1. Summaries of Doctor Theses

Study on partitioning evapotranspiration into transpiration and soil evaporation

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It is important for more precise irrigation planning and management to evaluate transpiration and soil evaporation in evapotranspiration individually. Then, this study examined measuring techniques and simulation models for partitioning transpiration and soil evaporation from evapotranspiration.

Maize was planted in an unheated and naturally ventilated greenhouse at different plant densities. Evapotranspiration was measured by weighing lysimeters and soil evaporation was measured by micro-lysimeters. Transpiration was determined as a difference between evapotranspiration and soil evaporation. The fixed and Uchijima's variable light extinction coefficients were used to estimate transpiration and soil evaporation. The Uchijima's variable light extinction coefficient gave a better estimation of transpiration at all plant densities in this study than the fixed light extinction coefficient. A modified variable light extinction coefficient was proposed for a more precise estimation. Cumulative transpiration and soil evaporation were estimated better for 8 plants/m^2 than those for 4 plants/m^2. Daily crop coefficients were related to days after emergence and different crop coefficient curves were obtained for two plant densities. Then, daily crop coefficients of two plant densities were related to leaf area indexes and an exponential relationship was obtained.

Energy balance on a field is the main factor for evapotranspiration. Then, maize was planted at an open field. The Bowen ratio energy balance method (Method 1) was used to measure latent heat fluxes from maize field and soil. Then, latent heat flux from canopy was determined as a difference between those from maize field and soil. A weighing lysimeter and sap flow gauges (Method 2) were used to measured latent heat fluxes from maize field and canopy, respectively. Then, latent heat flux from soil was determined as a difference between those from maize field and canopy. The coefficients of determination in latent heat fluxes by Method 1 and Method 2 were 0.71 for maize field, 0.74 for canopy and 0.36 for soil. Method 1 underestimated latent heat flux from maize field and overestimated that from canopy. It resulted in an underestimation of latent heat flux from soil. Measurements of energy balances among maize field, soil and canopy by Method 1 indicated that soil had a major impact on the energy balance between canopy and maize field. During a dry period, sensible heat from the soil contributed about 31 % to latent heat flux from canopy.

It was clear by this study that the light extinction coefficient was important to estimate transpiration and soil evaporation. Then, the modified variable light extinction was proposed. It became clear that the Bowen ratio energy balance method was useful to validate evapotranspiration models.

Study on drought tolerance of *Salix psammophila* and *Salix matsudana* used for afforestation in semi arid land, China

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In Mu-us sandy area of Inner Mongolia, China, *Salix psammophila* C. Wang et Ch. Y. Yang and *S. matsudana* Koidz. have been planted for sand dune stabilization and shelter woods of pasture. *S. psammophila* is a native species in Inner Mongolia, but *S. matsudana* is an exotic. *S. psammophila* and *S. matsudana* are major tree species of afforestation in this region but little is known of the ecophysiological responses of these species to drought stress. The growth of these species was influenced by soil moisture conditions depending on the ground water level and there was drought damage on upper part of the dune. Consequently, an understanding of ecophysioligical responses to environmental changes is required for a more insightful selection of species for reforestation in arid land. The objectives of the present study were to clarify the drought tolerance of *S. psammophila* and *S. matsudana*.

Firstly, the effect of drought stress on leaf water relations was investigated in *Salix psammophila* and *S. matsudana* by the pressure-volume technique. Under the moist soil water condition, *S. psammophila* and *S. matsudana* showed high values of leaf water potential at the turgor loss point (ψ_w^{tlp}) and osmotic potential at saturated point (ψ_s^{sat}). Shoot growth and total biomass of both species were decreased in responses to drought treatment. The results suggest that both *S. psammophila* and *S. matsudana* were sensitive to drought. It was also observed that ψ_w^{tlp} and ψ_s^{sat} in *S. matsudana* markedly decreased during the drought treatment period whereas those in *S. psammophila* showed very little changes, implying a higher ability of osmotic adjustment for *S. matsudana* than for *S. psammophila*.

In the second experiment, ecophysiological responses to drought stress were investigated in cuttings of *Salix psammophila* and *S. matsudana*. Photosynthetic rate, transpiration rate, stomatal conductance and leaf water potential were measured using 3-month-old cuttings of both species grown under drought (-0.005Mpa soil water potential) and control (well-watered) conditions. Under the drought stress, *S. psammophila* showed decreases in transpiration rate through stomatal closure and maintained high value of leaf water potential, suggesting a high ability of dehydration postponement. *S. matsudana* also exhibited control of transpiration rate as a result of decreases in stomatal conductance during the drought treatment period, but these responses were less than *S. psammophila*. It was suggested that *S. matsudana* consumed much water under drought condition. Photosynthesis and growth of both species decreased as a result of drought stress. However, these decreases were less in *S. matsudana* than in *S. psammophila*.

In the third experiment, responses of water potential and transpiration rate to drought stress were investigated in cuttings of *S. psammophila* and *S. matsudana*. 4-month-old cuttings of them were prepared in pots and water-withheld. Soil water potentials, predawn and midday leaf water potentials, stomatal conductance, transpiration rate and photosynthetic rate of them were measured. The predawn and midday leaf water potential in *S. matsudana* decreased more rapidly than in *S. psammophila* as a result of drought stress. There was no difference in leaf water potentials between two species when transpiration rate began to decrease. However, the soil water potential at steep decline of stomatal conductance, transpiration rate

and photosynthetic rate was lower for *S. matsudana* than for *S. psammophila*. Similarly, decrease in stomatal conductance, transpiration rate and photosynthetic rate occurred earlier in *S. psammophila* than in *S. matsudana*, which was caused by decrease leaf water potential. The results suggest that both *S. psammophila* and *S. matsudana* were sensitive to leaf water deficit, but their responses of transpiration rates to soil water depletion were different between them. *S. psammophila* with less water consumption could tolerate withholding water longer than *S. matsudana*.

Finally, leaf water relations of six tree species, *Salix psammophila*, *S. matsudana*, *Salix cheilophila*, *Artemisia ordosic, Caragana korshinskii* and *Sabina vulgaris*, living in Mu-us sandy area in Inner Mongoria, China, were examined by the pressure-volume technique. *S. psammophila* and *S. matsudana* tolerated drought stress more than other tree species, because *S. psammophila* and *S. matsudana* showed lower values of leaf water potential at the turgor loss point (ψ_w^{tlp}) and osmotic potential at saturated point (ψ_s^{sat}) than the others. It was also observed that ψ_w^{tlp} and ψ_s^{sat} in *S. matsudana* markedly changed under the different conditions in ground water level whereas those in *S. psammophila* showed very little changes.

The overall results of the present study reveal that *S. psammophila* and *S. matsudana* of survival strategy to drought stress were different. *S. matsudana* had higher ability of osmotic adjustment than *S. psammophila*, while consumed much of water under drought condition. *S. psammophila* showed decreases in transpiration rate through stomatal closure with soil water depletion and maintained high value of leaf water potential, suggesting a high ability of dehydration postponement.