Remote Sensing for Estimating Genetic Parameters of Biomass Accumulation in Alfalfa

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Alfalfa (*Medicago sativa* L. subsp. *sativa*) is an important perennial legume forage crop, widely cultivated in the world for its higher yield, wider adaptability, nutritional quality, abiotic stress tolerance, resistant to frequent cuttings, and nitrogen fixation properties. However, the intricate genetic architecture, environmental interactions as well as physiological complexity present challenges for traditional breeding program. Leveraging high-throughput phenotyping (HTP) using multi-spectral imaging (MSI) via unmanned aerial vehicles (UAVs), we can study the longitudinal relationship between vegetative indices (VIs) and forage biomass across different cuttings and years in a non-destructive and high throughput approach to measure biomass accumulation of alfalfa harvests. The main objectives of this study were to: utilize remote sensing for estimating genetic parameters (heritability and genetic correlation) of VIs and biomass and fit longitudinal random regression models to study genetic variation in growth patterns across environments and growing seasons.

We found that VIs of GNDVI, NDRE, NDVI, NIR, and simple ratio had moderate heritability with the median values of 0.64, 0.56, 0.45, 0.45, and 0.40 respectively for the Ithaca, NY trial; 0.3967, 0.3813, 0.3751, 0.3239 and 0.3019 respectively for Normal Irrigation trial in Leyendecker, NM and 0.11225, 0.1389, 0.1375, 0.2539 and 0.1343 respectively for Early Termination Trial in Leyendecker, NM. Genetic correlations between harvest biomass and NDVI ranged from 0.25 – 1.00 in 2020 and 0.44 to 1.00 in 2021 for the Ithaca, NY trial. Similarly, genetic correlations for "Normal Irrigation" trial in NM for NDVI ranged from 0.72 – 1.00 in 2021 and for "Early Termination" ranged from 0.1 – 0.9 in 2021. Furthermore, random regression models with third order Legendre polynomials were found to provide the best fit for growth curves.

Our study indicates the strong correlations between VIs and biomass harvest that can be utilized for more efficient cultivar screening, and utilizing remote sensing to capture VIs could potentially reduce the need for extensive biomass phenotyping, thereby lowering overall phenotyping costs.

Abbreviations:
GGE: genotype main effects and genotype by environment; G*E: genotype by environment; GNDVI: green normalized difference vegetation index; NDRE: normalized difference red edge index; NDVI: normalized difference vegetation index; NIR: Near-Infrared; NM: New Mexico; NY: New York