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Comparison of Non-structural Carbohydrate Concentration Between Zoysiagrass and Creeping Bentgrass During Summer Growing Season

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하계 생육기 동안 Zoysiagrass와 Creeping Bentgrass의 비구조적 탄수화물 함량의 비교

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ABSTRACT

To compare the Carbon metabolic response to high temperature stress in Zoysiagrass [*Zoysia matrella* (L.) Merr.] and Creeeping bentgrass (*Agrostis palustris* Huds) with respect to heat tolerance, C metabolites were determined from April to September. Sampling was carried out on an established golf course (Muan Country Club, Chonnam, Korea). Shoot mass(g Dry weight per hole cup) of creeping bentgrass started to decrease from June and recovered from August, whereas that of zoysiagrass was less varied. Chlorophyll content in creeping bentgrass was significantly higher than zoysiagrass until July, and then decreased by 43% from July to August. Zoysiagrass contained higher soluble sugar than creeping bentgrass throughout experimental period. Soluble sugar in zoysiagrass increased about 58% from April to May, and less varied until August. Soluble sugar in creeping bentgrass slightly increased until July and sharply decreased at August. Starch concentration in zoysiagrass continuously decreased to September after a significant increase from April to May. A remarkable fluctuation in both starch and fructan concentration was observed between June and August, showing high accumulation for June to July and high degradation for July to August. These results suggest that through creeping bentgrass suffers much severely from high temperature stress than zoysiagrass especially June to August. An active accumulation and degradation in nonstructural carbohydrate in creeping bentgrass during this period might be associated with heat stress.

(**Key words** : Zoysiagrass, Creeping bentgrass, Non-structural carbohydrate, Summer adaptation)

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Ⅰ. INTRODUCTION

Creeping bentgrass (*Agrostis palustris*) and Zoysiagrass (*Zoysia matrella*) are being widely used for golf course green and fairway in Korea. Zoysiagrass has a good drought- and heat-hardiness. However, the establishment and recuperative rate is very poor because of a slow growth rate (Gary, 1967; Hume and Freyre, 1950). The optimal growth temperature for zoysiagrass is 27~35℃ (Youngner, 1961) and the starting of growth is a middle of April. The optimal growth temperature of creeping bentgrass, which is often used for golf green in Korea, ranged from 15 to 24℃ for shoot growth (Beard, 1973). Thus, creeping bentgrass suffers from high temperature stress during summer season in Korea when aerial temperatures are often higher than 30℃.

It has been largely reported that the growth inhibition of cool-season grasses under supraoptimal temperature (Baker and Jung, 1968; Martin and Wehner, 1987), such a physiological problem has been pointed out as a major limiting factor for use of cool-season grasses in golf course during summer season at sub-tropical region as like Korea. Supraoptimal temperature is a major limiting factor for the use of most cool-season grasses in warm climatic region (Beard, 1997; Carrow, 1996).

Non-structural carbohydrates play a major role in physiological processes controlling plant growth since it provides energy and carbon skeletons. It has been proposed from long time ago that plant growth reduction under supraoptimal temperature has been attributed to the exhaustion of available carbohydrate (Brown, 1939, 1943; Sullivan and Sprague, 1949). The relationships between quantitative changes in carbohydrates and stress tolerance have been largely reported in various plants exposed to heat stress (Younger and Nudge, 1968, 1976), drought stress (Jiang and Huang, 2001) and cold acclimation (Pollock et al., 1991; Livingston, 1996).

Most studies on carbohydrate metabolism in response to environmental stress has been paid attention for the crops in general cropping system. However, turf grasses in golf course are severely and frequently mowed under normal management condition. The understanding of C metabolic responses to environmental stress in turf grasses currently used for golf course could be a fundamental for establishing the guideline of golf course management. The objectives of present study were 1) to compare the persistency of vegetative growth between warm-season grass (zoysiagrass) and cool-season grass (creeeping bentgrass) through April to September, and 2) to investigate the difference of carbohydrate metabolism in response to high temperature stress in both species in relation to heat tolerance.

Ⅱ. MATERIAL AND METHODS

Sample collecting site and growth condition

Sampling was made from green and fairway, established in 1998, of Muan Country Club (35°05'32" N, 126°17'12" E) in Korea. The turfgrasses were maintained by general turf management. Minimum daily temperature in green field ranged from 4.6 to 24℃ during the experimental period. It reached to 31℃ at mid-August, remained at above heat stress temperature until mid-September. Maximum daily temperature ranged from 14.3 to 31.1 ℃ (Fig. 1).

