Screening common bean genotypes for drought resistance using high-throughput phenotyping

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Introduction

Common bean is one of the most important grain legumes for human consumption because of its high nutritional value. It is a valuable source of protein, fiber, vitamins, and minerals. In addition to its nutritional value, it also has a high economic value, with seed yield being the most important criterion for its production. In the face of rapid climate change, drought is considered the most damaging environmental stress to agricultural production. Even a short-term water deficit leads to significant losses in crop yields and hinders sustainable agricultural production worldwide.

Drought affects all important physiological and developmental plant processes, such as:
- disrupting the normal function of stomata
- inhibiting gas exchange capacity of plants
- strongly inhibits cell division
- enlargement of the leaf surface
- stem and root growth

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a decline in the photosynthesis rate

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significant losses in crop yields

To achieve sustainable agricultural production in drought-prone areas, the development of drought-tolerant varieties is one of the most important drought adaptation strategies.

With advances in modern technology, we can effectively combine knowledge of phenotype and genotype to promote breeding programs.

plant phenotype + genotype = promote breeding programs

Traditional cultivars represent valuable genetic material that can be used for the selection of desirable agronomic traits. Through genetic analysis, we can detect markers associated with properties responsible for drought tolerance. To find genetic regions associated with phenotypic parameters, those data are needed to perform association mapping.

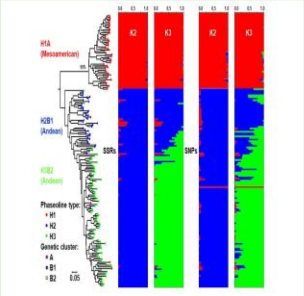
High-throughput phenotyping (HTP) methods have many advantages, such as rapid data acquisition and processing, non-destructive, accurate insights into plant performance under different conditions, and excellent morphological and biochemical characterization of plants.

The most commonly used methods are:
- chlorophyll fluorescence analysis
- multispectral analysis
- 3D multispectral scanning

An in-depth analysis of the physiological background of gas exchange capacity will help select tolerant and susceptible bean genotypes. Resistant plants are known to develop various physiological and biochemical responses of adaptive character under water stress conditions. These include changes in water use efficiency, pigment content, osmotic adjustment, and photosynthetic activity

Materials and methods

Genotyping



According to phaseolin type analysis the accessions were classified into phaseolin type H1 ("S") of Mesoamerican origin and phaseolin types H2 ("H" or "C") and H3 ("T") of Andean origin.

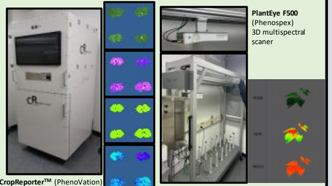
The population structure of landraces based on SSRs is shown here and the accessions were classified into two clusters at K = 2 separating the accessions according to the centers of origin, while at K = 3, the accessions of Andean origin were further classified into two clusters of accessions that differed in phaseolin type (H2 and H3).

Using SNP markers, a model-based analysis of population structure was performed, the results of which were consistent with those of SSR markers.

Phenotyping

200 different bean genotypes will be grown in a growth chamber under controlled conditions, inducing two treatments: control (well-watered plants) and drought stress treatment

High-throughput phenotyping (HTP) techniques will include chlorophyll fluorescence imaging, multispectral imaging, and 3D scanning



CropReporter™ (PhenoVation) Chlorophyll fluorescence and multispectral chamber

PlantEye F500 (Phenospex) 3D multispectral scaner

A detailed and in-depth analysis of the physiological background of gas exchange capacity will be performed on the selected tolerant and susceptible bean genotypes

LI-6800 (LI-COR Biosciences) **LI-600**

Measured traits with the abbreviations

Color and multispectral traits	
Abbreviations	**Traits**
R_{Red}	Red reflectance
R_{Green}	Green reflectance
R_{Blue}	Blue reflectance
R_{FarRed}	FarRed reflectance
R_{NIR}	Near-infrared reflectance
R_{SpcGrn}	Specific green reflectance
HUE	Hue
SAT	Saturation
VAL	Value
CHI	Chlorophyll index
ARI	Anthocyanin index
GI	Greenness index
NDVI	Normalized difference vegetation index
PSRI	Plant senescence reflectance index

Chlorophyll fluorescence traits	
Abbreviations	**Traits**
F_v/F_m	The maximum quantum yield of PSII
$F_{q'}/F_{m'}$	The effective quantum yield of PSII
ETR	Electron transport rate
NPQ	Non-photochemical quenching

Morphological traits	
Abbreviations	**Traits**
DV	Digital volume
PH	Plant height (mm)
TLA	Total leaf area (cm^2)
LAI	Leaf area index
LANG	Leaf angle (°)
LINC	Leaf inclination
LPD	Light penetration depth (mm)

Gas exchange traits	
Abbreviations	**Traits**
gs	Stomatal conductance
E	Transpiration rate
C_i	Intercellular CO_2 concentration
A	Photosynthetic rate

Contribution

This PhD will help:

1. To select potentially resistant bean genotypes to drought stress.
2. Select the most important (sensitive) plant phenotypic traits which could be used for the detection of drought stress.
3. Combine modern phenotyping and genotyping techniques
4. By performing phenotypic analyses of physiological parameters, association mapping will be carried out to find genetic regions associated with phenotypic parameters of chlorophyll fluorescence, gas exchange parameters, and vegetation indices
5. Contribute to the development of breeding programs and agricultural production itself

Environment

Interaction ⟷

Genotype

Phenotype