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An Analysis of Root Biomass in a Sapling Cultivation Experiment for Afforestation on Salt Affected Land

Katsuhiko KUROSAWA*[1], Shin-ichi AIKAWA[2], Yusuke ODA[1], Toshinori KOJIMA[1], Satoko KAWARASAKI[2], Masahiro SAITO[2], Hideki SUGANUMA[1], Richard HARPER[3] and Hiroyuki TANOUCHI[4]

Abstract: The purpose of this study is to analyze the data of root biomasses measured in a sapling cultivation experiment reported by Oda *et al*. (2009). In the experiment, *Eucalyptus rudis* × *E. camaldulensis*, *E. camaldulensis* and *E. sargentii* were cultivated in a glasshouse at Tsukuba, Japan, and those were watered with 0, 100 and 200 mmol-NaCl/L solution. The dry weight of the roots tended to decrease with increase of NaCl concentration. The significant relationship were observed between the tree height and the dry weight of the roots (r = 0.818-0.851, p < 0.001). These suggest that the root biomass of the tree species may be able to be estimated by the allometry equations. The biomass ratios of the root to the shoot did not increase with NaCl concentration despite that the reduction of shoot growth is generally much greater than the reduction of root growth under saline condition. The biomass ratio of the root to shoot of *Eucalyptus* saplings might not increase with NaCl concentration because same tendency was reported by Marcar (1993).

Key Words: Carbon sequestration, Root biomass, Salt affected land, Sapling cultivation experiment, Semi-arid land

1. Introduction

In recent years, risk of salinity and waterlogging has been indicated in the wheat belt of Western Australia. The area had been the forest area dominated by *Eucalyptus* species, however, those were deforested and used as farmland on a large scale (Aikawa *et al*., 2008). The groundwater balance was disrupted by the deforestation because the transpiration rates of the crops typified by wheat were lower than those of the *Eucalyptus* species and the depths of water uptake by the crops were much shallower than those by *Eucalyptus* trees. The groundwater level rose and salt was accumulated at the surface soil as a result from the disrupted ground water balance (Kurosawa *et al*., 2010), and it is predicted that by 2050, up to 17 million hectares (about 2.21% of Australian land) may be at high risk (Jolly *et al*., 2002). The afforestation is expected to be the most useful method to decrease the groundwater level and to restore the groundwater balance (Kurosawa *et al*., 2009).

Afforestation trial has been carried out since 2004 at the sites in the wheat belt of Western Australia in our GHG-SSCP (Development of Greenhouse-gas Sink/Source Control Technologies through Conservation and Efficient Management of Terrestrial Ecosystems) project aiming at carbon fixation and restoring groundwater balance by systematic afforestation (Yamada *et al*., 1999). The study experiments for the systematic afforestation have been done in the afforestation sites on natural fields but also the laboratories and the glasshouses.

Oda *et al*. (2009) showed the results of cultivation experiments of *Eucalyptus* saplings in the glasshouse under the irrigation conditions with fresh or saline water (100 or 200 mmol-NaCl/L), and they determined the best *Eucalyptus* species for the afforestation to the salt-affected land. They analyzed the planted *Eucalyptus* heights and total-dry weights (aboveground and underground parts) of the saplings, however, the dry weight of the roots, expecting to be affected by the water salinity, has not been analyzed in detail. In general, under saline condition, the reduction of shoot growth is much greater than the reduction of root growth (Cheeseman, 1988). The afforestation sites of our study project are built around the marge area of the salt affected land, and it is important the effects of the salinity stress to the underground biomass (the fixed carbon in the roots). The purpose of this study is to elucidate the change and the tendencies of the underground biomass of the cultivated saplings and to consider the estimate method of the root biomass with the size data of the above part of the planted trees by analysis the data of root biomasses measured in the sapling cultivation experiment reported by Oda *et al*. (2009).

