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Woody Biomass Production by Utilizing Coppice of *Eucalyptus camaldulensis* in an Arid Area in Western Australia

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Abstract: In order to reduce the cost for CO_2 fixation by arid-land afforestation, possibility of utilizing coppicing of the planted trees was examined in the arid area in Western Australia. The seven-year-old planted trees and the native trees of various sizes of *Eucalyptus camaldulensis* were cut down and the growths of coppice growing from the stumps after cutting were observed for one and a half years. The resprouting rate for both planted and native trees reached 100% until six months after cutting. The results for the native trees indicated the bigger the tree was when it was cut, the quicker the coppice grew. The growth rate of the coppice for the planted trees was comparable to that of the coppice for the native trees. These results indicated that utilization of coppicing for increasing CO_2 amount fixed by the planted trees was highly possible even in the arid areas.

Keywords: Arid region, Coppicing, *Eucalyptus camaldulensis,* Western Australia

1. Introduction

Woody biomass production by afforestation in arid areas is expected to be a promising countermeasure against the global warming and the depletion of energy resources such as fossil fuels because the arid areas widely exist all over the world and cannot be utilized for crop production. Yamada *et al*. (2003) demonstrated that afforestation with embankments for water-harvesting and soil structure modification by hardpan blasting was effective in tree growth in an arid area in Western Australia. Yamada *et al*. (2005) also estimated the CO_2 fixation cost (input cost/fixed carbon amount) as around 16,000 yen/t-C. The CO_2 fixation cost must be reduced to make the arid-land afforestation feasible.

An effective way to reduce the CO_2 fixation cost is to maximize the amount of CO_2 fixed by the planted tree. Since trees cannot fix carbon any more when they reach a mature state, utilization of coppicing is an effective way to increase the carbon fixed by a tree over its lifetime. And also, coppicing is expected to be more economical than replanting, especially in arid regions where a large investment is necessary for the initial afforestation works.

The coppicing ability is much different among species. Although *Eucalyptus* species generally have a high coppicing ability, the ability significantly differs even among *Eucalyptus* species (Sims *et al*., 2001). Moreover, a coppicing ability and a growth rate of the coppice depends upon climatic conditions as well. Many researches concentrate on coppicing of trees growing in tropical and temperate climate. However, there is little information on coppicing of trees growing in arid regions. The objective of this study is to clarify the possibility of biomass production by utilizing coppicing in arid areas, aiming to reduce the CO_2 fixation cost by arid-land afforestation.

2. Materials and Methods

Several afforestation trial sites were constructed by a Japanese research project in an arid area near Leonora in Western Australia where annual rainfall is around 200 mm (Kojima *et al*., 2006). At these sites, some afforestation techniques such as embankments for water-harvesting and hardpan blasting with explosives for soil structure modification were examined for successful tree growth in the arid area. The coppice experiment was carried out at one of the afforestation trial sites, named as Site B. **Fig. 1** shows the layout of planting at Site B. Prior to planting, hardpan blasting with explosives was done at all the planting points at intervals of 7 m and in three rows. The rows were along the contour lines and an embankment of 1 m high, 3 m wide and 100 m long was build along the bottom row for harvesting runoff

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water from the upstream and enhancing water penetration into the blasted holes. Three tree species including *Eucalyptus camaldulensis* were planted at the site in 1999. The trees still grew well after one-month-interval irrigation was terminated in 2004, indicating that the employed afforestation techniques were effective in tree growth. It was also found out that *E. camaldulensis* was quick to grow and a species suitable to arid-land afforestation with those techniques, especially hardpan blasting (Shiono *et al.*, 2007). Therefore, *E. camaldulensis* was selected as a species to be examined in this study.

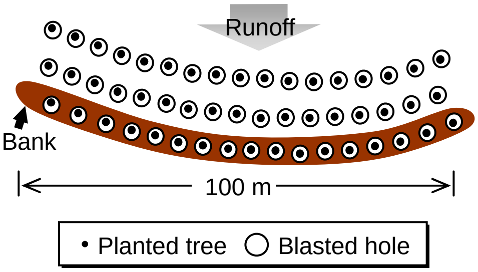

Fig. 1. Layout of the planting site, Site B.

There were sixteen trees of *E. camaldulensis* in the two rows on the upstream side. The coppice experiment was started by cutting down nine trees of them in September, 2006. The trees were cut with a chain saw at around 10 cm above the ground. The rest were remained uncut for continuous observation of growth and comparison in growth rate with coppice from the stumps of the cut trees. Girths at a breast height (GBH) of these trees ranged from 40 - 90 cm when they were cut. The average aboveground biomass of all the trees of *E. camaldulensis* in these two rows was estimated as 150 kg-DM (dry matter), and there was no significant difference (p>0.1, ANOVA) between the cut and uncut trees.

