Rapid Detection of Drought Stress Using Field Radiometry for High Throughput Screening

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My typical role as Extension Turfgrass Pathologist

Ph.D. Focus

- Expanding the application of spectral reflectance measurements in turfgrass systems
  - Hyperspectral radiometry
  - Reflectance mapping
  - Early onset stress detection

RESEARCH

Enhanced Soil Moisture Assessment using Narrowband Reflectance Vegetation Indices in Creeping Bentgrass

D. S. McCall,* X. Zhang, D. G. Sullivan, S. D. Askew, and E. H. Ervin

ABSTRACT

Turfgrasses are measured aesthetically and by their ability to withstand stressors. Historically, researchers quantified acceptability by visual quality, but inconsistencies necessitate the use of vegetation indices (VIs) as an objective measurement. Indiscernible relationships have been established between turfgrass canopy normalized difference vegetation index (NDVI) and important variables such as soil moisture and leaf chlorophyll content. Alternative and variable–specific indices have been established in cropping systems. The water band index (WBI) is used for predicting water availability in cropping systems but has not been explored within turfgrass systems. The objective of this study was to compare the relationships of established VIs with chlorophyll content of 'L-93' creeping bentgrass (*Agrostis stolonifera* L.) and water content of a sand-based root zone maintained under greenhouse conditions. All VIs were moderately to strongly correlated to total chlorophyll content (r = 0.49–0.85). Turf color was more closely related to chlorophyll indices than to wet-lab quantification. Only WBI ($r \geq 0.80$) and the green/red ratio index (GRI; $r \geq 0.50$) were consistently related to soil water content. The NDVI was weakly related to soil water content in one trial (r = 0.49). Nonlinear regression showed that WBI can be useful for estimating a decline in soil water content as water first becomes limiting for creeping bentgrass and may offer a viable means to assess water availability independently of non-moisture-related stresses and more accurately compared with previous indices. Future research will evaluate WBI on broader geospatial scales to assess practical application for turfgrass irrigation management.

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Abbreviations: GNDVI, green normalized difference vegetation index; GRI, green/red ratio index; NDVI, normalized difference vegetation index; PEI, photochemical efficiency index; PRI, photochemical reflectance index; RGI, red/green ratio index; RVI, simple ratio vegetation index; SGI, sum green index; TDR, time-domain reflectometry; VI, vegetation index; WBI, water band index.

Water conservation for intensively managed turfgrass is a critical priority, as water quality and availability are widely recognized as increasing global concerns. Golf courses alone used an estimated 2.93×10^{15} L (775 trillion gallons) of water in the Unites States in 2005 (Throssell et al., 2009). Conservation strategies employed by golf course superintendents and their staff resulted in an estimated water savings of 21.8% by 2013 (Gelernter et al., 2016). Although these savings are significant, further reductions are needed to offset a growing global water demand. While some facilities chose to reduce total irrigated acreage, many were able to conserve water through other practices such as hand watering, maintaining a drier soil profile, using moisture sensors, and scheduling irrigation based on evapotranspiration rates. Evapotranspiration-based irrigation provides a more precise prescription in terms of frequency and amount required for a general area from weather station data but does not provide sufficient spatial resolution for site-specific water needs (Feldhake et al., 1983). The use of hand-held moisture meters has become increasingly prevalent on golf greens to rapidly assess site-specific irrigation needs but is much less feasible across larger fairway acreage (Gatlin, 2011). Additionally, root-zone moisture content

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Relationship between vegetation indices and water availability

	Total Chlorophyll		Tissue Water Content		Soil Water Content	
Index	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
NDVI	0.63	0.65	0.54	NS	0.49	NS
GRI	0.49	0.67	NS	NS	0.73	0.50
WBI	0.69	0.85	0.52	0.82	0.80	0.81

(McCall et al., 2017)

EXIT

Research Objectives

1. Determine whether vegetation indices (NDVI, GRI, and WBI) can objectively estimate moisture stress by grass species (creeping bentgrass and hybrid bermudagrass) in varying soil textures (USGA 90:10 sand, sand loam, clay) and).

2. Investigate vegetation indices as early predictors of moisture stress compared to visual symptom development of bent and bermudagrass in varying soil textures.

