Remote sensing for estimating genetic parameters of biomass accumulation in alfalfa

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Multi-spectral imaging in alfalfa

- Motivation:
  - Advancement in high-throughput phenotyping (HTP) systems, including multi-spectral imaging (MSI) platforms
  - Need to assess relationship between visual indices (VIs) and biomass yield
  - Opportunity to monitor crop growth over growing season to understand dynamic interactions of crop and environment

- Project development over time
  - 2019-2021: alfalfa trials in NY and NM
  - 2021-2023: alfalfa trials in NY and NM; wheat trials in VA; analysis of private sector trials for maize, soybean, cotton, canola

PI: Kelly Robbins, Associate Professor, Cornell University

NAFA

USDA NIFA

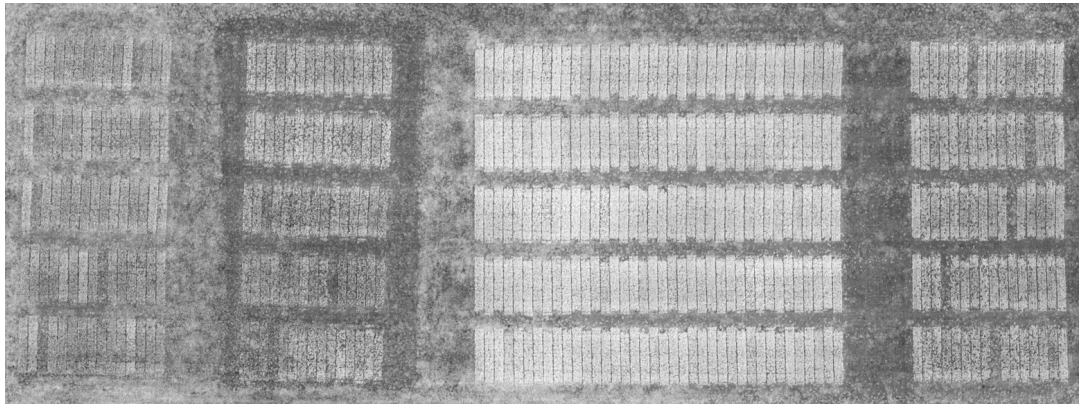
FFAR

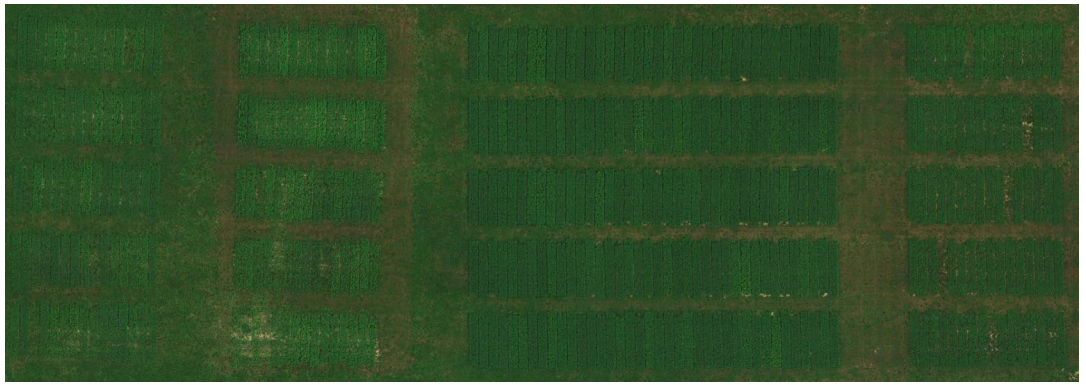
Project objectives

1. Determine the heritability and genetic variation for image features collected through the growing season;
2. Identify predictive image features for modeling growth and development curves for alfalfa; and
3. Estimate the relationship between observed stability for development/growth parameters and stability for alfalfa biomass yield.

