Evaluating Turfgrass color through Digital Image Analysis using GreenIndex+ Turf app

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INTRODUCTION

Evaluating turfgrass color

- Turfgrass color is an important component of overall turf quality, as well as a valuable indicator of plant health pertaining to nutrient and water status can be (Beard, 1973)
- While visually rating turf color using a 1-9 scale is a longstanding practice in turfgrass research, even among experienced raters, visual evaluations are an inherently subjective process which encounter both temporal and spatial limitations due to effects of ambient lighting (Horst et al., 1984, Ikemura, 2003, Krans and Morris 2007)
- Digital image analysis (DIA) is an accepted method for measuring and comparing turfgrass color across time and location through the use of standardized, artificial lighting conditions to improve objectivity and consistency in evaluations (Karcher and Richardson 2013)
- However, necessity for specialized equipment and software, as well as the time required to collect and process images limit DIA application beyond research settings

Dark green color index (DGCI)

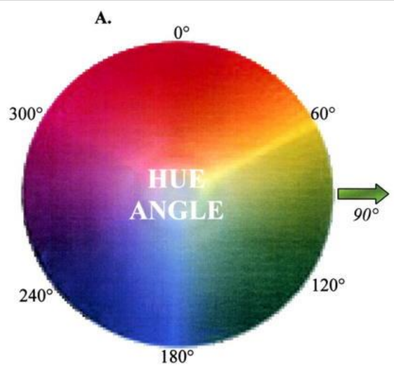
- Color information for each pixel within a digital image is described by red, green, and blue (RGB) light intensities, as well as spatial (X,Y) coordinates for that pixel's location within the image (Karcher and Richardson, 2013)
- Translating the RGB color numbers into a scale more representative of how the human eye perceives color: hue, saturation, brightness (HSB) values is important for further analysis (Rorie et. al 2011, Karcher and Richardson, 2013)
- Creating a single DGCI value from HSB parameters allows for more direct comparison of DIA data to visual ratings (Rorie et. al 2011, Karcher and Richardson, 2013)
- $DGCI = [(H-60)/60 + (1-S) + (1-B)]/3$ (1)
- Values of DGCI range from 0 to 1, with dark green color increasing as values approach 1 and are calculated according to equation 1 (Karcher and Richardson, 2013)
- Inclusion of calibration discs within digital images taken under ambient lighting conditions shown to improve the precision of DGCI in DIA of corn leaves (*Zea mays* L.) (Rorie et. al 2011)

GreenIndex+ Turf App (Spectrum Technologies)

- Designed for use in smart phone/device equip with a digital camera and performs DIA without the need for an artificial light source and enclosure when collecting images
- Similar to work by Rorie et al., this app captures images under ambient lighting conditions and references a target board with color standards (green and yellow) in order to determine necessary adjustments to compensate for varying lighting conditions when analyzing turfgrass color
- Images are analyzed in the field, calculating DGCI values without the need for additional software

OBJECTIVE

The objective of this research was to compare the GreenIndex+ Turf app to traditional DIA methods for measuring turfgrass color.



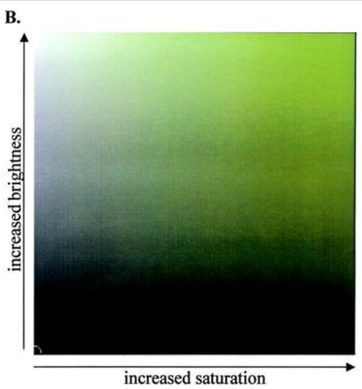
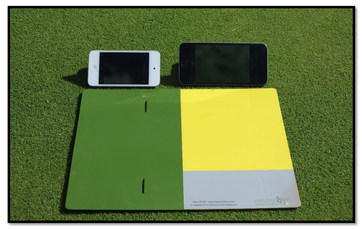


