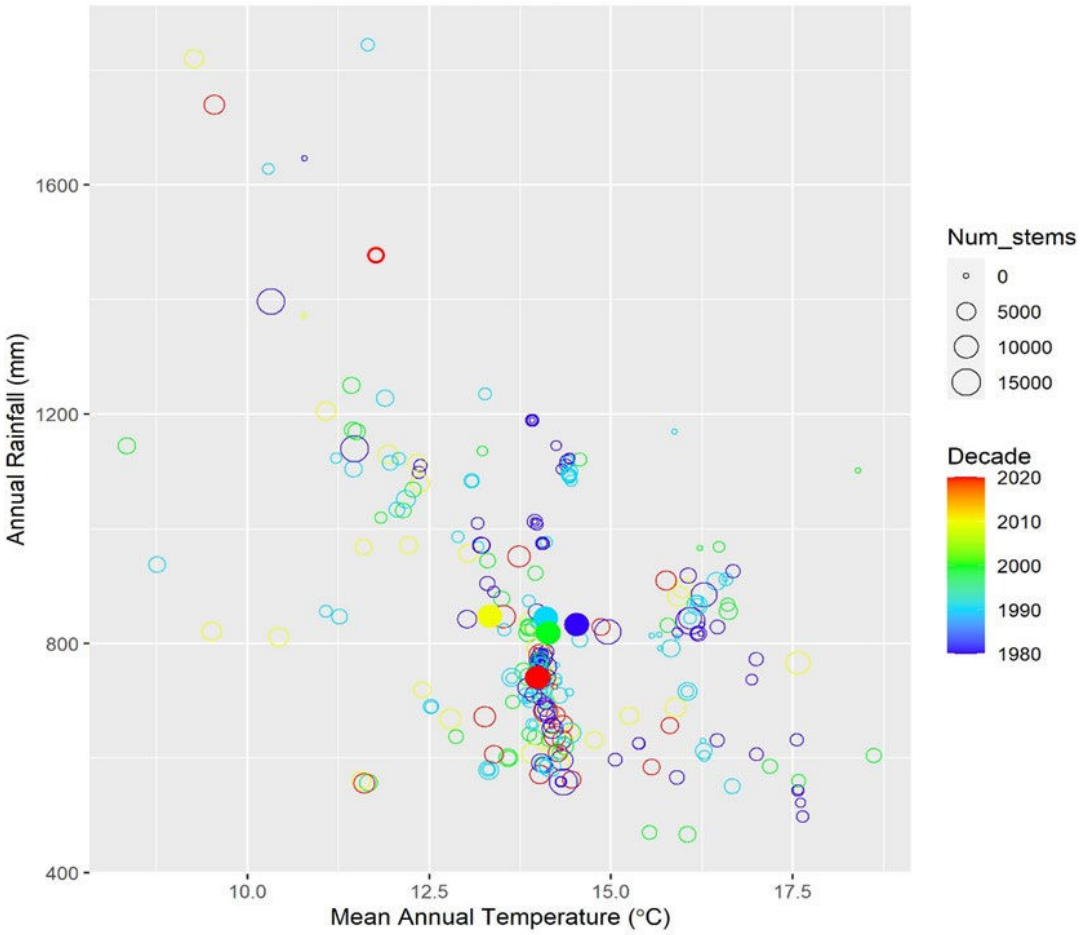

Figure 2 Mean annual temperature vs. annual rainfall for radiata pine genetic trial locations over last four decades. Solid points are the averages for those locations and decades. The size of open circles represents the number of stems in a trial.

Assessments of radiata pine trials

Survival assessments have been completed for most trials in Series I (7 trials), II (9 trials) and III (6 trials). Other assessments during this project in older trials have included height, Resi instrument (DBH and wood density, form and acoustic wave velocity (Table 2).

Table 2 Trial assessments radiata pine. Survival assessments have been completed for most trials in Series I (7 trials), II (9 trials) and III (6 trials). Other assessments have included Height, Resi, Form and Acoustic Wave Velocity (Awv).

