Pre-breeding Alfalfa With Crop Wild Relatives: The Power of Long-term Investment


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Summary

Crop wild relatives hold essential solutions for climate-resilient agriculture. By pre-breeding cultivated alfalfa with wild relatives, researchers have developed promising pre-breeding lines, some of which are high-yielding varieties capable of withstanding hot and dry summers combined with severe winters in Kazakhstan, Kyrgyzstan, Chile and China. These pre-breeding materials were further introduced in Zambia to improve mixed livestock production focusing on dairy. These achievements were made possible through sustained, long-term investment under the *Adapting Agriculture to Climate Change: Collecting, Protecting and Preparing Crop Wild Relatives* (CWR) project (2010–2021) and its continuation, the *Biodiversity for Opportunities, Livelihoods and Development* (BOLD) project (2021-present). Both initiatives demonstrate how continuous funding made complex pre-breeding possible by using conserved wild material and developing CWR-derived varieties to directly benefit farmers, consumers and contribute to global food and nutrition security.

Background

Crop genetic diversity is lost during the process of domestication, limiting the stress adaptive capacity of modern cultivars under climate uncertainties. Pre-breeding offers a pathway to restore this lost diversity by viable hybridization between crops and crop wild relatives (CWR), allowing stress-resilient traits from wild species to be integrated with beneficial agronomic traits such as high yield.

However, pre-breeding is costly, labor-intensive and time-consuming and often requires multiple generations of hybridization and trait evaluation (Dempewolf *et al*., 2017). Despite these challenges, the economic benefits of using CWR for crop improvement are significant: Tyack and Dempewolf (2015) estimated global annual benefits range from USD 8 million to USD 165 billion.

For efficient conservation and use of CWRs, the Crop Trust launched the 10-year *Adapting Agriculture to Climate Change: Collecting, Protecting and Preparing Crop Wild Relatives* Project (2010–2021; also known as the CWR Project). This was the first systematic, long-term global initiative to support the conservation and use of CWR in pre-breeding for 19 food-security crops (Kilian *et al*., 2021). Building on the success of the CWR project, the *Biodiversity for Opportunities, Livelihoods and Development* (BOLD) Project established another 10-year plan to extend the development and evaluation of CWR pre-bred lines for seven crops, with the goal of providing seed and distribution networks of new varieties released to benefit farmers.

The Challenges for Alfalfa

Alfalfa (*Medicago sativa*) is a globally important legume and a vital forage crop for livestock. It contributes directly to dairy, meat, fiber, egg, honey and human food system worldwide. Climate change poses challenges to existing cultivated alfalfa varieties through increasingly frequent, prolonged droughts and harsh winters. The CWR and BOLD projects focused on alfalfa pre-breeding using CWRs in collaboration with partners in Kazakhstan, Kyrgyzstan, China, Chile and Zambia where diverse wild relatives are naturally adapted to drought, heat and harsh winters. These wild relatives harbor adaptive alleles that are not present in existing cultivars. However, transferring these into agronomically valuable alfalfa requires extensive pre-breeding to overcome genetic incompatibilities and to maintain key traits such as yield and forage quality. This is a lengthy process and is not possible without a continuous, long-term investment to support it.

The Solutions and Impacts

For decades, alfalfa wild relatives have been deliberately conserved and utilized for alfalfa improvement. When Alan Humphries and his team at the South Australian Research and Development Institute (SARDI) joined the CWR project in 2015, they significantly expanded the global wild alfalfa diversity pool through multi-year field collections, evaluation and partnership with alfalfa breeding groups facing similar climate challenges in Kazakhstan, China and Chile.

By the end of the CWR project in 2021, this cross-region alfalfa breeding network acquired, distributed and evaluated 710 novel wild alfalfa populations and developed a subset of 28 wild populations collected from environments with extreme summer heat, prolonged drought and harsh winter conditions (Humphries *et al.,* 2022; Eastwood *et al*. 2022).

