The combination of an increasing human population and a rapidly changing climate bring up many questions about how society will feed the world in the future. Understanding these conditions, plant breeding programs are working to increase food production with cultivars that are resilient against climate change. However, these programs are also expensive, requiring a lot of time and resources. Plant breeders and those that fund their work want to make sure that there is a return on investment.

Breeding programs need to periodically assess their progress by quantifying gains in production, being aware if genetic gains are slowing, and assessing traits that are most relevant to combat the conditions they are grown in. Assessing the gains in a breeding program requires growing the same cultivars at multiple locations or analyzing long-term data sets. Some recent examples of assessments and progress in breeding programs were published in *Crop Science*.

**Increasing Biomass for Biofuel Production**

Some crops, like wheat and corn, have a long history of selective breeding. In contrast, biofuel crops like switchgrass and big bluestem have breeding programs that started in the early 1990s. Breeding programs for biofuel focus on increasing biomass yield. Switchgrass and big bluestem have broad ranges across North America. Growing across a range of hardiness zones or soil types, each species has gen-
otypes adapted to their local conditions. When high-yielding cultivars are identified, the genotype may not perform well in other regions.

Given the genetic diversity of these species, and because these breeding programs are relatively recent, there is a need for uniform regional testing programs to evaluate cultivar growth in different regions. Researchers used a regional testing program to determine if industry needs are being met (https://bit.ly/2nqpQ2d). They established experimental plots at 13 locations in Hardiness Zones 3–6 (North-Central U.S.). In 2012, they planted switchgrass from 22 populations and big bluestem from 12 populations, and in 2014, they planted switchgrass from 20 populations and big bluestem from 11 populations.

The authors reported that switchgrass has more distinct ecotypes than big bluestem. Switchgrass populations exhibited strong photoperiodicity and showed distinct differences in cold hardiness based on the original population location. Big bluestem showed similar patterns when moving southern populations to northern locations, but differences in adaptation were less distinct than for switchgrass. Photoperiodicity, time to flowering, and cold hardiness were important factors in determining biomass yield.

The authors recommend breeding programs focus on selection for later flowering and greater range tolerance to increase biomass yield. Establishing breeding programs in cooler climates would aid in the selection for greater cold tolerance. In the Crop Science article, the authors state, “these two species are still undomesticated and contain a wealth of genetic variability for adaptive traits that allow breeders to create new, high-biomass populations with broader adaptation than can be found within natural populations.”

Wheat in Brazil

In Brazil, approximately half of the wheat used on an annual basis is produced domestically, and the remainder is imported. For decades, wheat breeders have worked to increase domestic production and have made large gains. It is estimated that production increases since the 1970s average

• Plant breeding programs need to periodically review the progress of their research and development.
• Researchers use long-term and geographically broad data sets to determine if gains in yield are due to genotypes, management practices, or changes in climate.
• Assessments can reveal historical patterns in genetic gains, traits to focus on in future research, and performance differences due to geography.
43 kg ha$^{-1}$ yr$^{-1}$. While seeing gains in production indicate a breeding program is effective, it is still important to look at how genetic gains change over space and time.

Brazil has a range of habitat types, ranging from cool, humid growing conditions to arid, hot environments. These differences can affect the production of any crop, and wheat yield gains may be stagnating in some regions if cultivars are not well suited to the environment and soils. In this study (https://bit.ly/2vBdzfV), researchers reviewed data from 836 trials that had taken place at 40 locations from 2004 through 2013. The Central Cooperative of Agricultural Research (COODETEC) in Brazil performed all trials, so the same standard and methods were used, making the data easier to compare.

The authors compared regions based on broad ecoregions, known as the value of cultivation and use regions (VCUs). The authors report that the genetic gain ranged from 31.38 kg ha$^{-1}$ yr$^{-1}$ in VCU 4, which is the hot and dry Cerrado region, to 115.33 kg ha$^{-1}$ yr$^{-1}$ in VCU 1, which is cold and humid.

The authors concluded that, in general, there is not a stagnation in genetic gains, but the gains are highly influenced by climate conditions. The authors point out the need for future research that focuses on maximizing yields in the hot, dry regions of the country, which may require different management strategies.

**Rice Breeding in Brazil**

Irrigated rice is another important crop for Brazil. Breeding programs have focused on developing cultivars with high productivity, healthy grains, and adaptation to growing conditions. Yields have been steadily increasing since the 1980s as new cultivars were released and farming techniques have improved.

Researchers sought to estimate genetic progress for the major agronomic characteristics (yield, flowering date, and plant height) of irrigated rice. This study (https://bit.ly/2vN309P) used data from the Brazilian Agricultural Research Corporation (Embrapa), a data set from 1972 through 2016. They authors outline the use of two methods to estimate genetic gains. One was a comparative analysis of cultivars grown in the same environment—a regression analysis. The other was a meta-analysis of line yield trials.

These analyses revealed there have been three phases of development in genetic gains for irrigated rice. Prior to the Green Revolution (1972–1983), there was little genetic gain in irrigated rice. After 1983, and through 2000, there were yield gains of 96.12 kg yr$^{-1}$. From 2000–2016, gains averaged 116.31 kg yr$^{-1}$, and the authors explain that during this time, breeders intensified their selection for traits that increase yield.

In this evaluation of the breeding program, the authors benefited from a large data set. Having data from many experiments and environments over several decades enabled them to estimate the genetic progress with less influence of environmental effects. In the article, the authors describe what each analysis offers. “The method of meta-analysis must be used when one wants to obtain specific information regarding the program management procedures and transition procedures. On the other hand, when one requires the effective contribution of the breeding program to the crop, the cultivar comparison method should be used.”

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**Dig Deeper**

View the full-length articles in *Crop Science*:

- 30 Years of Progress toward Increased Biomass Yield of Switchgrass and Big Bluestem: [https://bit.ly/2nqpQ2d](https://bit.ly/2nqpQ2d)