Artificial Intelligence in Plant Phenomics

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Artificial Intelligence Applications to Agriculture
Texas A&M
16 July 2020

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P2IRC Plant Phenotyping and Imaging Research Centre

UNIVERSITY OF SASKATCHEWAN

Crop Development Center, Saskatoon, Canada

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Growing science for life

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P²IRC Plant Phenotyping and Imaging Research Centre

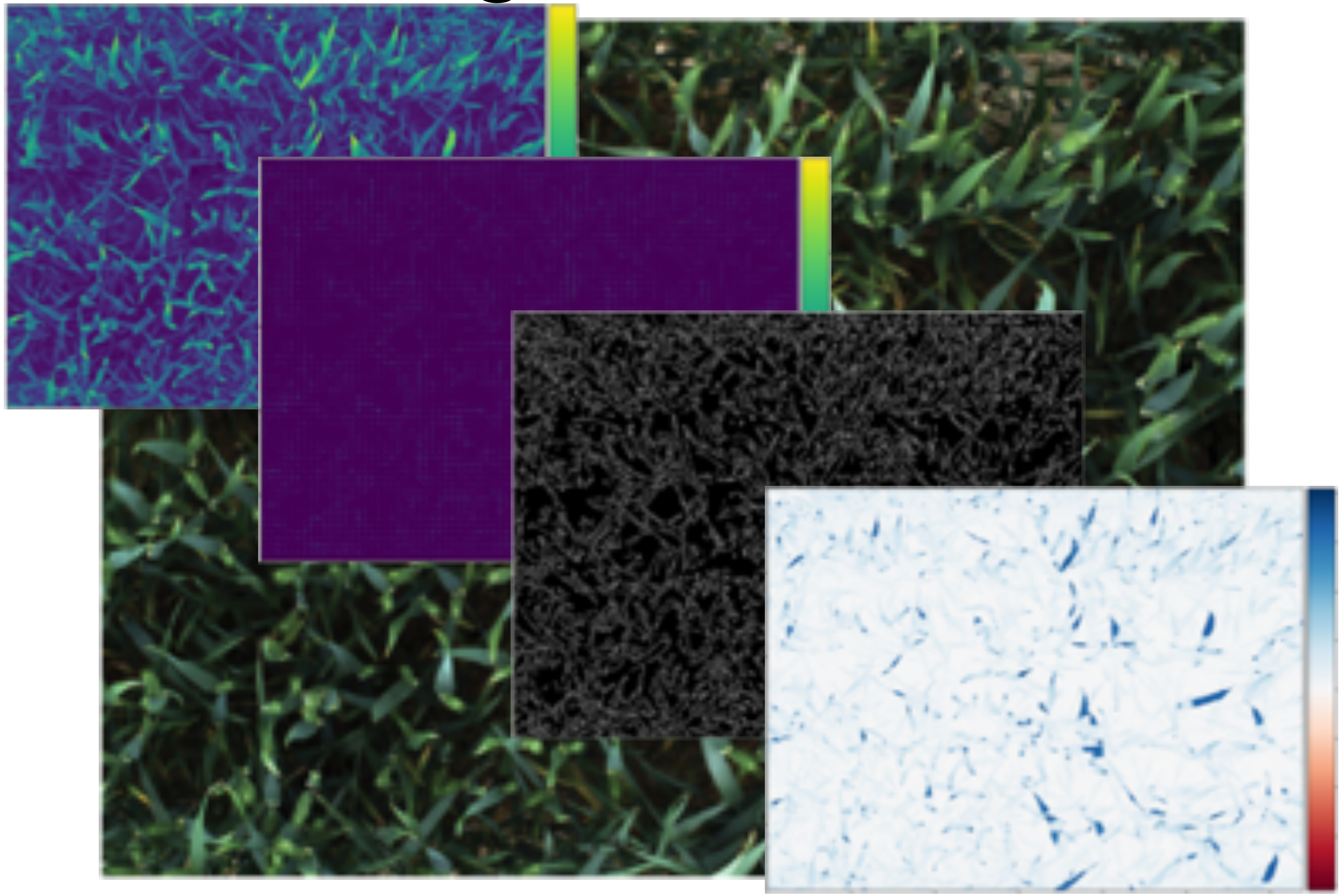
Crop imaging

Roots/Soil

Deep learning

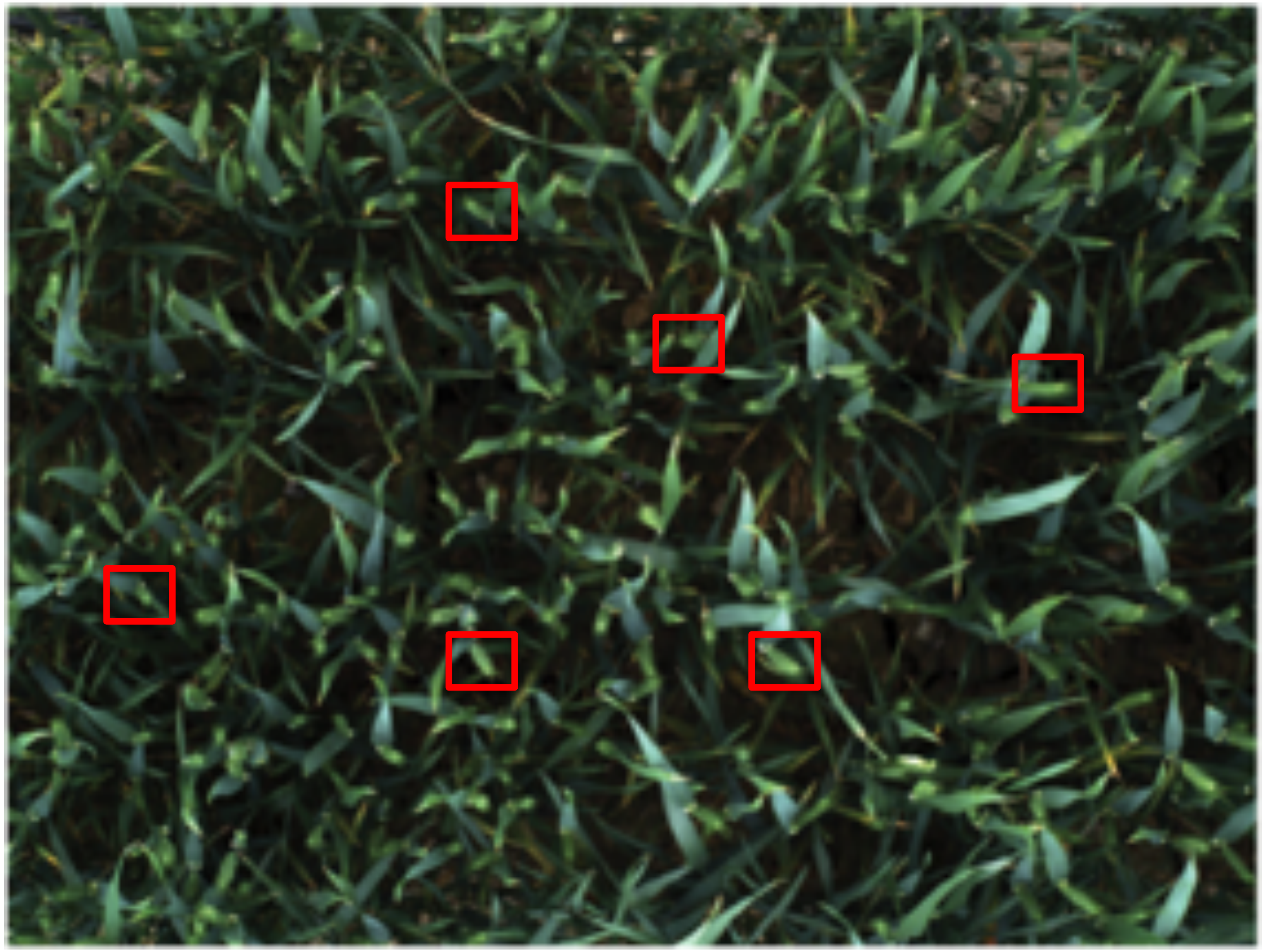
Plant breeding

Selecting features is hard



Sadeghi-Tehran et al. (2017). Automated Method to Determine Two Critical Growth Stages of Wheat: Heading and Flowering. *Front. in Plant Sci.*, *8*(February), 1–14.

Deep learning is **representation** learning

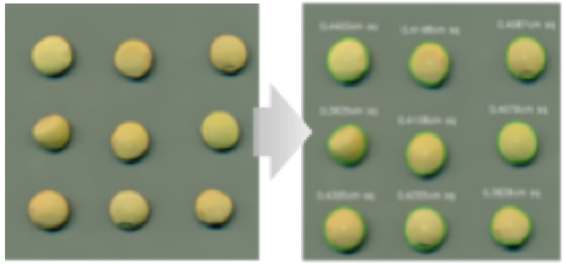


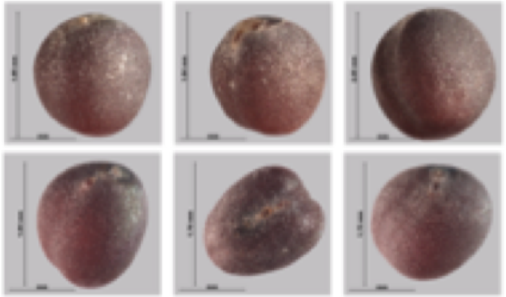
Sadeghi-Tehran et al. (2017). Automated Method to Determine Two Critical Growth Stages of Wheat: Heading and Flowering. *Front. in Plant Sci.*, *8*(February), 1–14.

Imaging & Deep Learning for Agriculture

Seed scale

seed phenotyping, provenance

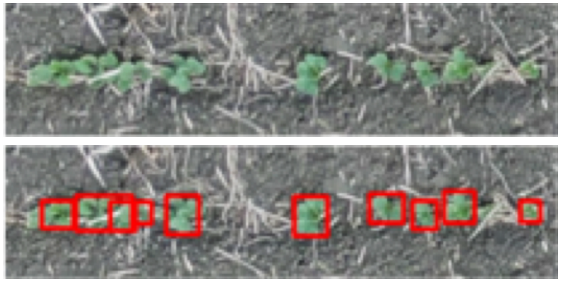




automated seed inspection

Plant scale

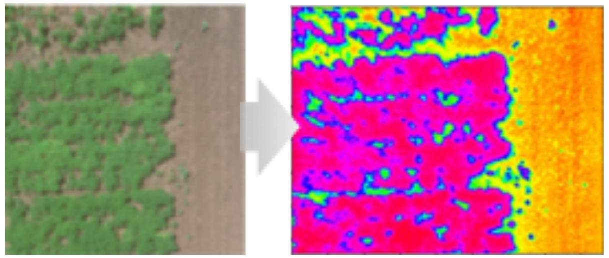
identifying plants, estimating traits

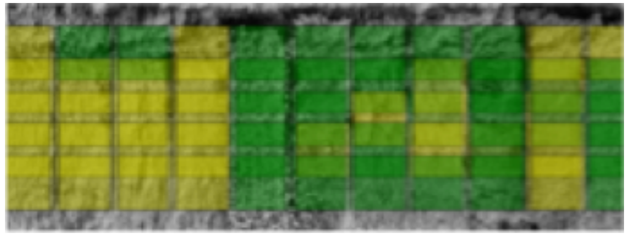


early disease detection

Field scale

crop health, precision management

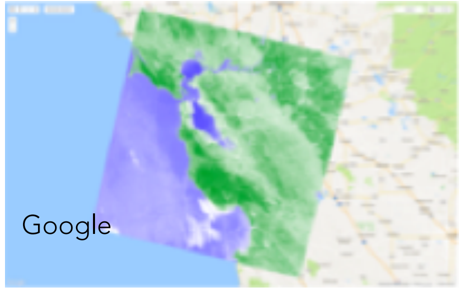


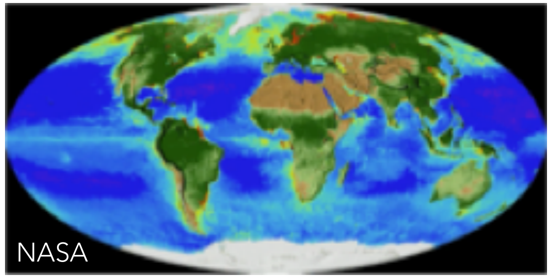


crop damage, crop insurance

Global scale

yield prediction, price forecasting

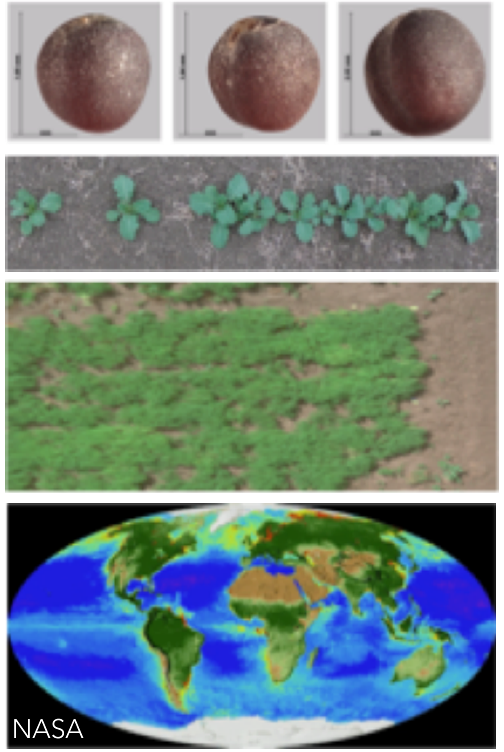




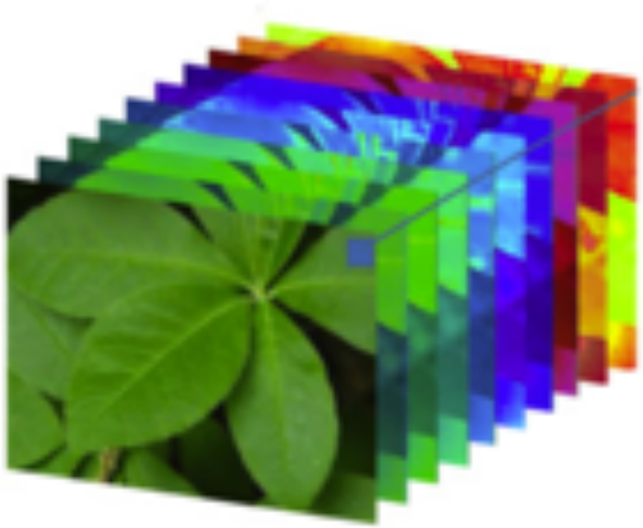
weather prediction, logistics

Learned Features across Scales

Spatial



Spectral



(Mishra et al. 2017)

