Measuring greens firmness using the USGA TruFirm and the Clegg Soil Impact Tester at Victoria Country Club: A preliminary study

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Summary

Two tools designed to quantify surface firmness, the USGA TruFirm and the Clegg Soil Impact Tester (Clegg), were compared in a preliminary study that measured the firmness of *Poa annua* greens at the Victoria Club, Riverside, CA. There was a good correlation between the two devices, with the strongest relationship ($r^2 = 0.71$, $p<0.001$) between the first drop of each device. Further work is needed, however, to identify the potential role of each of these tools in greens management programs.

The Clegg is a general-purpose soil strength tool that has been used in a wide variety of situations including golf course and sports field firmness testing. The USGA TruFirm was specifically developed to recreate golf ball impacts, and thus assist in preparation and monitoring greens for consistent tournament play day in and day out. Although both devices appear to be useful in measuring greens surface firmness, the TruFirm displayed advantages in terms of ease of use when compared to the Clegg, including its lighter weight and minimal impact on the turf.

Background

Management of golf course turf for optimum levels of firmness is a goal of superintendents and golfers alike. Yet until recently, only preliminary work had been done in identifying objective criteria for firmness and the tools with which to measure it. However, recent efforts may help bring the measurement and monitoring of turf firmness into the realm of science-based procedures that are useful to turf managers as well as golfers.

In 2006, PACE Turf embarked on project with David Zahrte (Santa Ana CC) to characterize the factors involved in variations in greens firmness. Using a tool known as the Clegg Soil Impact Tester, we identified a range of values that produced acceptable levels of firmness (70 – 125g) at Santa Ana Country Club, as well as the important role that soil moisture played in soil firmness. Because firmness and soil moisture were well correlated, we were able to identify a range of 15% - 25% volumetric water content that would produce optimal firmness levels on sand-based greens (see http://www.paceturf.org/PTRI/Documents/060123sj.pdf for a full version of the report).

We also identified the practice of light sand topdressing, or dusting, as essential in maintenance of consistent firmness throughout the year. We have found that weekly dusting, by diluting out the organic matter and modifying the thatch and mat layer, allowed greens to remain firm, even when soil moisture was relatively high. In other words, the correlation between soil moisture and greens firmness was reduced by the practice of sand topdressing, a beneficial outcome that allowed the superintendent to provide consistently firm greens, even during rainy periods and periods of high irrigation demand.

The USGA has recently introduced a tool known as the TruFirm, which is designed to measure surface firmness. In addition to the fact that it was specifically developed for use on golf turf, the TruFirm has the advantage of being easier to use and also less damaging to turf than the Clegg.

In this study, we evaluated the relationship between firmness readings provided by the TruFirm and the Clegg, as well as the relationship between soil moisture and firmness readings produced by both devices.

Materials and Methods

Design

Readings with the Clegg, the TruFirm and the TDR Moisture meter were taken in 14 locations, spread over 4 Poa annua greens (green 1, 2, 17 and putting green). All readings were taken on the afternoon of January 12, 2009. The locations for each reading are shown in Figure 3.

Measuring firmness with the Clegg meter

At each sampling site, three drops of the 2.25 kg Clegg Impact Soil Tester (Model 95049A, available from Lafayette Instrument Company, Lafayette, IN) were made, and the “g” values for each drop recorded.

The Clegg measures surface firmness by obtaining a measurement of the deceleration of a free falling mass (2.5 kg hammer) from a set height (18 inches) onto a surface under test. The impact of the hammer produces an electrical pulse, which is converted and displayed on the Control Unit in units of gravities "g". The higher the impact that is recorded on the digital readout, the firmer the green surface.

