SUSCEPTIBILITY OF *CORYMBIA CITRIODORA* SUBSP. *VARIEGATA*, *EUCALYPTUS CLOEZIANA* AND *E. GRANDIS* TO THE CUT-STUMP APPLICATION OF GLYPHOSATE FOLLOWING PRE-COMMERCIAL THINNING OPERATIONS IN NORTH-EASTERN AUSTRALIA

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Over the past ten years, there has been an increase in the area of eucalypt timber plantations established throughout Australia (Wood *et al.* 2001) and the world (Klemarewski *et al.* 2000). Although the majority of these plantations are for the production of woodchips for pulp and paper manufacture, an increased proportion is used for the production of high value solid wood products, in particular sawlogs, poles and veneer. In Queensland, early age pre-commercial thinning of sawlog plantations has become a standard operational management technique (Dickinson *et al.* 1998). The use of unimproved seed of high genetic variability necessitates the use of high initial stocking (commonly 1000 to 1200 trees ha^{-1}) to achieve a satisfactory number of vigorous well-formed trees of commercial value (commonly 400 to 500 trees ha^{-1}) following thinning. For eucalypts, it is important that pre-commercial thinning of malformed and subdominant trees be conducted at an early tree age (1.5 to 3.5 years) to minimise intraspecific competition and hence maximise the growth of the retained stems (Chapola *et al.* 1995, Gerrand *et al.* 1997, Dickinson *et al.* 2000).

In Queensland, pre-commercial thinning and the immediate treatment of the cut-stumps with herbicides, is commonly practised within hoop pine (*Araucaria cunninghamii*), slash pine (*Pinus elliotii* var. *elliotii*), Caribbean pine (*P. caribaea* var. *hondurensis*) and various *Pinus* hybrid plantations (Anonymous 1998). For this method, young trees (< 3 years) are felled 15 cm above ground level and, depending on stump size, the cut surface is drenched with 2 to 8 ml of herbicide solution (15% glyphosate a.i.). Benefits of this technique include rapid and effective stump mortality at a low cost with no follow-up coppice treatment necessary (Anonymous 1998). A risk associated with the treatment of the cut-stump is the translocation of the herbicide from the treated stump to adjacent retained trees via root grafts, causing damage of the retained stem. This process is commonly termed "flashback" (Anonymous 1988). Root grafting increases with proximity of adjacent trees (Hibbs *et al.* 1989), tree age and size, and is enhanced by cultivation and mounding practices (Anonymous 1988). Flashback has been recorded in a number of plantation species including *A. cunninghamii*, *P. elliotii* var. *elliotii* and *P. caribaea* var. *hondurensis* (Anonymous 1998), loblolly pine (*P. taeda*) (Troth *et al.* 1986) and red alder (*Alnus rubra*) (Hibbs *et al.* 1989).

In north-eastern Australia, the Queensland Forestry Research Institute has established numerous hardwood plantation experiments over the past five years. In late 2001, a number of these experiments were pre-commercially thinned and the cut stumps treated with glyphosate, resulting in flashback at three sites. These trials were all located within a 45-km radius and included an *Eucalyptus cloeziana* (Gympie messmate) fertiliser trial (Trial 1), an *E. grandis* (rose gum) establishment silviculture trial (Trial 2) and a *Corymbia citriodora* subsp. *variegata* (CCV or spotted gum) seedling seed orchard (Trial 3). Trial locations and establishment details are shown in Table 1.

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Prior to the thinning operation, tree height and diameter at breast height (dbh) were measured in each experiment (Table 1). Selection of trees for thinning was primarily based on tree size and straightness, with the majority of thinned stems < 8.0 cm dbh. Pre-commercial thinning was then conducted in late winter/early spring 2001 using chainsaws (Table 1). Immediately after thinning, the surface of each cut stump was drenched with a measured application of 4 ml herbicide solution (15% glyphosate a.i.). Damage to the retained trees was observed within 15 days of treatment, with tree health deteriorating over the following months. Symptoms included death of lateral branches, apical leader and, in the most severe cases, complete tree death. Assessment of flashback damage was performed 16 to 20 weeks after the treatment of cut-stumps during thinning operations (Table 1), using a visual technique whereby individual trees were graded on a scale of 1 to 4 (Table 2). It is likely that flashback damage also caused growth reduction without obvious foliage damage symptoms. However, as no untreated controls were available for comparison, this could not be quantified in this study.