On the other hand, fifty-one native trees of various sizes of *E. camaldulensis* growing along a wadi were also cut down for comparison with the planted trees. The fifty-one trees were classified into five classes of every 20 cm in the range of 20 – 120 cm in GBH. **Table 1** summarizes the number and aboveground biomass of the cut trees for both the planted and native ones.

Resprouting rates and growth rates were investigated. A diameter of a stem at 0.3 m from its base, $D_{0.3}$ [cm], and its length, L [cm], were measured for coppicing shoots longer than 0.3 m. The following allometric relations between size and dry mass of a shoot were obtained by the destructive sampling.

$$W_{stem} = 0.00803\left(D_{0.3}{}^{2}L\right)^{0.900} \quad (n = 10,\ R^{2} = 0.979) \qquad (1)$$

$$W_{leaf} = 0.00866\left(D_{0.3}{}^{2}L\right)^{0.874} \quad (n = 10,\ R^{2} = 0.954) \qquad (2)$$

$$W_{coppice} = \sum_{i}\left(W_{stem,i} + W_{leaf,i}\right) \quad (i : \text{index for a stem}) \qquad (3)$$

where W_{stem} is a dry mass of a stem [kg-DM] and W_{leaf} is a dry mass of leaves from the stem [kg-DM]. $W_{coppice}$ [kg-DM] is a dry mass of coppice from a stump and calculated as a sum of dry masses of all the shoots growing from the stump. And also, the statistical analysis was performed by a Steel-Dwass's multiple comparison test.

3. Results and Discussion

3.1 Resprouting rate

A resprouting rate is an important factor in coppice forestry. It depends on various conditions such as stock density and time of harvest. The stock density at Site B was 204 trees/ha, which is considered to be sufficiently low to avoid a mutual interference. September, early spring in Australia, was selected as the time of harvest to avoid an increase in mortality due to both dryness and frost (CALM, 2002).

Table 1. Number and aboveground biomass of the cut trees at the time of cutting for the planted and native trees (GBH stands for a girth at a breast height).

		Planted tree (GBH:40-90cm)	Native tree				
			Range of GBH [cm]				
			20-40	40-60	60-80	80-100	100-120
Number of cut trees		9	13	14	10	9	5
Aboveground biomass [kg-DM/tree]	Mean	132	28	86	132	283	547
	S.D.	48	9	27	41	59	138

Figure 2 shows the resprouting rates three and six months after cutting. The resprouting rates reached 100 % for both the planted and native trees in all the classes six months after cutting. From the results three month after cutting, it seemed that the bigger the tree was when cutting, the earlier resprouting occurred.

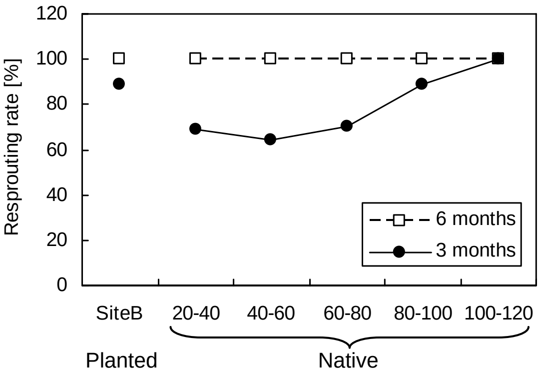

Fig. 2. Resprouting rate three and six months after cutting.

3.2 Comparison of coppice growth between the planted and native trees

Figure 3 shows multi-stem coppice growing from a stump of the planted tree at Site B one and half years after cutting. Thinning is important for such multi-stem coppice and recommended for a good shape of a tree. In this study, however, thinning was not performed at all because an extra cost for thinning should be avoided in practical afforestation aiming at economical biomass production. Several dominant stems seemed to start growing more quickly as a consequence of self-thinning.

Fig. 3. Coppice of the planted tree one and half years after cutting (Site B).

Figure 4 shows the number of stems growing from a stump one year after cutting. Stems of $D_{0.3}$ larger than 10 mm were counted. From the results for the native trees, the bigger stumps seemed to produce more resprouting stems although any combination between the classes of DBH did not show a significant difference (p>0.05). On the other hand, the stem number for the planted trees at Site B was greater only than that for the class of 40-60 cm for the native trees (p<0.05). Considering the range of DBH of the cut trees at Site B, the planted trees have a comparable or higher coppicing ability compared with the native ones.

