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A two-year field study was initiated at the University of Maryland to examine the effects of coring on rates of photosynthesis and whole plant respiration and to quantify water soluble carbohydrates, storage carbohydrates, and total non-structural carbohydrates in creeping bentgrass leaves and roots during the summer. In general, photosynthesis and respiration were not negatively impacted by coring. In fact the study showed that coring in spring + summer resulted in enhanced carbohydrate levels in leaves and roots by September which would benefit plants in their recovery from drought and other summer stresses.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 350 projects at a cost of $29 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Carbohydrate Metabolism in Creeping Bentgrass as Influenced by Spring and Summer Coring

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SUMMARY

Carbohydrates provide energy required to maintain healthy plant growth in summer. Coring is performed periodically on creeping bentgrass (*Agrostis stolonifera* L.) putting greens for numerous reasons; however, its impact on carbohydrate metabolism in creeping bentgrass is unknown. The objectives of this two-year field study were to examine the effects of coring on rates of photosynthesis (Pn) and whole plant respiration (Rw); and to quantify water soluble carbohydrates [WSC (i.e., glucose, fructose, and sucrose)], storage carbohydrates [SC (i.e., fructan and starch], and total non-structural carbohydrates [TNC (i.e., WSC plus SC)] in creeping bentgrass leaves and roots during the summer. The study site was 'Providence' creeping bentgrass grown on a sand-based rootzone and was maintained as a putting green. Three coring treatments were assessed as follows: spring only coring, spring plus three summer corings, and a non-cored control. Results include:

- Coring with large diameter times in the spring resulted in an increase in respiration on the initial rating date in each year. In general, however, photosynthesis and respiration were not negatively impacted by coring.
- Photosynthesis was unchanged when measured about 21 days following coring. On the final rating in September of each year photosynthesis was higher in spring + summer cored bentgrass.
- Leaf and root WSC, SC, and TNC levels were similar among coring treatments throughout the summer of each year. Root TNC levels were lower in July of each year in spring + summer cored bentgrass versus other coring treatments.
- Coring in spring + summer resulted in enhanced carbohydrate levels in leaves and roots by September, which would benefit plants in their recovery from drought and other summer stresses.
- Seasonal carbohydrate status of creeping bentgrass support the use of large and small diameter times in spring versus summer corings, respectively.

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Core cultivation or coring is routinely performed on putting greens for a multitude of beneficial purposes as outlined by McCarty (6). Coring, however, is disruptive to the putting surface and causes mechanical injury to turf. Mechanical injury to plants would be expected to result in an increase in respiration and possibly a reduction in photosynthesis. A concomitant decrease in photosynthesis and increase in respiration could cause a harmful depletion of carbohydrates.

The rate of turf recovery from mechanical injury can depend on the availability of carbohydrates (2). Carbohydrates in turfgrasses consist of the monosaccharides glucose and fructose, the disaccharide sucrose, and various starches and fructans (10). Fructans can be hydrolyzed into fructose, which can be converted to glucose or

In the spring coring program, plots were cored once annually on April 27, 2006 and April 29, 2007 using a Miltona Handi Aerifer (Miltona Turf Products, Miltona, MN). This hand-held, manual device had seven 1.27-cm-diameter (0.5-inch) hollow tines which penetrated to a depth of 9.0 cm (3.5 inches).

used to form sucrose. Both mono- and disaccharides are depleted during respiration when new leaves and roots of perennial ryegrass (*Lolium perenne* L.) are produced (1). Root growth in some grasses is more sensitive to a decrease in the availability of carbohydrates than leaf growth (2). Root regrowth following coring may require considerable amounts of carbohydrates.

Understanding how leaf and root carbohydrate levels change following coring may be important for maintaining high quality creeping bentgrass greens. This is especially true in summer when high temperature stress reduces photosynthesis, root growth, and quality in creeping bentgrass (13). The effects of coring on carbohydrate metabolism during summer months in creeping bentgrass have not been documented. The objectives of this field study were to quantify photosynthesis and whole plant respiration rates, as well as carbohydrate levels (i.e., water soluble, storage, and total non-structural) in creeping bentgrass leaves and roots in response to spring only coring versus spring plus summer coring.

Materials and Methods

This field study was conducted on a research green built using USGA recommendations (11) at the University of Maryland Turfgrass Research Facility in College Park in 2006 and 2007. Soil was a modified sand mix (97% sand, 1% silt, and 2% clay) with a pH of 6.5 and 10 mg of organic matter per gram of soil. In September 2005, the study site was treated with a non-selective herbicide, and the sod was removed to expose bare ground.