At the time of flashback assessment, all of the cut-stumps treated with glyphosate were dead. In every case where flashback was observed in a retained tree, a treated stump was located on either or both sides of the damaged tree. The results of the flashback assessment, across four dbh size classes for each trial, indicate a clear trend of increasing flashback

Table 1 Location, management and measurement details for the three trial sites

	Trial 1	Trial 2	Trial 3
Location*	Yurol SF, 32 km SE of Gympie	Imbil SF, 33 km S of Gympie	Tuan SF, 45 km N of Gympie
Experiment no.	565	583	451/2c
Latitude (S)	26° 22'	26° 28'	25° 46'
Longitude (E)	152° 56'	152° 37'	152° 38'
Rainfall (mm)	1470	1186	1070
Altitude (m asl)	100	90	65
Australian soil classification	Yellow Kandosol	Black Dermosol	Red Kandosol
Planting date (month/year)	05/1998	01/1999	03/1999
Tree spacing (inter × intra-row)	5 × 2 m	4 × 2.5 m	5 × 1.8 m
Initial stocking (trees ha^{-1})	1000	1000	1111
Post-thinning stocking (trees ha^{-1})	400	400	555
Thinning date (month/year)	08/2001	08/2001	10/2001
Age at last dbh measure	3.1 years	2.0 years	2.5 years
Age at thinning	3.3 years	2.6 years	2.5 years
Flashback assessment (weeks after thinning)	20 weeks	19 weeks	16 weeks

*SF = State Forest

Table 2 Assessment scale for flashback damage

Scale	Rating	Health description
1	Nil	No evidence of herbicide damage
2	Light/moderate	Obvious foliage death, but apical leader unaffected
3	Severe	Extensive foliage death including apical leader
4	Death	Tree dead

severity with increasing stem diameter for all three species (Table 3). For *E. cloeziana*, flashback was not observed in any stems with dbh < 7.9 cm. Flashback damage then progressively increased with increasing stem diameter, with maximum damage (25.3%) recorded in the largest dbh class (12 to 15.9 cm). For *E. grandis*, there was no flashback damage observed for trees ≤ 3.9 cm dbh, but maximum damage (6.9%) was recorded in the dbh class of 8 to 11.9 cm. There was no flashback damage observed for *C. citriodora* subsp. *variegata* with dbh ≤ 3.9 cm, and minimal damage (2.1%) was recorded for the 4.0 to 7.9 cm dbh class. Maximum damage for this species (10.3%) was recorded in the largest dbh class (12 to 15.9 cm).

Table 3 Distribution of individual trees within each flashback assessment score for each dbh size class at the three study sites

Trial and species	Dbh class (cm)	Flashback score 1	2	3	4	Total	% flashback*
Eucalyptus cloeziana	0.0 – 3.9	3	0	0	0	3	0.0
	4.0 – 7.9	50	0	0	0	50	0.0
	8.0 – 11.9	109	5	6	1	121	9.9
	12.0 – 15.9	68	8	15	0	91	25.3
	Total	230	13	21	1	265	13.2
Eucalyptus grandis	0.0 – 3.9	11	0	0	0	11	0.0
	4.0 – 7.9	132	3	4	1	140	5.7
	8.0 – 11.9	95	5	1	1	102	6.9
	12.0 – 15.9	0	0	0	0	0	-
	Total	238	8	5	2	253	5.9
Corymbia citriodora subsp. *variegata*	0.0 – 3.9	172	0	0	0	172	0.0
	4.0 – 7.9	184	2	2	0	188	2.1
	8.0 – 11.9	237	8	7	0	252	6.0
	12.0 – 15.9	139	13	3	0	155	10.3
	Total	732	23	12	0	767	4.6

* % flashback = proportion of total individuals with a score of 2, 3 or 4 within each dbh size class

The results of this study indicated that in north-eastern Australia, the treatment of cut-stumps with herbicides can result in substantial damage to the retained stems. For the three species examined, the largest and most desirable stems within the retained plantation (dbh > 8.0 cm) were the most likely to be damaged by flashback.

As hardwood plantation forestry is a relatively new industry in Queensland, forest managers have only limited experience in pre-commercial thinning operations. In recent years, there have been increasing anecdotal reports of flashback damage from the treatment of cut-stumps with herbicides within red mahogany (*E. pellita*) in the tropics (Lee, pers. comm.) and *E. cloeziana* in the subtropics (Lewty, pers. comm.). In the temperate regions of Australia, flashback associated with the cut-stump technique has also been recorded. However, it is considered a relatively low risk (Stackpole 1998).