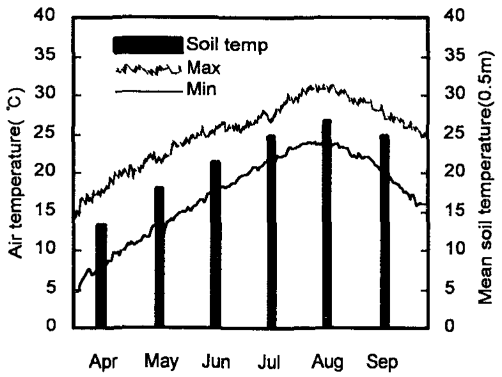

Fig. 1. Daily maximum temperature(), and minimum temperature(—), and mean soil temperature(■) from April to September 2001 at Muan city, Korea.

Creeping bentgrass and Zoysiagrass were sampled using a hole cutter (Ø108mm) at three randomly selected sites, from April to September, 2001 with about one-month interval. The samples were obtained to a depth of approximately 20 cm. Thereafter, shoots were removed with a clipper, and roots were separated from the above-ground portion. Samples were washed free of soil under a stream of cold water. Plant tissues immediately frozen in liquid nitrogen, and lyophilized. Freeze-dried samples were finely ground and stored under vacuum for further analysis. The data obtained from the shoots are presented in this paper.

Chlorophyll content

Leaf chlorophyll was extracted by soaking 0.1g of leaves in 8mL dimethyl sulfoxide for 72h as described by Hiscox and Israelstam (1979). Absorbance of extractants was measured at 663nm and 645nm with a spectrophotometer (Shimadzu UV-1601). Leaf chlorophyll content was calculated by the formula of Arnon(1949).

Carbohydrate analysis

About 30 mg of finely ground sample was extracted with 1 mL of 92% (v/v) ethanol. Tubes were shaken for 10 min at room temperature, centrifuged at 14,000 rpm for 10 min at 4℃. The ethanol extraction was repeated three times, and the combined supernatant was diluted to a final volume of 10 mL with 92% (v/v) ethanol. The soluble sugar concentration in extracts was determined with anthrone reagent (Van Hande, 1968) using glucose as a standard. The residue was dried at 80℃ to remove ethanol. Deionized water was adjusted to pH 5.1 by adding 0.2N Na-acetate buffer. Starch was digested by adding amyloglucosidase (Sigma product A3514) and α-amylase (Sigma product A0273) in the acetate buffer to each sample. Tubes were incubated at 50℃ for 24h with occasional shaking. Tubes were centrifuged as described above and glucose in the supernatant was determined using glucose oxidase (Glucose Trinder, Sigma product 315-100). Starch concentrations were defined as 0.9 × glucose concentration. Fructan presented in the starch extracts was hydrolyzed with 0.1 N H_2SO_4 and fructose released quantified using resorcinol (Davis and Gander, 1967). Glucose liberated from the fructan was determined as described. Fructan concentration was estimated by multiplying the sum of fructan-glucose and fructose with 0.9.

Table 1. Shoot dry masses of zoysiagrass and creeping bentgrass during experimental period. Each value is the mean ± S.E. for n=3.

Turf species	Dry weight(g) per hole cup					
	April 20	May 20	June 17	July 20	August 20	September 20
Zoysiagrass	1.85±0.16	2.08±0.26	2.38±0.17	2.83±0.15	2.74±0.37	1.95±0.23
Creeping bentgrass	5.09±0.66	6.41±1.64	4.85±0.53	4.09±0.98	2.80±0.35	3.83±0.33

Ⅲ. RESULTS

Growth

Plant growth, defined as shoot dry mass, of zoysiagrass and creeping bentgrass is given at Table 1. Shoot mass per hole cutter in zoysiagrass gradually increased until July, and then decreased. The decrease in shoot dry weight was distinct at September when minimum daily temperature were below 20℃. Shoot mass of creeping bentgrass increased from April to May, and then decreased until August when the plants were exposed to over 30℃. Between July and August, shoot dry weight decreased about 35%. These results indicated that creeping bentgrass much sensitively responded to high temperature during summer period compared to zoysiagrass.

Chlorophyll Content

The changes in leaf chlorophyll content of zoysiagrass and creeping bentgrass are shown in Fig. 2. In creeping bentgrass, a significant reduction in leaf chlorophyll content occurred from July to August when minimum daily temperature was over 30℃. Chlorophyll content of zoysiagrass slightly increased until August, and then decreased. Leaf chlorophyll content in creeping bentgrass was significantly higher than zoysiagrass except August when leaf chlorosis of creeping bentgrass was generally observed.

