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Client: Torrey Pines Golf Course, Candice Combs

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General description of sample group: Firmness and soil moisture survey preliminary results

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## Summary

This report provides a summary of the data collected on 7/9/2010 and 7/19/2010 following a 10 day dry-down period combined with organic matter content (OM) for the surface two inches of all greens collected on 7/20/2010. The results indicate a strong interaction between soil moisture and firmness and a weak interaction between one measure of organic matter content that represents the leaves and stems of plants. There was no significant interaction between the humus fraction of the soil organic matter content and firmness. These results suggest that soil moisture has the greatest impact on firmness, greatly outweighing soil organic matter content. Regardless of the organic matter content of the greens, it will be important to have the capability to cover greens during heavy rainfall events in the winter when rainfall may result in saturated greens.

**Organic Matter:** The greens at Torrey Pines currently average 3.9% organic matter (A2LA loss by ignition at 360 C). This OM level is higher than the target 3% organic matter content targeted by the PGA and USGA. The organic matter content is not excessive for normal turf performance, but is at the upper limit for desired tournament conditions based upon PGA and USGA guidelines.

There was no correlation between organic matter content (humus, 360 C) and surface firmness. However, when the leaf and stem fractions of organic matter were evaluated (difference between loss by ignition at 440 C and 360 C), there is a positive and significant ( $p < 0.05$ ) correlation with firmness. This data suggests more stems and foliage results in increased firmness – essentially higher shoot density increases firmness.

**Firmness:** PACE Turf Guidelines recommend Clegg Soil Impact Tester (CSIT) GMAX values range between 75 and 125 for optimum conditions depending upon course layout and golfer expectations. The before dry-down average firmness for all greens on the South Course was 70 GMAX (range 56 – 96 g) and average soil moisture content was 41% (range 21 – 59%). The after dry-down average firmness was 98 GMAX (range 60 – 136) and average soil moisture content was 23% (range 6.6 – 52%). Table 1 summarizes the average values for the front, middle and back of greens for both the before and after dry-down measurements.

**Quality:** Turfgrass quality was evaluated using the Spectrum Technologies CM1000 over a range of soil moisture readings. The results (see Fig. 4) indicate that turf quality begins to decline at VWC levels less than about 30%. Turf quality declines rapidly at levels below 20% VWC. These results coupled with the firmness data suggests that 25%  $\pm$  5% VWC is a good target soil moisture level for the current time.

**Soil Moisture:** Ideally, greens firmness will not be severely affected by soil moisture content. The target firmness that the PGA is looking for is a maximum of 0.4 on the USGA TruFirm after rainfall. This value interprets to approximately 68 g on the Clegg – about where the average reading is now - only there has not been any rainfall. For premiere conditions, the Clegg would report more than 80 g immediately following rainfall. Increased sand application is currently the only method I am aware of for reducing the negative impact of soil moisture on greens firmness evaluations.

Soil moisture content varies widely throughout the course. This variation may be the result of a non-uniform soil matrix or poor irrigation distribution uniformity. If the soil matrix is not uniform – areas of high organic matter content will hold more moisture and greens will be difficult to manage. However, if the soil moisture variation is due to irrigation distribution problem, only hand watering will solve the problem. Preliminary observations suggest that some approach or surrounds heads impact the greens – as would be expected. When the greens heads are turned off, these surrounds heads are not affected – some edges of the greens receive water from the surrounds irrigation

heads. Soil moisture is therefore difficult to control using the irrigation system and careful hand water application will be needed to even the surface moisture content.

**Firmness target:** Following a conversation with Paul Vermulen, the target for greens performance is adequate firmness so that the greens surfaces do not collapse as a result of foot traffic following rainfall as took place in 2010. A TruFirm reading of 0.4 is the target after rainfall or heavy leaching (40 - 60 minute irrigation cycle). Pat Gross of the USGA also feels that a TruFirm reading 0.4 (68 GMAX using the CSIT) is a good firmness reading for routine golf play – low for tournament conditions but after rainfall might be acceptable. The current assumption is that there is excessive organic matter content in the surface two inches that moves easily underfoot when wet. If this is the case, increased sand topdressing and aeration will help dilute organic matter content. Increased sand application during routine weekly sand topdressing events will have a great impact on surface performance under rainfall conditions – even more impact than attempting to reduce organic matter content by core aeration or other methods of aeration.