Based on a literature review (see Citations below) and our own work, we have identified a range of 70 – 125 g (as determined by the 3rd drop of the hammer) as a general target firmness for greens at most golf courses. This range can of course be adjusted up or down, depending on the expectations and conditions at each individual golf course. Three hammer drops are used because we found a stronger correlation between the Clegg reading and soil moisture with successive number of hammer drops on the same spot (Figure 2). At the same time, we produced deeper and deeper dents in the turf with successive drops (Figure 1). Three hammer drops produced a good correlation with soil moisture, while producing less turf damage than 4 drops. The dent made in the turf surface with 3 drops was still significant, however, and requires repair, a task that adds time to the overall procedure. Based upon comparison of results between the Clegg and TruFirm in additon to a comparison between the first and third drops of the Clegg, a single drop of the Clegg may be sufficient for survey of golf green firmness. However, the guideline values that we have provided will have to be adjusted to a lower "g" rating for suitable firmness.

Measuring firmness with the TruFirm

The USGA TruFirm device was recently developed to measure surface firmness on golf courses. Firmness was measured using a single drop of the hammer. Results are recorded in terms of depth, with lower depth values indicating firmer surfaces. One drop of the TruFirm was made at each of the 14 sampling sites.

Soil moisture

Soil moisture readings were taken in areas closely adjacent to those where Clegg and TruFirm readings were taken. The Spectrum TDR 300 soil moisture probe (4.8 inch probes) was used to monitor volumetric water content. The average of three readings was taken in each test location.

Mapping

Global positioning system (GPS) and geographic information system (GIS) tools were used to map test greens, irrigation heads and sampling locations (for details, see "Precision Management Tools", http://www.paceturf.org/index.php/journal/precision_tools/).

Results

Firmness estimates

A strong correlation between firmness estimates from the Clegg meter and the TruFirm was determined Figure 3, Table 1). As expected the correlation was negative, with increasing values on the Clegg indicating increasing firmness and decreasing values on the TruFirm indicating increasing firmness.

The strongest correlation $r^2 = 0.71$, $p<0.000$ exists between the first drop of the Clegg meter and the TruFirm. With each additional drop of the Clegg, the correlation between the Clegg reading and the TruFirm became slightly weaker (Figure 3). It is likely that additional drops of the TruFirm would have correlated well with additional drops of the Clegg. However, because we dropped the TruFirm only once, this cannot be confirmed.

Firmness guidelines

Based on the scientific literature (see citations below) as well as readings taken at several different golf courses, in combination with input from superintendents and golfers, a range of 70 – 125 g (Clegg meter) has been previously established by PACE Turf. Although the USGA has not yet issued firmness guidelines based on use of the TruFirm, the correlation equation for the Clegg (3rd drop) vs. the Trufirm (Figure 3), suggests that a range of 0.45 – 0.20 inches on the TruFirm would correspond to a range of 70 – 125g on the Clegg. Likewise, the TruFirm values of 0.35 – 0.32 inches targeted at the 2008 Open at Torrey Pines would correspond roughly to a range of 93 – 100g (3rd drop of Clegg).

Correlation with soil moisture

It had previously been established (Figure 1) that there was a fairly strong correlation between firmness (as measured by the Clegg) and soil moisture (as measured by the TDR 300 moisture meter), with successive drops on the Clegg producing an increasingly strong correlation. This relationship was confirmed in the current study (Figure 4, Table 1), where the third drop of the Clegg produced the strongest correlation with soil moisture content.

The relationship between TruFirm readings and soil moisture content was weaker (Figure 4, Table 1) and was similar to that between soil moisture and the first or second drops of the Clegg.

Damage to turf

Although the Clegg has been very useful as both a diagnostic tool and a monitoring tool, the relatively deep dent that it produces (Figure 5) requires additional time for repair in each sampling location, and poses the risk of damage to turf. In contrast, the TruFirm had minimal impact on the turf surface (Figure 5).

Citations

Baker, S.W. Hind, P.D., Lodge, T.A., Hunt, J.A., Binns, D.J. 1996. A survey of golf greens in Great Britain IV. Playing quality. J. Sports Turf Res. Inst. 72:9-23.

