Using Sensors for Phenotyping and Assisting in Selection in Spring Wheat

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Research Questions

A continuous pipeline of new, higher yielding varieties with tolerance to biotic and abiotic stresses is needed to sustain a viable spring wheat sector in the region. Developing new spring wheat cultivars is a costly endeavor and requires the evaluation of thousands of lines for each variety that is ultimately released. Not only is the process of selection time consuming and expensive, it is not an exact science and the possibility of discarding genotypes that could become highly successful varieties is quite high. Our research question is, can the use of canopy spectral reflectance, and other indices obtained from sensors mounted on an ATV help breeders select genotypes with superior yield and stress tolerance.

Results

We were not successful in collecting data in a useable form in 2016, given that the equipment was damaged early in the season and had to be replaced and techniques for collecting and analyzing data had to be developed and tested. In 2017, prior to and shortly after flowering, data from the sensor suite described below were collected from six advanced yield trials planted by the NDSUspring wheat breeder in Casselton, North Dakota. We have not yet completed the analysis of the data, as it requires multiple steps and we are still developing procedures that could be used to streamline the process. Never the less, we found very high and stable correlations between several of the variables measured and yield (these data were predictive of yield). NDVI, NDRE, LAI, estimated chlorophyll content were positively correlated and canopy temperature was negatively correlated with yield. We anticipate that by using multiple regression analysis, we can increase the predictability of yield with these sensors.

Application and Use

The primary application of this research will be to assist breeders in identifying genotypes that may have the traits needed to be high yielding and stress tolerant. Once the data have been completely analyzed, we will have a better idea on how well some of the measurements can be used to predict the performance of advanced lines and will work towards integrating sensor-based phenotyping into the regular breeding programs with the intent of improving selection efficiencies.

Materials and Methods

A suite of sensors developed by Holland Scientific (Lincoln, NE, USA) and used by other breeding programs in the USA was chosen for use in this project. This suite is a combination of active and passive sensors consisting of a three-band active optical sensor, a multi-parameter data acquisition sensor and geospatial data logger. The active optical sensor provides measurements for red, red-edge and near infrared reflectance, red and red-edge normalized difference vegetation indices (NDVI and NDRE) and estimation models for leaf area index (LAI), plant canopy chlorophyll content (CCC) and optical sensor-to-plant distance. The multi-parameter sensor provides measurements for passive upwelling and downwelling photosynthetic active radiation (PAR), passive temperature for both canopy and ambient air, humidity and atmospheric pressure. These sensors were mounted on an ATV and connected to a Trimble RTK system so that all measurements were georeferenced. Data were collected from several breeding trials in Casselton, North Dakota several times from about late tillering to early grain filling. The degree of correlation between these data from these sensors and yield was determined and multiple regression analysis will be conducted to see if a combination of measured traits can improve predictability of these measurements and yield.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

At this stage, this research will have no direct economic benefit at the farm level. If this system of phenotyping advanced lines proves to be helpful to breeders, the value of this research will be determined by the number of lines that are identified, released and used by farmers.

Related Research

This is a topic of intense interest in the breeding circles. There are a number of programs using this type of methodology in other classes of wheat to assist in line selection.

Recommended Future Research

We need an additional year testing in order to effectively evaluate the current platform as to its future usefulness. No significant changes in our research approach is proposed for the next year.