Trial ID	Location	Planted	State	Land Holder	Traits	Trees
BRGT2301	Mount Pleasant	2023	SA	FSA	Survival (98.6%)	5000
BRGT2302	Penola North	2023	SA	TPPL	Survival (88.8%)	6000
BRGT2303	McGillivrays	2023	SA	OFO	Survival (99.7%)	4500
BRGT2304	Caroline Headquarters	2023	SA	OEO	Survival (99.2%)	5400
BRGT2305	Thorpedale	2023	Vic	HVP	Survival (99.1%)	5400
BRGT2306	Sylvia Vale	2023	NSW	AKD	Survival (52.5%)	7200
BRGT2201	Penola South	2022	SA	TPPL	Survival (99.8%)	7200
BRGT2202	Niggl Road	2022	Vic	HVP	Survival (scheduled)	4320
BRGT2203	Elfin South	2022	Vic	AKD	Survival (95.6%)	4800
BRGT2204	Myora	2022	SA	OFO	Survival (99.3%)	9720
BRGT2205	Bowskill Road	2022	TAS	Forico	Survival (98.3%)	5120
BRGT2206	Westerway	2022	TAS	Lenah Estate	Survival (98.6%)	5832
BRGT2207	Baudin	2022	WA	FPC	Survival (pending)	6318
BRGT2208	McKenzie	2022	WA	Mitsui	Survival (99.8%)	3510
BRGT2209	McAlinden	2022	WA	FPC	Survival (97.5%)	3780
BRGT2101	Muellers	2021	SA	FSA	Survival (97.1 %)	5000
BRGT2102	Windigi	2021	SA	TPPL	Survival (99.3%)	5000
BRGT2103	South Patchells	2021	SA	OFO	Survival (99.4%), Height	9600
BRGT2104	Powers Creek	2021	Vic	AKD	Survival (99.6%), Height	6000
BRGT2105	Shelley	2021	Vic	HVP	Survival (93.4%)	8000
BRGT2106	Stockdale	2021	Vic	HVP	Survival (to be updated)	5400
BRGT2107	Kaingoroa	2021	NZ	Timberlands	Survival (to be advised)	5760
BRGT2001	Mount Burr	2020	SA	OFO	Survival, Height, Fecundity	9600
BRGT2002	Rennick	2020	Vic	HVP	Survival, Height	9000
BRGT1901	Mount Crawford	2019	SA	FSA	Survival (scheduled)	4500
BRGT1902	Lowan Lane	2019	SA	OFO	Survival, Resi, Form, Awv, Fecundity	9000
BRGT1903	Kentbruck	2019	Vic	GTFP	Survival, Resi, Form	6000
BRGT1904	Beechworth	2019	Vic	HVP	Survival (scheduled)	5000
BRGT1905	Myalup	2019	WA	FPC	Survival (poor)	7500
BRGT1801	Middlesex	2018	TAS	Forico	Survival (scheduled)	4920
BRGT1802	Four Springs	2018	TAS	Forico	Survival (scheduled)	3300
BRGT1803	Durham	2018	Vic	HVP	Survival, Resi	3600
BR1804	Noolook	2018	SA	OFO	Survival, Resi, Form, Awv	4240
BRGT1701	Dicksons	2017	SA	OFO	Survival, Resi, Form	6000
BRGTI 702	Dorodong	2017	Vic	TPPL	Survival, Resi, Form, Awv	6000
BRGT1703	Strathbogie	2017	Vic	HVP	Survival, Resi	4000
BRGTI 704	Muja	2017	WA	FPC	Survival, Resi, Form	6000
BRGT1601	Blackwarry	2016	Vic	HVP	Survival, Resi	6750
BR1602	Westerway	2016	Tas	Lenah Estate	Survival, Resi, Form	5000
BR1603	Upper Blessington	2016	TAS	Forico	Survival, Resi	5000
BRGT1501	Johnsons Lane	2015	SA	OFO	Survival, Resi, Form, Awv	6000
BRGT1502	Green Hills	2015	NSW	FCNSW	Dbh, destroyed	5000
BRGT1503	Shelley	2015	WA	FPC	Survival, Resi, Form	6900
					TOTAL trees	**252,170**

Blue gum trials

The following *E. globulus* field trials (Table 3, Figures 3 and 4) were established in the Series III and IV in 2023 and 2024 planting seasons, respectively.

Table 3 - *E. globulus* field trials established in the 2023 and 2024 planting seasons.