* Corresponding Author: kurosawa@ejs.seikei.ac.jp
Seikei University, 3-3-1 Kichijoji-kitamachi, Musashino, Tokyo 180-8633, Japan
1) Faculty of Science and Technology, Seikei University, Japan
2) Forestry and Forest Products Research Institute, Japan
3) Research Institute for Sustainable Ecosystems, Murdoch University, Western Australi
4) Shikoku Research Center, Forestry and Forest Products Research Institute, Japan

2. Materials and Methods

The cultivation experiments were carried out in a glasshouse of Forestry and Forest Production Research Institute at Tsukuba City from May 2007 to January or February 2008. The tree species and the cultivation periods were *Eucalyptus rudis* × *E. camaldulensis*, *E. camaldulensis* and *E. sargentii*, respectively (Oda *et al*., 2009). The trees were germinated and cultivated in plastic pipes (1m height and 10cm diameter) filled with Kanuma soil (the general gardening soil in Japan), and nets were put on the bottom of the all cultivation pipes for gravitational drainage of the surplus water. After the germination, all plants were grown under wet condition by irrigation with fresh water for about one month. After that, those were watered for 2 weeks interval with 2.0 L of fresh water (0 mmol-NaCl/L) or saline water (100 or 200 mmol-NaCl/L). The 100 and 200 mmol-NaCl/L were equivalent to 12.64 dS/m (moderate salt tolerant) and 25.28 dS/m (highly salt tolerant), respectively (Marcar and Crawford, 2004). The supplied water volume was sufficient to saturate the soil layer. After the cultivation period, all the saplings were measured the tree height, and then those were harvested for the measurement of those dry weights. The harvested saplings were separated as aboveground and underground parts. The separated parts were dried out 60˚C condition in laboratory ovens for a few days. After the procedure, the dry weights of the sapling parts were measured in the laboratory. The dry weight data of the parts were sorted by the items of the parts, species and cultivation conditions for statistical analyzes. Turkey-Kramer test (Yanai, 2004) was adopted to the analyzes for elucidation of significant difference between each data groups. Sminov test (Ichihara, 1990) was adopted for the detection of outlier in a data group.

3. Results and Discussion

Figure 1 shows mean dry weight of the roots and the results of the comparison test of the roots weight classified the data group by the NaCl concentrations of the irrigated water. Mean the dry weight of the roots decreased with the concentrations of the NaCl concentrations. Mean dry weight of the sapling roots grown with fresh water were 14.96 (*E. rudis* × *E. camaldulensis*), 12.26 (*E. camaldulensis*) and 5.22 (*E. sargentii*) g, respectively. Mean dry weights of the roots of *E. rudis* × *E. camaledulensis* and *E. camaldulensis* were significantly higher ($p < 0.01$) than that of *E. sargentii* under the cultivation condition with fresh water and 100 mmol-NaCl/L solution. Under the cultivation condition with 200 mmol-NaCl/L solution, mean dry weight of the roots was lower than those under the any other conditions, and there was

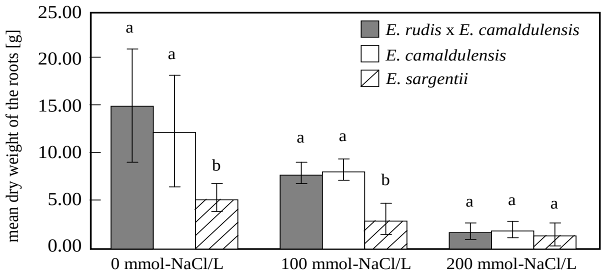

Fig. 1. Mean dry weights of the roots of the cultivated saplings. The different letters show the significant differences analyzed by Tukey-Kramer test in the interspecies conditions.

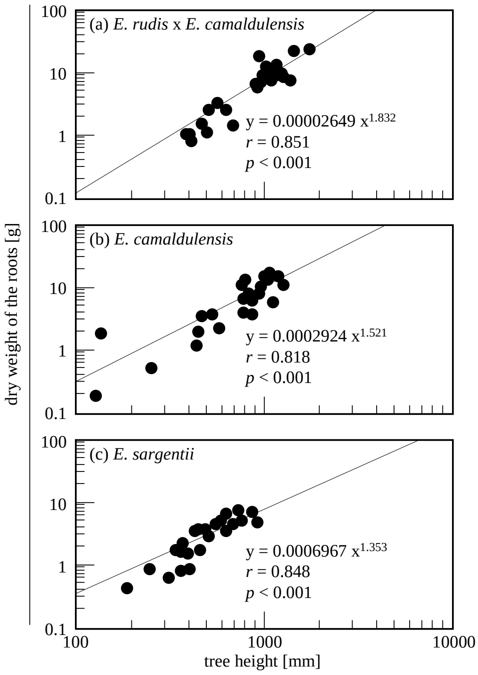

Fig. 2. Allometry relationships between the dry weight of the roots of the cultivated saplings and the tree heights.

