Evaluation of Rice Growth Characteristics Based on Non-destructive Measurements of Leaf Area Index

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Summary

Rice has spread as the dominant staple food in Asia countries, and increase of yield per unit land area is needed. Not only improving rice cultivars but precision farming are strongly recommended, and therefore, gathering information about rice growth characteristics under various environments is considered to be very important for high rice productivity. Especially, leaf area index (LAI), defined as the ratio of leaf area to a given unit of land area, is one of the important biophysical and ecological parameters. Although measurement of LAI dynamics and spatial characteristics is useful to evaluate crop growth and canopy productivity, a laborious work of destructive samplings is commonly necessary. Non-destructive measurement methods with plant canopy analyzers such as LAI-2000 and LAI-2200 (LI-COR) and can be utilized to overcome the disadvantages. However, estimation accuracy of non-destructive measurement is needed to improve. By using frequent measurements and simple mathematical model, evaluation method of rice growth characteristics was developed in this study. This study aims to apply this method to evaluation of genotypic variation and field research in farmers' fields in developing countries.

First, field experiments were conducted for 6 rice cultivars under 5 treatments in 2010 and 2011, and LAI was measured non-destructively one or two times per week with a plant canopy analyzer. Five parameters were calculated by applying non-destructive measurements to four equations such as a logistic equation. By using these parameters, we analyzed cultivar characteristics and the effects of growth environment of LAI dynamics quantitatively. Maximum interception growth rate was considered as characterizing each cultivar and growth environment because the parameter had no interaction between cultivar and environment. Therefore, this evaluation method is believed to apply to many cultivars and be contributed to investigation of farmers' fields because this method facilitates measuring many plots.

Secondly, experiments were conducted for 5 rice cultivars under 2 fertilizer treatments in 2013 and for 3 cultivars under 3 plant density levels in 2014, and stratified LAI was measured with a plant canopy analyzer. The stratified LAI measurements with a plant canopy analyzer were closely correlated with that by stratified clipping method at every

cultivar and treatment. The parameters calculated from the stratified LAI measurements with a plant canopy analyzer and four moment equations numerically represented LAI vertical distribution in each growth stage. The differences in the parameters could also be used to quantify the effect of cultivars, fertilizer treatments and plant density treatments. This evaluation method might help us to understand the effect of canopy structure on photosynthetic ability and dry matter productivity.

This study also parameterized leaf dynamics for a rice diversity research set of germplasm (RDRS) and high yielding cultivars (total 58 cultivars). The significant differences among genotypic groups were observed in relative LAI growth rate and the maximum interception growth rate. High-yielding cultivars released by IRRI had higher values of the maximum interception growth rate, suggesting that the varieties have been improved in terms of canopy development. In contrast, since Takanari and Milyang23 didn't have extreme characteristics in the LAI dynamics, further improvement may be possible.

In farmers' fields in Vientiane province, Lao PDR, we analyzed the LAI dynamics and the relationship between the rice productivity and soil. Because the LAI in the farmers' fields increased almost linearly in this study, a straight-line regression was used for the analysis. The slope of the regression line was defined as LAI growth rate. The rice yield in the farmers' fields was correlated with the maximum LAI. The variability in the maximum LAI was explained by the LAI growth rate but rarely by the effective accumulated temperatures from the estimated transplanting date. The LAI growth rate was associated with the nitrogen and carbon content in the soil. These results suggest that the rice productivity in farmers' fields is governed by the soil fertility through LAI growth, and that LAI monitoring is an effective tool to evaluate the production.

In 77 farmers' paddy fields in the Bakan district, Pursat province, Cambodia, LAI was measured by using a plant canopy analyzer and yield, water status and soil investigations was conducted. The variability in the maximum LAI was mainly explained by that in the LAI growth rate, while the growth period had a significant correlation with the maximum LAI only in the broadcast fields, where earlier planting led to larger LAI. The variability in the LAI was mostly explained by that in the LAI growth rate. The LAI growth rate was affected by water status, planting method (transplanting/broadcasting) and soil condition (C content and C/N ratio), but the effect of N fertilizer was non-significant. These results suggest that the key means to improve rice productivity are earlier broadcasting, water-saving-irrigation methods, effective application of fertilizer and selection of planting methods dependent on the soil fertility.

Synthetic aperture radar (SAR) is proposed as a more suitable method to evaluate rice

growth in this area because it is independent from cloud and solar illumination. We analyzed the relationship between the back scattering coefficient (BSC) in SAR images and LAI of rice. 30 farmers' paddy fields were selected for surveying throughout the growth period in the wet season of 2013, and LAI was measured at 4 time periods before the heading period for each field. X-band SAR images from the COSMO-SkyMed system were used in this study. BSC at 28 of 30 fields was positively correlated with days after transplanting (DAT), and 10 of these results were significant. The increased rate in BSC obtained at the fields where BSC and DAT had a significant correlation, were significantly correlated with LAI growth rate. This finding suggests that if SAR images demonstrate significant increases of BSC against DAT, the increased rate may also represent LAI growth rate, although uncontrollable water levels and weeds occasionally interrupt observation. This study demonstrates the capacity of SAR to evaluate rice production in developing countries.

Although non-destructive measurement was used as replacement of destructive measurement in previous studies, the advantage of non-destructive measurement method was focused in this study. Non-destructive method enables us to measure LAI growth traits easily and to measure the same canopy continuously. By measuring LAI frequently, and applying to simple mathematical model, new evaluation method of rice growth dynamics and canopy structure was developed. Applying this method to various cultivars and rice growth environments reveals genotypic difference of LAI dynamics and variation factor of cultivation environment. In addition to this, I discussed the applicability of SAR to evaluate rice production in developing countries. Combining these methods with another non-destructive measurements might help us to evaluate rice canopy traits efficiently and optimize cultivation management in field level.