Temporal

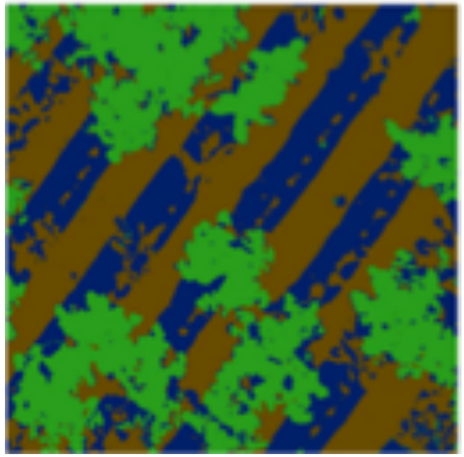
"Camera On A Stick"

Image-based Phenotyping

Classification / Regression

Local Regression

Object Detection



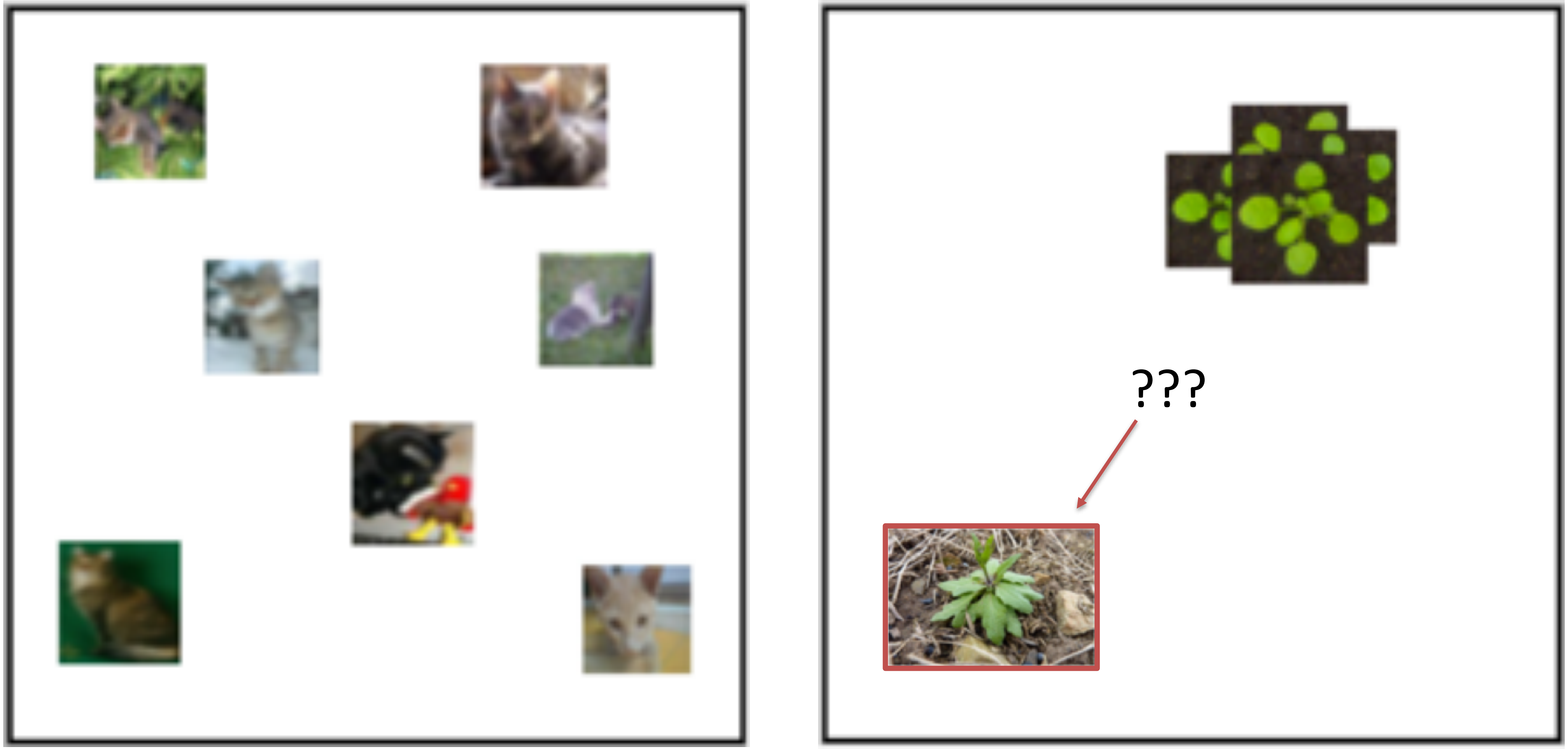
Semantic Segmentation

Instance Segmentation

Deep Plant Phenomics

https://github.com/p2irc/DeepPlantPhenomics

Challenge #1: Large diverse datasets

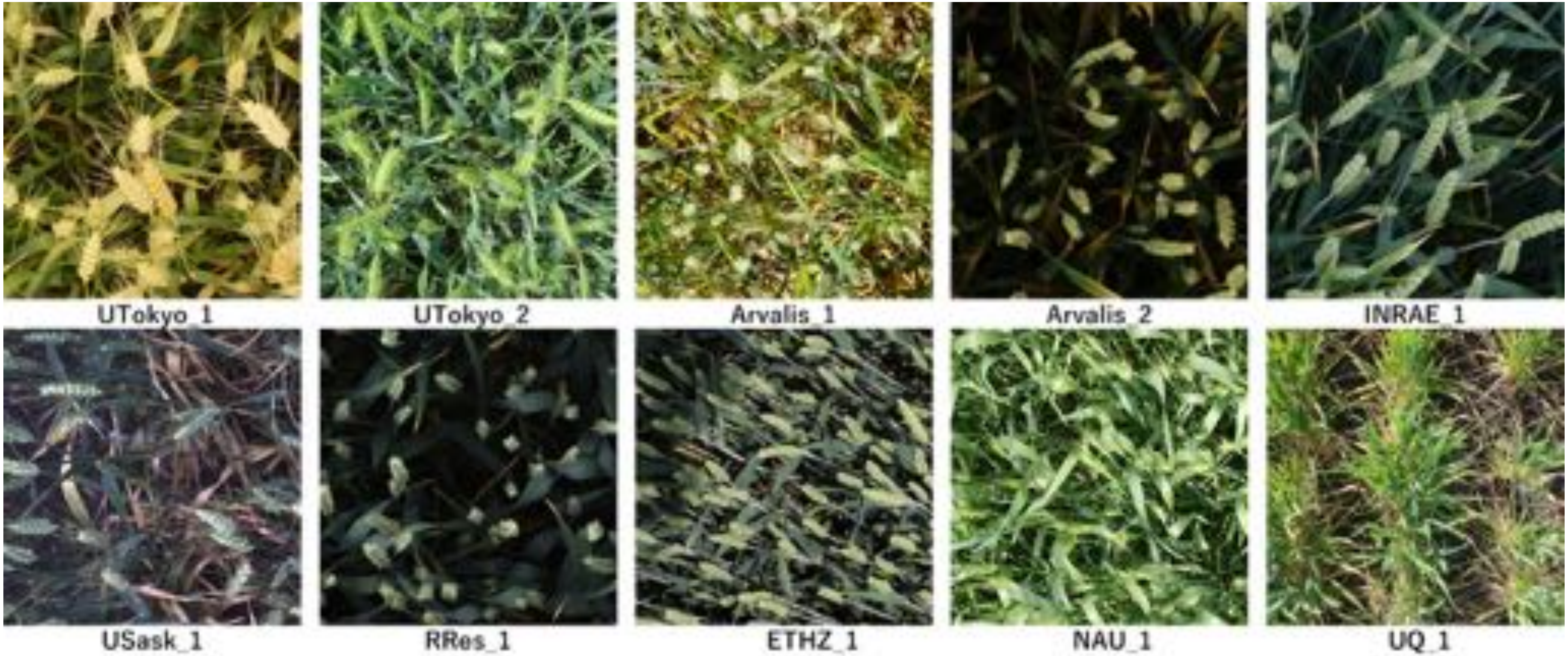


New *open* datasets

Global Wheat Head Dataset

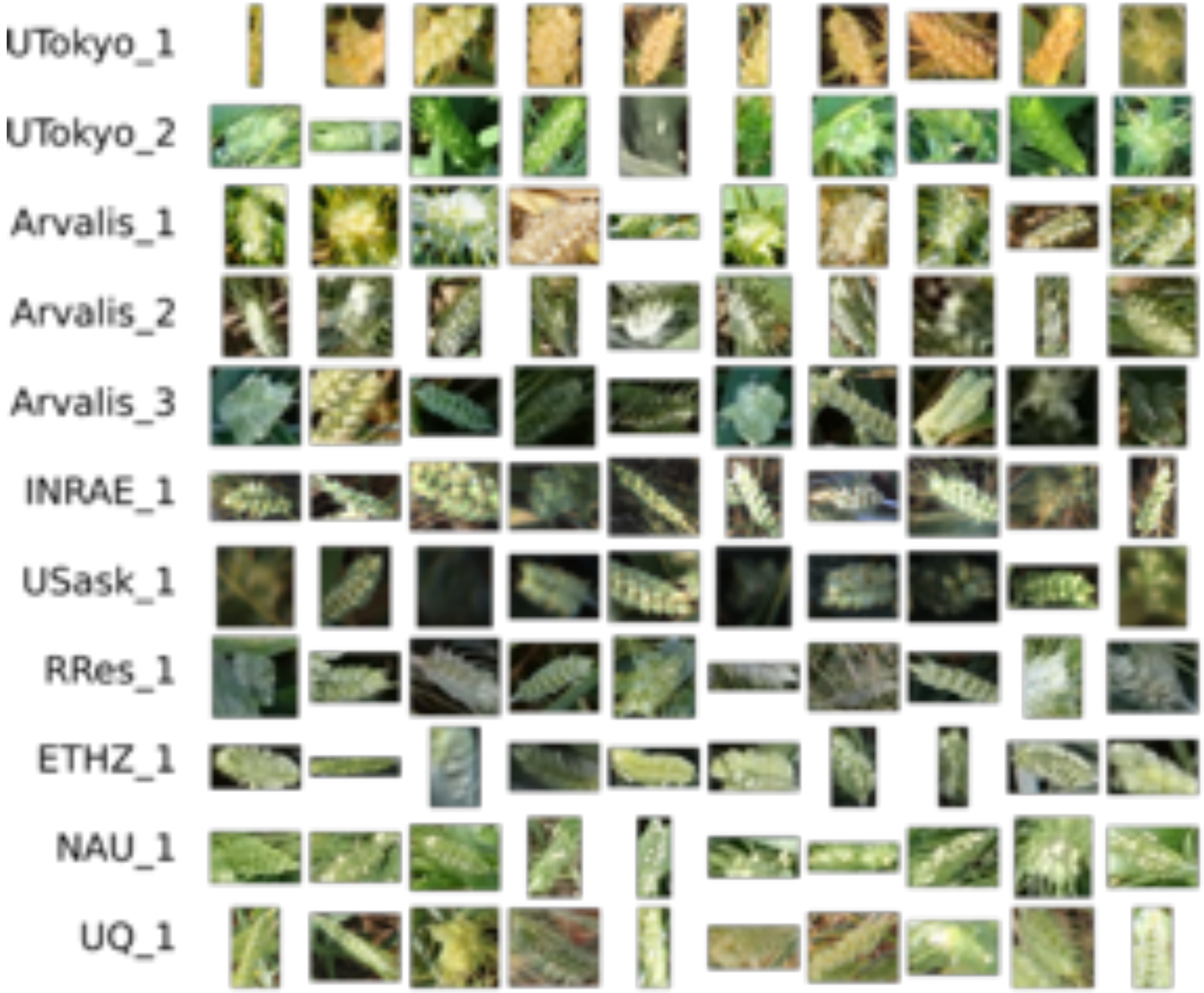
https://global-wheat.com

Global Wheat Head Detection Dataset



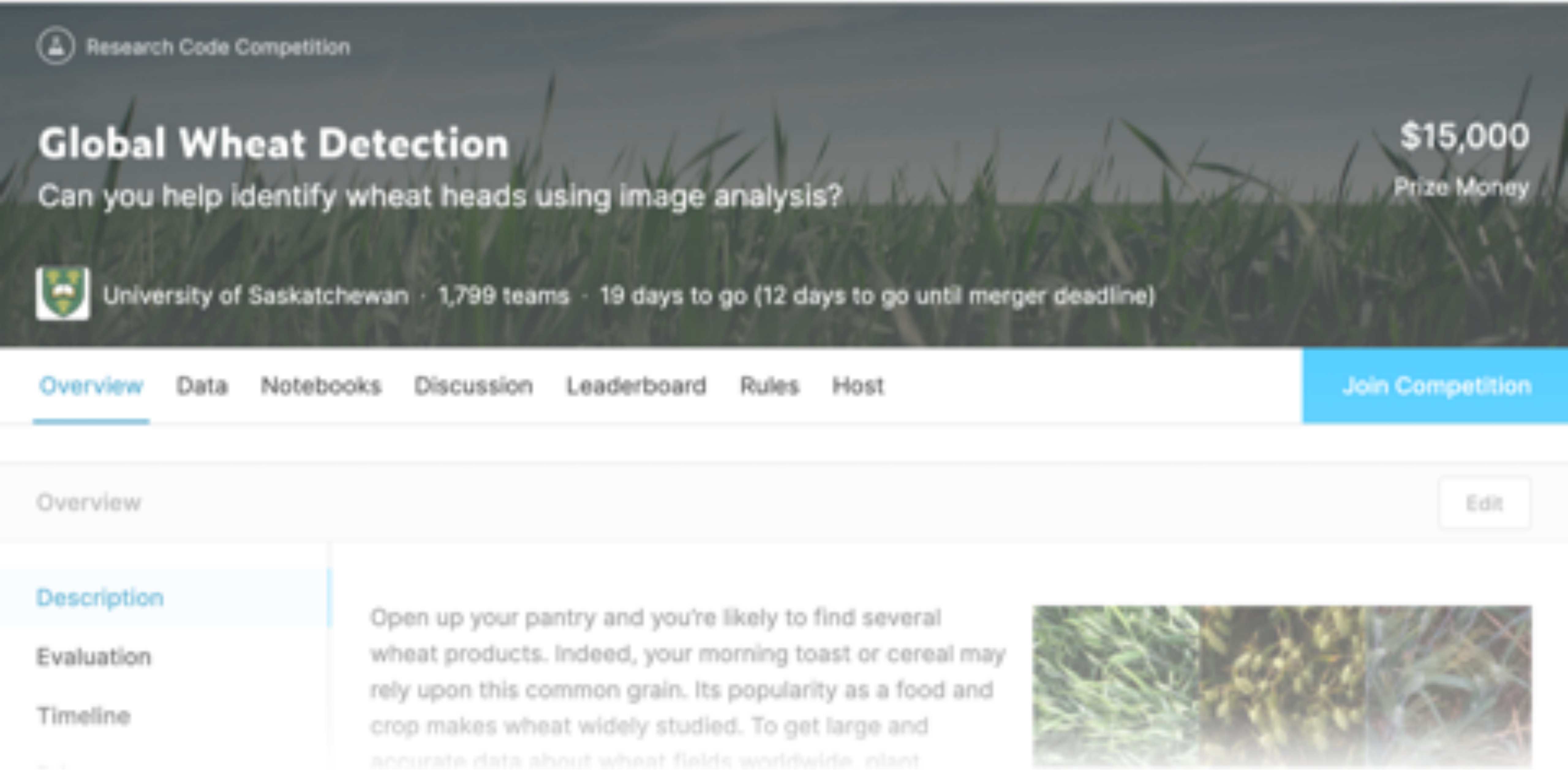
David, E., Madec, S., Sadeghi-Tehran, P., Aasen, H., Zheng, B., Liu, S., Pozniak, C., Stavness, I., Guo, W. (2020). Global Wheat Head Detection (GWHD) dataset. Plant Phenomics, *in press*.

Global Wheat Head Detection Dataset



kaggle

Competition for *CVPPP 2020*



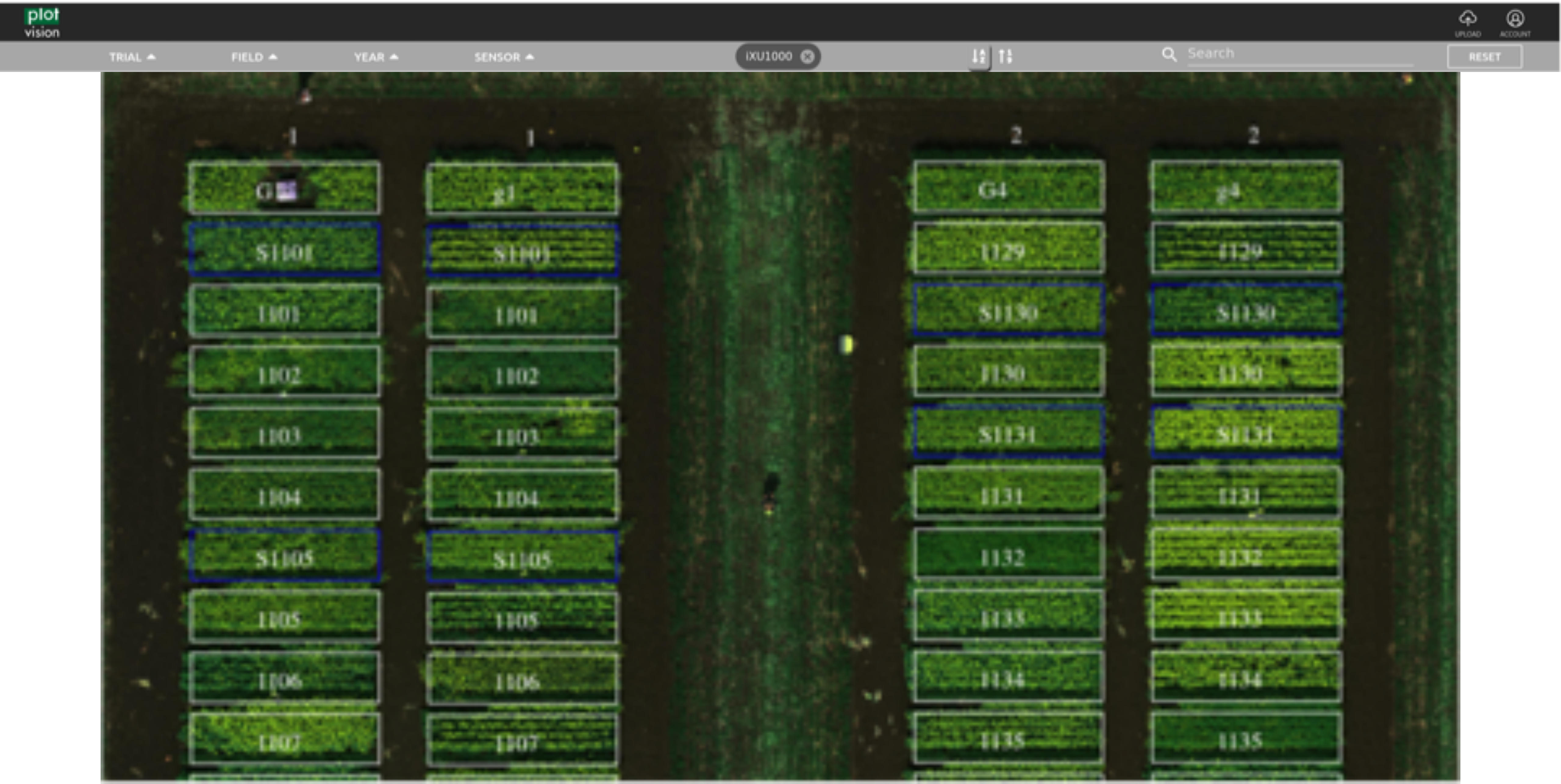
Global Wheat Data: Future Contributions

https://global-wheat.com

PlotVision


PHENOCANOLA
Llewelyn AAFC Farm
2018
iXU1000
Trial Map
GCPs Uploaded
2018-07-30
GCPs Georeference
Camera Georeference
Drone Logs
PHENOLENTIL
Nasser Kernen
2018
iXU1000
Trial Map
GCPs Uploaded
2018-07-09
GCPs Georeference
Camera Georeference
Drone Logs
PHENOWHEAT
Nasser Kernen
iXU1000

PlotVision



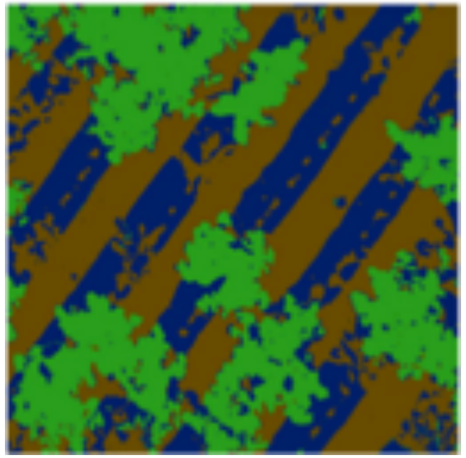
plot
vision
UPLOAD
ACCOUNT
TRIAL
FIELD
YEAR
SENSOR
iXU1000
Search
RESET

