FORESTS NSW' SPOTTED GUM (*CORYMBIA* SPP.) TREE IMPROVEMENT AND DEPLOYMENT STRATEGY

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ABSTRACT

Forests NSW manages approximately 8000 ha of spotted gum plantations established post-1994 on the north coast of New South Wales (NSW). In support of this plantation program, the organisation has invested in comprehensive tree improvement programs for species of commercial importance in the *Corymbia* genus. *Corymbia citriodora* subsp. *variegata* and *C. maculata* have been widely tested in progeny trials from the Hunter Valley to the Queensland border. Currently 659 families of *C. citriodora* subsp. *variegata* are represented in one or more of eight progeny trials and 152 families of *C. maculata* are being tested over three sites. More modest sized progeny trials of *C. citriodora* subsp. *citriodora, C. henryi* and *C. torelliana* are being established in 2006/07.

Growth, form and *Quambalaria* shoot blight were assessed in the 1999–2001 series of *C. citriodora* subsp. *variegata* progeny trials and based on analysis of this data, superior genotypes were selected and established in two clonal seed orchards. Forests NSW favours a deployment strategy for commercial plantations based on seedlings grown from genetically improved seed, due to the high costs and unreliable results of vegetative propagation for *Corymbia* spp. The clonal seed orchards have estimated operational genetic gains of 30 and 40% for volume and the second clonal seed orchard has estimated gains of 28% for *Quambalaria* shoot blight tolerance, over the trial mean for the best unimproved provenance. These orchards will provide the main source of improved genetic material for commercial deployment by Forests NSW.

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The first clonal trials of *C. citriodora* subsp. *variegata* were planted by Forests NSW in 1997, and to date, a total of eight clonal trials have been established. Eight clones have been selected from the trials for pilot scale propagation and currently over 25 ha of pilot scale plantations of *C. citriodora* subsp. *variegata* have been established.

Keywords: *Corymbia citriodora* subsp. *variegata*, *Corymbia maculata*, tree improvement, *Quambalaria* shoot blight, clonal deployment

INTRODUCTION

The spotted gums are a complex of species that naturally occur in New South Wales (NSW) and Queensland. The two main species of commercial interest within northern NSW and south-eastern Queensland are *Corymbia maculata* (Hook.) K.D. Hill & L.A.S. Johnson and *Corymbia citriodora* subsp. *variegata* (F. Muell.) A.R. Bean & M.W. McDonald. Other species within the complex include *Corymbia citriodora* (Hook.) K.D. Hill & L.A.S. Johnson subsp. *citriodora* (lemon-scented gum) and *Corymbia henryi* (S.T. Blake) K.D. Hill & L.A.S. Johnson (broad-leaved spotted gum). *Corymbia citriodora* subsp. *variegata* occurs through an area from west of Maryborough, Queensland, inland to Carnarvon Range and south to Coffs Harbour in NSW (Brooker & Kleinig 2004). *Corymbia citriodora* subsp. *citriodora* is scattered in eastern Queensland, with the main region being from Maryborough to north of Rockhampton and to west of Springsure, as well as extensive tracts inland of Mackay near the Eungella Range, areas west of Townsville and north to the Atherton Tableland, Hann Tableland, and north along the Herberton Range to near Helenvale (Brooker & Kleinig 2004). The species grows on ridges and steep hills and favours clay loams, but also occurs on basaltic soils (Boland *et al.* 2006) over a wide range of rainfall (600–2000 mm), under a summer rainfall regime.

The natural distribution of *C. maculata* is in the coastal areas of NSW from the Manning Valley south to Bega and with one disjunct population near Orbost in Victoria (Brooker & Kleinig 1999). It grows on valley slopes and ridges, on a wide range of soils but prefers well drained, moderately heavy textured soils derived from shales (Boland *et al.* 2006). The species grows naturally in zones with a mean annual rainfall (MAR) of 680–1250 mm in a uniform seasonal regime, although it has been observed to grow well on sites with 500–800 mm rainfall (Rob 2004). *Corymbia* *henryi* occurs naturally from near Grafton in northern NSW, north to Brisbane and west to Toowoomba in south-eastern Queensland. The species grows mainly on the sub-coastal plains and in the foothills of adjacent ranges, on sandy loams to clays derived from granite or shale (Boland *et al.* 2006).