Experimental Design: 2x3 Factorial

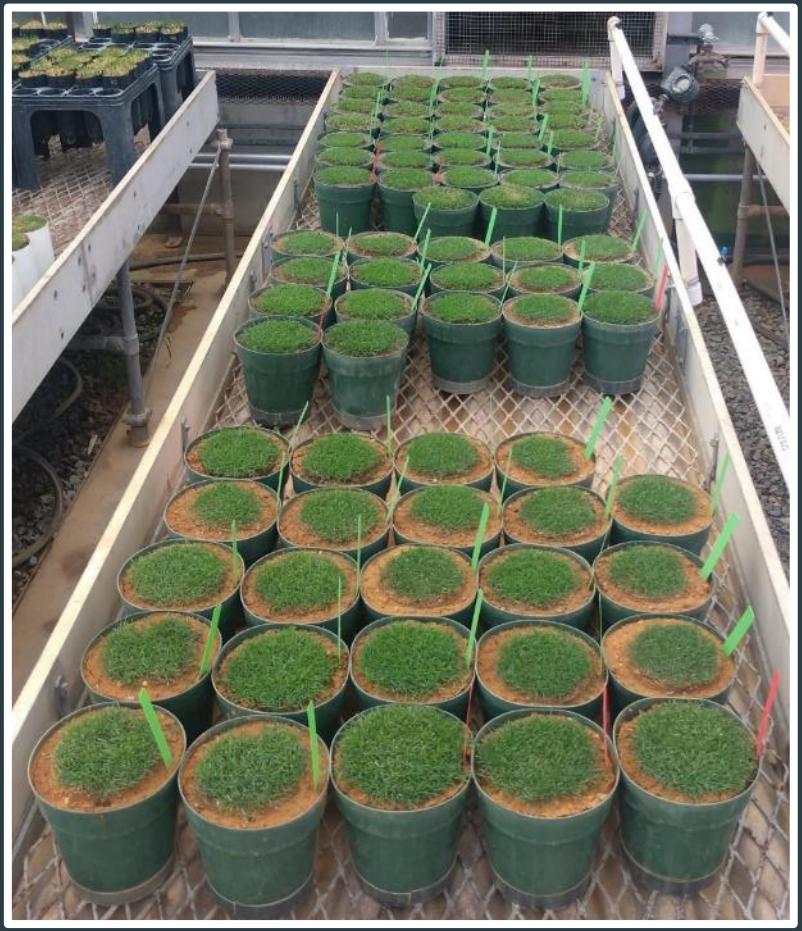
Grasses

- ‘007’ creeping bentgrass
- ‘Latitude 36’ hybrid bermudagrass

Soils

- USGA 90:10 sand/peat
- Sand loam
- Clay

CBG

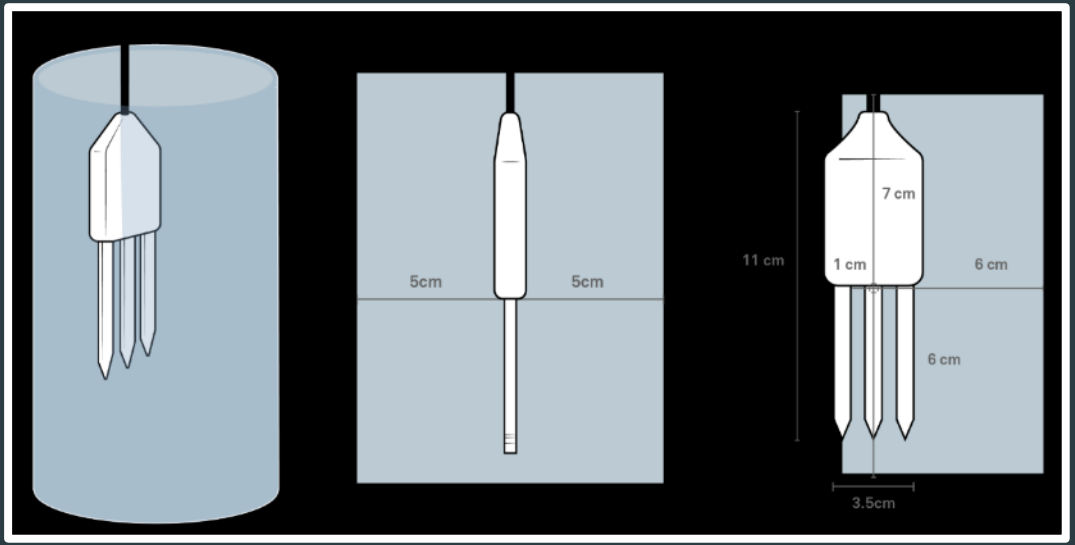


HBG

Greenhouse Study

- Six dry-down cycles (rep)
- Treatments Saturated
  - 2-10 min cycles of water (0.2 gal/min)
- Fan: 5-7 MPH
- Data Collection: 7am – 7pm