Material conserved in genebanks was then integrated into pre-breeding through controlled hybridization between wild material and existing elite cultivars. Surviving hybrids were evaluated under field conditions across multiple generations and climate-adaptive lines were identified by natural selection.

For perennial crops such as alfalfa, evaluation typically requires several years to complete. Failure at any stage may lead to loss of pre-bred material, but over many years of dedication and collaborative effort among the alfalfa breeding network, the CWR project resulted in a diverse panel of 39 CWR-derived alfalfa pre-breeding lines resilient to climate challenges (Humphries *et al*., 2021). Followed by the CWR project, partners in

The BOLD Project

BOLD (Biodiversity for Opportunities, Livelihoods and Development) is a 10-year initiative to strengthen global food and nutrition security through the conservation and use of crop diversity. Funded by the Government of Norway, BOLD was launched in 2021 and builds on the work and achievements of the decade-long Crop Wild Relatives Project (2011–2021).

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China, Chile and Kazakhstan successfully released three CWR-derived alfalfa varieties – Zhongcao No. 3, Kauke and Tozimdi – which are accessible by farmers to improve alfalfa production.

Alfalfa reproduction primarily relies on insect pollination. To maintain high quality alfalfa seed production, the CWR project carried out a large-scale study in south Kazakhstan (for more information, see here), where honeybees were introduced in farms. Researchers reported positive outcomes as increased pollination increased alfalfa yield by 80% and additional value from honey production diversified farmer's income.

Small farmers face logistical challenges in forage conservation due to the availability or cost of contractors or shared equipment; some therefore cut alfalfa by hand daily and conserve only very small areas. We demonstrated to these small farmers they can instead conserve alfalfa as silage in sealed drums, gradually building a store that maintains high quality for at least three seasons. The conserved fodder improved their resilience to future climate variability and drought while reduced losses by allowing earlier processing with better nutrition (leaf retention), and protection from weather and rodents. This approach is being adopted by small farmers in China, Kazakhstan, and Zambia, while also giving new value to recycled plastic containers.

The BOLD Project continued to advance the pre-bred lines with further evaluation and identified the best lines for developing varieties for potential registration and farmer use in Kazakhstan. These alfalfas were also introduced to new parts of the world, such as the dry and hot sub-Saharan Africa, to improve dairy and mixed livestock production in Zambia. Livestock farmers in Zambia reported a three-fold increase in milk production when using CWR-derived alfalfa lines as feed, along with higher fat and protein content. Farmers also observed a yellowish hue in milk from alfalfa-fed cattle, an indicator of enhanced nutritional quality that is preferred by local consumers.

The CWR and BOLD projects highlight the power of continuous, long-term investment to overcome pre-breeding barriers using wild material and integrating the CWRs into the breeding pipeline. The CWR-derived climate-resilient alfalfa varieties now support dairy, meat, fiber, egg, honey and food production across multiple regions, strengthening global food and nutrition security. Both initiatives have also raised international awareness and built global commitment to conserving and utilizing CWRs thanks to visionary donors such as the Norwegian Agency for Development Cooperation (NORAD), whose long-term support has helped bring the world closer to a more secure and resilient food future.

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Additional Reading

- A BOLD Future for Alfalfa: More with Less Water
- An Alfalfa That Loves the Cold
- Kauke Alfalfa Gives Farmers' Livelihoods a Boost in Chile's Central Valley
- New Climate-Resilient Alfalfa Gives Hope to Drought-Stricken Farmers in Kazakhstan

Additional details can be found at https://bold.croptrust.org/

Suggested citation: Yu, Y., Humphries A.W., Kilian, B., Sharma, S., Major, M., & Jamora, N. (2026). Pre-breeding Alfalfa with Crop Wild Relatives: The Power of Long-Term Investment. Genebank Impacts Brief No. 27. Crop Trust. https://doi.org/10.5281/zenodo.18885834.

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