Challenge #2: Image annotation

Label for whole image

Dot on each object

Box around each object



Draw outlines

Draw outlines for each object

Low cost

High cost

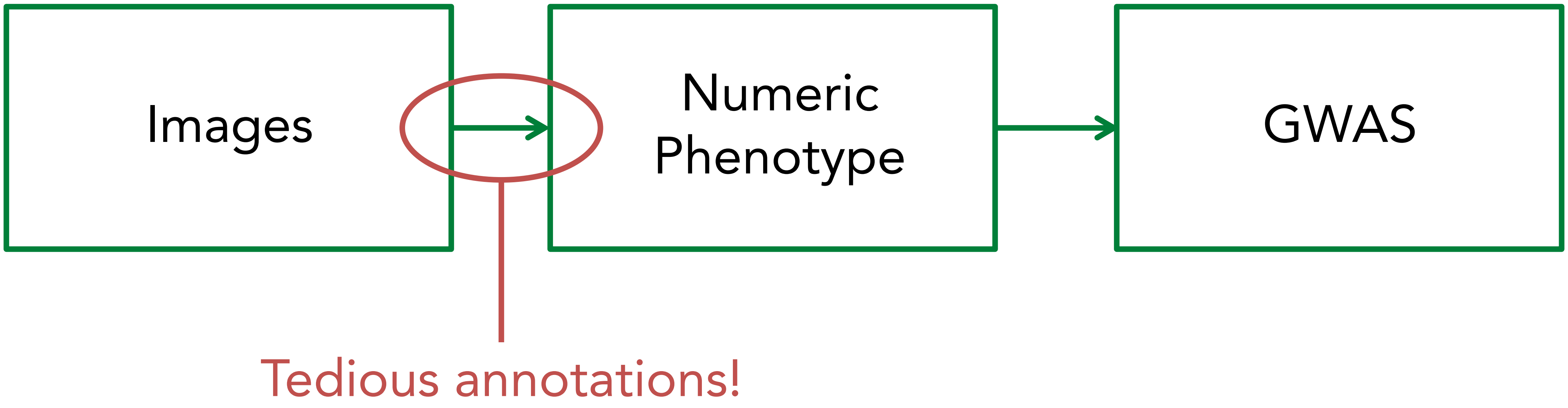
Latent Space Phenotyping

Phenotype-to-genotyping mapping for stress resistance

https://github.com/p2irc/LSPlab

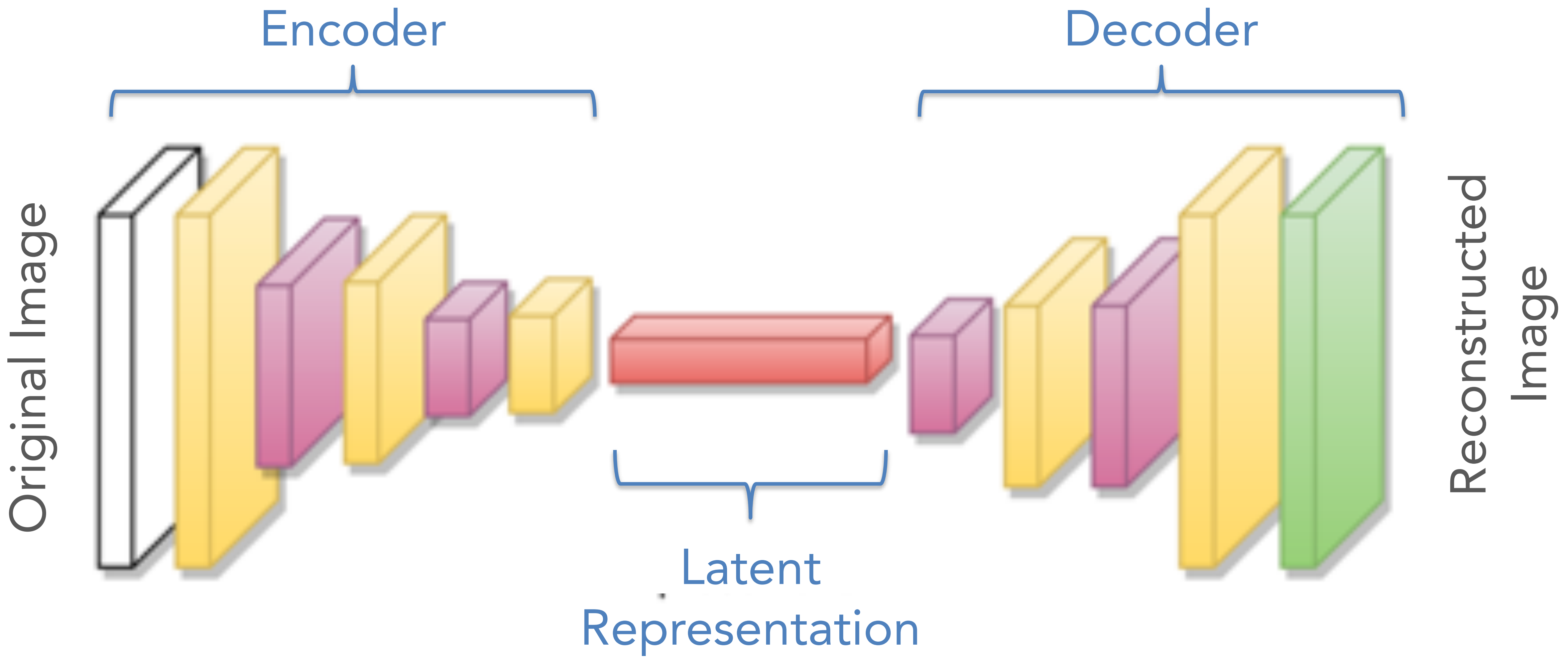
Ubbens, J., Cieslak, M., Prusinkiewicz, P., Parkin, I., Ebersbach, J., & Stavness, I. (2020). Latent space phenotyping: automatic image-based phenotyping for treatment studies. Plant Phenomics, 2020, 5801869

Image-based Phenotyping

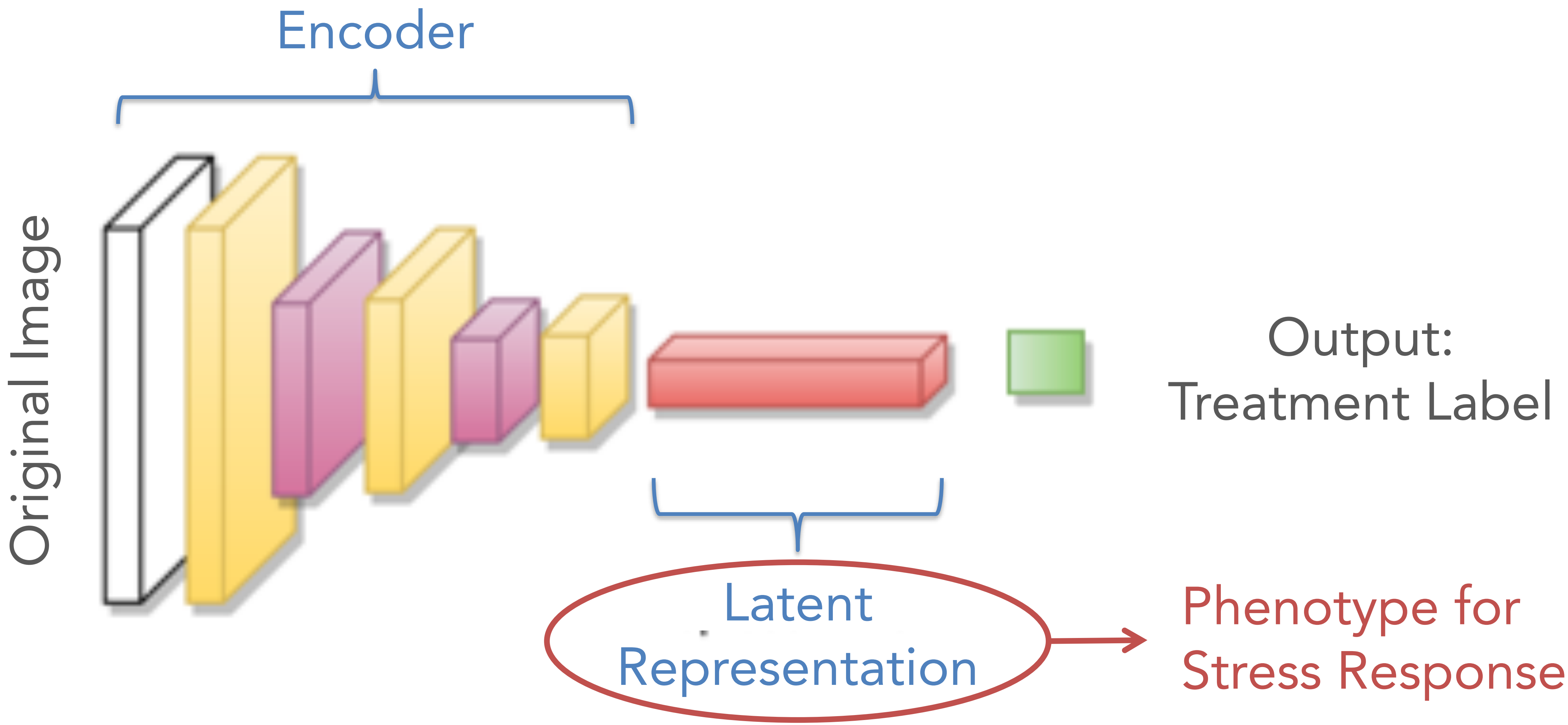


Latent Space Phenotyping

Latent variable models



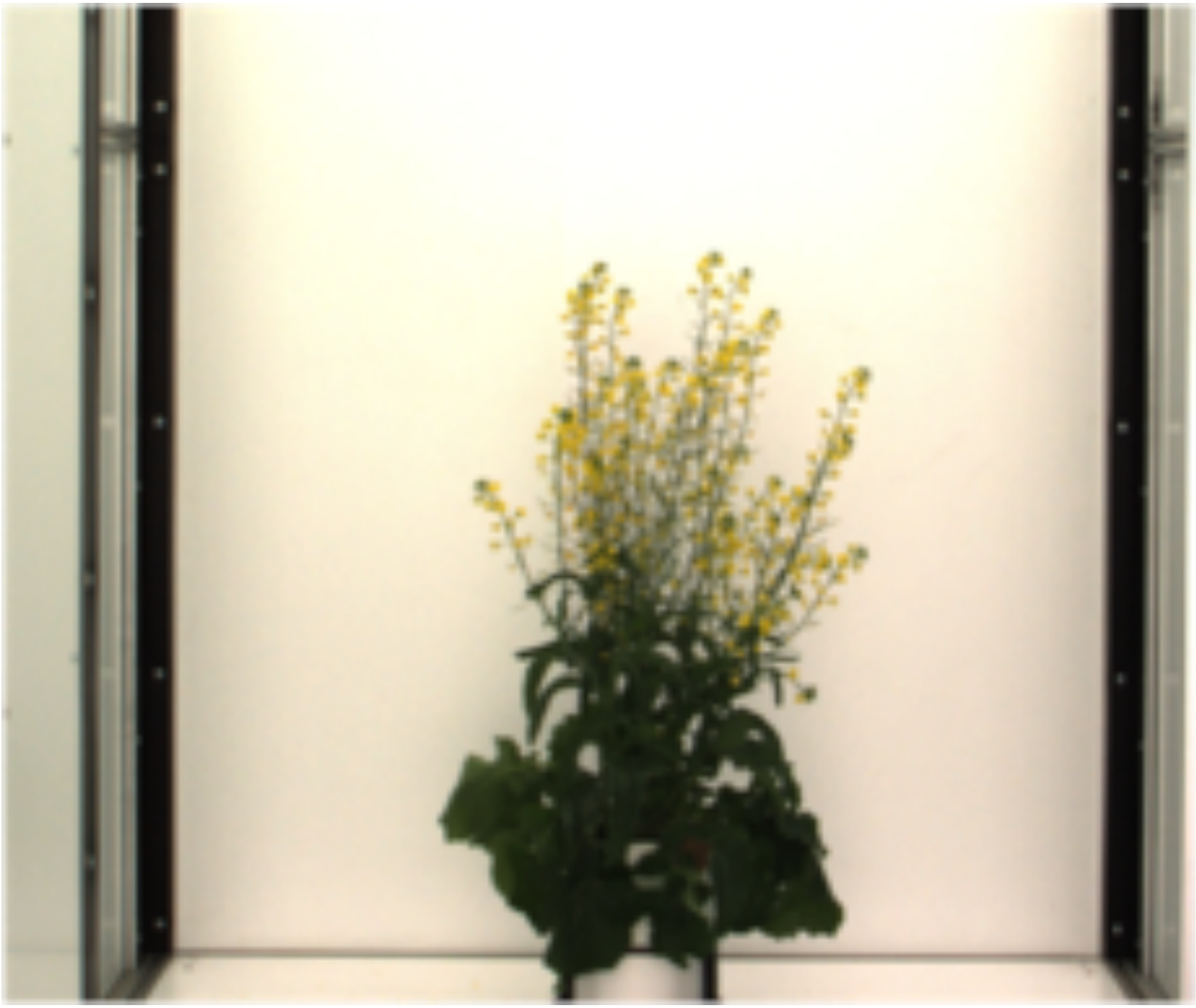
Latent variable models



Datasets: Setaria RIL

Feldman et al. (2018). Components of Water Use Efficiency Have Unique Genetic Signatures in the Model C_4 Grass *Setaria*. *Plant Phys.*, *178*(2), 699–715.