Biomass of the coppice one year after cutting is shown in **Fig. 5**. Kamo (1997) reported based on the one-year investigation on coppice of *E. camaldulensis* in Thailand that the coppice from a bigger stump was quicker to grow. In this study, from the results of the native trees, the bigger trees seemed to have a greater growth rate although there was no significant difference for any combination between the classes of DBH for the native trees (p>0.05). The reason for the large variations may be that the environment conditions such as light and soil water were not the same among the coppice because the native trees were selected from various places around the wadi.

On the other hand, the biomass of the coppice for the planted trees was significantly greater only than that of the class of 40-60 cm for the native trees (p<0.05). The results also indicated that the coppice growing the stumps of the planted trees had a growth rate comparable to that for the native trees.

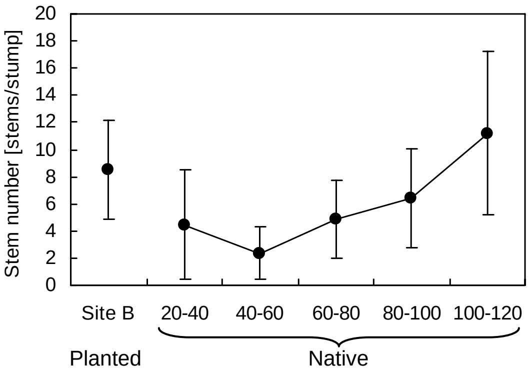

Fig. 4. Stem number one year after harvesting (Mean±S.D.).

3.3 Comparison of growth between the coppice and the planted single trees

In order to efficiently increase CO_2 fixation amount by using coppicing, cutting should be performed when the growth rate of a planted tree declines and is exceeded by the growth rate of coppice. **Figure 6** shows time variations in aboveground biomass of the planted single tree after planting and in biomass of the coppice after cutting at Site B. The uncut trees grew at a steady rate after cutting and their average

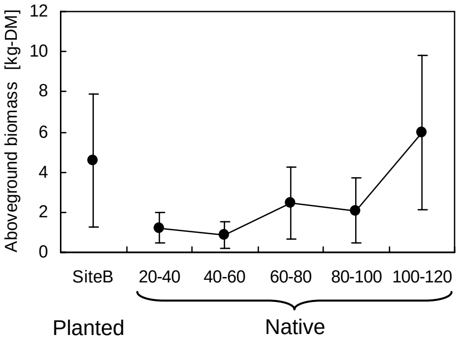

Fig. 5. **Biomass of coppice growing from a stump (Mean±S.D.).**

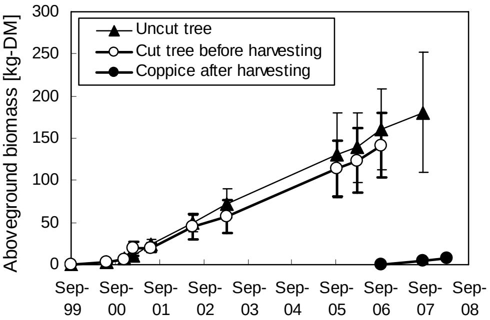

Fig. 6. **Time variations in biomass of the coppice and the planted single trees at Site B (Mean ± S.D.).**

growth rate during one year after cutting was 21 kg-DM/(y·tree), which was 4.2 t-DM/(ha·y) if multiplied by the stand density of 204 trees/ha. On the other hand, the growth rate of the coppice averaged over one and half years after cutting was estimated as 4.9 kg-DM/(y·tree). The growth rate of the coppice was much lower than that of the uncut planted trees. This indicates the coppice rotation period should be longer than seven years at least. Furthermore, the initial growth rate of the planted single tree during about one and half years after planting was 11 kg-DM/(y·tree) as the average. Generally, the growth rate of first coppice exceeds that of the original single tree (Sims *et al*, 2001). The growth rate of the coppice, however, was much lower than the initial growth rate of the planted trees in this study. It was because the planted trees were irrigated for early root development while the coppices were not irrigated at all. Moreover, as seen in Fig. 5, the growth rate of the coppice largely varied. This large variation may be caused by the difference in root development in the soil structures formed by the hardpan blasting. However, some coppice showed a growth rate comparable to the initial growth rate of the planted trees, indicating the coppice can have a high growth rate even without irrigation when the conditions are right.

4. Conclusion

The growth rate of the coppice for the planted trees was comparable to that of the coppice for the native trees. The results of this study indicate that biomass production by utilizing a coppice growth is highly possible even in an arid area if root systems fully develop in the modified soil structure. Although longer observation of the coppice growth is necessary for more reliable conclusion, the cost for CO_2 fixation by arid-land afforestation is expected to be reduced by utilizing coppicing.

Acknowledgement

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