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Relation between Growth of Planted Trees and Soil Chemical Properties in Afforestation Sites of Semi-arid Land, WA

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Abstract: The purpose of this study is to discuss the relation between growth of planted trees and soil chemical properties in our afforestation sites (mean rainfall: 350-550 mm/y) of semi-arid land. The average values of height growth tended to decrease with mean rainfall at each sites, the maximum of the mean height growth was *E. cladocalyx* at Bakers Hill (167±31 cm/y (1σ)). Height growth of planted trees at lower altitude site generally tended to be lower than that at high site. In Calingiri, the mean height growth of *A. acuminata* at low site (79±25 cm/y (1σ)) was 40 % lower than that at high site (132±30 cm/y (1σ)). The EC(1:5) value of the surface at Bakers Hill and 1.0 m depth at high site of Tammin reached 0.55 and 1.15 dS/m, respectively. EC(1:5) of 1.0 m at high site in Tammin was contributed by high concentration of Na, however, that of surface in Bakers Hill was affected by high concentration of K and Ca. pF values at Bakers Hill were almost between 1.8 and 4.2, and that suggested that those pore water are almost useful for uptake by planted trees. At high site of Calingiri and low site of Tammin, pF values of shallow layer were almost hygroscopic water level (pF > 4.2), and physical condition of water permeability may have to be improved for carbon sequestration. The range of height growth of *E. camaldulensis* var. *Lake Albacutya* at low site of Calingiri and Tammin tended to be wider than that at high site, however, the average of height growth of those at low site were similar to those at high site. This may suggest that the main factor of carbon fixation of growth of *E. camaldulensis* var. *Lake Albacutya* is not soil chemical properties and physical condition for water permeability but mean rainfall.

Keywords: Afforestation, Height growth, Soil chemical properties, Wheat belt

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). By the deforestation, the groundwater level rose and salt was accumulated at the surface soil as a result from disrupted ground water balance. The afforestation is expected to be the most useful method to decrease the groundwater level and to restore the groundwater balance.

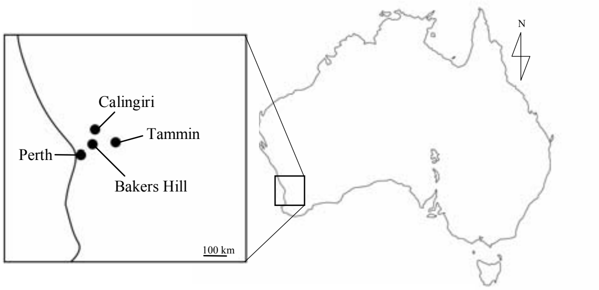

Fig. 1. Location of afforestation site in WA.

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

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Conservation and Efficient Management of Terrestrial Ecosystems) project aiming at carbon fixation and restoring groundwater balance by systematic afforestation. The trial sites are characterized by the mean annual rainfall of 350-550 mm. The purpose of this study is to discuss the relation between growth of planted trees and soil chemical properties in our afforestation sites of semi-arid land.

2. Materials and Methods

The surveys have been carried out at afforestation sites at Bakers Hill (S31˚42', E116˚28'), Calingiri (S31˚11', E116˚27') and Tammin (S31˚36', E117˚29') of WA (**Fig.1**). Mean annual precipitation in each trial sites are 350, 450 and 550 mm/y, respectively (Matsumoto *et al*., 2006). There are each two afforestation sites in Calingiri and Tammin, and those are denominative high site and low site after relationship of each altitude. Tree heights were observed at each sites from 2004 to 2006, and values of height growth were divided difference of tree height between 2004 and 2006 by time period. Soil samples were taken in September 2004 by a soil sampler (DIK-1640: Daiki Rika Kogyou Co., Ltd.). Soil samples were used for measurements of EC(1:5), concentrations of water-soluble ions (Na, Mg, Ca, K, and phosphate) and nitrogen and carbon contents. Concentrations of water-soluble ions were determined with ICPM-8500 (Na, Mg, Ca and K, Shimadzu Co.) and UV-1700 ultraviolet absorptiometer by colorimetric method (phosphate, Shimadzu Co.). Content of carbon and nitrogen in soil sample were determined by high temperature combustion method (830 ˚C) with Sumigraph NC-22 analyzer (Sumika Chemical Analysis Services Ltd.). Probes of soil moisture monitoring system (Unidata Pty Ltd.) were installed in each afforestation sites (0.3, 0.5 and 1.0 m of soil depth) and were used for measurement of volumetric water content with time. Volumetric water content were converted to pF value by results of permeability experiment in the field and laboratory (Koyanagi, personal communications).