The taxonomy of these species has undergone significant review in the last 12 years, with the elevation of the subgenus *Corymbia* in *Eucalyptus* to a genus in its own right (Hill & Johnson 1995). There are varying opinions on the use of the *Corymbia* as a genus (Brooker 2000; Ladiges & Udovicic 2000), but in this paper we follow the system of Hill & Johnson (1995) with use of the genus *Corymbia* and McDonald & Bean (2000) for classification of the species within Section Politaria. For older literature cited we have used the genus and species names as reported in the literature, with reference to the corresponding current names where possible. Shepherd *et al*. (2007) have suggested alternative population groupings for *Corymbia* based on molecular genetics studies.

All of these species are closely related and are jointly known as 'spotted gum' when describing wood properties (Bootle 2005). It is a sought after high-quality timber that is commercially harvested in both NSW and Queensland and is a favoured species with sawmills on the north coast of NSW. The wood from native forests is dense (basic density 740 kg m^{-3}), strong and moderately durable at Class 2 (Timber Development Association (NSW) Ltd 2003). It is commonly used for heavy construction, ship building, flooring, poles and posts, plywood and is the preferred Australian species for high impact tool handles (Bootle 2005). Although the main use of the species in northern NSW and south-eastern Queensland is for solid wood products, the lower basic density (642 kg m^{-3}) of plantation-grown wood at 12 years means it is also suitable for export chip and for production of fine papers (Hicks & Clark 2001). Gardner (2007) supported this finding with results from trials in Zululand, South Africa that demonstrated *C. henyri* and *C. citriodora* subsp. *citriodora* both had timber suitable for pulp production at age 7 years.

Within NSW, Regional Forest Agreements (RFAs) between the State and Commonwealth governments have led to a reduction in the area of native forest that is available for harvest. Forests NSW reintroduced a hardwood plantation program in

1994 with the aim of eventually supplementing the wood supply from native forests. Forest NSW manages over 50 000 ha of eucalypt plantations, with approximately 26 000 ha in the post-1994 estate. Of this, over 8 000 ha of this has been planted to spotted gum, primarily *C. maculata* and *C. citriodora* subsp. *variegata* (Forests NSW MIS data).

Spotted gums are subjected to several factors that impact on the productivity of plantations. Infection by *Quambalaria pitereka* is the most significant disease threat to spotted gums in NSW (Carnegie 2007b) and south-eastern Queensland (Pegg *et al*. 2005). This fungal pathogen infects the young growing tips of the trees, causing necrosis and distortion of young expanding leaves and shoots, leading to shoot die-back (Walker & Bertus 1971; Simpson 2000; Carnegie 2007a). The three species that have been commercially planted in northern NSW, *C. citriodora* subsp. *variegata*, *C. maculata* and *C. henryi*, are highly susceptible to the disease and are commonly infected (Carnegie 2002). In young plantations in NSW, up to 35% of trees can be severely damaged but this number is significantly lower (5%) in older plantations (Carnegie 2007b). Trees that are severely infected are often stunted (Simpson *et al*. 1997; Carnegie 2007a,b) and, although they may grow through the damage, may have poor form as a result of the disease. The vast majority of *Corymbia* plantations in NSW now have some proportion of trees with significant *Quambalaria* shoot blight damage (Carnegie 2007b) and this disease would be considered as the major constraint to the economic viability of commercial plantations of spotted gums in northern NSW and south-eastern Queensland. Differences have been observed in susceptibility to *Quambalaria* shoot blight and it is possible to select provenances, families and individuals that show field tolerance to this disease (Johnson *et al*. 2004; Lee *et al*. 2004; Lee 2007).

An emerging insect problem in spotted gum plantations is erinose mite (*Rhombacus* sp.), which was first observed in NSW plantations in 1997 (Carnegie & Henson 2005). These microscopic mites produce blisters on the leaves which gradually become necrotic, with severely affected leaves dropping from the tree (Queensland Department of Primary Industries & Fisheries 2007). Growth and stem form can be severely affected by infestations of the mite. Significant differences have been observed in susceptibility to the mite between spotted gum provenances (Lawson &

McDonald 2005) and between families and tested clones (Carnegie & Henson 2005), with severity of incidence also varying with site environment (Carnegie & Henson 2005).