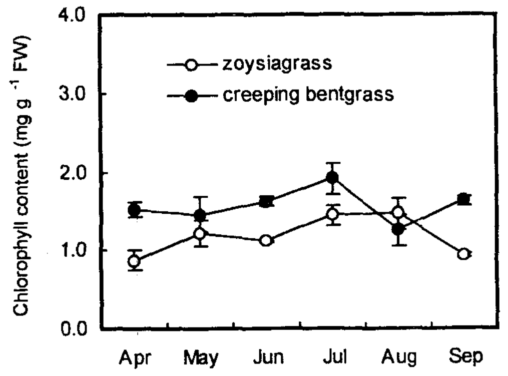

Fig. 2. Changes in chlorophyll content of zoysigrass(○) and creeping bentass(●) from April to September. Each value is the mean ± S.E. for n=3.

Carbohydrates concentration

Zoysiagrass contained higher sugar concentration compared to creeping bentgrass at all points measured (Fig. 3). Soluble sugar concentration of zoysiagrass highly increased from April (33.3 mg g^{-1} DW) to May (52.9 mg g^{-1} DW), and less varied until August, and then sharply decreased at September (23.3 mg g^{-1} DW). In creeping bentgrass, it slightly increased until July (28.8 mg g^{-1} DW) and decreased largely at August (12.3 mg g^{-1} DW), when maximum daily temperature arrived to 30℃.

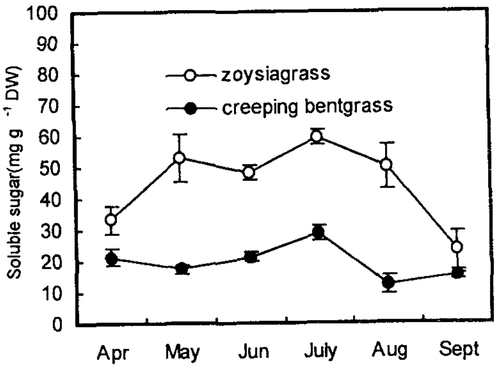

Fig. 3. Changes in soluble sugar in the shoots of zoysigrass(○) and creeping bentgrass(●) from April to September. Each value is the mean ± S.E. for n=3.

The changes in polysaccharide in zoysiagrass and creeping bentgrass are shown in Fig. 4. In zoysiagrass, a remarkable increases of starch concentration was found between April (39.5 mg g^{-1} DW) and May (55.9 mg g^{-1} DW), thereafter continuously decreased to September (18.9 mg g^{-1} DW) (Fig. 4A). Starch concentration in creeping bentgrass showed a slight decreases from April (50.2 mg g^{-1} DW) to June (33.0 mg g^{-1} DW). In creeping bentgrass, an increase between June and July (about 43%) and a sharp decreased between July to August (67%) was noticeable.

Fructan concentration in zoysiagrass was less varied within a range from 12.0 to 20.2 mg g^{-1} DW throughout experimental period (Fig. 4B). The fluctuation of fructan concentration in creeping bentgrass was much dynamic. From April to June, it was decreased 43% until June and then dramatically increased between June (67.8 mg g^{-1} DW) and July (131.8 mg g^{-1} DW), and followed by a great decline at August (34.8 mg g^{-1} DW).

Ⅳ. DISCUSSION

Shoot mass of zoysiagrass maintained high level for July and August, while that of creeping bentgrass after June significantly decreased through August, when both plants exposed to high temperature (Table 1). This result indicate that the shoot dry weight in zoysiagrass coincided with the high temperature

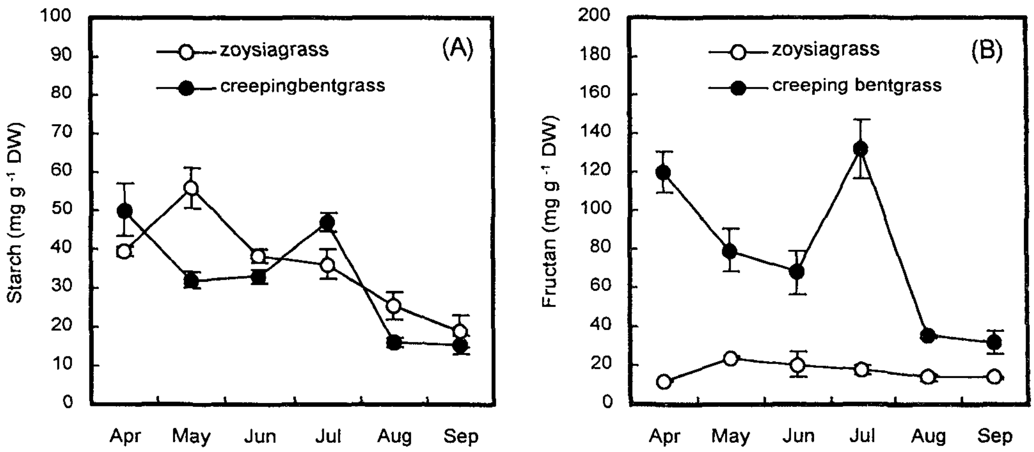

Fig. 4. Change in starch (A) and fructan (B) in shoots of zoysigrass(○) and creeping bentgrass(●) from April to September. Each value is the mean ± S.E. for n=3.

tolerance during summer season (Beard, 1973).

