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Thermal Imaging Detects Early Drought Stress in Turfgrass Utilizing Small Unmanned Aircraft Systems

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Abstract

Plots of fairway-height creeping bentgrass were watered differently to create a gradient of drought stress from severe deficit irrigation to well-watered, under an automatic rainout shelter in Manhattan, KS. Canopy temperature (Tc) measured by a small unmanned aerial system (sUAS) predicted drought stress approximately 5 days or more before drought symptoms were evident in either turfgrass visual quality (VQ) or percentage green cover (PGC). The ability of Tc to predict drought stress was comparable to the best spectral parameters acquired by sUAS on companion flights [i.e., near infrared (NIR) and GreenBlue VI], and slightly better than with spectral data obtained from handheld sensors. Better drought-prediction ability combined with faster data collection using sUAS indicates significant potential for sUAS-based compared with ground-based drought stress monitoring methods.

Keywords

drought stress, drone, thermal imaging, creeping bentgrass fairway, spectral reflectance

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Thermal Imaging Detects Early Drought Stress in Turfgrass Utilizing Small Unmanned Aircraft Systems

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Summary
Plots of fairway-height creeping bentgrass were watered differently to create a gradient of drought stress from severe deficit irrigation to well-watered, under an automatic rainout shelter in Manhattan, KS. Canopy temperature (Tc) measured by a small unmanned aerial system (sUAS) predicted drought stress approximately 5 days or more before drought symptoms were evident in either turfgrass visual quality (VQ) or percentage green cover (PGC). The ability of Tc to predict drought stress was comparable to the best spectral parameters acquired by sUAS on companion flights [i.e., near infrared (NIR) and GreenBlue VI], and slightly better than with spectral data obtained from handheld sensors. Better drought-prediction ability combined with faster data collection using sUAS indicates significant potential for sUAS-based compared with ground-based drought stress monitoring methods.

Rationale
Recent advances in aerial platforms and thermal imaging provide opportunities to improve turfgrass management, including early drought detection and water conservation, but research on this topic has been limited.

Objectives
The objectives of this study were to 1) evaluate the ability of Tc imaging from sUAS to detect drought stress early in turfgrass; and 2) compare early drought-stress

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detection ability of Tc imaging with that of spectral reflectance measurements from sUAS-mounted and handheld optical sensors.

Study Description

This 1-year study was a companion study of Hong et al. (2018) conducted from June 7 to August 31, 2017, under an automatic rainout shelter at the Kansas State University Rocky Ford Research Center, Manhattan, KS. 'Declaration' creeping bentgrass was mowed at 5/8-inch height and treated from severe deficit irrigation to well-watered with 15, 30, 50, 65, 80, and 100% reference evapotranspiration (ET) replacement. A thermal camera (FLIR VUE PRO R 336, 35° FOV, 9-mm focal length), mounted on an IRIS+ (3D Robotics), was used to attain Tc weekly when weather permitted. One thermal image containing all the plots was selected for each measurement date, and average Tc was retrieved from the center of each plot using the FLIR tool (v. 5.13.), which also produced color-enhanced thermal maps. A modified Canon S100 camera was used to take airborne spectral reflectance measurements, including reflectance of three individual bands (NIR, green and blue bands), and their eight derived vegetation indices (VI). Traditional measurements included soil volumetric water content (VWC), VQ, and PGC using digital image analysis, and spectral reflectance measurements from handheld optical sensors.

Results

Stress in deficit-irrigation treatments was detected with Tc measurements from sUAS as the dry down progressed (Figure 1). Thermal imaging detected rises of Tc in 15% and 30% compared to 100% ET plots on June 15, corresponding to declines in VWC, before evident decreases in VQ and PGC (Table 1; Figure 1A). However, declines of PGC and VQ in 30 and 15% ET treatments compared to 100% ET were not observed until 5 days and 16 days later on June 20 and July 1, respectively. It is not certain that Tc detected drought stress symptoms a full 16 days early, and it is possible that drought symptoms became visible before July 1, because VQ was not evaluated on days between sUAS flights (e.g., between June 20 and July 1). This indicated the ability of Tc imaging from sUAS to detect drought stress more than 5 days before it became visible in turfgrass.