Sensitivity to frost can impact greatly on the productivity of spotted gum plantations, with trees being particularly susceptible in the first two years after establishment. This trait is under genetic control (Harwood *et al.* 2001) and frost hardiness could be improved by breeding. Laboratory studies by Lamour *et al*. (2000) using measurement of electrical conductivity of the leachate of leaf discs, showed that there are differences in frost tolerance between species of *Corymbia*, provenances within species and families. *Corymbia citriodora* subsp. *variegata* was significantly more frost tolerant than *C. citriodora* subsp. *citriodora*, *C. maculata* and *C. henryi* and inland high altitude provenances of *C. citriodora* subsp. *variegata* and *C. maculata* had greater frost tolerance than low altitude coastal provenances. However, these findings were not related to field performance for frost tolerance in the same study. A significant frost event in 2002 caused severe damage to over 735 ha of *Corymbia* plantations in northern NSW, with over 280 ha of trees killed (Murray Wood, Forests NSW Grafton, unpublished data), and another frost event in 2006 damaged over 500 ha of *C. citriodora* subsp. *variegata* plantations (A. Carnegie, NSW Department of Primary Industries West Pennant Hills, 2007 *pers. comm*.).

In South Africa (Poynton 1979) and Brazil (Alves da Cunha *et al*. 1979) kino production has been reported as a major source of down grade in plantation-grown *Corymbia* species. A factor of 38% was allowed for degrade in *E. maculata* (now *C. maculata* and *C. citriodora* subsp. *variegata*) sawn timber in Zululand, South Africa, as a result of kino pockets (De Villiers 1973), although the incidence of defect was considerably lower in the Transvaal. Van der Sijde (1978) found no significant difference in kino formation between a South African land race and two Queensland natural provenances of *E. maculata* (due to its place of origin this species would now be classified as *C. citriodora* subsp. *variegata* (McDonald and Bean 2000)). In Brazil *E. maculata* was considered to have inferior wood quality but less kino rings that *E. citriodora* (Alves da Cunha *et al.* 1979), but in South Africa both species are reported to have similar levels of kino pockets (Poynton 1979). It was suggested by Poynton (1979) that the viability of the species in South Africa would depend on the success achieved in selecting and propagating genotypes which are not prone to kino ring formation.

In South Africa Darrow (1985) found no significant differences between 13 natural provenances of *E. maculata* (now *C. maculata* and *C. citriodora* subsp. *variegata*) for 'kino ring' formation, but found major differences between sites. He concluded that the occurrence of kino damage in the stem was more influenced by the environment and individual tree sensitivity than by provenance differences. Kino was considered such an important trait in South Africa that 16 "kino-free" clones were selected in stands in South Africa and established in a clonal seed orchard in 1976 (Mather 1991) and an open pollinated progeny trial from this orchard was established in 1981 (Darrow 1985). The extent of degrade caused by kino rings in Australia plantations is unknown owing to the age of the resource, however there is mounting evidence that kino is an increasing problem, especially on harder sites (A. Carnegie, NSW Department of Primary Industries West Pennant Hills, 2006 *pers. comm*.).

Plantation establishment of spotted gums has traditionally been through deployment of seedlings. Vegetative propagation has been varied in success. Catesby and Walker (1997) considered the spotted gums to be recalcitrant in vegetative propagation, with less than 5% of cuttings striking roots. Results of initial Forests NSW studies using semi-hardwood cutting material were similar[1], although successful protocols for the micropropagation (tissue culture) of some clones of *C. citriodora* subsp. *variegata* were developed. Subsequent studies on *C. citriodora* subsp. *variegata* clones using potted mother plants, flood irrigated with defined nutrient solutions to promote shoot production and optimise rooting of minicuttings, has found that rooting was higher but still erratic over time and between clones (C. Moran, Forests NSW Grafton, *pers. comm*. 2007).