Linde, D. 2005. Assessing golf course conditions in New Zealand. Golf Course Management

Figure 1. Relationship between TDR300 VWC (volumetric water content as a percentage) and Clegg deceleration (G). Higher G values indicate increased firmness. Note that firmness drops when soil moisture levels increase above 25%. The upper left graph represents the first drop of the Clegg hammer, the upper right graph represents the second drop of the Clegg hammer, the lower left represents the third drop of the Clegg hammer and the lower right represents the fourth drop of the Clegg hammer. Data generated January, 2006, Santa Ana Country Club (David Zahrte, superintendent).

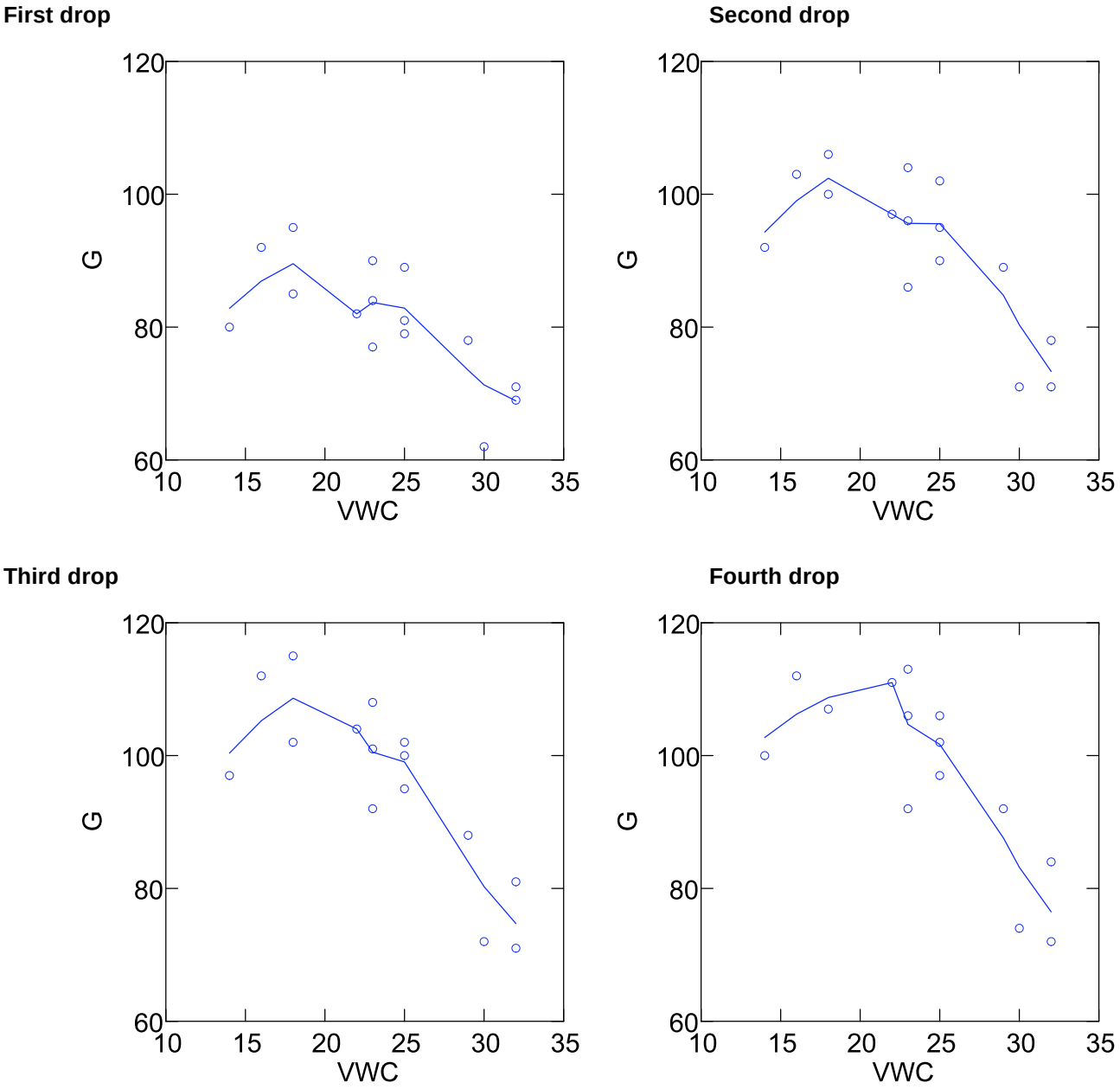
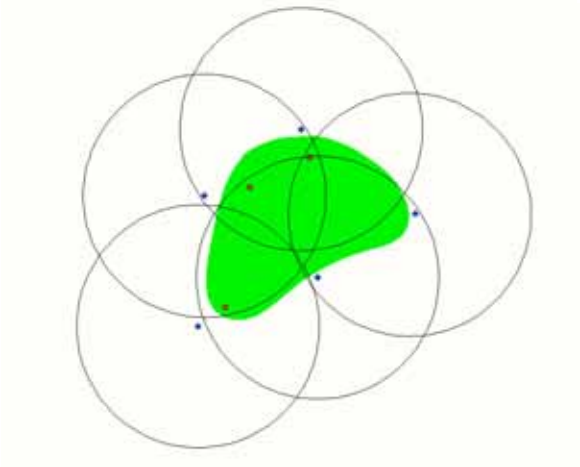
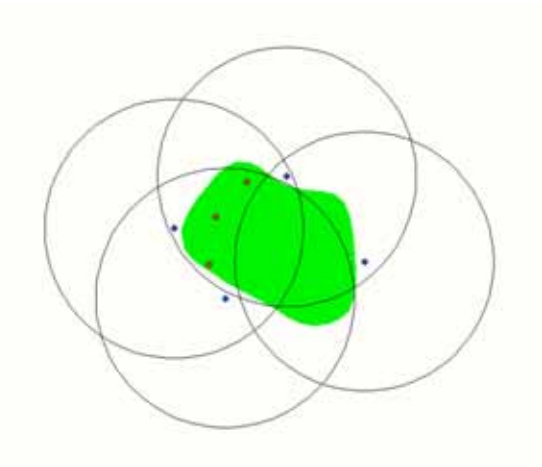


