

Genetically-Enhanced Winter-Hardy Faba Bean (*Vicia faba* L.)

Germplasm

for Cover Crop Cultivar Development

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Abstract: Cover crop utilization in North American farming systems is expanding. In response to a recent surge in demand for diverse sources of cover crops, we are working on enhancing the winter-hardiness of faba bean (*Vicia faba* L.) for use as a winter leguminous cover crop. Faba bean is grown world-wide as a pulse (grain legume) crop and several studies have demonstrated a net N benefit (up to 100–200 kg N ha⁻¹) for the following crop in rotation. The USDA faba bean germplasm collection of ~800 accessions from 60 countries is maintained at the Western Regional Plant Introduction Station in Pullman, WA. This germplasm collection has captured a sufficient amount of genetic variation and contributed to our effort in enhancing winter-hardiness by using natural selection for over-wintering in southeastern Washington. We have recently released four winter-hardy faba bean germplasm lines after selection over five consecutive winter seasons for pulse and cover crop development in the U.S. Pacific Northwest and other regions up to USDA Plant Hardiness Zone 6b. Progress is being made in selecting for higher biomass yield and smaller seed size, important traits for economical use of faba bean as a cover crop. A new line with high yield potential (over 2,300 kg ha⁻¹) in two consecutive years and small seed size (0.4 grams seed⁻¹) is in the process of germplasm release for cover crop development.

The USDA-ARS National Plant Germplasm System (NPGS)

The USDA-ARS National Plant Germplasm System (NPGS) is charged with the specific role of acquiring, characterizing, preserving, documenting, and distributing germplasm to scientist users for research and breeding, not just in the US but worldwide. As of 21 September 2017, the NPGS holdings were 583,755 accessions belonging to 15,692 species in 2,522 genera and 244 families. Most of the collections are managed as seed and some are vegetatively propagated. Through a well-coordinated network, these accessions are assigned to 28 genebank localities that were set up according to climatic and political needs (Fig. 1).

