Evaluation of genetic-related tree traits and work method on *E. globulus* harvesting productivity – A case study in Western Australia

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Introduction

Overseas studies have demonstrated the potential for positive economic impact of genetic improvement in Eucalyptus species along the supply chain. Tree genetics can affect tree traits that impact on harvesting costs at the individual tree level, including stem size, straightness, forking, and branch size. In addition, at the block scale, variability in sporadic mortality and work methods may also affect the performance of harvesting operations. A genetic mapping trial established by the Southern Tree Breeding Association (STBA) in an *E. globulus* plantation in Western Australia (WA) provided an opportunity to link phenotypic and genetic variation in tree traits to harvest productivity. This bulletin reports on an operational trial where the primary objective was to evaluate the effect of genetic related tree traits and work method on *E. globulus* harvesting productivity.

Study area and research methods

A genetic mapping trial was established by STBA in September 2001 near Manjimup, WA. The trial contained 126, 25-tree (5 x 5) blocks (randomly distributed) of nine control crossed families in an area of 3.15 ha. The plantation was harvested in November 2011, 10.2 years after establishment, and took approximately 38 working hours. At the time of harvest, stocking was 881 trees/ha, and trees had an average diameter of 21.2 cm, an average height of 27.3 metres, and an average piece size of 0.44 m^3. The site was relatively flat with an average and maximum slope of 2° and 4°, respectively. The soil was firm and deep, while the ground was stable and even, and clean of understory vegetation.

Harvesting was carried out using a tracked excavator-based Cat 511 single grip harvester equipped with a 16-inch Waratah HTH616C felling/processing head. The harvester operator had 11 years of experience working with similar equipment. Product specification focused on the production of 5.4m debarked logs without a minimum small-end diameter. For the harvesting study, each 5-row block was split into two harvest plots of 2 rows and 3 rows, respectively. A total of 252 harvest plots (2774 merchantable trees) were measured in the treatment plots prior to harvest and subjectively assessed as to the expected impact of three form criteria (branchiness,

forking and sweep) on harvester productivity. Total harvesting activity was timed on a tree-by-tree basis for all blocks. A generic productivity model was developed from elemental time models (felling, processing, moving, stacking, brushing, and travelling) which included piece size, tree form traits, and work method (2-row versus 3-row harvesting) as explanatory variables.

Results

Tree and Plot Factors

Table 1 shows a summary of tree and plot factors by crossed family. The number of harvest plots per family in relation to the total number of plots varied from 3.2% (crossed family I) to 23% (crossed family F). Mortality averaged about 9.4% at a coupe level. Only two crossed families exceeded 10% of mortality (family B with a 27.5% and family I with 11%). As a proportion of the total number of trees per crossed family, merchantable trees* varied from 71% (crossed family B) to 96% (crossed family G). Genetic related tree traits (piece size, branching, and forking) also varied across families. Average merchantable tree volume ranged between 0.345 m^3 (crossed family C) and 0.538 m^3 (crossed family I). The percentage of merchantable trees in Class 1[1] branching was low and didn't exceed 5.6% in any of the families, while there were practically no trees where stem sweep was expected to impact productivity. Forking was the most important tree form factor expected to affect harvest productivity. Excepting crossed families D, E and I, the percentage of merchantable trees in Class 1 forking was close to 10% across the families. The proportion of merchantable trees in Class 1 Branchiness was highly correlated (r = 0.86) with the proportion of trees in Class 1 Forking.

Table 1. Tree and plot factors by crossed family.

	Crossed family									All
Tree and plot factors	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	
Harvest plots	32	44	8	44	34	58	12	12	8	252
Number of planted trees	400	550	100	550	425	725	150	150	100	3150
Living trees	386	399	93	499	409	692	145	143	89	2855
Merchantable trees* & (% survival)	382 (96)	391 (71)	92 (92)	463 (84)	407 (96)	664 (92)	144 (96)	142 (95)	89 (89)	2774 (88)
Avg. merchantable volume (m^3/tree & (m^3/ha))	0.468 (447)	0.534 (380)	0.345 (318)	0.377 (318)	0.520 (498)	0.372 (341)	0.427 (410)	0.501 (474)	0.538 (479)	0.445 (392)
Merchantable stocking (trees/ha)	955	711	920	842	958	916	960	947	890	881
Branching: % of merchantable trees in Class 1	2.1	1.3	2.2	1.5	0.5	4.5	3.5	2.8	5.6	2.7
Forking: % of merchantable trees in Class 1	9.9	10.2	8.7	6.7	4.7	12.0	9.0	9.9	14.6	9.5

* Merchantable trees are trees with at least one stem being >7.5cm dbhob with >3m straight bole. Dead, fallen or broken trees were deemed as non-merchantable for this study.