Figure 2. Sampling locations for firmness evaluation. Readings were taken from 14 sites indicated by the red dots on the four greens shown below. Irrigation heads on greens 1, 2 and 17 are designated with blue dots, and the predicted throw of the irrigation heads shown with large black circles.

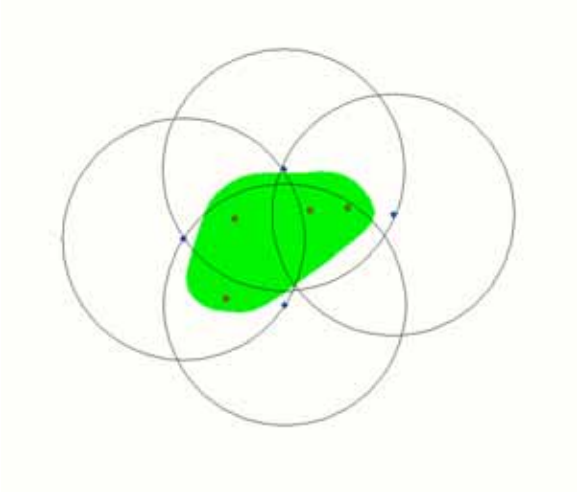
Green 1



Green 2



Green 17



Putting green

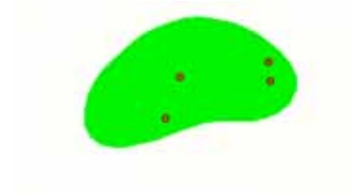


Figure 3. Correlation between firmness readings taken with the USGA TruFirm and the 1st drop, 2nd drop or 3rd drop of the Clegg Impact meter. Note that the strongest correlation exists between the 1st drop of the Clegg, and the first drop of the Trufirm. January 12, 2009, Victoria Golf Club.

