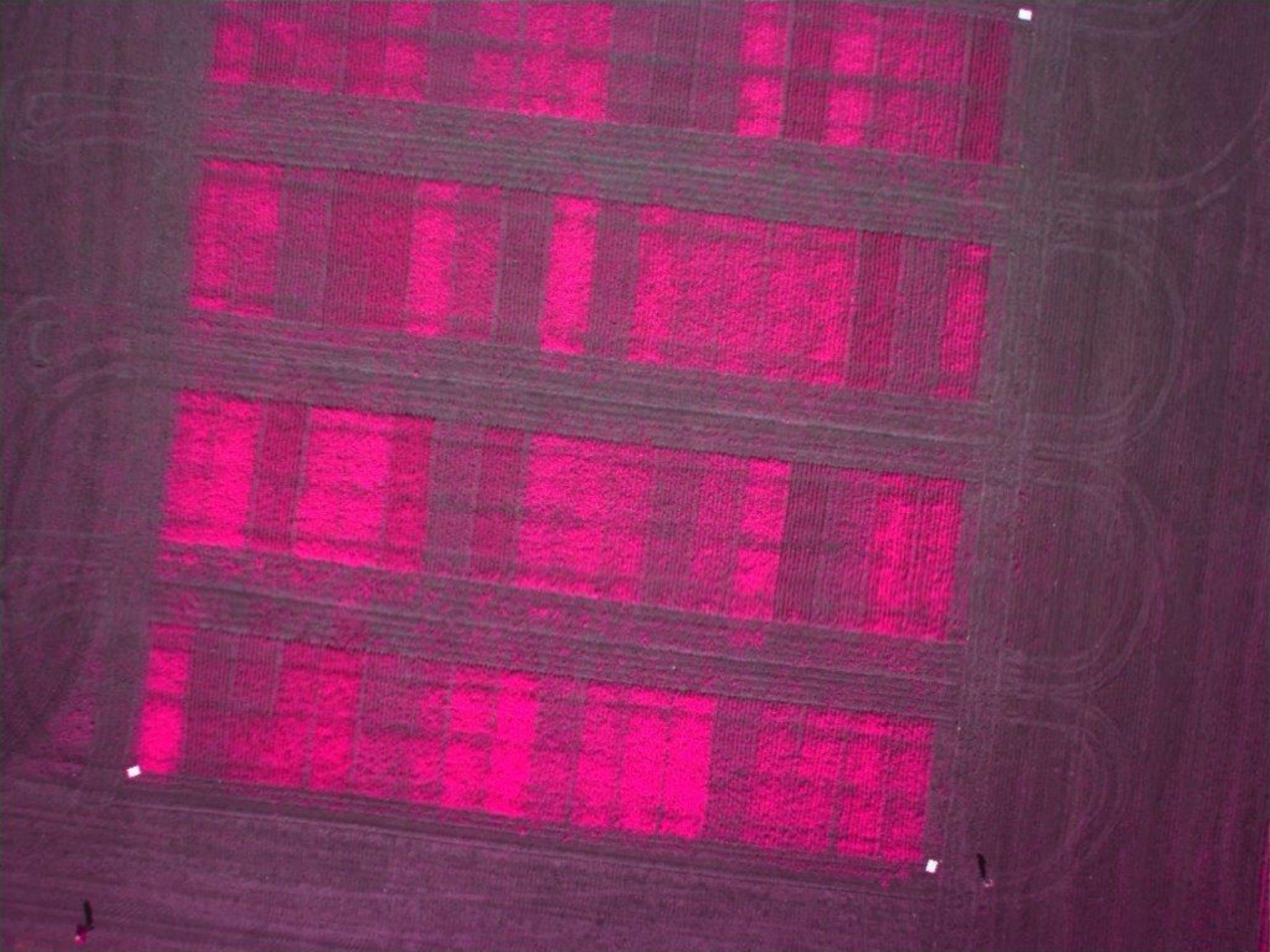
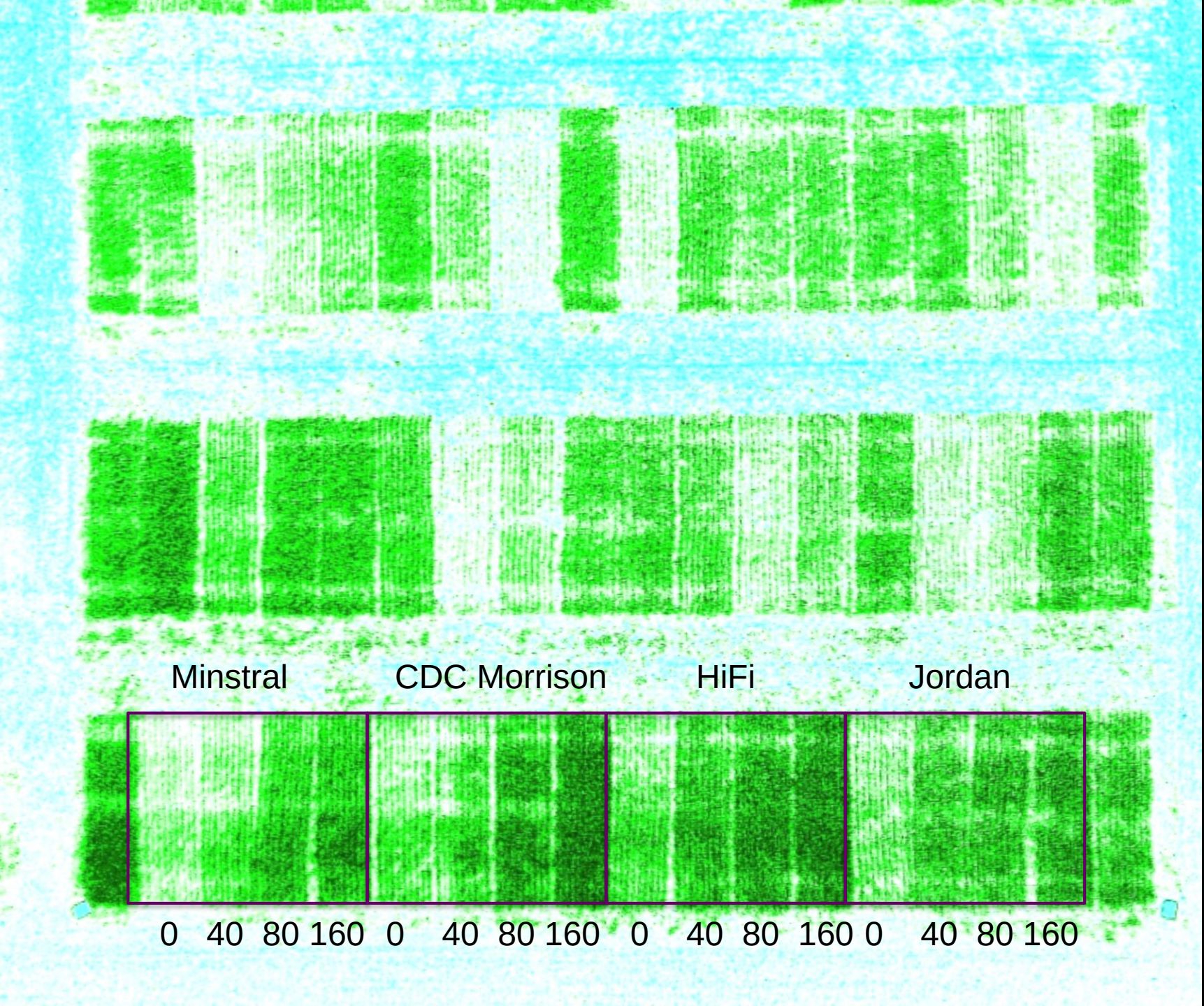
How Can Drones be Used for Crop Diagnostics?

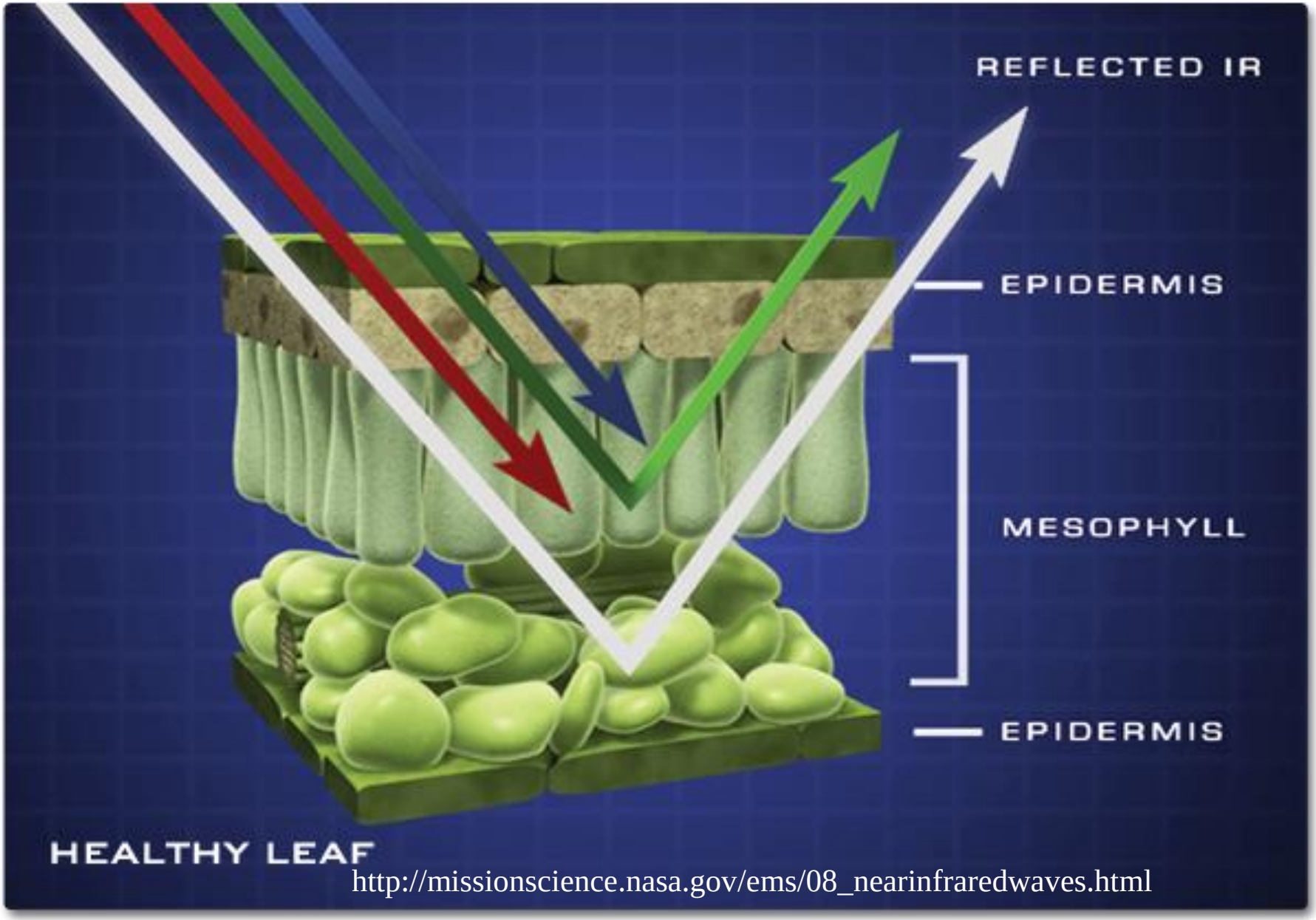
Steve Shirtliffe, Sudhakar Duddu, Menglu Wang, Ti Zhang, Vladimir Pajic, Kirstin Bett, Scott Noble, Sally Vail, Lena Syrovy, Shaun Campbell, Seungbum Ryu, Austin McGill, Amanda Wuchner, Kevin Stanley, Ian Stavness

UNIVERSITY OF SASKATCHEWAN
College of Agriculture and Bioresources
DEPARTMENT OF PLANT SCIENCES
AGBIO.USASK.CA

2014: Gordon Gray, Kirstin Bett, Vlad Pajic and Draganfly

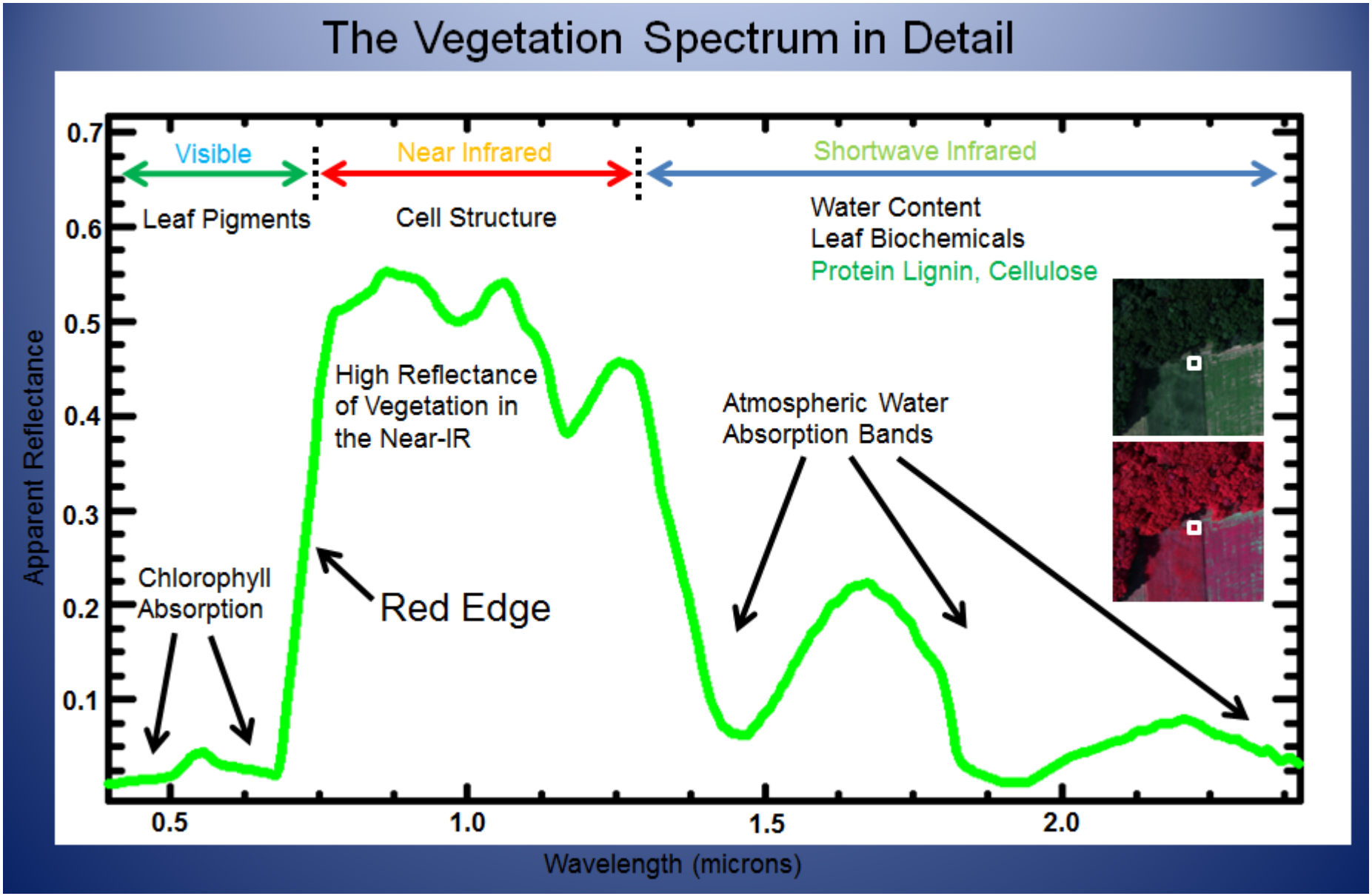


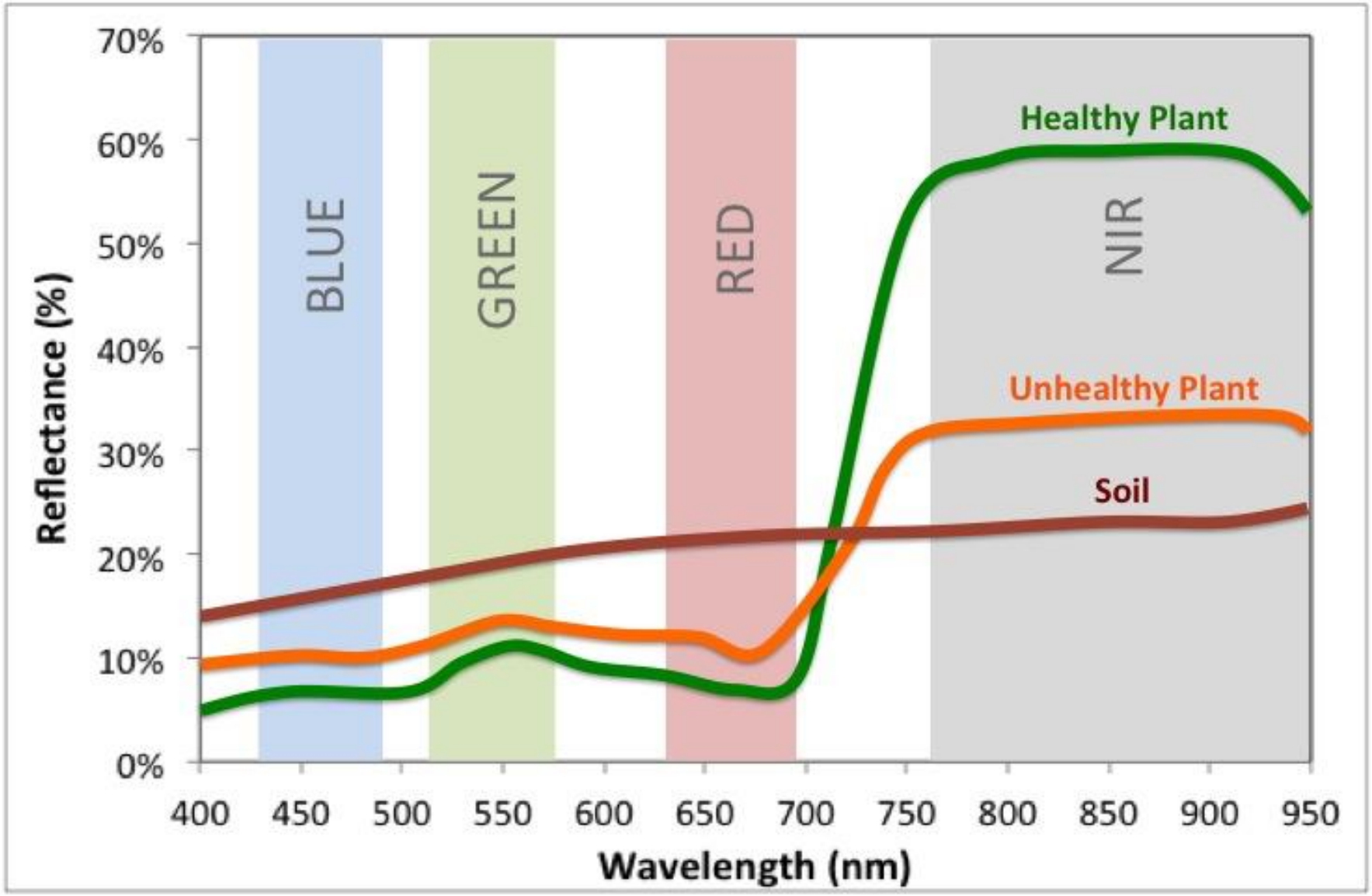

Minstral
CDC Morrison
HiFi
Jordan
0 40 80 160 0 40 80 160 0 40 80 160 0 40 80 160
0.588
5.2 %
0.471
7.4 %
0.353
8.3 %
0.235
9.9 %
0.118
19.4 %



http://missionscience.nasa.gov/ems/08_nearinfraredwaves.html

The Vegetation Spectrum in Detail




70%
60%
50%
40%
30%
20%
10%
0%
Reflectance (%)
BLUE
GREEN
RED
NIR
Healthy Plant
Unhealthy Plant
Soil
400
450
500
550
600
650
700
750
800
850
900
950
Wavelength (nm)

2015 we bought a UAV

Got trained

Certificate of Completion

This certifies that

Steve Shirtliffe

Completed the

Civil and Commercial UAS Training Course

On the 23st April 2015

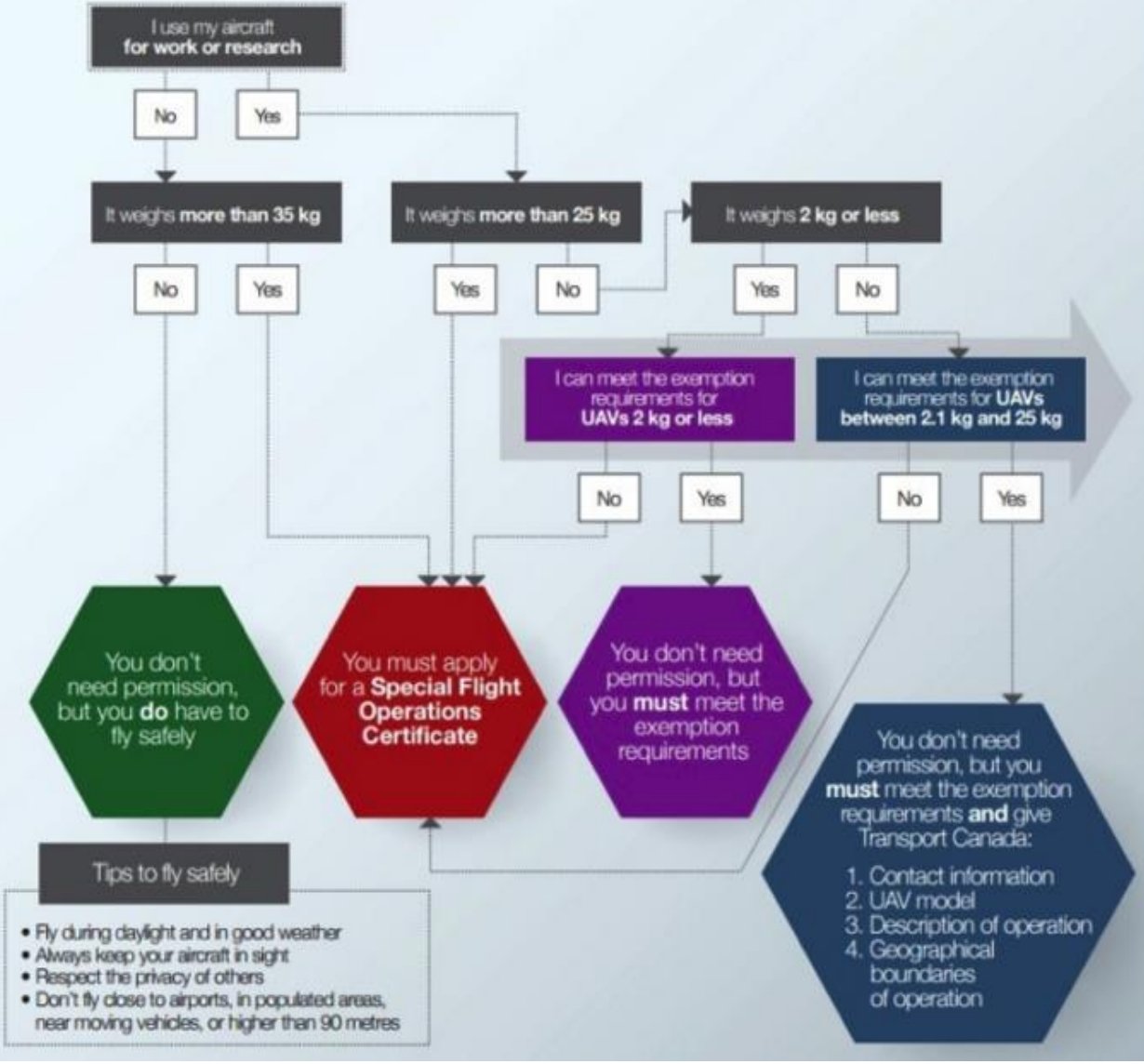
Canadian Centre for Unmanned Vehicle Systems
Medicine Hat, Alberta

Sterling Cripps Chief Operating Officer

Transport Canada Transports Canada

Flying an unmanned aircraft?

You may need permission from Transport Canada



Transport Canada | Transports Canada

Flying an unmanned aircraft?

You may need permission from Transport Canada

I use my aircraft **for work or research**

No → You don't need permission, but you **do** have to fly safely

Yes → It weighs **more than 35 kg**

- No → You don't need permission, but you **do** have to fly safely
- Yes → You must apply for a **Special Flight Operations Certificate**

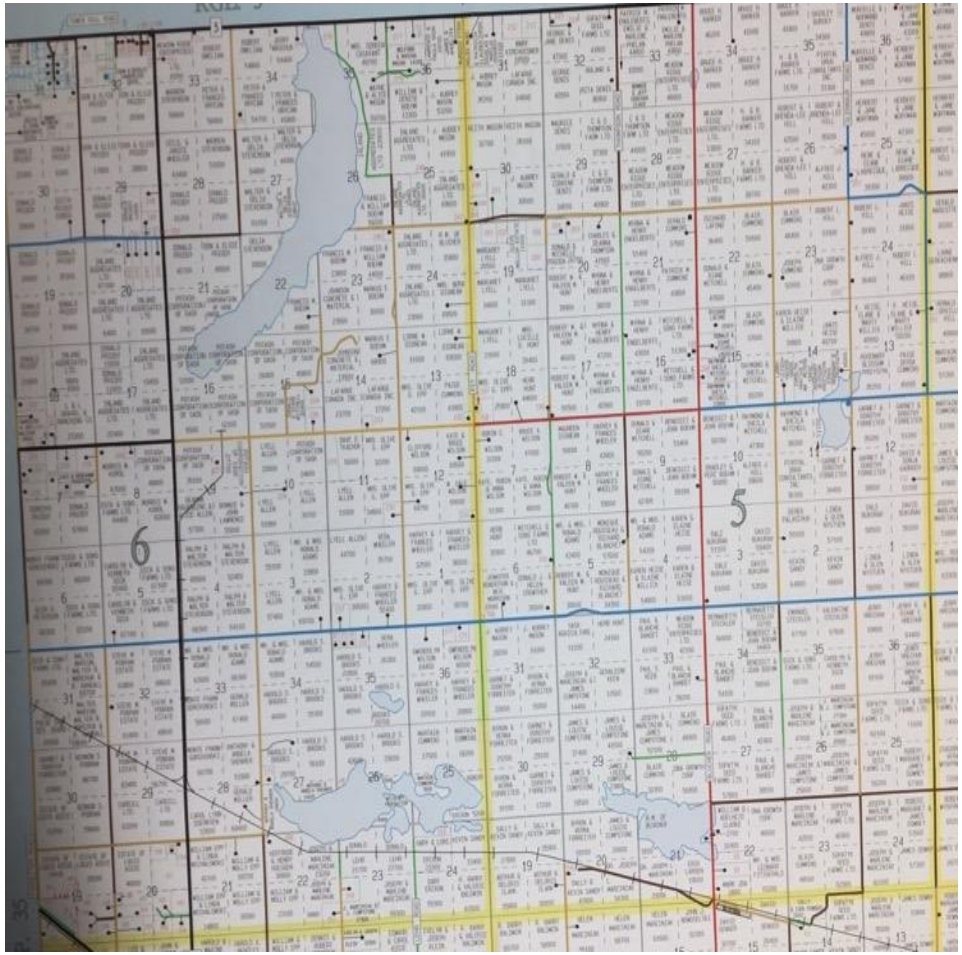
Yes → It weighs **more than 25 kg**

- Yes → You must apply for a **Special Flight Operations Certificate**
- No → It weighs **2 kg or less**

  - Yes → I can meet the exemption requirements for **UAVs 2 kg or less**
    - No → You must apply for a **Special Flight Operations Certificate**
    - Yes → You don't need permission, but you **must** meet the exemption requirements
  - No → I can meet the exemption requirements for **UAVs between 2.1 kg and 25 kg**
    - No → You must apply for a **Special Flight Operations Certificate**
    - Yes → You don't need permission, but you **must** meet the exemption requirements **and** give Transport Canada:
      1. Contact information
      2. UAV model
      3. Description of operation
      4. Geographical boundaries of operation

Tips to fly safely

- Fly during daylight and in good weather
- Always keep your aircraft in sight
- Respect the privacy of others
- Don't fly close to airports, in populated areas, near moving vehicles, or higher than 90 metres

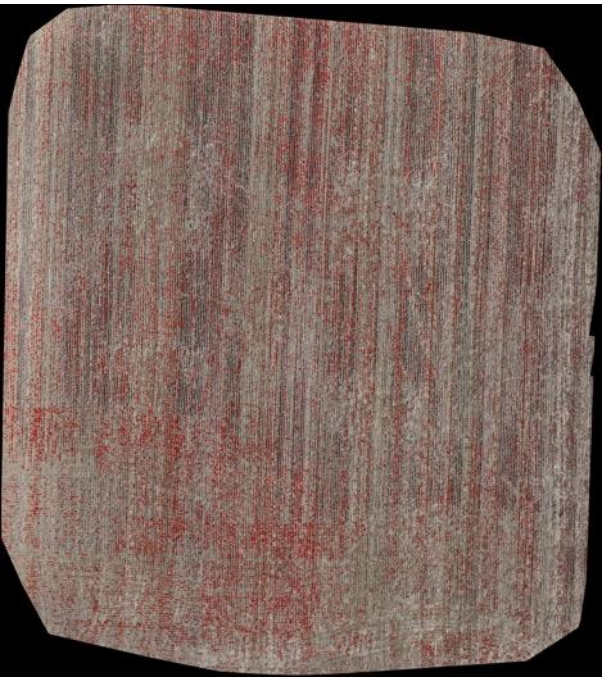



Tips to fly safely
• Fly during daylight and in good weather
• Always keep your aircraft in sight
• Respect the privacy of others
• Don't fly close to airports, in populated areas, near moving vehicles, or higher than 90 metres

Flight Conditions

15. The pilot operating under this exemption shall maintain continuous unaided visual contact with the UAV sufficient to be able to maintain operational control of the UAV, know its location and be able to scan the airspace in which it is operating to decisively see and avoid other air traffic or objects.
16. The pilot operating under this exemption shall not use a first person view device.
17. The pilot operating under this exemption shall only operate a UAV from a single control station and control relays or visual observers to extend the operational area are prohibited.
18. The pilot shall operate no more than one UAV at any one time.
19. The pilot operating a UAV shall give way to manned aircraft at all times.
20. The pilot operating under this exemption shall only operate a UAV during daylight hours.
21. The pilot operating under this exemption shall operate a UAV at or below 300 feet above ground level (AGL).
22. The pilot conducting operations under this exemption shall only operate a UAV in Class G airspace.
23. The pilot operating under this exemption shall not operate a UAV over a forest fire area, or over any area that is located within five nautical miles of a forest fire area.
24. The pilot operating under this exemption shall not operate a UAV in airspace that has been restricted by the Minister under Section 5.1 of the *Aeronautics Act*.
25. The pilot operating under this exemption shall only operate a UAV at least five (5) nautical miles away from the centre of any aerodrome.
26. The pilot operating under this exemption shall only operate a UAV at least five (5) nautical miles away from a built-up area.
27. The pilot operating under this exemption shall operate a UAV at a lateral distance of at least 500 feet from any

RGB Sensor – 15m – 27 Days After Seeding



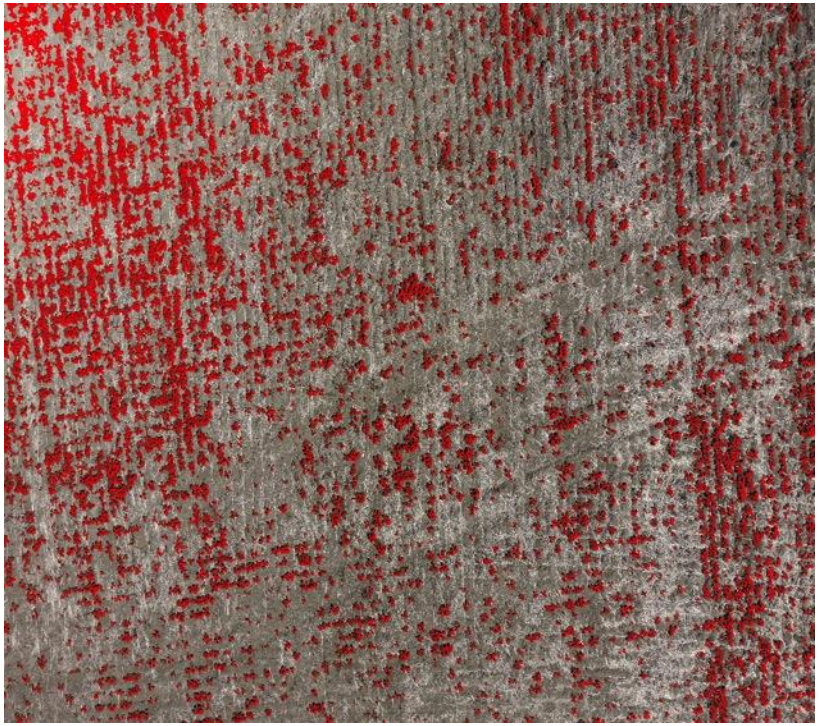
Resolution

RGB – RX100M3

Altitude (m)	Resolution (mm)
15	4.1
30	8.2
45	12.3
60	16.4

Multi-specrtral

Altitude (m)	Resolution (mm)
15	13.4
30	26.8
45	40.2
60	53.6



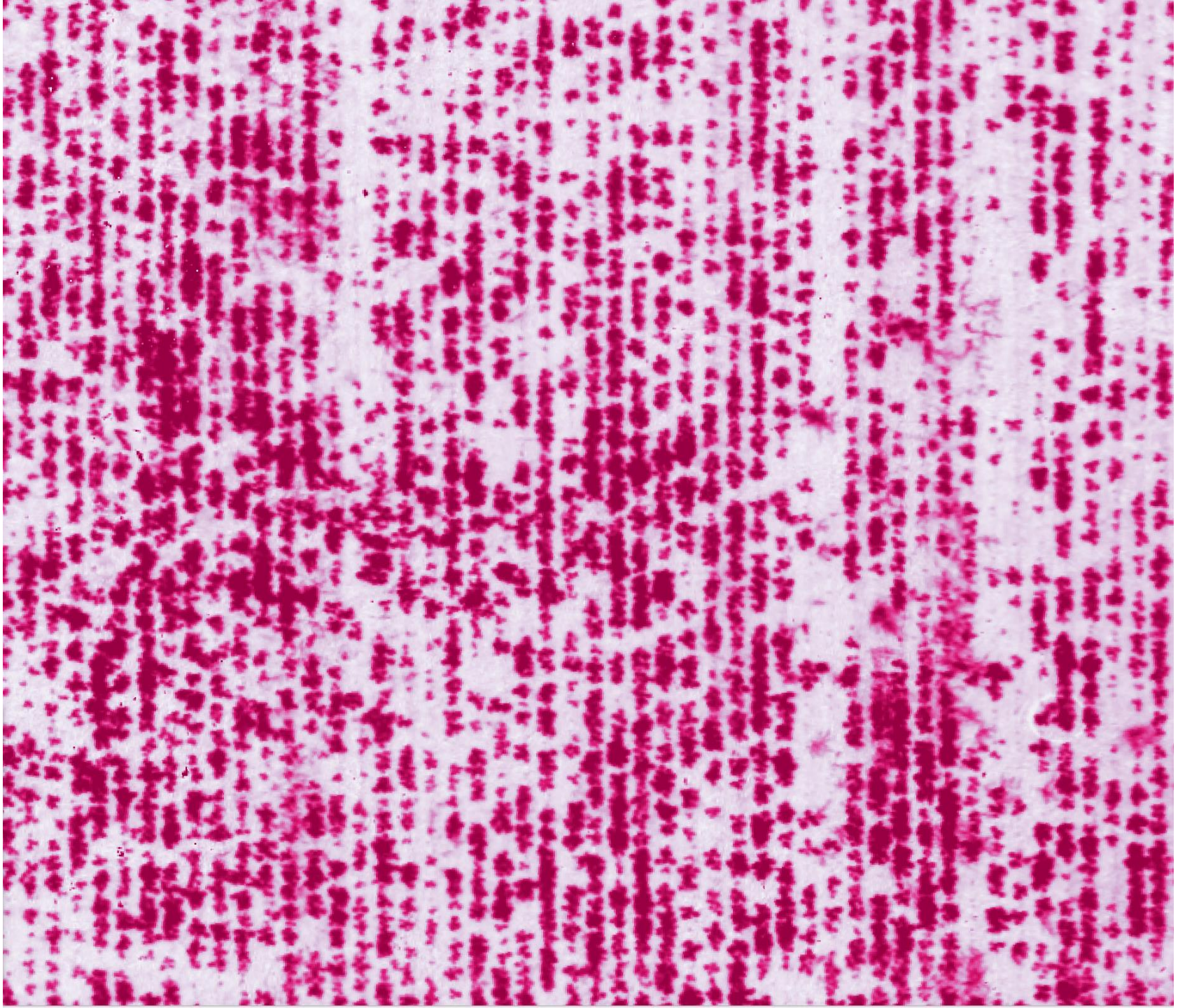
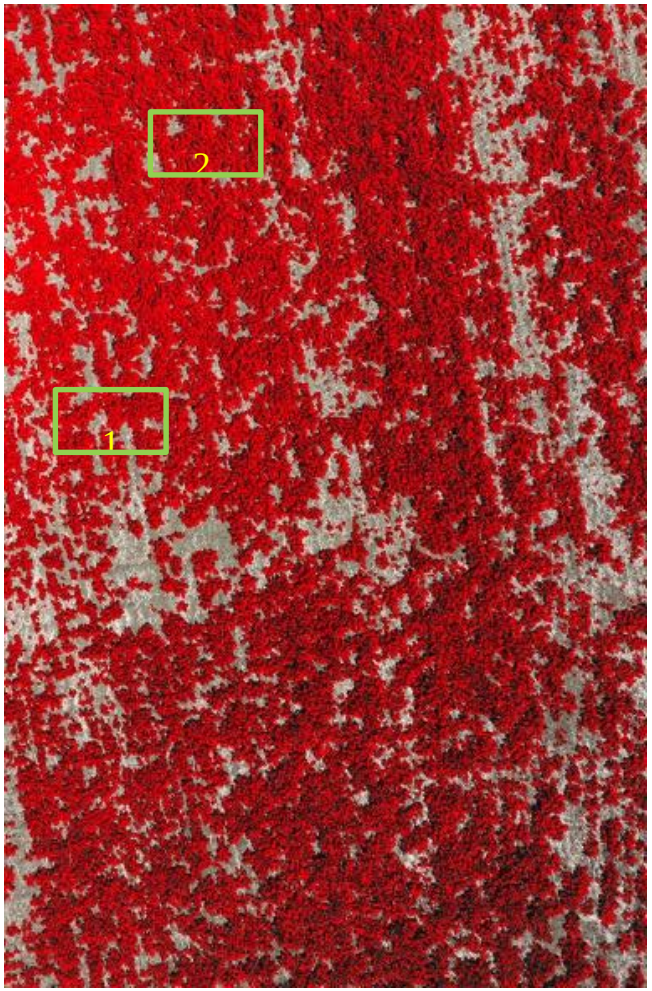
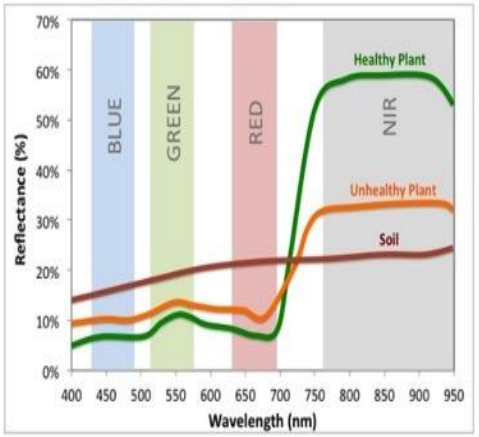