1 Class 1: there is an expected impact of factor (branchiness or forking) on harvesting/processing productivity

Effect of work method on harvesting productivity at coupe level

Piece size and work method (2-row and 3-row harvesting) explain the variation in felling time and harvesting productivity (Figure 1). Productivity was calculated assuming a 1:1 (m^3:tonne) conversion factor. The difference in productivity between the two work methods was very small (on average about one tonne per PMH_{15} across the range of piece size) and tended to increase slightly with bigger piece sizes. Felling time was slightly longer when working on a 3-row strip since it took more time for the operator to reach trees with the boom and to lay down trees on the ground after felling.

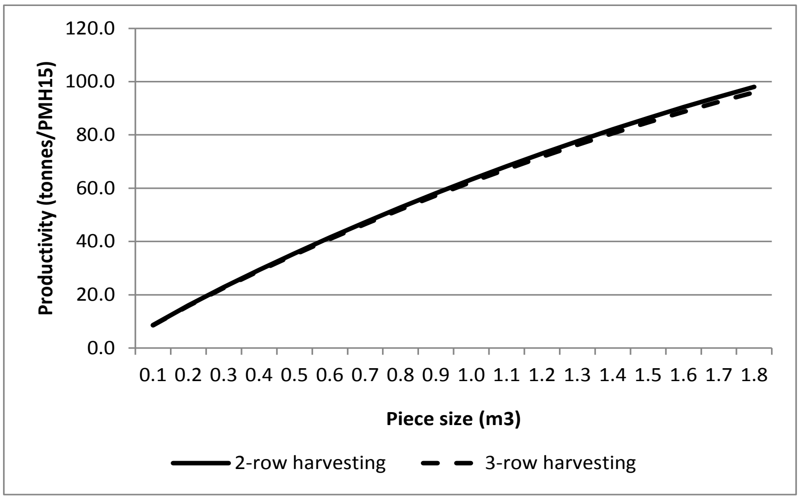

Figure 1. Productivity (tonnes/PMH15) by work method.

Effect of tree form traits on productivity and costs at coupe level

Piece size, branching and forking explained the variation in processing time per tree and harvesting productivity (Figure 2). At a coupe level, productivity (combined 2-row & 3-row harvesting) was 31.6 tonnes/PMH_{15} for an average piece size of 0.44 m^3, 9.5% Class 1 forking and 2.7% Class 1 branching. Harvesting productivity ranged from 27.0 tonnes/PMH_{15} (100% forking and branching) and 32.0 tonnes/PMH_{15} (no trees affected by forking or branching). These differences tended to increase slightly with piece size and reached a maximum difference of 14.3 tonnes/PMH_{15} for a piece size of 1.8 m^3.

The expected impact of each factor on harvesting/processing productivity at a coupe level was mainly determined by the proportion of trees affected by forking and to a lower extent by branching. Despite some variability between crossed families, this coupe presented a low overall ratio of trees where form was likely to affect machine productivity. At 2.7% for Class 1 branching and 9.5% for Class 1 forking, this incidence was significantly less than the local industry “rule of thumb” where incidence of malformation needs to be >20% of trees with an individual tree form trait or >30% of trees with combined tree form traits in order to effect machine productivity to a significant extent. Furthermore, the severity of individual tree malformation, although meeting minimum criteria for Class 1, was not considered significant to warrant special consideration in selection of harvesting system.

For the range of piece sizes present in the study, Figure 3 shows unit costs ($/tonne) by branching and forking class assuming a harvesting cost of 220 $/$PMH_{15}$. At a coupe level, unit cost (combined 2-

row & 3-row harvesting) was 7.0 $/tonne for an average piece size of 0.44 m^3, 9.5% Class 1 Forking and 2.7% Class 1 branching. Cost differences between the two branching and forking classes (100% and 0% of the trees affected by forking and branching, respectively) tended to decrease with piece size, and they were lower than 0.5 $/tonne for piece sizes exceeding 1.2 m^3.

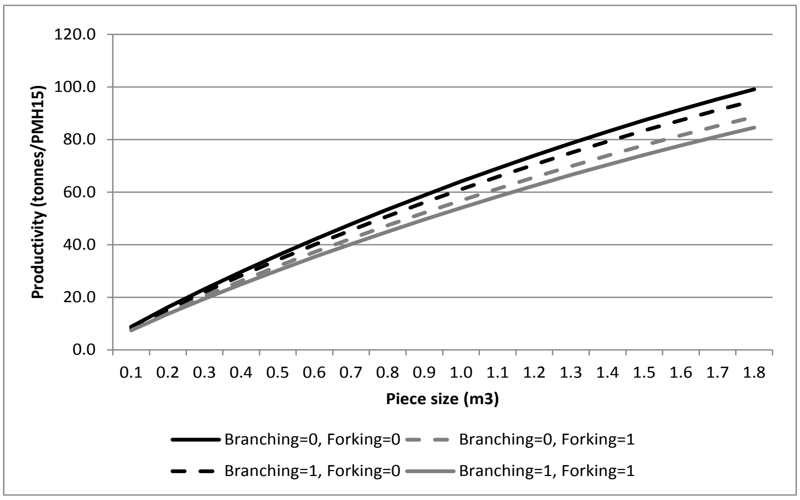

Figure 2. Productivity by branching and forking class.