Image 1 (ABOVE LEFT): Hue angle used in dark green color index (DGCI) calculations represented on 360° continuous cirucular scale (Karcher and Richardson 2013)
Image 2 (ABOVE RIGHT): Saturation as a measurement of a color's purity, ranging from 0% (gray) to 100% (fully saturated) and brightness ranging from 0% (black) to 100% (white) scale used in DGCI calculations (Karcher and Richardson 2013)



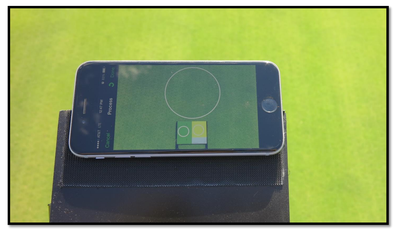


Image 3 (ABOVE LEFT): Smart phone devices and target board used in GreenIndex+ Turf app image collection; green and yellow sections for ambient light adjustment, gray section for locking camera white balance
Image 4 (ABOVE): Process screen for selecting color references on target board and turf being evaluated
Images 5 (FAR LEFT) and 6 (LEFT): Enclosed light box and camera used in digital image analysis (DIA) along with produced image for turfgrass color analysis

MATERIALS & METHODS

Location

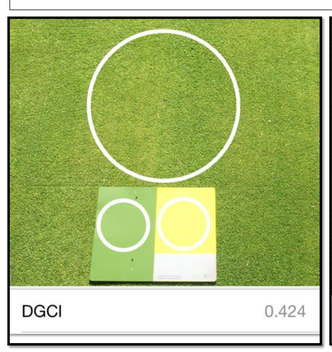
All research was carried out at the University of Arkansas Agricultural Research Center in Fayetteville, AR on a creeping bentgrass (*Agrostis stolonifera* L), sand based putting green built to USGA specifications and maintained under typical management practices (3.2 mm height of cut)

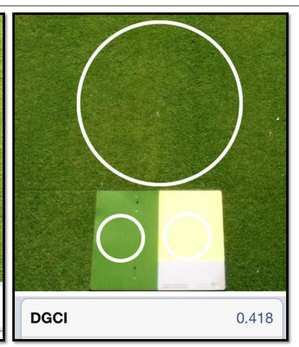
Equipment and Materials

- Field Scout GreenIndex+ Turf app version 2.0 and target board (Item#2910TA, and 2910T, Spectrum Technologies Inc., Aurora, IL)
- GreenIndex+ Turf app utilized through Apple iPod touch (model A1367, Apple Inc.,Cupertino, CA) with 0.7 Megapixel camera was used in 2014 and Apple iPhone5 (model A1428, Apple Inc., Cupertino, CA) with 8.0 Megapixel camera was used in 2015
- Published DIA methods carried out with Canon Powershot G1X 14 Megapixel digital camera (Canon USA Inc., Melville, NY), and portable enclosed light box (NexGen Turf LLC, Albany, OR) using TCP 9W compact fluorescent light bulbs (TCP, Inc., Item#4890965, Aurora, OH), and Sigma Scan Pro 5 (Systat Software, Chicago, IL) using Turf Analysis 1-4 macro was used to calculated DGCI

Experimental Areas and Evaluations

- Five nitrogen fertility rates (0, 0.5, 1.2, 2.4, and 4.9 g N m^{-2}) were applied monthly with CO_2 sprayer create range of green color; four replications of each treatment were evaluated
- In 2014 0.9 x 0.9 m plots of "Tyee" creeping bentgrass were evaluated ten times over nine weeks from August 15 to October 14; data for each evaluation date were analyzed separately
- In 2015, 1.5 x 1.5 m plots of "Penn G2" creeping bentgrass plots were evaluated seven times over a 16 hour period; photosynthetically active radiation (PAR) was measured throughout the evaluation period using LightScout Quantum Light Sensor (Item# 3668I, Spectrum Technologies, Aurora, IL); data for each image set were analyzed separately
- SAS 9.3 PROC REG was used for regression analysis of data





