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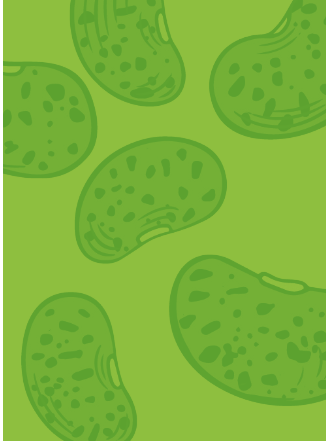

Target Population of Environments for bean breeding in Africa

October 2022

Key message

The target population of environments (TPE) approach aims at enhancing the effectiveness of crop improvement programs to achieve yield and/ or genetic gains by helping to classify and prioritize regions based on stress patterns (frequency, onset, intensity and duration) and uses it to recommend improvement in the selection strategy. The bean-growing environments in Ethiopia, Tanzania, and Uganda can be categorized into six different environmental groups (EGs) on the basis of seasonal variation of drought stress under historical and future climates projected using crop-climate prediction models (Jha et al, under review). This brief is based on the results from that study.

Although stress-free conditions generally dominate (50–80% frequency) under the historical (1991–2010) climatic conditions, in future terminal drought stresses of various intensities (moderate, severe and extreme) are projected to become prevalent in 34% of Uganda, around a quarter of Ethiopia, and 40% of the bean growing environments in Tanzania by 2050.

Apart from these, there are some regions under intermittent drought stress in Tanzania and under the flowering-to-grain-filling stress in Ethiopia, with relatively lower frequency of occurrence.

The EGs identified in each country serve as a basis for prioritizing breeding activities in national programs. However, at international level common bean breeding programs should focus primarily on identifying genotypes with tolerance to severe terminal drought, with co-benefits in relation to adaptation to moderate and extreme terminal droughts.

Rationale

Common bean is very important from dietary and nutritional perspectives for poor in Africa (Pachico, 1993, Gardner and Kassebaum, 2020). The demand for bean is projected to grow in future due to increase in proportion of legumes in diet with the increase in income and urbanization (Schiek et al., 2021). However, various studies report decrease in supply of bean with adequate nutrients due to climate change combined with the other abiotic and biotic stresses (Beebe et al., 2011, Hummel et al., 2018). Bean crop improvement programs have been facing the challenges of developing varieties that are not only high yielding but also drought resistant (Beebe et al., 2011). Effectiveness of a trait or allele to confer drought resistance depends on drought stress patterns, which results from the complex interactions of weather, soil, CO_2 and the genetic properties of a cultivar. Therefore, setting priority for bean breeding under future climatic conditions requires a nuanced understanding of how drought stress patterns evolve and act during the growing season along with their relative importance for a given area of interest.

To the best of our knowledge, such analyses, however, are hardly available to crop improvement teams, especially for the public funded programs in East Africa. Since it takes more than a decade to develop and adopt a new variety for commercial production, considering the pace of climate change, inaction on such analyses would be very costly.

