Getting to the core of carbs

A two year field study by US researchers Jinmin Fu and Peter Dernoeden was initiated to examine the effects of coring on rates of photosynthesis and whole plant respiration and to quantify carbohydrates in creeping bentgrass leaves and roots during the summer.

Core cultivation or coring is routinely performed on putting greens for a multitude of beneficial purposes. 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 (Donaghy and Fulkerson, 1998). Carbohydrates in turfgrasses consist of the monosaccharides glucose and fructose (reducing sugars), disaccharide sucrose and various starches and fructans (Smith, 1972). Fructan can be hydrolyzed into fructose, which can be converted to glucose or 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 (Amiard et al., 2003).

Root growth in some grasses is more sensitive to a decrease in the availability of carbohydrates than leaf growth (Donaghy and Fulkerson, 1998). Therefore, root regrowth following coring may require a considerable amount of carbon investment.

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 (Xu and Huang, 2000).

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The effects of coring on carbohydrate metabolism during summer months in creeping bentgrass have not been documented. Therefore, the objectives of this field study were to quantify photosynthesis (P_n) and respiration (R_w) rates as well as carbohydrate levels – water soluble carbohydrates (WSC; i.e.: glucose, fructose and sucrose), soluble carbohydrates (SC i.e.: fructan and starch) and total non-structural carbohydrates (TNC = WSC plus SC) 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 (2004) recommendations at the University of Maryland Turfgrass Research Facility in College Park during 2006 and 2007. Soil was a modified sand mix (97 per cent sand, 1 per cent silt and 2 per cent clay) with a pH of 6.5 and 10mg 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 (50kg/ha) with 'Providence' creeping bentgrass later that month. A total of 250kg/ha N was applied between 20 September and 11 November 2005. (NB: Northern Hemisphere spring is March-May, summer is June-August and autumn September to November).

The bentgrass was fertilised bi-weekly with 4.9kg/ha N from urea between 1 May and 7 June and then weekly through 24 August for a total of 78.4kg/ha N during the experimental period in 2006. In autumn 2006, 71kg/ha N was applied between September and November. In 2007, the bentgrass was fertilised weekly with 4.9kg/ha N from urea between 30 April and 27 August to provide a total of 88.2kg/ha N during the experimental period.

The green was mown to a height of 4mm five times weekly and clippings were removed. Turf was irrigated to prevent wilt and was syringed frequently during dry, windy periods. Each plot measured 1.8m x 2.4m and was separated by a 60cm creeping bentgrass perimeter border. Three coring treatments were assessed as follows:

- Non-cored (NC);
- Spring-only coring (SP); and
- Spring plus summer coring (SP+SU).

Typically, large diameter tines are used to core greens in the spring and small diameter tines are used in the summer (O'Brien and Hartwiger, 2003). In the spring coring programme, plots were cored once annually in late April using a Miltona Handi Aerifer. This hand-held, manual device had seven, 0.5inch hollow tines, which penetrated to a depth of 9cm (3.5").

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 equipped with a quadra-tine holder on 6 June, 28 June and 25 July 2006 and 6 June, 3 July and 31 July 2007. The four, 0.25" hollow tines penetrated to a depth of 5.5cm (2.1").

Topdressing, using the previously described 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 (P_n) and whole plant respiration (R_w – including plant and soil microbe respiration), were measured on a two- to three-week interval between 6 June and 7 September 2006 and on a three- to four-week interval between 31 May and 6 September 2007 using a portable gas exchange system.

P_n and R_w were determined by enclosing the turf canopy in a transparent plexiglass chamber attached to a LI-6400 CO_2 analyser as described by Fu et al. (2007). Measurements of P_n and R_w 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 WSC and SC levels. Clippings were collected on 25 May, 21 June, 21 July, 4 August and 7 September 2006 and 1 and 28 June, 17 July, 15 August and 6 September 2007.

Roots were sampled by removing four soil cores from each plot on the aforementioned 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 analysed.