**Research:** A study conducted by Kauffman et. al. (2006) indicates there was no significant difference in surface hardness, thatch depth, root mass, soil moisture or organic matter content when ½ inch diameter hollow core (quad tine spacing ) aeration was compared to Graden verticutting using a 1 mm blade. However, the turfgrass recovered more rapidly from core cultivation than when the Graden unit was used. Infiltration rate was faster when core cultivation was used. Only when the Graden was equipped with the 3 mm blades, was thatch depth reduced and surface hardness increased significantly compared to core cultivation. There was no significant difference in organic matter content when the Graden with 3 mm blades was compared to hollow core cultivation as described above. Although the Graden may be an excellent tool for thatch management when the 3 mm blades are used, the time to recovery is excessively long for a daily fee golf course.

Reference:

Kauffman, John; Karcher, Douglas; Richardson, Michael. 2006. *Abstracts: 2006 International Annual Meetings [ASA/CSSA/SSSA]*. p. [11].

## Methods

Each green was sampled in 9 locations for volumetric water content using a Spectrum Technologies TDR300 soil moisture meter and Clegg Soil Impact Tester with a 2.5 kg hammer (Clegg). Three measurements were collected from the front, middle and back of the green with the approach being used to identify the front of each green. The Clegg reading was taken first and then a Spectrum Technologies TDR 300 was used to take the soil moisture in the exact location where the Clegg reading was collected. The Clegg reading was collected for one drop of the hammer.

Organic matter content was evaluated by collecting five cores to a depth of two inches from the front, middle and back of each green and compositing the cores for each green into a single sample. The 15 cores per green ores were pulverized using a food processor until the blend was uniform. Following pulverization of the cores, each sample was placed into a Ziploc freezer bag and stored at 4 C until shipped. Samples were shipped overnight to Brookside Laboratories in New Knoxville OH where organic matter was determined by ignition at 360 C (A2LA protocol oxidizes humus fraction) and 440 C (A2LA, ASTM D2974-C protocol oxidizes humus, stems and leaves). Results are reported in Table 2.

## Recommendations

- Increase application of sand between now and winter, apply 50-75 lbs #30 sand/1000 sq ft weekly unless detrimental impacts on greens health is observed.
- Aerify using ½ inch tines on quad-tine holders. Top dress heavily and brush sand into the holes to fill all holes.
- Target a post-rainfall or post-leaching (soil moisture in the 50 – 60% range) surface firmness of 70g using the Clegg soil impact tester with 2.5 kg hammer or 0.4 using the USGA TruFirm. Firmness should exceed 80 g for premiere conditions. The firmness target values may change as additional research results are obtained.

