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Pigeonpea Crop Wild Relatives and Pre-Breeding: Unlocking Genetic Resources for Sustainable Agriculture

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Introduction

Pigeonpea (*Cajanus cajan*) is an important legume crop widely cultivated in semi-arid regions of the world. It serves as a critical source of protein, income, and soil fertility improvement for millions of smallholder farmers. However, like many crops, pigeonpea faces numerous challenges, including biotic and abiotic stresses. To address these challenges, pigeonpea pre-breeding programs have turned to the utilization of crop wild relatives (CWRs) as a valuable genetic resource. This explores the significance of pigeonpea CWRs and the pre-breeding strategies aimed at improving this crop for enhanced sustainability and resilience in agriculture.

Pigeonpea and Its Importance

Pigeonpea is native to the Indian subcontinent, and its domestication history dates back over 3,500 years. It is recognized for its ability to fix atmospheric nitrogen and improve soil fertility, making it an integral part of traditional cropping systems. The crop is nutritionally rich, providing a valuable source of dietary protein, especially in regions where meat consumption is limited. Pigeonpea has been traditionally consumed in various forms, from dhal (split pigeonpea) to a variety of curries and snacks.

Despite its importance, pigeonpea faces several constraints that limit its productivity. Drought, diseases, and insect pests are among the primary challenges that pigeonpea farmer's encounter. The long growth duration of pigeonpea cultivars often makes them susceptible to these challenges, leading to yield losses and diminished farmer livelihoods. To address these limitations, the use of pigeonpea CWRs has become vital in pigeonpea improvement programs.

The Significance of Pigeonpea Crop Wild Relatives

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Crop wild relatives are species closely related to cultivated crops, sharing a common gene pool. They are essential genetic resources for crop improvement, as they often possess unique traits that can be transferred to cultivated crops through breeding. Pigeonpea has several wild relatives within the *Cajanus* genus, such as *Cajanus scarabaeoides* and *Cajanus platycarpus*. These wild relatives have evolved in diverse environments and carry traits that can be valuable for enhancing pigeonpea resilience and adaptability. Some of the notable traits include resistance to diseases and pests, tolerance to abiotic stresses like drought and salinity, and early maturity.

Pre-breeding Importance

While wild Cajanus species offer abundant resistance potential, their underutilization in pigeonpea breeding programs remains a significant issue. This limitation primarily stems from linkage drag and incompatibility barriers between cultivated and wild species. In such circumstances, pre-breeding represents a distinct opportunity to enhance the primary gene pool by tapping into the genetic diversity present in both wild species and cultivated germplasm. This approach ensures a consistent influx of fresh and valuable genetic variation into breeding pipelines, facilitating the development of new cultivars characterized by robust resistance and a wide genetic foundation.

Pre-breeding Strategies in Pigeonpea Improvement

Pre-breeding is a critical phase in crop improvement where genetic diversity from CWRs is incorporated into cultivated varieties. This process aims to develop breeding lines with improved traits that can subsequently be used in commercial breeding programs. In pigeonpea pre-breeding, several strategies have been employed to harness the potential of CWRs:

1. **Trait Introgression:** The primary objective of pre-breeding is the identification of desirable traits and/or genes from unadapted germplasm such as exotic landraces/wild species (donors) and introgress them into cultivated pigeonpea varieties. The introgression of traits like disease resistance and drought tolerance from CWRs has shown promise in developing improved pigeonpea lines. Advanced genomic tools, such as molecular markers, have facilitated the tracking of target traits during introgression.
2. **Population Development:** Pigeonpea pre-breeding programs often focus on developing populations following hybridization for transferring these traits into well-adapted genetic backgrounds. Several pre-breeding populations have been developed

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at ICRISAT utilizing wild species from *C. cajanifolius*, *C. acutifolius*, *C. scarabaeoides* and *C. platycarpus* having useful traits such as tolerance to salinity and pod borer resistance in crop improvement programs.

3. **Genetic Mapping and Marker-Assisted Breeding:** The availability of genomic resources and molecular markers has revolutionized pre-breeding efforts in pigeonpea. By identifying and mapping genes associated with target traits, such as resistance to Fusarium wilt or pod borer resistance, breeders can efficiently select and cross lines to develop improved cultivars.
4. **High Throughput Phenotyping:** Accurate phenotyping is crucial in pre-breeding to evaluate the performance of introgressed traits under different conditions. High-throughput phenotyping techniques, including remote sensing, can help breeders identify promising lines with stress tolerance, ensuring the success of pigeonpea improvement programs.
5. **Conservation and Preservation:** Pigeonpea CWRs are invaluable genetic resources, and their preservation is essential. Conservation efforts are essential to safeguard the genetic diversity found in these wild relatives, ensuring that they remain available for pigeonpea improvement in the future.

Conclusion

Pigeonpea is a crucial crop in the context of global food security and sustainable agriculture. As the world faces increasing challenges from climate change, pigeonpea pre-breeding programs are turning to crop wild relatives to enhance the resilience and productivity of this crop. Pigeonpea CWRs carry valuable traits that can address the challenges faced by farmers, including drought, diseases, and pests. Through pre-breeding strategies such as trait introgression, heterosis and hybrid development, genetic mapping, and advanced phenotyping, pigeonpea improvement programs are well-positioned to harness the potential of these wild relatives and develop more robust and sustainable pigeonpea varieties for the future. By doing so, they can contribute to global food security and the well-being of smallholder farmers worldwide.

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