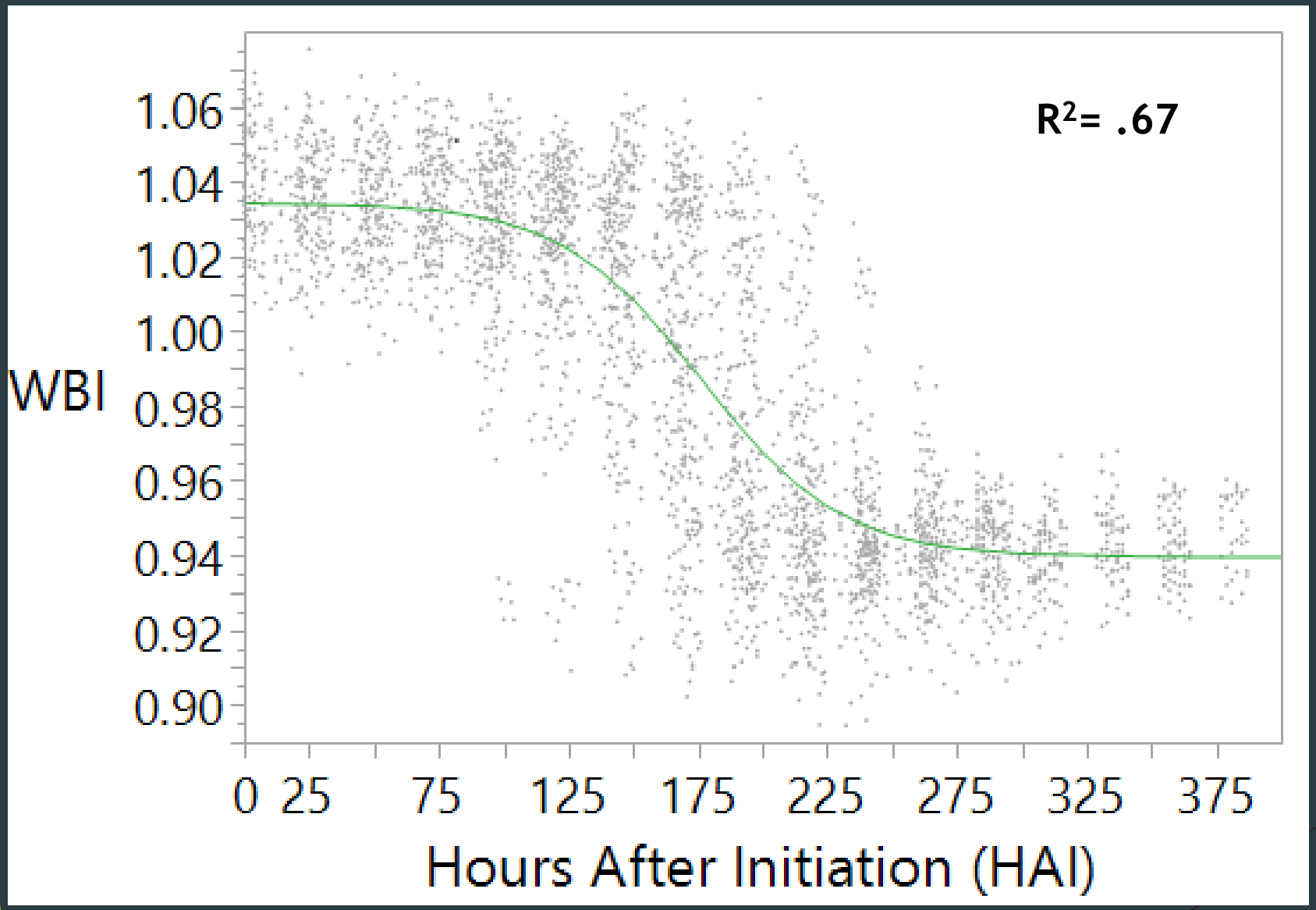
Volumetric Water Content (VWC)