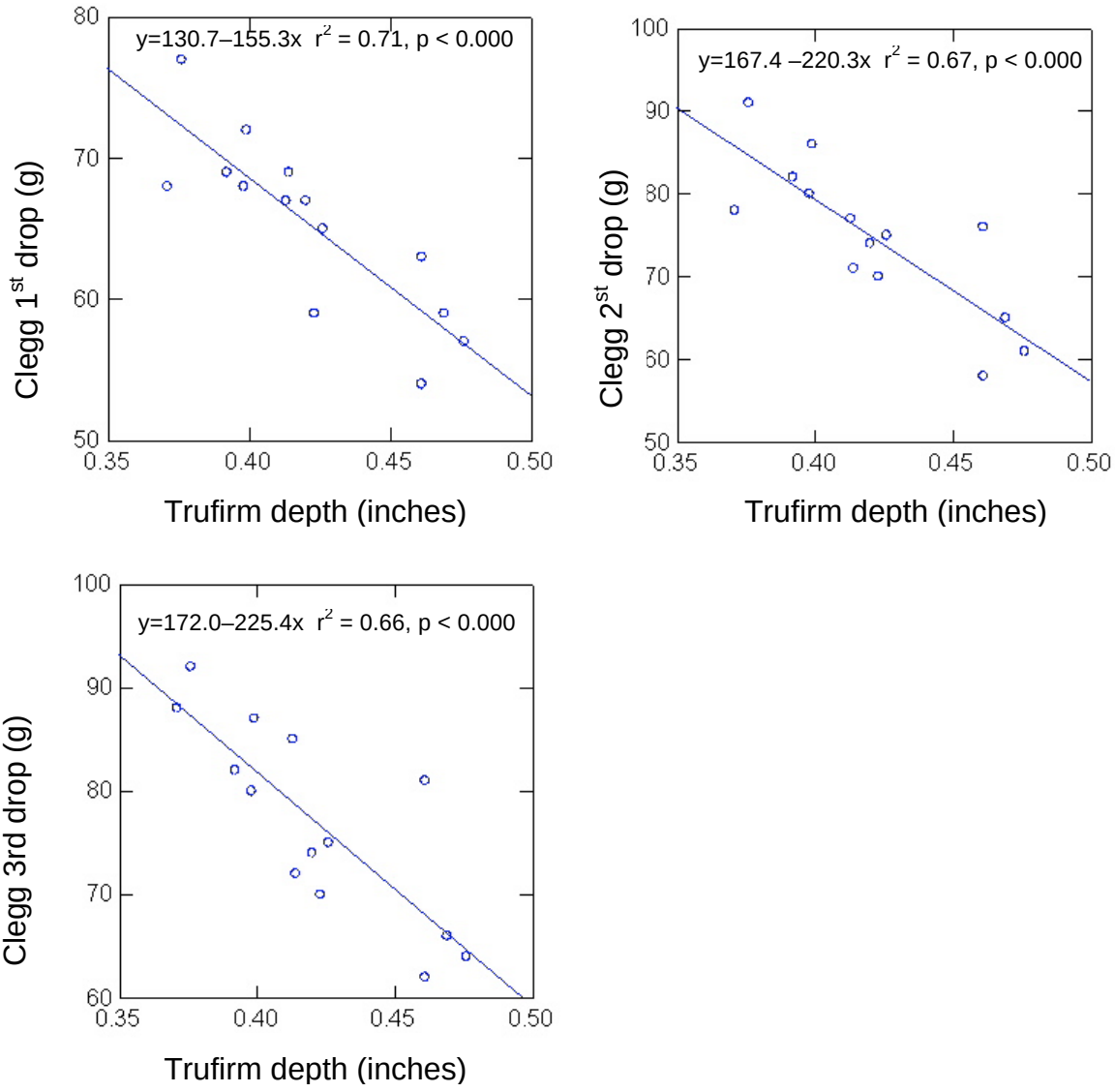


Figure 4. Correlation between firmness readings and volumetric water content (VWC) of soil. January 12, 2009, Victoria Golf Club.