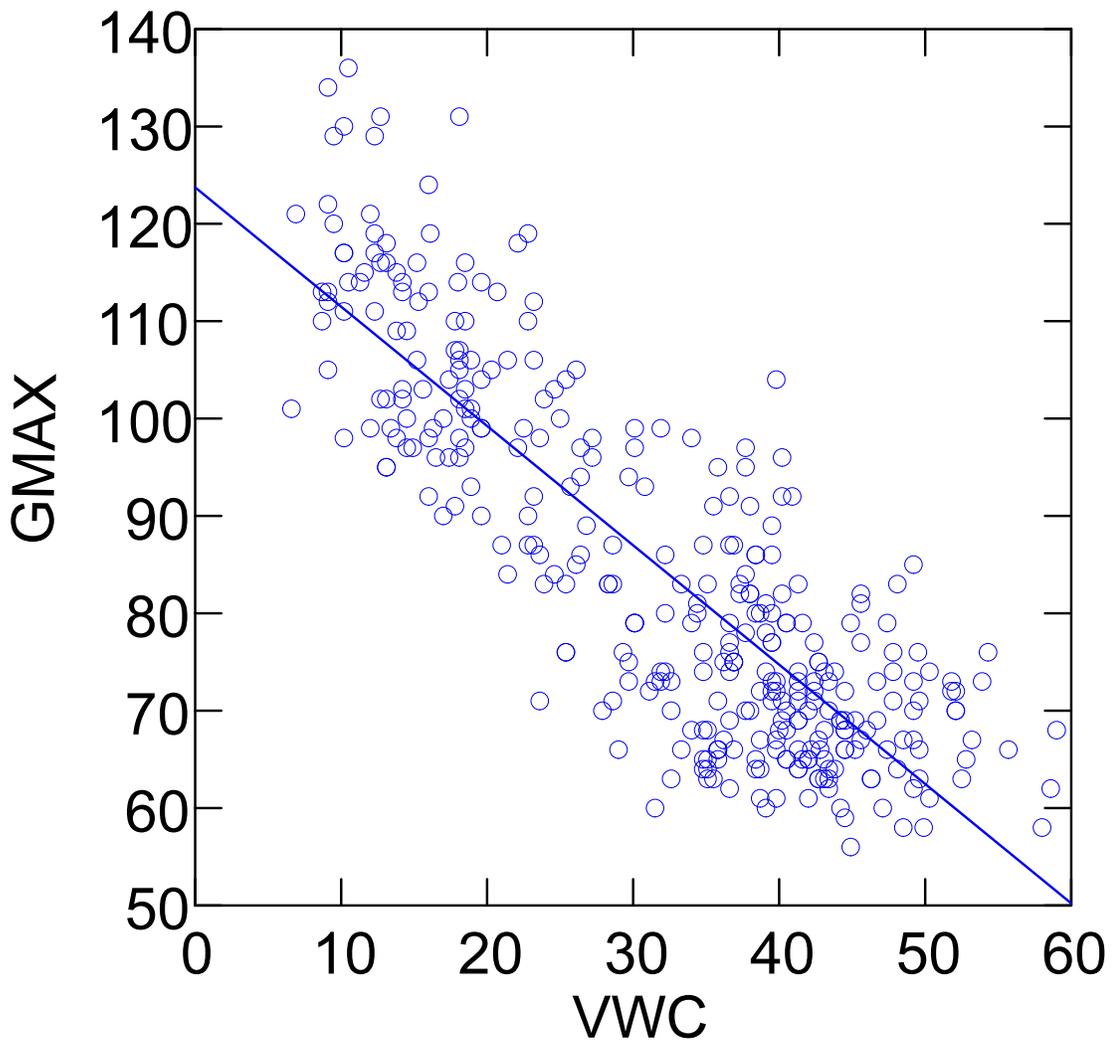
- Perform an irrigation audit to determine the uniformity of greens irrigation system. Determine whether the computer reports the correct amount of water being delivered to greens.
- If irrigation uniformity is poor, consider switching to hand watering 2 weeks prior to major golfing events to insure uniform soil moisture.

**Table 1. Analysis of variance comparing the front, middle and back of greens VWC and GMAX before and after dry-down.**

Values in the same column followed by the same letter are not significantly different. Results represent the average of all front, middle and back sample locations.

