Efficient Irrigation of Golf Turf in the Cool–Humid New England Region

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Objectives:

Develop research based crop coefficients (K_c) for efficient irrigation practices in recreational turf (golf and sports) under maintenance and climatic conditions typical of the New England region.

Scheduling irrigation according to actual turfgrass evapotranspiration rates (ET_a) reduces waste and increases irrigation efficiency. Landscape and crop coefficients (Kc values) are used in association with weather station reference ET (ET_0) to predict ET_a. Experimentally derived Kc values need to be developed at the local level to ensure optimum turf function and effective irrigation efficiency specific to the region.

In this study we compared ET_a measured using weighing mini–lysimeters with reference ET_0 for one golf turf species (creeping bentgrass, CBG) maintained as green and fairway, and two sports grass species (Kentucky bluegrass, KBG and perennial ryegrass, PRG). The reference ET_0 was measured using the standard reference value computed using the United Nations Food and Agricultural Organization report 56 (FAO 56 equation). Studies were initiated in 2011 at the Joseph Troll Turf Research Facility, South Deerfield, MA. Pure stands measuring 5 by 10 ft of "Exacta" PRG and "Touchdown" KBG were established to represent sports grass while 'Memorial' CBG was used as green and fairway turf. Sports grass height of cut (HOC) was maintained at 1.25 and 2.5 inch while CBG plots were maintained at 0.125 and 0.5 inch HOC. All treatment plots received either 2 or 4 lbs N 1000 ft^{-2} yr^{-1}. During the irrigation season in summer the 2 lb N 1000 ft^{-2} yr^{-1} rate received no fertilizer while the 4 lb N 1000 ft^{-2} yr^{-1} treatment received 1 lb N 1000ft^{-2}. Fertilizer was applied during the irrigation season during the first week of July.

Two methods were used to calculate Kc values. Method 1 calculated Kc values as a simple ET_a–to–ET_0 ratio based on yearly (seasonal) averages for each year of the test, which were derived from daily ET measurements. As an alternative to the ET_a–to–ET_0 ratio method, Method 2 derived the Kc values for each year using linear regression analysis with ET_a as the dependent and ET_0 as the independent variable. The regression intercept was forced through zero and the regression slope was used as a surrogate for Kc. In 2011, 23 daily ET_a and ET_0 measurements were used to derive Kcvalues during the summer months beginning late June and ending late August. In 2012, 30 daily ET measurements were made to calculate Kc values over the same period. In the last year of the test (summer of

Figure 1. Installation of mini–lysimeters into tall grass perennial ryegrass plots.

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2013) 26 daily ET measurements were used to derive Kc values.

Reference ET_0 values derived using the FAO 56 equation were significantly correlated with ET_a for year 2011 ($r=0.69$, $P\leq0.001$), 2012 ($r=0.92$, $P\leq0.001$), 2013 ($r=0.82$, $P\leq0.001$) and when all observations were pooled across all years ($r=0.82$, $P\leq0.001$, $n=79$). Therefore, FAO 56 ET_0 was effective in predicting actual turf ET. Figure 3 shows regression derived estimates of Kc values using Method 2 for each year across all grass species, HOC, and N levels. The same regression analysis was used for individual species, N and HOC,

Figure 2. Taller grass plots used more water as ET and in turn exhibited higher Kc values. The different heights of cut for perennial ryegrass were 3.2 (1.25 inches) and 6.4 cm (2.5 inches).

Figure 3. Differential height of cut with creeping bentgrass in the immediate foreground and tall perennial ryegrass and Kentucky bluegrass plots in the background.

Table 1. Results for crop coefficient (K_c) values measured over three years (2011, 2012, and 2013) calculated using regression analysis (slope estimate) and as ET_a-to-ET_0 ratio derived from daily ET measurements from late June to late August. Twenty four daily ET measurements were made in 2011, 30 measurements were made in 2012, and 26 daily ET measurements were made in 2013