Corymbia torelliana (F.Muell.) K.D. Hill & L.A.S. Johnson (cadaga) is the only species in the Section Cadagaria, and is of interest as a hybrid parent with the spotted gums. De Assis (2000) reported that hybrids between *C. citriodora* (now *C. citriodora*

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[1] Smith, H. J.; Bacon, K.B. 2003: Vegetative propagation of plantation eucalypts. A practical manual for the propagation of eucalypts for the North Coast region of NSW. State Forests of NSW Confidential Internal Report, West Pennant Hills, NSW. 75 p.

subsp. *citriodora*) and *C. torelliana* rooted as cuttings better that pure *C. citriodora*, particulary if *C. torelliana* was used as the mother, due to its greater amenability to vegetative propagation. Lee *et al*. (2005) have since reported that hybrids between *C. torelliana* and the spotted gums exhibit a range of beneficial growth and performance traits, according to the parents involved in the cross, including *Quambalaria* shoot blight tolerance, frost resistance, amenability to vegetative propagation and hybrid vigour for growth.

BREEDING OBJECTIVES

The Forests NSW Tree Improvement Strategic Plan[2] identifies three generic breeding objectives which are common for all species under genetic improvement. These are:

i) Growth — to optimise the productivity in terms of volume of the plantation crop
ii) Quality — to ensure that every plant established has the potential to produce an economic stem (i.e. one that is ‘fit for purpose’); and
iii) Adaptability — to reduce risk of economic losses through plantation failure, by breeding trees that are resistant or tolerant to pests and/or diseases and are adapted to their target planting environment (e.g. frost and drought tolerant).

In the next few years Forests NSW plans to complete a comprehensive breeding objectives study for eucalypt plantations and associated processing industries on the north coast of NSW. It is expected that one of the outputs of that study will be the production of economic weights for key improvement traits for important commercial species.

A high priority for Forests NSW for spotted gums will always be increasing productivity of the forest estate, by improving growth and form traits, while maintaining desirable solid wood properties. Wood property studies on the Forests NSW spotted gum breeding population are yet to be undertaken, but will be carried out when the trees reach a suitable size, expected to be at an approximate age of 10 years.

[2] Forests NSW Tree Improvement Program 2006: Strategic Plan 2006–2007. Forests NSW Confidential Internal Report, Coffs Harbour, NSW. 6 p.

In addition to growth, *Quambalaria* shoot blight is the main factor that affects productivity and quality of commercial plantations of *Corymbia*, and therefore improving tolerance to and minimising damage caused by this disease is the main driver of the *Corymbia* breeding program. Improving tolerance to other biological factors such as frost and possibly erinose mite will be other considerations in the improvement programs for spotted gums.

GENETIC RESOURCES

The breeding strategy for Forests NSW has concentrated on *C. citriodora* subsp. *variegata*, as it is currently the predominant spotted gum species planted by Forests NSW, for sawn wood, in northern NSW. Eight progeny trials (Table 1, Figure 1) have been established, along with a further three trials that are comprised of CCV and other species of *Corymbia*. In 2001, one progeny trial was established at Quirindi under the auspices of the Australian Low Rainfall Tree Improvement Group (ALRTIG) program. In addition, a genetic gain trial was established at Quirindi in 2003 under the ALRTIG program. Since 2004, three trials of *C. maculata* have also been established using improved and native populations, with this species becoming of greater interest for low rainfall and marginal site plantations.

[Insert Figure 1 near here]

[Insert Table 1 near here]

Trial Assessments

The 1999–2001 series of *C. citriodora* subsp. *variegata* progeny trials were assessed for height, Diameter at Breast Height over Bark (DBHOB), straightness, branching and *Quambalaria* shoot blight damage at age 40 months, and the Casino trial established in 1999 was assessed again at 66 months. In addition, *Quambalaria* damage was assessed at one site near Casino at ages 12 and 25 months and frost damage at 17, 40 and 66 months. Damage caused by *Quambalaria pitereka* was assessed by a range of methods including qualitative scoring and quantitative assessment using the Crown Damage Index (Stone *et al.* 2003).

The *C. maculata* progeny trial established at Casino in 2004 was assessed for height, form and *Quambalaria* damage at age 23 months and the Singleton trial was assessed for survival and height at age 34 months.

