Phenotyping in breeding using UAV and consumer-grade cameras

Key reflections/results from a Ph.D. study.

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Questions and research

- Is phenotyping reliable if you use different RGB cameras under different conditions (reality check!), and is there a need to use spectral correction?

- Are there any added value from multispectral and thermal measurements to select resilient genotypes?
RGB imaging and spectral correction

- 59 W. barley genotypes
- 2 RGB cameras (P3, X5)
- Sunny conditions, 50 m
- Diverse genotypes in color and vigor

- Datasets with and without spectral correction
- Estimating coefficients for accuracy and precision
- Testing camera*light*altitude*genotype interactions
Spectral correction procedure

- Incident irradiance
- Surface irradiance
- At-sensor radiance
- Radiance map
- R, G and B digital number
- Reflectance Greyscale (VideometerLab)
- Vegetation indices
- Crop coverage etc.
- Grey-scale reflectance panels
- R, G and B digital number adjusted to reflectance

ELM

Color corrected

\[ ExG = \frac{(2G - R - B)}{G + R + B} \]
Precision and accuracy with/without correction

Overall high $r$ (0.96-0.99)

NSE improved from correction, esp ELM (-8.68 to 0.19)

Overall SRD decreased using calibration (0.12 to 0.06)

$r = \frac{\sum(y_1 - \bar{y}_1)(y_2 - \bar{y}_2)}{\sqrt{\sum(y_1 - \bar{y}_1)^2 \sum(y_2 - \bar{y}_2)^2}}$

$\text{NSE} = 1 - \frac{\sum(y_1 - y_2)^2}{\sum(y_1 - \bar{y}_1)^2}$

$\text{SRD} = 1.96\sqrt{2\sigma_r^2}$
Interaction between camera and genotype
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Mixed anova analysis showed, that

- Several cases with camera by genotype interaction

- High r (=1.00) and spectral correction not enough to remove interaction

- Minute differences between genotypes = challenge – important?

- Light changes during flight, SfM and procedure not optimal

- Crop color, soil
Conclusions of paper

- Overall precise measurements seen from Pearson correlation coefficient.
- Overall especially ELM improved accuracy and reproducibility – close to benchmark.
- Light is an issue, altitude is not.
- Correction did not remove camera effect despite good r and NSE.
- Interaction between camera and genotype due to minute differences between genotypes with no practical importance.
- Spectral correction may be overrated from agronomical/breeding pov.
Drought – RGB vs MS vs Thermal
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<table>
<thead>
<tr>
<th>Camera</th>
<th>Date</th>
<th>Time (CET)</th>
<th>Wheat Growth stage</th>
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<td></td>
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<td>At noon</td>
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<td>27 June</td>
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<td>Late grainfill</td>
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<td>6 July</td>
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<td>26 June</td>
<td>At noon</td>
<td>Late grainfill</td>
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</tbody>
</table>
Drought – RGB vs MS vs Thermal

- T canopy (°C)
- nExG
- NDRE
- NDVI

- TKW
- $^{13}$C
- Yield

High TKW
Low $^{13}$C
High Yield
High VI
Low T

Low TKW
High $^{13}$C
Low Yield
Low VI
High T

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- High $^{13}$C
- Low Yield
- Low VI
- High T
Overall results

**Thermal measurements:**
- No early symptoms
- No treatment x genotype
- Low genotype repeatability
- Fine correlation to genotype yield
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- Surface roughness problematic
- Facility + soil surface problematic
- Single rows difficult
- Stay-green interesting – both RGB and MS; Thermal challenging
- 2020 data being analysed now!!
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Some main conclusions of the Ph.D.

- RGB cameras are reliable, and camera effect most likely overestimated in breeding – camera setup IMPORTANT
- Light during flight need attention, fly high!
- Cheap consumer grade UAVs add value – lot’s of applications, however need finetuning
- Include spectral correction if possible during repeated flights, however no need if single campaigns. Stick to the same camera.
- Multispectral needs to become cheaper and higher resolution, however have advantages for some purposes
- Thermal imaging have potentials, however so does stay-green - multisensor
- First step = validation of UAV done! Next step: How to use data and variation...not yet unfolded (Reynolds et al 2020 is inspirational)
Thank you for your attention

• Thank you to enthusiastic partners and colleagues

- Jesper Rasmussen
- Fulai Liu
- Eva Rosenqvist
- Svend Christensen
- Signe Jensen
- Jesper Cairo Westergaard
- Simon Fiil Svane
- Kristian Thorup Kristensen
- Mira Arpe Bendevis
- Saiful Azim
- Jon Nielsen
- Kasper Jakob Jensen
- Tomke S. Wacker
- All at CROP SCIENCE

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