Image analysis

Percent groundcover



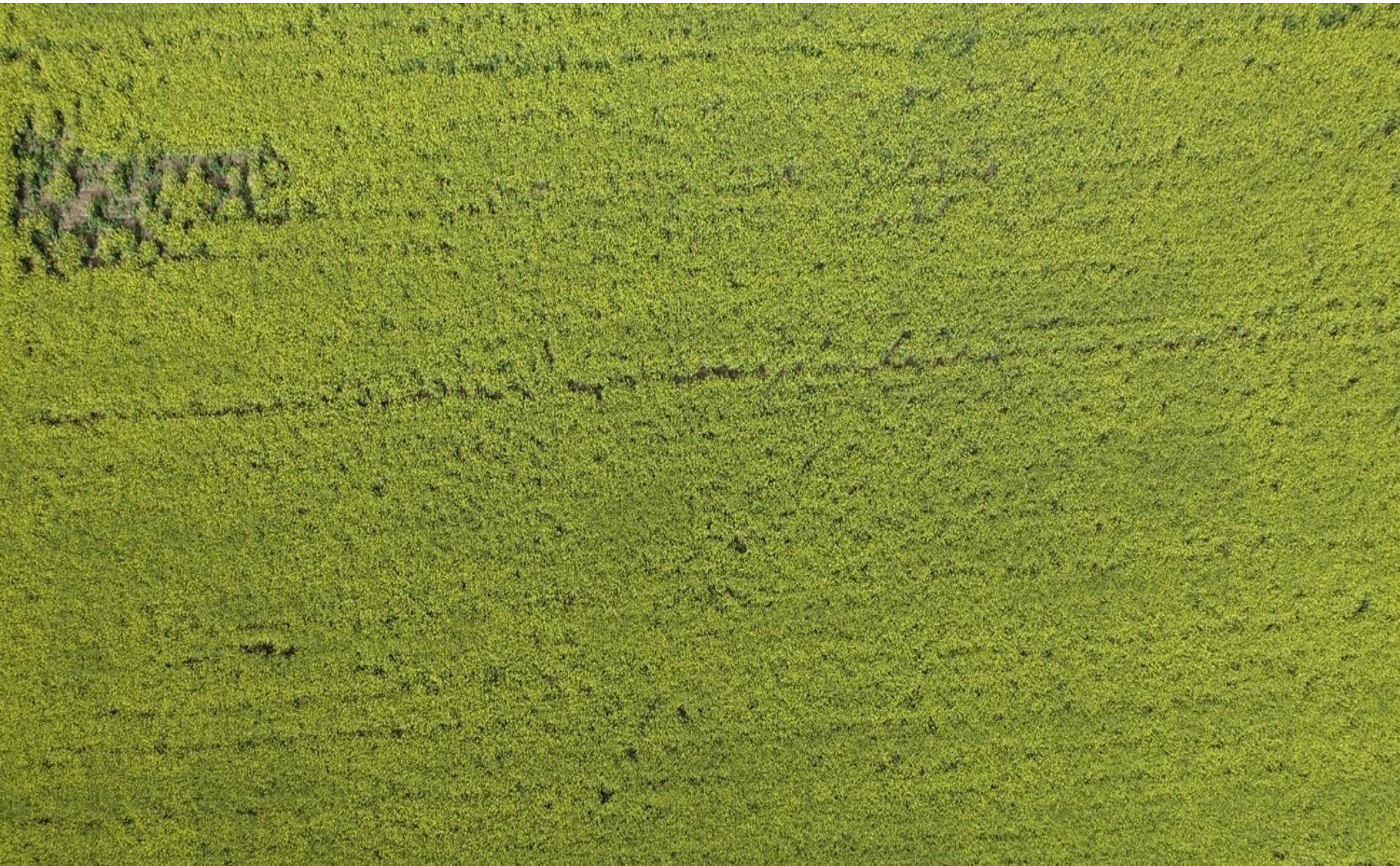
Normalized Difference Vegetation Index (NDVI)



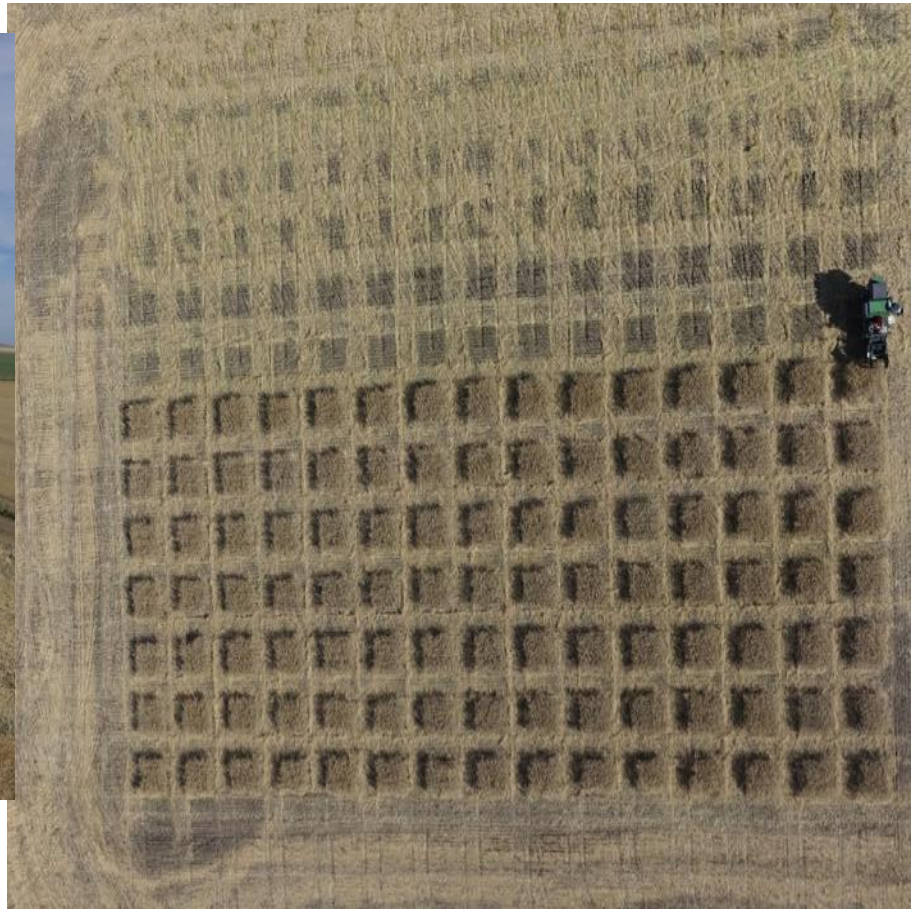
$$NDVI = \frac{(NIR - VIS)}{(NIR + VIS)}$$

Canola imaged at 15m July 16

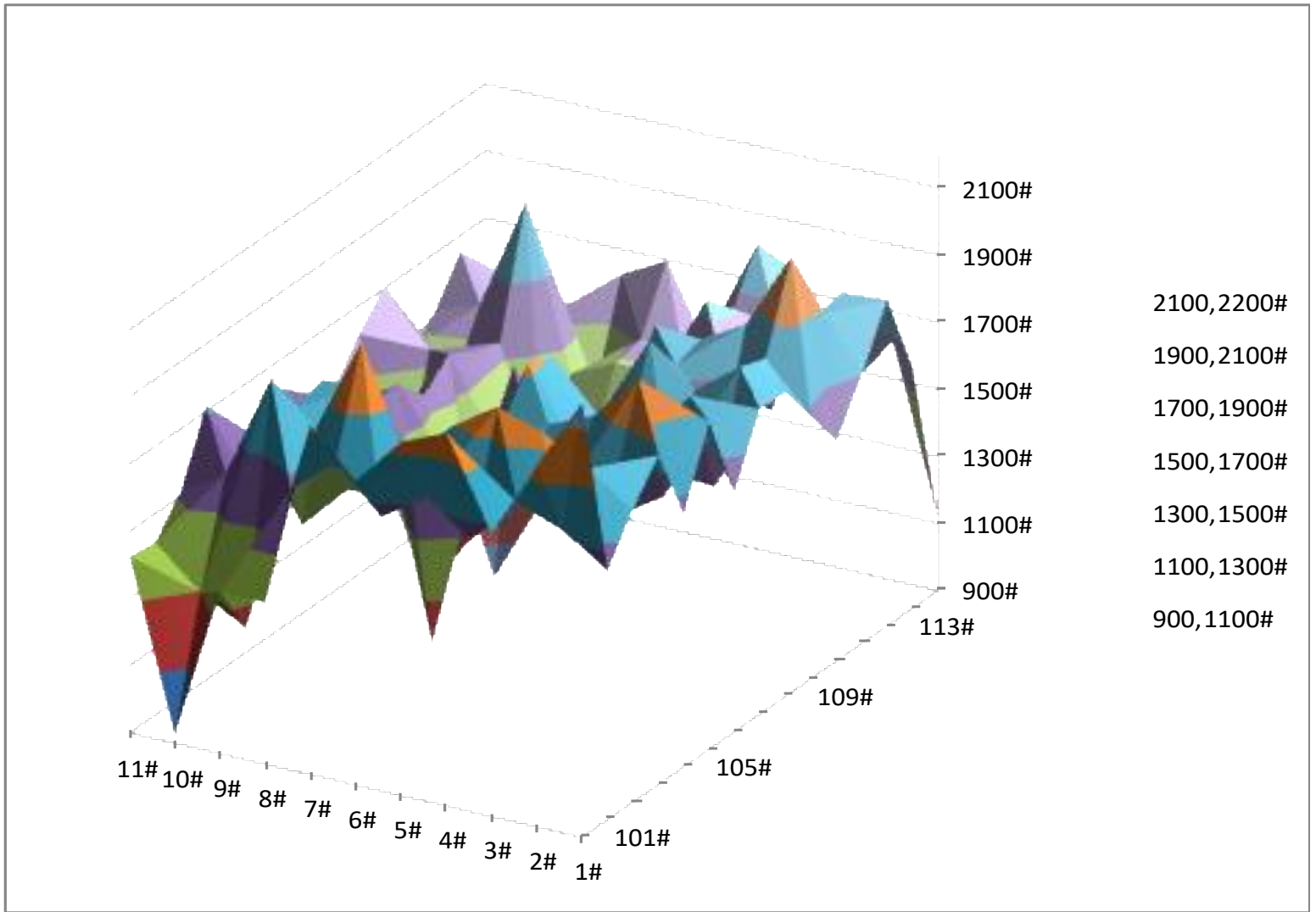
Canola imaged at 60m July 16



Canopy still uneven at flowering



How does spatial variability in stand affect crop yield?



2016

- Recieved funding
- Obtained SFOC
- Training additional people
- Aerial imaging team

Transport Canada Transports Canada
344 Edmonton Street
Winnipeg, MB
R3C 0P6

April 5, 2016

File Number: 5812-11-533
ATS: 15-16-00069131
RDIMS: 11799349

Steven James Shirtliffe
Professor/Head of Research Group
Department of Plant Science, University of Saskatchewan
51 Campus Drive
Saskatoon, SK S7N 5A8

Dear Mr. Shirtliffe:

Please find attached the requested Special Flight Operations Certificate **Restricted Operator – Complex** for operations in Class G and Class E airspace in accordance with your Special Flight Operations Certificate application dated March 2, 2016 and supplementary documents April 3, 2016.

Nothing in this Special Flight Operations Certificate **Restricted Operator – Complex** relieves you, the UAV Certificate Holder, from complying with the provisions of any of any other relevant Acts, Regulations or laws or from any level of government.

Should you have any questions or concerns please do not hesitate to communicate them via PNRSpecialFlightOps@tc.gc.ca .

Yours truly,

Paul Mcculloch
Technical Team Lead Flight Operations
Civil Aviation Winnipeg
Prairie and Northern Region
For Minister of Transport

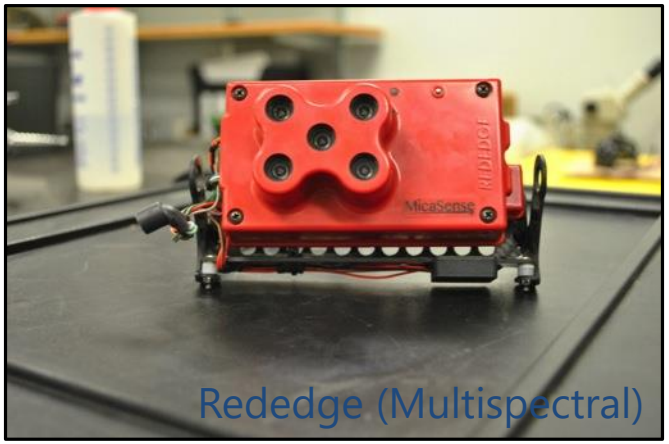
Image Acquisition Infrastructure

DRAGANFLY X4 - P

DRAGANFLY COMMANDER

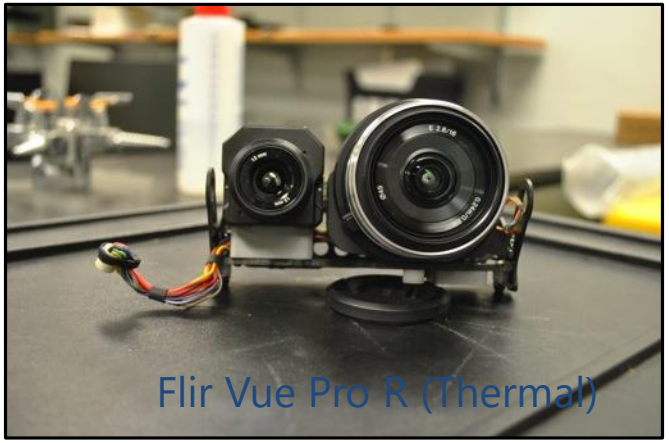
Image sensors (cameras)

Sony RX100 iii (RGB)



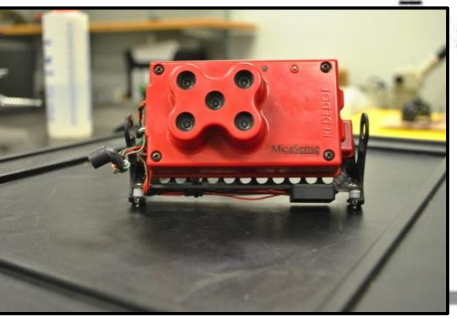
Rededge (Multispectral)

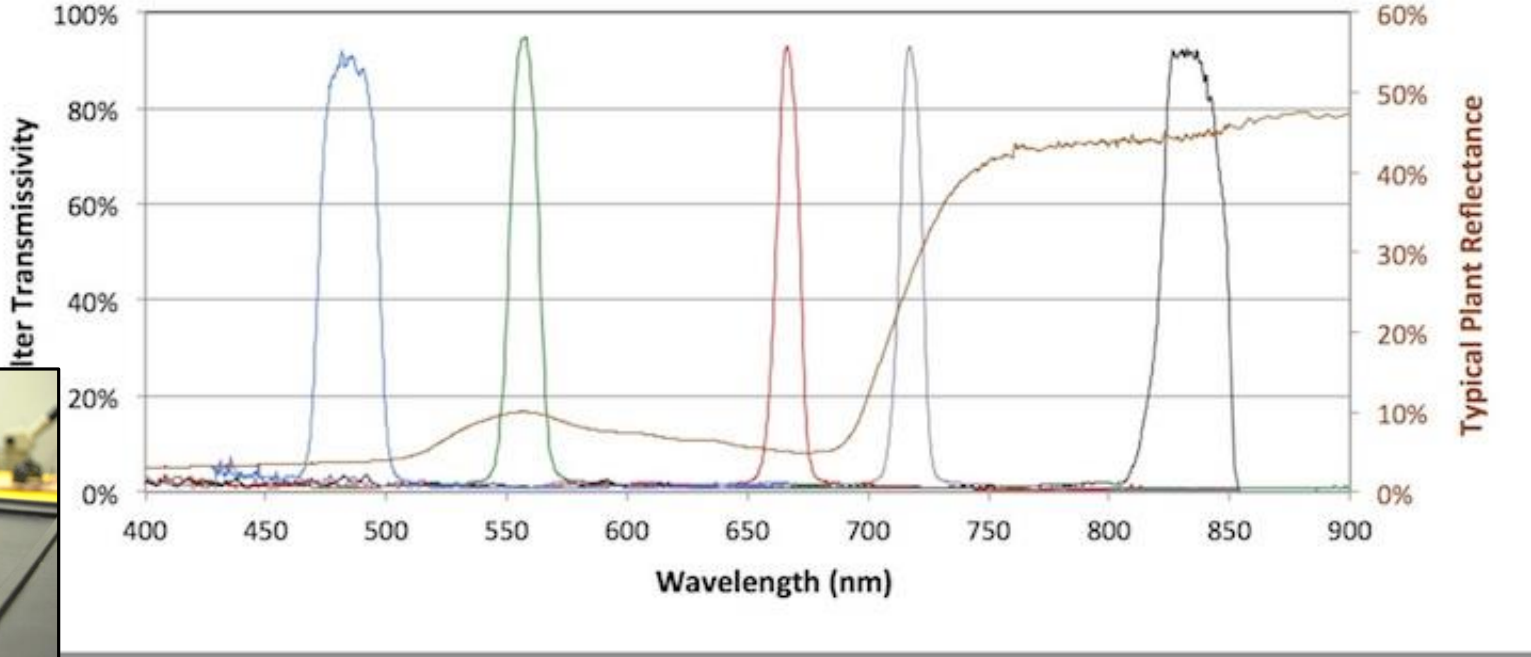
Sony 5100 (Modified GBNIR)



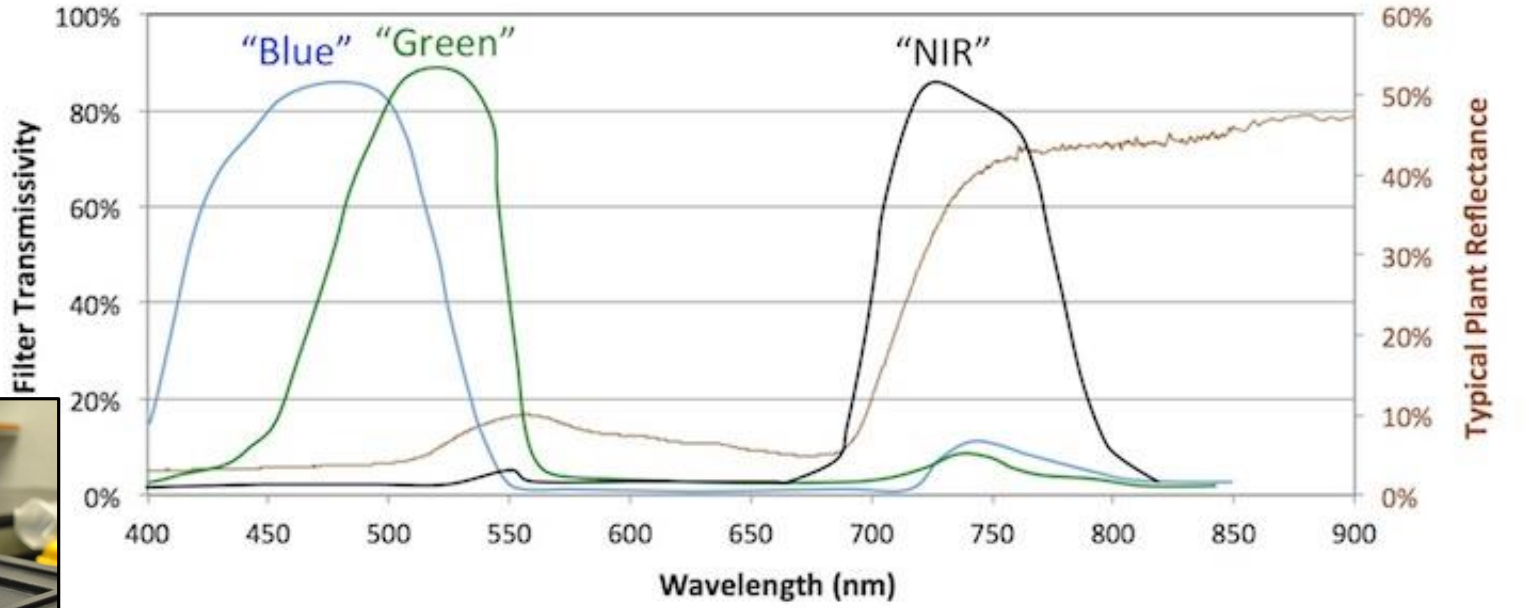
Flir Vue Pro R (Thermal)

True Multispectral Camera





Single-Imager Converted Camera



https://www.micasense.com/faq/

Software

- Flight Planning
  - Draganfly SURVEYOR
- Image Stitching and processing
  - Pix4D
  - Agisoft
- Geographic Information Systems
  - ArcGIS
  - QGIS
- Image analysis
  - ImageJ
  - Photoshop
  - ENVI
  - Custom (Computer Science)
- Programing/Statistical
  - Python
  - R
  - SAS

Image Acquisition - Planning and Flying

- Experimental plan (Drone GPS and Surveyor)
- Ground Control points
- Calibration targets

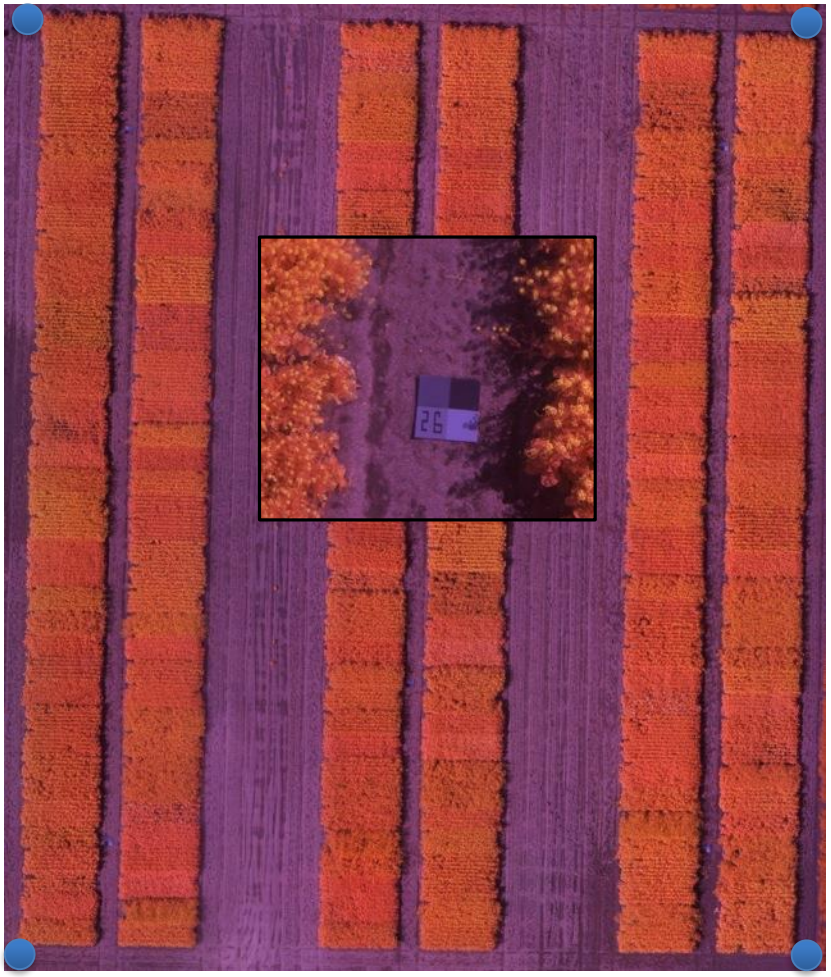
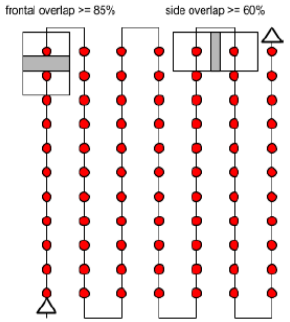


Image Processing

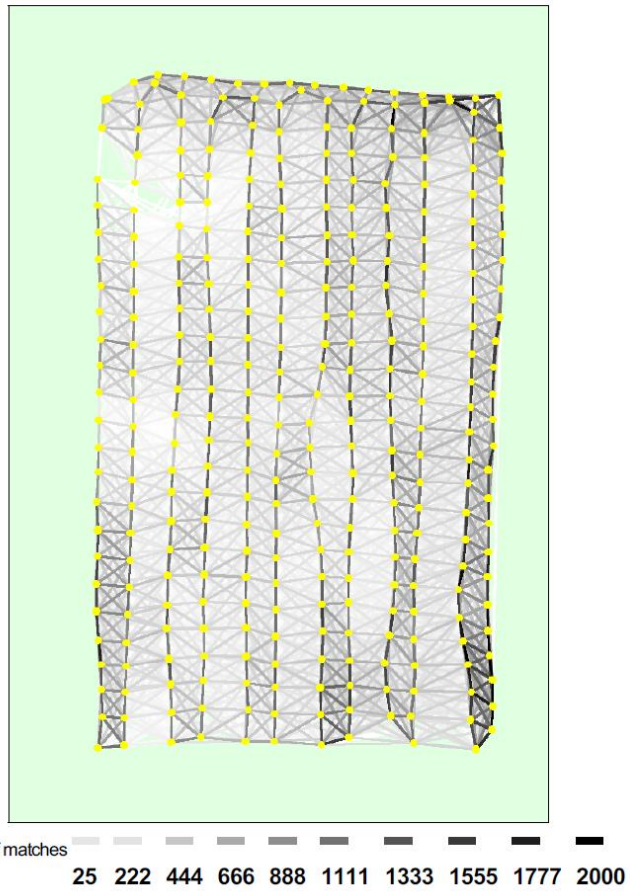
Image Acquisition - Planning and Flying

Ideal flight plan

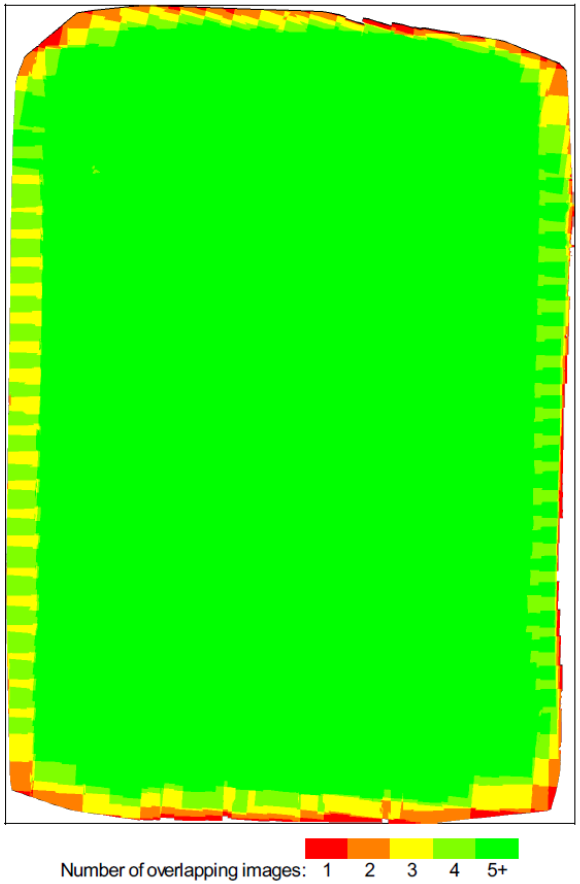
- regular grid flight plan
- easy terrain: 75% frontal, 50% side
- difficult terrain: 85% frontal, 60% side



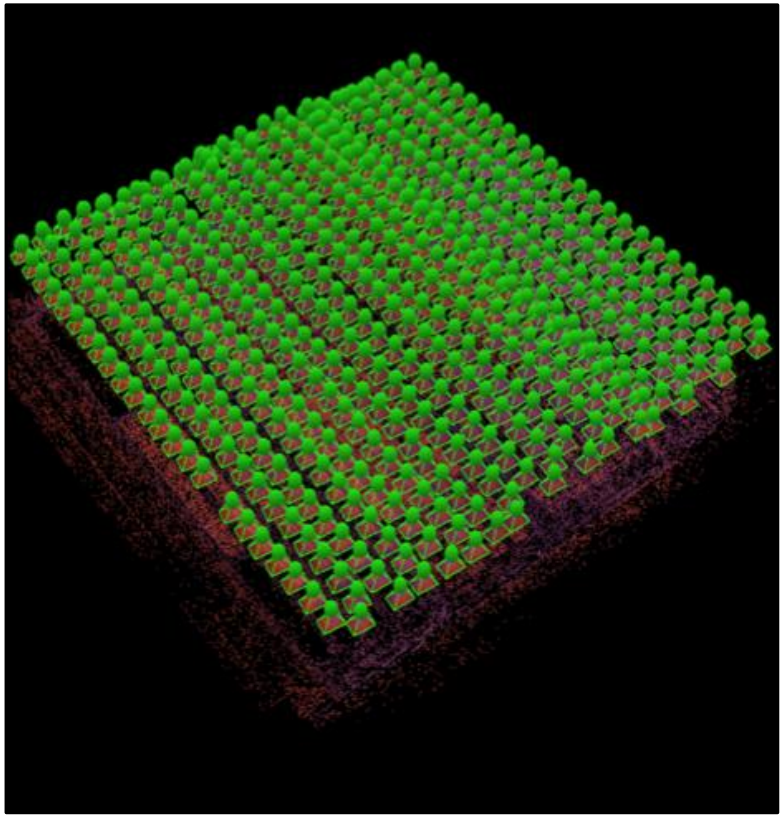
Keypoint matching



Overlapping



Point cloud and mesh



Orthomosaic generation

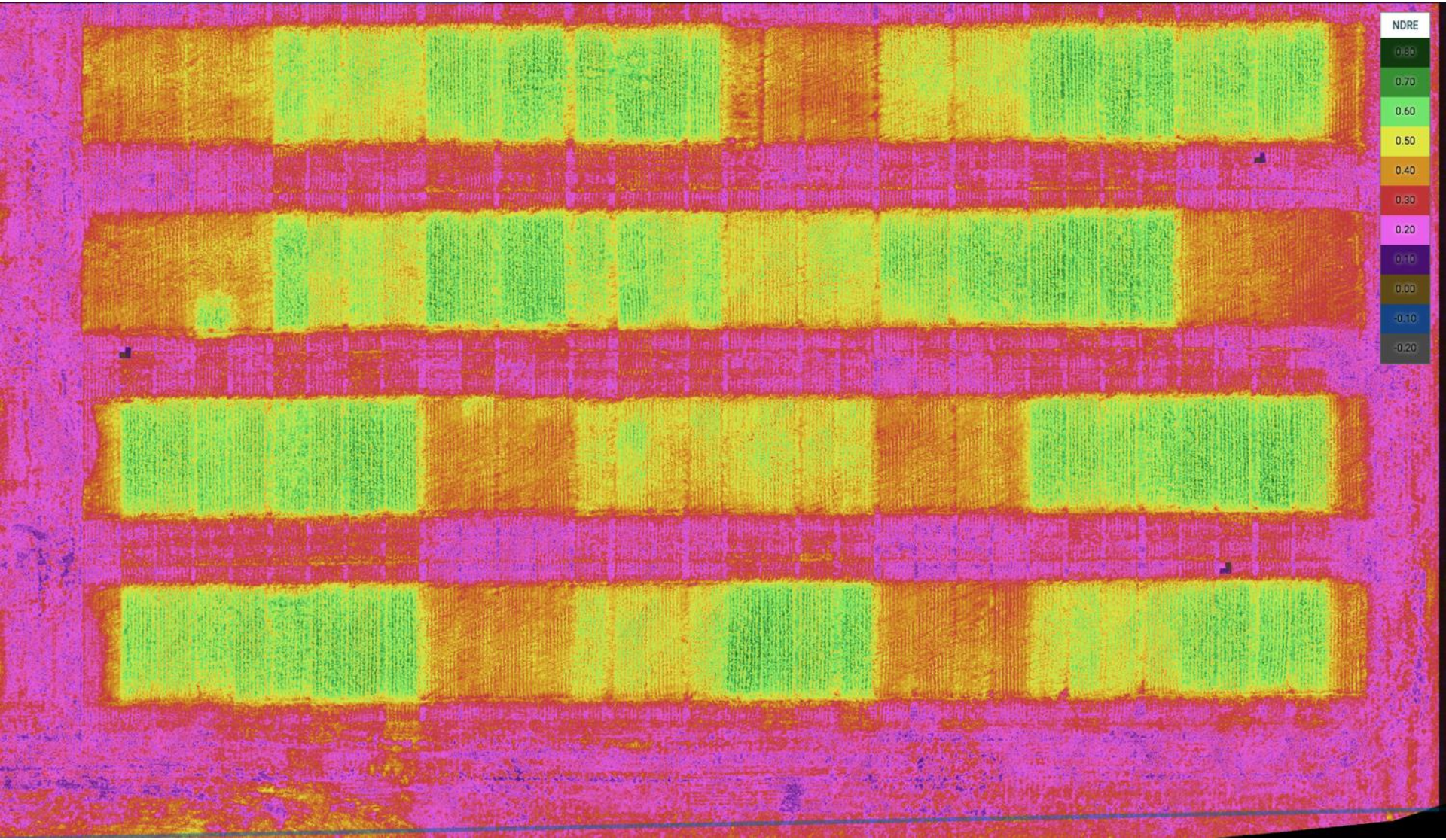
What crop diagnostics can aerial imagery be used for?