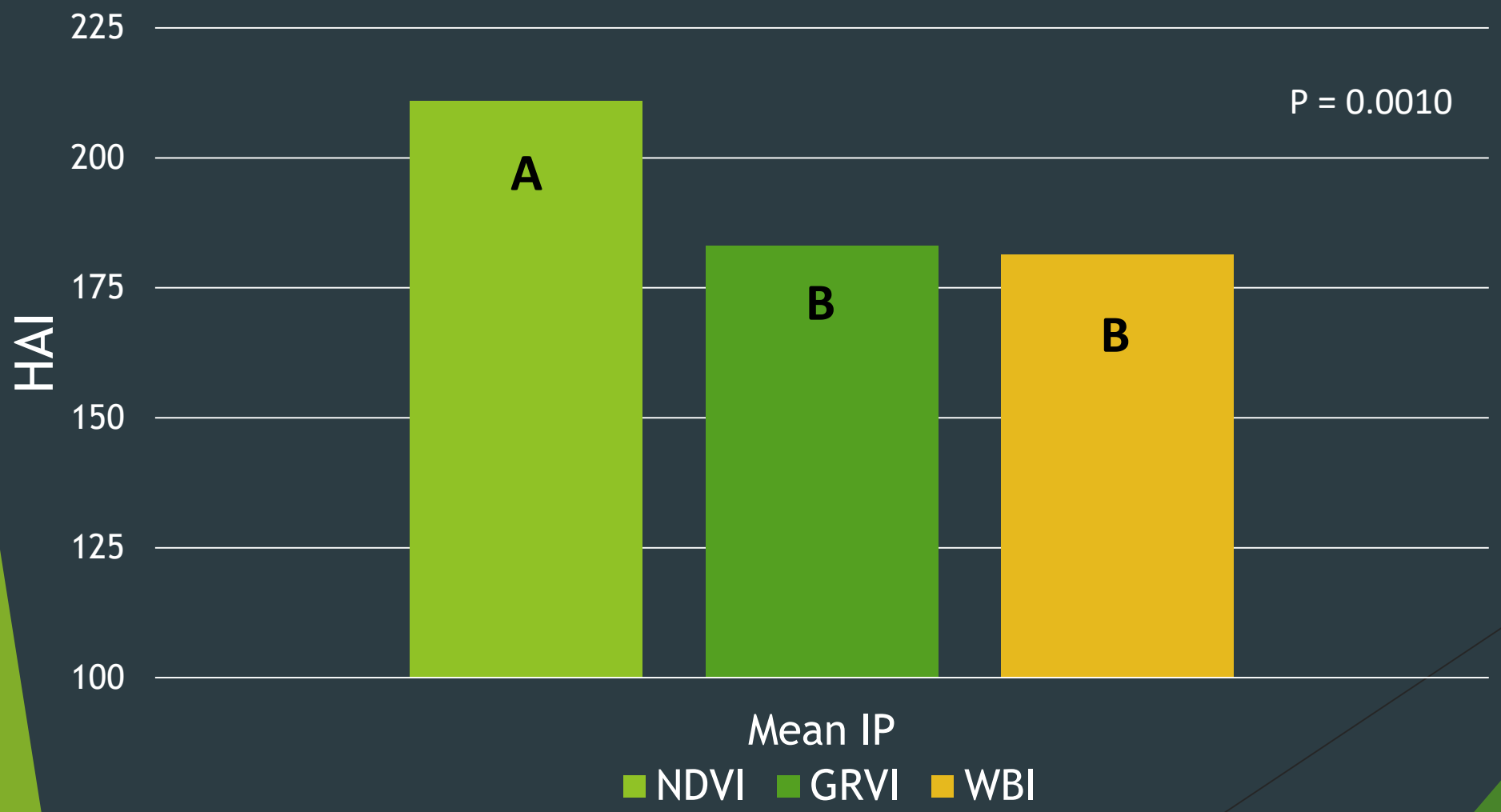
Light Reflectance

- Spectral Evolution PSR-1100F
  - 350 – 1100 nm spectral range
  - 1.4 nm bandwidth
- Contact probe - 2.5 cm lens
- $BaSO^4$ white reference calibration

Data collection over time



Hours after initiation (HAI) to reach inflection point (IP) using 4PL regression

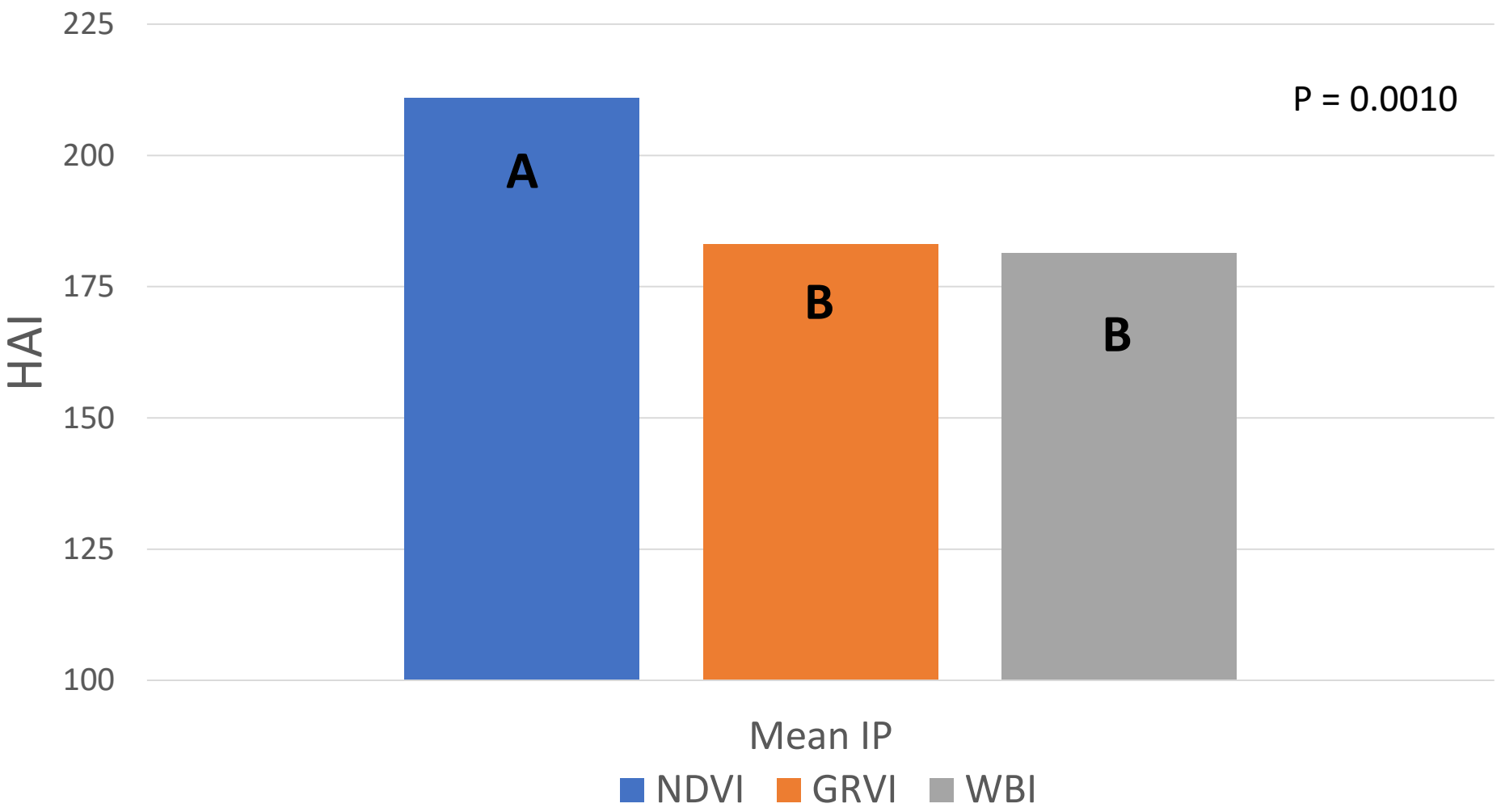


Index Comparison:
WBI and Green/Red more closely related to volumetric water content than NDVI