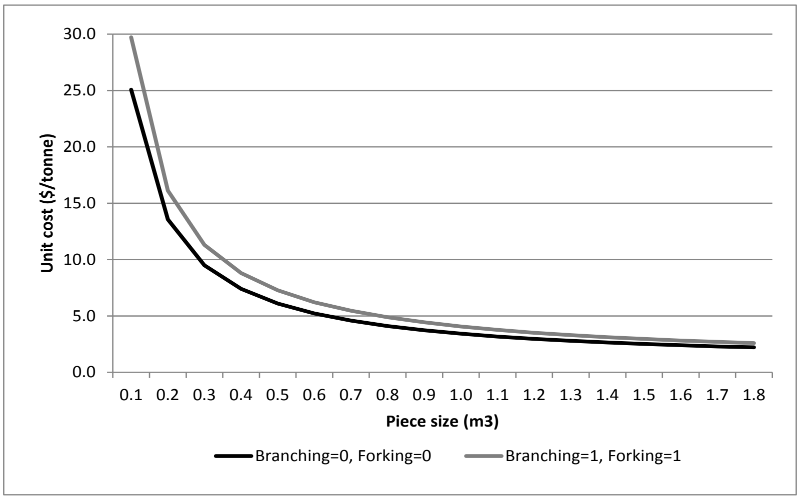

Figure 3. Unit costs by branching and forking class.

Predicted harvesting productivity and unit costs by crossed family

Harvesting productivity per productive machine hour (PMH_{15}) and unit costs were estimated for each crossed family from elemental cycle time models (Figure 4). Piece size and to a much lower extent forking were the main drivers explaining the harvesting productivity and the differences among crossed families. The differences in productivity and cost resulting from the work method (2-row versus 3-row harvesting) were quite small, and did not exceed 2% in any of the crossed families included in the study. The unit cost across families ranged from 6.0 $/tonne for family E (which contained the equally highest survival (stocking), highest merchantable volume/ha, 3rd largest average tree volume and the least class 1 malformation) to 8.5 $/tonne for family C which, despite having above average survival and stocking, the second smallest family sample size and lower than average class 1 malformation, also contained the lowest merchantable volume per ha and the smallest average tree size. Whilst all tree and plot variables cannot be directly attributed to genetics, there is a 2.5 $/tonne difference – a differential saving of 21% between harvesting the genetics family least favoured compared to the family most efficiently harvested in this coupe.

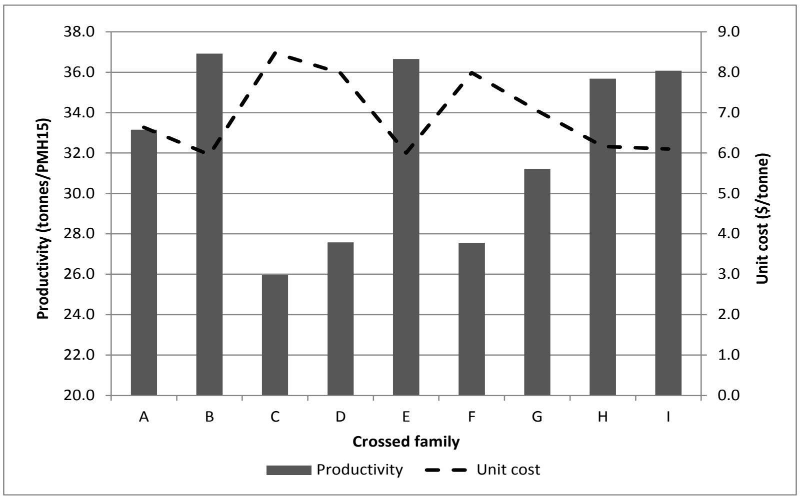

Figure 4. Productivity and unit cost by crossed family.

Take-home messages

- Tree genetics can affect final plot volume and tree traits that impact on harvesting costs at the individual tree level, including stem size, forking and branch size. Whilst all tree and plot variables cannot be directly attributed to genetics, there was a differential saving of 21% in harvest unit costs between the genetics family least favoured compared to the family most efficiently harvested in this coupe.
- Piece size was the main driver explaining the variation in harvesting productivity and unit cost differences among crossed families.
- Despite some variability between crossed families, this coupe presented a low overall ratio of trees where form (branching and forking) and mortality were likely to affect machine productivity. After accounting for piece size, differences in productivity attributed to tree form traits were quite low across families.
- Work method employed (2-row versus 3-row harvesting) made very little difference to harvesting productivity, and averaged about one tonne per PMH^{15} across the range of piece sizes present in the study.

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More information

AFORA website:
http://www.usc.edu.au/research/research-partnerships/australian-forest-operations-research-alliance-afora

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