not significant difference among mean dry weights of the roots of the each species. These suggest that the roots of all the cultivated *Eucalyptus* under the salinity tolerant conditions were inhibited their own growth by the salinity stress, and the dry weight data of the roots were not so different as the result.

Figure 2 shows the relations between the final tree heights and the dry weight of the roots after the harvesting of the saplings. The dry weight of the roots increased with the tree height. The equations in the figures were the results of the regression analysis determined by the least square method, and the significant correlations were detected between the tree heights and the dry weight of the roots in all the cases (r = 0.818-0.851, $p < 0.001$). These mean that the dry weight of the underground part of the cultivated saplings could be unified by the allometry relationships during the cultivation period despite the difference of NaCl concentration of the irrigated water and the biomass of the roots can be estimated by the allometry relations and the data of the tree height.

Figure 3 shows the relationships between the biomass ratio of the root to shoot (the dry weight ratio of the underground and the aboveground parts) and the tree heights of the saplings, and **Figure 4** shows the biomass ratios of the root to shoot and the tree heights after the Sminov test. The data surrounded by the dotted line in Figure 3 were the significant outliers detected by Sminov test. The equations in the Figures 3 and 4 showed the results of the regression analysis determined by the least square method. The slopes of the regression equations in Figure 4 were near 0, and the significant relationships were not detected in the analyses. The biomass ratios of the root to shoot of each tree species were ranged from 0.18 to 0.50 (*E. rudis* × *E. camaldulensis*), from 0.39 to 0.70 (*E. camaldulensis*) and from 0.14 to 0.45 (*E. sargentii*), respectively. The minimum and maximum values of the biomass ratios of the root to shoot of *E. camaledulensis* tend to be higher than those of the other tree species. This means that the biomass ratios of the root to shoot tend to be depended on the tree species. **Table 1** shows the average of the biomass ratios of the root to shoot, the standard deviations (S.D.) and the coefficients of variation (C.V.) on the tree species and NaCl concentrations. Cheesman (1988) showed that the reduction of shoot growth is much greater than the reduction of root growth, however, in this study, the biomass ratios of the root to shoot under fresh water condition on each tree species were similar to those under saline water conditions. The biomass ratios of the root to shoot ratios did not increase with the NaCl concentrations.

Marcar (1993) showed the results of the experiments of 4 types of *Eucalyptus* saplings (including *E. camaldulensis*) cultivation in a glasshouse, and the significant differences was not detected between the biomass ratio of the root to shoot under control (fresh water cultivation) condition and those under saline water condition. There were same experimental points between this study and Marcar (1993), *Ecucalyptus* saplings (under 1 year old) and cultivation experiment in a glasshouse. In a journal about arboriculture, Harris (1992) showed that the biomass ratios of the root to shoot is 5 or 6 for most trees under normal natural condition, and the biomass ratios of the root to shoot in this study tend to be higher than those in Harris (1992). These indicate that the biomass ratio of the root to shoot of young *Eucalyptus* saplings under laboratory experimental condition may not tend to be changed by salinity stress.

4. Conclusion

The data of the cultivation experiment of *Eucalyptus* saplings, especially the dry weight data of the root and shoot, were analyzed in this study, and the following were main findings:

