Original paper

A basic study of greening of dry-zone in Myanmar ; Physiological responses to drought stress in *Eucalyptus camaldulensis* and *Quercus phyllyraeoides* grown in different soil conditions [*1]

Min Zaw Oo [*2]　・　Nakao Toshio [*2]

Eucalypt (*Eucalyptus camaldulensis*) and Ubamegashi (*Quercus phyllyraeoides*) seedlings were planted in green house of Miyazaki University, using two types of soil (clay and silt) and 3 different sizes of pots(3 liters,7.5 liters,11 liters). Transpiration rate, electron transport rate and soil water content were measured before and after stopping irrigation. Those parameters were used to compare drought tolerance and water usage by Eucalypt and Ubamegashi ; and to study the effects of soil type and soil volume on two species under water stress. The results show that Ubamegashi can survive longer period than Eucalypt under the same severe drought stress; Ubamegashi uses less water than Eucalypt ; Ubamegashi seedlings in silt soil indicate better physiological responses than those in clay soil under severe drought stress; and much volumes of soil can maintain more available soil water for plants to use.

Ⅰ. Introduction

Although 50% of total land area of Myanmar is still covered with vast and diverse forests, its central part is barren and with no forest cover, threatening desertification. This dry zone occupies about 12% of the total land area, facing the harsh conditions for tree growth (about 700 mm annual rainfall, 40 ℃ mean maximum temperature) and the rainfall in dry season (from Dec. to Mar.) is nearly zero. Nowadays, dry-zone greening programs are being established by plantations and conservation of remaining natural vegetation. In dry- zone greening plantations, Eucalypts were planted extensively because of its adaptability to all poor soils and fast growth rates with coppicing ability. In the first year of plantations, the planted seedlings have to overcome four months period of severe drought ; and survival rate of plantations are very low. For successful establishment of plantations in dry- zone greening, it can be considered to practice irrigation methods; to use drought tolerant species (preferably indigenous species) ; and to change the soil conditions to be effective for water retention (soil volume, soil type, use of input materials to improve soil water retention).

Since irrigation methods are very difficult to practice in Myanmar, the last two methods should be tried. This experiment aims to compare the drought tolerances of Eucalypt (*Eucalyptus camaldulensis*) and Ubamegashi (*Quercus phyllyraeoides*) ; and to find the appropriate soil conditions for effective good water retention to overcome four months period of severe drought.

Ⅱ. Materials and Methods

At mid-June, two years old Eucalypt and Ubamegashi seedlings were planted in green house, in Miyazaki University. 44 seedlings of Eucalypt and Ubamegashi were planted in two different soil types (clay and silt soils) using 3 different pot sizes of 11 liters, 7.5 liters, 3 liters respectively. They were cut at 30 cm height and every pot was irrigated until mid-August by pouring water of about 90 mm per month that is average monthly rainfall in planting season of dry-zone in Myanmar, and irrigation was stopped at 14, August. No fertilizers were treated to seedlings. Maximum temperature was around 37℃. Measurements were started from the beginning of August. At the time of measurement, Eucalypt and Ubamegashi seedlings were 40 cm and 34 cm in average height and 80 and 50 average leaves respectively, and leaf area of Eucalypt is 2. 3 times larger than that of Ubamegashi. Soil water content measurements were taken every two days from four ECHO sensors (Decagon Devices, Inc., USA) which were set up at 10 ～ 20 cm depths in each 11-liter pot of clay and silt soils of two species. Twelve representative seedlings were selected, and transpiration rates (TR) and electron transport rates(ETR) measurements were conducted to the two upper leaves of each seedling in every five days. The same leaves were used for measurements. Both

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[*2] Fac. Agri., Miyazaki Univ., Miyazaki 889-2192 宮崎大学農学部

measurements (TR and ETR) were conducted in same days under natural light until the seedling became permanently wilted.