The area was seeded (50 kg ha^{-1} seed; 1.0 lb seed/ 1000 ft^2) with 'Providence' creeping bentgrass in Sept. 2005. A total of 250 kg ha^{-1} N (5.0 lb N/1000 ft^2) was applied between September 20 and November 11, 2005. The bentgrass was fertilized biweekly with 4.9 kg ha^{-1} N (0.1 lb N/1000 ft^2) from urea between May 1 and June 7 and then weekly through August 24 for a total of 78.4 kg ha^{-1} N (1.6 lb N/1000 ft^2) during the experimental period in 2006. In autumn 2006, 71 kg ha^{-1} N

Treatments	Photosynthesis (micromol s^{-1} m^{-2})					
	2006					
	June 6	**June 21**	**July 7**	**July 24**	**Aug. 24**	**Sept. 7**
SP [z]	6.7 a [w]	8.4 a	4.6 a	4.1 a	4.8 ab	7.2 b
SP + SU [y]	7.2 a	7.7 a	5.4 a	4.1 a	6.7 a	8.3 a
N-C [x]	6.9 a	8.2 a	4.9 a	3.7 a	4.6 b	7.3 b
	2007					
	May 31	**July 2**	**July 24**	**Aug. 14**	**Sept. 6**	
SP	5.8 ab	6.0 a	7.0 ab	6.6 a	4.1 b	
SP + SU	7.0 a	6.4 a	8.5 a	6.9 a	5.4 a	
N-C	4.6 b	5.3 a	6.4 b	7.1 a	4.7 ab	

[z] Spring only (SP) coring was performed on April 27, 2006 and April 29, 2007.

[y] Spring + summer (SP+SU) corings were performed on April 2, June 6 and 28, and July 25 of 2006, as well as April 29, June 6, and July 3 and 31 of 2007.

[x] Non-cored (N-C) control.

[w] Means in a column in a given year followed by the same letter are not significantly different based on Fisher's protected least significant difference test (P 0.05).

Table 1. Photosynthesis in 'Providence' creeping bentgrass in response to spring only coring (SP), spring plus summer coring (SP+SU), or no coring (N-C) in 2006 and 2007.

(1.4 lb/1000 ft^2) was applied between September and November. In 2007, the bentgrass was fertilized weekly with 4.9 kg ha^{-1} N (0.1 lb N/1000 ft^2) from urea between Aprril 30 and August 27 to provide a total of 88.2 kg ha^{-1} N (1.8 lb N/1000 ft^2) during the experimental period.

The green was mowed at a height of 4 mm (0.158 inches) five times weekly and clippings were removed. Turf was irrigated to prevent wilt and was syringed frequently during dry, windy periods. Three coring treatments were assessed as follows: non-cored, spring only coring, and spring plus summer coring. Each plot measured 1.8 by 2.4 meters and was separated by a 60-cm creeping bentgrass perimeter border.

Typically, large diameter tines are used to core greens in the spring and small diameter tines are used in the summer (8). In the spring coring program, plots were cored once annually on April 27, 2006 and April 29, 2007 using a Miltona Handi Aerifer (Miltona Turf Products, Miltona, MN). This hand-held, manual device had seven, 1.27-cm-diameter (0.5-inch) hollow tines which penetrated to a depth of 9.0 cm (3.5 inches). Spring plus summer treatment involved coring in April as previously described combined with three summer corings using hollow tines.

Summer coring was performed using one leg taken from a CoreMaster *12 Aerator (GreenCare, Sydney, Australia) equipped with a quadra-tine holder on June 6 and 28 and July 25, 2006, and June 6, and July 3 and 31, 2007. The four 0.64-cm-diameter (0.25-inch) hollow tines penetrated to a depth of 5.5 cm (2.1 inches). Topdressing, using the previously described modified sand construction mix, followed spring coring to fill holes to the surface. Following summer coring, plots were brushed to incorporate sand from cores, but no additional topdressing sand was applied.