Factor	Kc slope ± 95% CI†				Kc ET_a–to–ET_0				Leaf growth, mm d^{-1}			
Species	2011	2012	2013	3–Yr avg.	2011	2012	2013	3–Yr avg.	2011	2012	2013	3–Yr avg.
KBG	1.29±0.08	1.29±0.04	1.05±0.07	1.21±0.06	1.28a‡	1.28a	1.08b	1.21a	2.5a	2.1a	1.1b	1.9b
PRG	1.14±0.08	1.19±0.05	1.21±0.04	1.18±0.06	1.13b	1.16b	1.22a	1.17a	2.4a	2.0a	2.0a	2.1a
CBG	0.99±0.10	0.95±0.08	0.94±0.05	0.96±0.08	0.98c	0.96c	0.96b	0.97b	1.3b	0.9b	0.7c	1.0c
N, lbs 1000ft^{-2}												
0	1.11±0.07	1.13±0.05	1.04±0.06	1.09±0.06	1.11a	1.10a	1.06a	1.09a	1.8b	1.5b	1.1b	1.5b
1	1.17±0.09	1.16±0.04	1.09±0.04	1.14±0.06	1.15a	1.16a	1.12a	1.14a	2.3a	1.8a	1.5a	1.8a
HOC												
Low	1.12±0.08	1.08±0.05	0.98±0.05	1.06±0.05	1.11a	1.07b	1.01b	1.06b	2.2a	1.6b	1.2b	1.6a
High	1.16±0.08	1.21±0.04	1.15±0.04	1.17±0.05	1.15a	1.19a	1.17a	1.17a	1.9a	1.8a	1.4a	1.6a
Year average	1.15±0.09	1.14±0.05	1.07±0.05	1.12±0.04	1.13	1.13	1.09	1.12	2.0	1.7	1.3	1.7
Regression r^2	0.479	0.837	0.675	0.672	–	–	–	–	–	–	–	–

†95% confidence interval derived from regression analysis. For comparison within the same factor.
‡Numbers followed by the same letter within the same factor are not statistically different at the 0.05 level.

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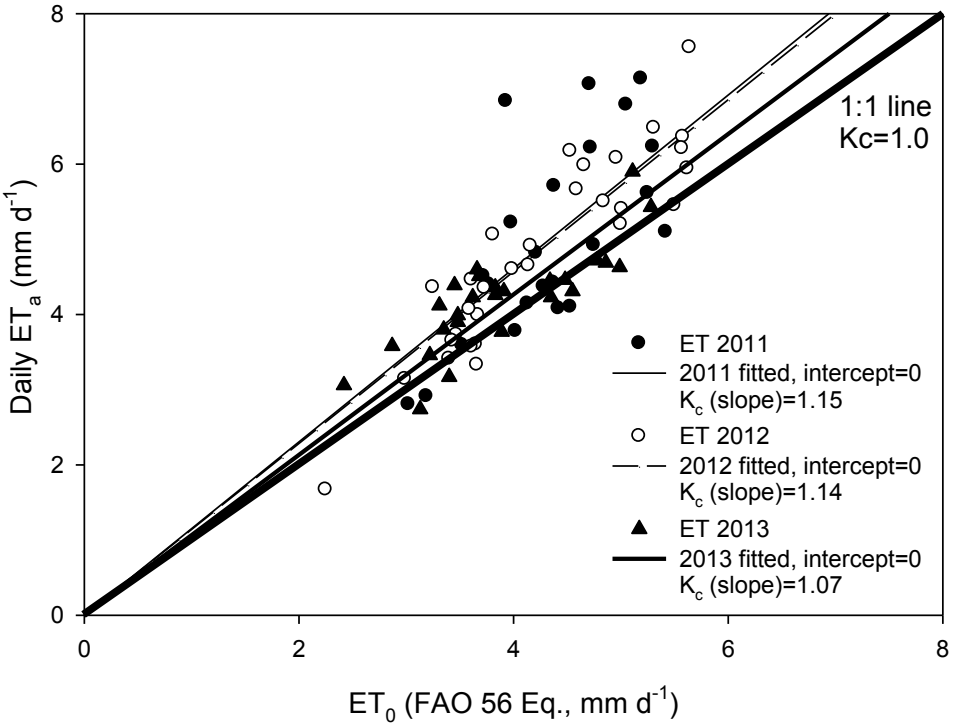

Figure 3. Relationship between predicted ET (ET_0) using the FAO 56 equation and actual ET (Et_a) measured using weighing mini-lysimeters. Data is shown for three years of daily ET for 2011, 2012, and 2013 using the regression method for estimating crop coefficients (Kc).

which are reported in Table 1. All reported yearly Kc values for the simple ET_a-to-ET_0 ratio method are within the 95% confidence intervals and match closely with Kc values reported using the regression method (Table 1).

Tall grass species such as KBG and PRG exhibited significantly higher Kc values than short grass CBG according to both Kc methods (Table 1). Moreover, tall grass species were 25% higher in Kc values than short grass CBG. Short grass CBG Kc values were statistically equal to Kc of "1" while tall grass species were significantly higher than "1" in their crop coefficients. Since Kc values are calculated directly from turf ET_a measurements, conditions or practices that increase or decrease turf ET_a also increase or decrease Kc values. Accordingly, a 25% decrease in crop coefficients with short grass green and fairway HOC is the direct result of a 25% lower ET_a.