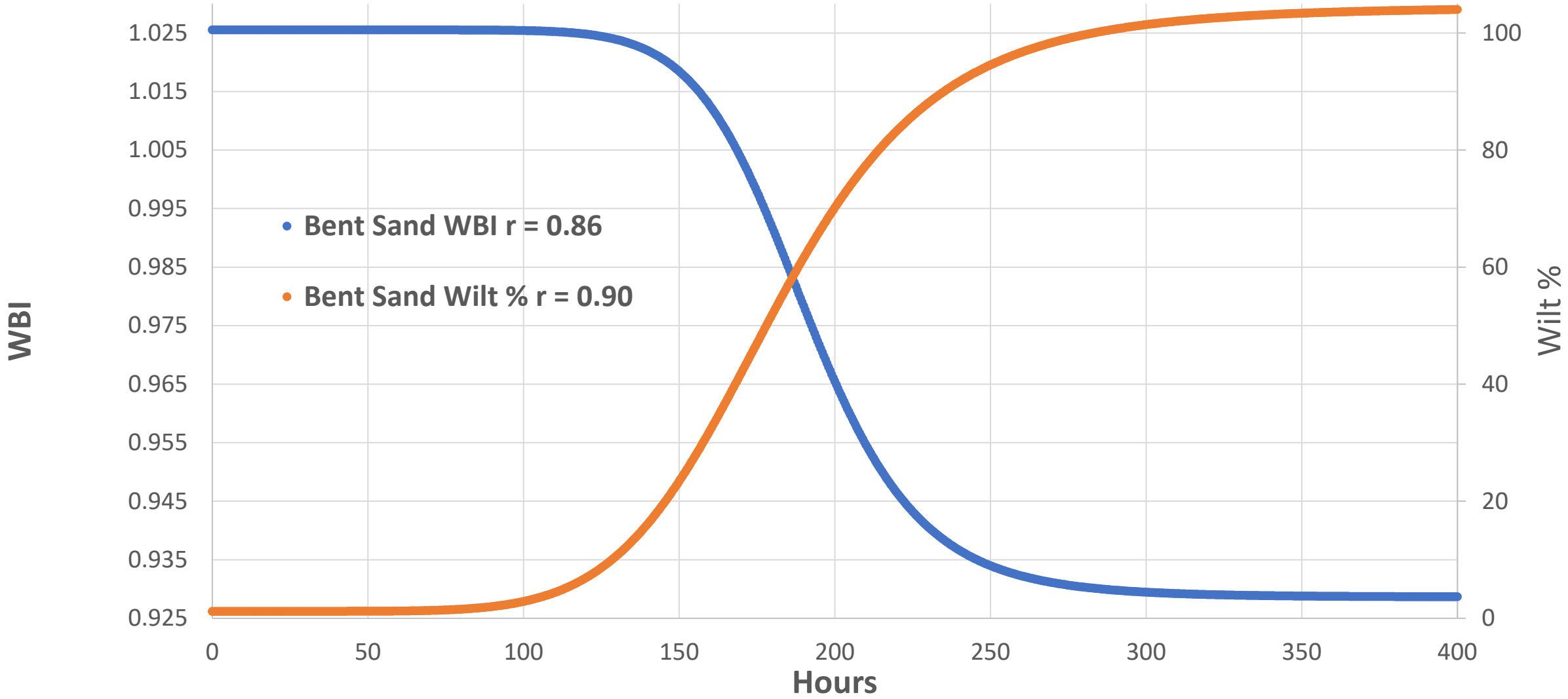
Multivariate Comparison to VWC	
Vegetation Index	R value
WBI	.6233
GRVI	.5566
NDVI	.4726

Dr. McCall Comparison to VWC		
Vegetation Index	Trial 1	Trial 2
WBI	.80	81
GRVI	.73	.50
NDVI	.49	NS