Transpiration rates were measured by using LI-1600 Steady State Porometer (LI- COR, inc., USA). Water loss from a leaf placed in the sensor head of LI-1600 porometer is determined by measuring the flow rate of dry air necessary to maintain a constant relative humidity inside the sensor head. Stomatal conductance and leaf transpiration rates are calculated directly from the measured values of relative humidity, leaf and air temperature, and flow rate.

$$F = [(Tc / 273.15) + 1]\,[101.3 / P]\,M$$

[Where F = volumetric flow rate ($cm^3 s^{-1}$) ; Tc = sensor head temperature (℃) ; P = barometric pressure at the measurement site (k Pa) ; M = standard volumetric flow rate of dry air into the sensor head as measured by LI-1600 mass flow meter]

$$E = (Pc - Pa)\,F / A$$

[Where E =transpiration rate ($\mu g\ cm^{-2} s^{-1}$) ; Pc =water vapor density in the sensor head ; Pa =water vapor density in the dry air stream entering the sensor head(constant RH of 2% is assumed) ; A= leaf area (cm^2).] Electron transport rates were measured by using portable pulse-modulated chlorophyll fluorometer (Mini-PAM, Heinz Walz, Germany) using the formula, (Schreiber *et al*., 1995; Mohammed *et al*., 1995)

$$ETR = 0.84 * 0.5 * PPFD * (Fm` - F) / Fm$$

[Where ETR= Electron transport rate (μ mol electrons $m^{-2} s^{-1}$) ; $(Fm' - F)/Fm$ = yield]

Soil water content measurements were made by the ECHO Sensor. Since the dielectric constant of water is much higher than that of air or soil materials, it can be used as a sensitive measure of water content. The ECHO probe measures the dielectric constant of the soil in order to find its volumetric water content. In this experiment, volumetric water content was transformed to water content (weight %) and again weight % was calibrated to soil moisture potential. Water content (Wt %) of soil profile was measured in laboratory using soil samples taken from different depths of the pots by a pipe, and then calculated to soil moisture potential.

Ⅲ. Results and Discussion

It is evident that physiological processes (TR & ETR) of Ubamegashi in every pot were still functioning up to 45 days after stopping irrigation (from 15th Aug to 3rd Oct) while transpiration rates and electron transport rates of Eucalypt decline to zero i e. the Eucalyptus seedlings are permanently wilting (Fig-1 and Fig- 2). In this experiment, all Eucalypt seedlings in 3 liter and 7.5 liter pots were permanently wilted and those in 11 liter pots also started wilting at 3rd, Oct (45 days after stopping irrigation). Although soil desiccation rate in Eucalypt can be affected by its larger seedling size and broader leaf area compared to Ubamegashi, it can be observed that Ubamegashi has longer survival period than Eucalypt in the same pot sizes of both soil types under the same drought stress.

Eucalypt shows normal responses of transpiration rates on water stress i e, when water stress become severe, TR also becomes lower (Fig-1.B). Under irrigated condition, transpiration rates of Eucalypt were higher than those of Ubamegashi in every size of pots, and then decline to nearly zero as water stress becomes severe. However in the case of Ubamegashi, transpiration rates show fluctuations even in severe water stress, and they can resume the same TR as in irrigated condition (Fig-1.A). It can be considered that the roots of Ubamegashi reached the deeper part of soil and can use retaining available water (Fig-4) ; and/or Ubamegashi shows adaptation to different water stress level by reducing transpiration process.

Electron transport rates have been used to estimate the drought tolerances of some species together with other parameters., showing decreased values when water stress becomes severe (Higuchi *et al*, 2001 ; Li. and Kakubari. 2001). In this experiment, the light curves of both species show that in comparison to those of irrigated stage, electron transport rates become lower when water stress seems severe (Fig- 2). When seedlings started to wilt, ETR values decline to nearly zero. But the patterns of ETR declination are different in two species. Ubamegashi shows fluctuations and Eucalypt first increase and then decrease to nearly zero faster than in Ubamegashi (Fig- 3). Electron transport rates of Ubamegashi in silt soil of every size of pots show higher values than those of seedlings in clay soil. In both species, physiological responses of seedlings grown in larger pots show significantly higher values than those of 3 liter pots. It is because the seedlings can use water maintained in deeper parts of larger pots although shallower parts (10 ～ 20cm soil depth) become dry (Fig- 4).

It is supposed to have parallel relation between TR and ETR . But in this experiment, when TR values are low, ETR values still show high level. In Eucalypt, TR started to decline 10 days after stopping irrigation, but ETR still shows moderately high values until 30 days after stopping irrigation. Therefore the damage effect of drought stress on stomatal opening was visible earlier than the effect on photosynthetic electron transport system. It can be considered that even the photosynthetic efficiency under light pressure shows high values, carbon dioxide fixation processes (Calvin cycle) has been damaged to some extent by drought stress.