It is probable that in situations where plantations experience fast early growth rates, high initial tree stocking and well-cultivated soil conditions, root grafting is likely to commence at a very early age (< 12 months). These factors were characteristic of all three trials examined in this study. Early tree growth rates were high, intra-row tree spacings were narrow (1.8 to 2.5 m) and the soils were well-cultivated from deep ripping and/or

disc cultivation prior to tree planting. In north-eastern Australia, thinning is also conducted during the dry season of winter or spring when trees experience the greatest moisture stress. This may further increase the susceptibility of these plantations to flashback damage. For the three trials examined in this study, climatic conditions in the year of thinning (2001) were extremely dry, with only 70 to 74% of the mean annual rainfall recorded at nearby government meteorological stations at Pomona, Imbil and Tiaro (Anonymous 2002). It is probable that a combination of all these factors contributed to the high levels of flashback damage experienced at the three trial sites within this study.

It is recommended that in north-eastern Australia, pre-commercial thinning of eucalypt plantations should be conducted using alternative methods to the treatment of cut stumps with herbicides. Methods which may pose a lower risk of flashback include chemical stem injection applied to standing trees or thinning (without chemical application to the cut surface) followed by an application of herbicide solution at a lower rate (4% glyphosate a.i.) to the resulting coppice shoots before the shoots are taller than 1 m. Further investigation is required to identify the most effective and economic pre-commercial thinning techniques, which have minimal detrimental effects on the overall plantation health.

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References

ANONYMOUS. 1998. *Silviculture Manual.* Pp. 1–13 in Volume 4b (Exotic pine) and Pp. 1–10 in Volume 5 (Hoop pine). Department of Primary Industries – Forestry, Brisbane.

ANONYMOUS. 1998. Pp. 1–13 in *Exotic Pine Management Manual.* Volume 4b. Department of Forestry, Queensland, Brisbane.

ANONYMOUS. 2002. *2001 Precipitation Data for the Pomona Post Office, Imbil Post Office and Tiaro Post Office Meteorological Stations. Information Report.* Climate and Consultancy Section, Brisbane Regional Office, Bureau of Meteorology. 3 pp.

CHAPOLA, G. B. J., MWABUMBA, L. & KUYUMA, O. T. B. S. 1995. Effects of initial spacing and thinning on yield and basic density of *Eucalyptus tereticornis* at Liwonde, southern Malawi. *Journal of Tropical Forest Science* 8(1): 1–14.

DICKINSON, G. R., LEWTY M. J. & WHITE, F. P. 1998. Growing eucalypt plantations in south-east Queensland: current forestry prescriptions and new directions. Pp. 381–385 in Grodecki, A. (Ed.) *Farm Forestry and Vegetation Management.* Proceedings of the 1998 Managing and Growing Trees Training Conference, Kooralbyn, Australia. Volume 2. (CD-ROM).

DICKINSON, G. R., LEGGATE, W., BRISTOW, M., NESTER, M. & LEWTY, M. J. 2000. Thinning and pruning to maximise yields of high value timber products from tropical and subtropical hardwood plantations. Pp. 32–42 in Snell, A. & Vize, S. (Eds.) *Opportunities for the New Millennium.* Proceedings of the 2000 Australian Forest Growers Conference, Cairns, Australia.

GERRAND, A. M., NEILSEN, W. A., & MEDHURST, J. L. 1997. Thinning and pruning eucalypt plantations for sawlog production in Tasmania. *Tasforests* 9: 15–34.

HIBBS, D. E., EMMINGHAM, W. H. & BONDI, M. C. 1989. Thinning red alder: effects of method and spacing. *Forest Science* 35(1): 16–29.

KLEMAREWSKI, A., MASSEY, R. & WEE, D. 2000. The opportunity for *Eucalyptus* in veneer and wafer-based wood products. Pp. 1–5 in *The Future of Eucalypts for Wood Products.* Proceedings of the 2000 International Union of Forestry Research Organisations Conference, Launceston, Australia.

STACKPOLE, D. 1998. *Thinning Eucalypts for Sawlogs.* Pamphlet published by Department of Natural Resources and Environment, Melbourne.

TROTH, J. L., LOWREY, R. F. & FALLIS, F. G. 1986. Herbicides as cut-stump treatments during pre-commercial thinning. Pp. 297–304 in *Proceedings of the Southern Weed Science Society, 39th Annual Meeting.* 20–22 January 1986, Nashville.

WOOD, M. S., STEPHENS, N. C., ALLISON, B. K. & HOWELL, C. I. 2001. *Plantations of Australia: A Report from the National Plantation Inventory and the National Farm Forest Inventory* (abridged version). National Forest Inventory, Bureau of Rural Sciences, Canberra. 10 pp.