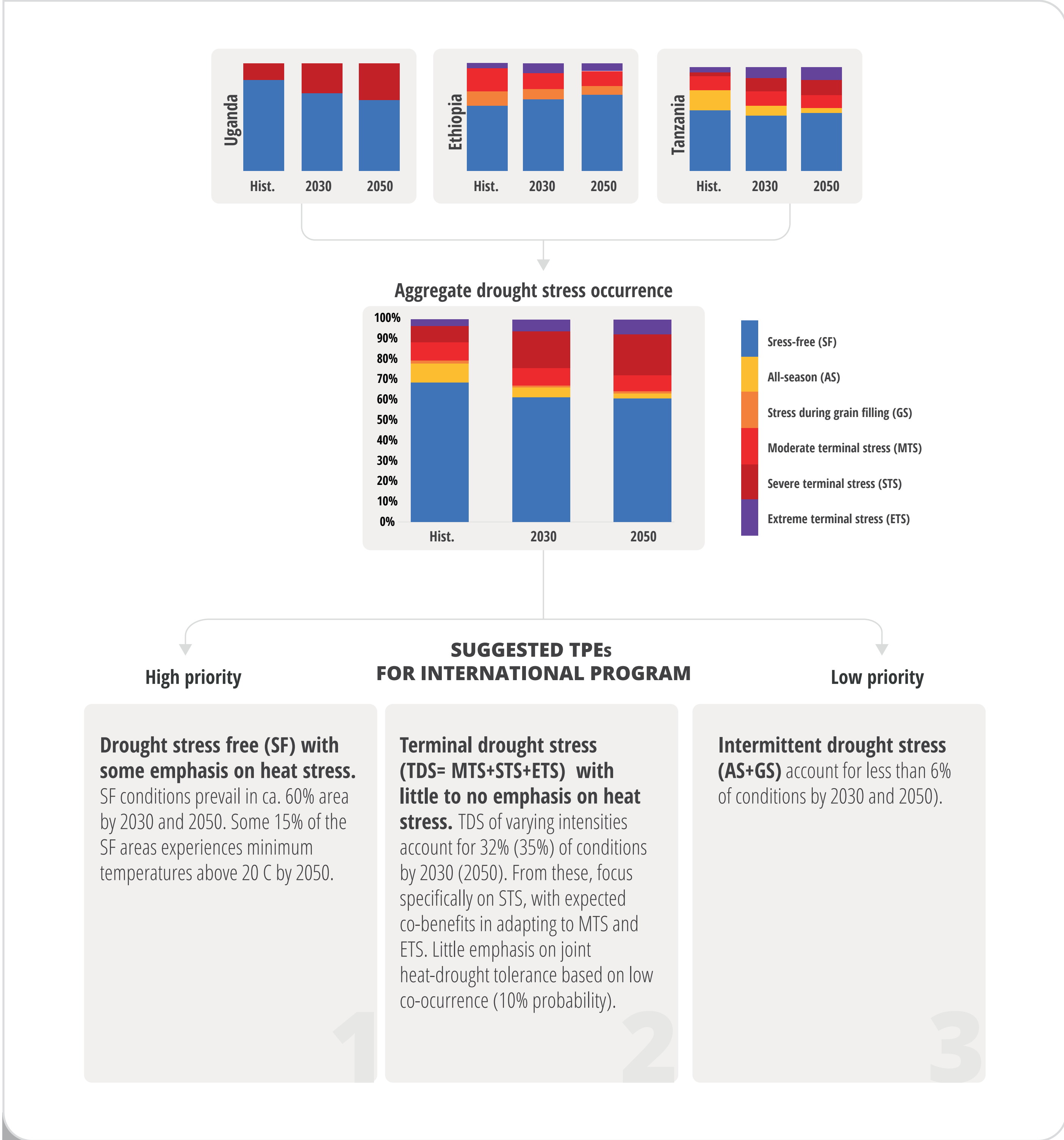

Figure 1. Aggregation of country level priorities to derive regional TPEs for the international bean crop improvement program in the CGIAR.

Implications

Currently, several international breeding programs of the CGIAR are undergoing a modernization process in which TPE analyses are part of the prioritization and product design process (CGIAR, 2018). Hence, priority TPEs are needed at both national and international levels. At the national level, Ethiopia and Uganda could implement weighted selection schemes according to the frequencies of drought environments found in these countries. In Tanzania, broader adaptation to drought is warranted. Only in small part of north-west Uganda and southern Tanzania, we see some levels of heat stress. At the international level, we identity two major TPEs, namely, a drought stress-free TPE with some emphasis on heat stress; and a terminal drought TPE with little to no emphasis on heat stress. The bean production-hub specific priority stresses for these three countries are available in Jha et al. (submitted).

The findings from this study can also be used to improve drought stress protocols in breeding trials and locate multi-locations trials, needed for testing genotypes of mid and advanced generation materials. The crop improvement program can mimic the specific drought patterns identified in this study including their onset, duration and intensity during the growing season, for example through rain shelters, and also to test genotypes under drought and high temperature conditions in greenhouse experiments or in hot environments. Furthermore, we believe the approach implemented here can be more broadly applied to other crops (e.g., maize, rice), hence contributing to greater breeding program efficiency and focus at the regional and global levels.

WAY FORWARD

The definition of TPE is a dynamic process that will be modified as additional parameters are included in this analysis. For example, the results from Jha et al (submitted) is based on only one genotype, but farmers in these three countries use various cultivars. Future work should update these TPEs using trial data from the Accelerated Varietal Improvement and Seed Delivery of Legumes and Cereals in Africa (AVISA) project using a number of varieties with a range of crop cycle lengths and drought tolerance levels. Future work should also consider low soil fertility including the deficiency of Nitrogen (N), Phosphorus (P) and Potassium (K) along with toxicity from Aluminum and Manganese, which are prevalent in bean growing areas in Africa (Thung and Rao, 1999). Similarly, future study should also include soil compaction (Buttery et al., 1998), water logging (Beebe et al., 2013), and pest and diseases (Chaloner et al., 2021).

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Authors

Prakash K. Jha[1], Steve Beebe[1], Patricia Alvarez-Toro[1], Clare Mukankusi[1], Julian Ramirez-Villegas[1, 2]

[1] Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT).

[2] Plant Production Systems Group, Wageningen University and Research, Wageningen, The Netherlands.

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