At the beginning of August, soil moisture potential of clay and silt soils of both species are nearly the same (Fig-5). But 45 days after stopping water, soil desiccation rates show different patterns. Soil moisture potential in clay and silt soils of Ubamegashi are much lower than those of Eucalypt showing that Eucalypt uses more water than Ubamegashi in both types of soil. It can be considered that although transpiration rates of Eucalypt are lower when drought stress becomes severe, it consumes more water because of broader leaf area and more leaves.

The results show that Ubamegashi has longer survival period than Eucalypt in the same size of pots though the larger seedling size and broader leaf area of Eucalypt can fasten its soil desiccation rate; Ubamegashi uses less water than Eucalypt ; Ubamegashi seedlings in silt soils show better physiological responses than those in clay soils under severe drought stress condition ; and much volumes of soil can maintain more available soil water for plants to use. It is possible to overcome four months drought stress by using larger volume of soil, Ubamegashi species and silt soil in green house. Now this experiment is still on-going and physiological responses of Ubamegashi are being studied. A later study of comparing drought tolerance of Ubamegashi and some indigenous species of dry-zone of Myanmar (*Acacia catechu*, *Albizzia lebbek*, *Cassia siamea*, etc.) is expected to get helpful information for dry-zone greening plantations.

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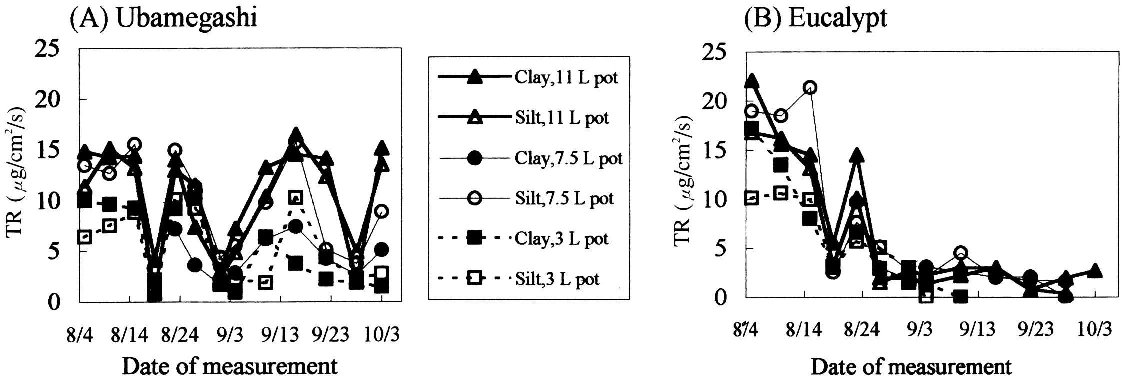
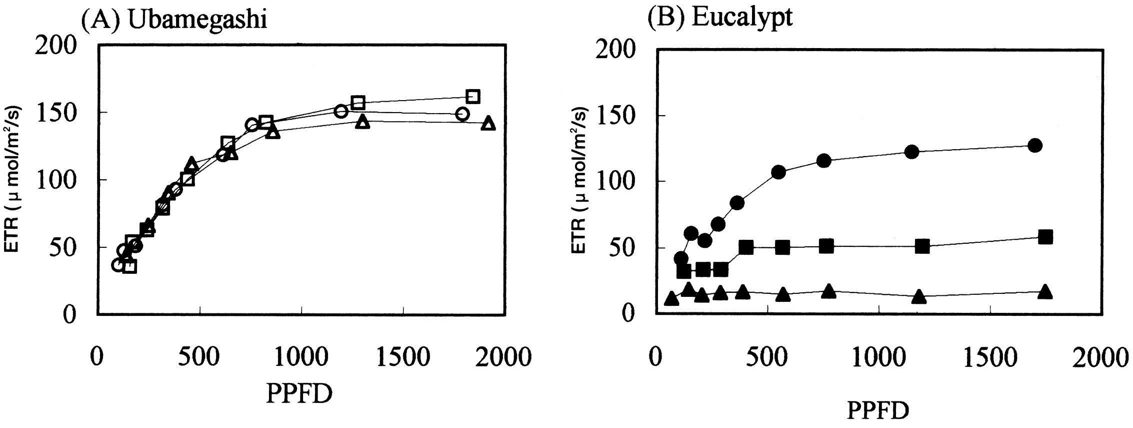
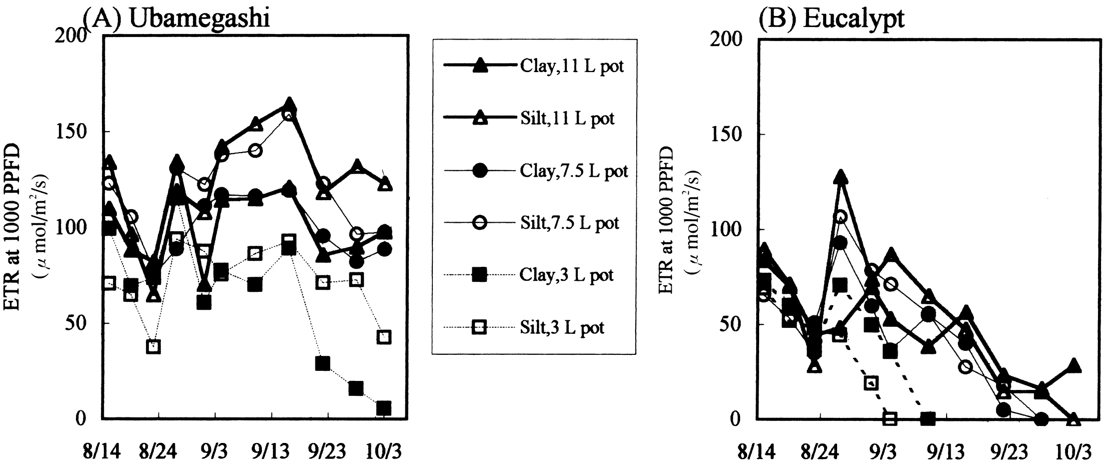