Materials and Methods

	Ithaca, NY	Las Cruces, NM
Cultivars	36	24
Irrigation treatments	None	Normal irrigation (NI) vs. summer irrigation termination (SIT)
Replications	5	4
Plot size	6 rows, 1m x 4m	3 rows, 0.9m x 3.35m
Planted	June 2019	September 2019
Harvests	3	6-7
Aerial phenotyping	2020-2021: 56 flights	2021 only: 25 flights





Julie Hansen

Nicolas Morales

Nicholas Santantonio

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Aerial phenotyping data & analysis

Ranjita Thapa

- Aerial phenotyping conducted with Micasense Rededge-MX multi-spectral camera
- Image processing:
  - Orthomosaics constructed using Pix4D
  - Imagebreed used to process images and calculate vegetative indices (VIs)
- Analysis
  - Random regression models using third order of Legendre polynomials (RRLP)
  - GGE biplot analysis
  - Pearson's correlation between variance in biomass yield and VIs

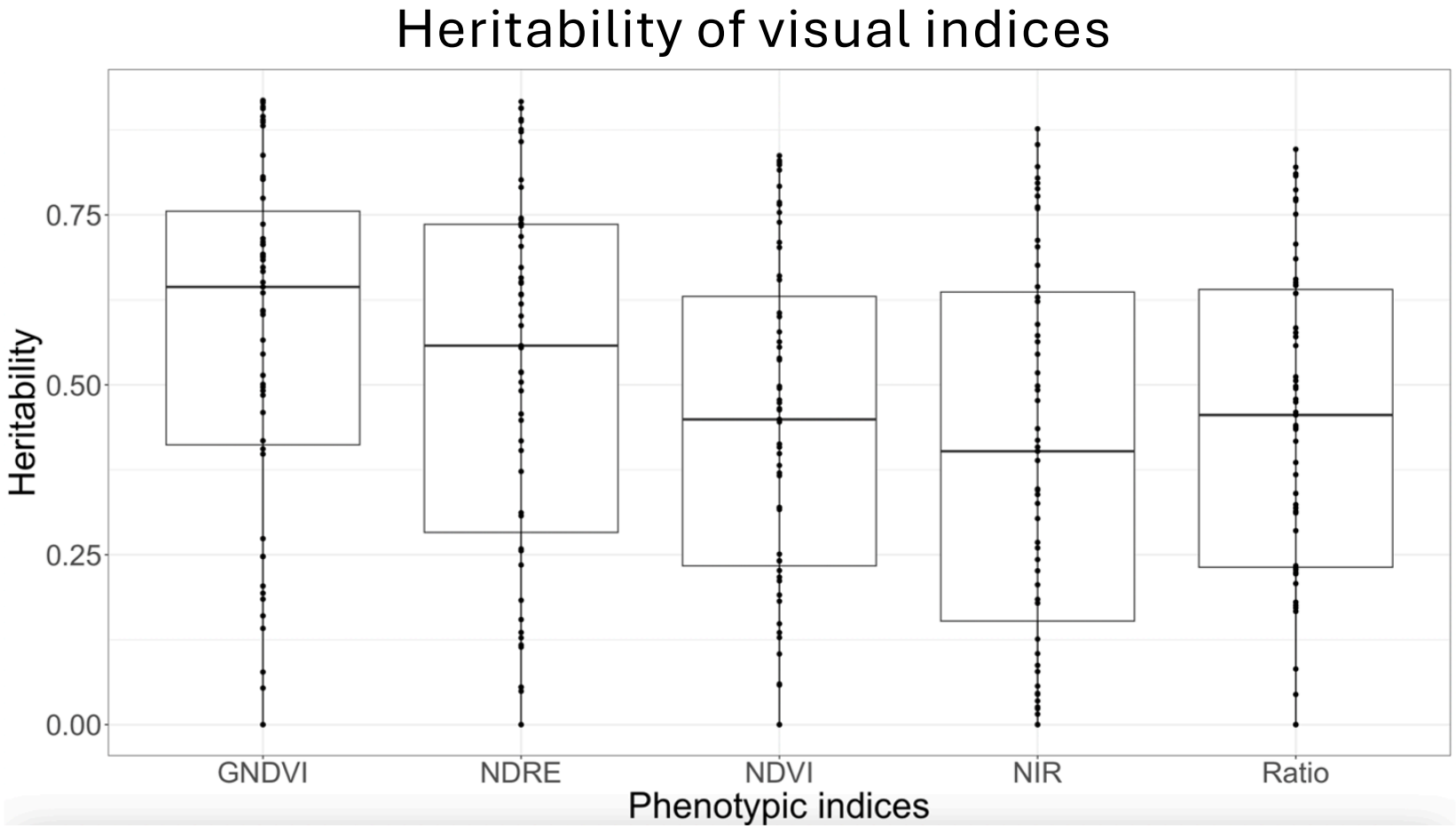
Karl Kunze

Dinesh Ghimire

Vegetation indices (VIs) evaluated

- Normalized difference vegetation index (NDVI) commonly used to estimate biomass
  - $NDVI = \frac{R_{NIR} - R_R}{R_{NIR} + R_R}$
- Green normalized difference vegetation index (GNDVI) used to estimate photosynthetic activity
  - $GNDVI = \frac{R_{NIR} - R_G}{R_{NIR} + R_G}$
- Normalized difference red-edge (NDRE) has been used to predict grain yield
  - $NDRE = \frac{R_{NIR} - R_{RER}}{R_{NIR} + R_{RER}}$
- Near-infrared reflectance (R_{NIR})
- Ratio of NIR:R reflectance
  - $NDVI = \frac{R_{NIR}}{R_R}$

Heritability of VIs & biomass yield (NY)