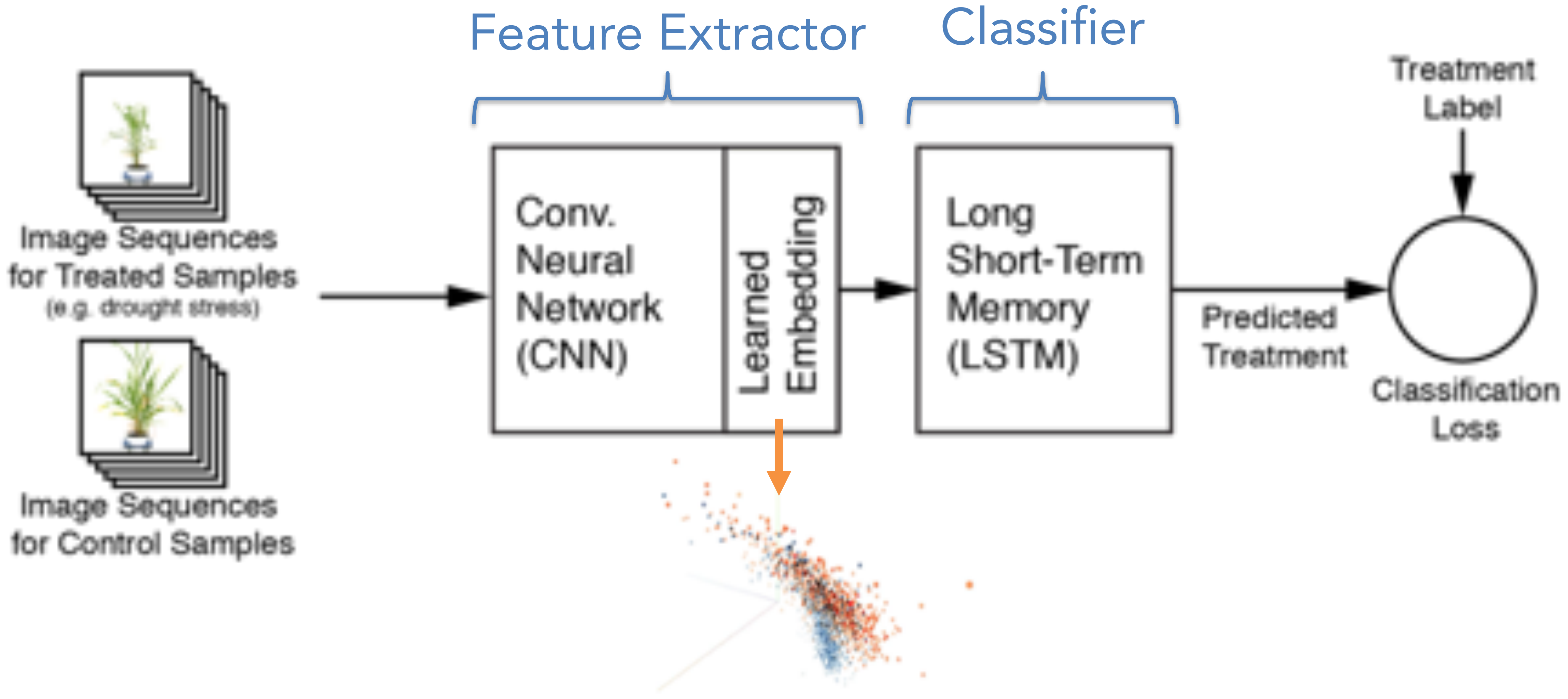
Datasets: Canola NAM



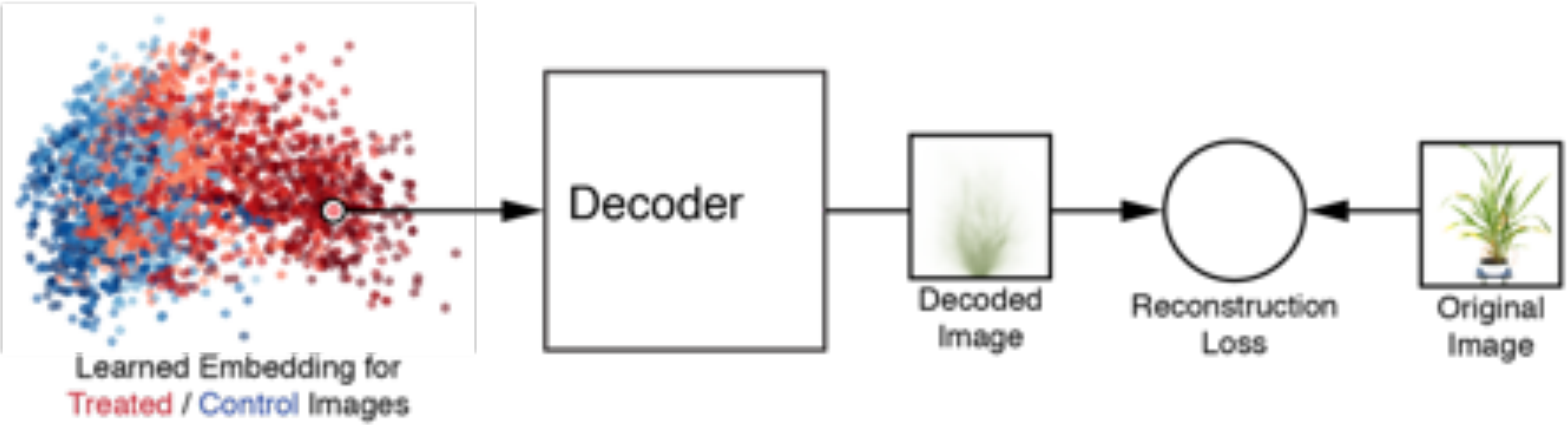
Datasets: Synthetic Arabidopsis

- Genomic data from the *A. thaliana polymorphism database*
- Images generated from a 3D L-system model