- Crop Nutrient deficiency
  - Nitrogen
- Early crop ground cover
  - Emergence, early growth
- Crop damage
  - Frost damage
  - Hail damage
  - Lodging
  - Herbicide

Crop Nutrient Deficiency

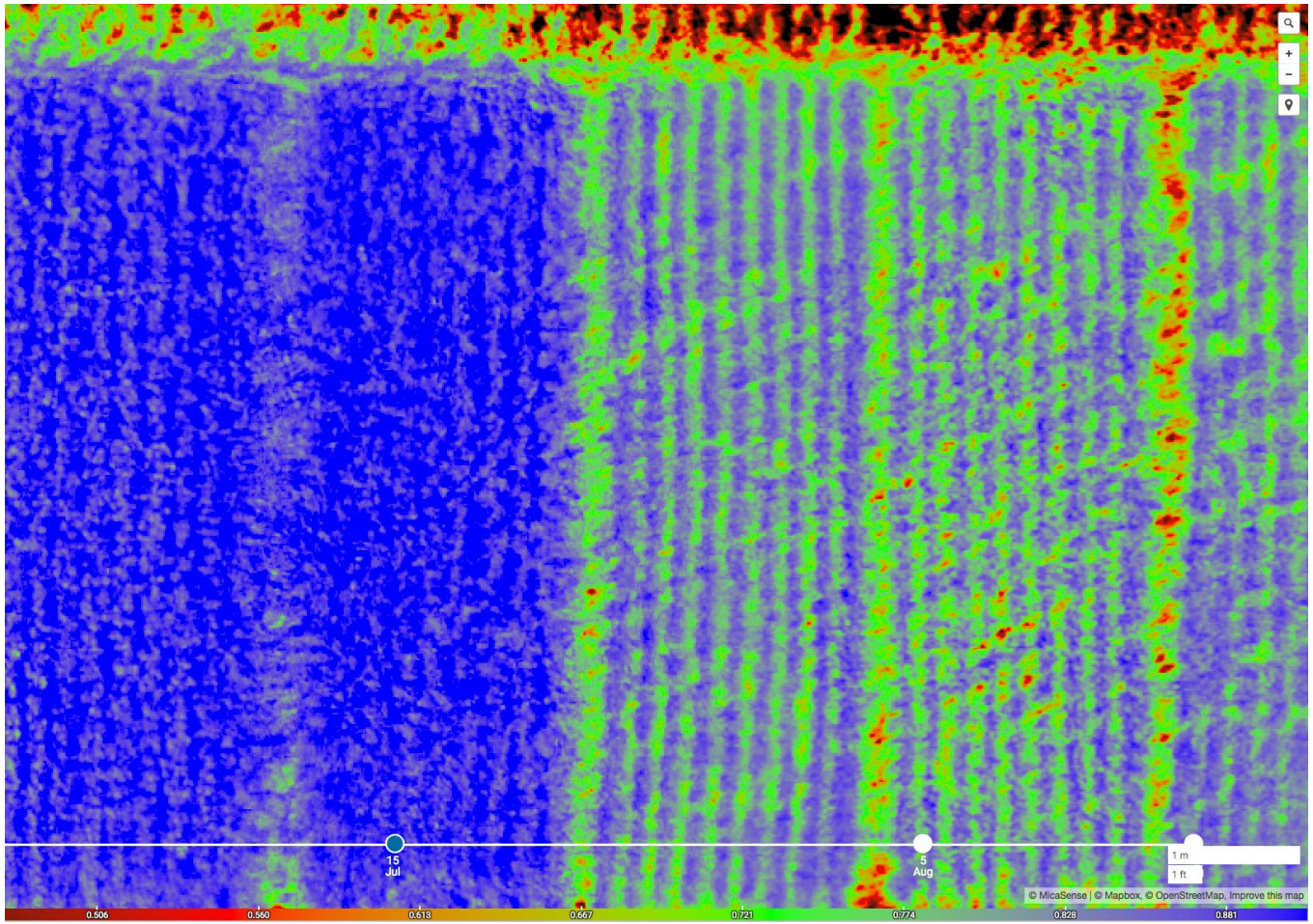
- Nitrogen

Agronomy trial in oat: Nitrogen seeding rate and fungicide

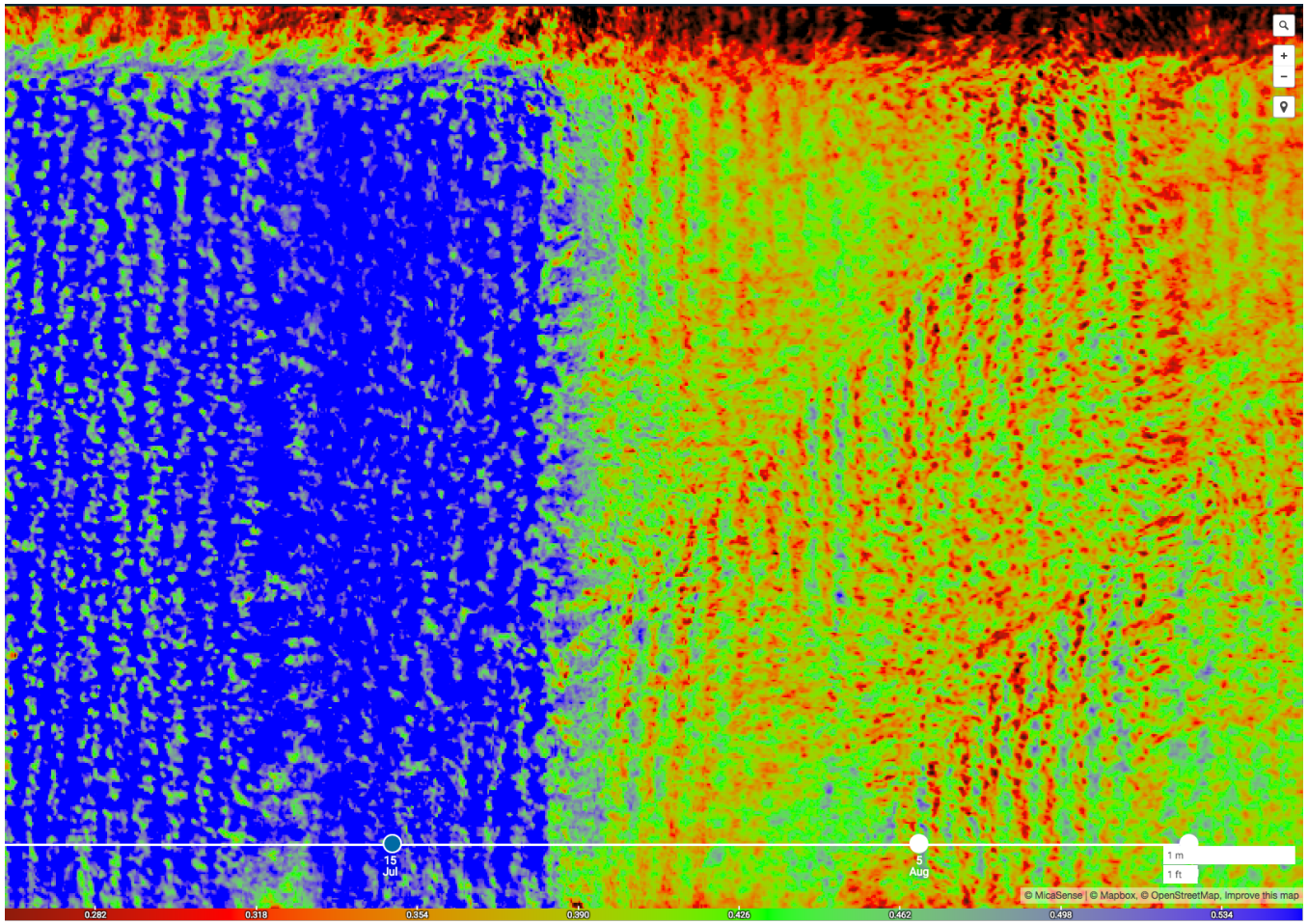


Agronomy trial in oat, Nitrogen seeding rate and fungicide RGB

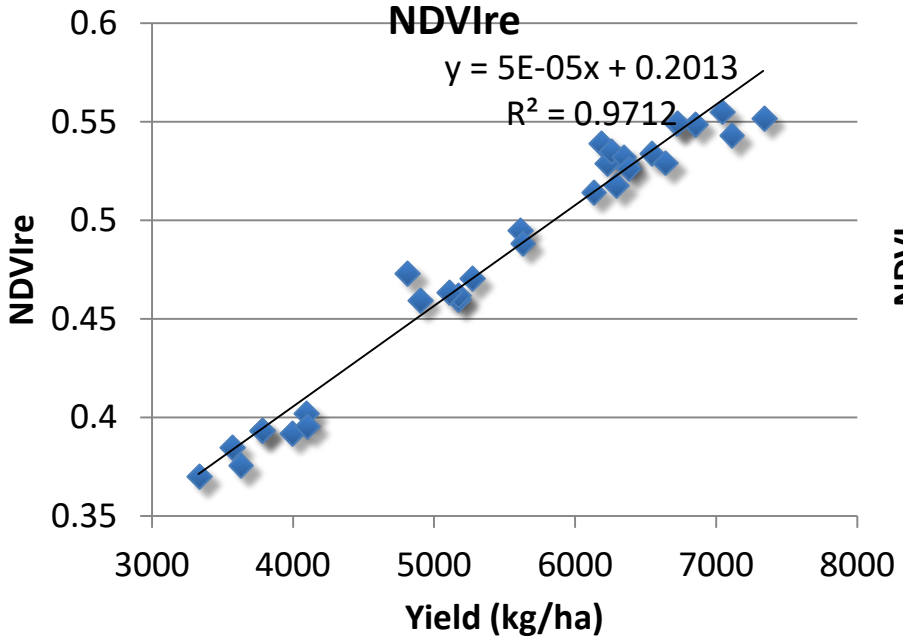
Agronomy trial in oat, Nitrogen seeding rate and fungicide NDVI

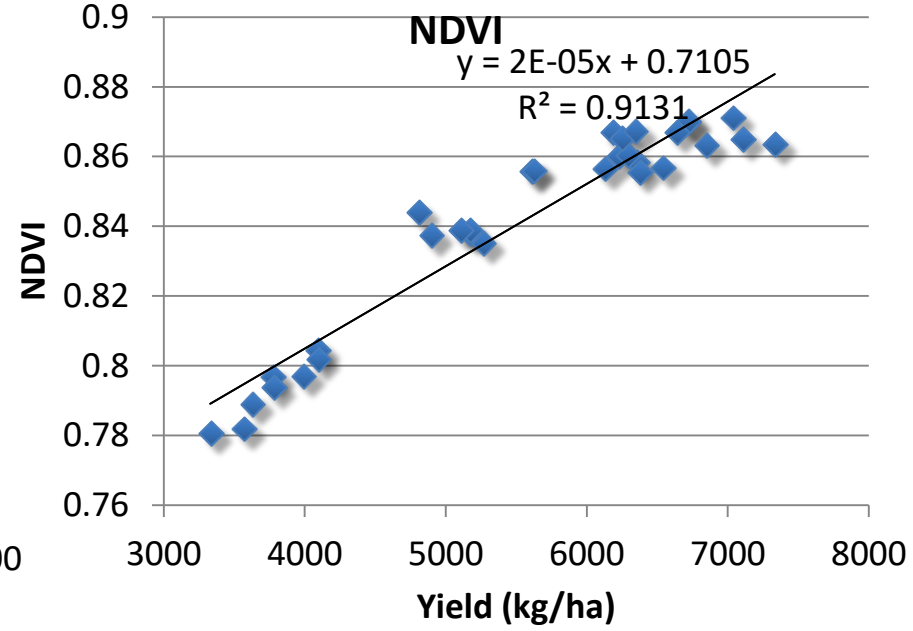


Agronomy trial in oat, Nitrogen seeding rate and fungicide NDRe



Agronomy trial in oat, Nitrogen seeding rate and fungicide RGB

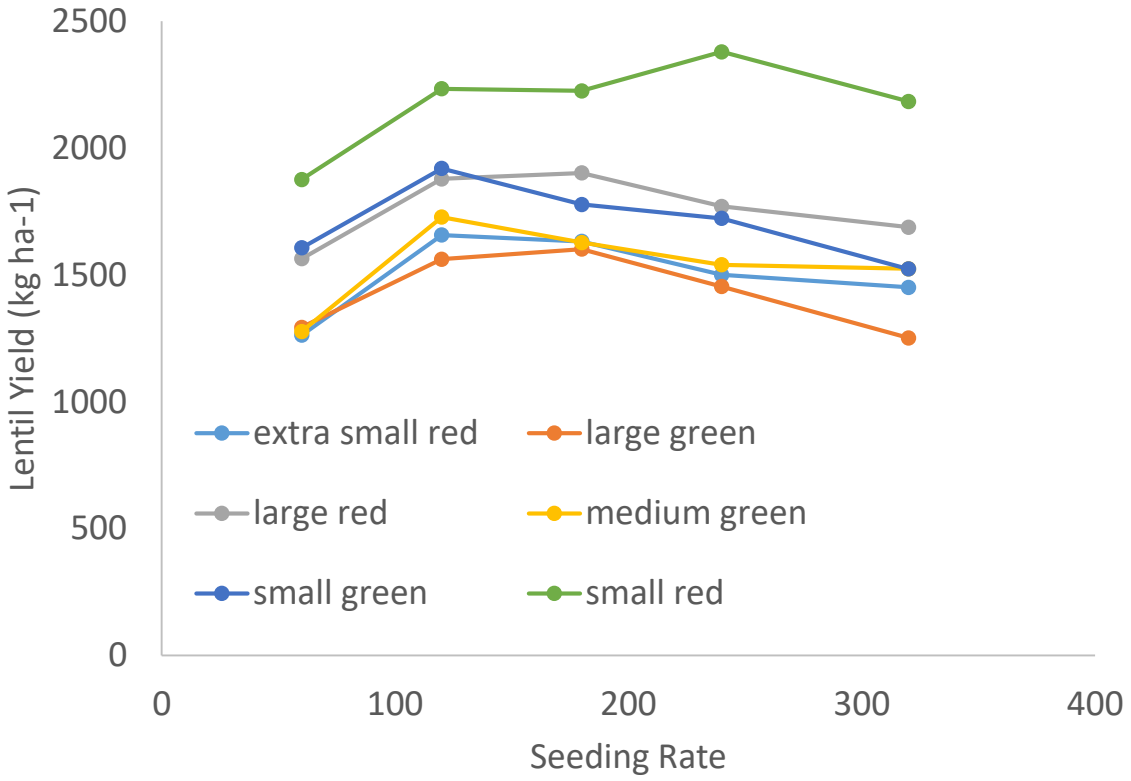

NDVIre
y = 5E-05x + 0.2013
R² = 0.9712
NDVIre
0.6
0.55
0.5
0.45
0.4
0.35
3000
4000
5000
6000
7000
8000
Yield (kg/ha)


NDVI
y = 2E-05x + 0.7105
R² = 0.9131
NDVI
0.9
0.88
0.86
0.84
0.82
0.8
0.78
0.76
3000
4000
5000
6000
7000
8000
Yield (kg/ha)

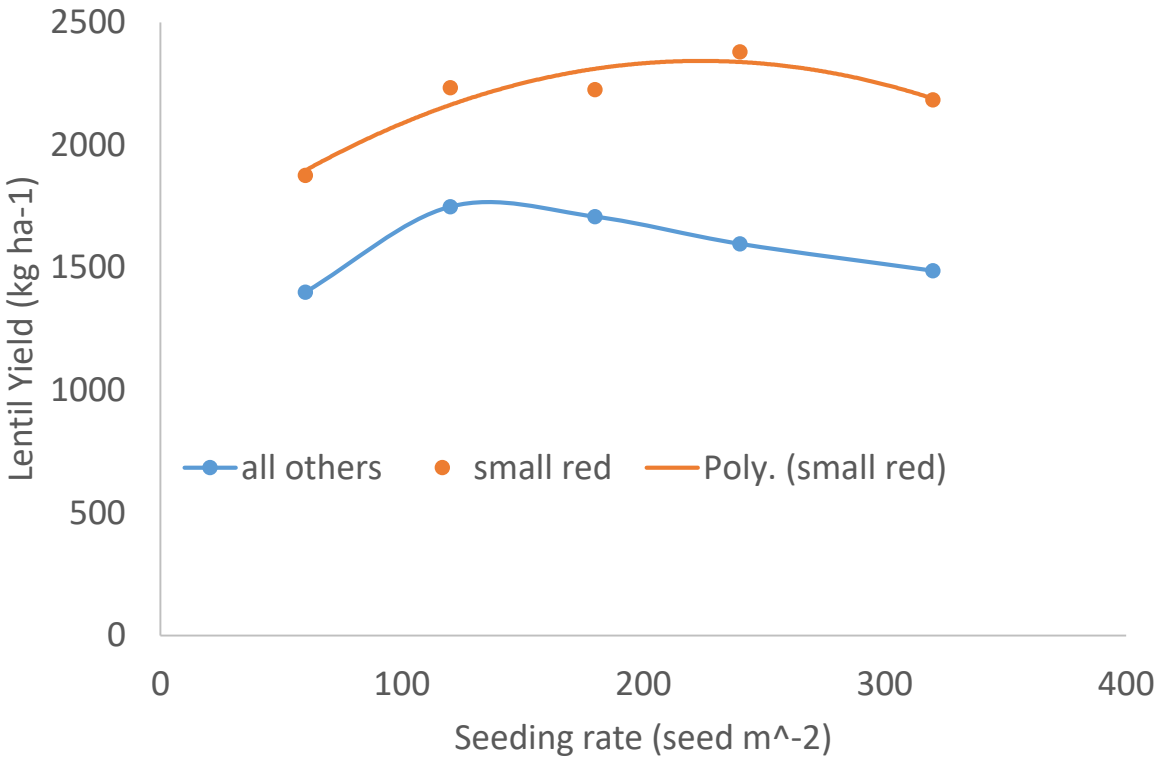
EARLY SEASON GROUND COVER

- Lentil

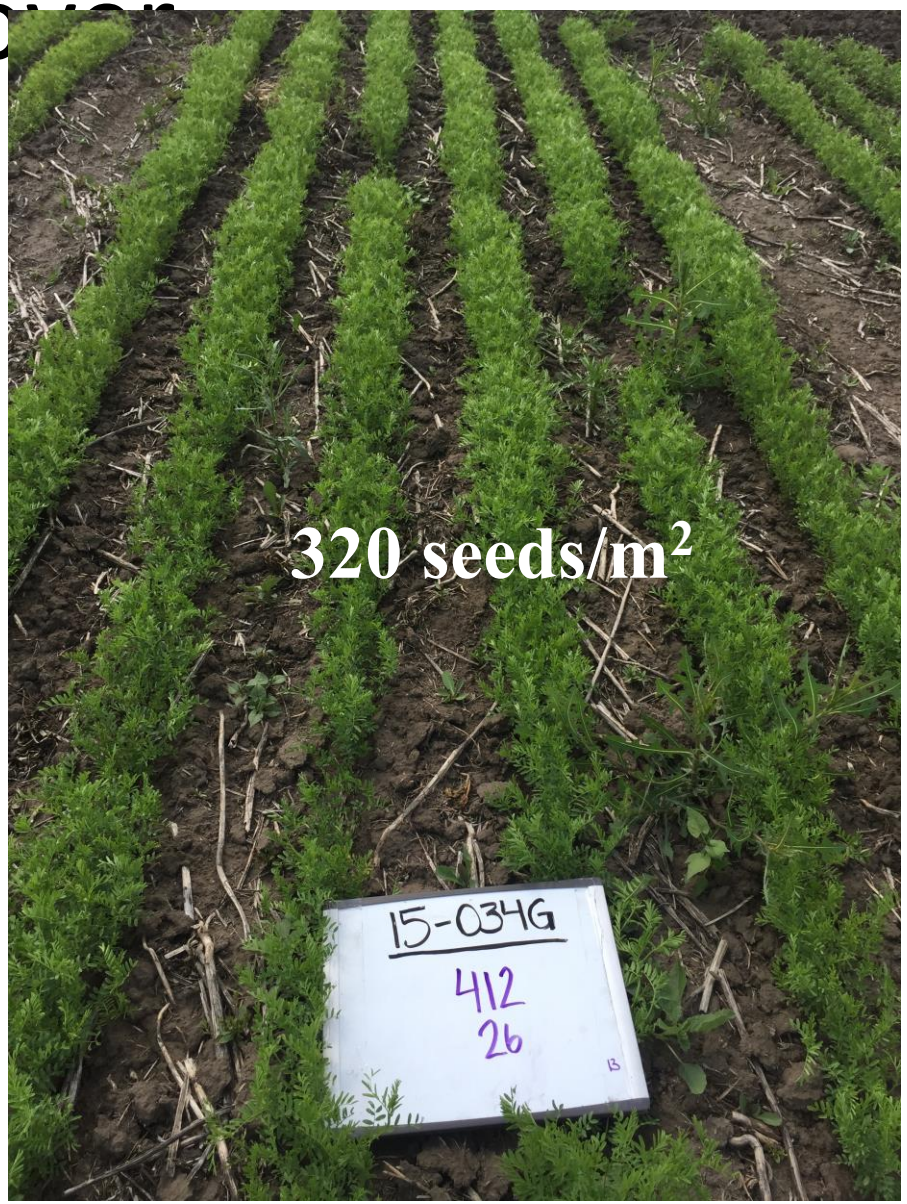
Effect of seeding rate and seed class on lentil yield (Average of 7 site years)



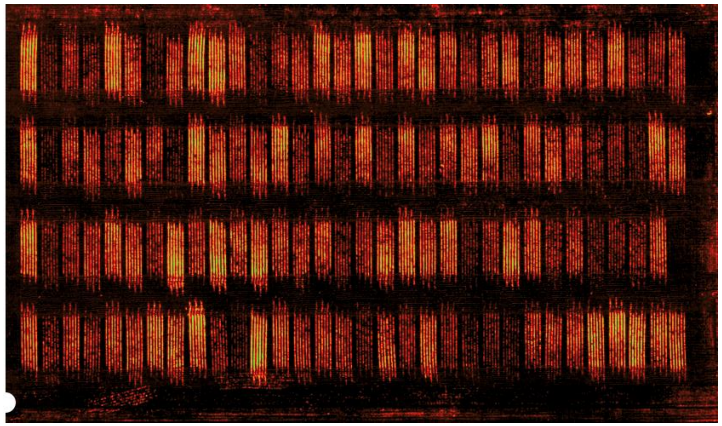
Effect of seeding rate and seed class on lentil yield (Average of 7 site years)

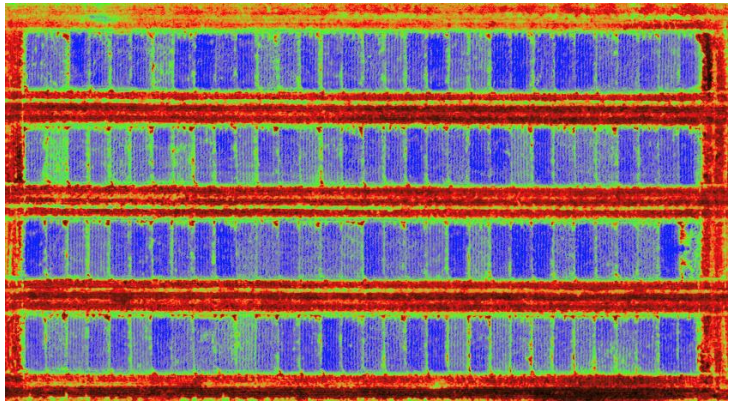


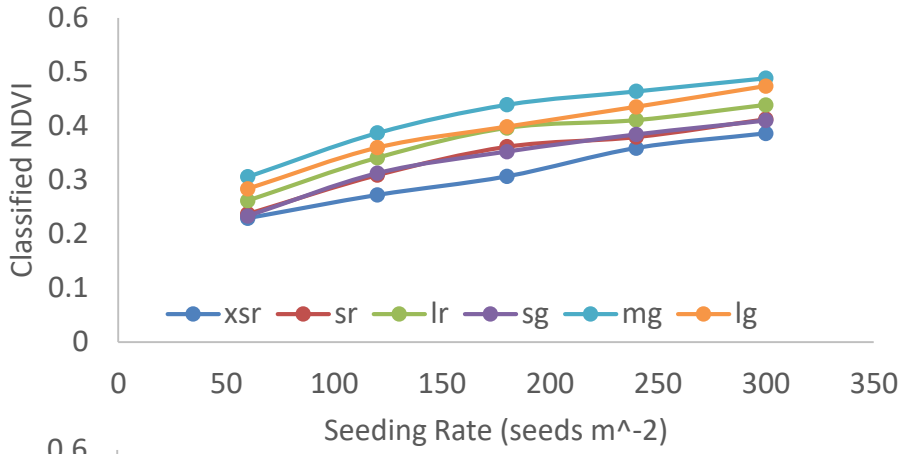
Quantifying differences in ground cover

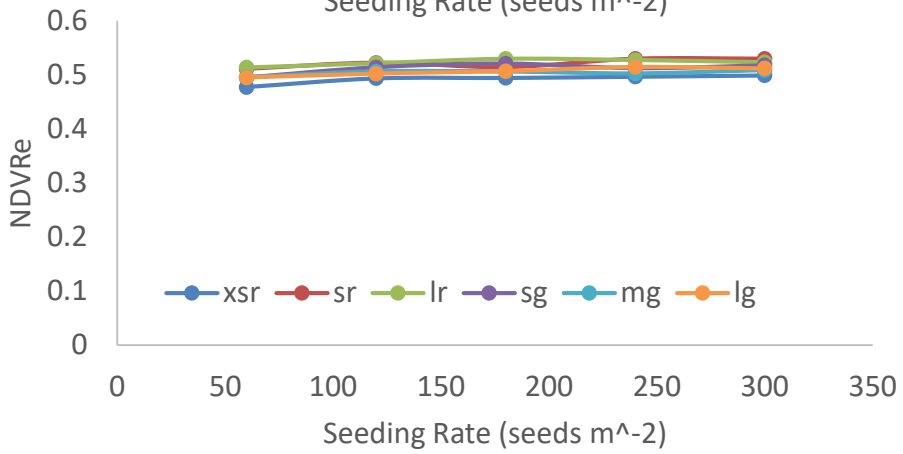


Vegetative Indices June 8 and July 18, 2016

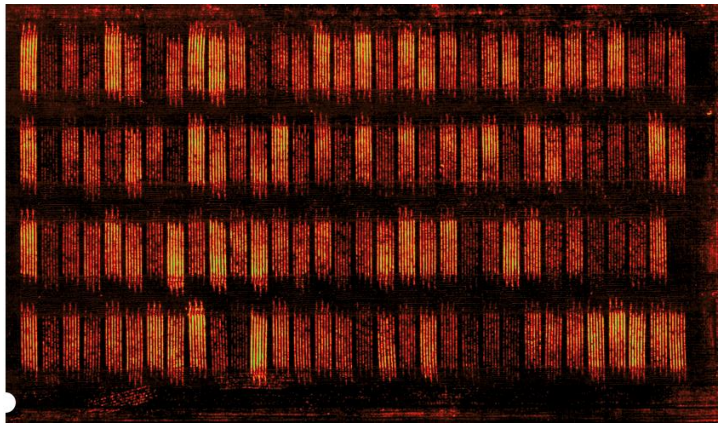


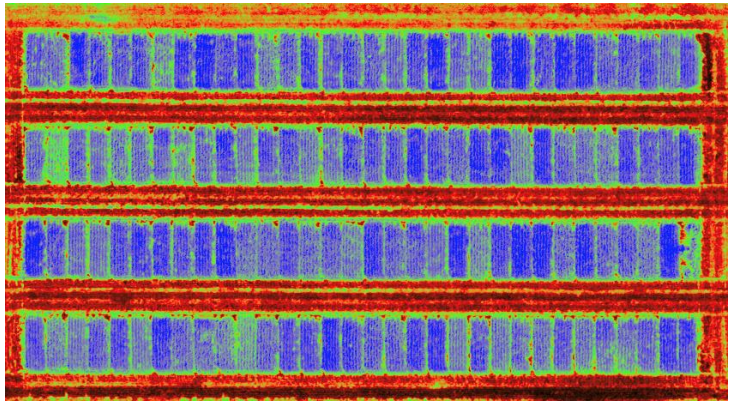


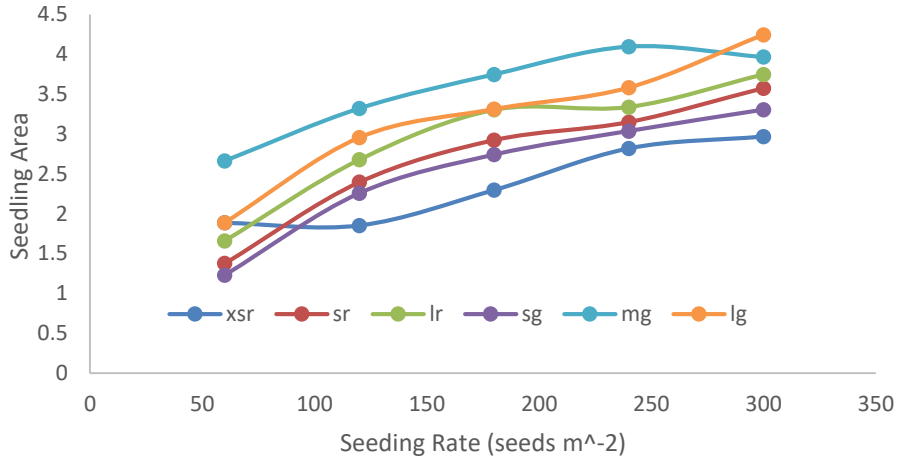


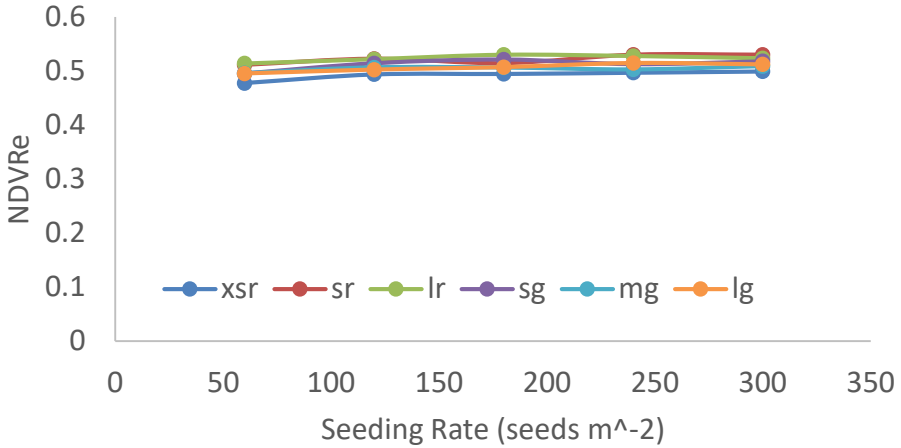


Vegetative Indices June 8 and July 18, 2016





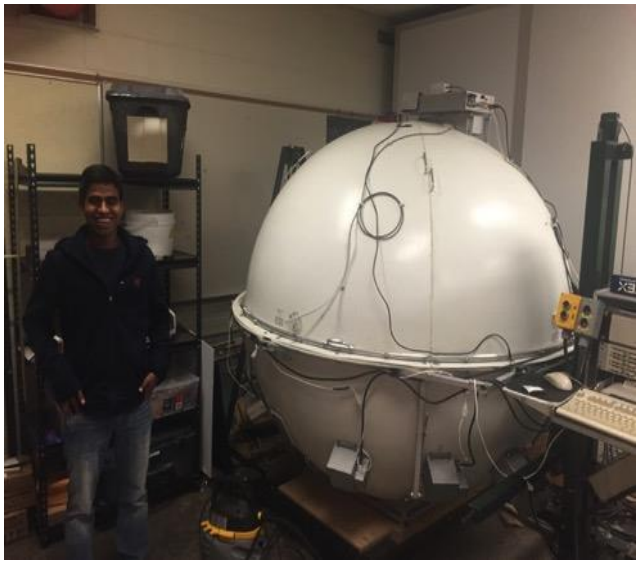




FROST DAMAGE

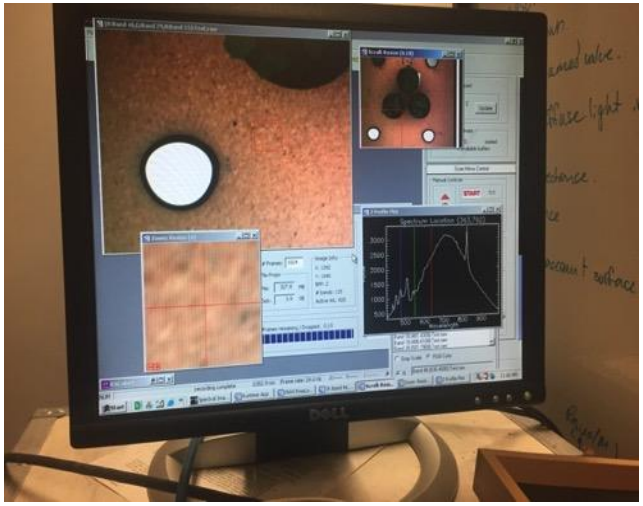
Can frost damage in canola be visualized with multi-spectral images?

May 29, 2015
Canola Frozen in field

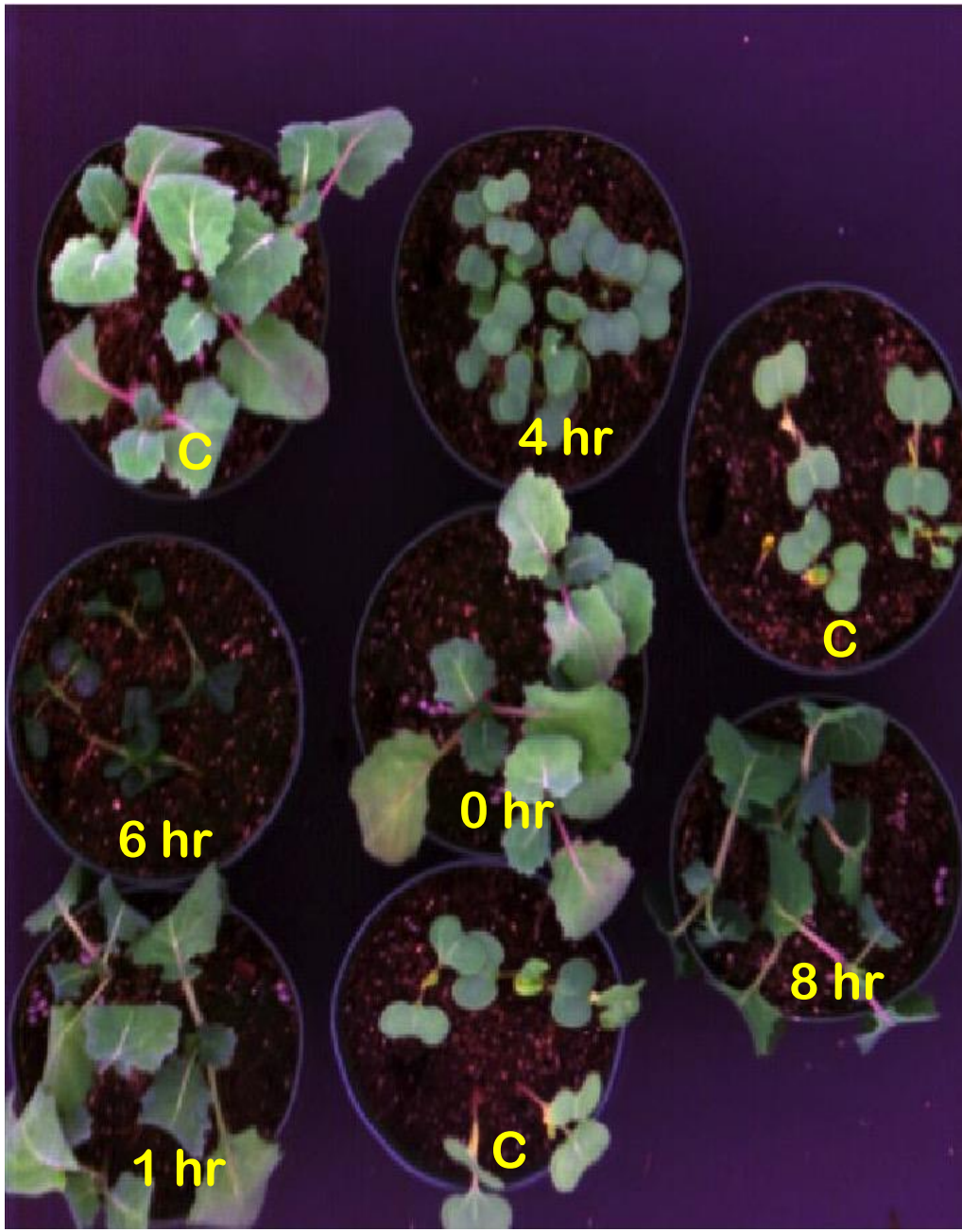



23
2

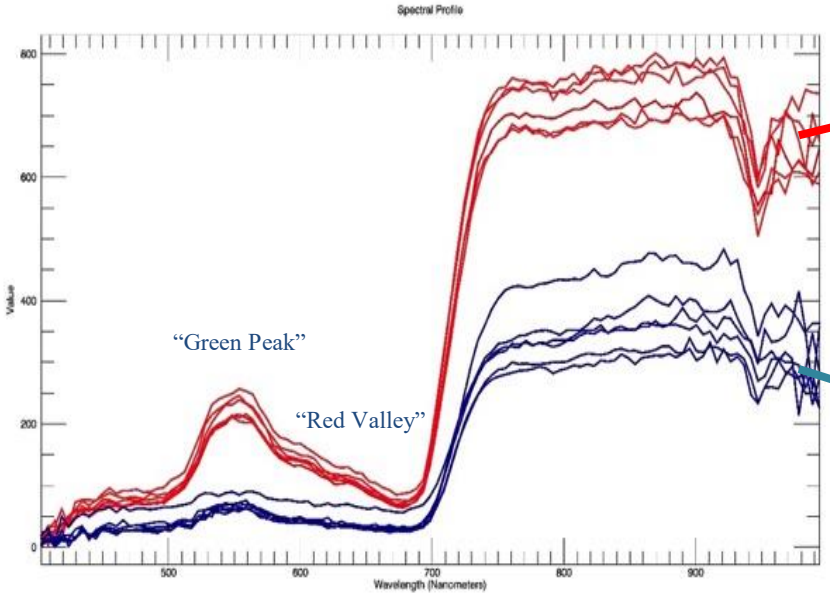

SANYO



Frozen Canola treatments



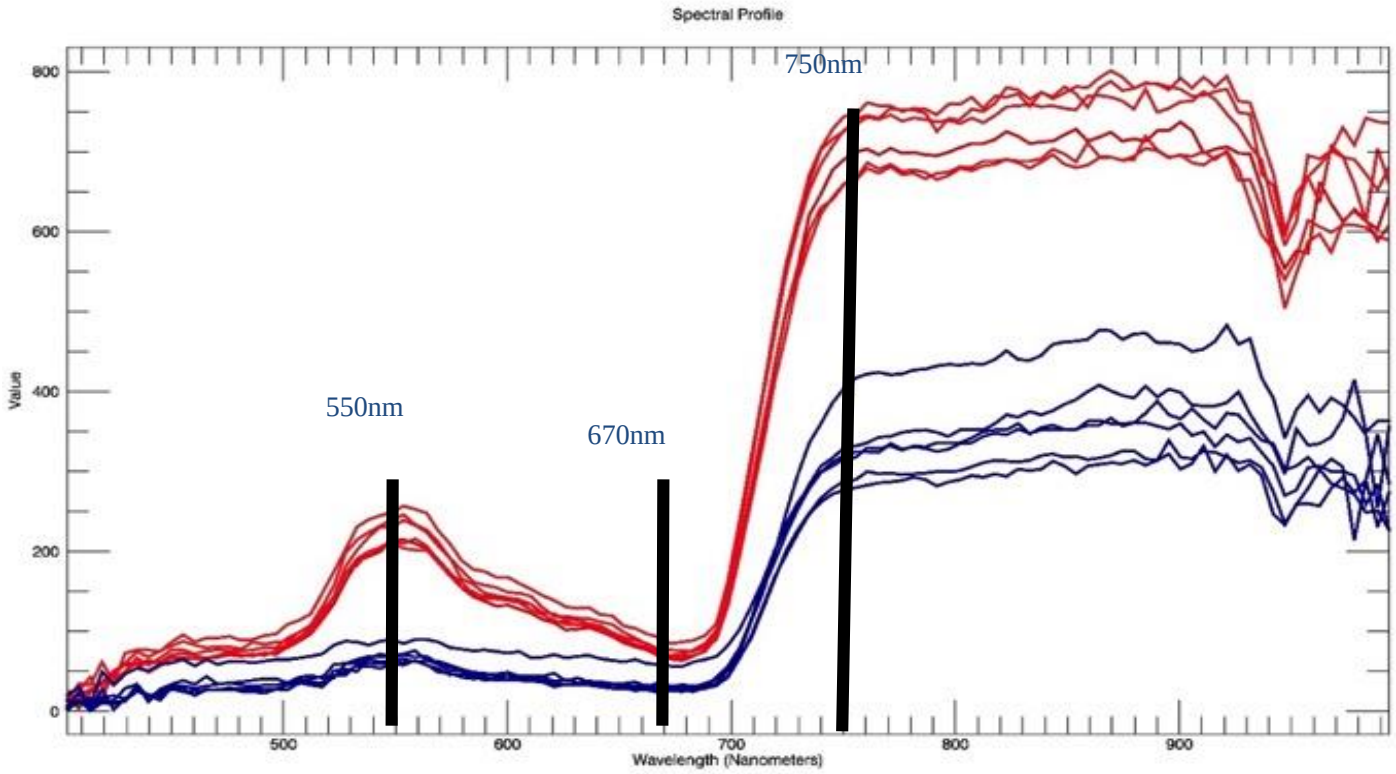
Spectral reflectance of Frozen vs unfrozen canola