Images 7 (FAR LEFT) and 8 (LEFT): Process screens along corresponding DGCI values from GreenIndex+ Turf app, evaluating the same physical location, using iPhone 5 and iPod respectively
(Traditional digital image analysis of the same are using standardized enclosed light source and Sigma Scan software produced DGCI = 0.370629)

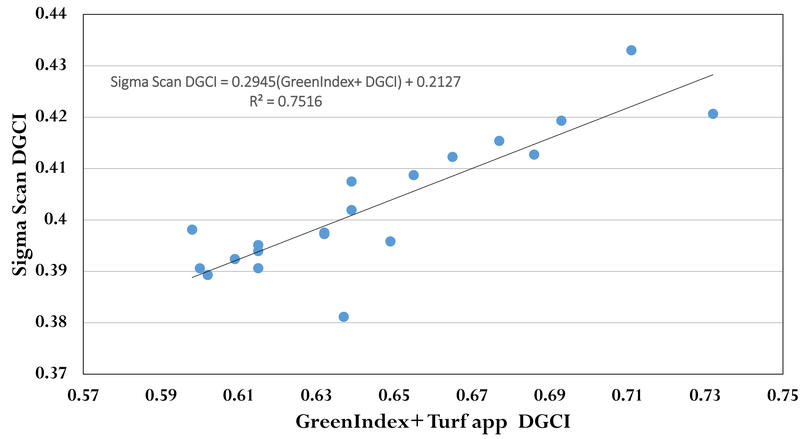


Figure 1 – ABOVE: Image set with maximum coefficient of determination (R2 = 0.75) during 2015 data collection; photosynthetically active radiation (PAR) light levels ranged from 7 to 24 µmol m^{-2} s^{-1} during this evaluation period

RESULTS & DISCUSSION

2014 Results & Discussion

- For each evaluation date, regression analysis produced significant linear models using DGCI from GreenIndex+ Turf app as a predictor of DGCI values obtained through published methodology
- Maximum coefficient of determination value ($R^2 = 0.94$) produced by October 14 data, where GreenIndex+ Turf DGCI values ranged from 0.427 to 0.742 ($\bar{x} = 0.551$), and Sigma Scan DGCI values ranged from 0.595 to 0.726 ($\bar{x} = 0.668$)
- Averaging linear prediction coefficients across all evaluation dates produced slope and intercept values of 0.451 and 0.424 respectively

2015 Results & Discussion

- Linear prediction models produced by each data set varied based on ambient light levels,
- Maximum coefficient of determination ($R^2 = 0.75$) occurred within ambient light range of 7 to 24 µmol m^{-2} s^{-1} (figure 1)
- Dark green color index values ranged from 0.598 to 0.732 ($\bar{x} = 0.645$) for GreenIndex+ Turf app, while Sigma Scan DGCI ranged from 0.381 to 0.433 ($\bar{x} = 0.403$) during this evaluation (figure 1)
- Linear regression model from this evaluation period had a slope coefficient of 0.295 and an intercept of 0.213
- Light levels for the next highest rated evaluation set of images ($R^2 = 0.733$) ranged from 56 to 114 µmol m^{-2} s^{-1}
- The lowest coefficient of determination ($R^2 = 0.352$) was produced from image collection at PAR light level of 0 µmol m^{-2} s^{-1}
- Image set during maximum PAR light (2177 µmol m^{-2} s^{-1}) produced coefficient of determination of 0.686

CONCLUSIONS

- Correlation of DGCI values produce by GreenIndex+ Turf app to those obtained through Sigma Scan analysis was observed in 2014 and 2015
- However DGCI values produced by GreenIndex+ Turf app and Sigma Scan were not equal
- Both iPod Touch and iPhone 5 cameras were capable of producing correlated DGCI values
- Correlation of DGCI values across a range of ambient lighting conditions varied considerably,
- Based on these data, DIA using GreenIndex+ Turf app performed in the early morning (06:37-06:59 CST) and evening (19:22-19:46) were best correlated to DGCI values obtained through published research methodology

Literature Cited
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