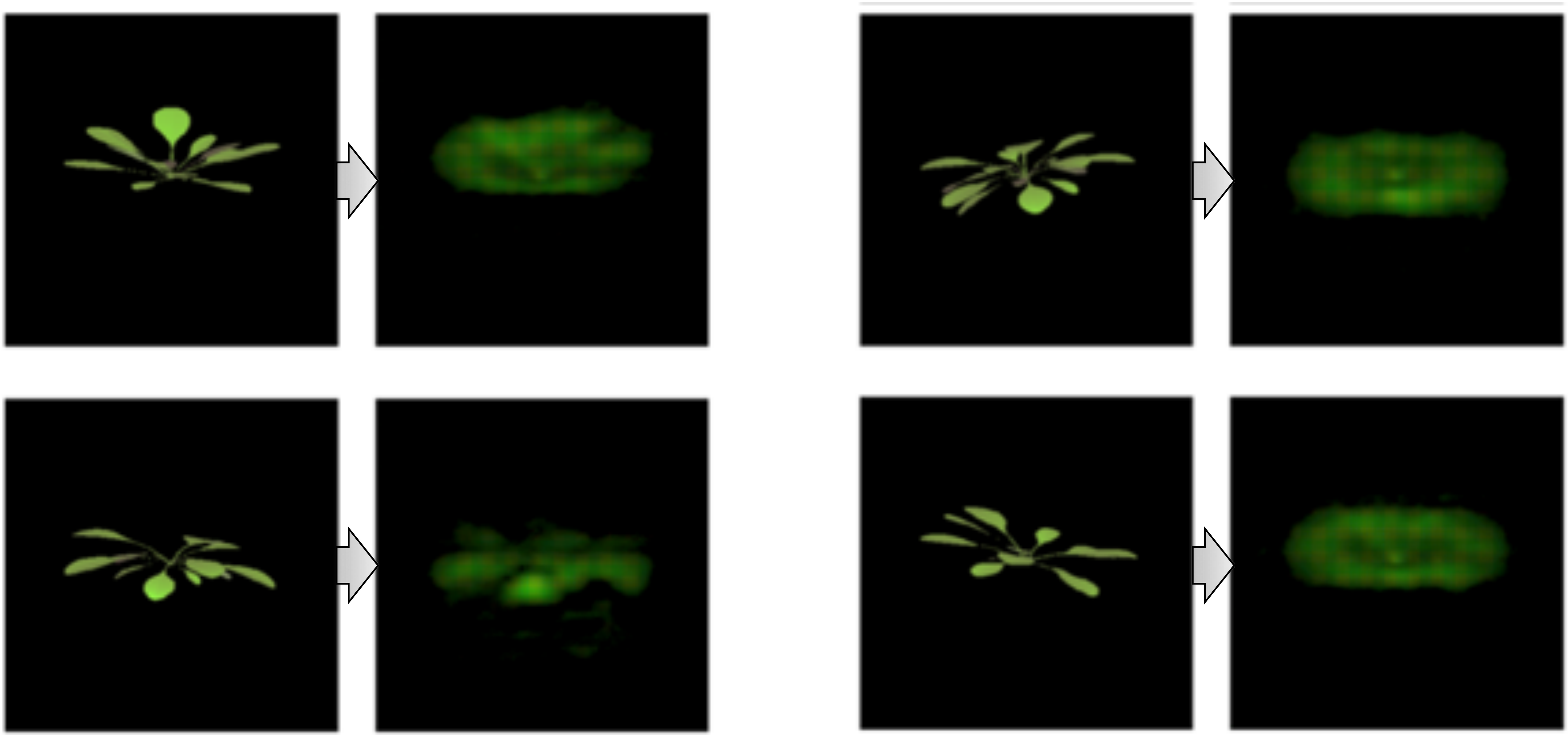
Embedding Process



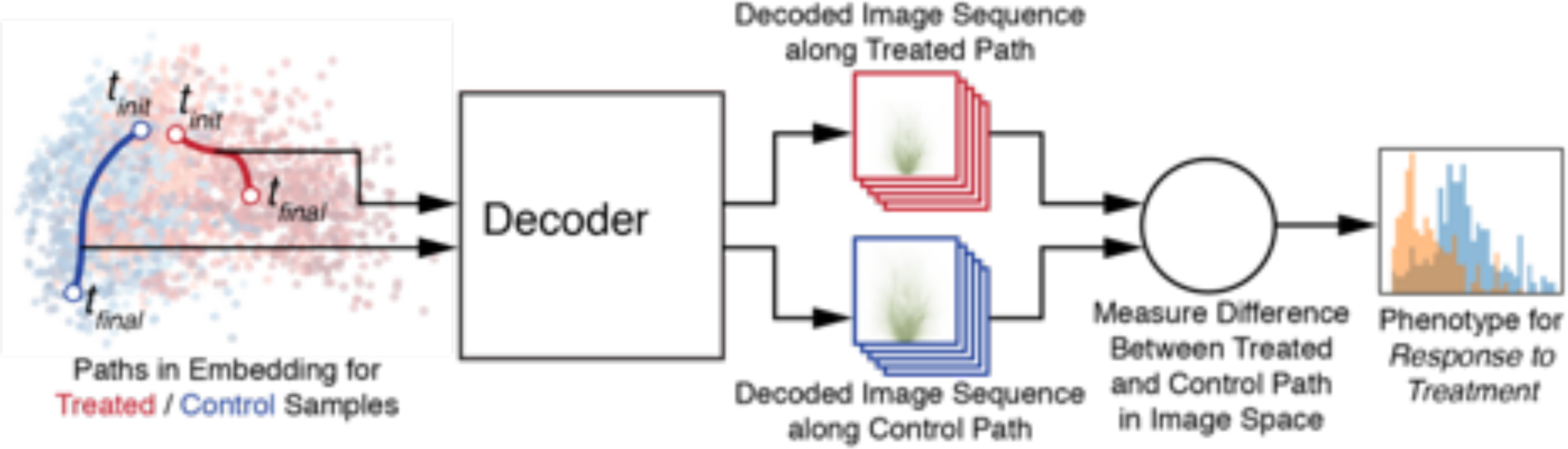
Decoding Process



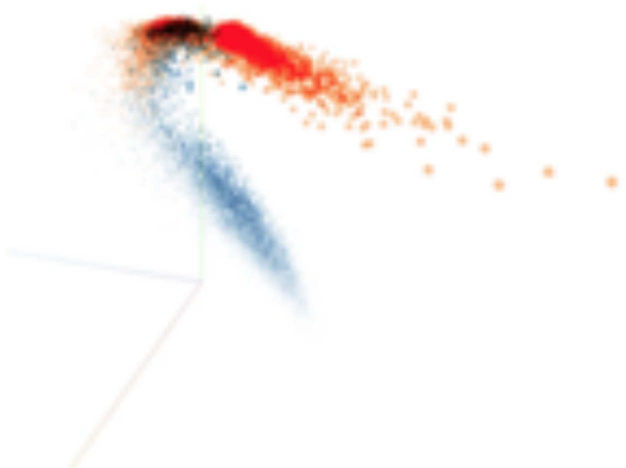
Example decoded images

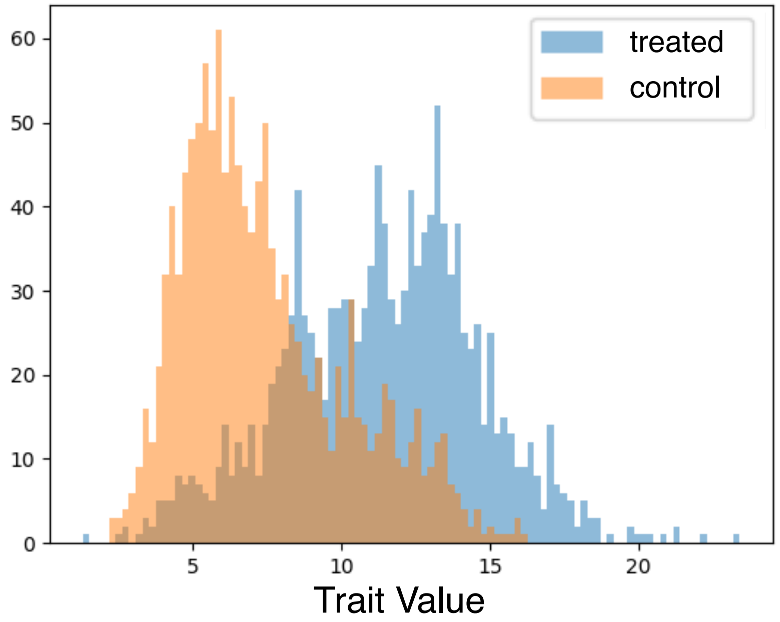


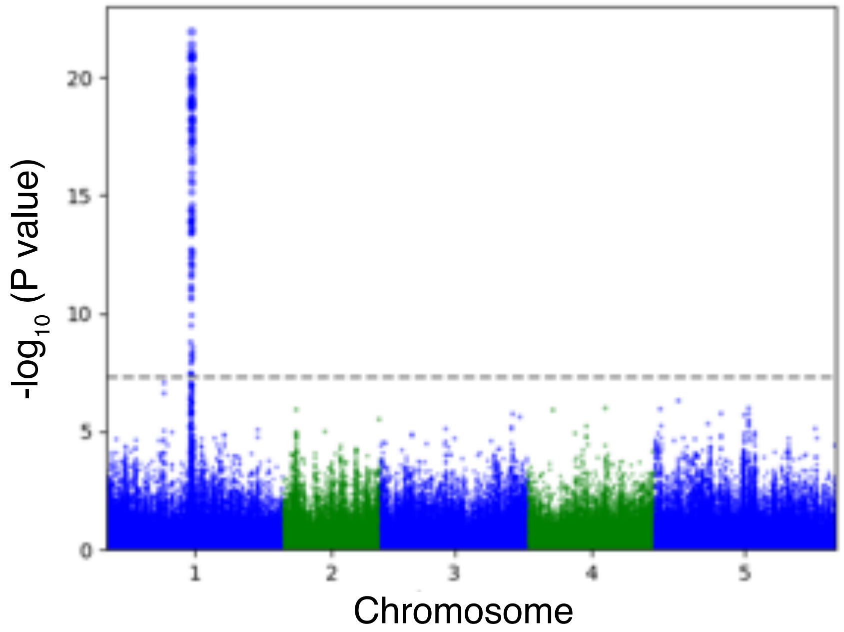
Measuring Response-to-Treatment



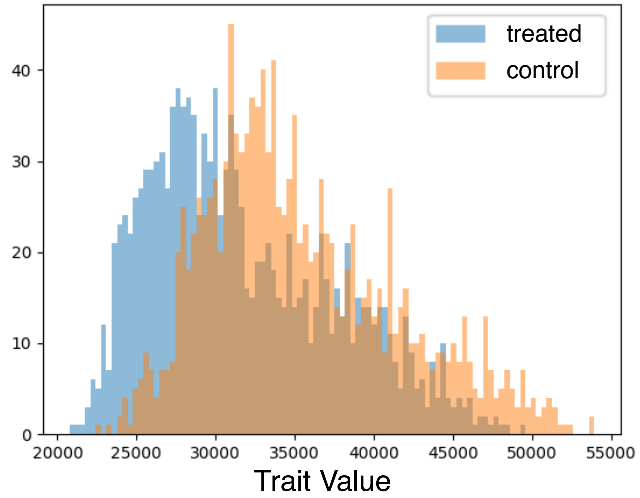
Results: Synthetic Arabidopsis

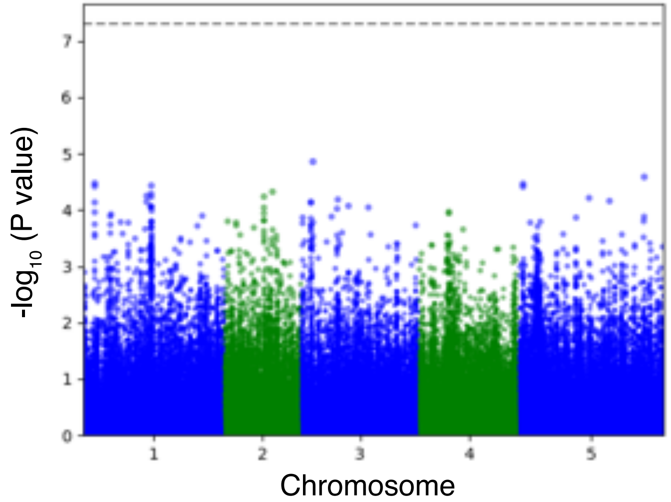




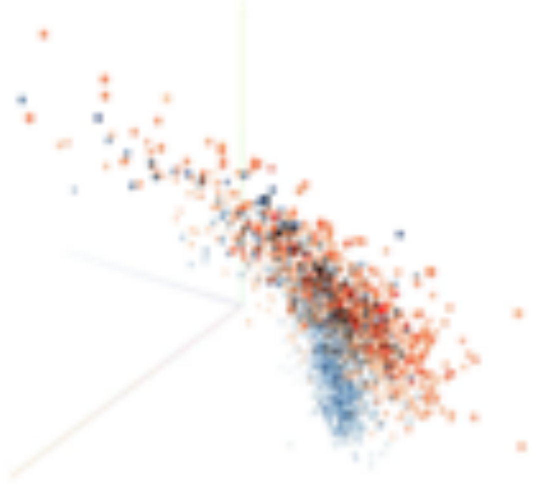


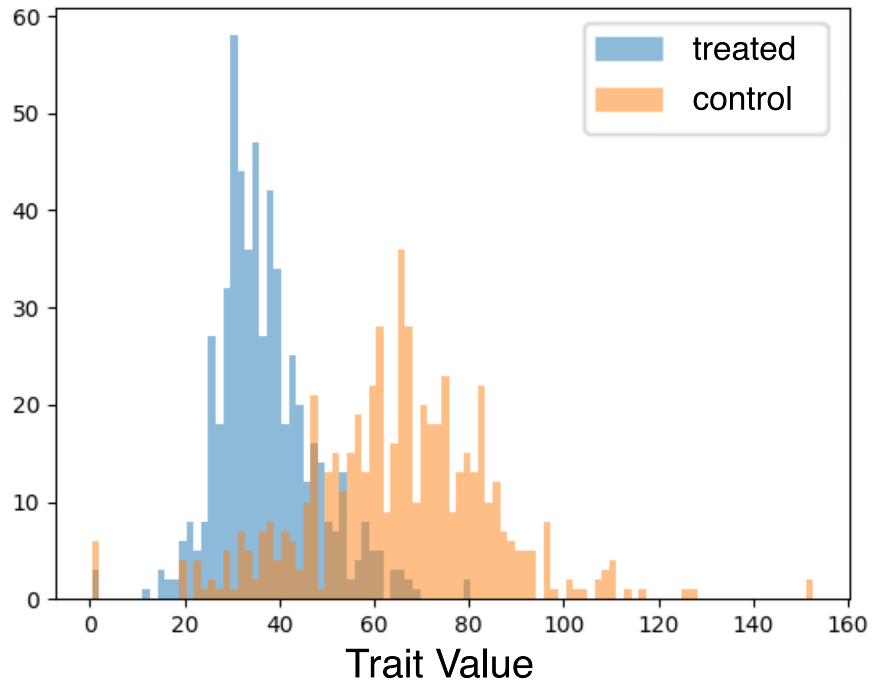
What if we use simple image distance instead?