"

Triangular Vegetation Index uses 550nm as base for calculation

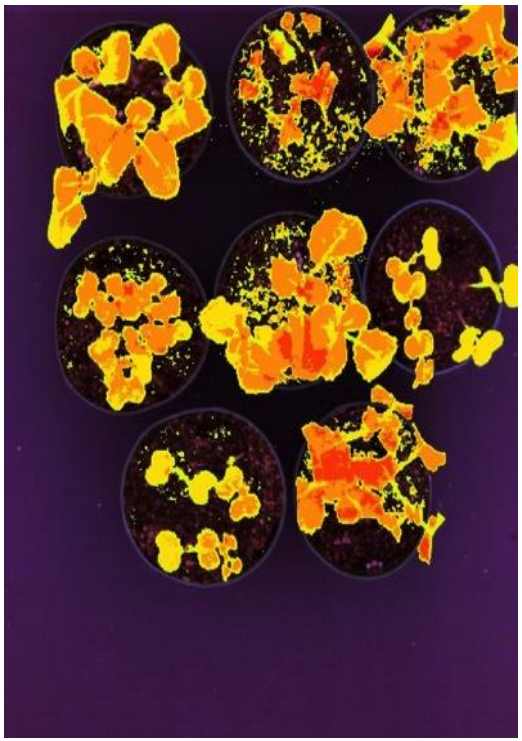
$TVI=0.5*[120*(R_{750}-R_{550})-200*(R_{670}-R_{550})]$



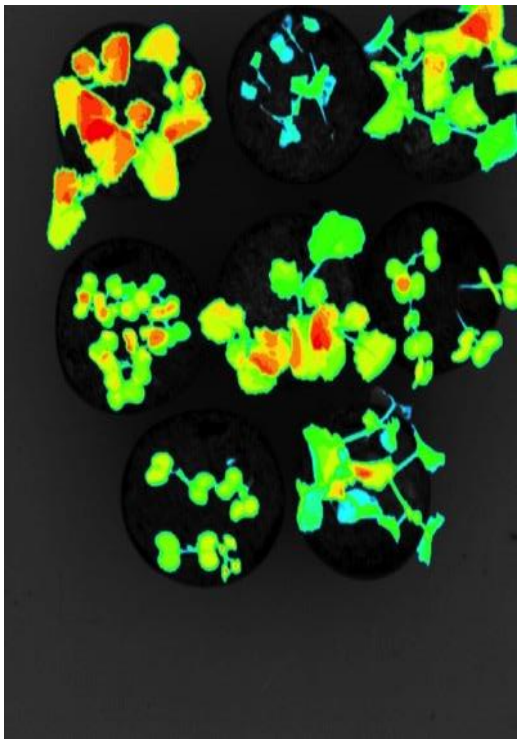
Cropped and more detailed next slide

RBG Image

NDVI Image

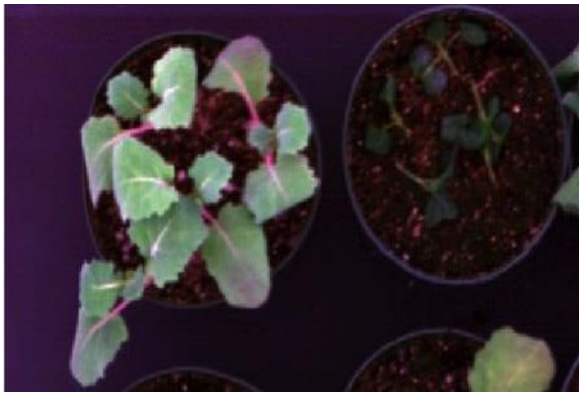


TVI Image

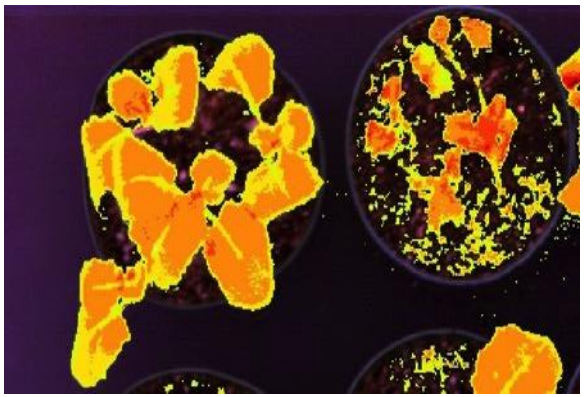


TVI Index differentiates frozen and healthy tissue better than NDVI

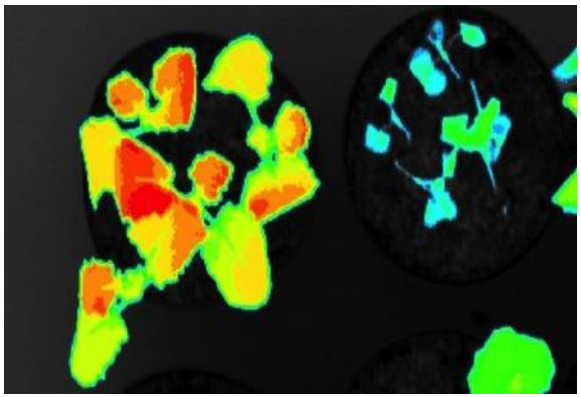
RBG Image



NDVI Image



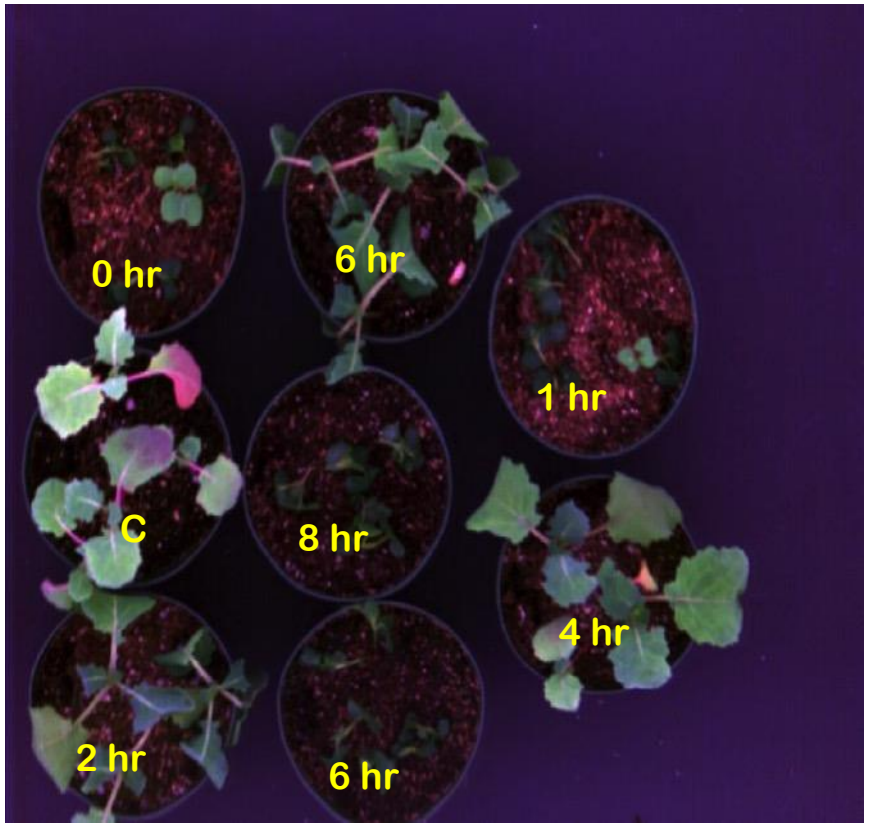
TVI Image

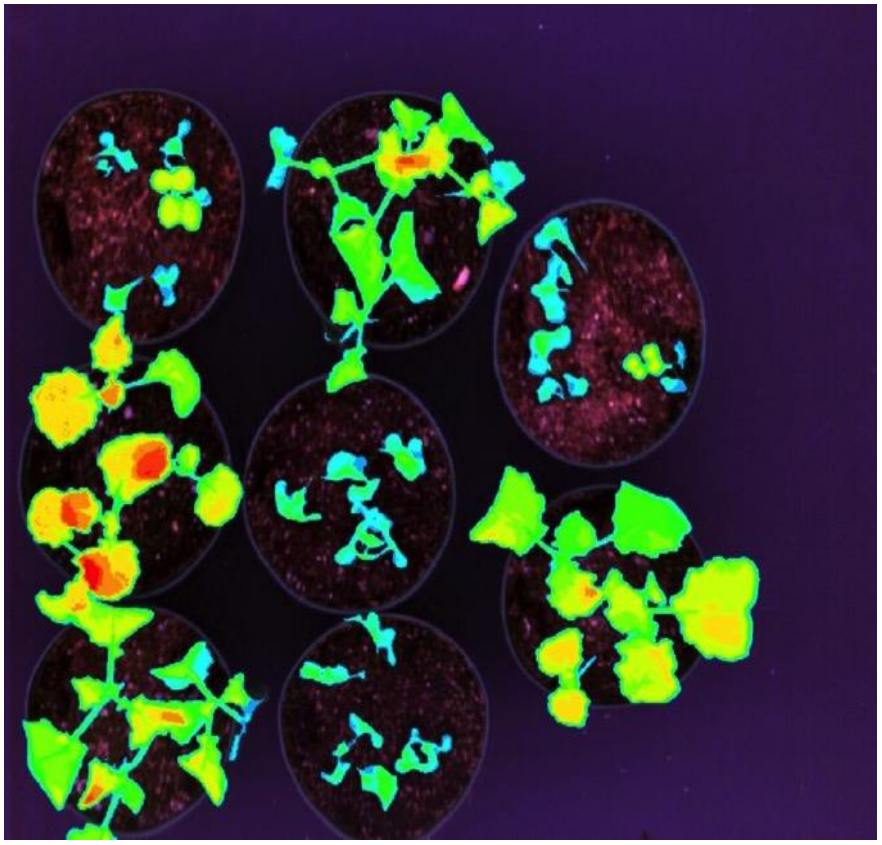


False colour and TVI image of frozen canola image Frozen tissue

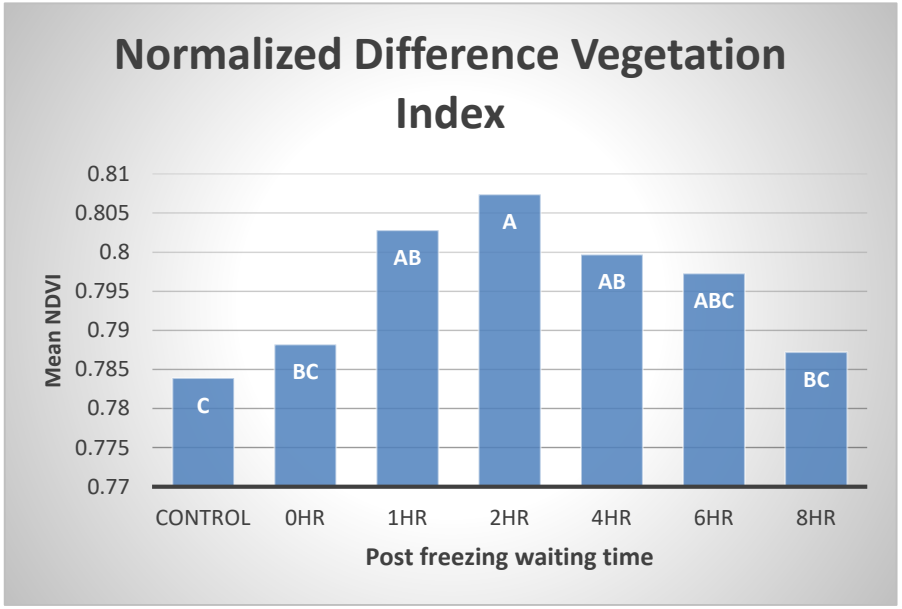
TVI Image

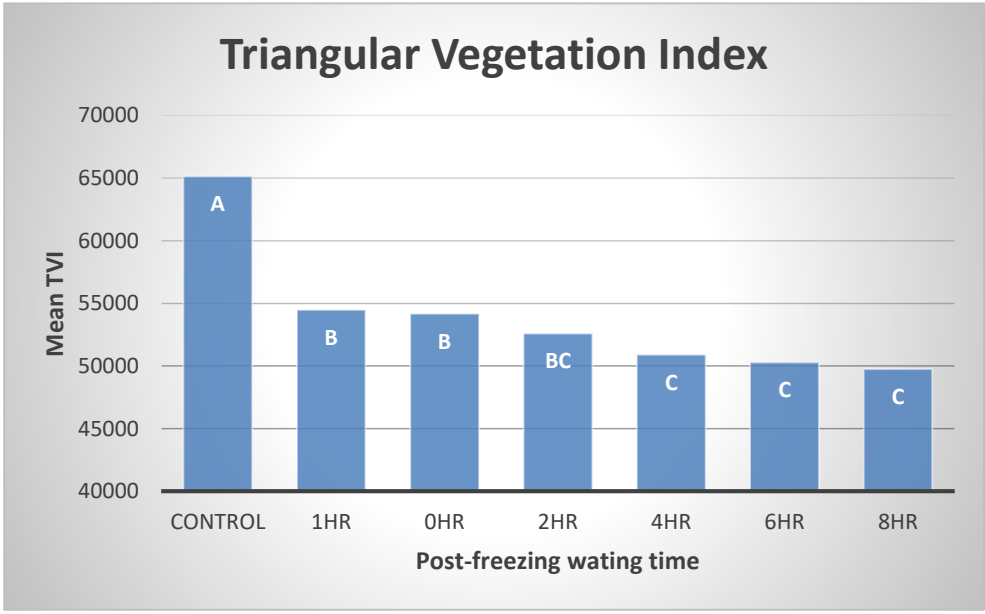
21000
86000





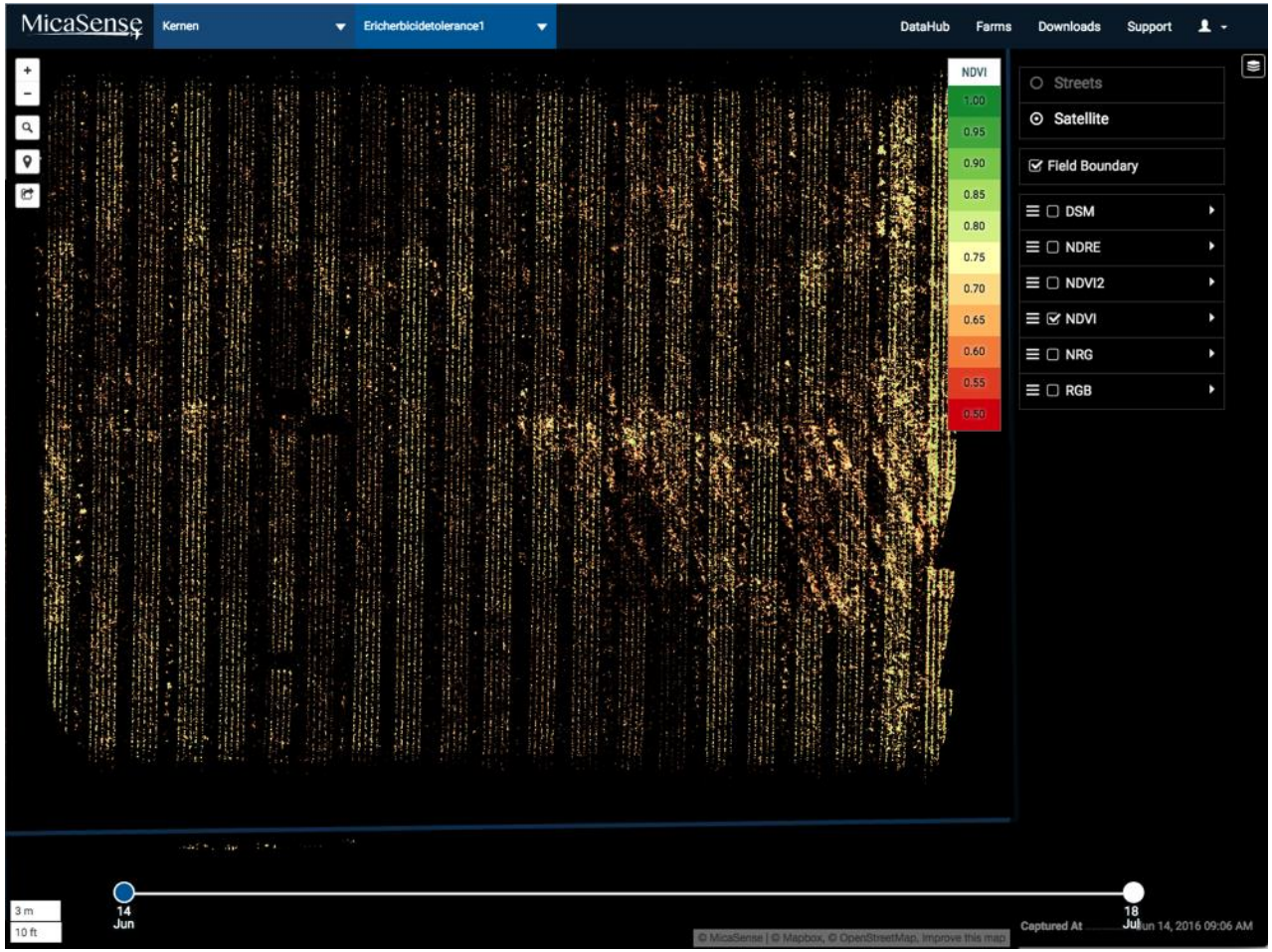
NDVI vs TVI


Normalized Difference Vegetation Index
Mean NDVI
0.81
0.805
0.8
0.795
0.79
0.785
0.78
0.775
0.77
C
BC
AB
A
AB
ABC
BC
CONTROL
0HR
1HR
2HR
4HR
6HR
8HR
Post freezing waiting time

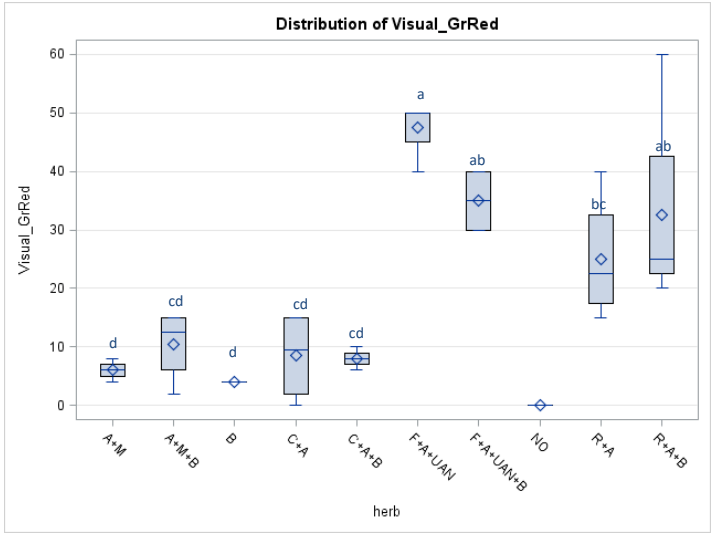

Triangular Vegetation Index
Mean TVI
70000
65000
60000
55000
50000
45000
40000
A
B
B
BC
C
C
C
CONTROL
1HR
0HR
2HR
4HR
6HR
8HR
Post-freezing wating time