Genetic Parameters

In the 1999–2001 *C. citriodora* subsp. *variegata* progeny trials the heritabilities for growth traits were low, with heritability (h^2; coefficient of relatedness 0.25) for DBHOB at 40 months ranging from 0.05 to 0.20 and heritability for height at 40 months being slightly higher, ranging from 0.15 to 0.27. Significant provenance differences were found in the 1999 Casino progeny trial for all growth traits, with the Queensland provenances of Woondum, Wolvi, Brooyer and Home being superior for volume (Johnson *et al*. 2004). There was little evidence of significant genotype by environment interaction for growth traits in the 1999–2001 series of trials, with across site genetic correlations ranging from 0.65 to 0.98 for height between the three sites.

Height was under moderate additive genetic control (h^2 = 0.42 s.e. 0.07) in the 2004 *C. maculata* progeny trial in Casino and there was significant ($p<0.05$) variation in height between provenances.

Significant differences between provenances were found in all trials assessed for *Quambalaria* shoot blight and within provenances there was moderate additive genetic control (Table 2). These results are similar to those from *C. citriodora* subsp. *variegata* progeny trials in Queensland where Lee *et al.* (2004) reported h^2 = 0.4 (0.01) for crown damage caused by *Quambalaria* shoot blight.
[Insert Table 2 near here]

DEPLOYMENT STRATEGY

To date, Forests NSW has found the vegetative propagation of *Corymbia* species problematic, with low and erratic rooting success. High costs associated with vegetative propagation, coupled with the long commercial rotation length required for saw logs on the typical low productivity sites where spotted gum is established, has led to Forests NSW favouring a seedling deployment strategy. Johnson *et al.* (2004) and Lee *et al.* (2004) found highly significant differences among provenances and families for both volume and *Quambalaria* shoot blight damage, showing that there is potential to select provenances, families or individuals for these traits. The high additive genetic control of *Quambalaria* shoot blight damage (Table 2), along with the variation between provenances, will enable improvement in tolerance to the disease through selection of germplasm.

Clonal Seed Orchards

Two clonal seed orchards (CSOs) have been established in southern NSW using grafted ramets from selected trees in the progeny trials. Planting in one is to be completed in spring 2007 and a third orchard to be established in northern NSW in 2007/08. These will provide the main source of improved genetic material for commercial deployment. The first CSO planted in 2005 is comprised of 50 clones, selected for volume, form (straightness), *Quambalaria* shoot blight tolerance and frost tolerance from the 1999–2001 series of progeny trials. In addition, it also contains 12 clones selected for frost tolerance in the ALRTIG *C. citriodora* subsp*. variegata* progeny trial at Quirindi. The estimated operational genetic gains from the clones selected from the progeny trials, over Woondum provenance trial mean at 40 months, are 30% for volume and 6% for straightness. Woondum provenance is considered a superior provenance for height growth performance and *Quambalaria* shoot blight tolerance (Dickinson *et al*. 2004; Johnson *et al.* 2004), and therefore this provenance was used as the baseline over which to measure gains. Operational genetic gain is calculated to be half of the additive genetic gain.

The second CSO contains 28 clones from Woondum and Home provenances. The estimated operational gain from these clones, over Woondum provenance trial mean at age 40 months, are 40% for volume and 7% for straightness. The estimated operational gain for *Quambalaria* shoot blight tolerance, over the Woondum provenance trial mean at age 25 months is 28% and for frost tolerance is 6%, over the Woondum provenance trial mean at age 40 months. Early flowering of *Corymbia* spp. has been observed in seed orchards in southern NSW, and the 2005 CSO had a very small flowering of ramets in 2006. The CSO to be established in northern NSW may not provide as early or prolific flowering as the more southern orchards.

Clone Development

Development of *C. citriodora* subsp. *variegata* clones from selected families was commenced by Forests NSW in 1995, using micropropagation of aseptically germinated seedlings. There is large clonal variation in productivity in culture, for both the multiplication phase and the rooting phase of propagation. Experience in Forest NSW Research Nursery would also suggest that propagation by minicuttings using flood irrigated potted mother plants is variable, with rooting being erratic and generally at lower levels than would be considered commercially viable (80% rooting). Although some settings of cuttings may give high rooting rates, it is doubtful that clones with consistently high rooting will be developed. This clonal variation in rooting limits the range of genetic material that is available for commercial deployment and therefore reduces the potential genetic gains that can be delivered to operational plantations – if rooting in vegetative propagation is a selection bottleneck, then it is likely that gains in other traits will be compromised.

