Seasonal Change in $C_3$/C$_4$ Mixed Vegetation Populations over Paddy Levees in South Korea

Myung-Hyun Kim$^1*$, Young-Ju Oh$^2$ and Miran Kim$^1$

$^1$Climate Change and Agro-Ecology Division, National Academy of Agricultural Science, RDA, 150 Suin-Ro Kwenseonku, Suwon 441-707, Korea

$^2$Korea Biodiversity Research Center Co., Ltd., 1007 Hoguk-Ro Sundan, Phochon 487-711, Korea

(Received September 28, 2012; Revised November 16, 2012; Accepted November 26, 2012)

ABSTRACT

Studies of seasonal changes in C$_3$/C$_4$ mixed communities are rare, particularly in Asian summer monsoon climate zones. In our present study, seasonal changes in the profile and coverage of C$_3$ and C$_4$ plants were investigated in 2009 in Haenam, Yeongdong and Cheorwon regions of South Korea (all at different latitudes). The aim was to estimate the impacts of temperature and sunshine duration on species composition and transition timing of the C$_3$ and C$_4$ plants. From our results, the number of C$_3$ plants was found to increase from early spring to mid-May, and then decrease again until September in the Haenam and Yeongdong regions, but continuously increase from early spring to September in the Cheorwon region under relatively low summer temperatures. On the other hand, the number of C$_4$ plants increased from June or July to September in all three regions. These seasonal changes in species number and ratio have a direct impact upon species diversity which is highest when there are no dominant species. The relative coverage and relative summed dominance ratio (SDR') of the C$_3$ plants decreased from spring to autumn, but increased for the C$_4$ plants during this time in an exponential fashion with increasing accumulated temperature and sunshine duration. The transition timing from C$_3$ to C$_4$ plants occurred when the sum of sunshine duration for the days with daily mean temperature above 5°C was 1017 hrs for the SDR'.

Key words: C$_4$ plant, Paddy levee, Seasonal change, SDR', Temperature response

I. INTRODUCTION

Most terrestrial plants can be classified as C$_3$ or C$_4$ plants in terms of photosynthetic metabolism (Kortschak et al., 1965; Hatch and Slack, 1966; Black, 1971; Takeda and Fukuyama, 1971). Plants in these two categories have different responses to light intensity (Moss et al., 1961; Hesketh and Moss, 1963), temperature (Long, 1999; Larcher, 2003), soil moisture (Takeda et al., 1977; Takeda et al., 1980; Long, 1999) and CO$_2$ concentration (Goudriaan, 1989; Tubiello et al., 1999; Kang et al., 2002). Hence, the distribution and growth patterns of C$_3$ and C$_4$ plants will be affected by climatic changes including alterations in the ambient CO$_2$ concentration, temperature and precipitation pattern (IPCC, 2007). Since the discovery of the C$_4$ photosynthetic pathway (Kortschak et al., 1965; Hatch and Slack, 1966), many studies have reported on the structural
analysis of C₃ and C₄ plants (Oshugi, 1989; Ueno, 2001; Bang et al., 2009; Voznesenskaya et al., 2010). There have also been numerous reports on the classification of plant species using these photosynthetic pathways (Takeda and Fukuyama, 1971; Noda and Eguchi, 1973; Downtown, 1975; Kyoda, 1992; Liu et al., 2004), and on the geographic distributions of these plant types and their relationship to climatic patterns (Teeri and Stowe, 1976; Teeri et al., 1980; Takeda and Hakyama, 1985; Ueno and Takeda, 1992; Ehleringer et al., 1997; Collatz et al., 1998; Pyankov et al., 2000).

The temporal and spatial variations of ecophysiological characteristics including biomass, species composition, photosynthesis, coverage, dominance and diversity in C₃/C₄ plant mixed regions have been evaluated in grasslands, deserts and prairies (Ode et al., 1980; Kemp, 1983; Ishikawa et al., 1990; Wang, 2004a, 2004b; Niu et al., 2008). However, only a few studies about temporal and spatial variations in regions of the Asian monsoon climate zone (Okuda, 1987; Mo et al., 2004; Shimoda et al., 2009). In South Korea, C₄ plants are commonly found in areas surrounding crop lands such as paddy levees, upland levees and off-road sides (Chang and Lee, 1983). Interestingly, C₄ plants such as Digitaria ciliaris, Eragrostis ferruginea, Eleusine indica and Pennisetum dactyloides are dominant species that grow in paddy levees (Chang and Lee, 1983). This indicates that C₃ plants (Oryza sativa L.) would be replaced by these C₄ plants if the cultivation of rice in paddy fields was discontinued for any reason. In a tropical region of south-western China, C₄ plants have been found to be more prevalent in disturbed and cultivated lands than in other habitat types such as river valleys, rangelands, wet lands, hillsides and the regions susceptible to frost (Wang, 2006). Although C₄ plants represent a large proportion of the vegetation around cultivated lands that could influence crop productivity directly, no research has yet been conducted on this issue.

In our present study, we have investigated the effects of seasonal change on C₃/C₄ mixed plant communities in paddy levees in terms of species number, species diversity, coverage, and dominance. Especially, we focused on the transition timing from C₃ to C₄ dominance.

II. METHODS AND MATERIALS

2.1. Study sites

Three survey sites at different latitudes in South Korea, Haenam (N34°31' E126°33', 5 m a.s.l.), Yeongdong (N36°08' E127°47', 169 m a.s.l.) and Cheorwon (N38°12' E127°15', 189 m a.s.l.), were selected in 2009 to monitor seasonal variations in the C₃ and C₄ plant profiles over paddy levees. Weather data including precipitation and sunshine duration were collected from weather stations nearest to each survey site, which were managed by the Korea Meteorological Administration. Air temperatures at 1.3 m above ground were measured at each study site using Hobo Data Loggers (TidbiT v2 Temp Logger, Onset®, Massachusetts). Mean annual temperature of Haenam (13.8°C) was highest, and Cheorwon (10.1°C) was lowest among the survey sites (Table 1). Annual precipitation was highest at the Cheorwon site (2044.5 mm) and lowest at the Yeongdong (900.0 mm) site. Annual sunshine duration was similar among the three survey sites (2055 hrs for Haenam, 2047 hrs for Yeongdong, 2075 hrs for Cheorwon).

2.2. Vegetation survey

In each survey site, five linear plots (2×1 m²) were set along the paddy levees. To evaluate the dominance of different plants and the species diversity in each plot, the height and coverage of all plant species were recorded through the growing season (from February to September in 2009). The surveys were conducted six times...