In creeping bentgrass, chlorophyll content in live leaves, an important factor in determining photosyntheic capacity, rapidly decreased through July to August when soil temperature is over 25 ℃ (Fig. 1 and Fig. 2). The decrease in chlorophyll level under heat stress has been observed in other species (Rensburg and Kruger, 1994; Kyparissis et al., 1995). These results indicate that photosynthesis of creeping bentgrass might be inhibited by high temperature through June to August. The reduction of photosynthetic activity by heat stress has been foun in other species (Berry and Bjorkman, 1980; Bose and Ghosh, 1995).

In comparison of sugar concentration between two species, zoysiagrass maintained always at higher level throughout experimental period (Fig. 3). The higher concentrations of soluble sugar in shoots of zoysiagrass during summer season may be relation to high temperature adaptation. In creeping bentgrass, a pattern representing a slight increase until July and a sharp decrease between July and August was generally observed. This pattern was coincided with chlorophyll change in this plant. A significant decrease in sugar concentration from July to August might be associated with the high demand of carbon for respiration and/or the low activity of photosynthesis during this period when creeping bentgrass might be exposed to high temperature stress (over 30℃ in maximum air temperature).

Continuous decrease in starch concentration of zoysiagrass was found from May to September (Fig. 4A), suggesting zoysiagrass may continue vegetative growth without physiological disorder. It could be assumed that under non-stressed condition the newly synthesized sugars might be translocated to stubble and roots to constitute the organic reserves. In creeping bentgrass, a remarkable fluctuation of starch (Fig. 4A) and fructan (Fig. 4B) from June to August, was observed. Polysaccharide accumulation in creeping bentgrass betwen June and July may be associated with the acclimation to high temperature. Duff and Beard (1974) reported that nonstructural carbohydrate accumulation in creeping bentgrass started at the early period of heat stress.

Reduction in carbohydrate accumulation under high temperature conditions may be resulted from the imbalance between photosynthesis and respiration (Huang et al., 1998; Prange et al., 1990). Schmidt and Blaser (1967) also reported adverse effects of high temperature on carbohydrate accumulation in creeping bentgrass, which was attributed to increased respiration rate. Therefore, the maintenance of balanced photosynthesis-respiration, and adequate carbohydrate accumulation are important for maintaining the persistency of turf grasses during heat stress.

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V. 요 약

Zoysiagrass [*Zoysia matrella* (L.) Merr.]와 creeeping bentgrass (*Agrostis palustris* Huds)에서 고온 스트레스에 대한 탄수화물대사 반응을 규명하기 위해 4월부터 9월까지의 식물체내의 탄수화물 대사산물의 변화를 비교 분석하였다.

각 초종의 샘플은 1998년 조성된 무안 Country Club의 green과 fairway에서 채취하였다. Creeping bentgrass의 지상부 수량은 6월부터 8월까지 점차 감소하였고 이후 회복되었다. 반면 zoysiagrass의 지상부 수량은 크게 변하지 않았다. Creeping bentgrass의 엽록소 함량은 7월까지 zoysiagrass의 엽록소 함량에 비해 현저하게 높았고, 그후 7월부터 8월까지 43%의 감소를 보였다. 가용성 당의 경우 zoysiagrass은 전 시험기간동안 creeping bentgrass보다 높게 유지되었다. Zoysiagrass의 가용성 당은 4월부터 5월사이 약 58%의 증가를 보였고, 이후 8월까지 유의적인 변화가 없었다. Creeping bentgrass의 가용성 당은 7월까지 다소 증가한 후, 8월에 급격하게 감소하였다. Zoysaigrass의 Starch의 농도는 4월부터 5월까지 증가한 후 9월까지 지속적으로 감소하였다. Creeping bentgrass의 경우 starch와 fructan 농도는 공히 6월과 7월 사이의 높은 축적 및 7월과 8월 사이의 급격한 감소하는 특이점을 보였다. 이상의 결과들은 zoysiagrass 보다 creeping bentgrass가 6월과 8월 사이의 고온 스트레스를 많이 받고 있음을 보여주며, 이 기간 중 creeping bentgrass의 비구조적 탄수화물의 활발한 축적과 가수분해는 고온 스트레스와 밀접한 관련이 있음을 잘 나타내고 있다.

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