Blue gum					
	Trial ID	**Trial Location**	**Site type**	**Trees in Trial**	**Status**
Series III	TBGL177	Corea plantation, Carapook VIC – PF Olsen	Sandy loam, 722 mm pa, Low productivity	4800	To be advised
	TBGL178	Dellyn plantation, Simpson VIC – Midway Plantations	Clay loam, 909 mm pa, High productivity	5179	Survival (93.5%)
	TBGL179	Bastiani, Kordabup WA – PF Olsen	Gravelly loam, 1068 mm pa, High productivity	1400	Survival good (99.1% at 3 months)
	TBGL180	Dellyn plantation Simpson VIC – Midway Plantations	Clay loam, 909 mm pa, High productivity	2304	Survival (93.8%)
			TOTAL trees Series III	**13,683**	
Series IV	TBGL181	Bentink, Yellanup, WA – PF Olsen	Sandy loam, 722 mm pa, Low productivity	1260	Planted 10 Jul 2024
	TBGL182	Branton, Branxholme VIC – PF Olsen	Low - Med productivity	4800	Planted 2 Aug 2024
	TBGL183	NE of Port Campbell, Vic – Midway Plantations	Med- High productivity	4800	Planted 30 Jul 2024 (initial deaths replaced)
			TOTAL trees Series IV	**10,860**	

Blue gum trials Series III

The *E. globulus* trials in Series III included progeny of advanced generation families (254). The trials also included some control seed lots - with a total number of 13,683 trees in the blue gum trials – the trials were about 1.5 to 4.5 ha in size (each containing some 1400 to 5179 trees). The seedlings were grown in the Mount Gambier SA (Gildera Forestry Services) and Manjimup WA (WAPRES) nurseries.

Blue gum trials Series IV

Seedlings for the 2024 Series IV of blue gum trials were grown at Mount Gambier (Gildera), Colac (Arborgen) and Manjimup (WAPRES) nurseries. Three trials were planted (about 10,860 trees) in the 2024 planting season. The trials included some other eucalypt species (*Corymbia maculata*, *E. cladocalyx*, *E. bicostata*, *E. maidenii*, *E. cideroxylon*, *E_dunnii*, *E_nitens* and *E_smithii*) – but survival and growth in the nursery was generally poor. Trials were planted in WA on WAPRES land, near Branxholme in Victoria on PF Olsen land and near Port Cambell on Midway land.

Trial assessments have been progressing with Resi assessments on four sites completed. A TREEPLAN run for blue gum was completed in June 2024. The single-step evaluation included the results of DNA assays completed as part of other research projects. The evaluation included data from 193 field trials with genetic values predicted for 18 measured traits on 383,236 genotypes.

