Predicting grain yield and related traits in wheat under heat-related stress environments using UAV-based hyperspectral imaging and functional regression

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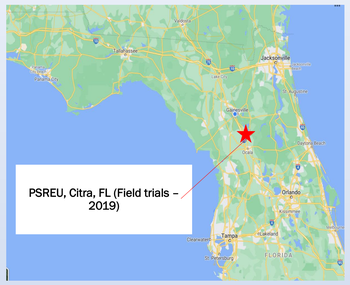
OBJECTIVE

To employ a functional regression approach that addresses the limitations of previous techniques to create a model for predicting grain yield in wheat under heat stress environmental conditions, and when data availability is constrained, by the processing of spectral data derived from the canopy reflectance of wheat plants collected via UAV-based hyperspectral sensing.

Materials & Design

Location & Plot Design



- 40 Genotypes
- Alpha-lattice plot design
- 2 Locations (1 location split into 2 planting dates)
- 1 Year
- 2 Replicates Per Location
- 5.1 m^{-2} plot size
- 160 plots in total

Hyperspectral Imaging

Spectral data collection done **via Matrice 600 Pro** hexacopter drone equipped with the **Pika L 2.4** hyperspectral sensing system.

Flight planning and mission control in the **Pix4DCapture** software app.

A white **calibration tarp** was placed in the region of data collection to be used to calibrate the hyperspectral data collected

Calibration, georectification, radiometric correction and data analysis done in the **Spectronon** software through the **Resonon** company.

RoI's were manually selected based on each plot position and the spectral wavelengths data were collected.

DJI Matrice 600

Resonon Pika L 2.4

Covers Bands within the 400 - 1000 nm spectral range (~150 bands).

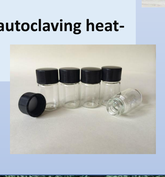
Data Collection

- **Machine harvested Grain Yield (GY) data was produced by the combine and adjusted at the 12% moisture level. It is presented in kilograms per hectare (kg/ha).**
- **Thousand Kernel Weight (TKW):** TKW = (Grain Weight / Seed Count) * 1000
- **Grain number per meter squared (Gnm^{-2}):** Gnm^{-2} = (Grain Yield / 10) / (TKW / 1000)

Membrane Thermostability (MT)

- **MT Collection:**
  - **1cm leaf discs collected from flag leaf of 10 plants per plot → stored in glass vials containing 20mL ice-cold DIW → put on shaker in lab for ~24hr → first conductivity reading → autoclaved for electrolyte release → put back on shaker for ~24hr → second conductivity reading.**
  - **MT quantified as the difference in electrolyte leakage before and after the autoclaving heat-death event.**

$$MT = \left(1 - \frac{First\ Reading}{Second\ Reading}\right) * 100$$



- MT was collected at 7 days and 14 days after anthesis, averaged values between the two were obtained.

RESULTS

Yield & Yield Related Trait Prediction

Grain Yield Prediction

	Group 1	Group 2	Group 3	Group 4	Group 5	Average
MAPE	15.6%	10.2%	12.2%	12.0%	17.1%	13.42%
RMSE	960.44 kg/ha	757.06 kg/ha	845.39 kg/ha	792.02 kg/ha	991.08 kg/ha	869.2 kg/ha

Gnm^{-2} Yield Prediction

	Group 1	Group 2	Group 3	Group 4	Group 5	Average
MAPE	8.69%	7.60%	8.93%	7.95%	12.39%	9.13%
RMSE	3.28 g	2.88 g	3.37 g	2.80 g	4.22 g	3.31 g

TKW Prediction

	Group 1	Group 2	Group 3	Group 4	Group 5	Average
MAPE	5.05%	4.09%	5.52%	4.24%	7.47%	5.28%
RMSE	5.03	4.14	4.76	4.08	7.23	5.05

Function on Function Regression & Cross Validation

Function on Function Regression with Signal Compression

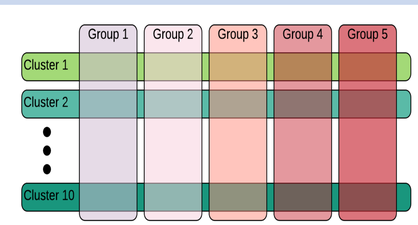
$$y_i = \alpha + \int_a^b \beta(t)\, x_i(t) dt + e_i,$$

Evaluation Metrics

$$MAPE = \frac{1}{n} \sum \left| \frac{Gt - Pv}{Gt} \right|$$

$$RMSE = \sqrt{(Pv - Gt)^2 / n}$$

Cross Validation Scheme using DAPC



Representation of the division of the dataset into five groups based on 10 clusters according to similar genomic data.

RESULTS

Membrane Thermostability Prediction

	Group 1	Group 2	Group 3	Group 4	Group 5	Average
MAPE	5.05%	4.09%	5.52%	4.24%	7.47%	5.28%
RMSE	5.03	4.14	4.76	4.08	7.23	5.05