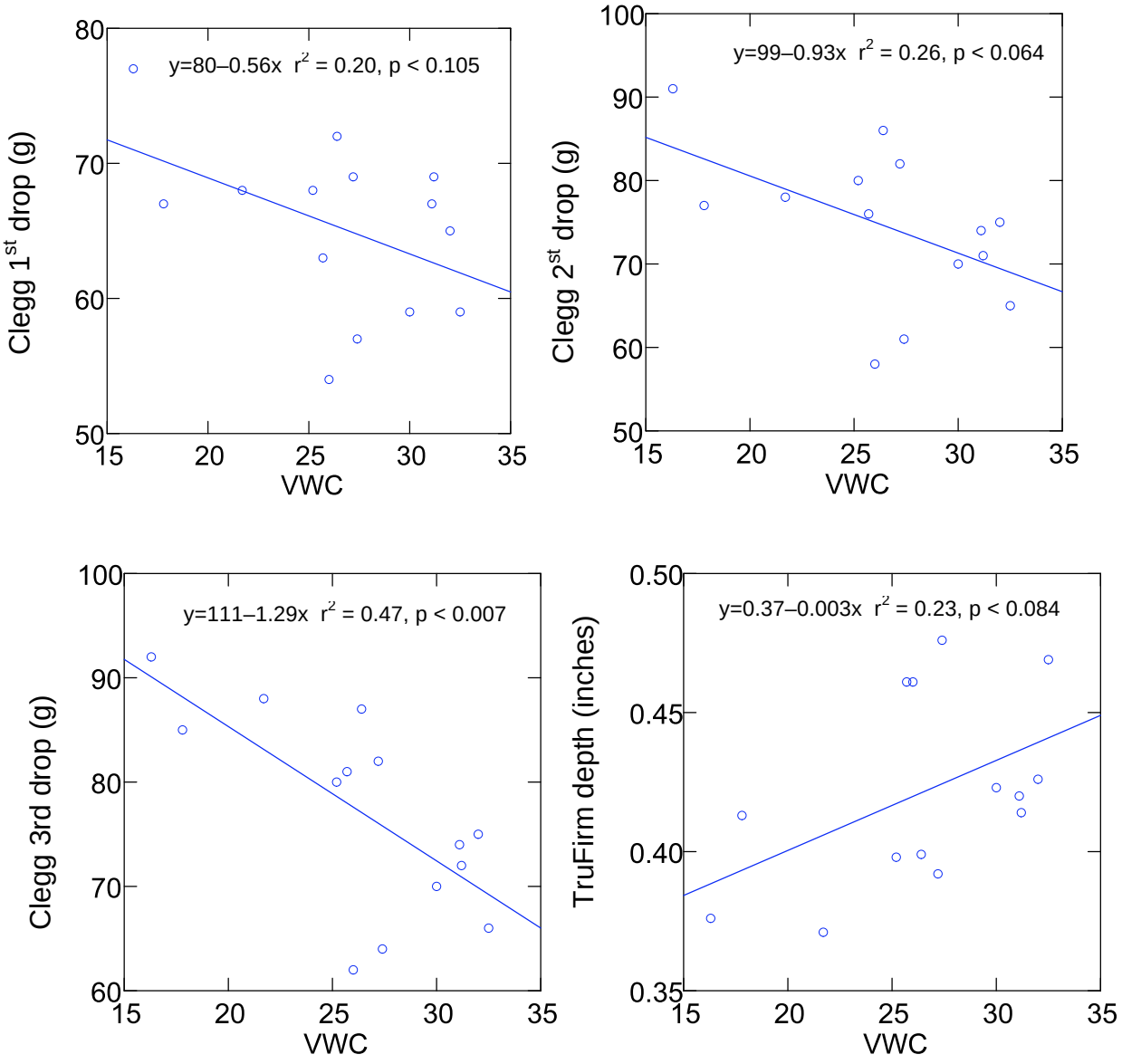


Figure 5. Comparison of turf damage produced by Clegg Impact meter (left) vs. the USGA TruFirm (right). January 12, 2009, Victoria Golf Club.

