Estimating rice growth parameters using X-band scatterometer data

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Ⅰ. INTRODUCTION

Rice is one of the major crops in Korea and primary food source for more than half of the world's population. Microwave radar can penetrate cloud cover regardless of weather conditions and can be used day and night. Especially a ground-based polarimetric scatterometer has advantage of monitoring crop conditions continuously using full polarization and various frequencies. Many plant parameters such as leaf area index (LAI), biomass, plant height are highly correlated with backscattering coefficients and according to frequency, polarization between plant parameters [1]–[2]. Kim *et. al.* (2008) have measured backscattering coefficients of paddy rice using L-, C-, X-band scatterometer system with full polarization and various angles during the rice growth period and have revealed the necessity of near-continuous automatic measurement to eliminate the effect of weather conditions such as wind, moisture [3]. In this paper, thereafter, we analyzed scattering characteristics of paddy rice obtained from X- band automatic scatterometer at the incidence angles of 45° during the whole growth period of the rice and investigated the relationships between scatterometer data and measured ground data such as LAI, plant height, and biomass. Finally, we performed estimation of rice growth parameters using backscattering coefficients.

Ⅱ. MATERAL AND METHOD

The study site was located at a National Academy of Agricultural Science (NAAS) experimental field, Suwon, Korea. The rice cultivar was a Japonica type, called Chuchung. The size field was about 660m^2. The rice seedlings were transplanted in the study site on May 18, 2009 and were harvested on October 12, 2009. We constructed X-band automatic polarimetric scatterometer system which is mainly composed of X-band dual polarimetric square horn antenna with dual-mode transducer, vector network analyzer (VNA), Radio Frequency (RF) cables, RF switch and a personal computer that controls frequency, polarization and data storage (Fig 1, Table 1). This system automatically measures fully-polarimatric backscattering coefficients of rice crop every 10 minutes by RF switch that changes three antennas same interval.

Table 1. Specification of the X-band automatic scatterometer system

X-band automatic scatterometer system	
Center Frequency	9.65 GHz
Bandwidth	1 GHz
Number of Frequency Points	1601
Antenna Type	Dual polarimetric square horn
Antenna Gain	22.4 dB
Slant Range Resolution	0.15 m
Wavelength	0.0031 m
Incident Angle	45°
Platform Height	4.16 m
Measurement time	1 per 10 minutes

Fig. 1. View of L, C, X-band automatic scatterometer system.

Polarimetric scatterometer provides a time domain radar return from a target as a fully polarimetric (HH, HV, VH, VV) amplitude and phase data. The system is calibrated using a calibration kit (SmA, 85052D). Growth data for the rice canopy, such as LAI, fresh and dry weight and plant height, were acquired once every week by destructive sampling. Backscattering coefficients were calculated by applying radar equation [4].

Ⅲ. RESULTS AND DISCUSSION

Backscattering coefficients of paddy fields at X-band ranged from about -54dB ~ -8dB. HH-, VV polarization backscattering coefficients steadily increased toward panicle formation stage and thereafter decreased and again increased near the harvesting season (Fig. 2). Fresh weight was decreased and heads of the canopy were easily show, so X-band as high frequency sensitive to heading or grain maturity after heading stage. This phenomenon agrees well with the finding that the peak of radar backscattering temporal plots occurred well before heads began to appear on wheat [5]–[6].