Hours after initiation (HAI) to reach inflection point (IP) using 4PL regression



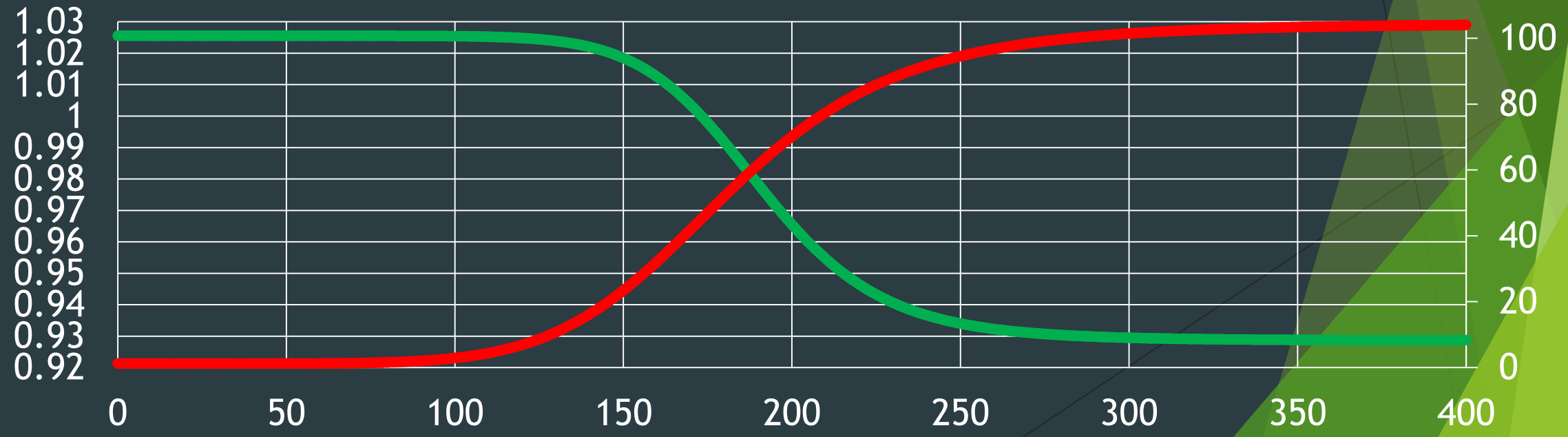
	HAI	WBI	NDVI	GRVI	VWC	Wilt %	Turf quality
HAI	1.0000	-0.7721	-0.7639	-0.7818	-0.7771	0.8310	-0.5897
WBI	-0.7721	1.0000	0.8277	0.8907	0.6233	-0.9152	0.6569
NDVI	-0.7639	0.8277	1.0000	0.9187	0.4726	-0.7971	0.6044
GRVI	-0.7818	0.8907	0.9187	1.0000	0.5566	-0.8931	0.6466
VWC	-0.7771	0.6233	0.4726	0.5566	1.0000	-0.6571	0.4532
Wilt %	0.8310	-0.9152	-0.7971	-0.8931	-0.6571	1.0000	-0.6800