Clone Trials

Forests NSW has established two series of clone trials of *C. citriodora* subsp. *variegata* on multiple sites to enable selection of clones for demonstration plantings and to study clone by site interactions (Table 3). In 1999, four sites were planted with a total of 69 clones from nine selected families from five NSW provenances (Figure 2). After assessments in 2001 and 2002, a subset of 33 clones was selected on height, DBHOB, *Quambalaria* tolerance and Crown Damage Index (CDI) for further testing. In 2003, these clones were planted on four sites and eight of the best performing clones selected for pilot scale production. A genetic gain trial of these eight clones was established at Grafton in 2006.

[Insert Figure 2 near here]

[Insert Table 3 near here]

Pilot Scale Clone Production

Forests NSW has currently planted over 25 ha of clones into pilot scale operational plantings. These plantings are considered demonstration plantings only and are comprised of the eight selected tested clones from the clone trials. Plants are propagated by micropropagation and the high cost of planting stock results in the plantations not being economically viable. Adding to the cost of the plants is the need to optimise the propagation protocol, sometimes to the level of individual clones. Future success of clonal plantations for *Corymbia* spp. is dependent on the development of vegetative propagation protocols that are cost effective and provide efficient propagation over a broad range of clones. Forests NSW is investigating more economic protocols for propagation of *Corymbia* spp., through both micropropagation and minicuttings.

Corymbia Hybrids

In Queensland, the development of *Corymbia* hybrids with *C. torelliana*, predominantly as the female parent, has become a focus of the breeding program (Lee 2007). Forests NSW is currently monitoring and evaluating the performance of the hybrids, but it is not a priority for the program. Forests NSW has chosen a low cost route to hybrid production. One open pollinated hybridising orchard has been established, with two blocks of different *C. torelliana* provenances, and selected families of *C. citriodora* subsp. *variegata* planted within them in the ratio of one *C. citriodora* subsp. *variegata* to eight *C. torelliana*. This orchard was established in 2004 and thus its success for producing open pollinated hybrid crosses is as yet unknown.

Forests NSW is also evaluating field performance of *Corymbia* hybrid germplasm, originating in Brazil and in Queensland. Two trials were established in 2005 in Grafton (Table 3, Figure 2), using germplasm from these sources. Vegetative propagation of *Corymbia* hybrids has been found by Forests NSW to be equivalent to that of the pure species. Longer term average rooting of minicuttings is less than 50% for the best clone, with many clones at less than 10% rooting, and therefore these hybrids have potential for the same deployment issues as pure *Corymbia* spp. Lee (2007) has suggested that family forestry, using young seedlings from selected superior hybrid families, as opposed to using tested individual clones, as hedge plants, may be a commercial option for deployment as the juvenility of the seedling hedge plants may result in higher rooting success.

DISCUSSION

In contrast to Queensland (Lee 2007), Forests NSW' primary strategy is the improvement of the pure *Corymbia* species and deployment of genetically improved seedlings through production of seed in clonal seed orchards. Clonal deployment of pure *Corymbia* spp. and hybrid germplasm is an alternative under investigation, but the economics of such a strategy is still to be proven. The concern for both is that pure *Corymbia* and hybrids have unreliable and poor rooting, and in a high cost environment such as Australia, this would be a major bottleneck to commercial deployment.

Forests NSW' preference for the pure species of *Corymbia* over the hybrid is based on both economic and potential environmental factors. *Corymbia* hybrids come at a high cost if development is through controlled crosses, and this is coupled with the high cost of deployment as rooted cuttings. Experience with the hybrid in Australia is still limited with the oldest trials still under 10 years and its long term productivity and adaptability to the range of sites where it is targeted for planting is still not fully understood. The wood quality and market acceptance of the wood product is still unknown, although Lee (2007) suggests the hybrid shows early potential for saw logs and pulpwood.