Canopy net photosynthesis (Pn) and whole plant respiration (Rw, including plant and soil

Treatments	Respiration (micromol s^{-1} m^{-2})					
	2006					
	June 6	**June 21**	**July 7**	**July 26**	**Aug. 16**	**Sept. 7**
SP [z]	8.7 ab w	9.4 a	7.0 a	9.8 a	8.4 a	7.8 a
SP + SU [y]	9.3 a	7.9 a	6.0 a	7.8 a	7.8 ab	8.5 a
N-C [x]	8.0 b	9.1 a	6.3 a	9.4 a	7.5 b	8.0 a
	2007					
	May 31	**July 2**	**July 24**	**Aug. 14**	**Sept. 6**	
SP	10.4 ab	10.8 a	10.1 a	8.6 a	10.6 a	
SP + SU	11.0 a	9.8 a	10.2 a	7.2 a	9.6 a	
N-C	9.8 b	10.0 a	10.2 a	8.8 a	10.3 a	

[z] Spring only (SP) coring was performed on April 27, 2006 and April 29, 2007.

[y] Spring + summer (SP+SU) corings were performed on April 2, June 6 and 28, and July 25 of 2006 as well as April 29, June 6, and July 3 and 31 of 2007.

[x] Non-cored (N-C) control.

[w] Means in a column in a given year followed by the same letter are not significantly different based on Fisher's protected least significant difference test (P 0.05).

Table 2. Respiration in 'Providence' creeping bentgrass in response to spring only coring (SP), spring plus summer coring (SP+SU), and no coring (N-C) in 2006 and 2007.

microbe respiration) were measured on a 2- to 3-week interval between June 6 and September 7, 2006 and on a 3- to 4-week interval between May 31 and September 6, 2007 using a portable gas exchange system (LI-6400; LICOR, Lincoln, NE). Photosynthesis and Rw were determined by enclosing the turf canopy in a transparent plexiglass chamber attached to a LI-6400 CO_2 analyzer as described by Fu et al. (4). Measurements of Pn and Rw were obtained in one location of each plot on each date and data were expressed as CO_2 uptake and evolution per unit area.

Clippings were the source of mostly leaf plus some sheath (hereafter leaf or leaves) tissue used to measure water soluble carbohydrates (WSC) and storage carbohydrates (SC). Clippings were collected on May 25, June 21, July 21, August 4, and September 7, 2006, as well as June 1 and 28, July 17, August 15, and September 6, 2007. Roots were sampled by removing four soil cores from each plot on these same dates. The four soil cores from each plot were mixed and roots were washed free of soil. Leaves and roots were placed in separate plastic bags and placed immediately in liquid nitrogen and stored in a freezer until analyzed as described by Fu and Dernoeden (3).

The treatments were arranged in a completely randomized block design with four replications. Treatment effects were determined by analysis of variance using the general linear model procedure of SAS (9).

Results

Photosynthesis and Respiration

Between June 6 and July 24, 2006, photosynthesis rates were similar among coring regimes (Table 1). A higher photosynthesis level was observed on August 16, 2006 in spring plus summer versus non-cored bentgrass, but was similar compared to spring only cored bentgrass. On the final measurement date in 2006, bentgrass subjected to spring plus summer coring had a higher photosynthesis level compared to spring only and non-cored bentgrass.

Photosynthesis and whole plant respiration were determined by enclosing the turf canopy in a transparent plexiglass chamber attached to a LI-6400 CO_2 analyzer. Measurements were obtained in one location of each plot on each date and data were expressed as CO_2 uptake and evolution per unit area.

In 2007, photosynthesis levels were higher on May 31 and July 24 in spring plus summer versus non-cored bentgrass, but were similar to spring only cored bentgrass (Table 1). No differences in photosynthesis were observed on July 2 and August 14, 2007 among coring regimes. On September 6, 2007, the photosynthesis level was higher in spring plus summer cored compared to spring only cored bentgrass. The photosynthesis level, however, was similar between spring only and non-cored bentgrass at the time of the final measurement in 2007.

Respiration rates generally were similar among coring regimes in 2006 (Table 2). Spring plus summer cored bentgrass, however, exhibited a higher whole plant respiration level on June 6, 2006 compared to non-cored bentgrass. Except on May 31, no differences in whole plant respiration were observed in 2007 among coring regimes (Table 2). On May 31, 2007, spring plus summer cored bentgrass had a higher whole plant respiration level compared to non-cored bentgrass.