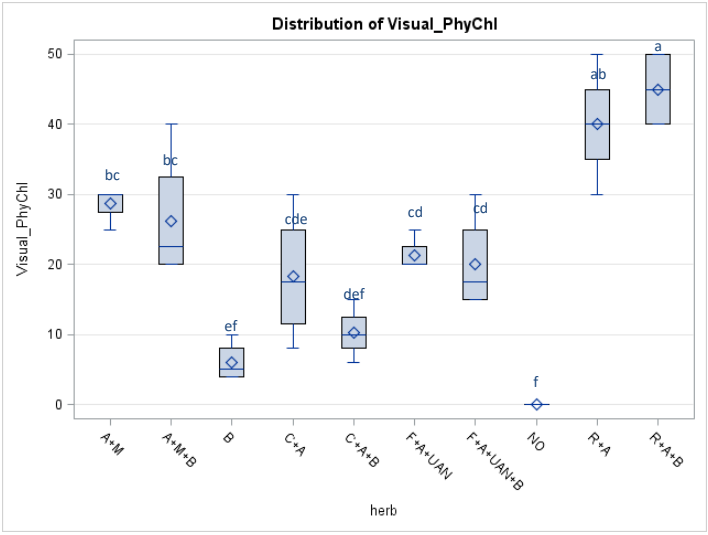
HERBICIDE TOLLERENCE/DAMAGE

Crop herbicide tolerance in fababean

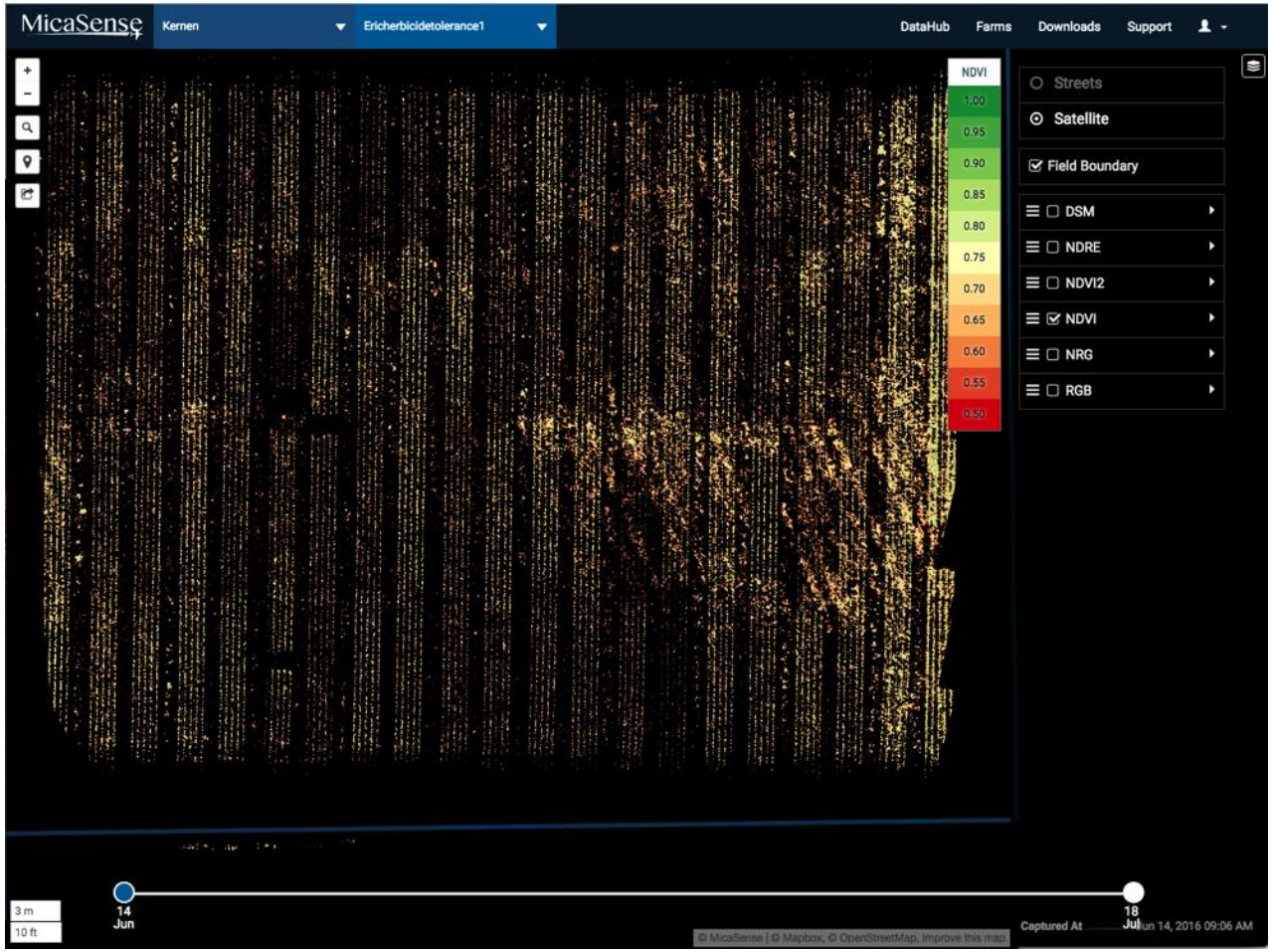


Tolerance of fababean to herbicides

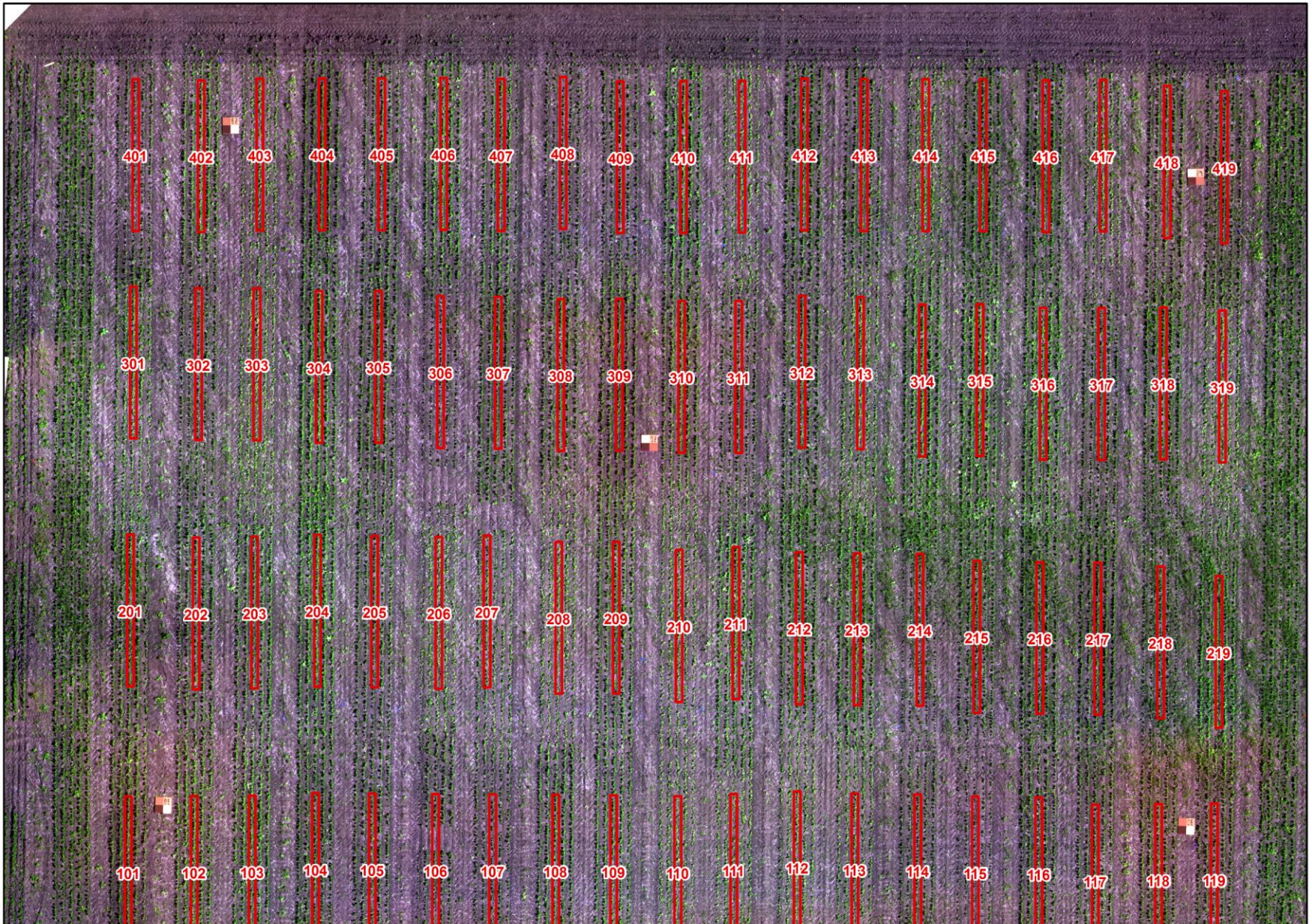




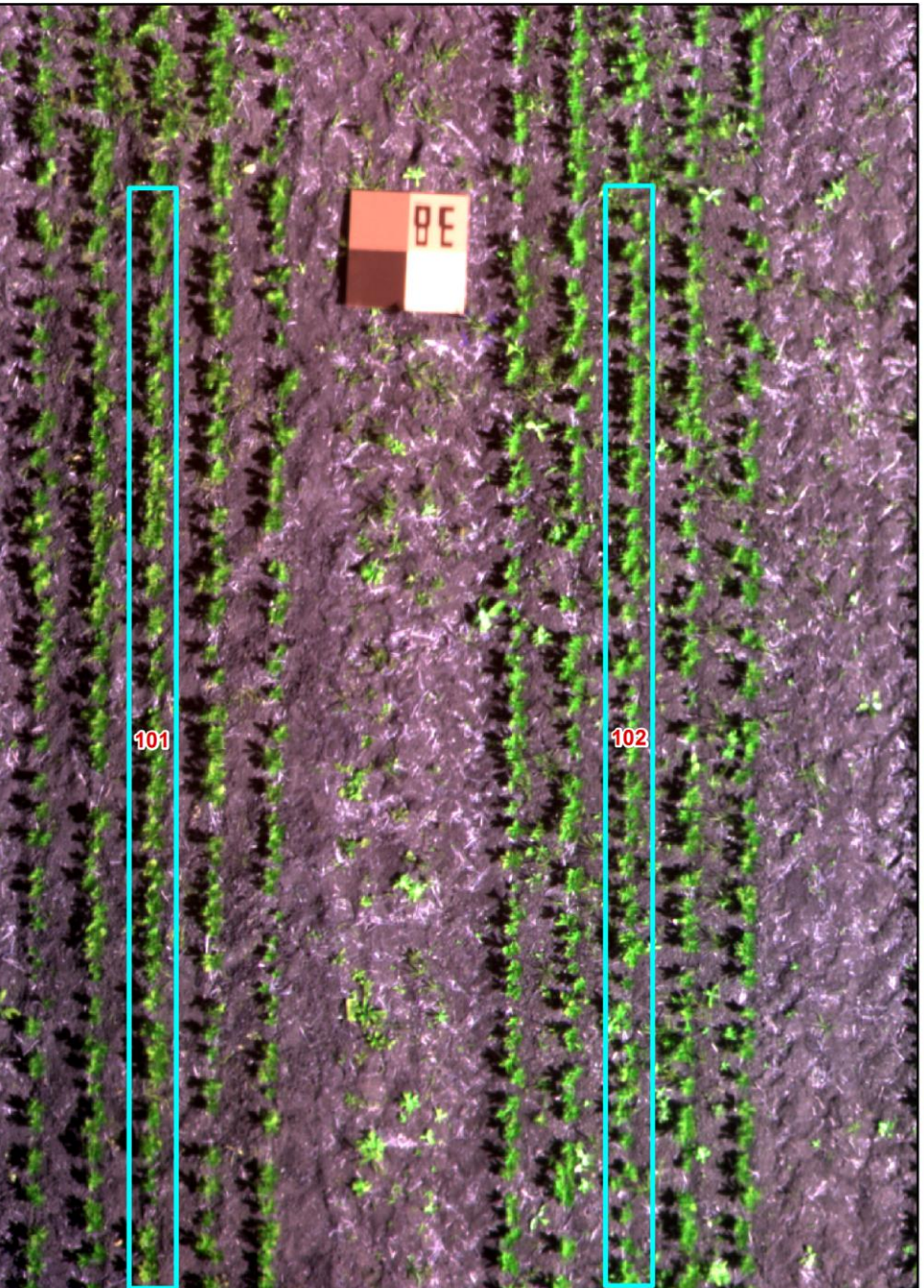
Crop herbicide tolerance in fababean

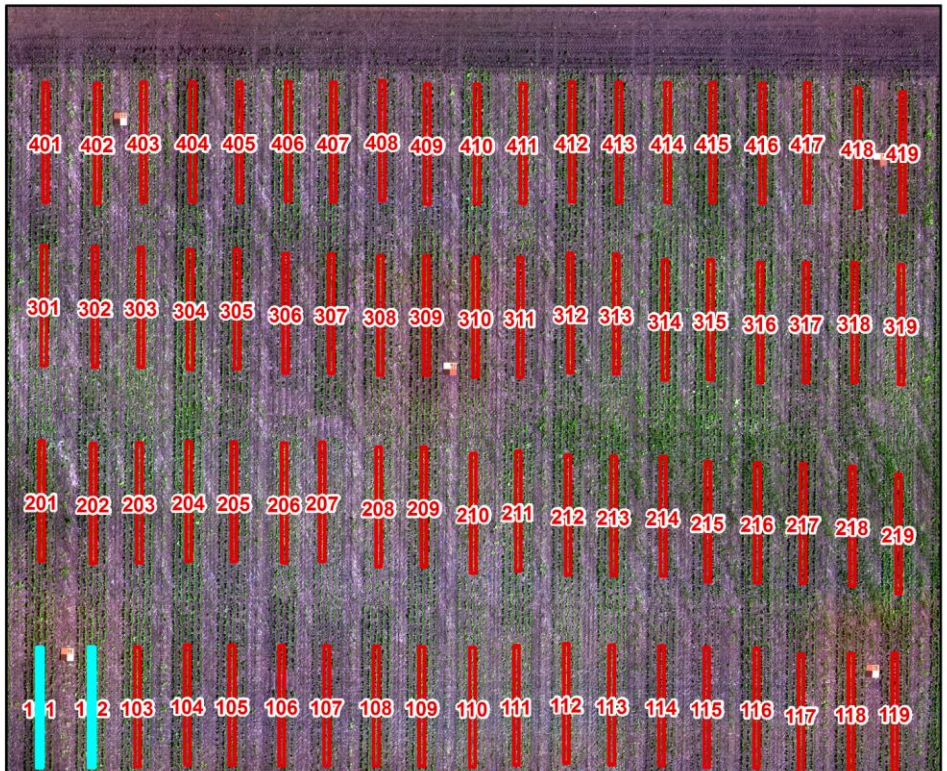


Herbicide Trail--RGB



Herbicide Trail--RGB

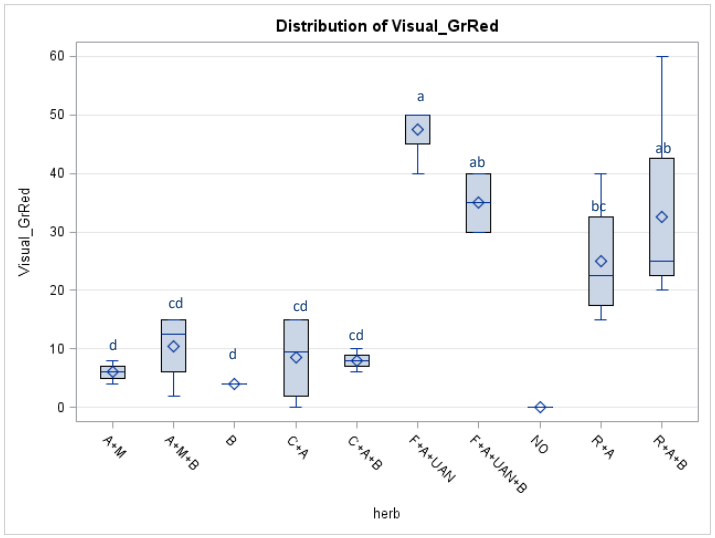


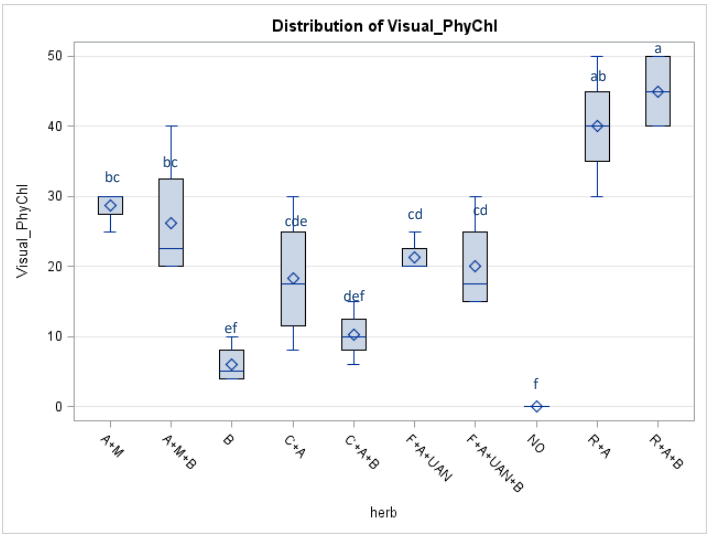


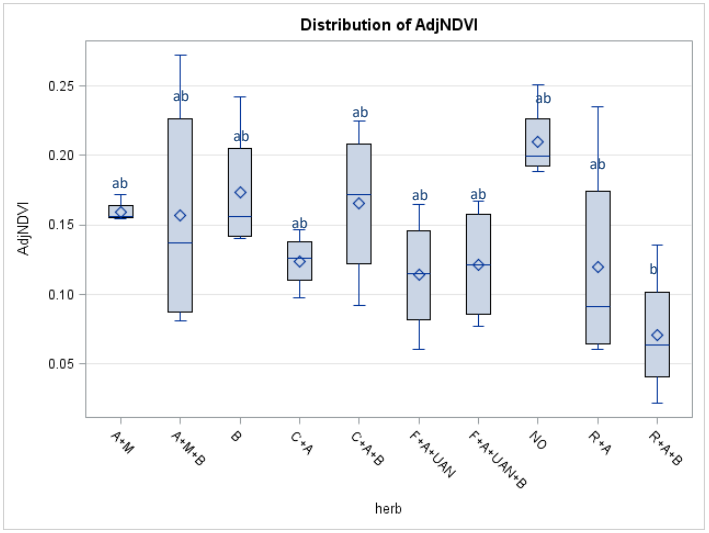
N

Plot

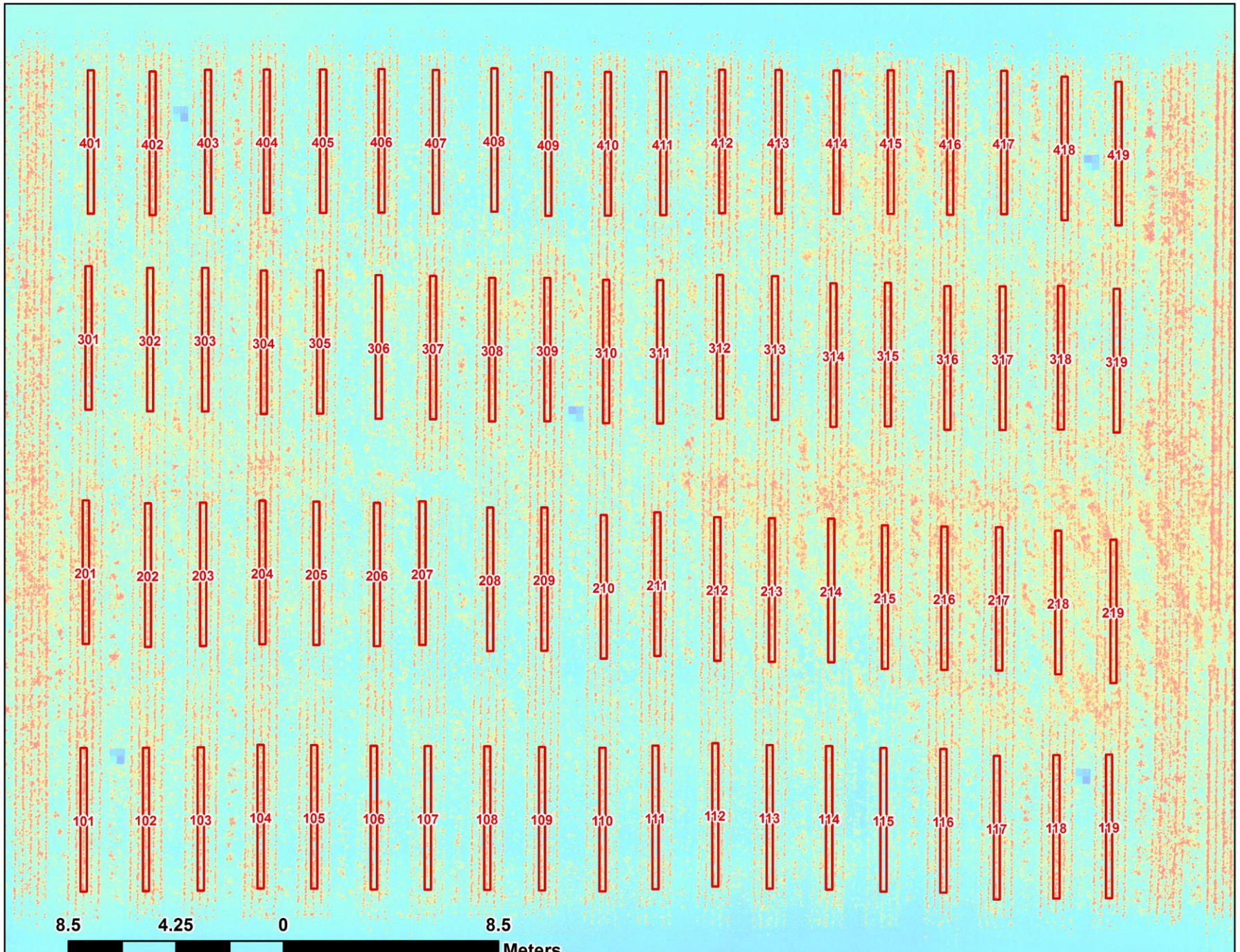
Tolerance of fababean to herbicides



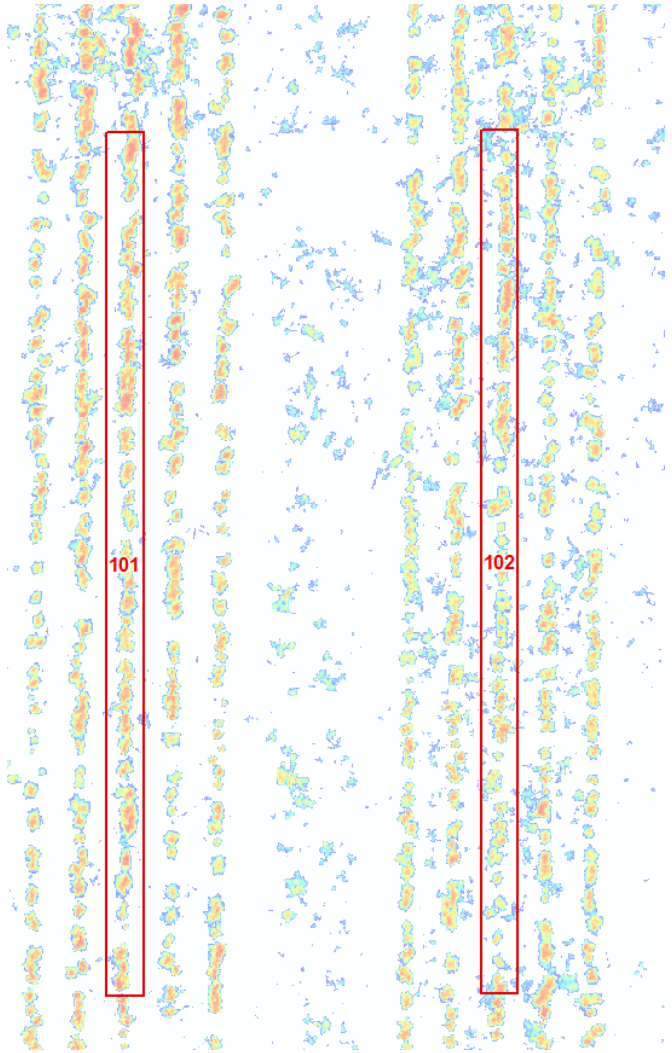


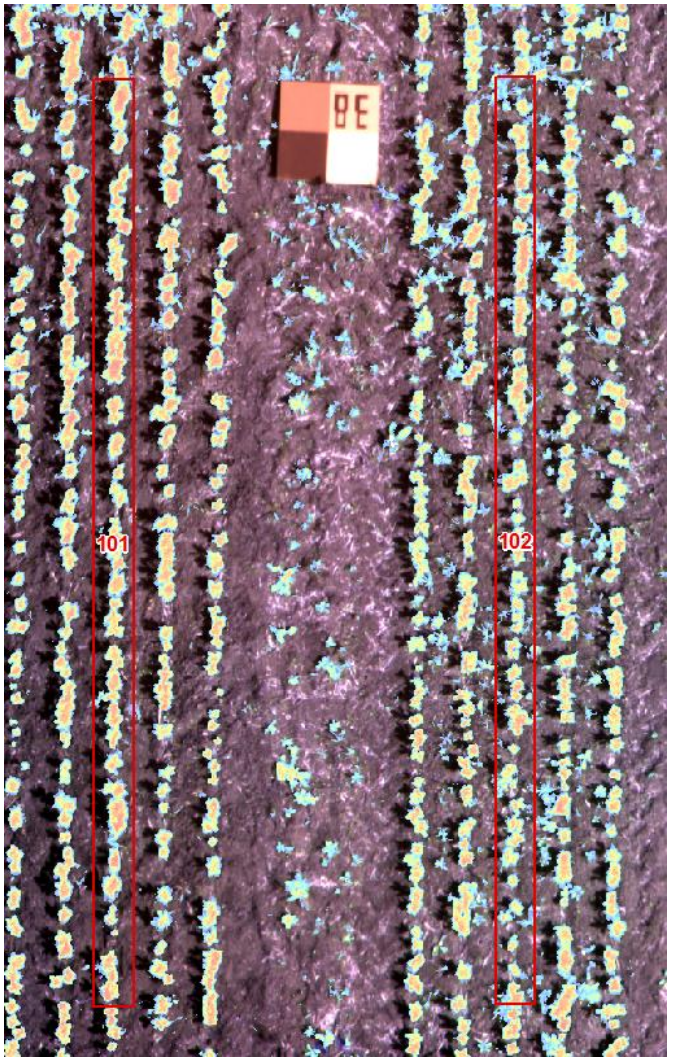


Herbicide Trail---OSAVI Map

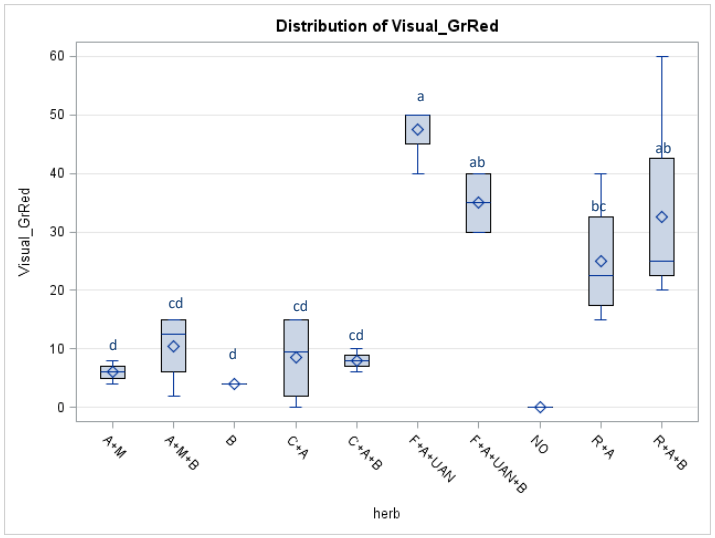


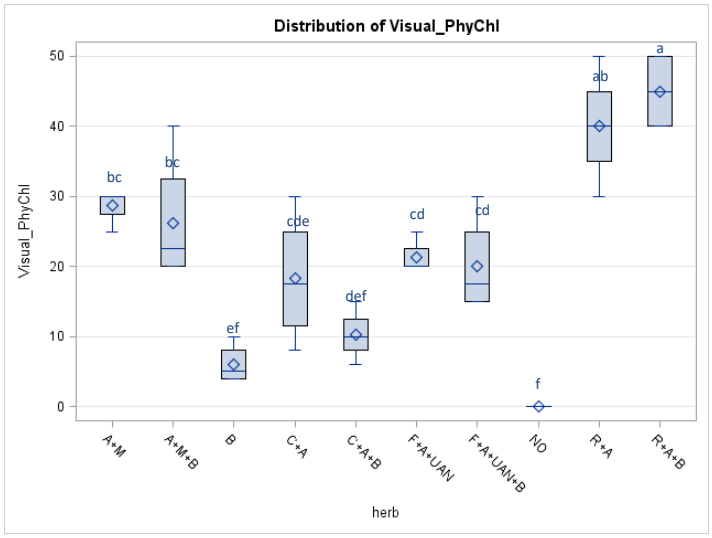
Thresholding

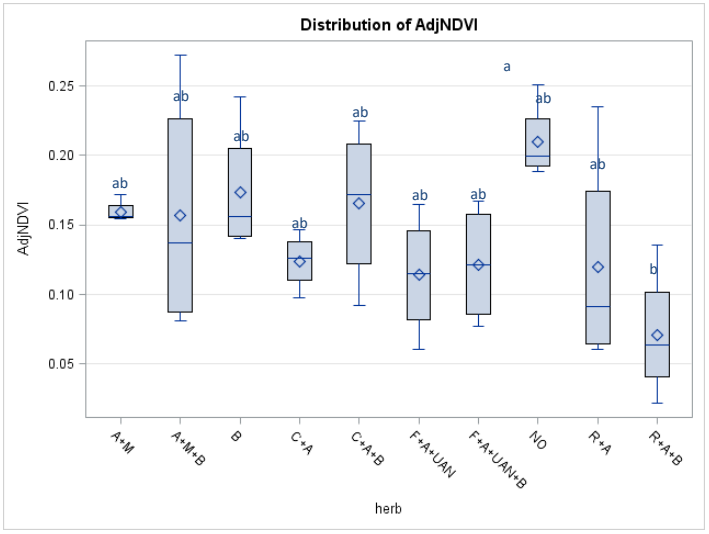


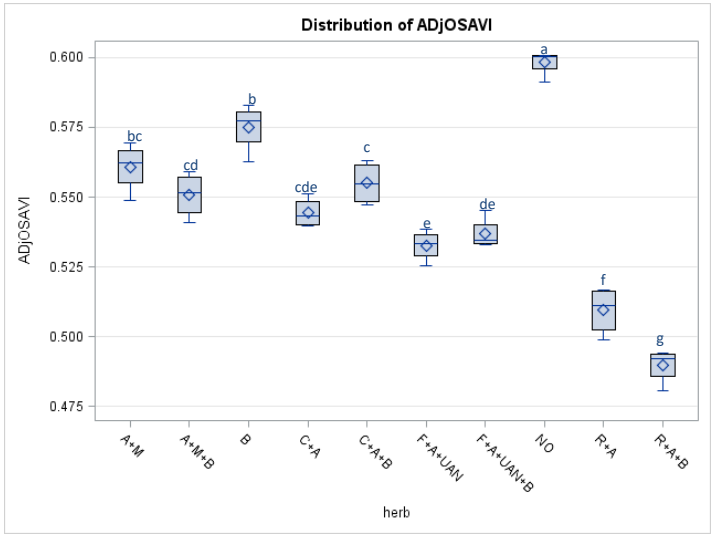


Tolerance of fababean to herbicides



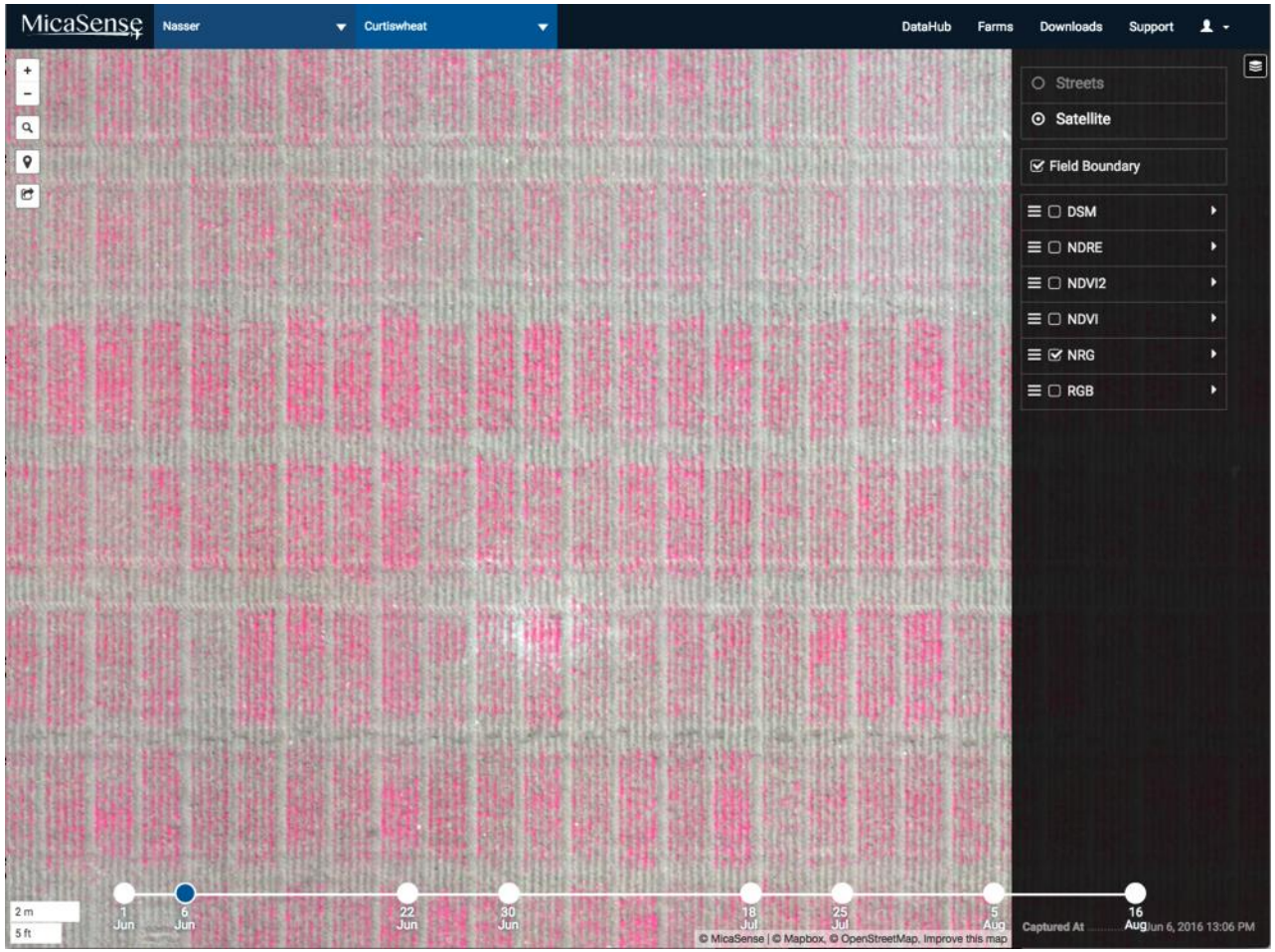




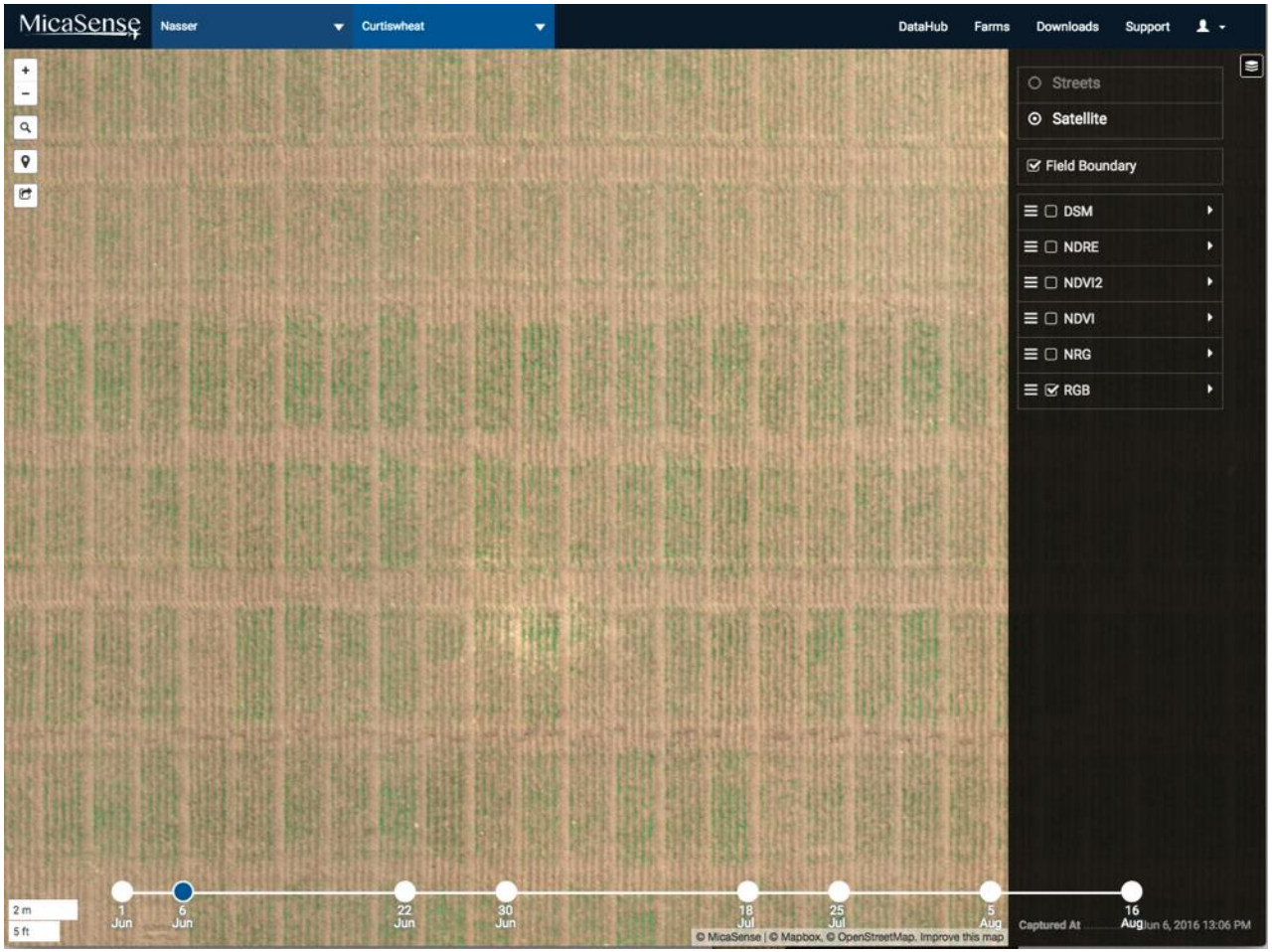


LODGING IN CROPS

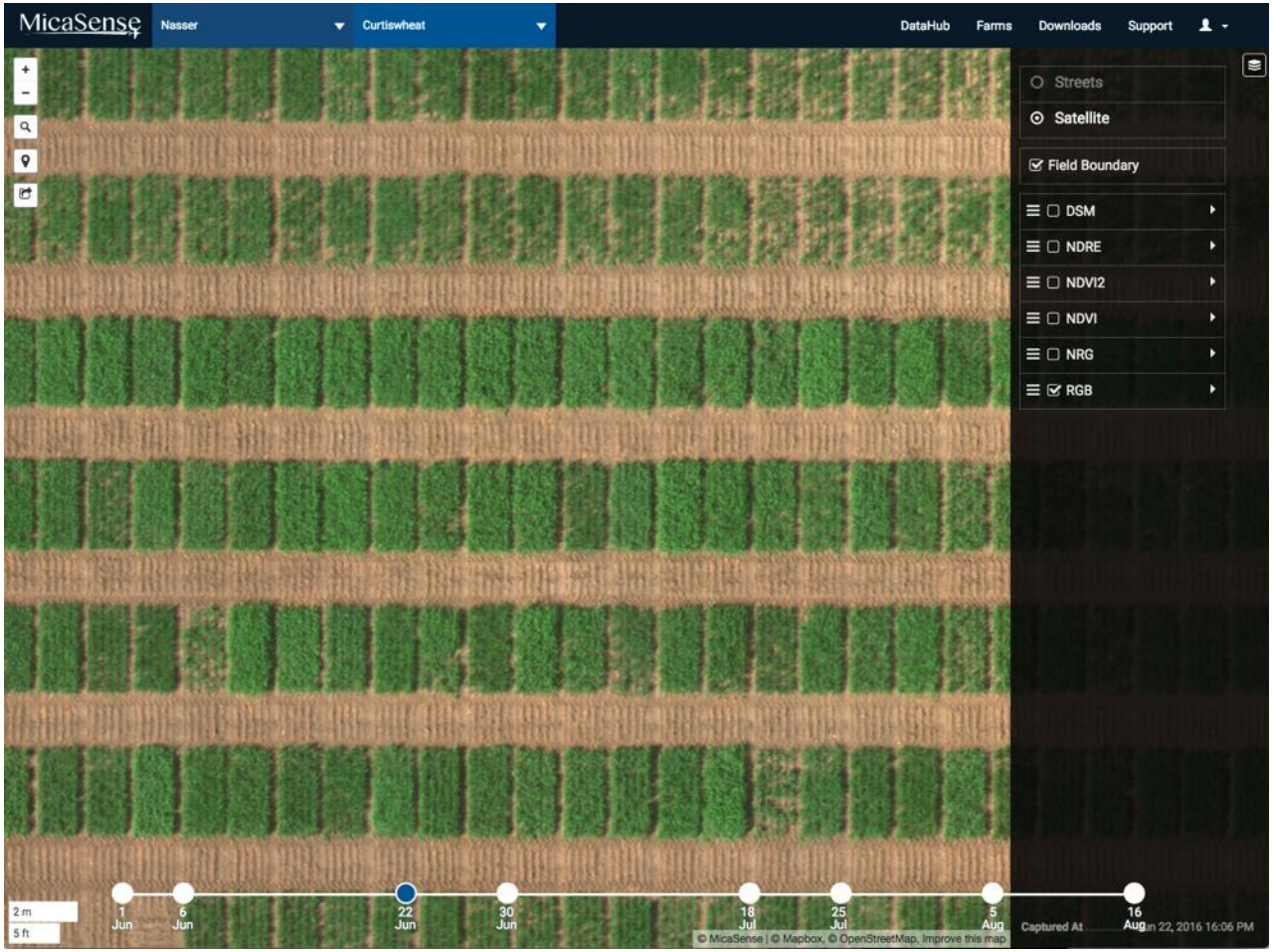
Early generation durum wheat lines, June 6



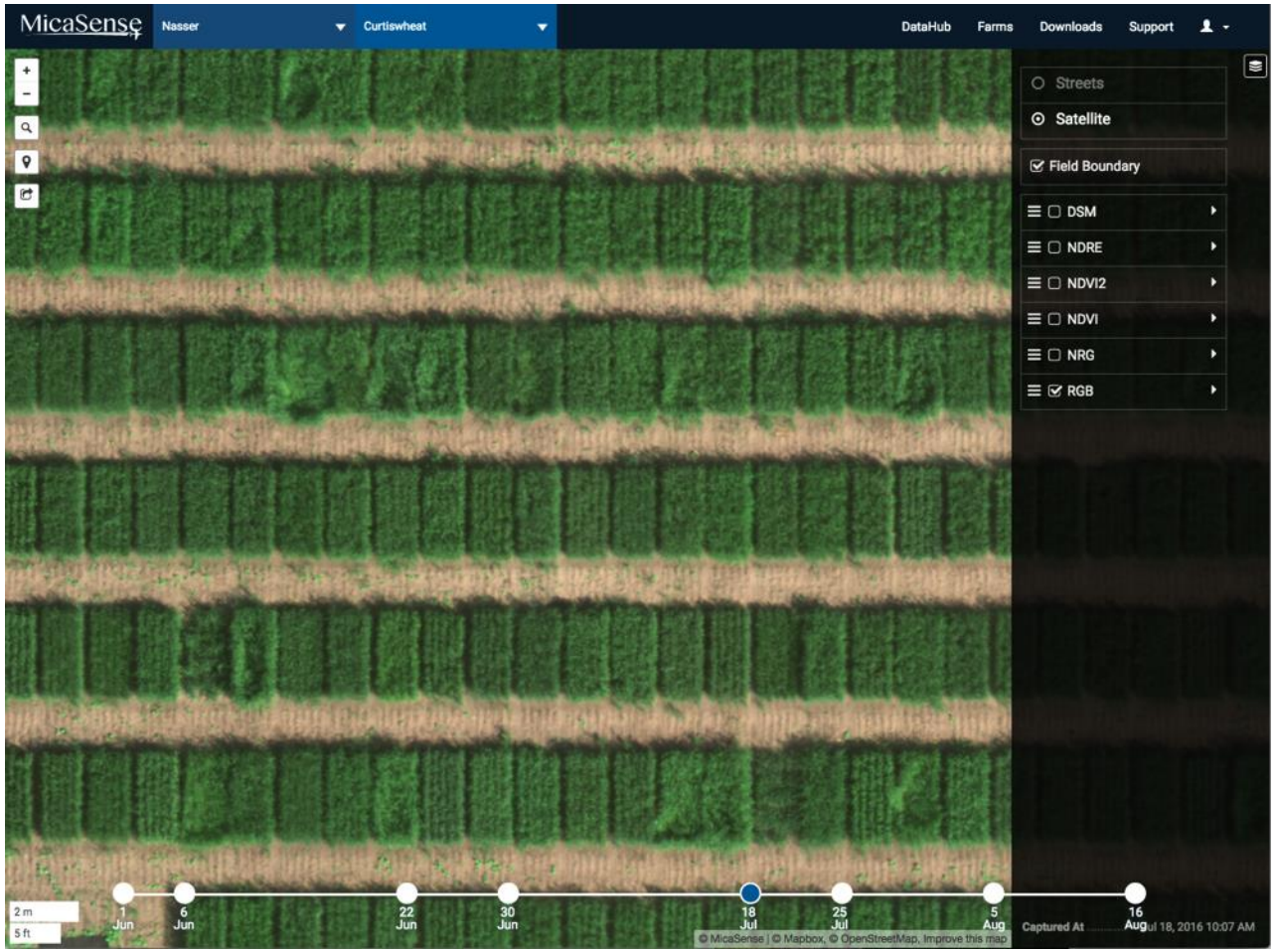
Early generation durum wheat lines, June 6