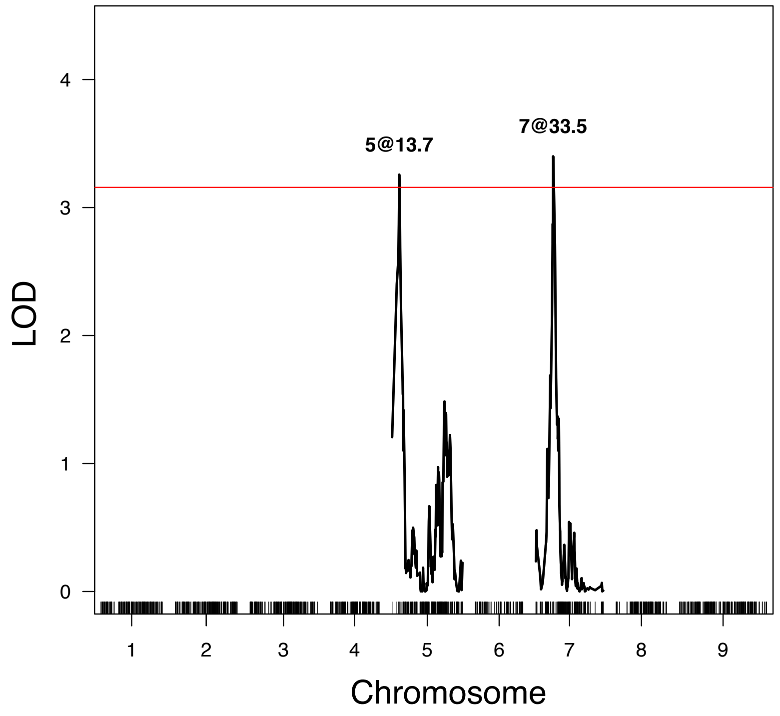




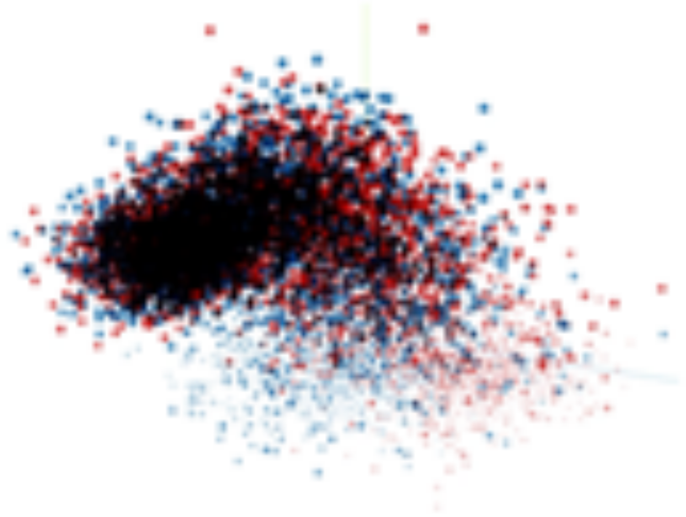
Results: Setaria

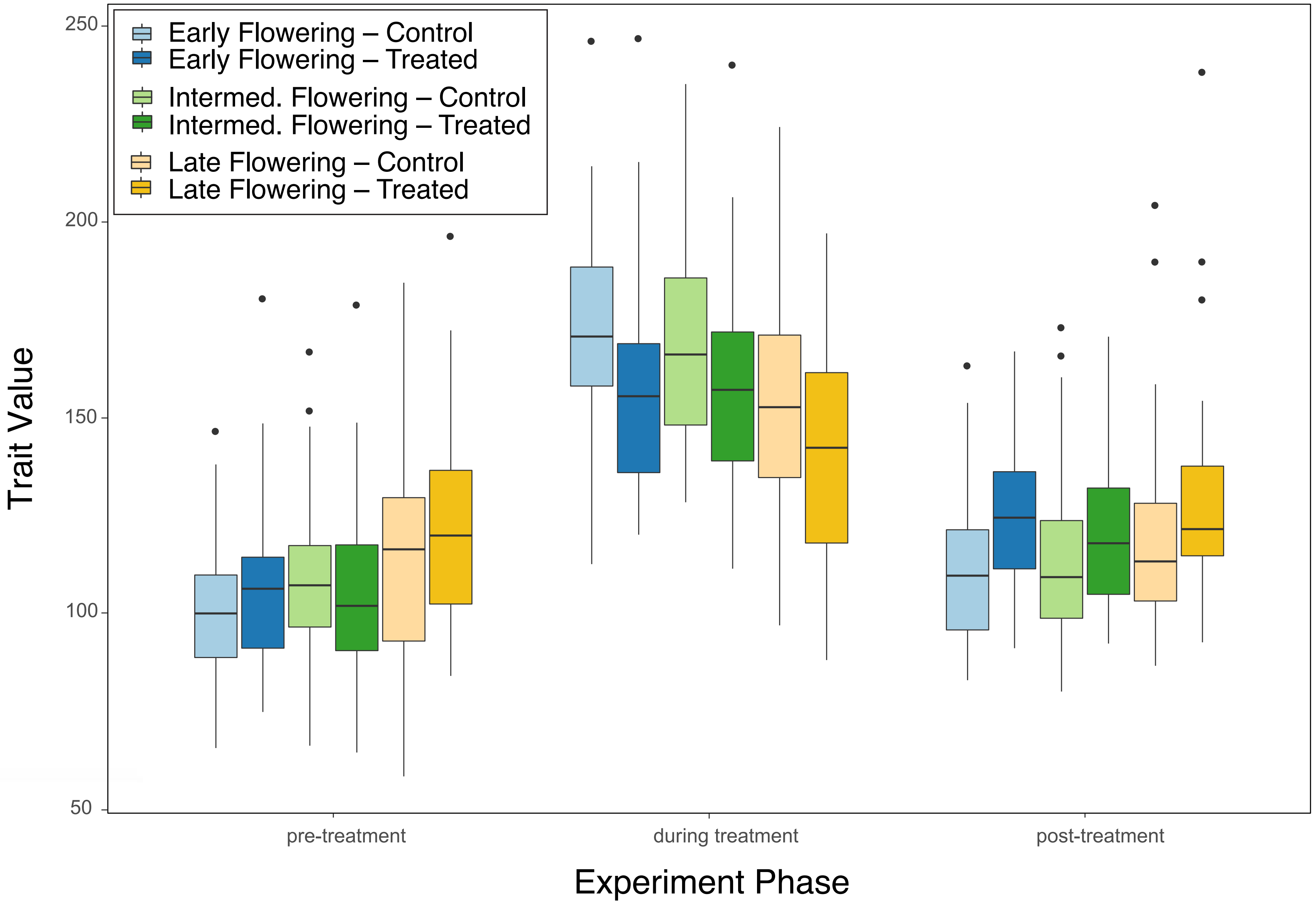




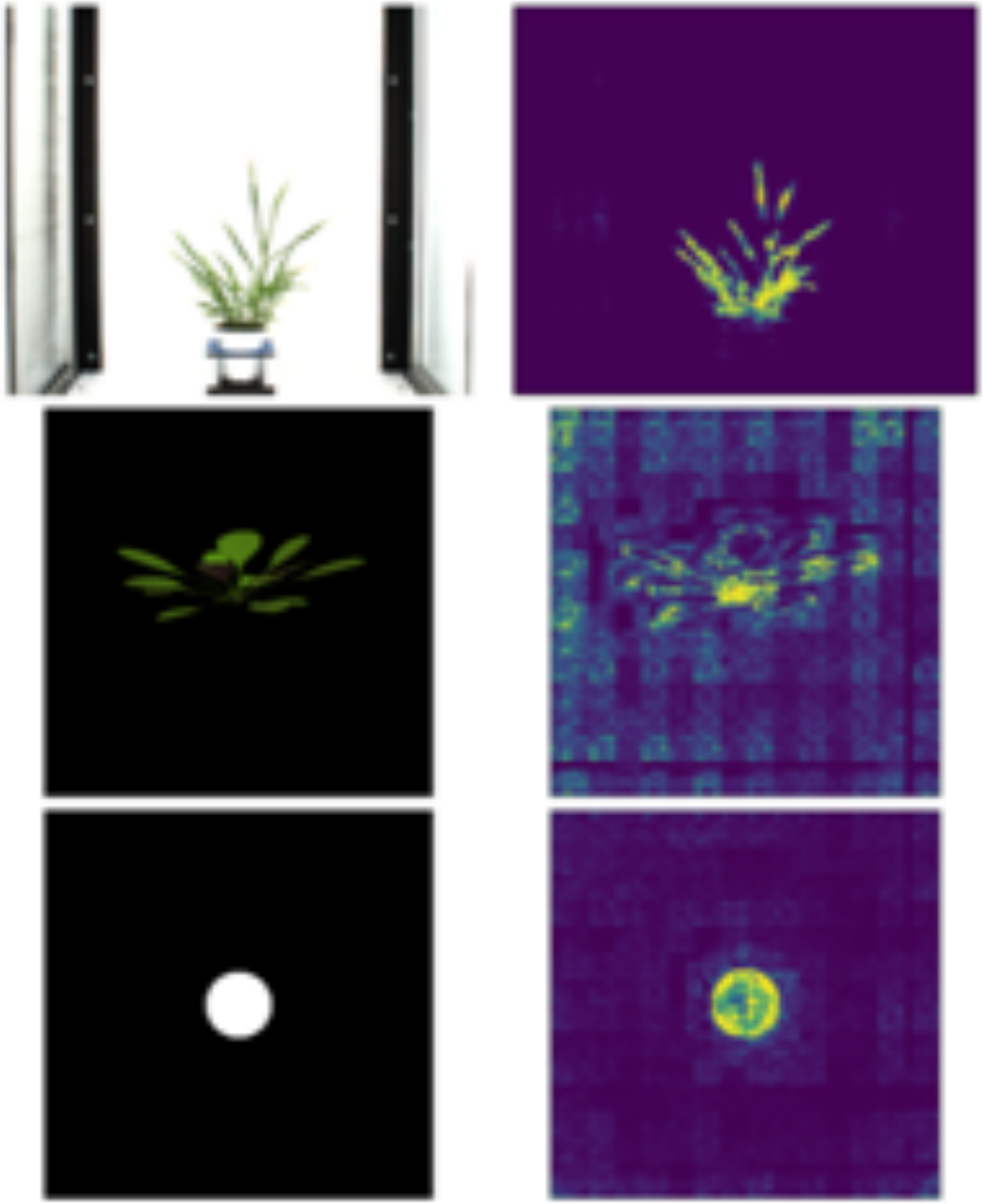


Results: Canola



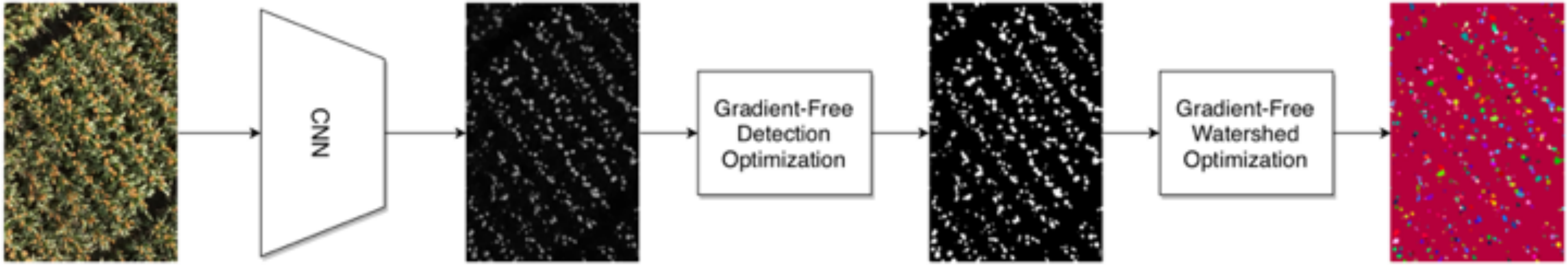


Limitation: Explainability



AutoCount: Unsupervised Organ Counting

To appear: www.plant-phenotyping.org/CVPPP2020



Ubbens, J., Ayalew, T., Shirtliffe, S., Josuttes, A., Pozniak, C. & Stavness, I. (2020). AutoCount: Unsupervised Segmentation and Counting of Organs in Field Images. ECCV Workshops, 2020, to appear.

AutoCount: Unsupervised Organ Counting