In 2011, HOC had no significant effect on Kc values regardless of the method used (regression slope or simple ratio) to estimate Kc values (Table 1). In 2012 and 2013, however, the lower HOC resulted in 10 to 15% lower Kc values (and lower ET_a) according to both methods used to estimate Kc. The rate of N applied as granular fertilizer in summer had no significant effect on Kc values or ET_a. The N source used in summer was derived from methylene urea with 82% of the total N as slow-release nitrogen (SRN). Fertilization in summer was no different in Kc and ET_a from unfertilized plots. The N source used had no statistical effect on ET_a even though leaf growth rates were greater for fertilized turf in all three years of the test (Table 1). There was a strong correlation in all years between leaf growth rates and Kc values, with Kc increasing with daily leaf extension rate (Table 1 and Figure 4). As such, practices that help to reduce vertical leaf extension rates will minimize Kc values and the amount of water applied as irrigation.

The Kc values calculated were statistically similar for all years of study using both methods to estimate Kc (Table 1). According to three year averages and 95% confidence intervals from regression analysis, tall grass species such as KBG and PRG exhibited Kc values ranging from 1.12 to high as 1.27 (Table 1). Conversely, short grass green and fairway CBG exhibited Kc values ranging from as low as 0.88 to 1.04 (Table 1). After three years of field study, results indicate that a lower Kc value will be more appropriate for golf fairway and green turf compared to taller grass. Short cut golf turf offers potential water savings that will require Kc values that are 25% lower compared to taller sports turf. In this study, the shorter HOC along with CBG slower leaf extension rates contributed to this species lower ET_a and Kc.

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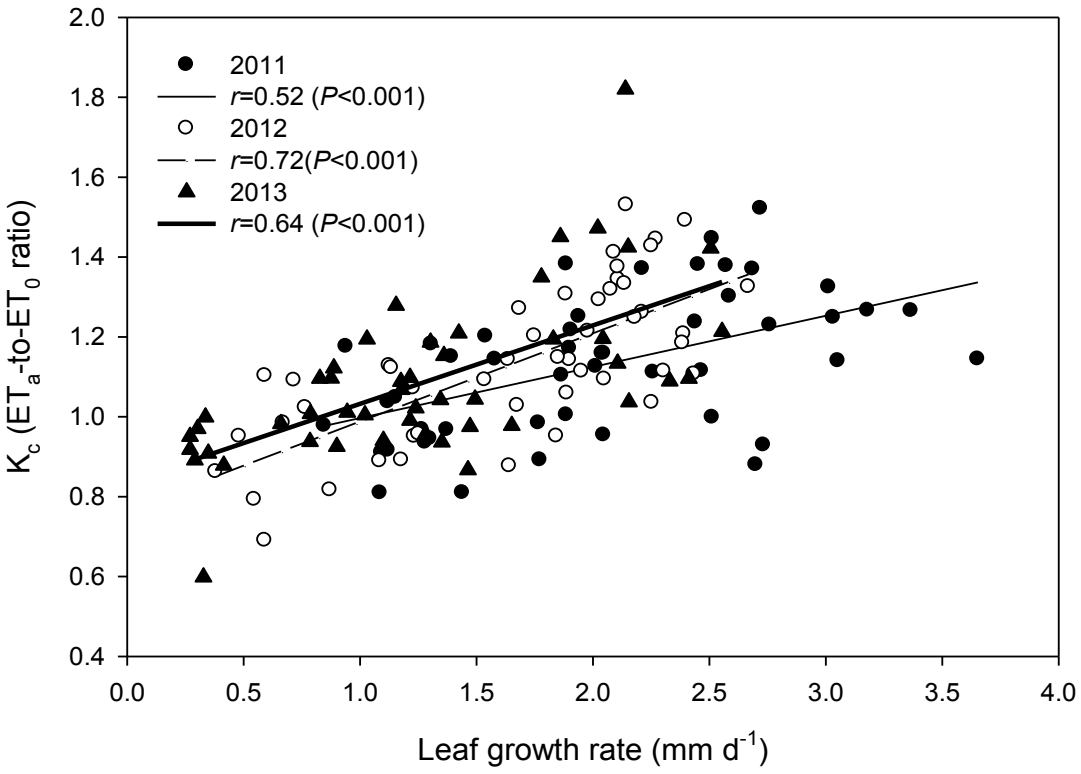

Figure 4. Relationship between leaf growth rate and K_c values derived from Et_a and ET_0 measurements over a three year period.

Summary Points

- The two computational methods that were compared to calculate FAO 56 derived Kc values did not affect the results between the different species, N fertility, and HOC that were evaluated over three consecutive years of irrigating in summer.
- CBG maintained as short grass green and fairway HOC averaged 25% lower in Kc values and ETa compared to tall grass PRG and KBG turf.
- Kc values derived from 95% confidence intervals based on three year averages ranged from 0.88 to 1.04 for short grass CBG while tall grass PRG and KBG ranged from 1.12 to 1.27.
- Kc values and ETa increased with leaf extension rates; KBG and PRG exhibited higher leaf growth rates than CBG.
- Fertilizing in summer with 1 lb N 1000ft^{-2} as 82% SRN was no different from unfertilized turf; fertilizer had no significant effect on Kc values and

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