3. Results and Discussion

Fig.2 shows the average of height growth of planted four tree species in the trial sites during 2004-2006. The average values of height growth tended to decrease with mean rainfall at each sites. The maximum of the mean height growth was *E. cladocalyx* at Bakers Hill (167±31 cm/y (1σ)), and the minimum value of those was *E. polybractea* at low site of Tammin (18±9 cm/y).

There were only two cases of different trend between the average of height growth and mean rainfall. The mean height growth of *A. acuminata* at high site of Calingiri (132±30 cm/y (1σ)) was greater than that at Bakers Hill (94±19 cm/y (1σ)). The average of height growth of *E. polybractea* at Bakers Hill (78±22 cm/y (1σ)) was highest, however, second highest site of that was high site of Tammin (35±10 cm/y (1σ)).

In salinity risk area, height growth of planted trees at lower altitude site generally tended to be slower than that at high site. Because groundwater depth at low site is shallower than that at high site and height growth of planted trees at low site tend to be suffered from salinity stress. In Calingiri, the mean height growth of *A. acuminata* at low site (79±25 cm/y (1σ)) was 40% lower than that at high site (132±30 cm/y (1σ)). In Tammin, the average values of height growth of *E. cladocalyx* and *E. polybractea* at low site were 58 and 51% of that at high site (*E. cladocalyx*: 52±16 cm/y (high site) and 30±22 cm/y (low site), *E.*

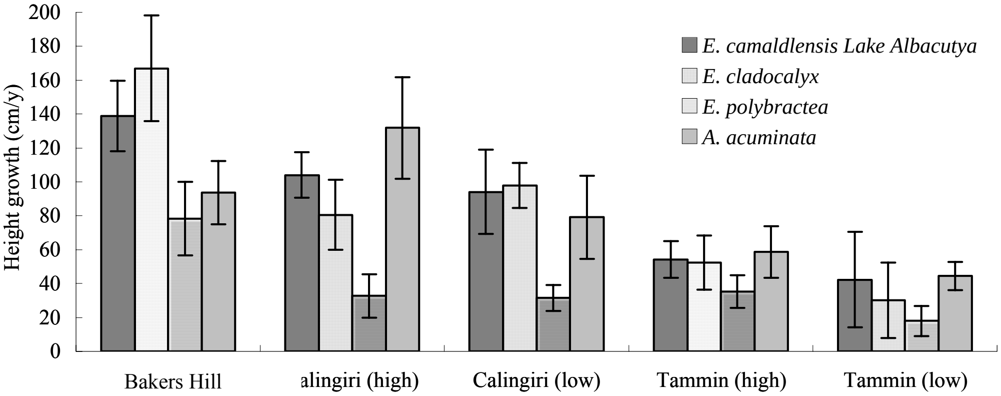

Fig. 2. The average of height growth of planted four tree species at each afforestation site.

polybractea: 35±10 cm/y (high site) and 18±9 cm/y (low site)). There was different relationship between altitude and the mean height growth of *E. cladocalyx* in Calingiri (high site: 80±21 cm/y, low site: 98±13 cm/y). The mean height growth of *E. polybractea* at low site was similar value to that at high site in Calingiri (high site: 33±13 cm/y, low site: 32±8 cm/y).