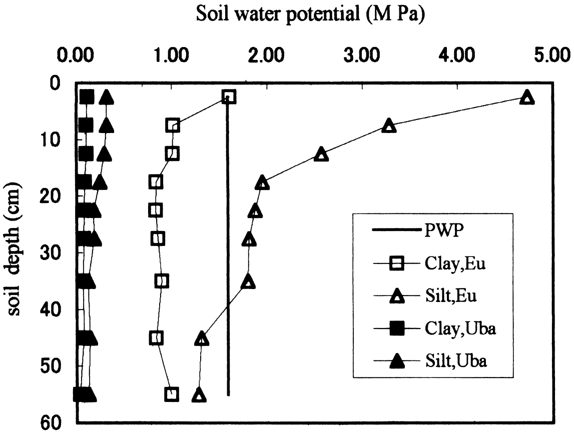
Fig－1. Transpiration rates of (A) Ubamegashi and (B) Eucalypt in different soil types and soil volumes (The same symbols are used for both graphs)



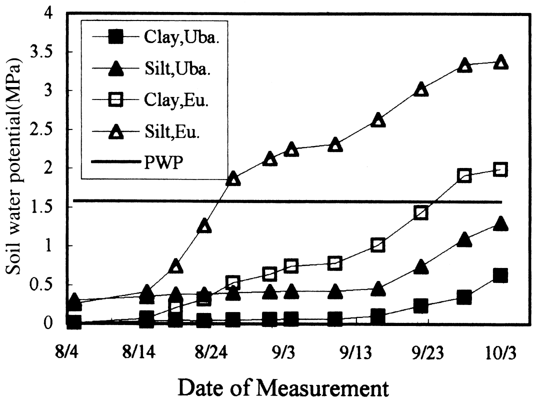
Fig－2. Light curves of (A) Ubamegashi and (B) Eucalypt in 11 L pots ; circles at irrigated stage, squares at 21 days after stopping irrigation, and triangles at 45 days after stopping irrigation



Fig－3. Electron transport rates (at 1000 PPFD) of (A) Ubamegashi and (B) Eucalypt in different soil types and soil volumes (The same symbols are used for both graphs)



Fig－4. Soil water potential of soil profile at 30 days after stopping irrigation (11 liter pots) (PWP=permanent wilting point)



Fig－5. Change of soil water potential in each treatment of 11 liter pots within two months (PWP=permanent wilting point)

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