Analysis of the Effects of Different Environmental Conditions on Root Elongation and Leaf Stomatal Dynamics in Crops

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Summary

Global climate change is increasing the risk of extreme temperatures, droughts, and floods. Plant roots are important organs for absorption of water and nutrients from the soil, respiration, and other metabolic processes, and understanding their dynamics is critical for improving crop production, especially in non-irrigated areas where a-biotic stresses are a problem. For example, root distribution in the soil indicates crop response to various soil moisture conditions. Therefore, comparing and studying the effects of changes in soil moisture from waterlogging to drying on root elongation is important for understanding plant survival strategies. At the same time, examining the behavior of stomatal conductance, which controls leaf transpiration and photosynthesis and is closely related to root dynamics, will lead to a systematic understanding of the environmental response of the entire plant body. Therefore, this study was conducted to compare the effects of environmental conditions on root elongation and leaf stomatal conductance in different C_3 and C_4 crops and to identify important traits related to environmental responses in crops.

In Chapter 2, the interaction between genotype and environment was analyzed in maize (*Zea may* L.), sorghum (*Sorghum bicolor* Moench), millet (*Echinochloa utilis* Ohwi), and rice (*Oryza sativa* L.) to determine root responsiveness to moderate, dry, and waterlogged soils. Results showed that in maize and sorghum, roots showed plasticity, extending more into shallow soil layers in waterlogged soils and into deeper soil layers in dry soils. Rice root distribution did not differ significantly among soil moisture treatments. Comparison of residual variances and regression coefficients showed that maize had a greater environmental response in both roots and shoots, while rice had a smaller response. Millet had a larger residual variance for roots than for shoots, and sorghum had a smaller residual variance for roots, indicating that some species had different environmental responses above and below ground. Next, in Chapter 3, we compared and examined the characteristics of the differences in root elongation under

waterlogged conditions from changes in oxygen concentrations in the inner root zone, using maize and rice, which showed markedly different root dynamics in Chapter 2. The results showed that the oxygen concentration in the roots was significantly lower in maize than in rice during waterlogging. The results suggest that this root hypoxia affects the reduction of stomatal conductance and dry matter weight in leaves. In Chapter 4, the effects of soil moisture and atmospheric environmental conditions on stomatal conductance and aboveground biomass were compared and examined with the aim of identifying variations in crop survival strategies. The experiment was repeated twice. The results showed significant relationships among soil moisture content, leaf area, and stomatal conductance and above-ground biomass for each of the prototypes. In particular, stomatal conductance was greater under dry to moderate soil conditions for maize and sorghum under high temperature conditions and moderate to waterlogged soil conditions for rice. Then next, crops were grown in a growth chamber under six environmental conditions combining atmospheric temperature and soil moisture, and the relationship between stomatal response to environmental factors and biomass production in each crop was compared and investigated. The results showed that stomatal conductance, photosynthetic rate, and transpiration rate of maize and sorghum decreased in waterlogged soils, as well as aboveground biomass, regardless of temperature change, suggesting that hypoxia in the soil limited their growth. On the other hand, stomatal conductance, photosynthetic rate, and transpiration rate decreased in the dry soil at lower temperatures. We hypothesized that this was related to the characteristic of the photosynthetic rate of C_4 crops, which is slow at low temperatures.

In conclusion, the differences in crop root plasticity in response to environmental changes could be a survival strategy of the roots in response to changes in soil conditions from anaerobic to aerobic environments. In arid soils, root water uptake is important, and for this reason, an increase in root length density in the deeper layers is important. Under high temperature conditions, stomatal conductance contributes to the maintenance of optimal photosynthetic rate in terms of leaf temperature regulation, as it was found to function to actively open stomata to increase transpiration rate and cool leaf temperature. The combination of soil moisture and atmospheric temperatures indicated that maize and sorghum growth was more affected by soil moisture conditions than by atmospheric temperatures. This is because stomatal opening and closing may be altered by the transmission of information about water stress received by the roots, and we conclude that the ability to maintain stomatal conductance function is important for maintaining photosynthesis in fluctuating soil moisture conditions.