Water Band x Wilt %

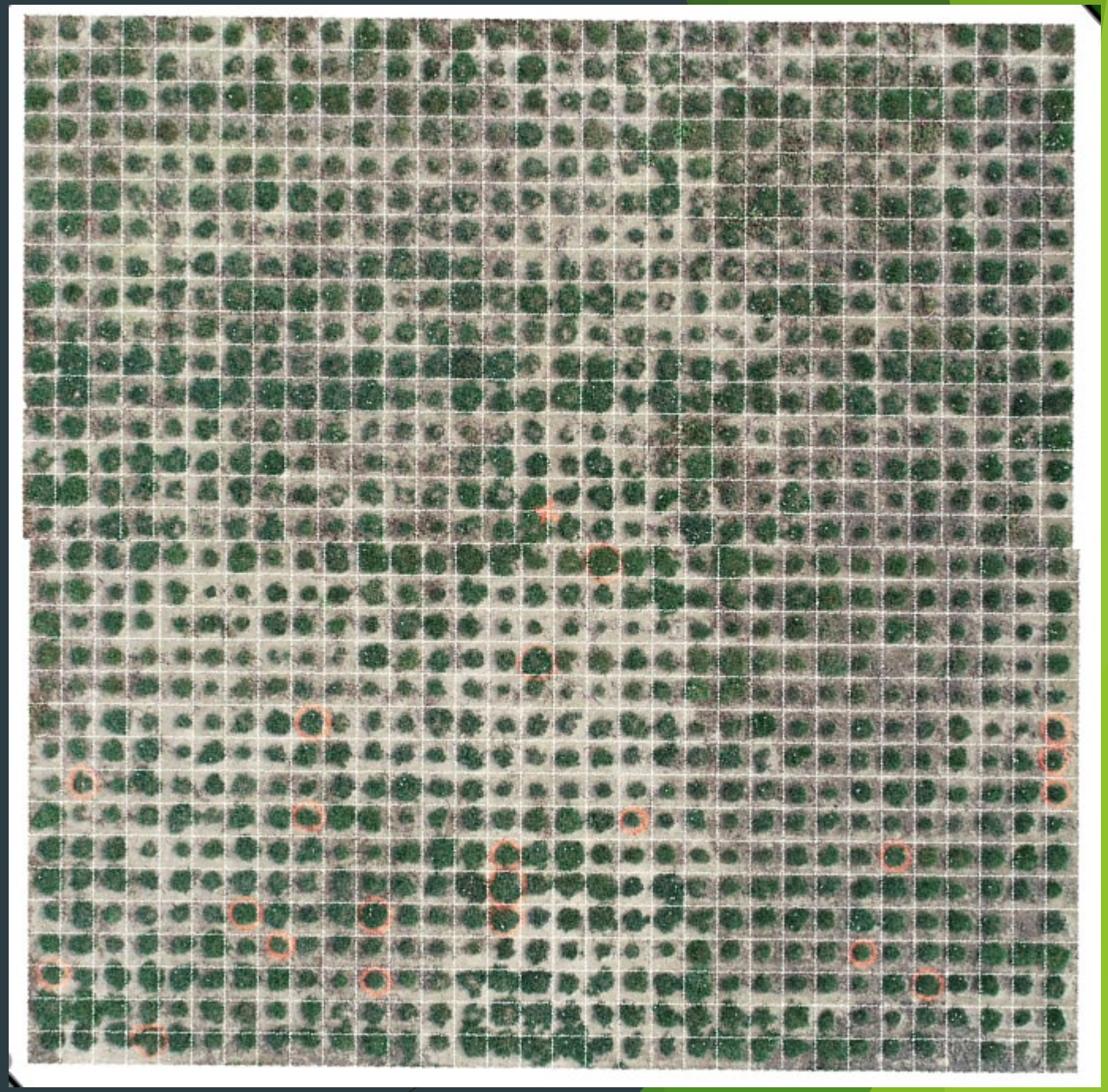
0% → 100%

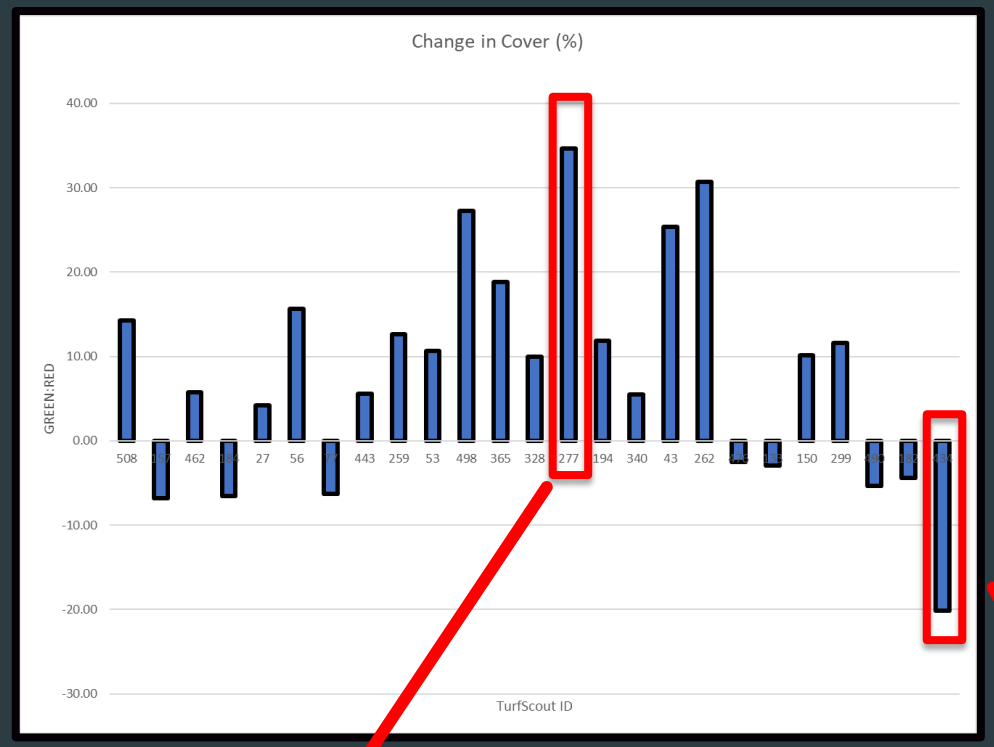
1.034	1.009	0.98	0.958	0.906



Translation to high throughput phenotyping

- G:R Ratio shown as a good estimator
  - Cost effective
- Ground validation with few points
  - In-ground TDR
  - Field radiometry
- Collaboration with Scotts ProVista Breeding Program & TurfScout, LLC.