RESULTS – PHOTOSYNTHESIS AND RESPIRATION

Between 6 June and 24 July 2006, P_n rate was similar among coring regimes (Table 1). A higher P_n level was observed on 16 August 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 P_n level compared to spring-only and non-cored bentgrass.

In 2007, P_n levels were higher on 31 May and 24 July in spring plus summer versus non-cored bentgrass, but were similar to spring-only cored bentgrass (Table 1). No differences in Pn were observed on 2 July and 14 August 2007 among

TAKE-HOME POINTS

- 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 and summer cored bentgrass.
- Leaf and root water soluble carbohydrate (WSC), storage carbohydrate (SC) and total non-structural carbohydrate (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 and summer cored bentgrass versus other coring treatments.
- Coring in spring and summer resulted in enhanced carbohydrate levels in leaves and roots by September (start of autumn), 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.

Coring is performed periodically on creeping bentgrass putting greens for numerous reasons, however, its impact on carbohydrate metabolism is unknown

coring regimes. On 6 September 2007, the P_n level was higher in spring plus summer cored compared to spring-only cored bentgrass. The P_n 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 R_w level on 6 June 2006 compared to non-cored bentgrass. Except on 31 May, no differences in R_w were observed in 2007 among coring regimes (Table 2). On 31 May 2007, spring plus summer cored bentgrass had a higher R_w level compared to non-cored bentgrass.

LEAF CARBOHYDRATES

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

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

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

Leaf SC levels were lower on 1 June, similar on 28 June and 17 July, and higher on 15 August and 6 September for spring plus summer versus non-cored bentgrass. Spring plus summer cored bentgrass had lower leaf SC levels on 1 June and 17 July, similar SC levels on 28 June, and higher leaf SC levels on 15 August and 6 September, when compared to spring only cored bentgrass tissues. TNC levels in leaves were similar on 1 June and 17 July, but greater on 28 June, 15 August, and 6 September 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 WSC levels on 25 May and 7 September compared to non-cored bentgrass (Table 4). No differences in root WSC levels were observed on the other three measurement dates between spring plus summer and non-cored bentgrass. Root WSC levels were similar between 25 May and 4 August, but greater in spring plus summer versus spring-only cored bentgrass on 7 September.

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

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

Root TNC levels were lower on 1 June and 17 July, similar on 28 June and 15 August, and higher on 6 September in spring plus summer compared

In the spring coring programme, plots were cored once annually using a hand aerifier containing seven 0.5-inch hollow tines which penetrated 3.5 inches

TABLE 1. PHOTOSYNTHESIS IN CREEPING BENTGRASS IN RESPONSE TO DIFFERENT CORING REGIMES.

Photosynthesis (mmol/s/m^2)

Treatments	6 June	21 June	7 July	24 July	16 Aug.	7 Sept.
			– 2006 –			
SP	6.7 a	8.4 a	4.6 a	4.1 a	4.8 ab	7.2 b
SP + SU	7.2 a	7.7 a	5.4 a	4.1 a	6.7 a	8.3 a
NC 6.9 a	8.2 a	4.9 a	3.7 a	4.6 b	7.3 b	
			– 2007 –			
		31 May	2 July	24 July	14 Aug.	6 Sept.
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
NC		4.6 b	5.3 a	6.4 b	7.1 a	4.7 ab

NB: SP=spring only, SP + SU = spring plus summer, NC= non-cored. Means in a column in a given year followed by the same letter are not significantly different.