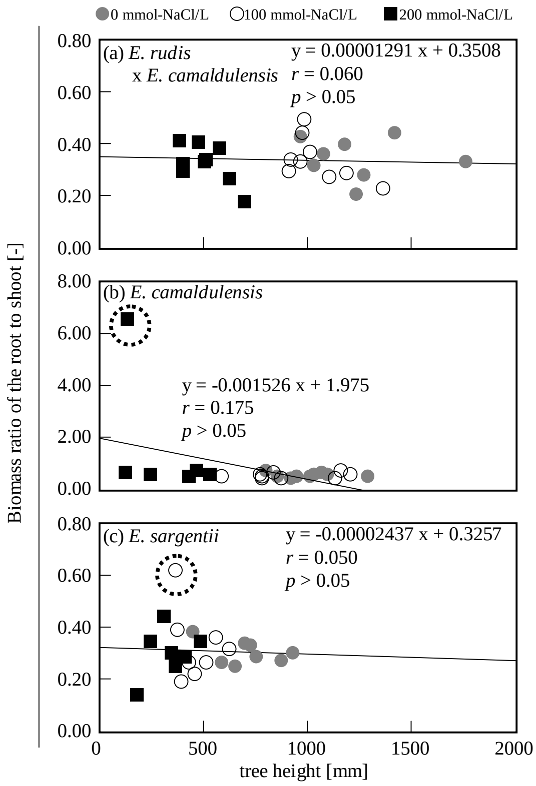

Fig. 3. The relationship between biomass ratio of the root to shoot and the tree height of the saplings. The data surrounded by dotted line were the significant outliers detected by Sminov test.

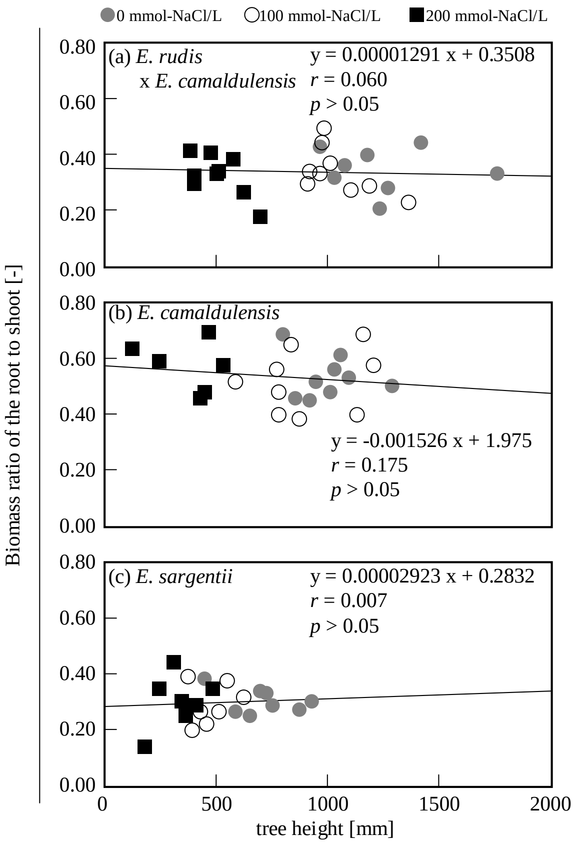

Fig. 4. The relationship between biomass ratio of the root to shoot and the tree heights of the saplings. (after Smirnov test for outliers)

Table 1. Mean biomass ratio of the root to shoot, the standard deviations and the coefficients of variation on the tree species and NaCl concentration.

		E. rudis x *E. camaldulensis*	*E. camaldulensis*	*E. sargentii*
0 mmol-NaCl/L	average	0.35	0.53	0.31
	S.D.	0.08	0.08	0.05
	C.V.	0.23	0.14	0.16
100 mmol-NaCl/L	average	0.34	0.52	0.33
	S.D.	0.09	0.11	0.13
	C.V.	0.25	0.21	0.39
200 mmol-NaCl/L	average	0.33	0.57	0.30
	S.D.	0.07	0.09	0.10
	C.V.	0.23	0.16	0.31

(a) There were significant relationships between the dry weight of the cultivated roots and the tree height after the harvesting of the saplings.

(b) Biomass ratio of the root to shoot did not increase with NaCl concentration of the irrigated water despite that the reduction of shoot growth is generally much greater than the reduction of root growth.

(c) The trends of the biomass ratio of the root to shoot were depended on the tree species.

These show that the allometry relationships can be utilized for the estimate of the underground biomass of the saplings. The biomass ratio of the root to shoot could be utilized too, however, the tendency of the ratio depending on tree species should be considered.

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