Interestingly, the early drought detection by thermal imaging was as early as NIR and GreenBlue VI [(green-blue)/(green+blue)] measured on a companion flights, and normalized difference vegetation index (NDVI) and Red band of a handheld active optical sensor (Table 1). The NIR and GreenBlue VI were the best spectral parameters reported in the companion study that consistently predicted drought stress throughout the 3-yr study (Hong et al., 2018). Moreover, Tc, NIR, and GreenBlue VI from the sUAS were more sensitive at detecting early drought stress in the lower irrigation levels in that they differentiated 100% ET plots from 15% and 30% ET plots, whereas the handheld sensor only detected early drought stress in 15% ET (Table 1). Better drought-prediction ability combined with faster data collection

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using sUAS indicates significant potential for sUAS-based compared with ground-based drought stress monitoring methods.

Reference

Hong, Mu; Bremer, Dale; and van der Merwe, Deon (2018) "Evaluating Small Unmanned Aerial Systems for Detecting Drought Stress on Turfgrass," Kansas Agricultural Experiment Station Research Reports: Vol. 4: Iss. 6. *https://doi.org/10.4148/2378-5977.7593*

Table 1. Analysis of irrigation main effects on volumetric water content (VWC), visual quality (VQ), percentage green cover (PGC), canopy temperature (Tc), spectral reflectance data acquired from the small unmanned aerial system (sUAS), and the RapidScan handheld optical sensor (NDVI and Red), for 'Declaration' creeping bentgrass on June 15, 20, and July 1, 2017.

ET[†]	June 15								June 20		July 1	
	VWC	VQ	PGC	Tc (°F)	NIR	GreenBlue[§]	NDVI[¶]	Red	VQ	PGC	VQ	PGC
100%	45.2A	7.3	90.5AB	104.7A[*]	201AB	-0.093A	0.78A[*]	4.5A[*]	7.6	91.2A	8.1A	98.0A
80%	43.8A	8	95.6A	105.6ABC	203A	-0.093A	0.81A	4.0A	8.8	95.8A	8.6A	99.0A
65%	40.7A	7.6	92.5A	105.4AB	199BC	-0.096AB	0.78A	4.6A	7.9	94.1A	7.8A	98.2A
50%	40.9A	7.9	94.9A	105.6ABC	199BC	-0.099B	0.80A	4.3A	8.4	95.6A	8.0A	98.5A
30%	34.3B	8	93.8A	106.5BC	197C	-0.101B	0.79A	4.4A	7.9	92.5A	6.1B	90.7B
15%	29.4C	6.6	84.5B	106.6C	191D	-0.110C	0.75B	5.3B	6.9	83.1B	5.6B	85.2B

*Treatment means were significantly different at $P < 0.05$ probability level, indicated by different letters; no letter presented when $P > 0.05$.
†Percentage of evapotranspiration (ET) replacement.
‡Visual quality based on a 1 to 9 scale, with 1 = dead; 6 = minimally acceptable; and 9 = uniform, green, dense turfgrass.
§GreenBlue = (G-B)/(G+B); G = green spectral reflectance, and B = blue spectral reflectance overlap between 400-580 nm.
¶NDVI = (NIR-Red)/(NIR+Red); NIR peaks at 780 nm, near infrared spectral reflectance; Red peaks at 670 nm.