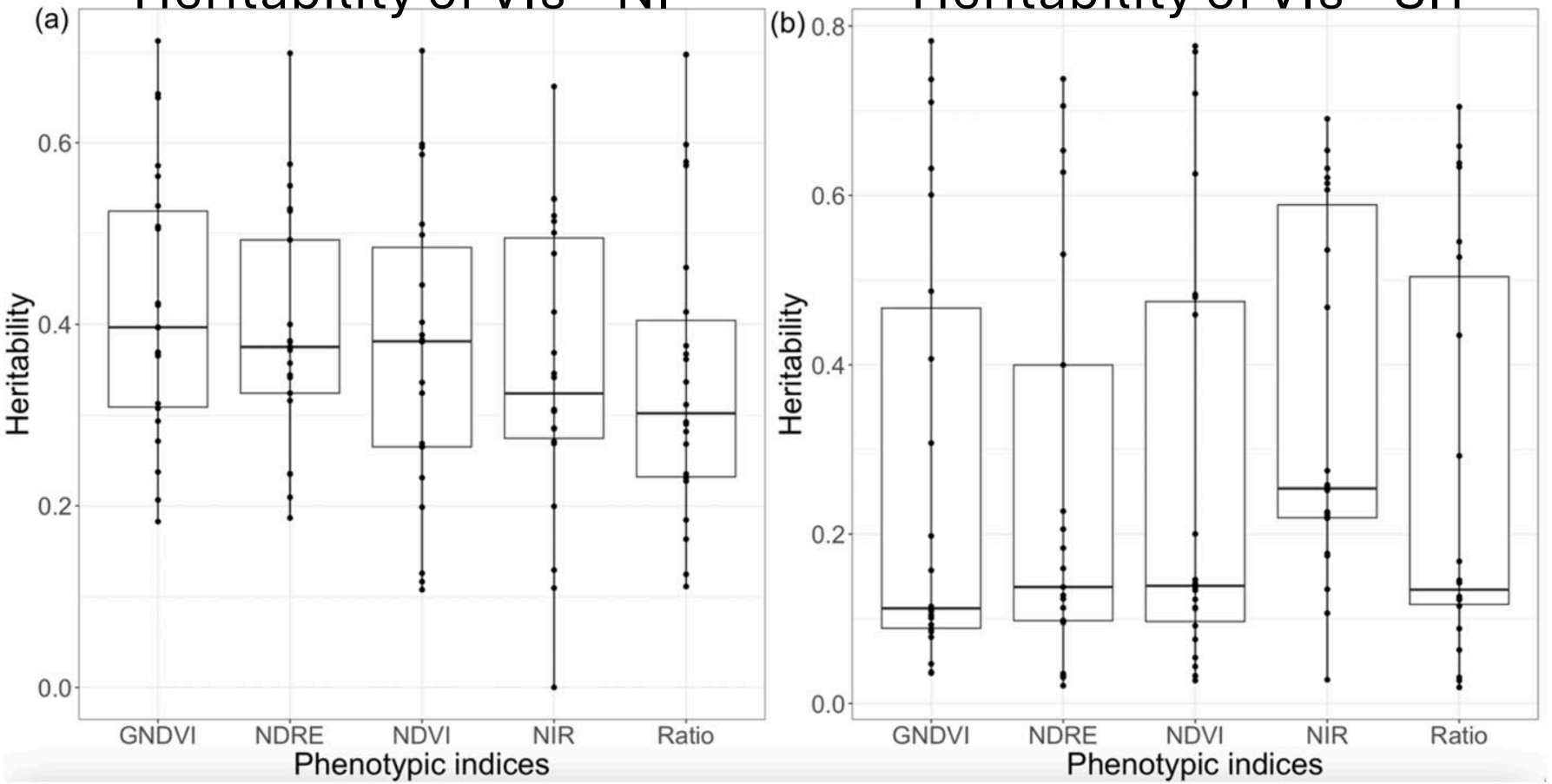
Heritability of biomass yield

	2020	2021
1st harvest	0.56	0.31
2nd harvest	0.31	0.57
3rd harvest	0.32	0.62

Heritability of VIs & biomass yield (NM)