Treatments	2006				
	May 25	**June 21**	**July 21**	**Aug. 4**	**Sept. 7**
	WSC [glucose (mg g^{-1} dry wt)]				
SP [z]	41.0 a [w]	45.3 b	31.2 b	51.4 a	37.6 a
SP + SU [y]	41.1 a	49.9 a	34.7 a	53.3 a	35.8 b
N-C [x]	44.3 a	42.5 b	32.9 ab	53.8 a	35.1 b
	SC [glucose (mg g^{-1} dry wt)]				
SP	58.4 ab	40.6 b	26.4 b	38.0 b	44.8 a
SP + SU	60.5 a	38.8 c	8.2 b	2.1 a	45.5 a
N-C	56.3 b	43.0 a	33.9 a	42.3 a	41.9 b
	TNC [glucose (mg g^{-1} dry wt)]				
SP	99.4 a	85.9 a	57.6 b	89.4 a	82.4 a
SP + SU	101.6 a	88.7 a	62.9 ab	95.4 a	81.3 a
N-C	100.7 a	85.5 a	66.8 a	96.0 a	77.0 b

Treatments	2007				
	June 1	**June 28**	**July 17**	**Aug. 15**	**Sept. 6**
	WSC [glucose (mg g^{-1} dry wt)]				
SP	40.9 a [w]	40.5 a	27.1 ab	30.4 a	30.1 a
SP + SU	38.9 a	40.9 a	25.7 b	29.9 a	27.6 b
N-C	40.5 a	39.9 a	30.0 a	30.5 a	28.6 ab
	SC [glucose (mg g^{-1} dry wt)]				
SP	88.8 a	43.6 a	45.2 a	43.8 b	36.2 b
SP + SU	78.9 b	44.5 a	41.6 b	50.2 a	39.4 a
N-C	87.5 a	43.1 a	40.9 b	45.3 b	36.8 b
	TNC [glucose (mg g^{-1} dry wt)]				
SP	129.7 a	84.1 b	71.3 a	74.2 b	66.3 b
SP + SU	117.8 a	85.4 a	67.3 a	80.1 a	67.0 a
N-C	128.0 a	83.0 b	70.9 a	75.7 b	65.4 b

[z] Spring only (SP) coring was performed on April 27, 2006 and April 29, 2007.

[y] Spring + summer (SP+SU) corings were performed on April 2, June 6 and 28, and July 25 of 2006 as well as April 29, June 6, and July 3 and 31 of 2007.

[x] Non-cored (N-C) control.

[w] Means in a column in a given year followed by the same letter are not significantly different based on Fisher's protected least significant difference test (P=0.05).

Table 3. Water soluble carbohydrate (WSC), storage carbohydrate (SC), and total non-structural carbohydrate (TNC) in 'Providence' creeping bentgrass leaf tissue subjected to spring only coring (SP), spring plus summer coring (SP+SU) or no coring (N-C) in 2006 and 2007.

Following summer coring, plots were brushed to incorporate sand from cores, but no additional topdressing sand was applied.

Leaf Carbohydrates

In 2006, creeping bentgrass leaf tissue from plots subjected to spring plus summer coring had a greater level of water soluble carbohydrates (WSC) on June 21 compared to spring only and non-cored bentgrass (Table 3). On July 21, water soluble carbohydrates were greater in spring plus summer versus spring only cored bentgrass. No significant differences in leaf water soluble carbohydrates levels were observed on May 25 and August 4 among coring treatments. Leaf water soluble carbohydrates level was lower on September 7 in spring plus summer and non-cored bentgrass compared to spring only cored bentgrass.

Storage carbohydrate levels were greater on May 25 and September 7, but similar on August 4 for spring plus summer versus non-cored bentgrass (Table 3). Spring plus summer cored bentgrass leaf tissues had lower storage carbohydrate levels on June 21 compared to spring only and non-cored bentgrass. Storage carbohydrate levels were higher on September 7, 2006 in spring only and spring plus summer regimes compared to non-cored bentgrass. Except on July 21 and September 7, no differences in leaf total non-structural carbohyrates were observed among coring treatments. On July 21, total non-structural carbohyrate levels were lower in spring only cored bentgrass leaves versus non-cored bentgrass. By September 7, lowest total non-structural carbohyrate levels were found in bentgrass leaves from non-cored plots.