Fig.3 shows the vertical profiles of EC(1:5), concentrations of water-soluble ions, carbon and nitrogen in soil at each afforestation sites. In general, if EC(1:5) are over 0.4 dS/m, the soil has risk of salinity stress for tree growth. The surface at Bakers Hill and 1.0 m depth at high site of Tammin reached 0.55 and 1.15 dS/m, respectively. EC(1:5) of 1.0 m at high site in Tammin was contributed by high concentration of Na, however, that of surface in Bakers Hill was affected by high concentration of K and Ca. Theoretical value of EC(1:5) converted by Na concentration in surface soil at Bakers Hill was 0.02 dS/m, and that contributes 3.6% to determined value of EC(1:5). In 1.0 m depth at high site in Tammin, that was 0.65 dS/m and contributes 57% to measured value. Water-soluble K and Ca are generally as nutrient for plants, those may affect high growth of planted trees at afforestation site in Bakers Hill. In surface soil of Bakers Hill, content of carbon and nitrogen were higher than any other sites and C/N ratio was relatively low value (13.0). Those could indicate that there was advantage for growth of seedling at afforestation site of Bakers Hill.

Fig.4 show volumetric water content and pF value at each afforestation sites. At Bakers Hill, the ranges of volumetric water content were 0.06-0.20 (0.3 m), 0.03-0.30 (0.5 m) and 0.03-0.17 (1.0 m), respectively. The volumetric water content at 0.3 and 0.5 m was almost higher than that at 1.0 m. Those pF values were almost between 1.8 and 4.2, and that suggested that those pore water were almost useful for uptake by planted trees. High growth of planted trees at Bakers Hill could be supported by this water environment in shallow soil layer. At high site of Calingiri, pF value at 1.0 m was almost gravitation water (pF < 1.8), however, those at 0.3 and 0.5 m were almost hygroscopic water level. The water environment in shallow layer of high site could be disadvantage for growth of seedling and young planted trees. At low site, values of volumetric water content at 3 depths were similar values and trend. The water permeability coefficients of saturated soil determined by field and laboratory experiments at 0.5 and 1.0 m depth soil were one order higher than that in same depth of high site (Koyanagi personal

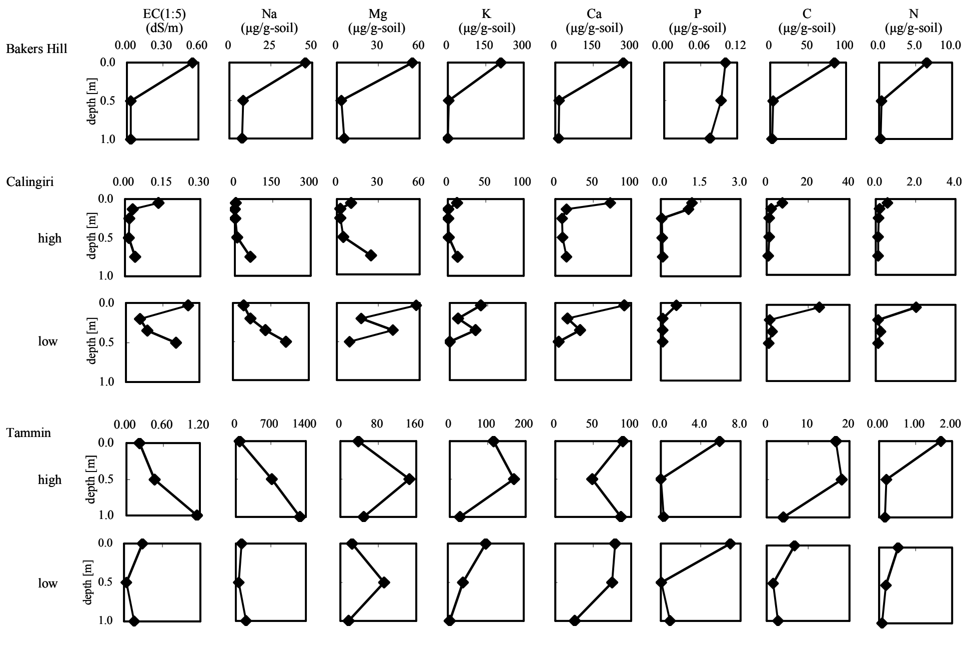

Fig. 3. Vertical profile of EC(1:5), concentrations of water-soluble ions, carbon and nitrogen in soil at each afforestation site.

communications), and the trend of volumetric water content could reflects the physical environment for water penetration. However, EC(1:5) and water-soluble Na concentration were relatively high values, height growth of *A. acuminata* at low site might be affected by stress of water-soluble Na concentration. Theoretical value of EC(1:5) converted by Na concentration is 0.09 dS/m at 0.5 m at low site of Calingiri, and that contributes 46% to determined value of EC(1:5).