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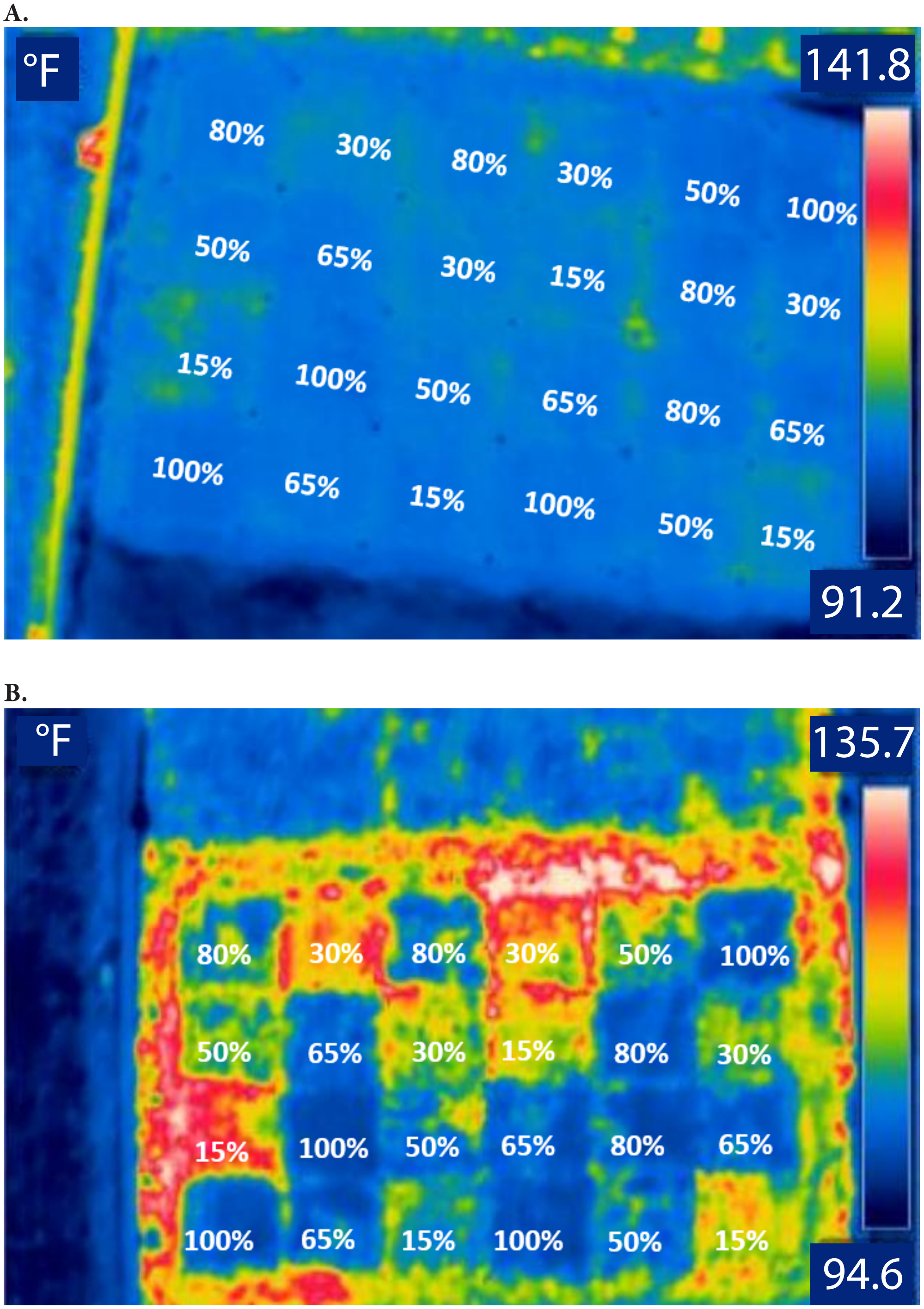

Figure 1. Color-enhanced canopy temperature image of plots on June 15 (A, one week into dry down) and August 31, 2017 (B, last day of dry down). Percentages denote evapotranspiration replacement irrigation treatments. A color bar on the right indicated the degree in Fahrenheit.

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