Early generation durum wheat lines, June 22

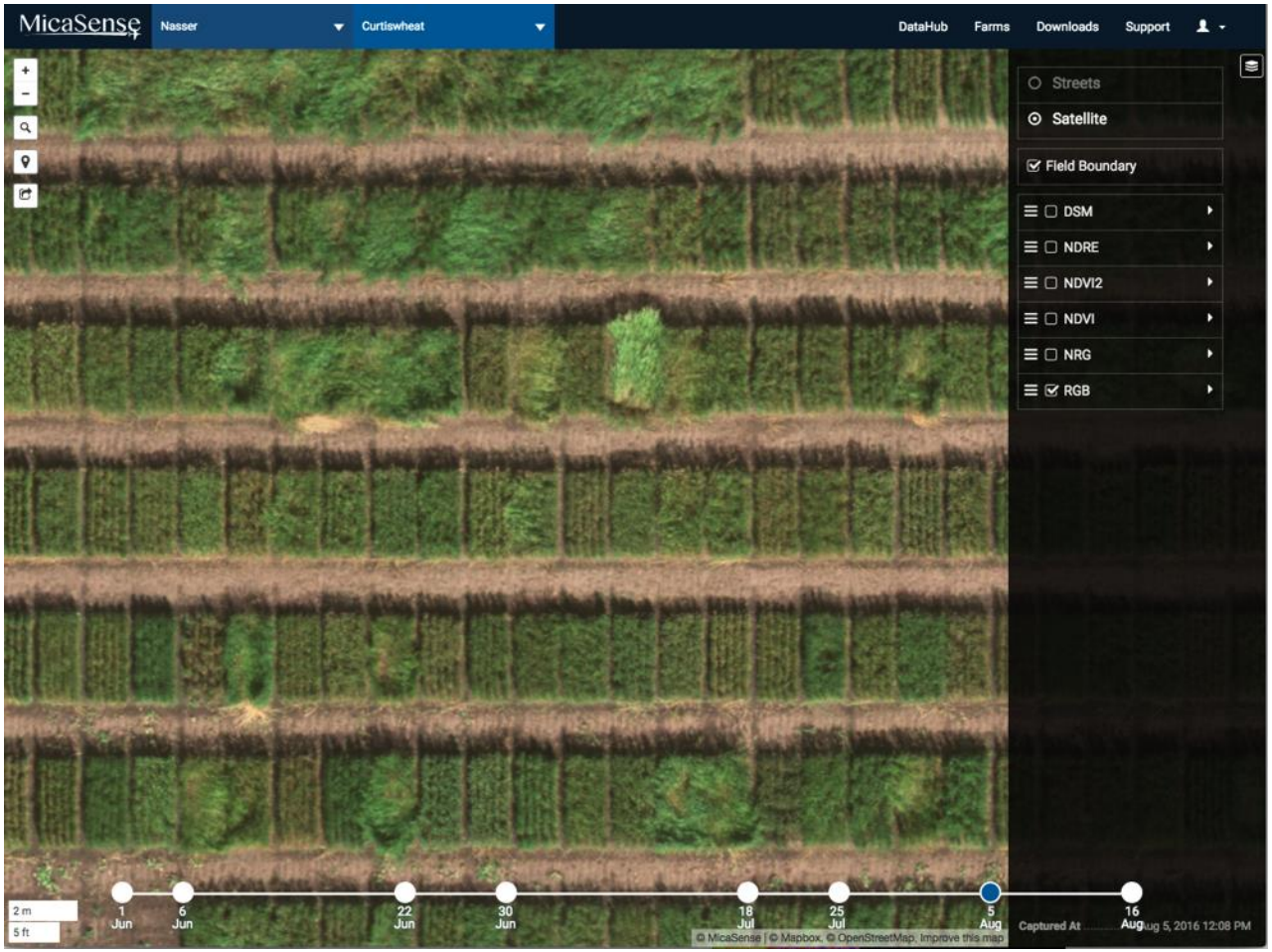


Early generation durum wheat lines, July 18

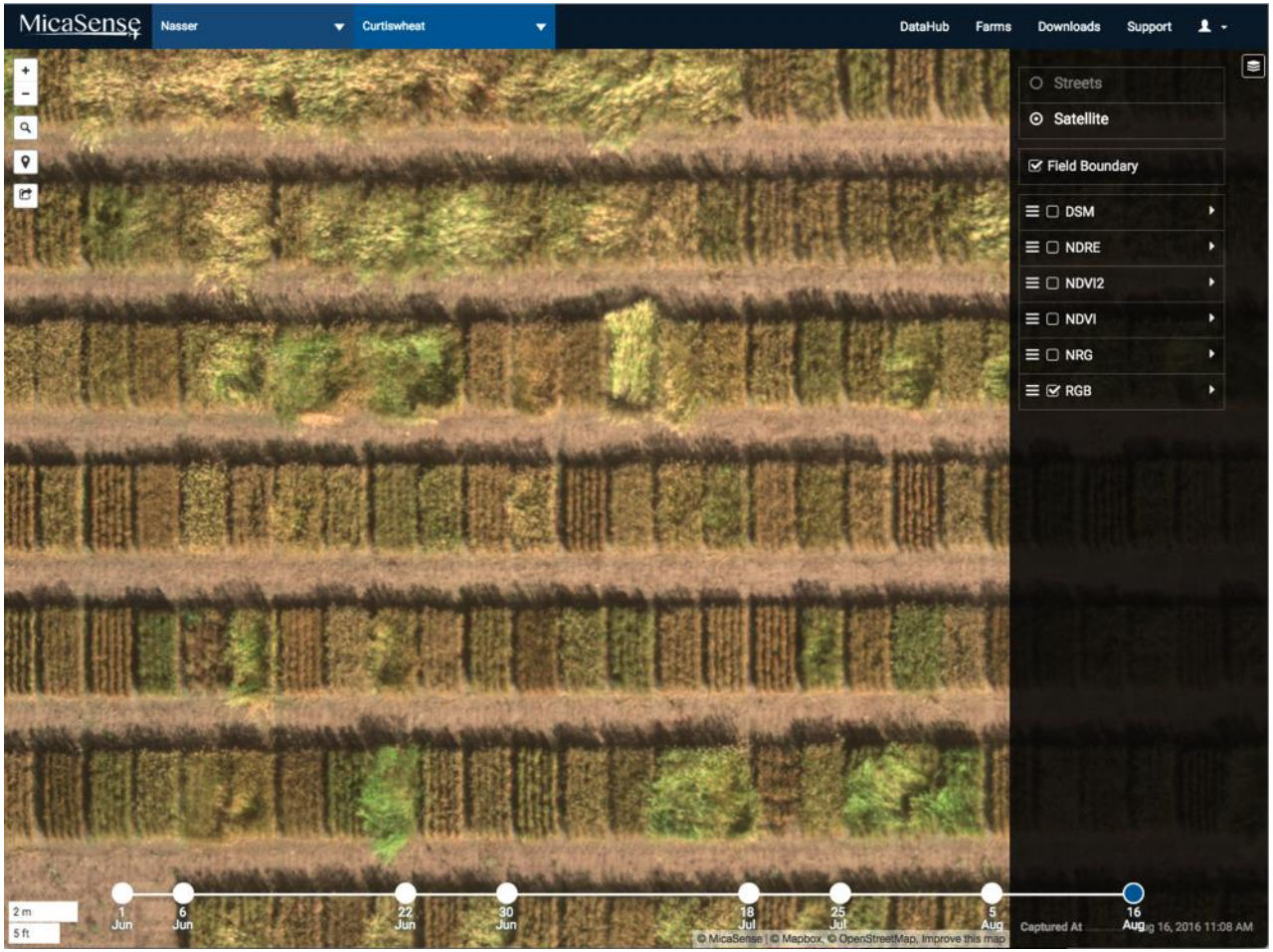


Early generation durum wheat lines, July 25

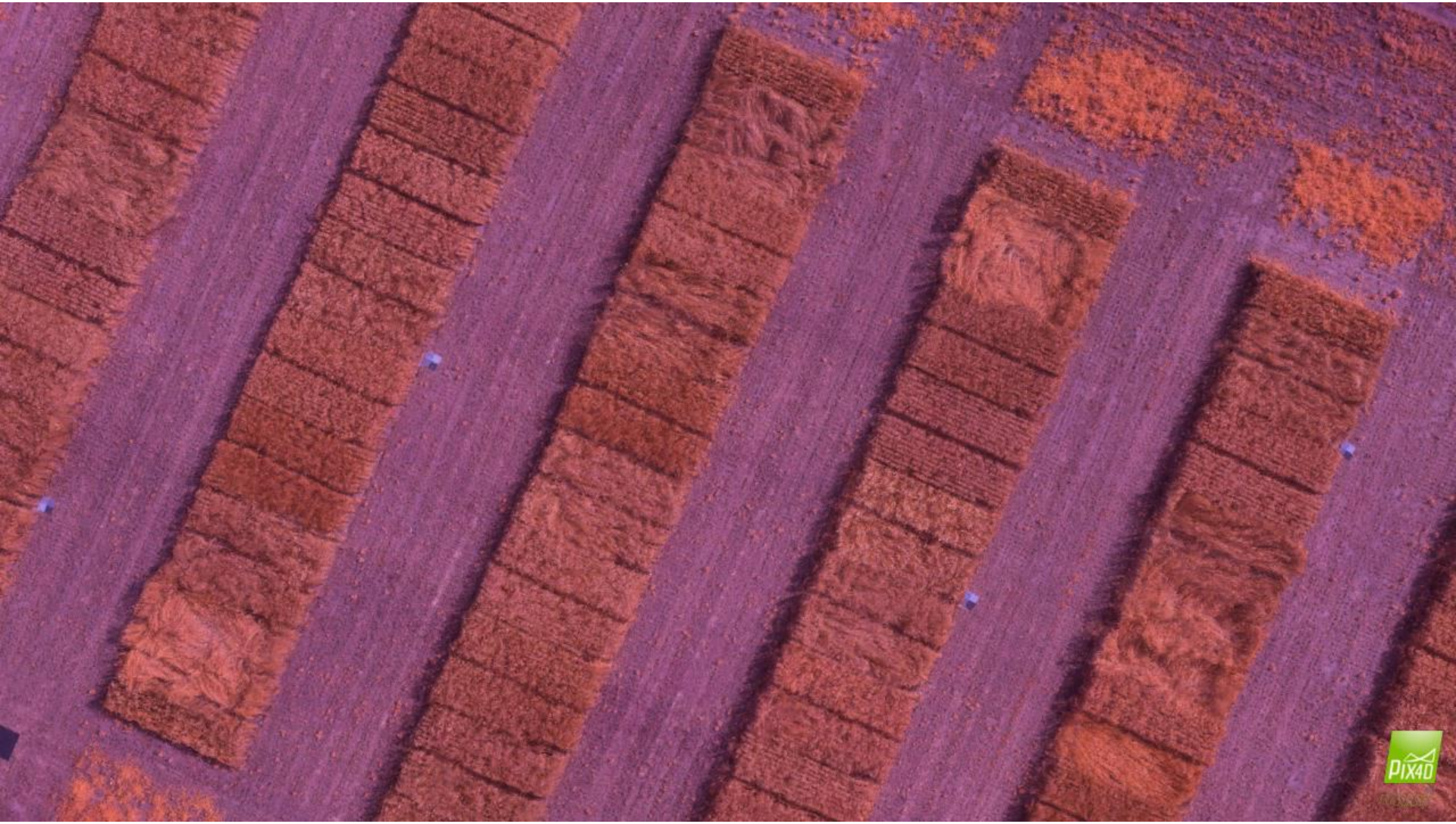
Early generation durum wheat lines, Aug 5



Early generation durum wheat lines, Aug 16



Using 3-D modelling



HAIL DAMAGE IN CROPS

Simulated Hail Damage in Canola

By: Steve Shirtliffe, Lena Syrovy, Shaun Campbell,

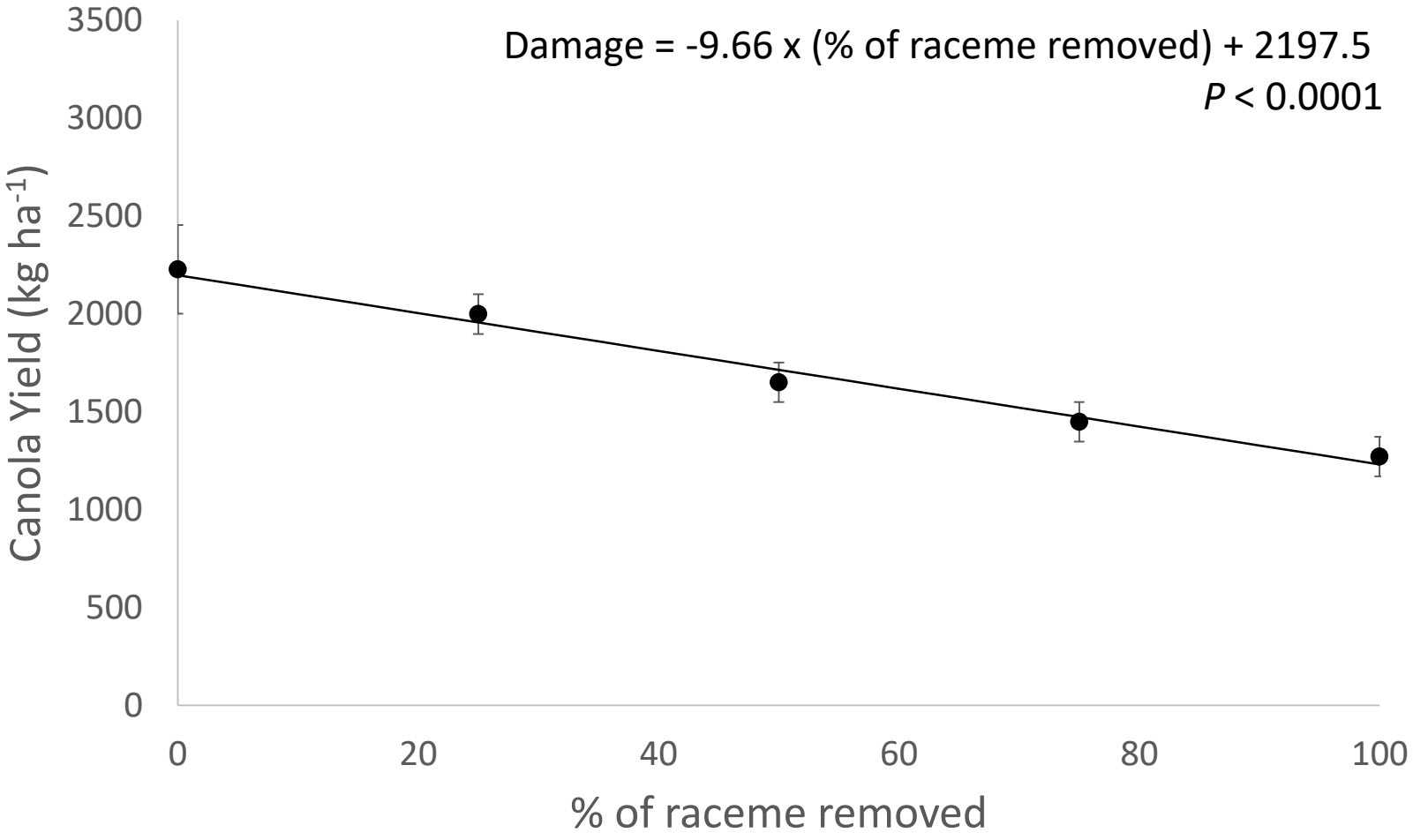
UNIVERSITY OF SASKATCHEWAN
College of Agriculture and Bioresources
DEPARTMENT OF PLANT SCIENCES
AGBIO.USASK.CA