In 2007, spring plus summer cored bentgrass tissue had a lower leaf water soluble carbohydrates level on July 17, but similar levels on June 1 and 28, August 15, and September 6 compared to non-cored bentgrass (Table 3). Except on September 6, leaves subjected to spring plus summer coring generally had similar water soluble carbohydrate levels compared to spring only cored bentgrass. On September 6, leaf water soluble carbohydrate levels were lower in spring plus

Treatments	2006				
	May 25	**June 21**	**July 21**	**Aug. 4**	**Sept. 7**
	WSC [glucose (mg g^{-1} dry wt)]				
SP [z]	45.4 a [w]	33.3 a	33.5 a	16.3 a	26.8 b
SP + SU [y]	46.4 a	34.1 a	31.2 a	17.2 a	29.2 a
N-C [x]	41.7 b	34.4 a	32.2 a	15.9 a	25.9 b
	SC [glucose (mg g^{-1} dry wt)]				
SP	27.9 a	31.1 a	20.9 a	23.8 b	15.5 b
SP + SU	31.5 a	29.0 a	17.7 b	34.3 a	18.7 a
N-C	30.4 a	28.8 a	20.0 a	20.6 b	12.0 b
	TNC [glucose (mg g^{-1} dry wt)]				
SP	73.2 a	64.3 a	54.4 a	40.1 b	42.3 b
SP + SU	77.9a	63.1 a	48.9 b	51.5 a	47.9 a
N-C	72.1 a	63.2 a	52.3 a	36.5 b	37.9 c

Treatments	2007				
	June 1	**June 28**	**July 17**	**Aug. 15**	**Sept. 6**
	WSC [glucose (mg g^{-1} dry wt)]				
SP	22.2 a w	18.2 a	35.4 ab	36.5 a	34.4 a
SP + SU	20.3 a	19.1 a	32.5 b	38.0 a	36.9 a
N-C	22.5 a	18.8 a	37.4 a	38.2 a	37.0 a
	SC [glucose (mg g^{-1} dry wt)]				
SP	61.9 b	38.1 ab	19.7 a	22.1 a	25.3 ab
SP + SU	67.2 b	36.9 b	18.2 a	20.0 a	27.0 a
N-C	73.8 a	40.3 a	19.2 a	21.9 a	22.2 b
	TNC [glucose (mg g^{-1} dry wt)]				
SP	84.1 b	56.3 a	55.1 a	58.6 a	59.7 b
SP + SU	87.5 b	56.0 a	50.7 b	58.0 a	63.9 a
N-C	96.3 a	59.0 a	56.6 a	60.1 a	59.2 b

[z] Spring only (SP) coring was performed on April 27, 2006 and April 29, 2007.

[y] Spring + summer (SP+SU) corings were performed on April 29, June 6 and 28, and July 25 of 2006 as well as April 29, June 6, and July 3 and 31 of 2007.

[x] Non-cored (N-C) control.

[w] Means in a column in a given year followed by the same letter are not significantly different based on Fisher's protected least significant difference test (P=0.05).

Table 4. Water soluble carbohydrate (WSC), storage carbohydrate (SC), and total non-structural carbohydrate (TNC) in 'Providence' creeping bentgrass root tissue from plots subjected to spring only coring (SP), spring plus summer coring (SP+SU), or no coring (N-C) in 2006 and 2007.

summer versus spring only cored bentgrass.

Leaf storage carbohydrate levels were lower on June 1, similar on June 28 and July 17, and higher on August 15 and September 6 for spring plus summer versus non-cored bentgrass. Spring plus summer cored bentgrass had lower leaf storage carbohydrate levels on June 1 and July 17, similar storage carbohydrate levels on June 28, and higher leaf storage carbohydrate levels on August 15 and September 6 compared to spring only cored bentgrass tissues. Total non-structural carbohydrate levels in leaves were similar on June 1 and July 17, but greater on June 28, August 15, and September 6, 2007 in spring plus summer cored compared to spring only and non-cored bentgrass.

Root Carbohydrates

In 2006, spring plus summer cored bentgrass had higher root water soluble carbohydrate levels on May 25 and September 7 compared to non-cored bentgrass (Table 4). No differences in root water soluble carbohydrate levels were observed on the other three measurement dates between spring plus summer and non-cored bentgrass. Root water soluble carbohydrate levels were similar between May 25 and August 4, but greater in spring plus summer versus spring only cored bentgrass on September 7.

Similar root soluble carbohydrate levels were observed on May 25 and June 21 among the three coring treatments. A lower root soluble carbohydrate level was observed on July 21 in spring plus summer compared to spring only and non-cored bentgrass. Root soluble carbohydrate levels were higher on August 4 and September 7, 2006 in spring plus summer versus spring only and non-cored bentgrass. Root total non-structural carbohyrate levels were similar on May 25 and June 21, lower on July 21, and higher on August 4 and September 7 in spring plus summer versus spring only and non-cored bentgrass.