Heritability of VIs – NI

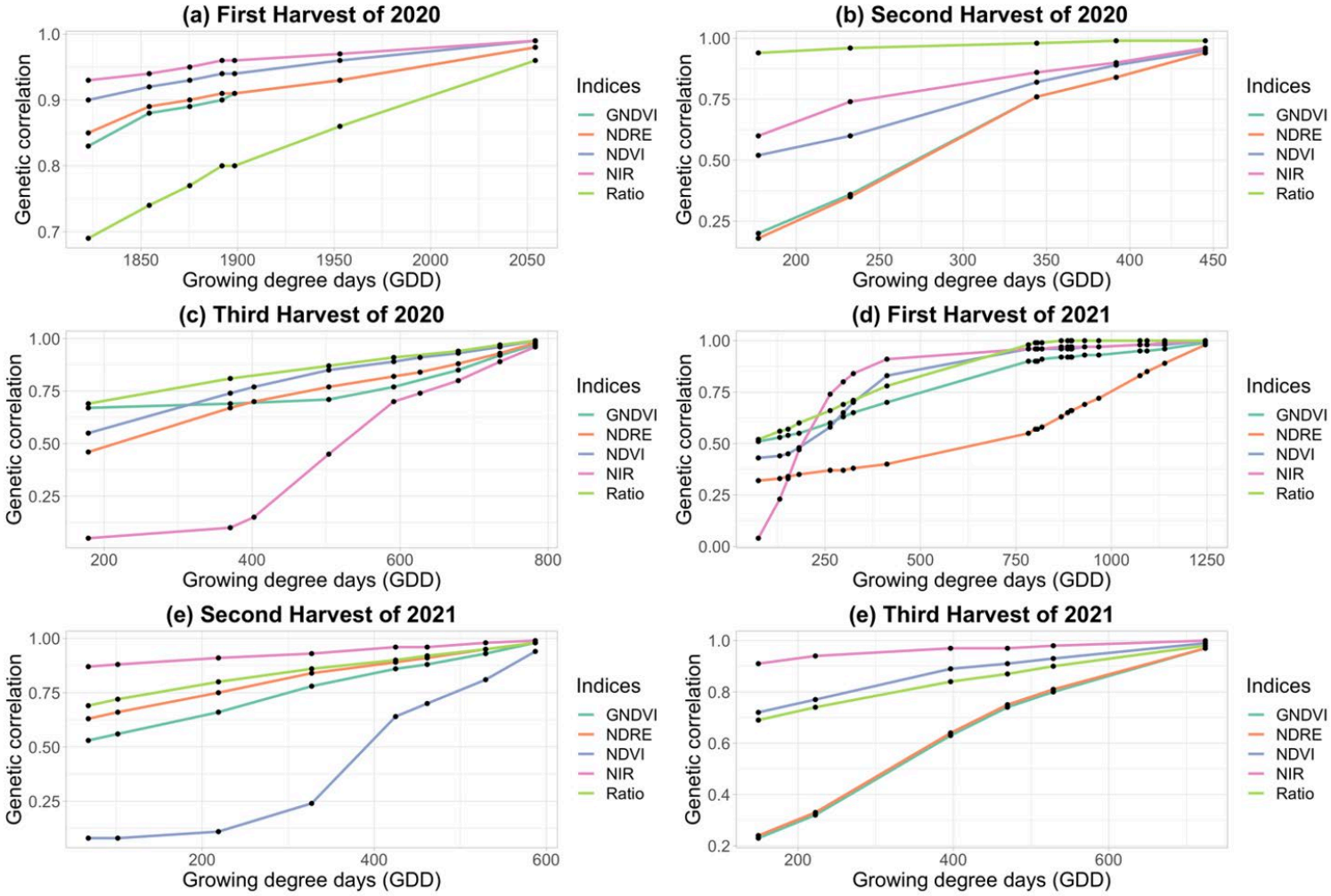
Heritability of VIs – SIT



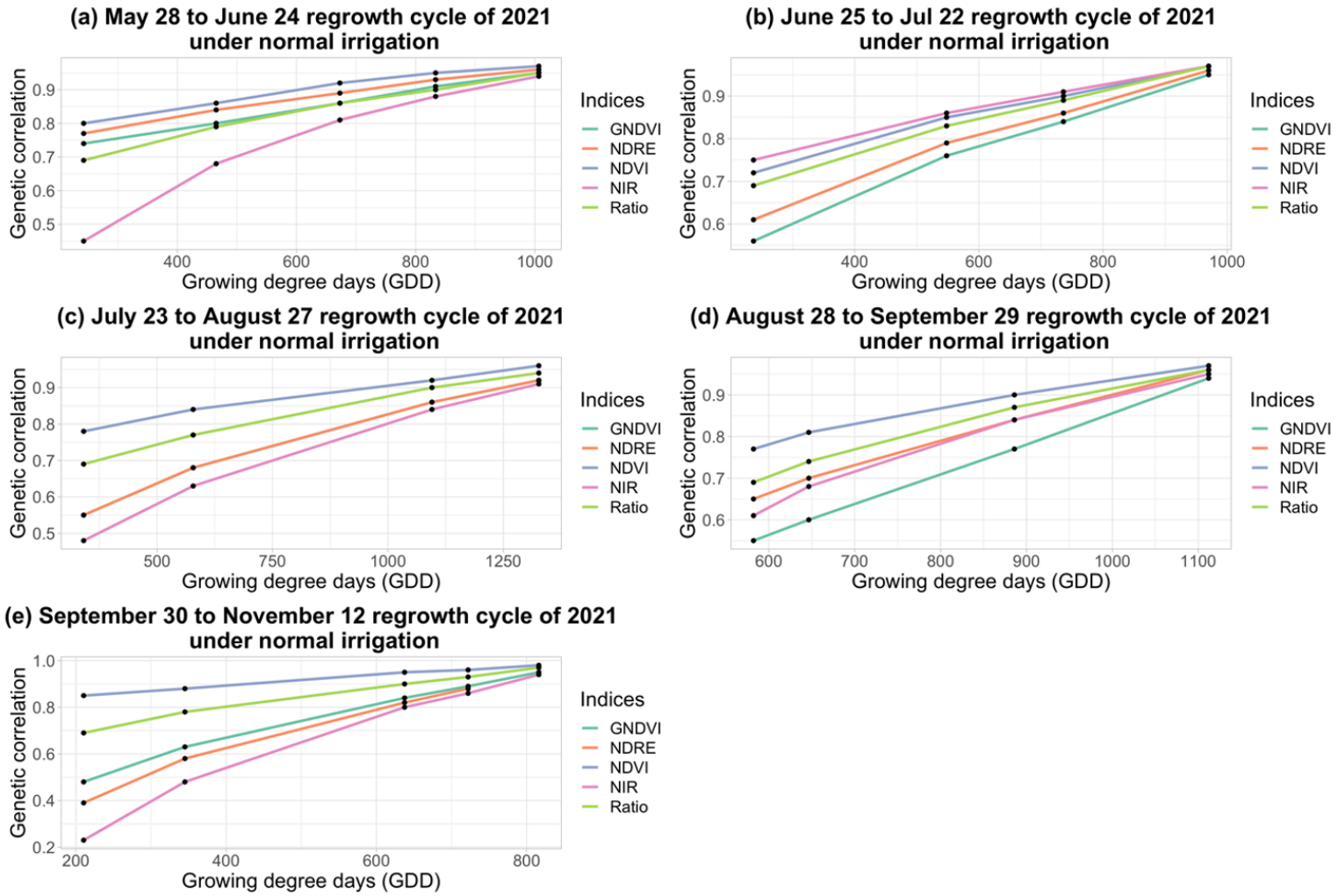
Heritability of biomass yield

- Normal irrigation: highest for 7th harvest (0.4) followed by 3rd and 4th (0.3)
- Summer irrigation termination: highest for 6th harvest (0.8) followed by 3rd (0.2)