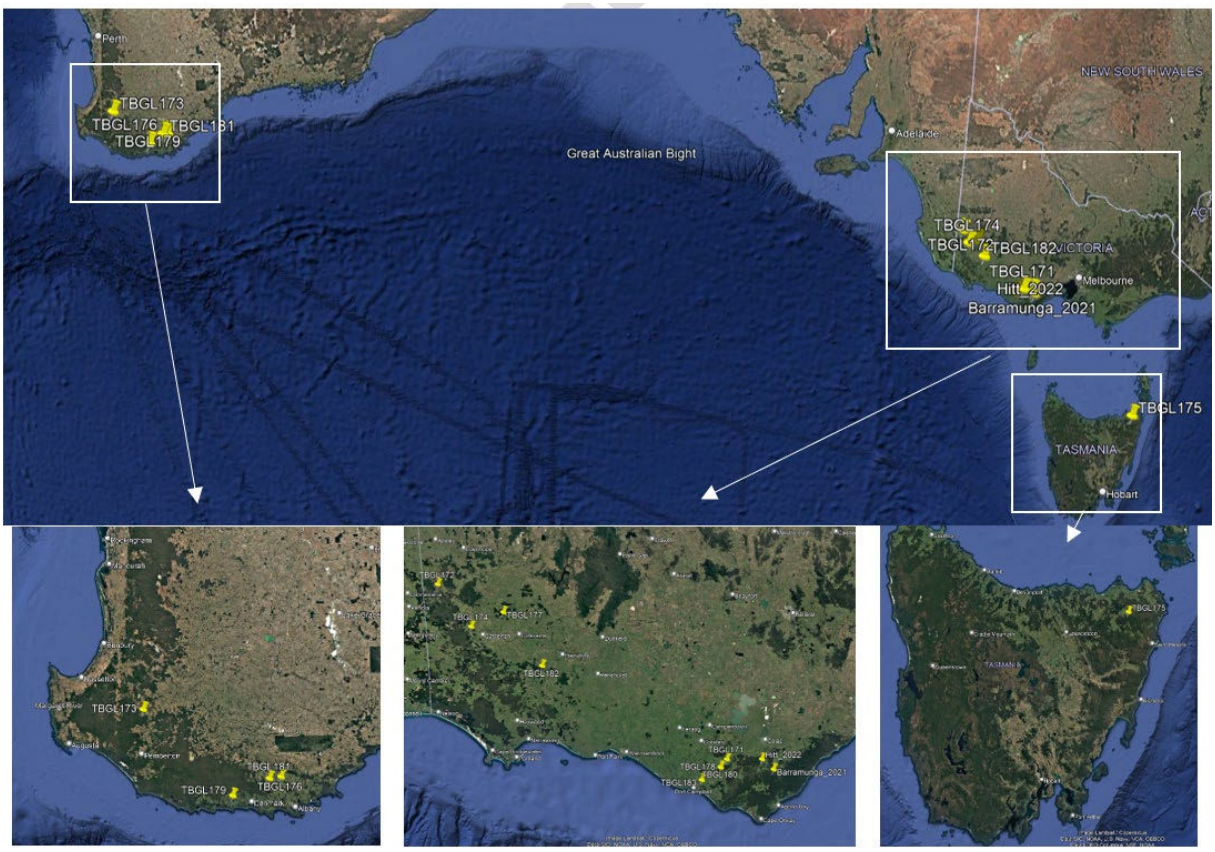

Figure 3 Locations of radiata pine trials planted in Series III 2023 and IV 2024.