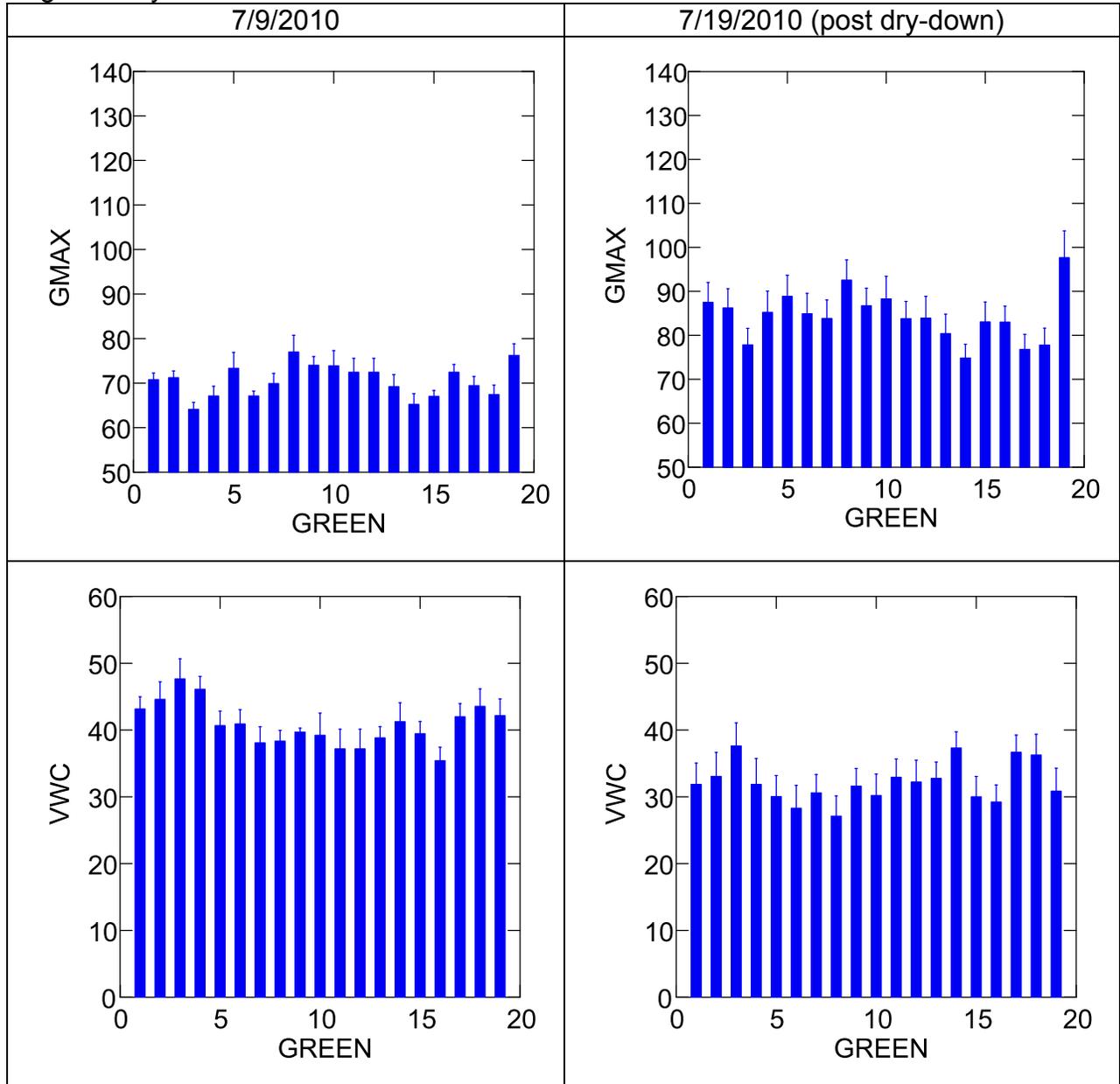
Location	7/9 VWC	7/9 GMAX	7/19 VWC	7/19 GMAX
Front	44 a	71 a	29 a	96 a
Middle	40 b	70 a	21 a	100 a
Back	38 b	71 a	21 a	98 a

**Figure 1. Correlation between volumetric water content (VWC) and greens firmness (GMAX) using 7/9 and 7/19 data. The regression is weak but significant ( $r^2 = 0.704$ ,  $p < 0.000$ )  $g = 123.7 - (1.2 \times VWC)$**