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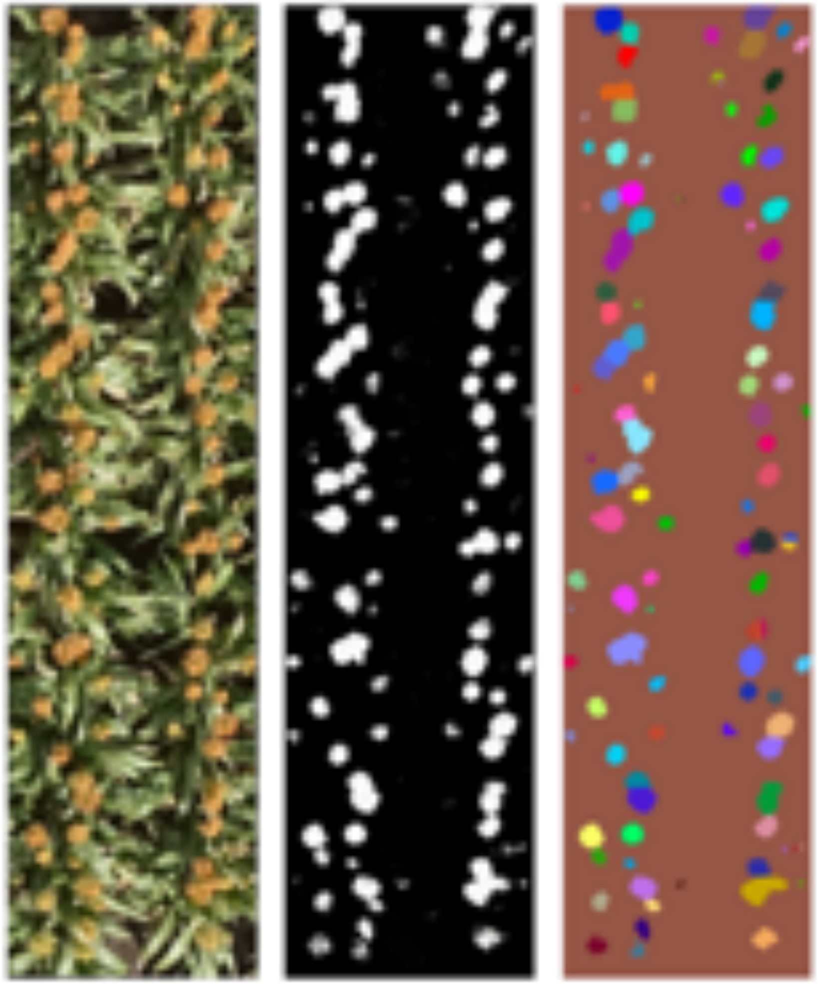

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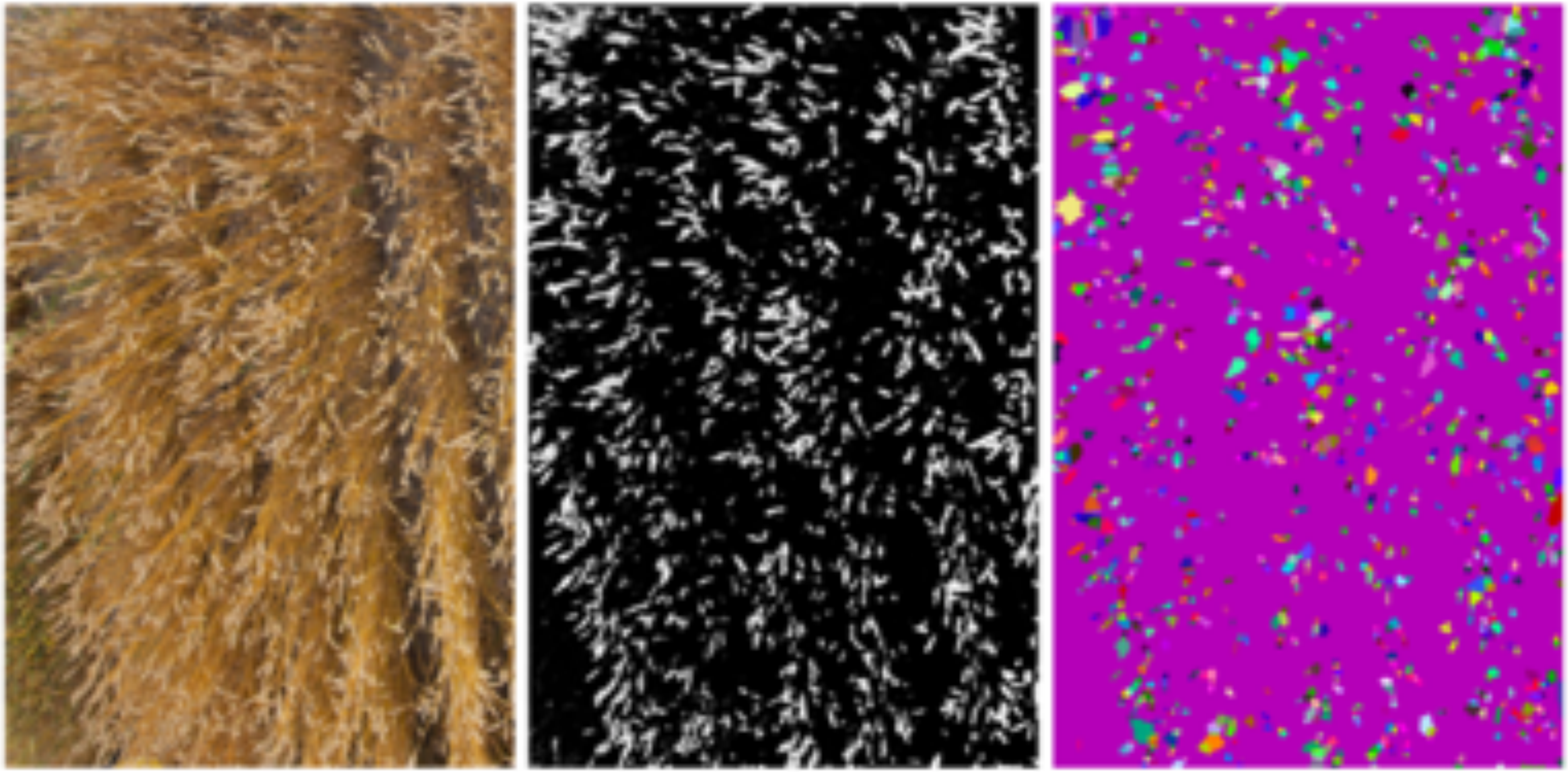

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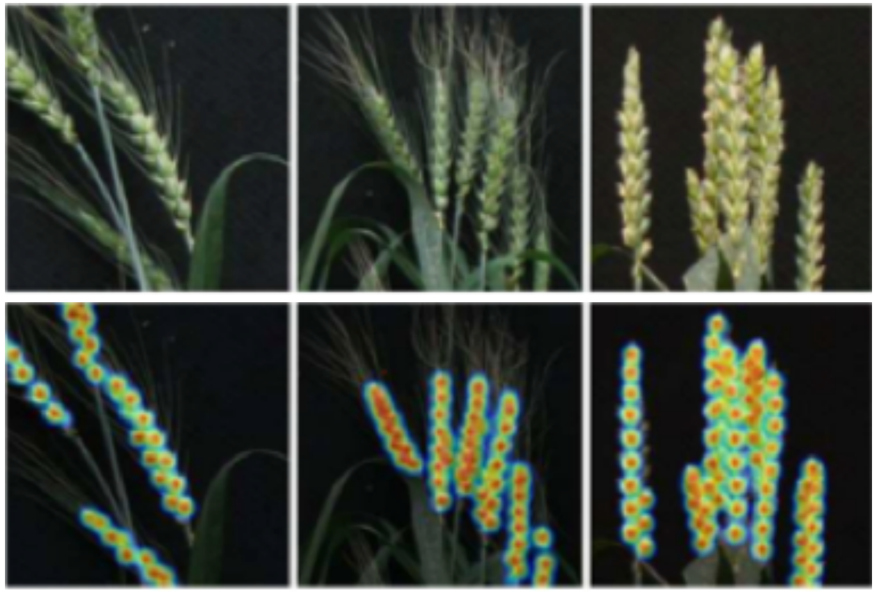
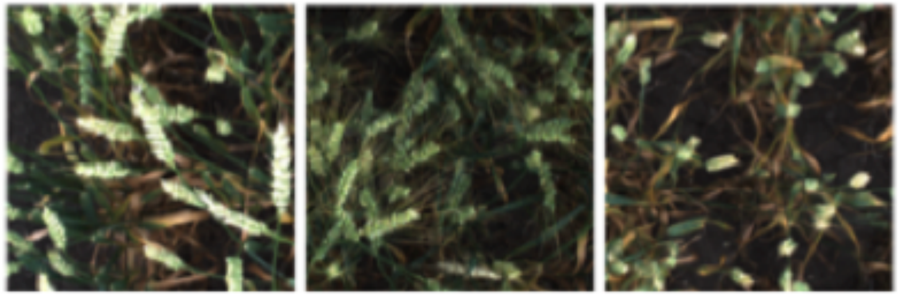
Domain Adaptation for Organ Counting

To appear: www.plant-phenotyping.org/CVPPP2020

Source:
Indoor labeled dataset



Target:
Outdoor *Unlabeled* dataset



GWHD

CropQuant

Ubbens, J., Ayalew, T., & Stavness, I. (2020). Unsupervised Domain Adaptation For Plant Organ Counting. ECCV Workshops, 2020, *to appear*.