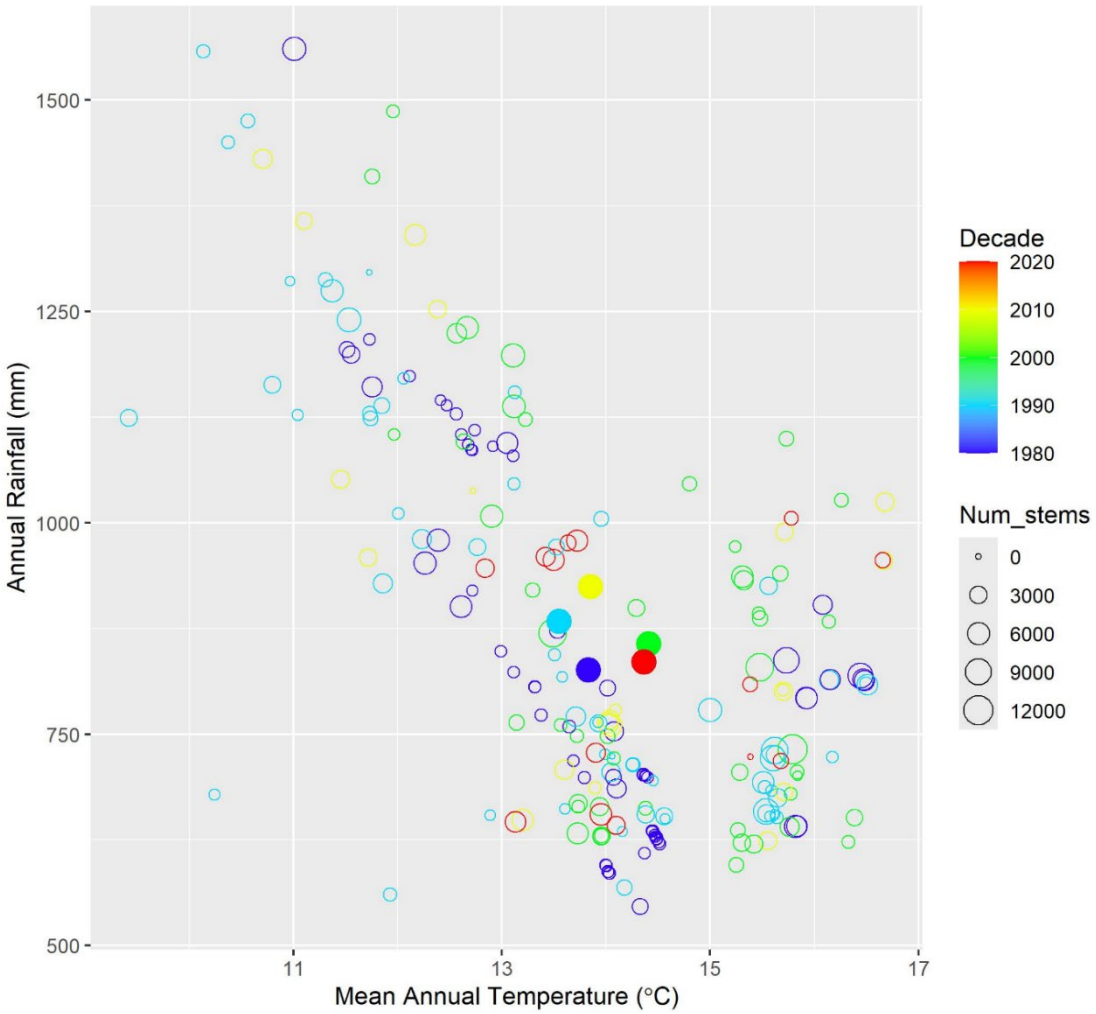

Figure 4 Mean annual temperature vs. annual rainfall for blue gum genetic trial locations locations over last four decades. Solid points are the averages for those locations and decades. The size of open circles represents the number of stems in a trial.

Discussion

Climate change is projected to result in increased mean annual temperatures and changes in rainfall amounts and seasonality (Bush *et al.* 2018, Ivkovic *et al.* 2016)). Climate conditions within most of the existing plantation estate in southern Australia are likely to become hotter, drier, and more variable, and alternative sites will most likely have dry climates. Various studies have highlighted the limitations of current plantation species for expansion into new areas with more marginal environments. The existing plantation estate is also subject to contraction should significant challenges associated with climate change materialise.

In this project genetic material was tested under a broad range of environments and site types in SA, the GT and other plantation regions, to increase accuracy of prediction and selection intensity. The trials span high-medium, medium-low, and low-marginal productivity site types. Strong genetic linkage among treatments across trials will enable data sets to be used to quantify the importance of genotype × environment interactions. This will enable the collection of performance data and selection of better adapted genotypes for use in deployment and breeding. The outcome will be more productive and resilient plantations.

More wood produced per unit area as an alternative to area expansion is desirable as it can introduce efficiencies and reduce competition with other agricultural commodities for a limited land base. An objective of this, and associated projects, is to more than double the current rate of genetic gain per unit time (to more than one percent p.a. cumulative without compromising resource quality) in the industry breeding programs. This is a cost-effective strategy – as any additional costs associated with growing plantations with better genetics that deliver higher yields are minimal – it does not require more land or additional silviculture inputs to deliver more wood.

Data generated in field trials as part of the project was entered into the national DATAPLAN database. Data was analysed on a within trial basis to estimate genetic parameters and determine the optimal statistical model to account for genetic and environmental effects. The project data was included in the recent TREEPLAN evaluation for radiata pine with results released to industry 25 March 2024. The run included field data for 653,005 genotypes from 10,145 families tested across 278 trials with predictions on 35 measured selection criteria traits. The run was a single-step evaluation producing genomically enhanced breeding values (noting the impact of DNA assays on the results is limited at this time). Changes included more phenotypic data (+162,011 measurements) and more genotypes (+45,711). Another TREEPLAN evaluation was done 17 June 2024 to include recent project data – and results used in breeding operations.

The objective of this and related projects is to double the rate of genetic gain in the breeding program, and the current trend lines suggest we are on target to more than achieve this objective - but a few more years data is needed to confirm this trend. The annual rate of gain trebled (to NPV $168 per ha) compared with the 2023 TREEPLAN evaluation.

Conclusions

This project has established radiata and blue gum trials on a range of site types, including ones likely to arise with changing environments due to climate change and industry expansion into new areas.

Trial establishment in Series I, II, III and VI has in general been excellent. Early age measurements and assessment of trees in these trials is progressing.

Resources will be needed to complete these and later age assessments associated with the additional trials. The researcher submitted a new project proposal to FWPA (and GRAC) requesting funds to progress these tasks. This proposal was resubmitted to AFWI with FWPA support.

The proposal will focus on further expanding the network of trials as well as undertaking detailed studies of GE interactions, using project data as well as historic data sets.

Recommendations

Collaborators have been requested to focus on post plant weed control - to ensure good tree survival and to minimise the potential adverse impacts from weed competition. Additional herbicide applications and the manual removal of weeds in some trials was necessary to achieve this outcome. We thank collaborators for their efforts in ensuring good growth and survival post planting.

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Researcher's Disclaimer (if required)

Appendix

(Label each appendix in numeric sequence e.g. Appendix1, Appendix 2 etc)