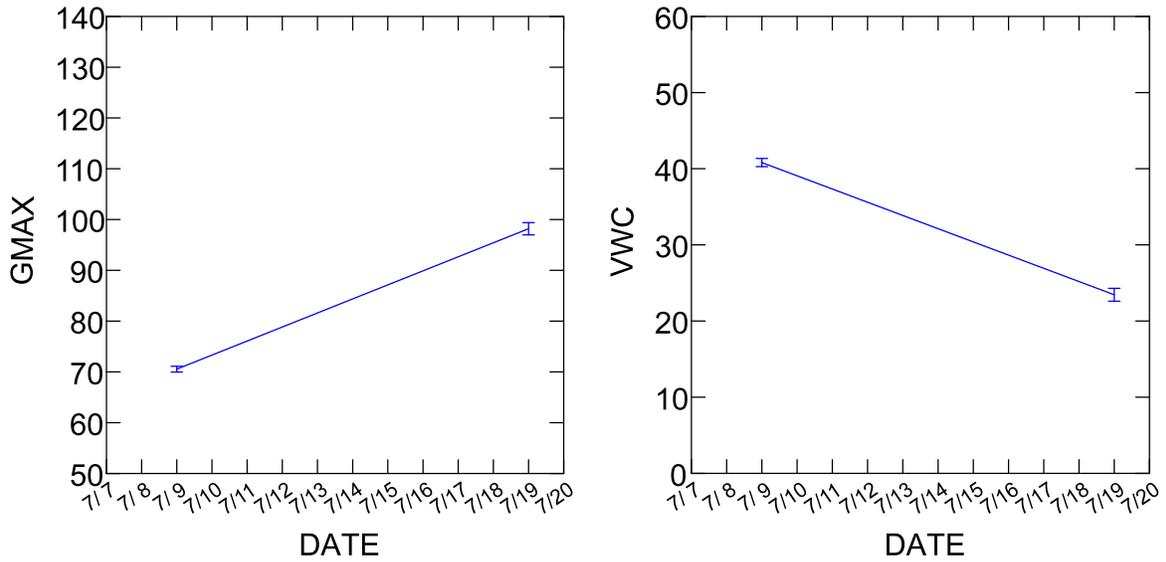
**Figure 2. Average greens firmness (GMAX) and volumetric water content (VWC).**

Whiskers represent the standard error of the mean. Whiskers that overlap are not significantly different



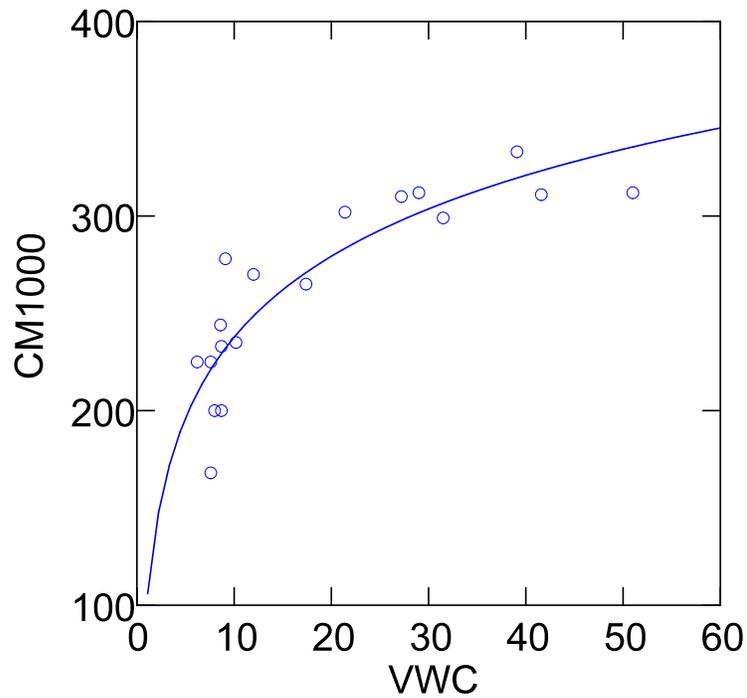
**Figure 3. Change in average greens firmness (GMAX) and volumetric water content (VWC).**

Whiskers represent the standard error of the mean. Whiskers that overlap are not significantly different



**Figure 4. Relationship between VWC and turf quality evaluated using the Spectrum Technologies CM1000 chlorophyll meter**

CM1000 values below 330 are associated with poor performing turf. When VWC drops below 30%, turf quality begins to decline.



**Table 2. Average firmness, volumetric water content and organic matter content by green.**

Firmness evaluated using the 2.5 kg CSIT (GMAX) on two dates, 7/9/2010 (GMAX0709) and 7/19/2010 (GMAX0719), volumetric water content (VWC) measured using a Spectrum Technologies TDR300 with 4.7 inch probes on two dates, 7/9/2010 (VWC0709) and 7/19/2010 (VWC0719) and soil organic matter (humus) content for composite core samples representing the top two inches of soil collected on 7/20/2010 reported as loss by ignition at 360 C (OM360, A2LA, for humus fraction) and 440 C (OM440, A2LA, ASTM D2974-C, for humus, stems and leaves). The OM440-OM360g is the difference between the 440 C and 360 C ignition organic matter content – an estimate of the leaves and stems (larger organic matter particles).