The ranges of volumetric water content at high site in Tammin were 0.07-0.38 (0.3 m), 0.09-0.23 (0.5 m) and 0.00-0.36 (1.0 m), respectively. pF values at high site in Tammin were almost over 4.2, and these values suggest that the water environment at high site was disadvantage for growth of planted trees. At low site in Tammin, volumetric water content at 0.3 m depth was relatively low (range: 0.00-0.29, median: 0.03) to that at deeper layer. pF value at 0.3 m depth was almost hygroscopic water level (pF > 4.2), and this could suggests that physical condition for water penetration in this depth was strongly disadvantageous to uptake of water by planted seedling and young trees.

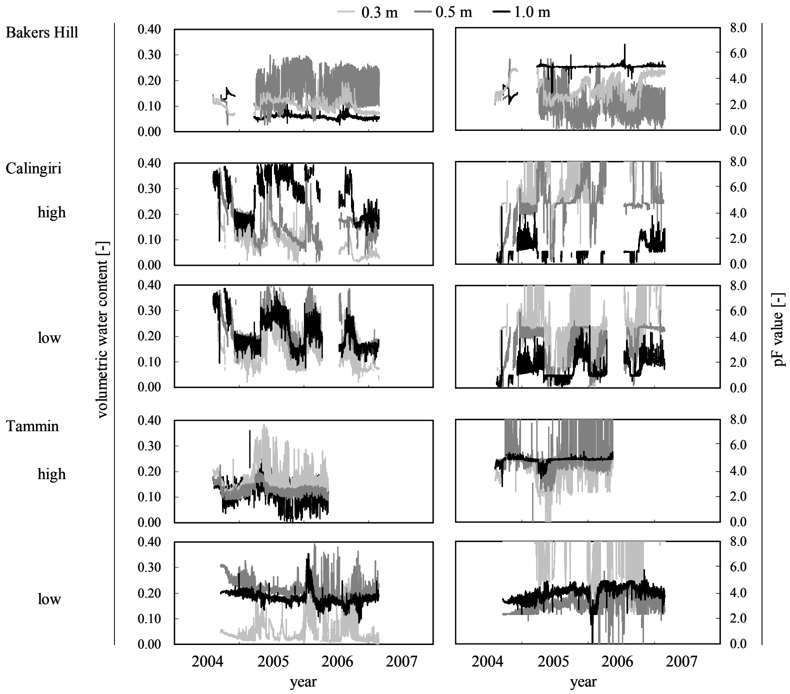

Fig. 4. Volumetric water content and pF values with time converted by volumetric water content at each afforestation site.

At afforestation site of Bakers Hill, height growth of some species (*E. camaldulensis* and *E. cladocalyx* and *E. polybractea*) were higher than any other sites, and those were supported by soil moisture (0.3 and 0.5 m) and concentrations of water-soluble nutrients in the soil. At high site of Calingiri and low site of Tammin, pF values of shallow layer were almost hygroscopic water level (pF > 4.2), and physical condition of water permeability may have to be improved for carbon sequestration. The range of height growth of *E. camaldulensis Lake Albacutya* at low site of Calingiri and Tammin tended to be wider than that at high site, however, the average of height growth of those at low site were similar to those at low site. This may suggest that the main factor of carbon fixation of growth of *E. camaldulensis Lake Albacutya* is not soil chemical properties and physical condition for water permeability but mean rainfall.

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References

Aikawa S., Oda Y., Kaneoya S., Hamano H., Kawarasaki S., Tanouchi H., Yamada K., Kojima, T. (2008): Development of sapling cultivation technology for afforestation of salt-affected land. *Journal of Ecotechnology Research*, **14**(1): 29-32

Matusmoto T., Kato S., Abe T., Kojima T. (2006): Estimation of water availability condition for afforestation in desert of Western Australia using carbon stable isotope ratio analysis. *Journal of Arid Land Studies*, **15**(4): 243-246.