Corymbia torelliana has been widely planted as an ornamental and windbreak tree throughout Australia. It is not native to NSW and is regarded as a weed in some shires. The ecological impacts of this species are unknown, but there is potential for gene flow from *C. torelliana* to native spotted gum forests, as *C. torelliana* has been observed to form natural hybrids with other *Corymbia* spp. (Hill & Johnson 1995; Forests NSW, unpublished). A study of the potential for genetic pollution of native stands of *Corymbia* spp. by *C. torelliana* is currently being undertaken.

Kino production may be a potential source of down grade in plantation-grown wood as has been found in other countries (De Villiers 1973; Alves da Cunha *et al.* 1979; Poynton 1979) and should be monitored over time for all *Corymbia* spp. Although the concentration of effort in the Forest NSW tree improvement programs at present is predominantly on growth and deployment aspects, studies of wood quality will commence on Forests NSW breeding populations at approximately 10 years age. At this time a range of wood properties will be assessed, including issues such as kino production.

Forests NSW expects it Clonal Seed Orchards to produce commercial quantities of seed from 2009 and it is expected that this will result in significant improvement in the economic viability of spotted gum plantations in northern NSW.

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FIGURES

FIG. 1–Locations of *Corymbia* spp. progeny trials and a genetic gain trial established by Forests NSW.

FIG. 2–Locations of *Corymbia* spp. clone trials and hybrid trials established by Forests NSW.

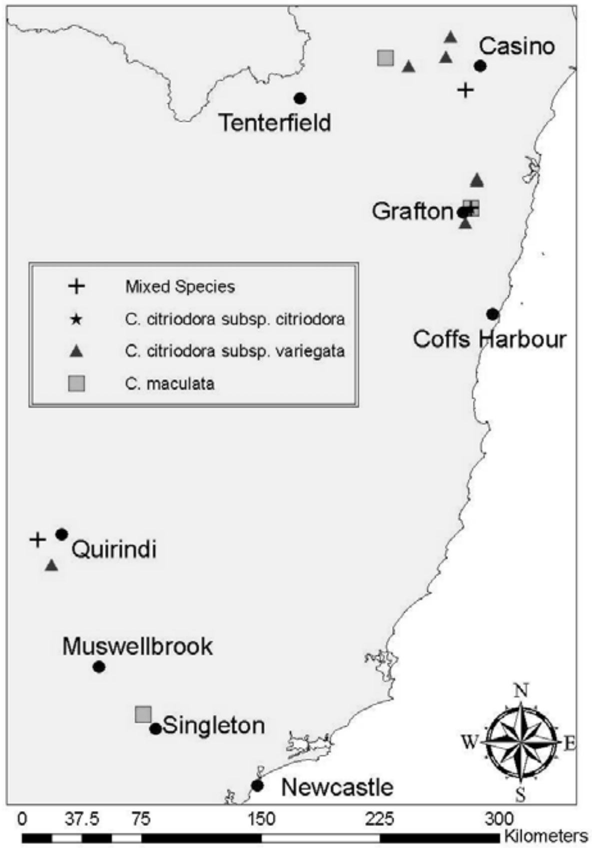

FIG. 1–Locations of *Corymbia* spp. progeny trials and a genetic gain trial established by Forests NSW.