In 2007, root water soluble carbohydrate levels generally were similar among coring treatments on most measurement dates (Table 4). Root soluble carbohydrate levels were lower on June 1 and 28, similar on July 17 and August 15, and higher on September 6 for spring plus summer cored versus non-cored bentgrass. No differences in root soluble carbohydrates were observed on all five measurement dates between spring plus summer cored and spring only cored bentgrass.

Root total non-structural carbohyrate levels were lower on June 1 and July 17, similar on June 28 and August 15, and higher on September 6 in spring plus summer compared to non-cored bentgrass. Creeping bentgrass roots subjected to spring plus summer coring had similar total non-structural carbohyrate levels on June 1 and 28 and August 15, and lower total non-structural carbohyrate levels on July 17 versus spring only cored bentgrass. On September 6, total non-structural carbohyrate levels were higher in spring plus summer cored than in spring only cored or non-cored bentgrass.

Discussion

Data showed that photosynthesis levels generally were similar among the three treatments throughout the experimental periods in both years. On the final measurement date in early September 2006 and 2007 (i.e., 37 to 42 days` since last cored), however, photosynthesis was higher in spring plus summer cored than spring only cored bentgrass. Coring in the spring, however, did

Spring plus summer treatment involved coring in April combined with three summer corings using hollow tines.

impact whole plant respiration rates on the initial measurement date in both years. On June 6, 2006 and May 31, 2007, whole plant respiration was higher in spring plus summer cored versus non-cored plots. Perhaps an increase in whole plant respiration occurred at this time because creeping bentgrass growth would be more rapid earlier in the year versus in summer. It also is possible that the larger diameter tines used in spring created more injury, resulting in an increase in whole plant respiration. Thereafter, whole plant respiration levels were similar among all coring regimes in both years. Hence, coring in general did not negatively impact photosynthesis or whole plant respiration.

The rate of leaf and root regrowth following coring depends on the availability of carbohydrates. Leaf carbohydrate levels were similar among rating dates and years. Highest levels of leaf carbohydrates were observed in spring at the time the first measurements were made in either May or June. Leaf water soluble carbohydrate levels in both years generally were lowest in July. Leaf water soluble carbohydrate levels were higher in September in spring plus summer versus the other coring treatments in 2006, but not in 2007. Leaf total non-structural carbohydrate levels also were higher in September in spring plus summer cored compared non-cored bentgrass in both years. Similarly, Narra et al. (7) found that total non-structural carbohydrate levels in creeping bentgrass clippings decreased in mid-July and August, but increased during the autumn months. There are no other known coring studies with which to compare our results.

Mowing causes mechanical injury and does impact leaf carbohydrate levels. For example, a reduction in fructans and glucose in leaves was reported in response to mowing (5, 12). Howieson and Christians (5) found that the duration and amount of fructan and glucose reduced was greatest in double-cut bentgrass. The aforementioned effects, however, were transient and leaf sugar levels were equivalent to those found in uncut bentgrass by 60 hours following mowing.

Root total non-structural carbohydrate levels were highest in the spring and lowest in late summer. The summer decline of total non-structural carbohydrate levels in creeping bentgrass roots was previously reported by Xu and Huang (14). Water-soluble carbohydrate levels in roots generally were similar on most rating dates. Storage carbohydrate and total non-structural carbohydrate root levels were highest in non-cored bentgrass in June 2007, and root total non-structural carbohydrate levels were lowest in spring plus summer cored bentgrass in July 2006 and 2007. Otherwise, root carbohydrate levels were similar among coring treatments until September. Like leaves, total non-structural carbohydrate levels in roots were highest in May and June. Thereafter, total non-structural carbohydrate levels declined in 2006, but remained static in 2007.

Root storage carbohydrate levels were on average 56% (2006) and 22% (2007) higher in September of each year in spring plus summer cored compared to non-cored bentgrass. Root total non-structural carbohydrate levels were 26% (2006) and 8% (2007) higher in spring plus summer cored versus non-cored bentgrass in September. Late-summer increases in total non-structural carbohydrate and storage carbohydrate levels associated with coring may have been due to improved nutrient (i.e., N) availability accorded by re-incorporation of soil and topdressing or improved oxygen availability.

The higher leaf and root total non-structural carbohydrate levels found in creeping bentgrass in spring would be useful in assisting the turf in recovering from injury caused by the more invasive, large-diameter tines. Lower total non-structural carbohydrate levels in summer, however, indicated that using a larger tine at this time would have a greater negative effect on plant recovery. Higher total non-structural carbohydrate levels in tissues of spring plus summer cored creeping bentgrass in September likely would enable plants to recover more rapidly from summer stresses in the autumn.

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