学 位 論 文 要 旨

Investigation of Alternate Wetting and Drying Irrigation Practice for Climate-Smart Water Management in Paddy Rice Fields

水田における気候変動に対応した水管理のための間断灌漑に関する研究

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Water is an integral component of food security and a valuable resource for paddy cultivation, primarily practiced using traditional flooding conditions. Paddy rice cultivation is expanding in Sub-Saharan Africa, East Africa in particular. However, the expansion is being affected by climate change events: droughts, floods, and other intensified hazards. These contribute to reduced rice yields and changes in traditional seasons, leaving the region in a vicious cycle of food insecurity and malnutrition. Despite the region's enormous agricultural potential, the region largely depends on rice imports (> 500,000 tons annually) from Asia. In this study, literature synthesis was conducted to assess the potential of AWD technology in East Africa. Research questions, including why AWD is less practiced in the region were formulated, to (i) unveil critical gaps and core issues on paddy rice production systems, water management and food security in four EA countries (Uganda, Kenya, Tanzania, and Ethiopia) and (ii) examine future trajectories to improve paddy rice production in the region for building stable food security under threats of climate change. The literature search was performed from electronic databases on key scientific papers, technical reports, and data on food insecurity, paddy rice production systems, water management, and government policies. This synthesis shows that water scarcity due to decreasing precipitation is a major threat to paddy rice production, while food insecurity is linked to low agricultural productivity. The region has registered increased rice production since 2000, attributed to a slight expansion in irrigated areas. Climate-smart agricultural technologies, including alternate wetting and drying (AWD) and system of rice intensification SRI are being practiced at the micro-research level promising for improving yields, though is little is known about AWD technology among farmers.

The study evaluated the effect of AWD regimes on paddy rice cultivation in phytotron from Feb/2021 to March/2022 at Tokyo University of Agriculture and Technology (TUAT), Japan. Three AWD regimes—AWD5, AWD10 & AWD15 as treatments, were defined when the water level in observation tubes dropped to -5, -10 and -15 cm below the ground surface, and continuous flooding (CF) as control—when water ponded water disappeared from the ground surface. Rice variety Ikuhikari, a short Japanese widely grown rice cultivar, was directly seeded during the pot rice cultivations. Agronomic parameters and soil hydrological conditions were measured, including crop growth, tillers, yield components, biomass, harvest index, and pressure head. The results showed no significant difference (5%) between irrigation treatments regarding yield components, including tiller and number of panicles, harvest index and water productivity. Any water stress due to different water management at panicle and grain formation affected crop growth. AWD regimes had high water productivity and improved irrigation water saving by up to 36 %. Hydrological conditions during crop growth indicate the low-pressure head among the water regimes even in CF. Similarly the pressured heads varied with the crop growth stage as observed towards the end of crop development to reproductive stages. However the changes in pressured head were proportional to water regimes although the lowest pressure head of -900 cm was observed in AWD15. The low pressure in AWD regimes was attributed to high transpiration and soil drying.

HYDRUS-1D model was applied to examine influence of different water management strategies (CF and AWD regimes) on water flow and soil water balance components in directly seeded paddy rice at pot scale. Initially the potential ET was estimated using the Penman-Monteith (PM) equation and was found inadequate for the closed system with pot rice cultivation due to low ET values. Adjusting potential ET for the pot rice conditions was done by obtaining the correction factor (Cf) based on the relationship of the ground surface area of the phytotron over the surface area of pots, the number of pots and crop density. The Cf was used for adjusting ET in HYDRUS-1D that gave ten times higher ET than the PM-FAO method. The high ET is attributed to the high potential transpiration component of ET. The simulated and observed pressured heads varied quantitively—not straightforward. Water balance and hydrological processes in pot conditions differ from field conditions.

We further evaluated the influence of deficit irrigation scenarios on the root water uptake of paddy rice using HYDRUS-1D model. Three deficit irrigation scenarios were defined by altering the total water applied (TWA) of CF by 80, 60 and 40 %, while maintaining irrigation frequency thus 80-TWA, 60-TWA, and 40-TWA. The simulated RWU accounted for 75, 83, 87 and 88 % of TWA corresponding to CF, 80-TWA, 60TWA, and 40-TWA. HYDRUS-1D is an important tool for simulating deficit irrigation scenarios and irrigation planning. Future research should consider carrying out pilot AWD technology and deficit irrigation scenarios in paddy rice field condition in East Africa—Uganda, to obtain evidenced data for promoting AWD technology in the region.