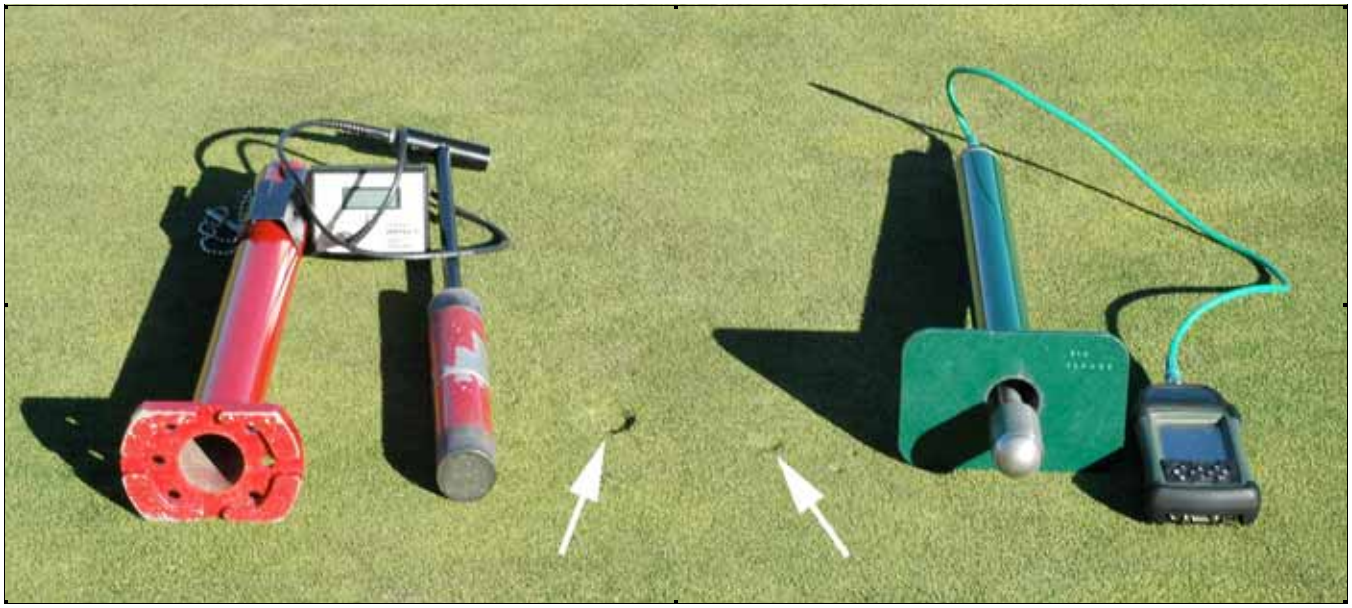


Table 1. Summary of statistical data illustrated in Figures 3 and 4.

X	Y	Slope	intercept	r^2	p
TruFirm depth (in)	Clegg 1st drop	-155.3	130.7	0.71	0.000
TruFirm depth (in)	Clegg 2nd drop	-220.3	167.4	0.67	0.000
TruFirm depth (in)	Clegg 3rd drop	-225.4	172.0	0.66	0.000
vwc	TruFirm depth (in)	0.003	0.3	0.23	0.084
TruFirm depth (in)	TruFirm coeff	-0.1	0.3	0.01	0.716
TruFirm coef	Clegg 1st drop	22.0	59.1	0.01	0.813
TruFirm coef	Clegg 2nd drop	94.3	48.0	0.04	0.483
TruFirm coef	Clegg 3rd drop	100.3	48.8	0.04	0.469
vwc	TruFirm coeff	0.0	0.3	0.02	0.597
Clegg 1st drop	vwc	-0.6	80.2	0.20	0.105
Clegg 2nd drop	vwc	-0.9	99.0	0.26	0.064
Clegg 3rd drop	vwc	-1.3	111.1	0.47	0.007