Domain Adaptation for Organ Counting

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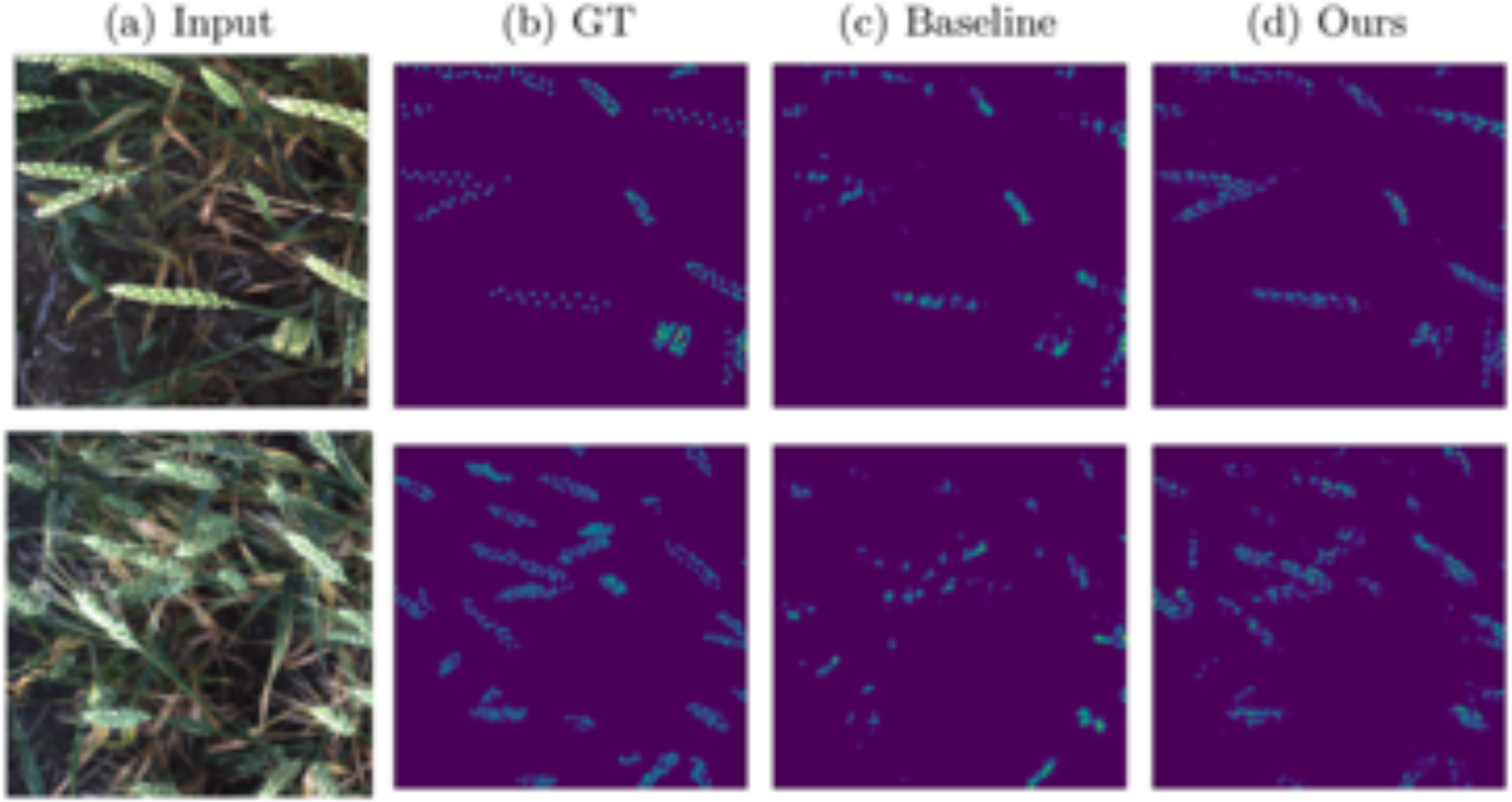

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Domain Adaptation for Organ Counting

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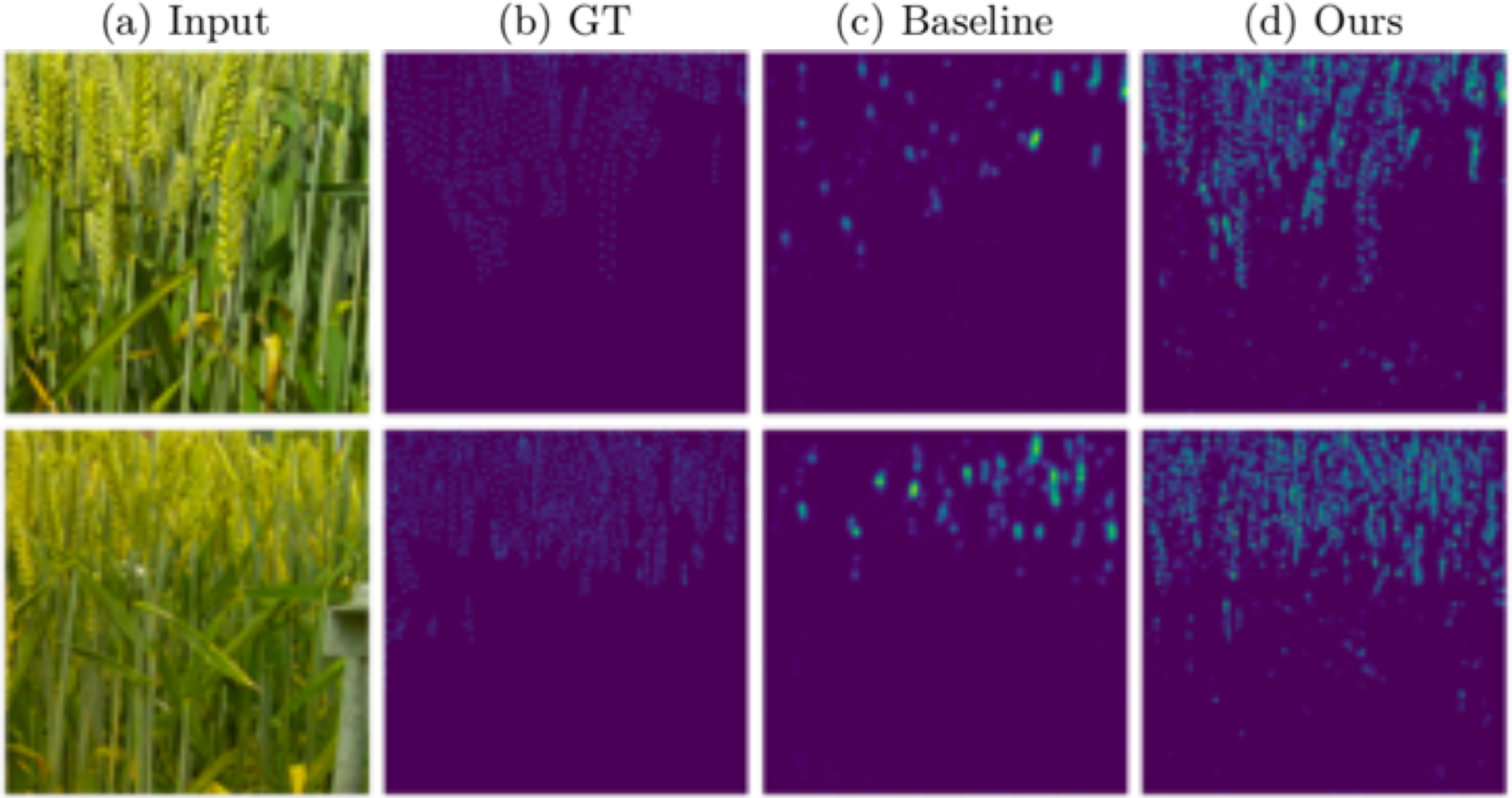

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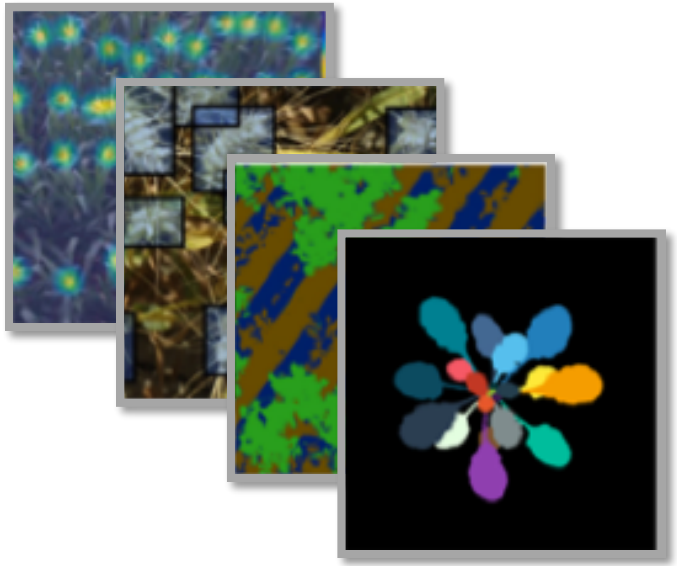

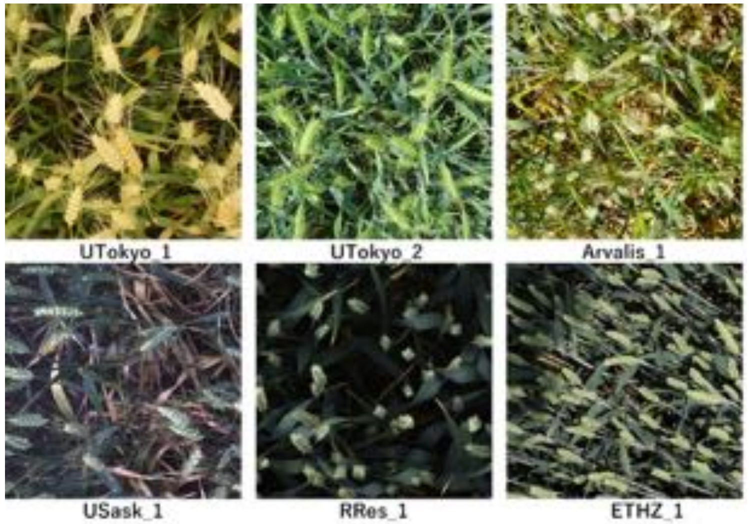

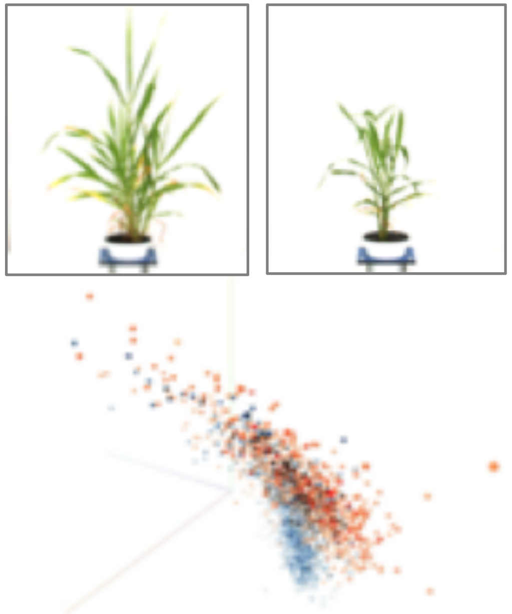

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