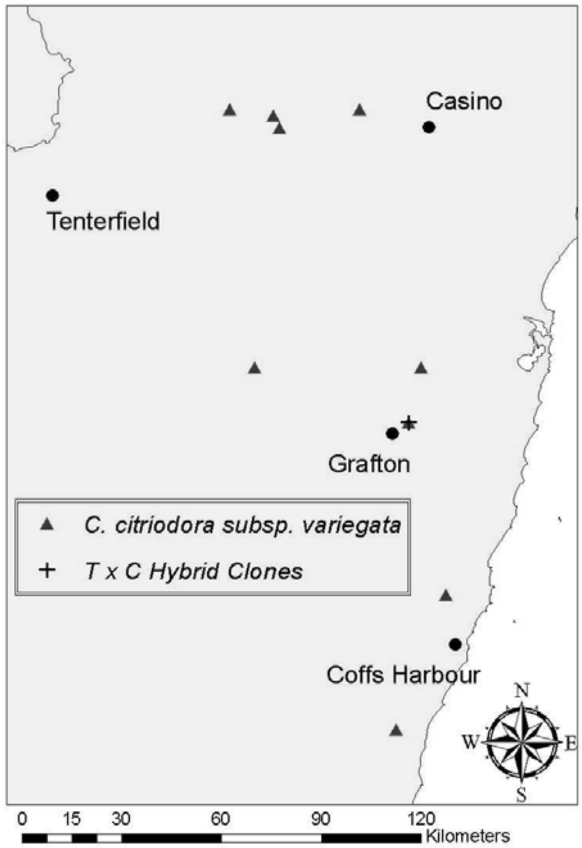

FIG. 2–Locations of *Corymbia* spp. clone trials and hybrid trials established by Forests NSW.

TABLE 1–Details of *Corymbia* spp. progeny trials and one genetic gain trial established by Forests NSW.

Species	Series	Location	Planted	Prov	Families	Trees
C. citriodora subsp. *variegata* (CCV)	1999–2001	Casino	Mar 99	38	205	4900
C. citriodora subsp. *variegata*	1999–2001	Casino PRS*	Apr 99	1	17	550
C. citriodora subsp. *variegata*	1999–2001	Grafton	Feb 01	17	88	1408
C. citriodora subsp. *variegata*	1999–2001	Casino	Mar 01	16	88	2640
C. citriodora subsp. *variegata*	2001	Quirindi	Oct 01	19	120	2400
C. citriodora subsp. *variegata*	2004	Grafton	Feb 04	60	548	6600
C. citriodora subsp. *variegata*	2004	Grafton	Mar 04	58	528	6336
C. citriodora subsp. *variegata*	2004	Casino	Mar 04	58	544	9792
C. maculata	2004	Casino	Mar 04	12	134	2680
C. maculata	2004	Singleton	Apr 04	12	133	2800
C. maculata	2006	Grafton	Nov 06	11	98	2000
C. citriodora subsp. *citriodora* (CCC)	2006	Grafton	Nov 06	5	24	500
CCV, C. maculata	2003	Quirindi	Sep 03	5	Genetic gain	1600
CCV, C. torelliana	2004	Casino	Apr 04	7	32	2176
CCV, CCC, C. henryi	2006	Grafton	Oct 06	80	319	6000
CCV, CCC, C. maculata, C. henryi	2007	Casino	Oct 07		Approx.400	

*Provenance Resource Stand

TABLE 2–Heritability of *Quambalaria* shoot blight damage in assessed *Corymbia* progeny trials.

Species	Series	Location	Age (months)	Method	Provenance significance	Heritability h^2 (s.e.)
CCV	1999	Casino A	12	CDI	<0.05	0.12 (0.10)
			25	CDI	<0.05	0.53 (0.12)
CCV	2004	Casino	12	CDI	<0.05	0.35 (0.08)
C. maculata	2004	Casino	23	Scale (0-4)	<0.05	0.56 (0.09)

TABLE 3–Details of Forests NSW *Corymbia citriodora* subsp. *variegata* clone trials and hybrid trials.

Species	Series	Location	Planted	Clones	Trees
C. citriodora subsp. *variegata (CCV)*	1999	Casino	Apr 99	64	576
C. citriodora subsp. *variegata*	1999	Casino	Apr 99	52	480
C. citriodora subsp. *variegata*	1999	Casino	Apr 99	34	320
C. citriodora subsp. *variegata*	1999	Grafton	Mar 99	56	512
C. citriodora subsp. *variegata*	2003	Coffs Harbour	Apr 03	33	600
C. citriodora subsp. *variegata*	2003	Casino	Feb 03	33	800
C. citriodora subsp. *variegata*	2003	Grafton	Feb 03	33	800
C. citriodora subsp. *variegata*	2003	Coffs Harbour	Mar 03	33	600
C. citriodora subsp. *variegata* (genetic gain)	2006	Grafton	Nov 06	8	800
Qld T x C Hybrid Family Trial	2005	Grafton	Apr 05	46	1000
T x C Hybrid Clones	2005	Grafton	Mar 05	43	480