TABLE 2. RESPIRATION IN CREEPING BENTGRASS IN RESPONSE TO DIFFERENT CORING REGIMES

Respiration (mmol/s/m^2)

Treatments	6 June	21 June	7 July	26 July	16 Aug.	7 Sept.
			– 2006 –			
SP	8.7 ab	9.4 a	7.0 a	9.8 a	8.4 a	7.8 a
SP + SU	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 –			
		31 May	2 July	24 July	14 Aug.	6 Sept.
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
NC		9.8 b	10.0 a	10.2 a	8.8 a	10.3 a

NB: SP=spring only, SP + SU = spring plus summer, NC= non-cored. Means in a column for each year followed by the same letter are not significantly different

Photosynthesis and whole plant respiration were determined by enclosing the turf canopy in a transparent plexiglass chamber attached to a CO_2 analyser

TABLE 3. LEAF TISSUE CARBOHYDRATE LEVELS.

Treatments	1 June	28 June	17 July	15 Aug.	6 Sept.
		– WSC [glucose (mg/g)] –			
SP	40.9 a	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
NC	40.5 a	39.9 a	30.0 a	30.5 a	28.6 ab
		– SC [glucose (mg/g)] –			
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
NC	87.5 a	43.1 a	40.9 b	45.3 b	36.8 b
		– TNC [glucose (mg/g)] –			
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
NC	128.0 a	83.0 b	70.9 a	75.7 b	65.4 b

NB: WSC = water soluble carbohydrates, SC = storage carbohydrates, TNC = total non-structural carbohydrates. Means in a column for each carbohydrate parameter followed by the same letter are not significantly different.

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

DISCUSSION

Data showed that P_n 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, P_n was higher in spring plus summer cored than spring-only cored bentgrass. Coring in the spring, however, did impact R_w on initial measurements.

On 6 June 2006 and 31 May 2007, R_w was higher in spring plus summer cored versus non-cored plots. Perhaps an increase in R_w 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 R_w. Thereafter, R_w levels were similar among all coring regimes in both years. Hence, coring in general did not negatively impact P_n or R_w.

The rate of leaf and root regrowth following coring could depend 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 WSC levels in both years generally were lowest in July. Leaf WSC levels were higher in September in spring plus summer versus the other coring treatments in 2006, but not in 2007.

Leaf TNC levels also were higher in September in spring plus summer cored compared non-cored bentgrass in both years. Similarly, Narra et al. (2004) found that TNC levels in bentgrass clippings decreased in mid-July and August, but increased during autumn. 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 (Howieson and Christians, 2008; Volenec, 1986). Howieson and Christians (2008) 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.

TABLE 4. ROOT TISSUE CARBOHYDRATE LEVELS.

Treatments	1 June	28 June	17 July	15 Aug.	6 Sept.
		– WSC [glucose (mg/g)] –			
SP	22.2 a	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
NC	22.5 a	18.8 a	37.4 a	38.2 a	37.0 a
		– SC [glucose (mg/g)] –			
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
NC	73.8 a	40.3 a	19.2 a	21.9 a	22.2 b
		– TNC [glucose (mg/g)] –			
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
NC	96.3 a	59.0 a	56.6 a	60.1 a	59.2 b

NB: WSC = water soluble carbohydrates, SC = storage carbohydrates, TNC = total non-structural carbohydrates. Means in a column for each carbohydrate parameter followed by the same letter are not significantly different.

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

Root TNC levels were highest in the spring and lowest in late summer. The summer decline of TNC levels in creeping bentgrass roots was previously reported by Xu and Huang (2003). Water-soluble carbohydrate levels in roots generally were similar on most rating dates. Storage carbohydrate and TNC root levels were highest in non-cored bentgrass in June 2007 and root TNC 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, TNC levels in roots were highest in May and June. Thereafter, TNC levels declined in 2006, but remained static in 2007.

Root SC levels were on average 56 per cent (2006) and 22 per cent (2007) higher in September of each year in spring plus summer cored compared to non-cored bentgrass. Root TNC levels were 26 per cent (2006) and 8 per cent (2007) higher in spring plus summer cored versus non-cored bentgrass in September. Late-summer increases in TNC and SC 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.

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

The higher leaf and root TNC 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 TNC levels in summer, however, indicated that using a larger tine at this time would have a greater negative effect on plant recovery. Higher TNC 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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