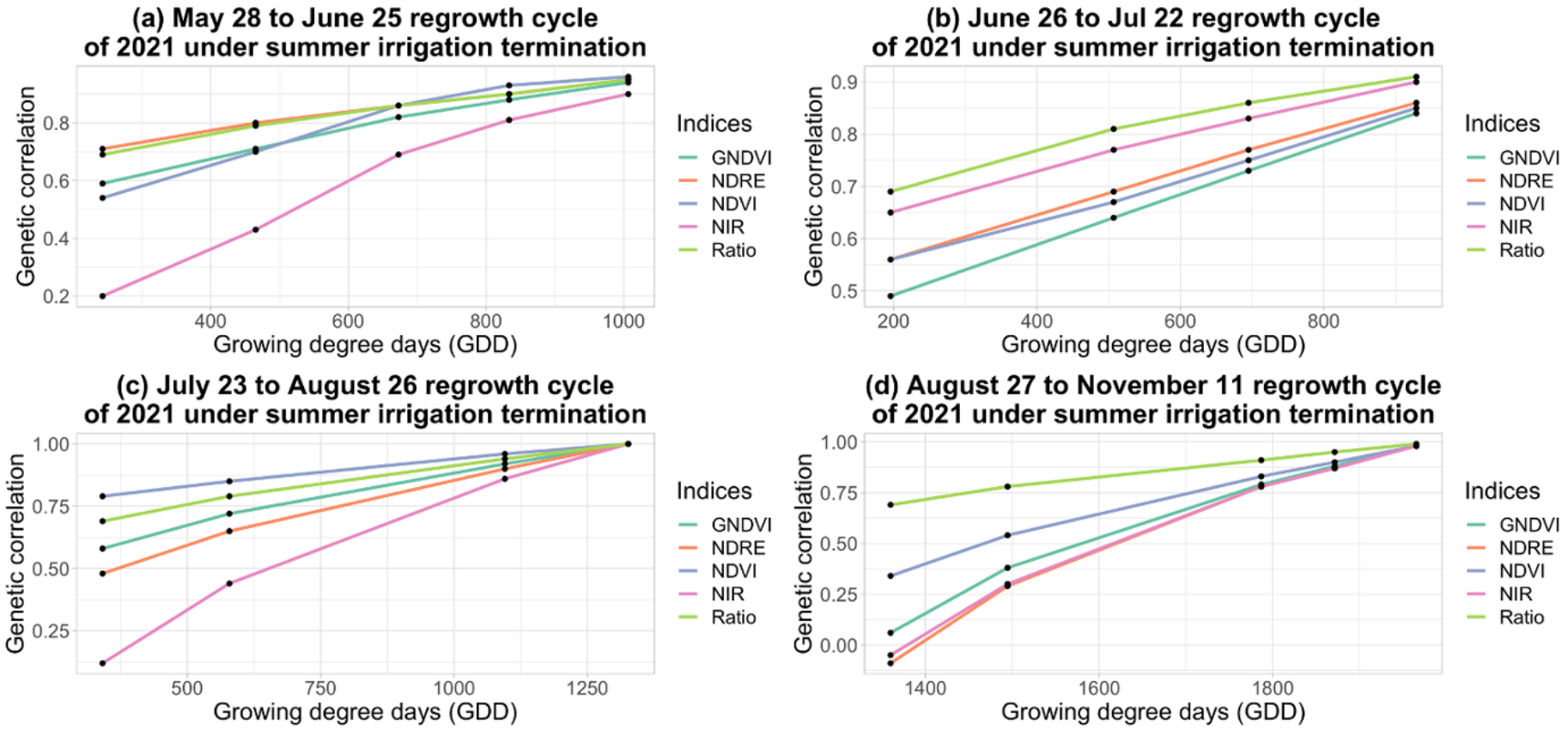
High genetic correlation between VIs & biomass yield (NY)