Treatments

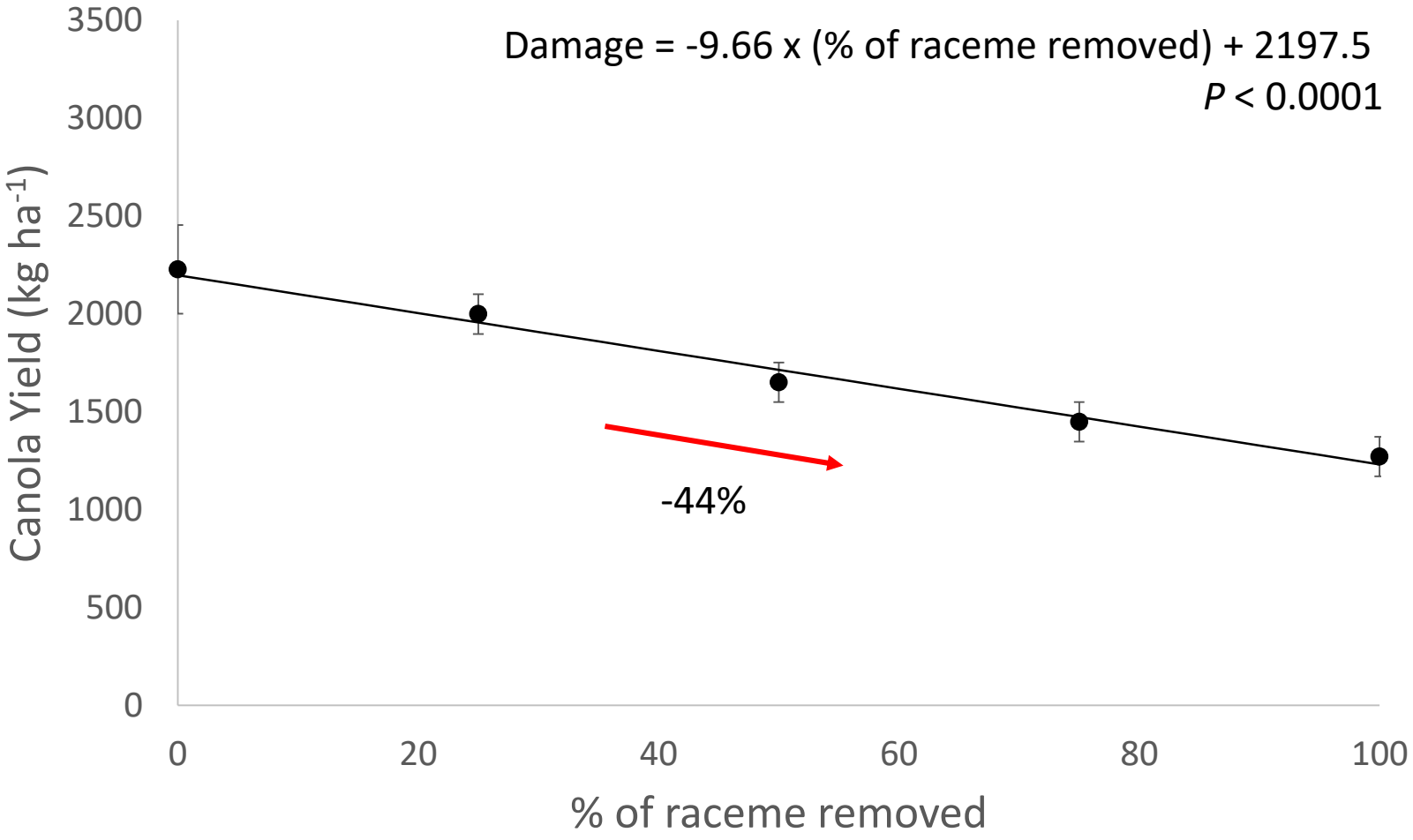
25% raceme removal

100% raceme removal

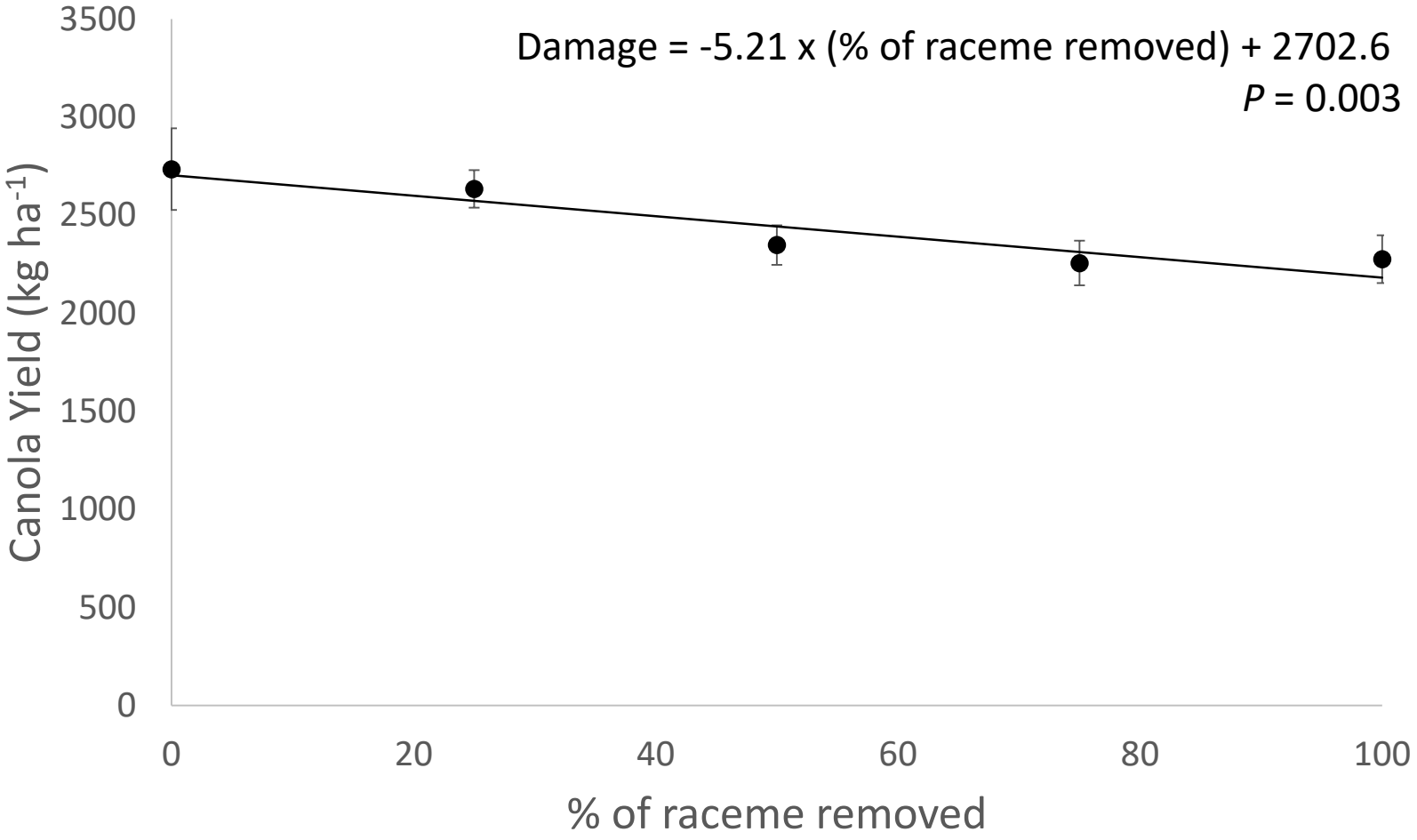
Saskatoon South Site



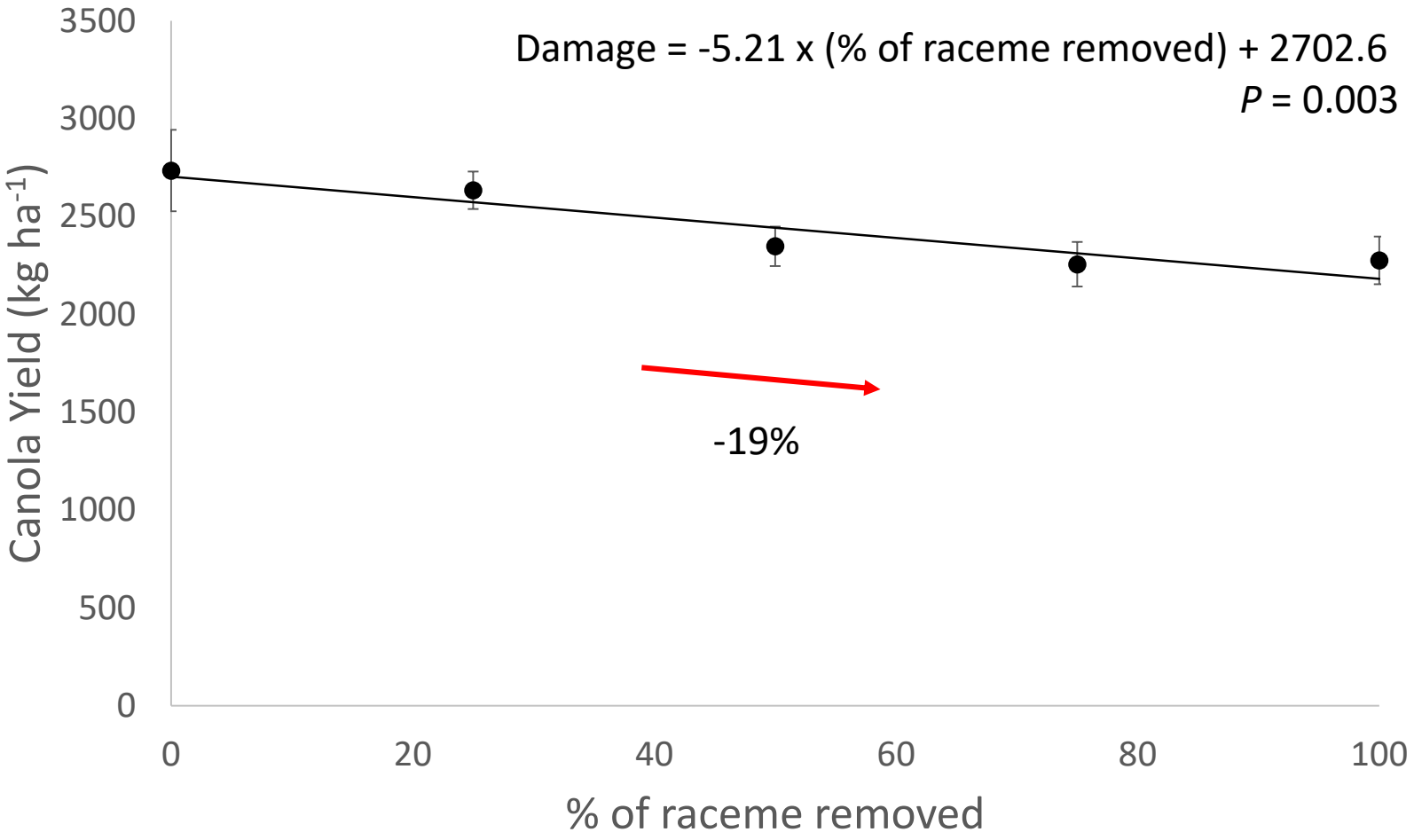
Saskatoon South Site



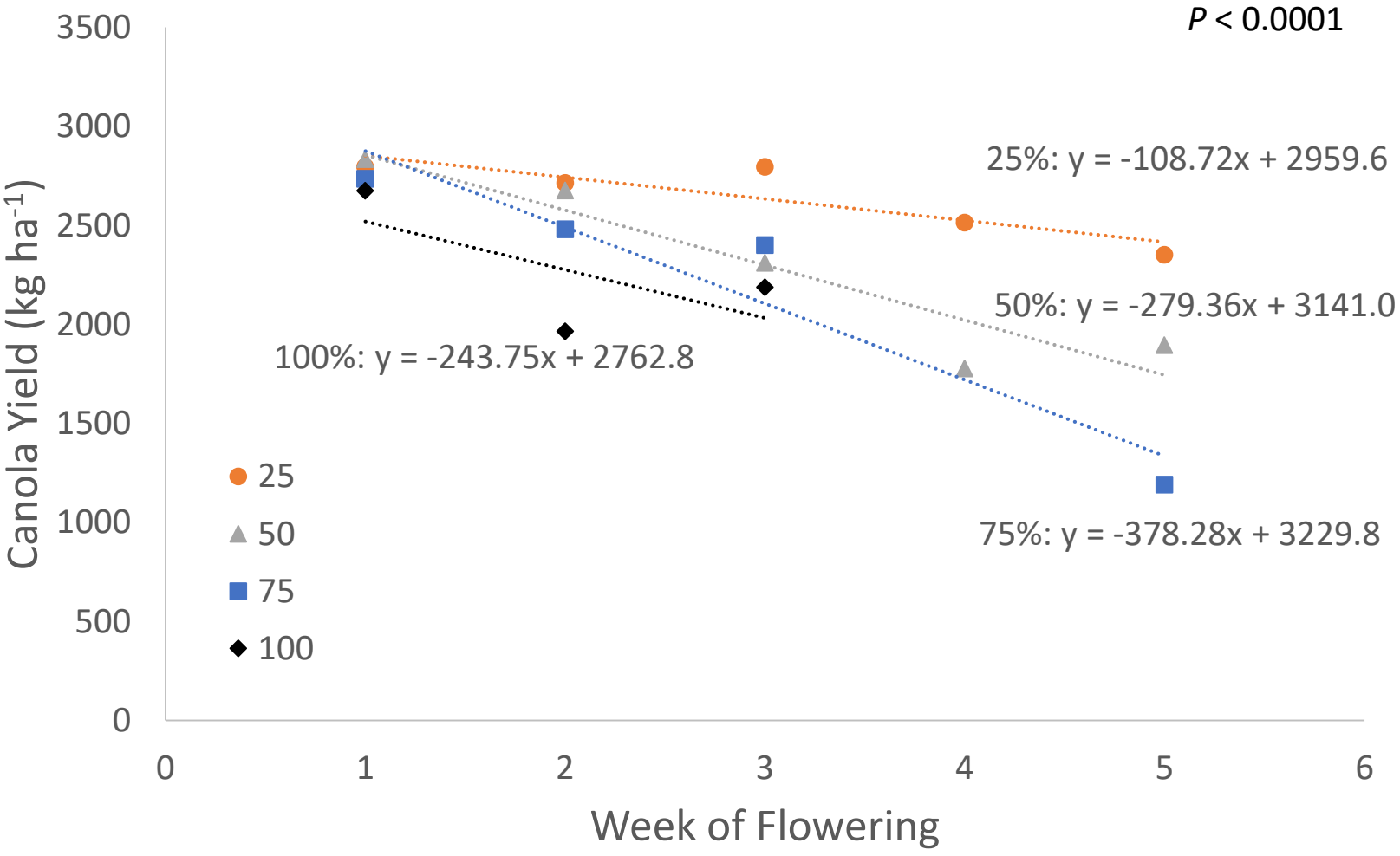
Saskatoon North Site

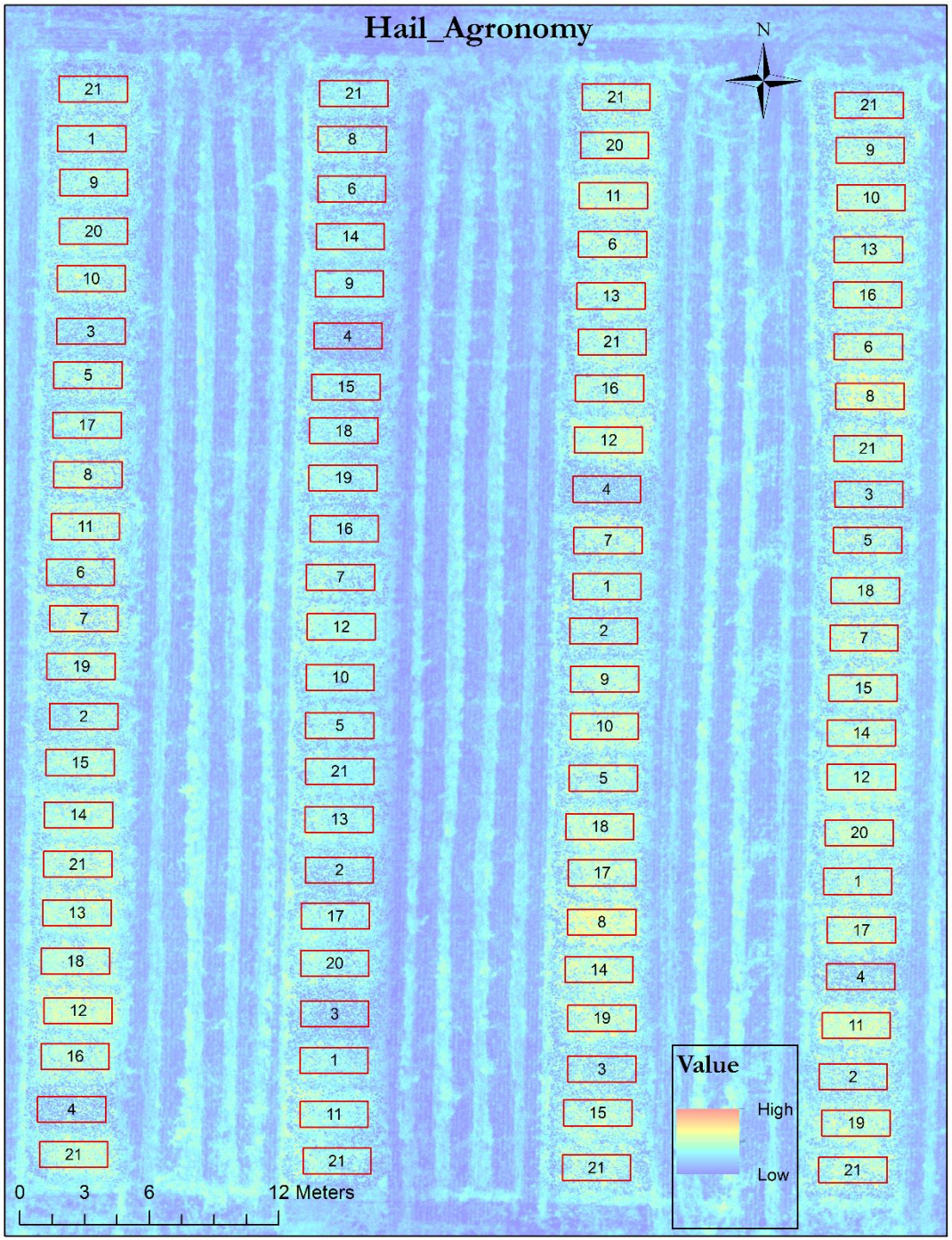


Saskatoon North Site

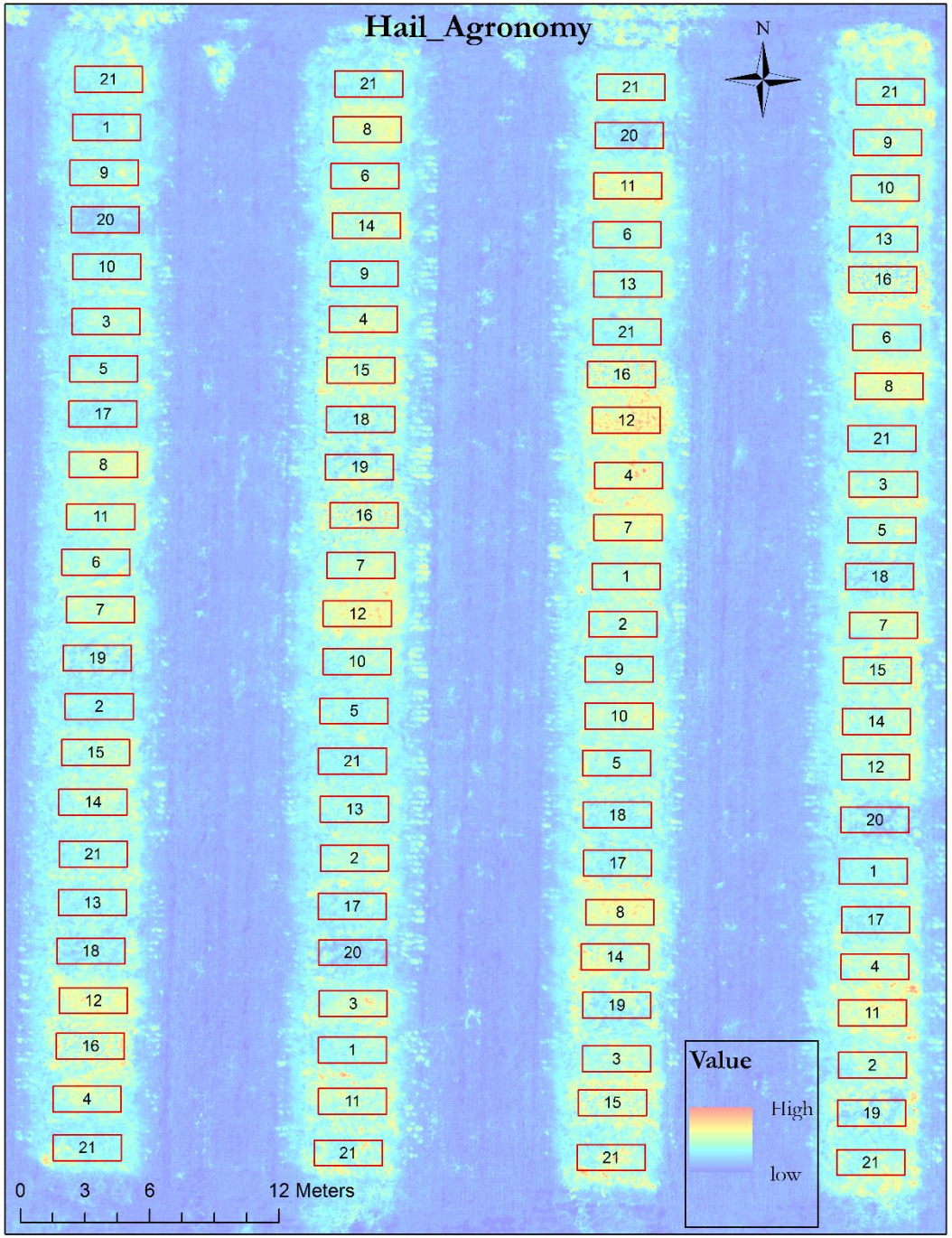


Saskatoon North Site





CIG Map – July 18

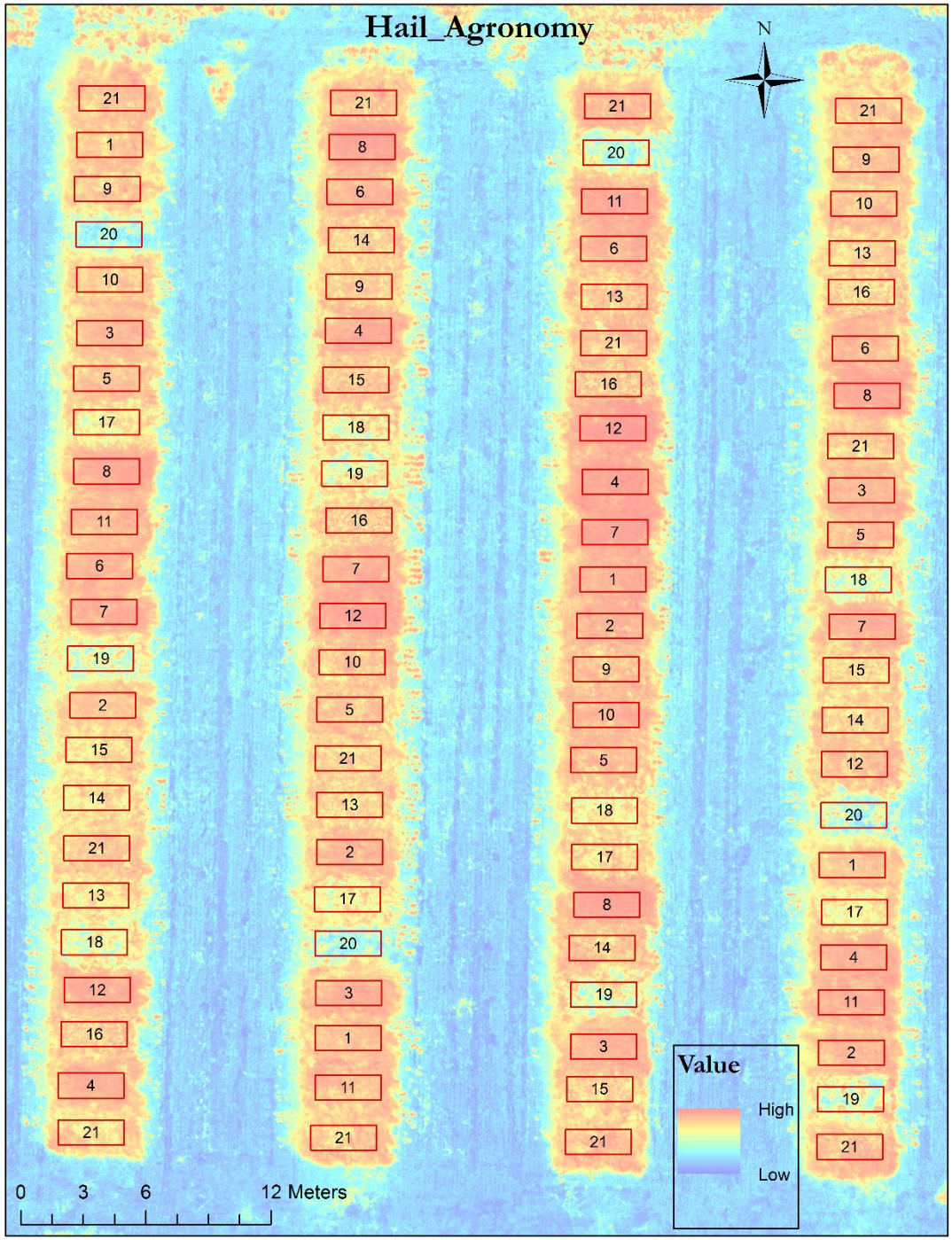


CIG Map – Aug 17

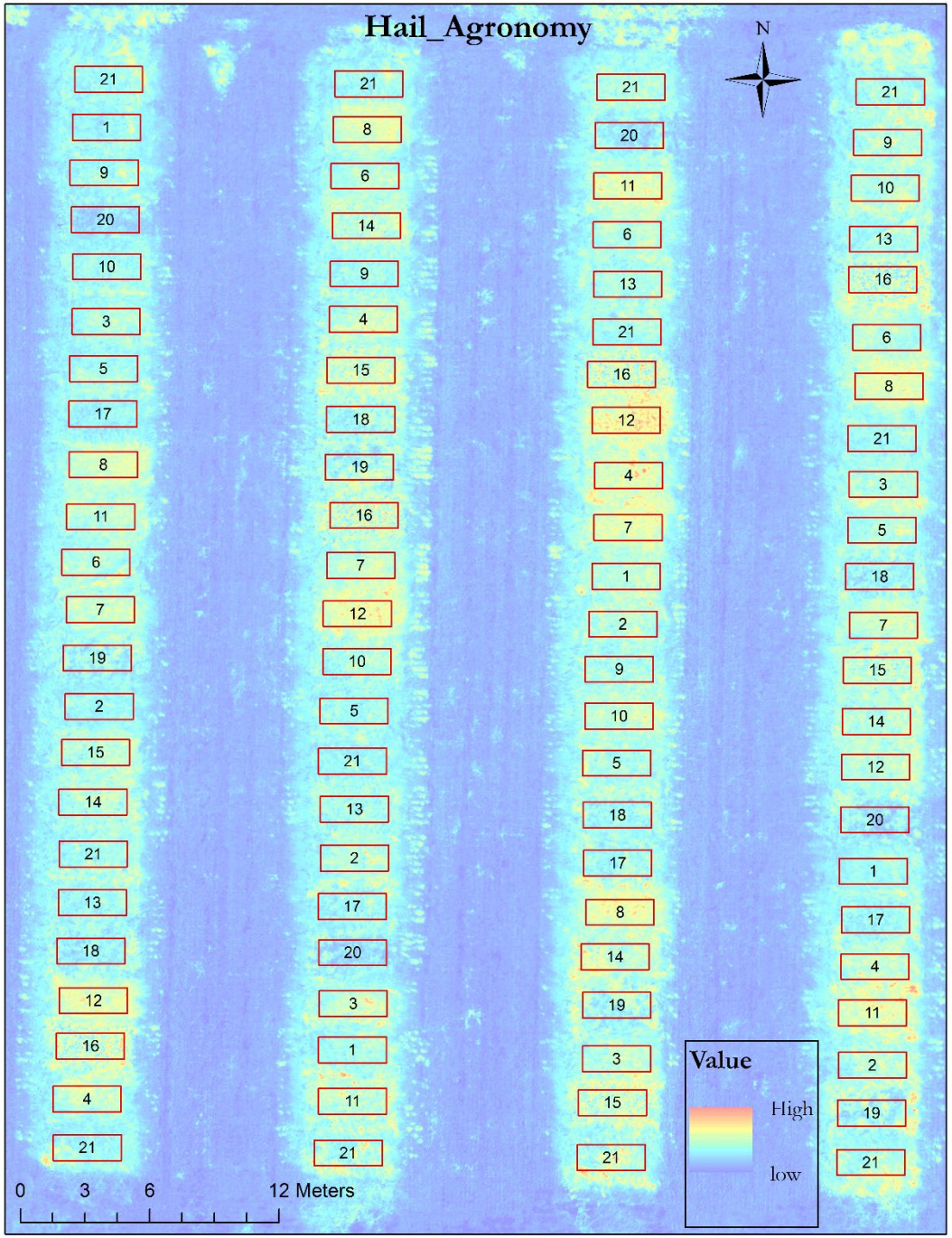
Treatments

25% raceme removal

100% raceme removal

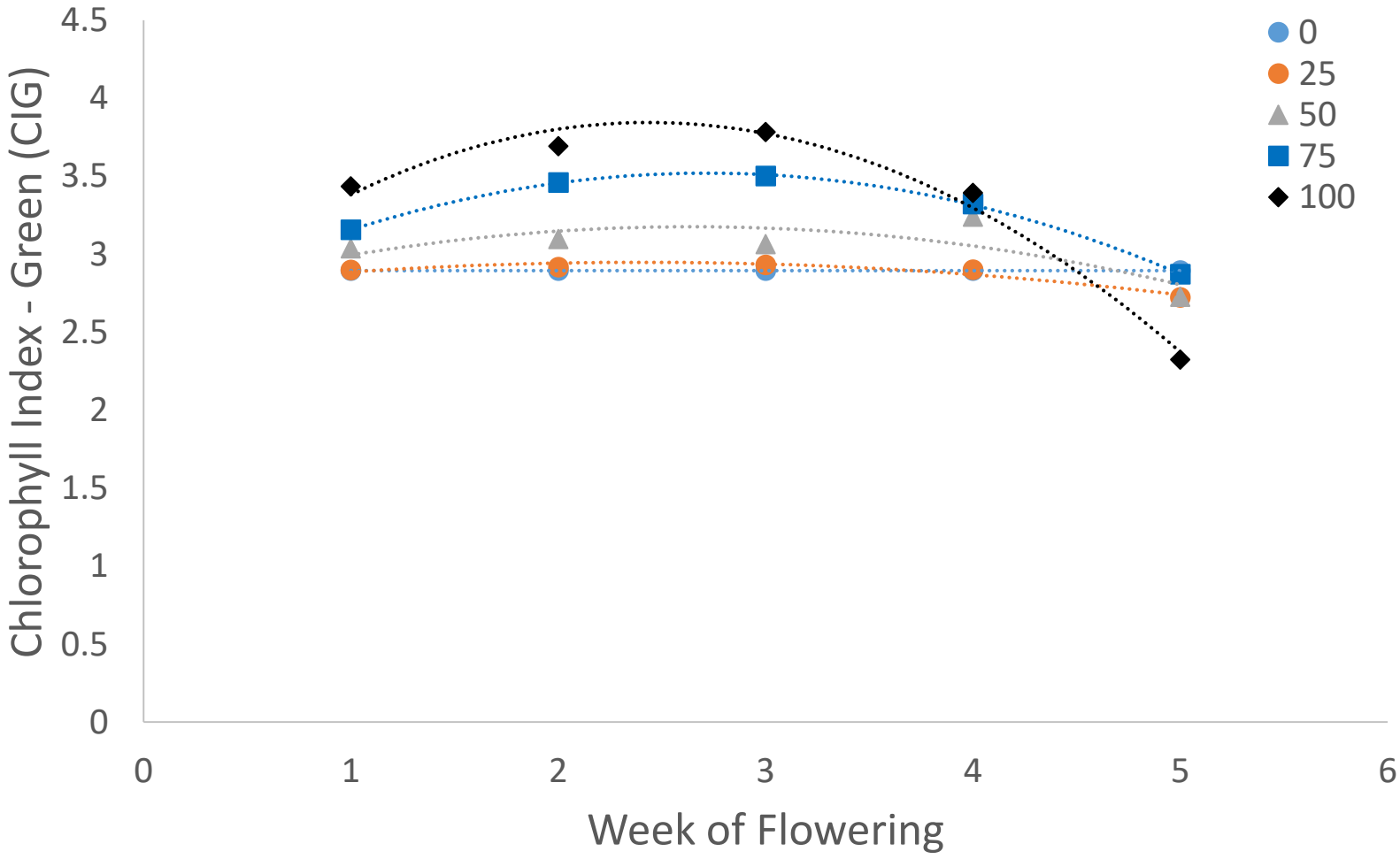


NDVI Map – Aug 17

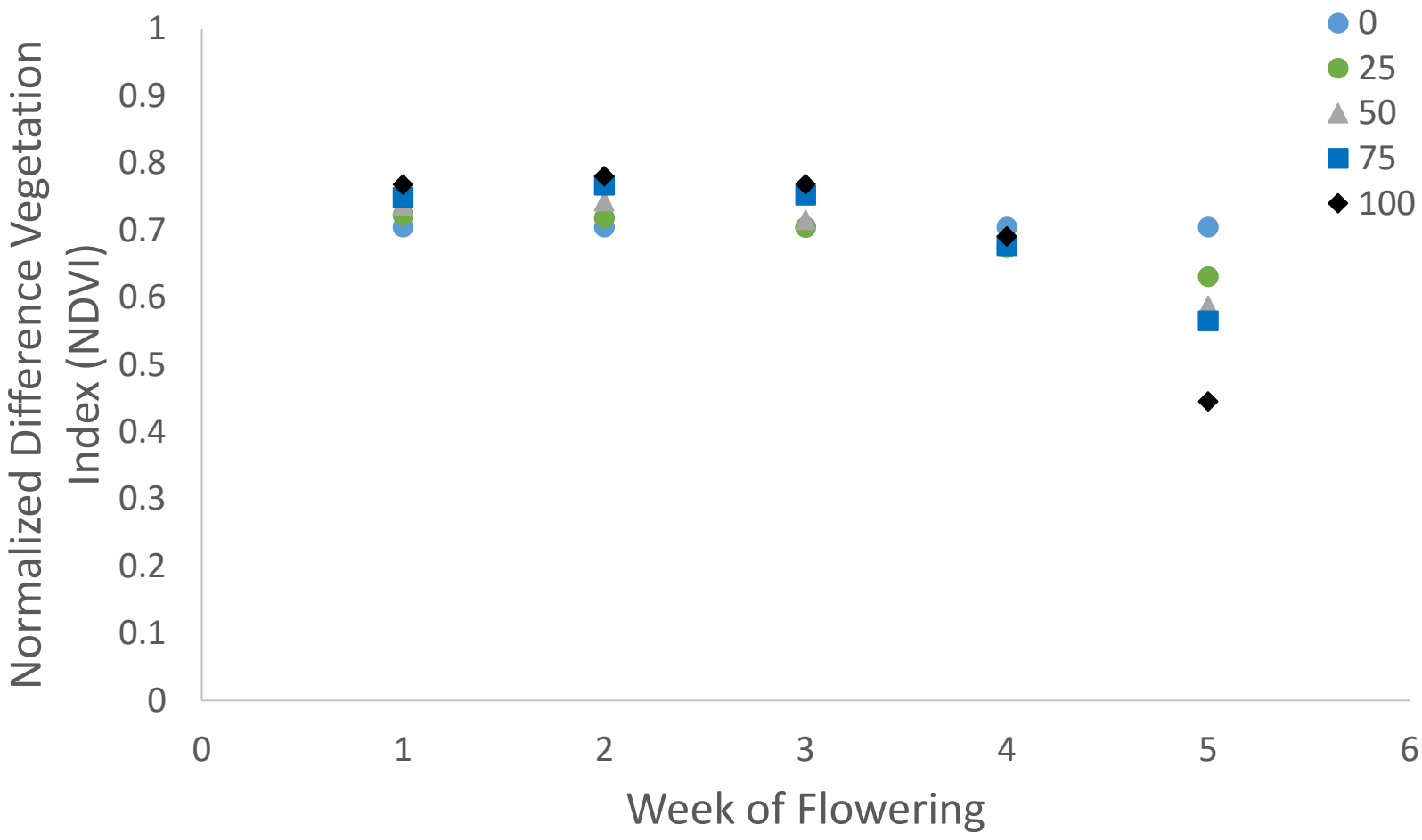


CIG Map – Aug 17

Saskatoon North CIG – August 17



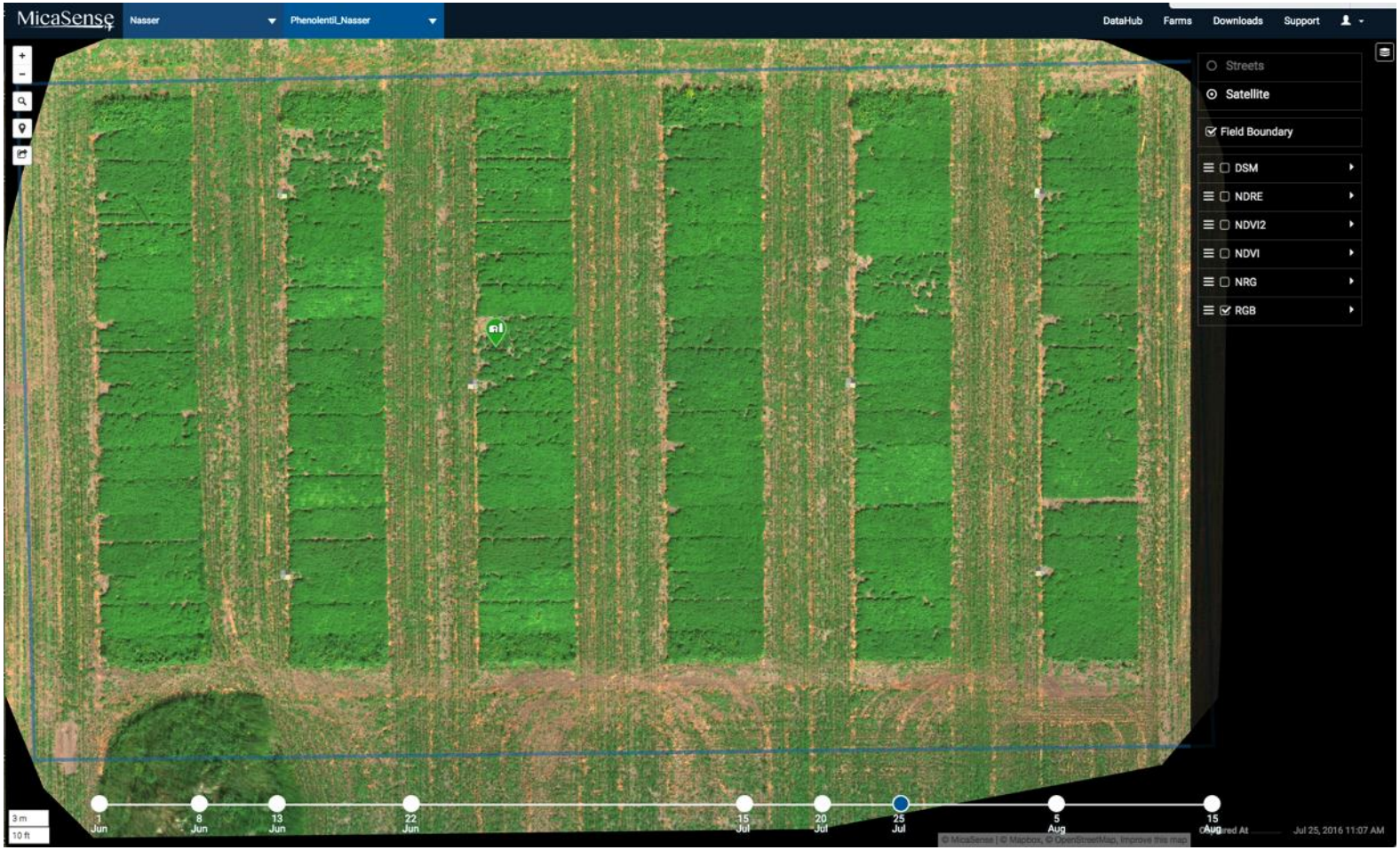
Saskatoon North NDVI – August 17




posted on Twitter from Daryl Frank, Jazz Aviation

EARLY DETECTION OF PLANT DISEASE

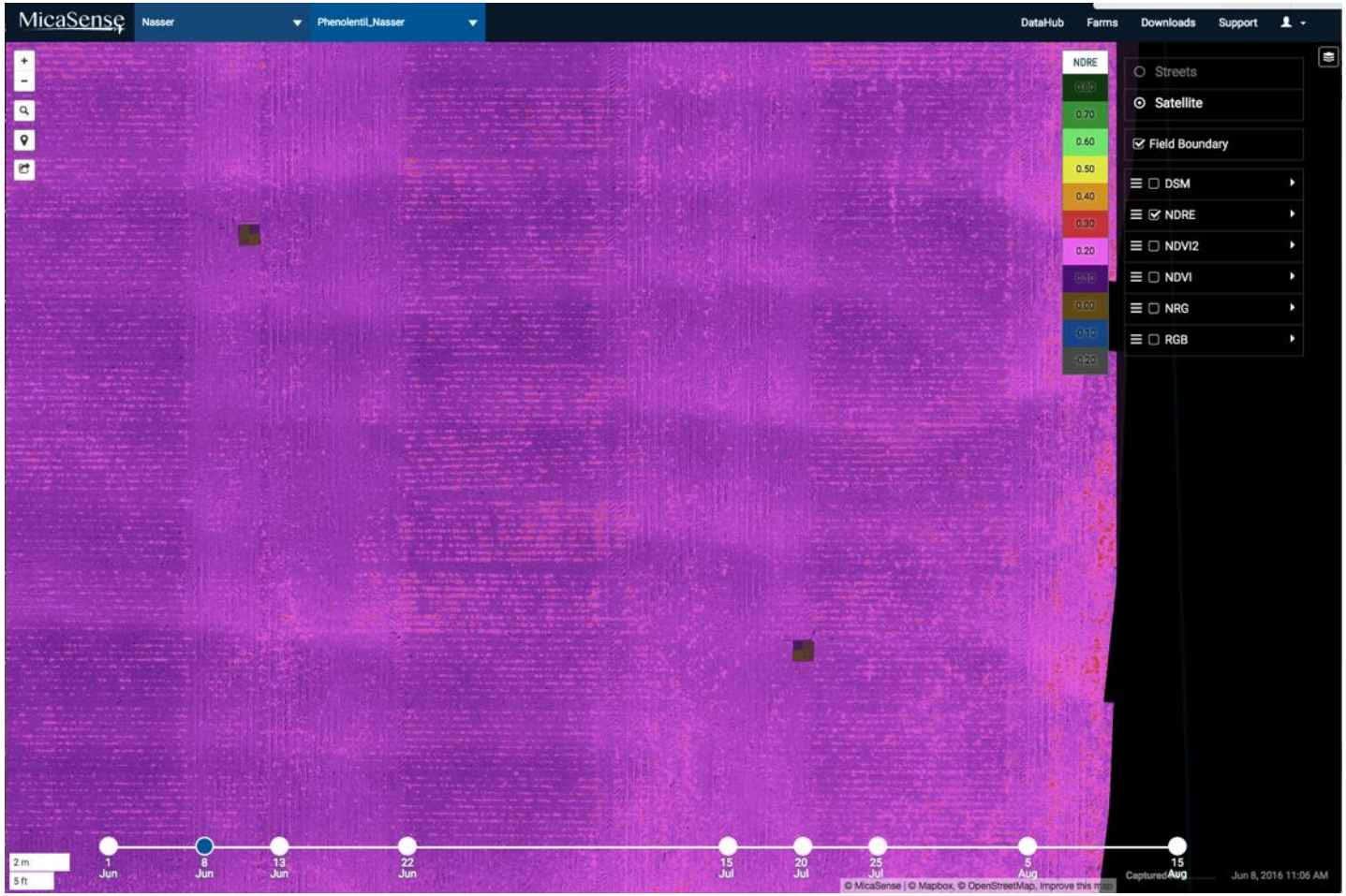
Lentil Phenotrial: 16 diverse cultivars



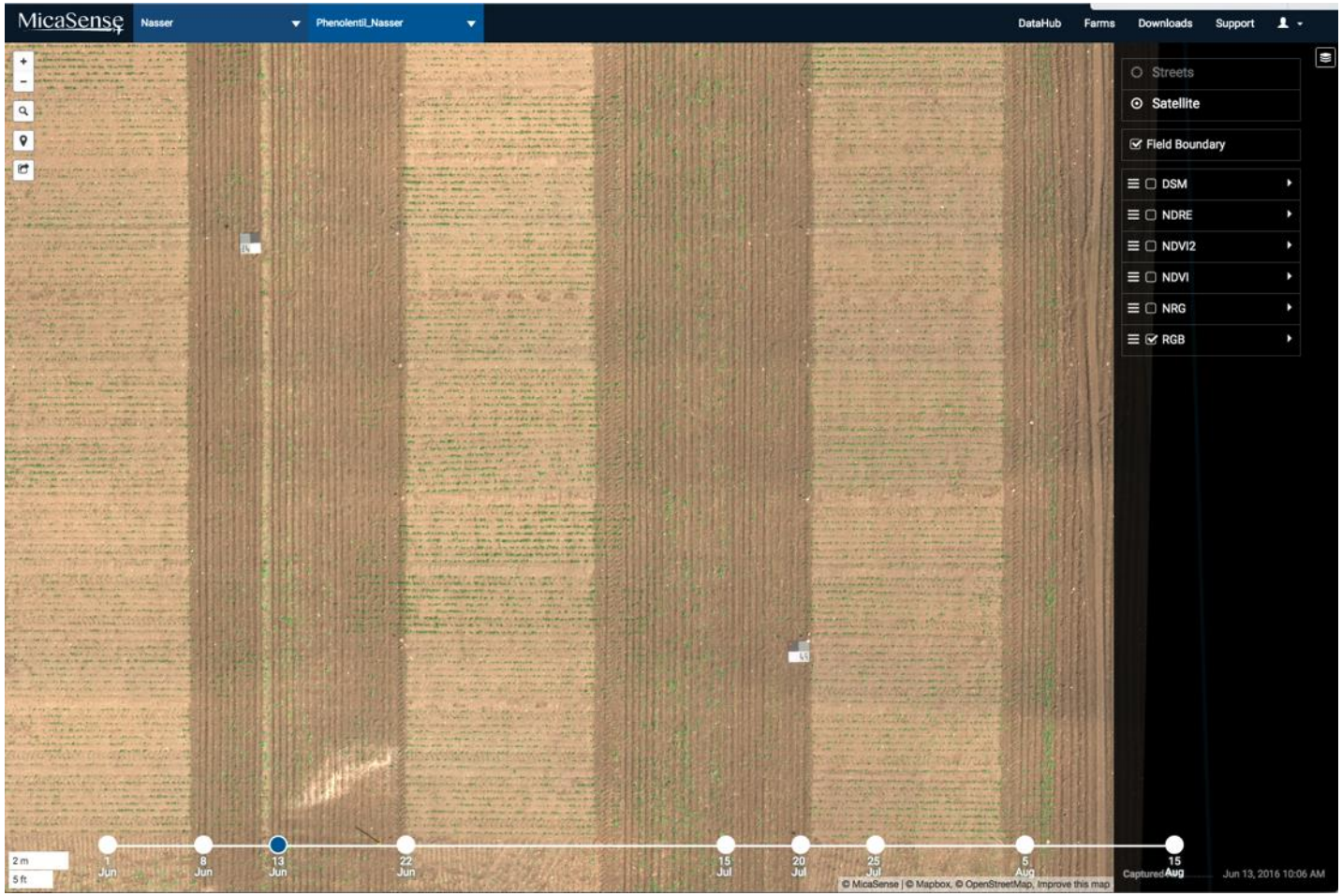
High temporal resolution measurements of lentil growth and development