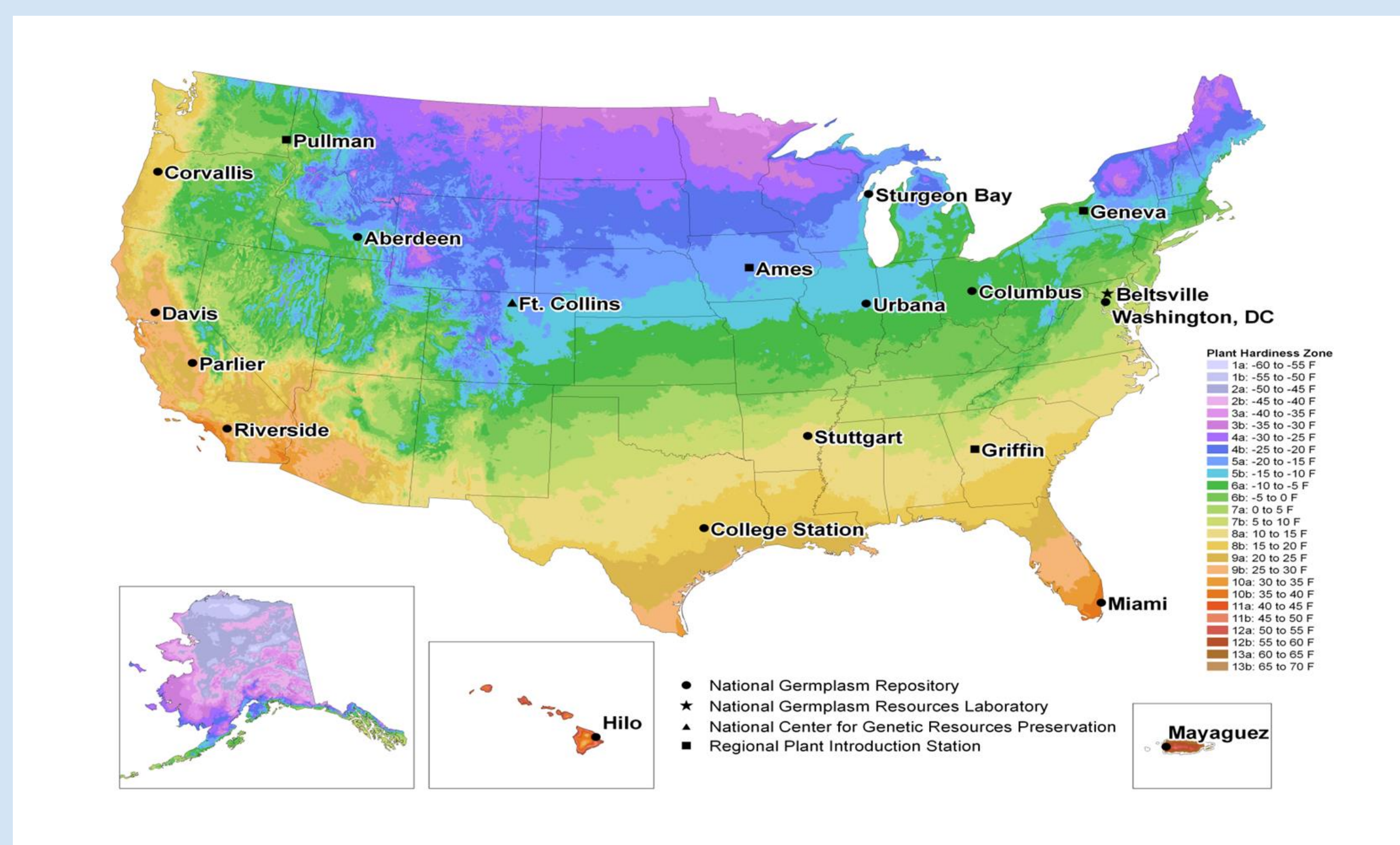


Fig. 1. Locations of the Regional Plant Introduction Stations (squares), Germplasm Repositories (round dots), Germplasm Resources Laboratory (star) and Genetic Resources Preservation Center (triangle) in the National Plant Germplasm System on the USDA Plant Hardiness Zone Map.

Faba bean Germplasm Enhancement Research at WRPIS, Pullman, WA

There are approximately 800 faba bean accessions collected worldwide and maintained at WRPIS. We have revealed that this small collection captured a high level of genetic diversity using the Target Region Amplification Polymorphism (TRAP) marker system (Kwon et al., 2010). It has been reported that faba bean has the highest capacity of biological nitrogen fixation (BNF) among major cool season food legumes and has a great potential to be used as a cover crop or a green manure crop to fit in the contemporary trends of organic farming and sustainable agriculture. Our screening for winter hardy materials from this collection started in 2009. After six years of consecutive selection using the natural winter field condition and a modified mass selection scheme (Landry et al., 2017) in the Palouse region, we released four winter hardy germplasm lines for pulse and cover crop development (Landry et al., 2015). These lines can survive the harsh winter field conditions (Fig. 2).



Fig. 2. High percentage survival of the enhanced winter hardy faba bean lines on the WRPIS' Pullman farm (46° 43' 55" N; 117° 09' 25" W). The plots were planted on October 25, 2016 and the picture was taken on February 10, 2017. Almost all the seedlings in the adjacent plots died during the winter months. The lowest temperature recorded on site were -10.5 °F (-23.6 °C) on December 17, 2016 and -6.2 °F (-21 °C) on January 5, 2017.

Faba bean is a cool season legume and is sensitive to heat. It was reported that temperature above 80 °F (23 °C) during the reproductive stage can lead to the termination of flowering. We initially identified materials that can tolerate temperature of 100 °F (37.7 °C) on our Pullman farm (Fig. 3). This year, we collaborated with the International Center for Agricultural Research in the Dry Areas (ICARDA) and evaluated 140 lines of the ICARDA faba bean reference set at our Central Ferry Research Farm to identify DNA markers associated with heat tolerance using the genotyping by sequencing and genome-wide association study approaches.



Fig. 3. A breeding line tolerant to high temperature on our Pullman Farm. This field picture was taken on June 28, 2015. The recorded temperature on site was 104 °F (40 °C). The pictures of the heat sensitive (right upper) and heat tolerant (right lower) plants were taken on June 29, 2015.

Potential Cover Crop Germplasm Lines on an Organic Farm in California

In 2014, we distributed ten breeding lines under an ARS Plant Evaluation Agreement to The Lundberg Family Farms for adaptability and suitability to its annual rice-faba bean double cropping system. After two years selection under the organic environment, two top lines with good biomass and seed yield were selected for seed increase (Fig. 4). This year, supported by a germplasm evaluation grant from the Food Legumes Crop Germplasm Committee, we evaluated 100 NPGS faba bean accessions in a replicated field experiment under organic conditions for desirable cover crop traits. The phenotypic trait data collected from this field experiment will be uploaded to our GRIN-Global data base.



Fig. 4. A new faba bean germplasm line developed in Pullman, WA with good cover crop traits (higher biomass and smaller seed) performed well on an the Lundberg Family Farm. These photos show that this faba bean line (right) did better than vetch (left) in competing with weeds on an organic farm near Knights Landing, California. Both vetch and faba bean in this field were planted on November 18, 2016. We are in the process of releasing this germplasm line for cover crop development.

References

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Landry, E.J., C.J. Coyne, R.J. McGee and J. Hu. 2017. A modified mass selection scheme for creating winter-hardy faba bean (*Vicia faba* L.) lines with a broad genetic base. *Euphytica*, 213(3), p.72.