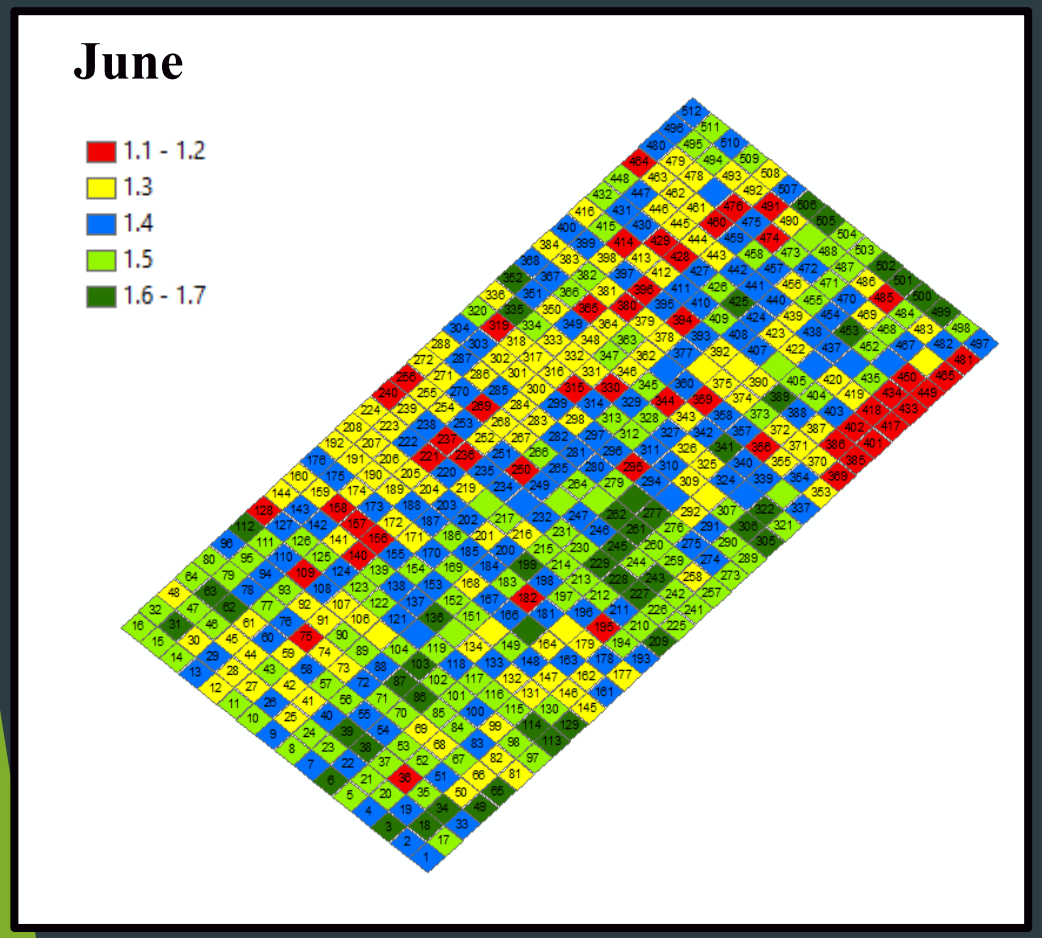


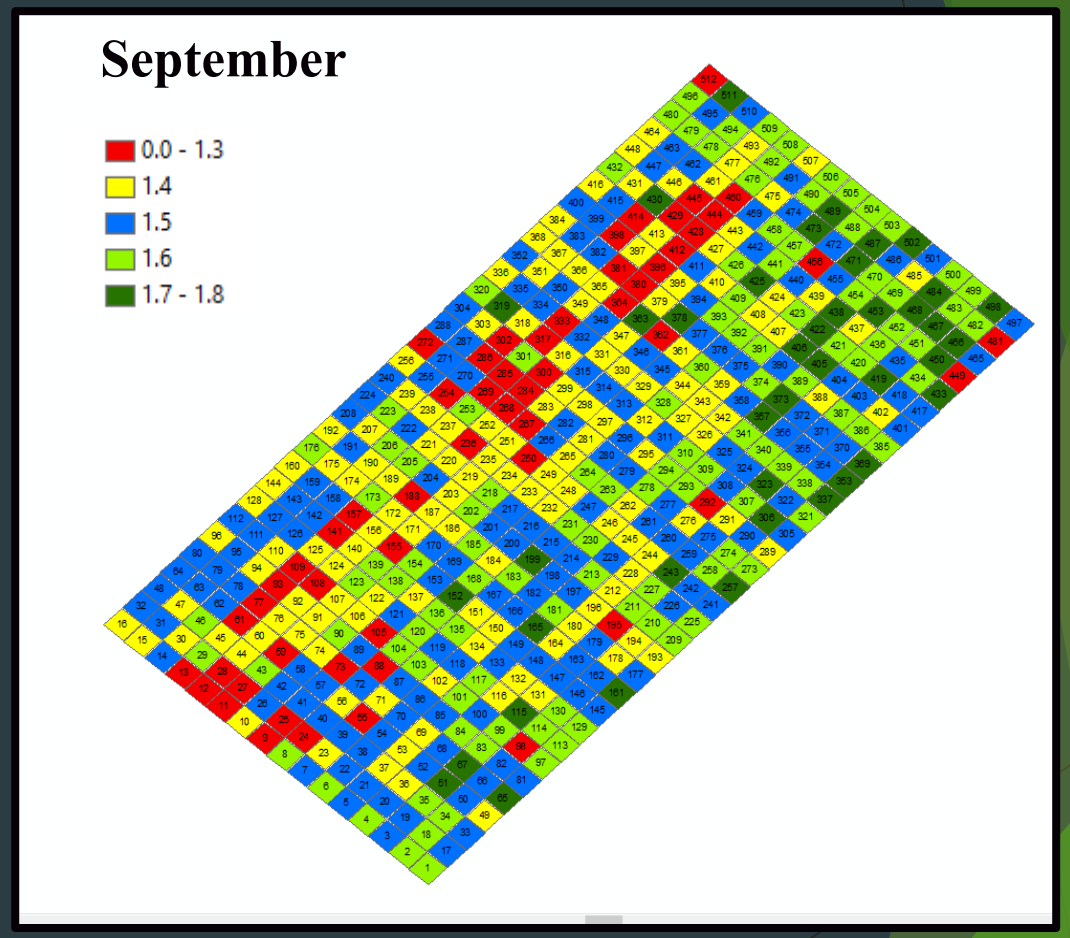

Change in Cover (%)
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
GREEN:RED
508
462
27
56
443
259
53
498
365
328
277
194
340
43
262
150
299
TurfScout ID

June
Sept

June
Sept

Line variability using the Green:Red vegetation index





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