Images by Kevin Stanley and Ian Stavness

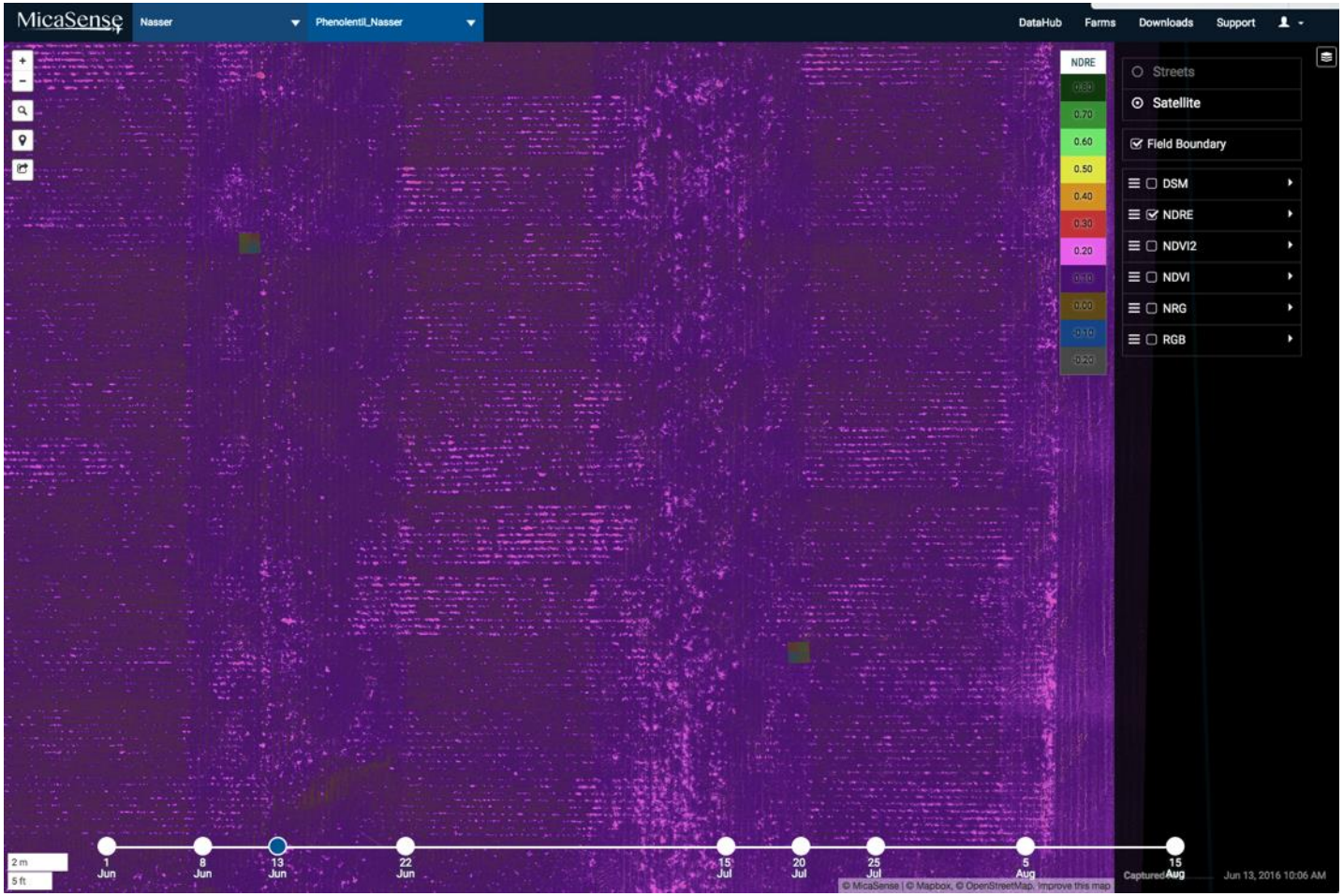
Lentil Phenotrial: 16 diverse cultivars



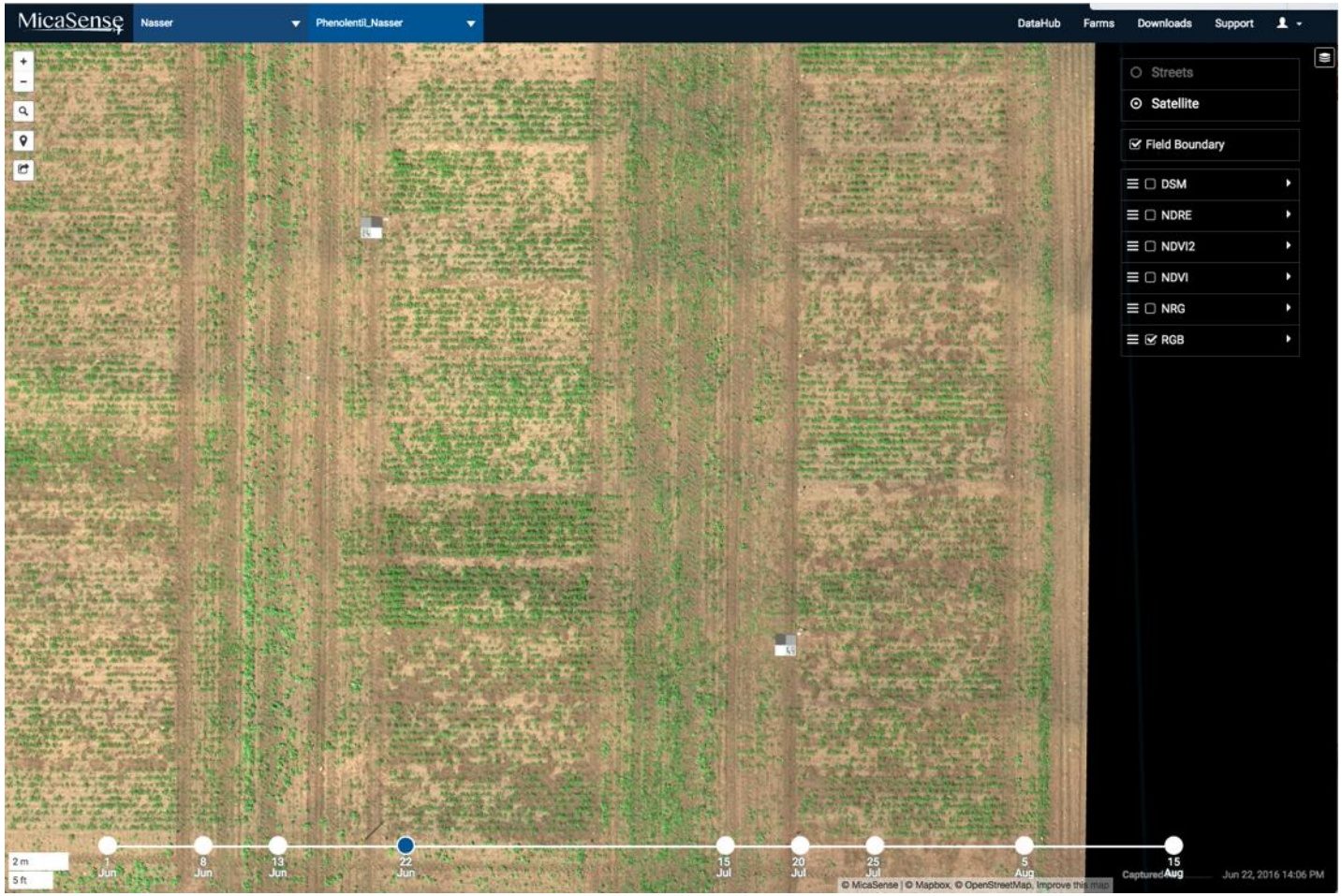
Lentil Phenotrial: 16 diverse cultivars



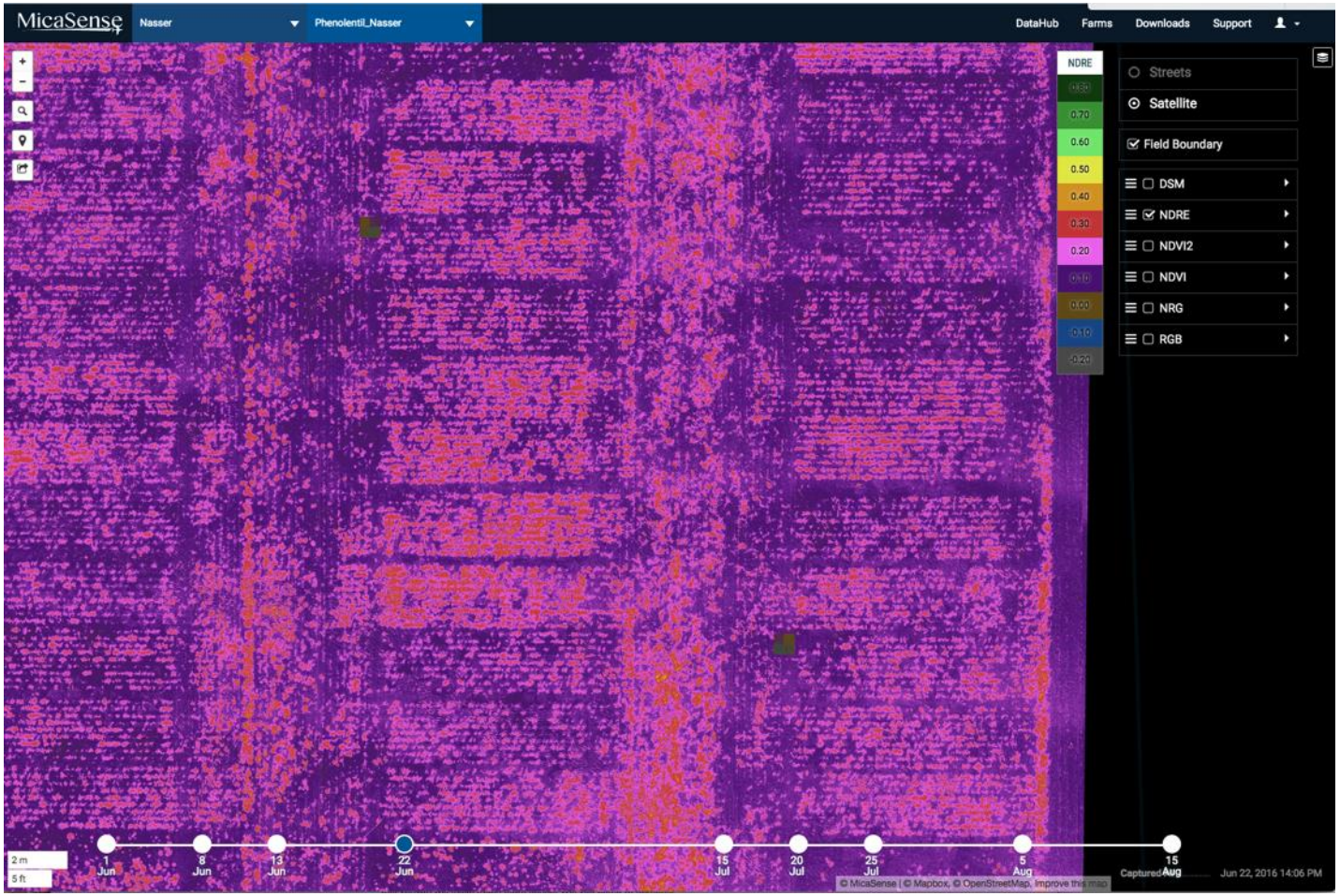
Lentil Phenotrial: 16 diverse cultivars



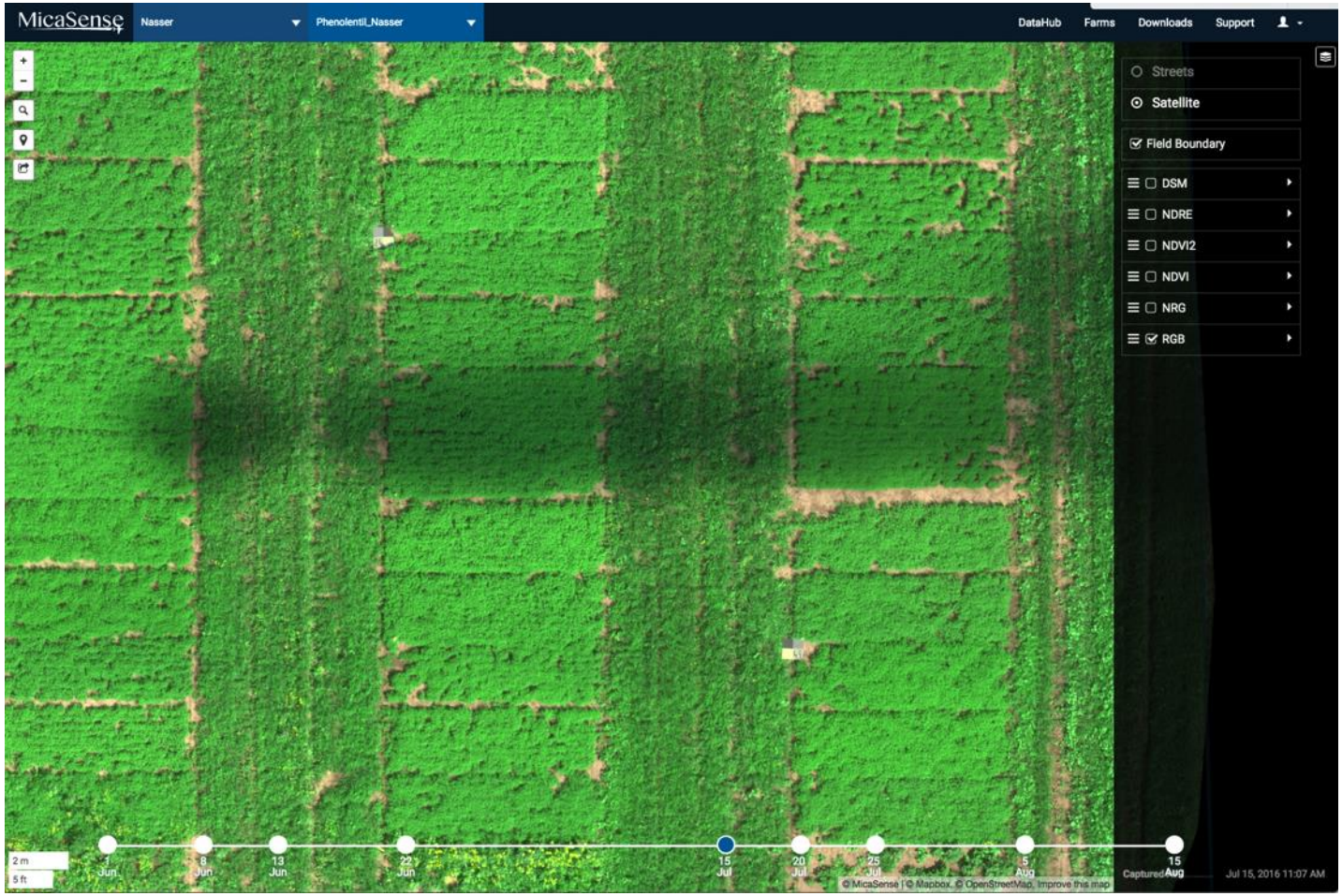
Lentil Phenotrial: 16 diverse cultivars



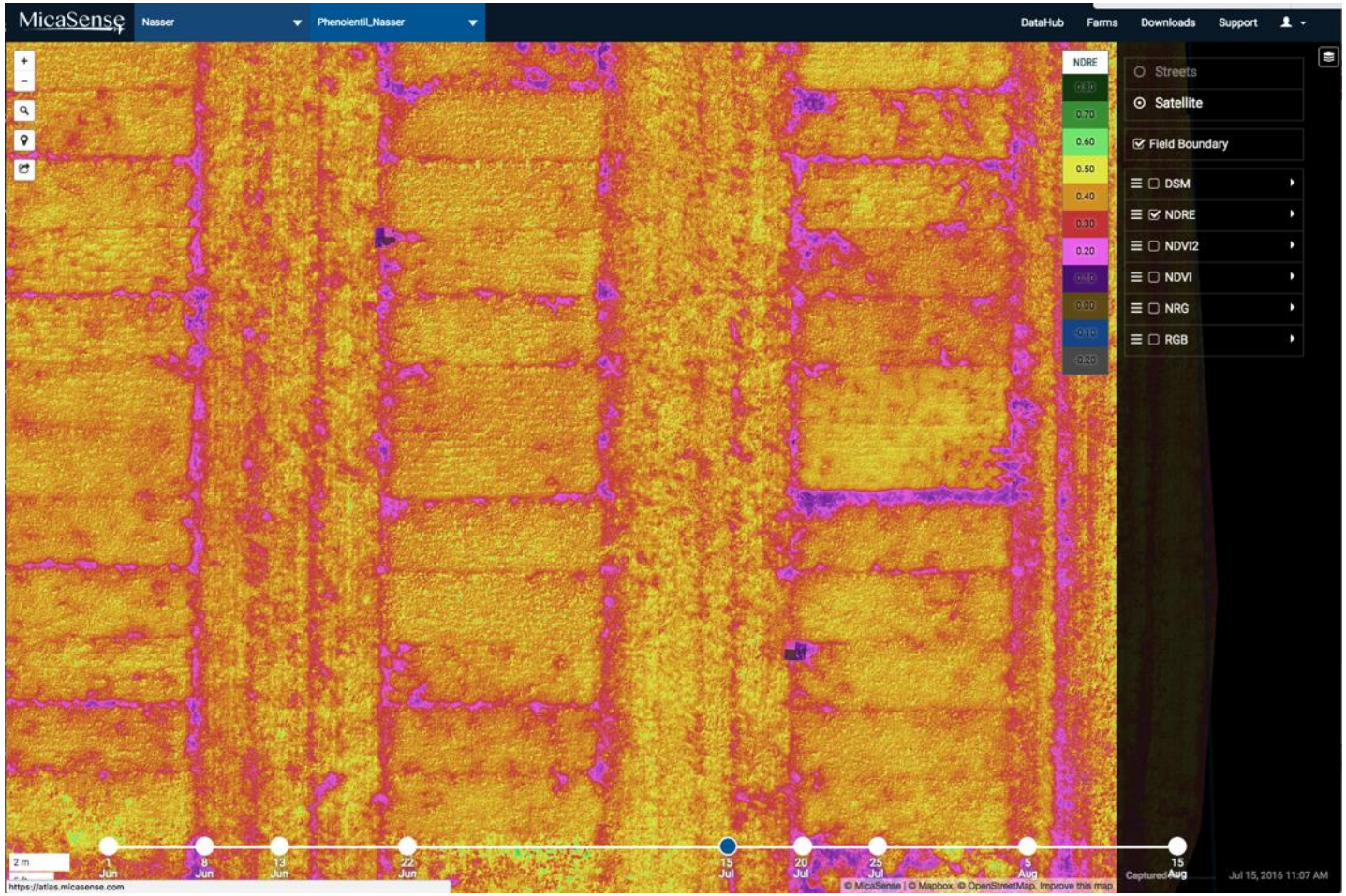
Lentil Phenotrial: 16 diverse cultivars



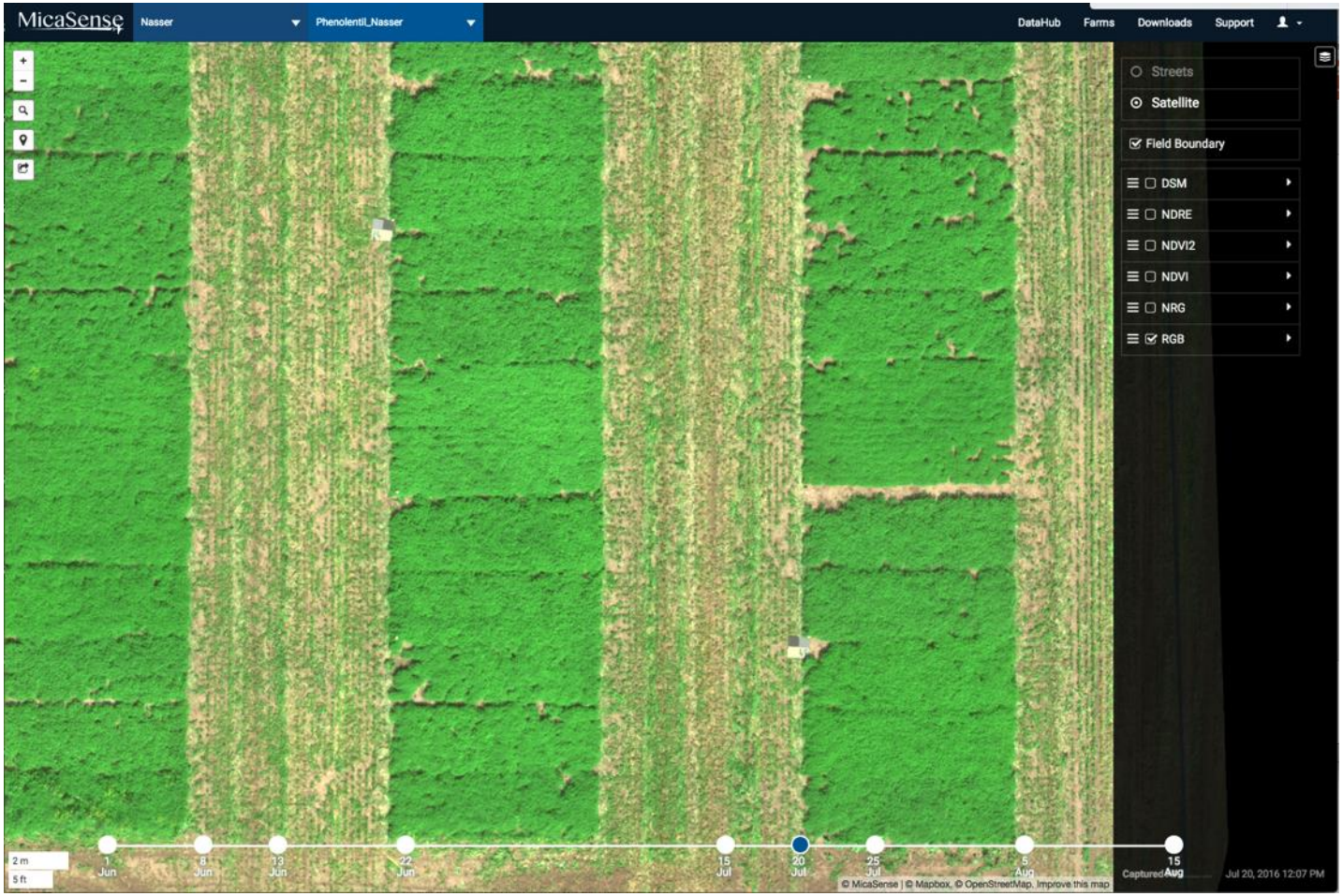
Lentil Phenotrial: 16 diverse cultivars



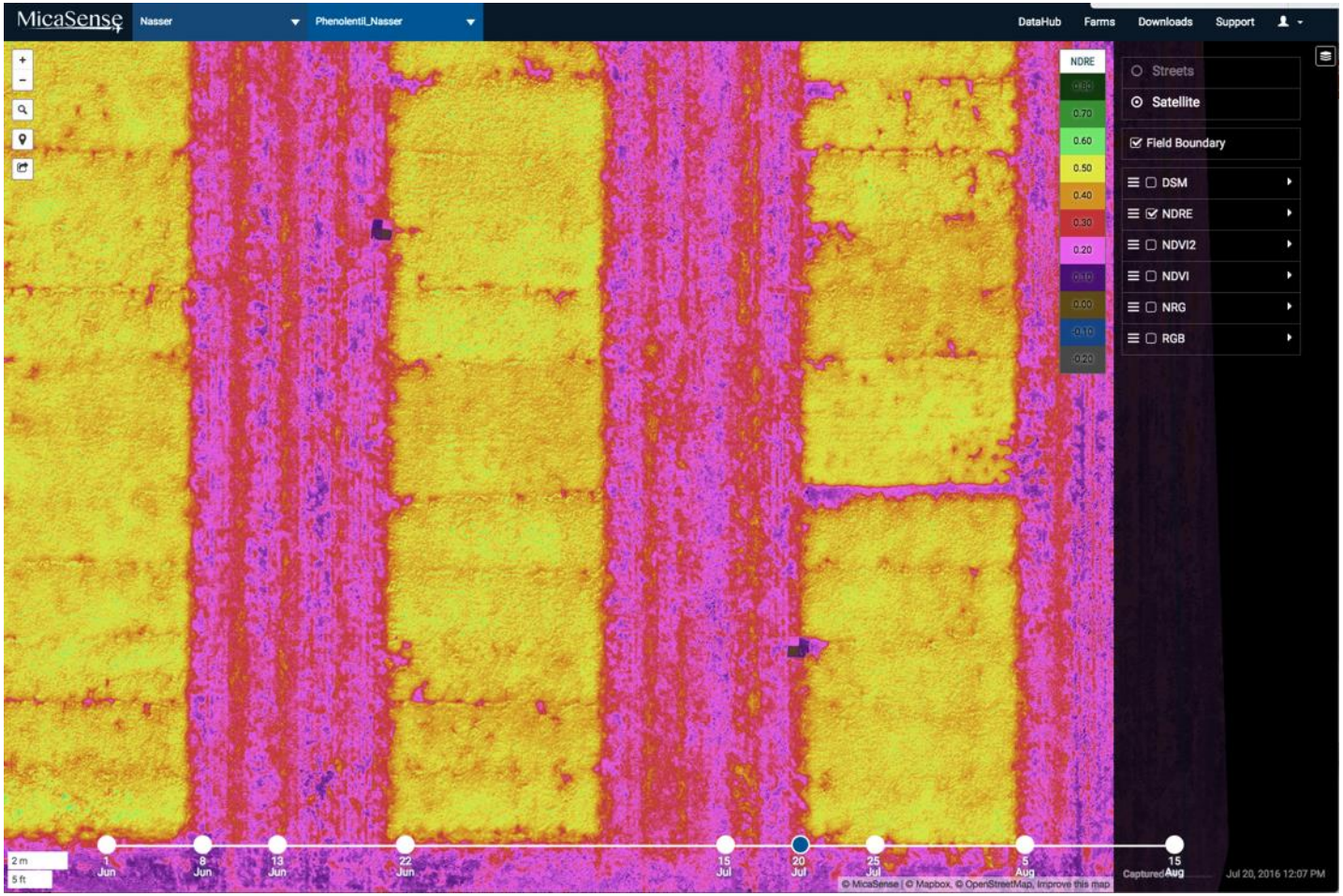
Lentil Phenotrial: 16 diverse cultivars



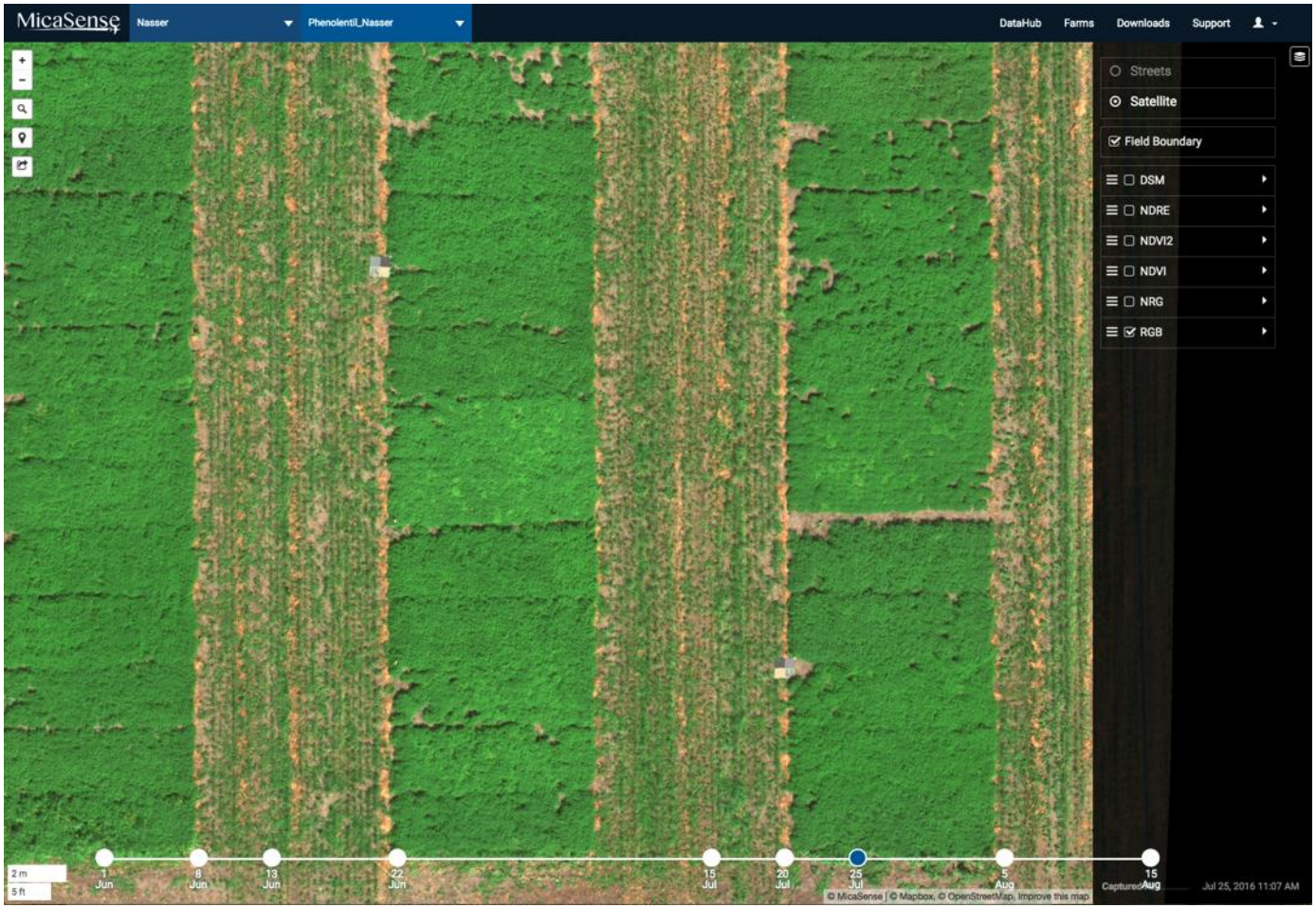
Lentil Phenotrial: 16 diverse cultivars



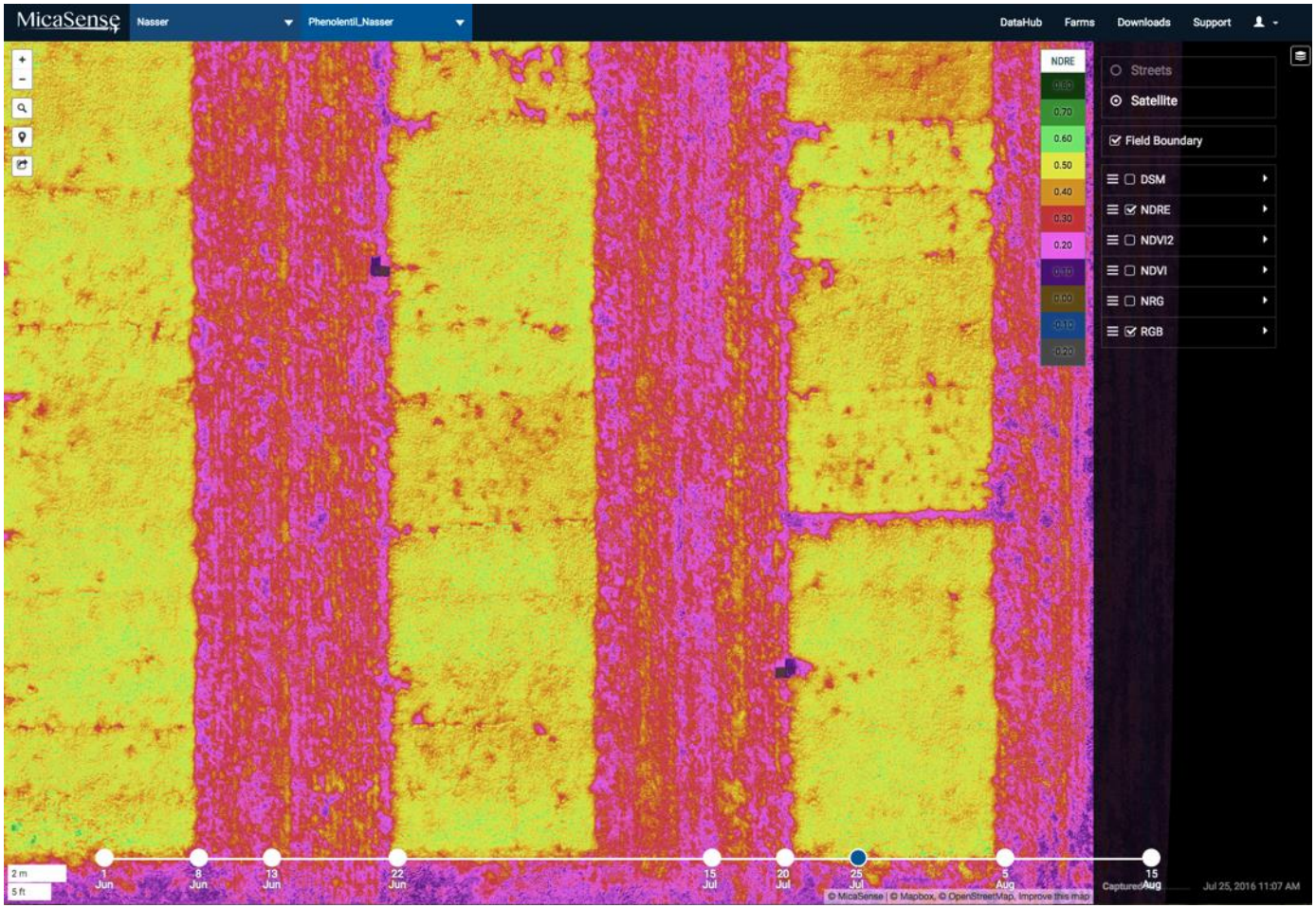
Lentil Phenotrial: 16 diverse cultivars



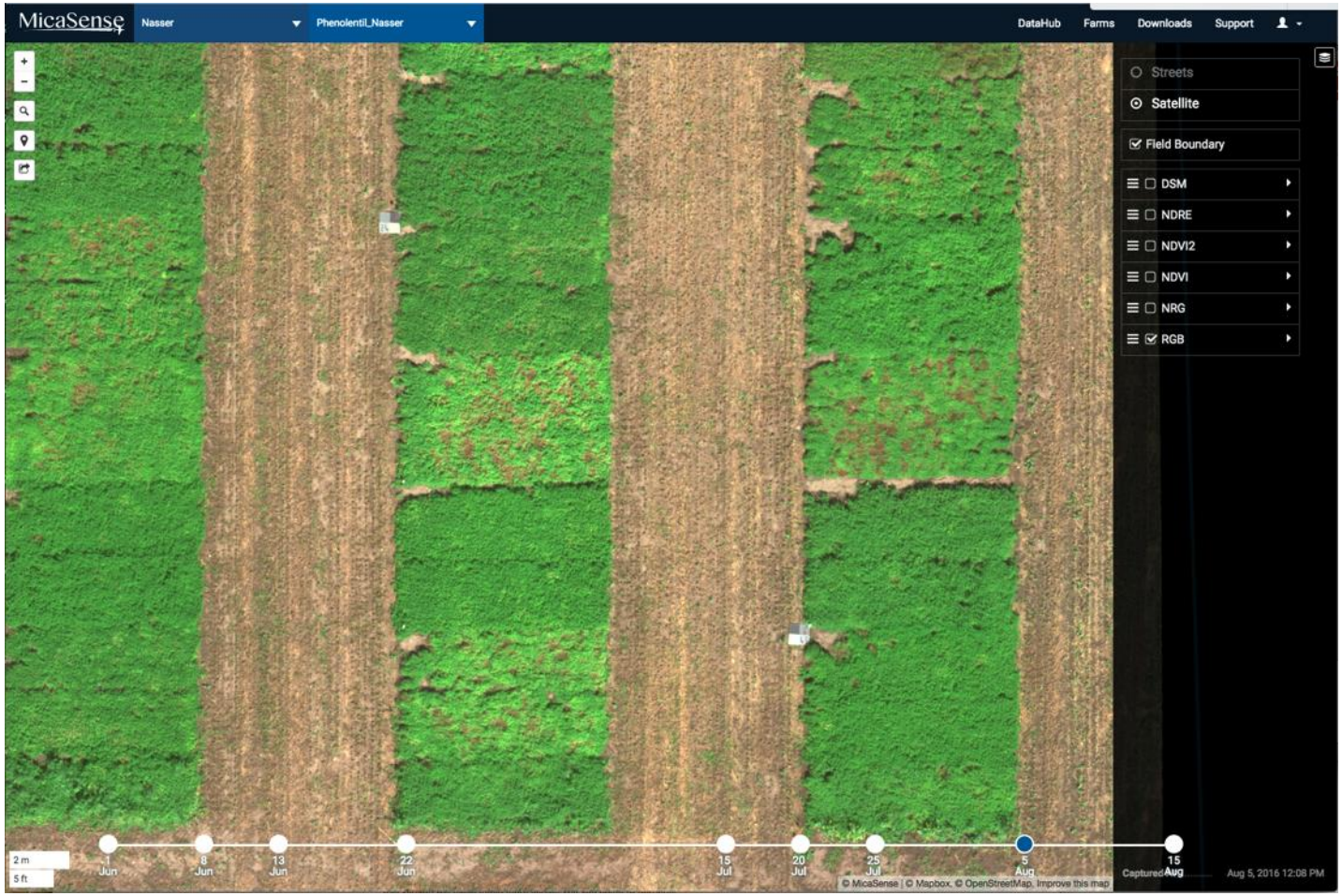
Lentil Phenotrial: 16 diverse cultivars



Lentil Phenotrial: 16 diverse cultivars



Lentil Phenotrial: 16 diverse cultivars



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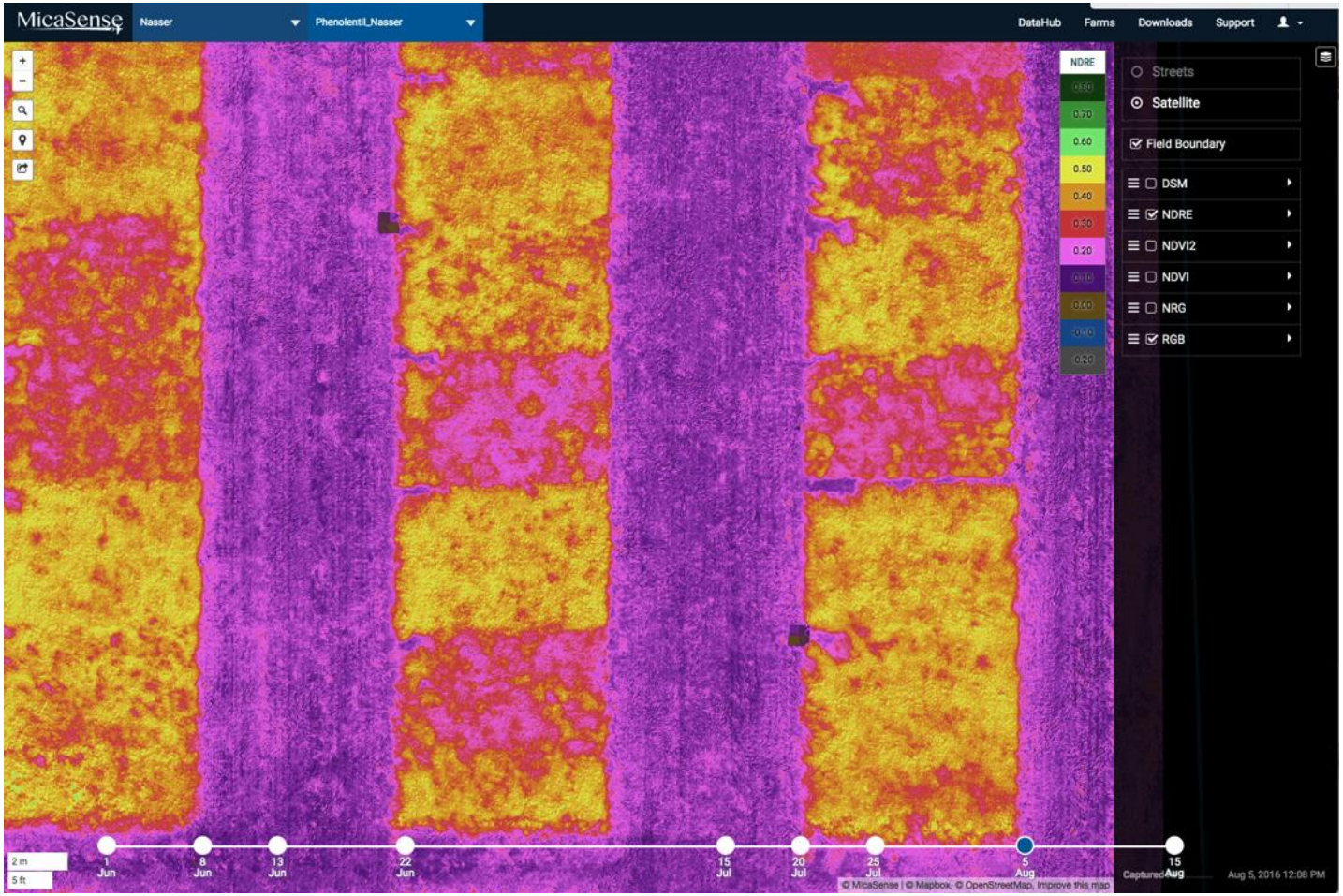

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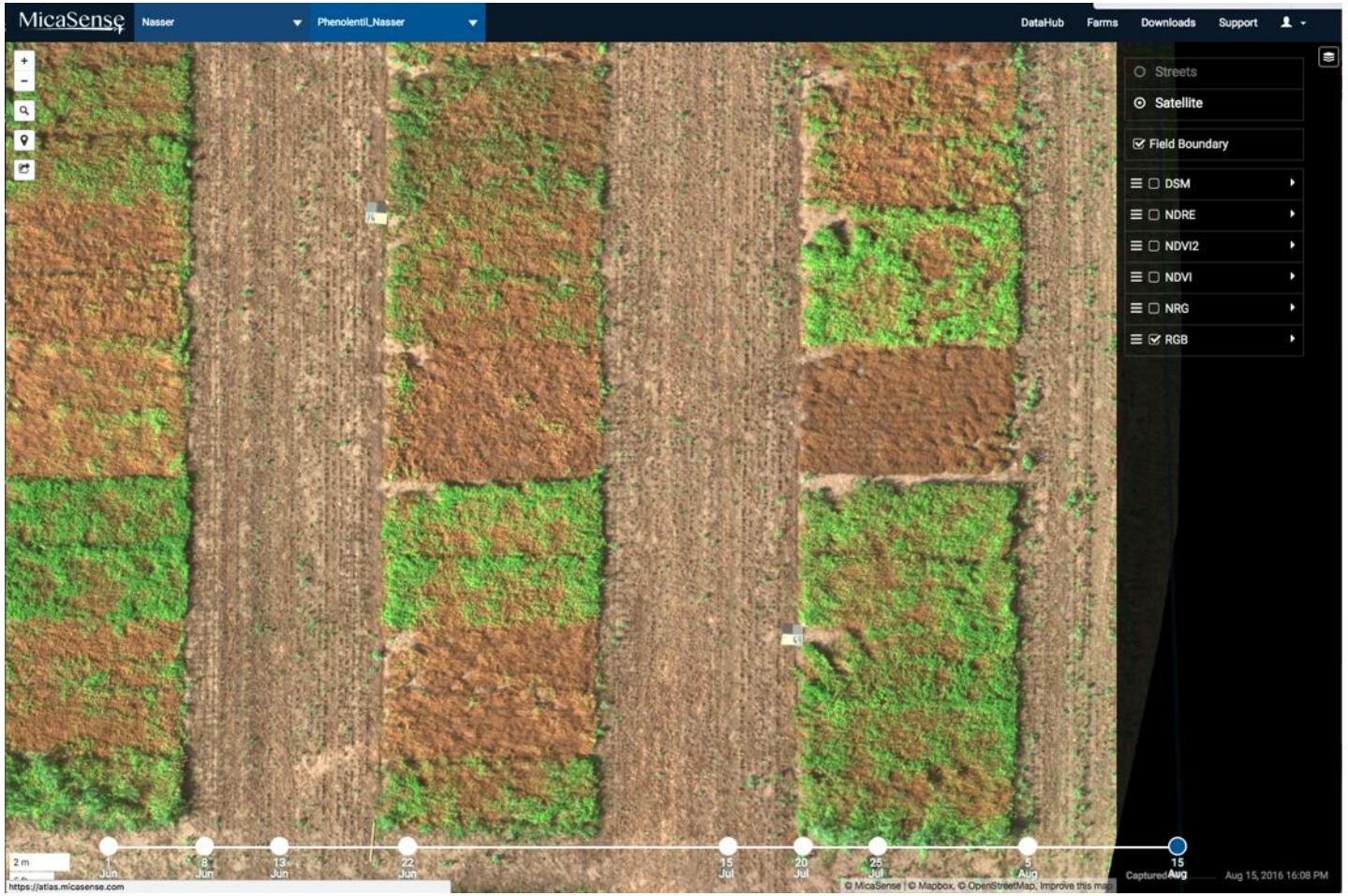

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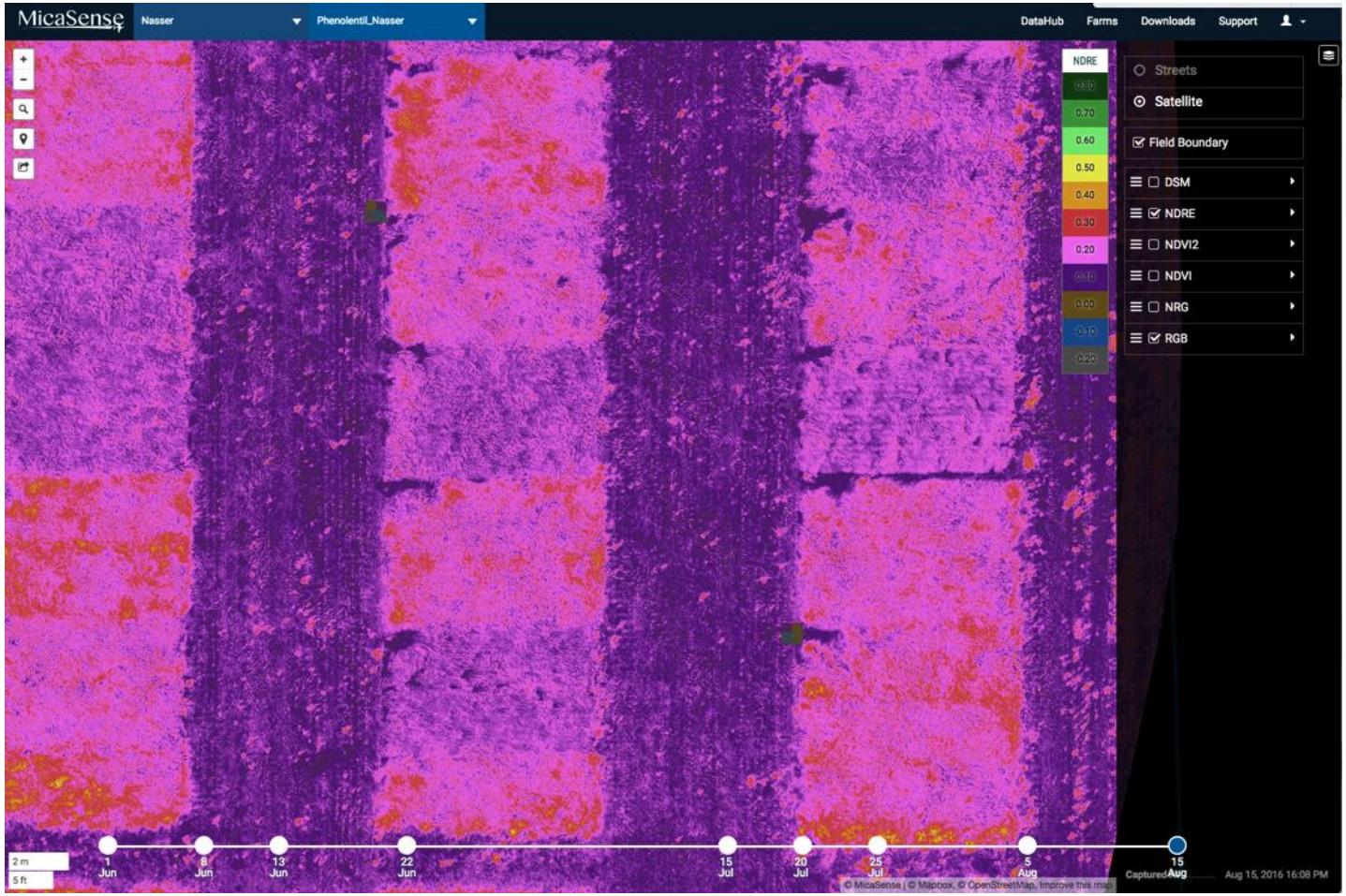
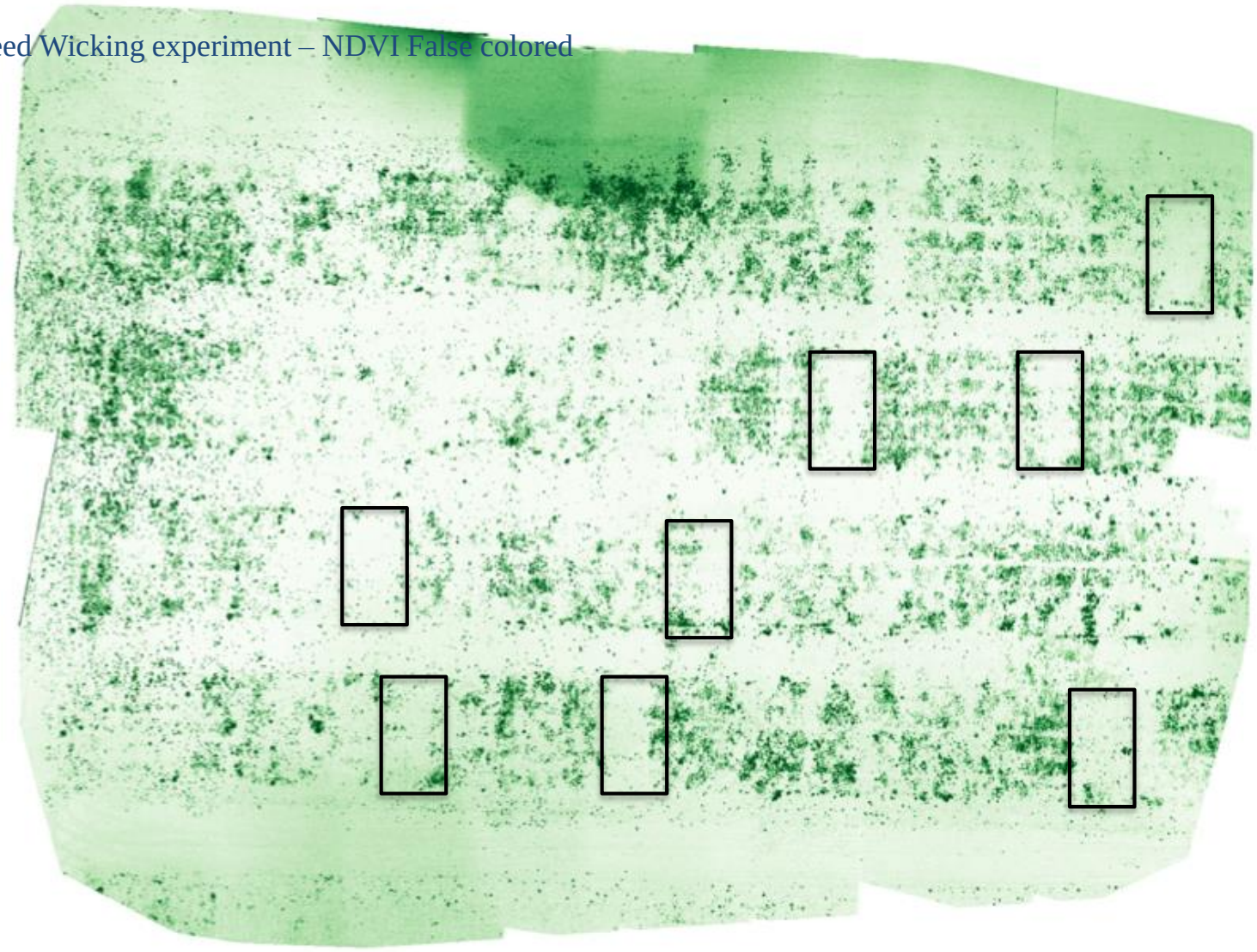


REMOTELY DETECTING WEEDS

Remotely detecting weeds

Mapping weed growth effects

Weed Wicking experiment – NDVI False colored



Challenges for crop imaging

- Workflow issues
- Processing images
  - Takes hours/days to produce 3D surface map
- Image analysis
  - Segmentation
- Modelling, mathematics
  - Reducing images to parameters
- Deciding what to focus on?
  - Important to agronomists and breeders

What do you need?

- The three Rs of remote sensing
- Spatial Resolution
- Spectral Resolution
- Temporal Resolution
- Depends on what you are trying to image

Future

- Expanded ‘fleet’
  - New drones and support vehicle (CFI IF 2017)
  - Two flight crews
- Data analysis (with Comp Sci – Pillar 3)
  - Pipeline for image processing
  - Image extraction and processing (machine learning)
  - Associative analysis with genomics / genetic data
  - Commercial and research agronomic applications
  - Dealing with huge data sets

P2IRC Plant Phenotyping and Imaging Research Centre

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