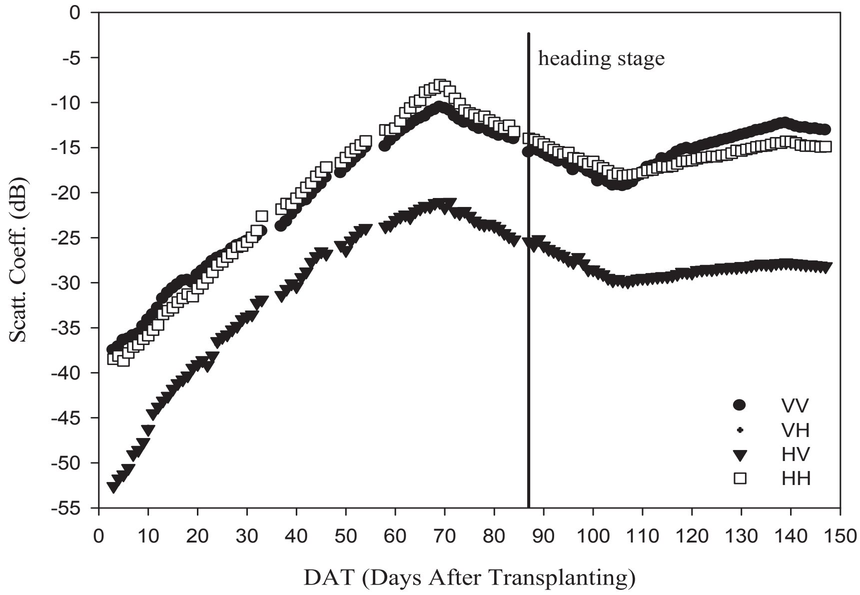

Fig. 2. Temporal variations of backscattering coefficients and incident angle 45° for the X-band.

We conducted a correlation analysis between the backscattering coefficients from X-band and rice growth variables. Backscattering coefficients in X-band were weakly correlated with LAI and biomass but grain weight which related with rice yield was highly correlated with backscattering coefficients with VV polarization. Based on the analysis of between backscattering coefficients in each band and rice growth parameters, we performed prediction of the rice growth parameters. Relationship between backscattering coefficients in X-band (VV, 45°) and grain weight were closely correlated ($R^2 = 0.94$). We compared with measured grain weight (2008 year) and predicted grain weight by modeling. Relationship between measured and predicted grain weight was positive correlated (Fig. 3).

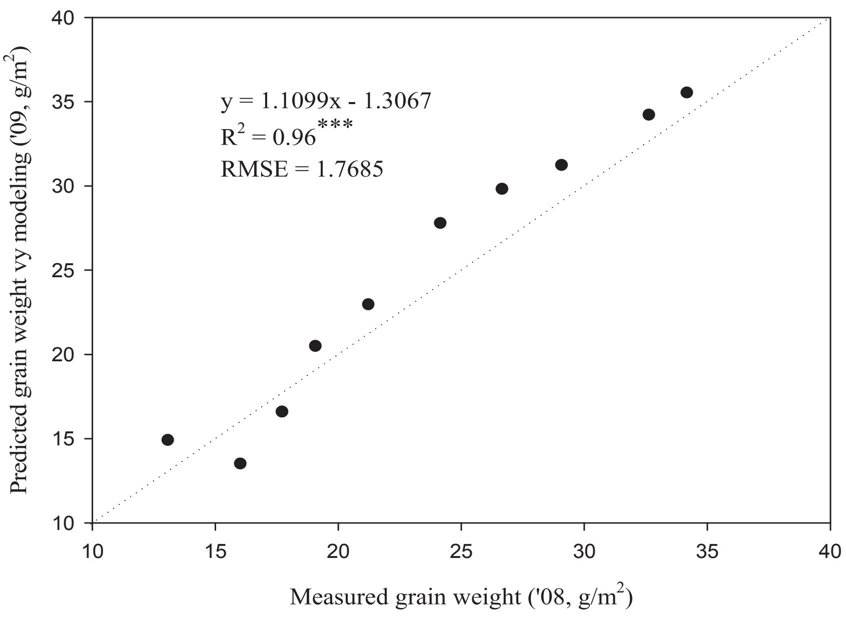

Fig. 3. Comparison between measured grain (2008year) and predicted grain weight by modeling (2009year).

Ⅳ. CONCLUSIONS

Backscattering coefficients of rice crop were investigated with an automatically-operating ground-based scatterometer. The temporal variations of the backscattering coefficients of the rice crop at X-band during a rice growth period. We conducted the relationship between backscattering coefficients with X-band and rice growth parameters. Grain weight was correlated with backscattering coefficients with VV polarization in X-band. We analyzed comparison between measured growth parameters and predicted growth parameter using scattering model. From this result, polarimetric scatteromter data appear positive to rice growth variables and growth monitoring.

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