Appendix

	Experiments					
Date Sensed	**AYT**	**EYT**	**URN**	**VT**	**WSS**	**WHT**
NDRE (vegetative index) X yield						
June 9, 2017	0.292	0.367	0.405	0.223	0.158	0.212
June 16, 2017	0.403	0.546	0.391	0.378	-0.009	0.193
June 26, 2017	0.344	0.555	0.600	0.358	-0.073	0.353
July 5, 2017	0.396	0.604	0.697	0.464	0.150	0.318
July 10, 2017	0.541	0.653	0.644	0.440	0.261	0.447
July 20, 2017	0.575	0.664	0.389	0.487	0.364	0.484
July 27, 2017	0.597	0.648	0.621	0.477		0.495
NDVI (vegetative index) X yield						
June 9, 2017	0.145	0.122	0.360	0.154	0.295	0.223
June 16, 2017	0.231	0.123	0.417	0.205	0.346	0.073
June 26, 2017	0.191	0.426	0.409	0.266	0.368	0.425
July 5, 2017	0.239	0.439	0.425	0.392	0.437	0.298
July 10, 2017	0.465	0.555	0.486	0.520	0.563	0.445
July 20, 2017	0.597	0.687	0.532	0.580	0.496	0.513
July 27, 2017	0.637	0.695	0.592	0.495		0.582
Plant height X Yield						
June 9, 2017	0.036	0.031	0.226	-0.018	0.387	0.102
June 16, 2017	0.082	-0.096	0.068	-0.081	0.468	-0.088
June 26, 2017	0.049	0.175	-0.082	0.163	0.590	0.332
July 5, 2017	0.044	0.226	-0.140	0.207	0.528	0.338
July 10, 2017	0.102	0.215	-0.217	0.463	0.615	0.401
July 20, 2017	0.071	0.188	-0.235	0.247	0.451	0.317
July 27, 2017	0.187	0.184	-0.020	0.257		0.434

LAI Estimation X Yield						
June 9, 2017	0.313	0.374	0.391	0.225	0.172	0.188
June 16, 2017	0.396	0.547	0.542	0.376	0.026	0.183
June 26, 2017	0.347	0.550	0.585	0.307	-0.068	0.332
July 5, 2017	0.391	0.591	0.672	0.449	0.164	0.283
July 10, 2017	0.504	0.642	0.600	0.535	0.231	0.427
July 20, 2017	0.527	0.625	0.497	0.483	0.340	0.460
July 27, 2017	0.555	0.609	0.581	0.475		0.447
Chlorophyll content estimation X Yield						
June 9, 2017	0.309	0.375	0.396	0.227	0.164	0.198
June 16, 2017	0.401	0.558	0.551	0.386	-0.019	0.195
June 26, 2017	0.350	0.550	0.593	0.296	-0.104	0.330
July 5, 2017	0.397	0.599	0.685	0.450	0.121	0.295
July 10, 2017	0.513	0.646	0.614	0.520	0.205	0.431
July 20, 2017	0.521	0.626	0.492	0.486	0.344	0.461
July 27, 2017	0.525	0.582	0.544	0.470		0.425
Canopy temperature X Yield						
June 9, 2017	0.053	0.165	0.064	0.133	-0.315	-0.053
June 16, 2017	-0.245	0.056	-0.378	-0.313	-0.103	-0.033
June 26, 2017	0.190	0.265	0.023	-0.238	-0.164	-0.165
July 5, 2017	-0.062	-0.039	-0.052	-0.103	-0.249	-0.193
July 10, 2017	-0.133	-0.159	-0.282	-0.432	-0.564	-0.504
July 20, 2017	-0.055	0.077	-0.049	-0.403	-0.432	-0.409
July 27, 2017	-0.554	-0.643	-0.679	-0.417		-0.156
Incident PAR X Yield						
June 9, 2017	-0.040	0.134	0.335	0.106	0.130	-0.183
June 16, 2017	-0.263	-0.012	-0.146	-0.276	0.083	-0.061
June 26, 2017	0.308	0.389	0.133	0.121	-0.007	0.277
July 5, 2017	0.212	0.328	0.512	0.493	0.047	0.471
July 10, 2017	0.471	0.519	0.469	0.385	0.224	0.521
July 20, 2017	0.393	0.505	0.531	0.468	0.233	0.503
July 27, 2017	0.323	-0.319	-0.250	0.005		0.036
Reflected PAR X Yield						
June 9, 2017	-0.114	-0.020	0.201	0.045	0.218	-0.094
June 16, 2017	-0.281	-0.015	-0.308	-0.320	0.159	0.027
June 26, 2017	0.221	0.420	-0.017	0.268	0.435	0.247
July 5, 2017	0.116	0.100	-0.100	0.158	-0.138	0.100
July 10, 2017	-0.094	-0.091	-0.197	-0.106	-0.182	-0.367
July 20, 2017	-0.172	-0.088	-0.226	-0.408	-0.137	-0.258
July 27, 2017	0.021	-0.467	-0.483	-0.215		-0.675