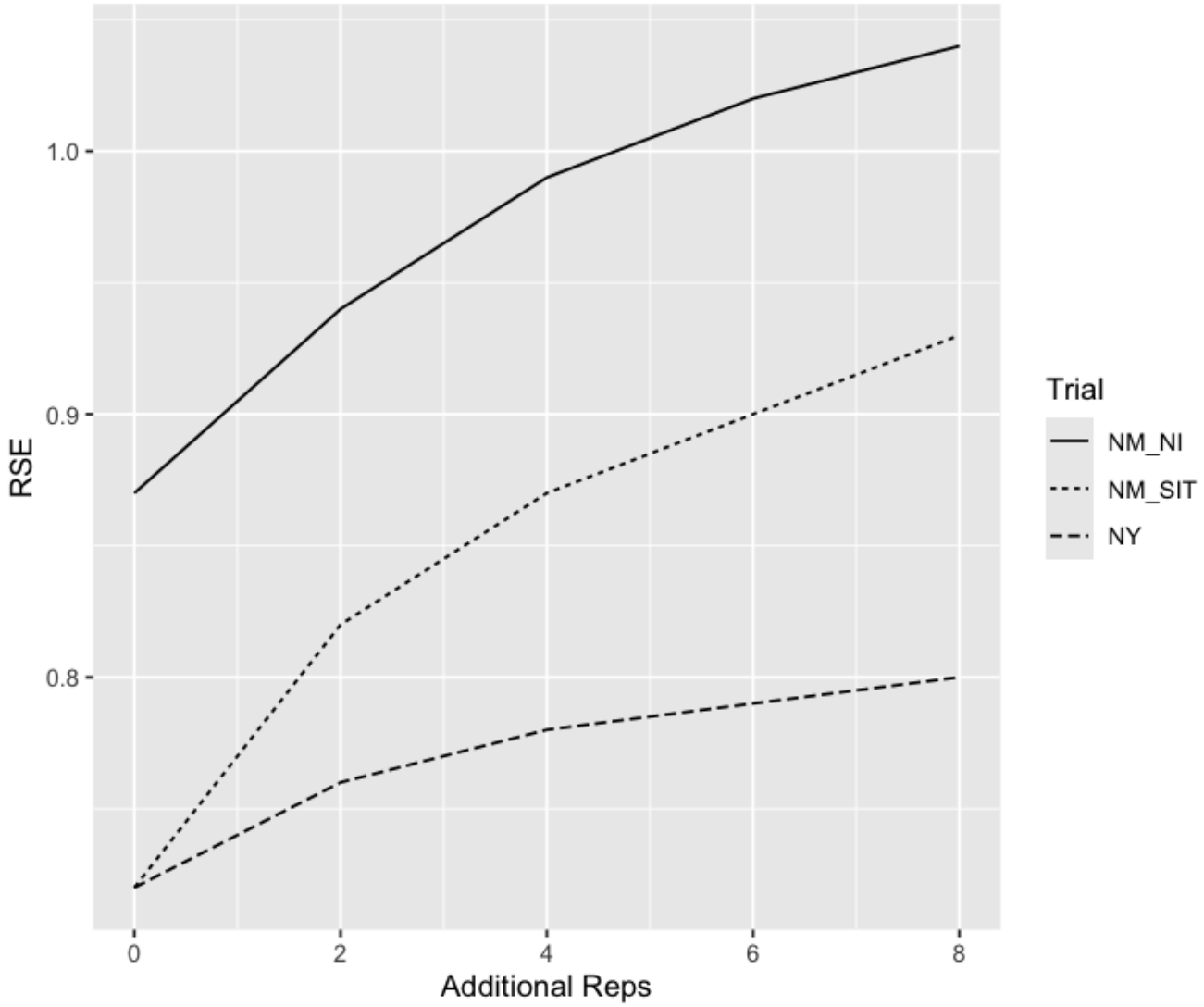
High genetic correlation between VIs & biomass yield (NM, normal irrigation)



High genetic correlation between VIs & biomass yield (NM, summer irrigation termination)



Integrating VIs in forage yield trials?



Opportunities to increase efficiency in variety testing through…

- Harvesting fewer reps?
- Harvesting at fewer timepoints?
- Planting more reps for MSI only?
- Other…?

New Results

Remote sensing for estimating genetic parameters of biomass accumulation and modeling stability of growth curves in alfalfa

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