Green	GMAX0709	VWC00709	GMAX0719	VWC0719	OM360	OM440	OM440-OM360
1	70.8	43.2	104.2	20.6	3.96	4.94	0.98
2	71.2	44.6	101.2	21.5	4.18	4.81	0.63
3	64.1	47.7	91.6	28.6	3.76	4.55	0.79
4	67.1	46.1	103.3	17.6	4.3	4.93	0.63
5	73.3	40.6	104.3	19.4	3.49	4.57	1.08
6	67.1	40.9	102.7	15.7	4.05	4.81	0.76
7	69.9	38.1	97.8	23.1	3.81	4.35	0.54
8	77	38.3	108.1	15.9	3.45	3.91	0.46
9	74	39.7	99.4	23.5	4	4.65	0.65
10	73.9	39.2	102.7	21.2	3.83	4.43	0.6
11	72.4	37.2	95.1	28.7	3.8	4.4	0.6
12	72.4	37.2	95.3	27.3	4.51	4.7	0.19
13	69.2	38.8	91.6	26.7	3.8	4.22	0.42
14	65.2	41.3	84.4	33.4	3.81	4.26	0.45
15	67	39.5	99.1	20.5	3.68	4.34	0.66
16	72.4	35.4	93.6	23.1	3.99	4.49	0.5
17	69.4	42	84.1	31.4	3.87	4.34	0.47
18	67.4	43.5	88.1	30	4.34	4.66	0.32
19	76.2	42.2	119.1	19.6	3.19	3.84	0.65

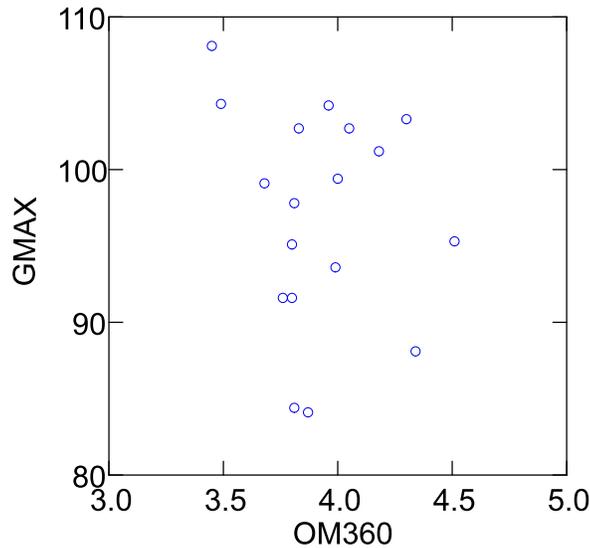
**Table 3. Correlations between greens firmness and organic matter content.**

Regression analysis for firmness measured using a 2.5 kg CIST and soil organic matter content in the top two inches of the greens surface. When the greens contained high soil moisture content on 7/9/2010, there were no correlations between organic matter content and firmness. When greens were drier on 7/19/2010, there was a significant ( $p < 0.10$ ) negative correlation between humus (OM 330) and firmness. In addition, there was a significant positive correlation ( $p < 0.10$ ) between firmness and the stem and leaf fraction of the organic matter (OM360-440).

	GMAX 7/9/2010			GMAX 7/19/2010		
	Slope	R <sup>2</sup>	p	Slope	R <sup>2</sup>	p
OM 360	NS	0.042	0.94	NS	0.032	0.48
OM 440	NS	0.052	0.36	NS	0.050	0.37
OM 440 - 360	NS	0.000	0.94	16.5	0.26	0.03

**Figure 5. Humus organic matter fraction fraction vs firmness**

Humus fraction (OM 360 C ignition) compared to firmness measured with a 2.5 kg CSIT. There is no significant correlation.



**Figure 6. Leaf and stem organic matter fraction vs firmness**

Leaf and stem fraction (OM 440 - 360 C ignition) compared to firmness measured with a 2.5 kg CSIT. The interaction is significant at the  $p < 0.05$ . Refer to Table 3 for regression results. Only 7/19/2010 firmness data provided a significant correlation.

