Perspectives on Wheat Variety Trials and Wheat Variety Trial Data

Scott Haley
CSU Wheat Breeder
Soil and Crop Sciences Department, CSU

Introduction

The Colorado State University (CSU) Crops Testing Program, under the leadership of Dr. Jerry Johnson, conducts winter wheat variety performance trials each year throughout Colorado. These trials are carried out as a service to the wheat industry to provide unbiased and reliable information to crop producers to assist with variety selection decisions. Together with the CSU Collaborative On-Farm Testing (COFT) program, variety trials serve to accelerate the adoption of improved varieties and – equally important – help foster the demise of inferior varieties. Thus, these trials provide immense economic benefits to the entire wheat industry in Colorado.

A fundamental reality – and complication – of all crop breeding and crop variety testing activities is what's commonly referred to as "*genotype-by-environment interaction*", or *GxE*, where G refers to the variety and E refers to anything that involves the environment (i.e., geography, climate, soil type, diseases/insects, fertility, management, etc). The concept of GxE is based largely on the inconsistency in grain yield (or other traits) that is observed when different varieties are tested in different years or locations. In a practical sense, this inconsistency across years or locations complicates selection in breeding programs and development of sound variety recommendations from crop variety trial data.

Proper use of data from wheat variety trials is essential to improve variety selection decisions by producers. Given the reality of GxE in variety testing, a common practice in Colorado and elsewhere is to present multiple-year, multiple-location averages of variety performance. This is most often reported as the "three-year average" with the assumption that this is the best predictor of future variety performance. While the "three-year average" has been in use for many years, very little evidence has been made available to document that this is really better than other possible ways to interpret the data, such as using a single trial location or a single year of trial data. The objective of this report is to provide tangible evidence that the "three-year average" is really the best available predictor of future variety performance.

Methodology

All of the grain yield data from CSU dryland variety trials from 1990 to 2015 was assembled to examine the predictability of dryland wheat variety trials in Colorado. This dataset included the High Moisture Variety Trial (HMVT) and Low Moisture Variety Trial (LMVT) from 1990 to 1999 and the Uniform Variety Performance Trial (UVPT) from 2000 to 2015. This enormous dataset included 22,392 total observations across 26 years, 25 trial locations, 220 unique year-location combinations, and 219 different varieties (released varieties and experimental lines). Most of the location/year combinations included three field replications though some trials only had two replications due to some problem that occurred with the trial (i.e., drought, winter injury, poor emergence, weed infestation, wayward combine or sprayer, etc).

This dataset was subjected to a comprehensive statistical analysis in order to:

1) determine the proportion of the total variation in the data that was due to years, locations, varieties, and all the possible interactions among these.

2) use these estimates to illustrate the effect of the numbers of years of testing and trial locations on variety predictability, or what's known as "broad sense heritability" in the plant breeding world.

3) estimate the correlation of yields at a given location with yields of the same varieties in the next three years at that location based on that single location only, the region-wide (northeast, southeast) three-year average, and the statewide three-year average.

Results

In the first part of the analysis, all of the sources of variation in the data going back to 1990 were estimated. A pie chart of these results is shown below in **Figure 1**. The most interesting revelation was that roughly 75% of all the variation in the data was due to effects that had nothing to do with the varieties, such as year, location, and their interaction (*dark green portion*). Only 25% of total trial variation was due to variety and interactions of the variety with years and locations. Another key finding was that the variety x year variation (*light blue slice*) was much larger than the variety x location variation (*pink slice*), which confirmed that year-to-year variation is a much more important part of the GxE for grain yield in Colorado.

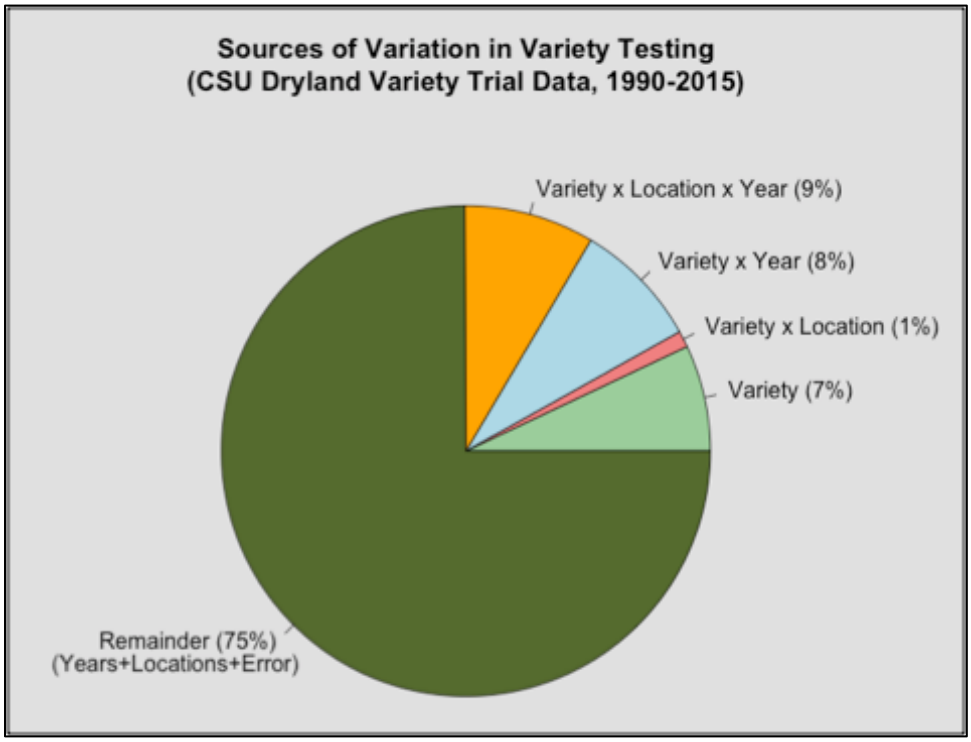

Figure 1 –Sources of variation estimated from CSU Dryland Variety Trial data (1990-2015).

In the second part of the analyses, the components of total trial variation related to variety effects (the 25% shown above) were used to illustrate the effect of the number of years of testing and trial locations on predictability. This is shown in **Figure 2**. The most striking observation was that the lowest level of predictability observed was with a single year of testing, regardless of the number of trial locations available in that year. Predictability did increase with increasing years of testing, but even with four years of testing and 20 locations in each year the predictability of variety performance was only about 70%.

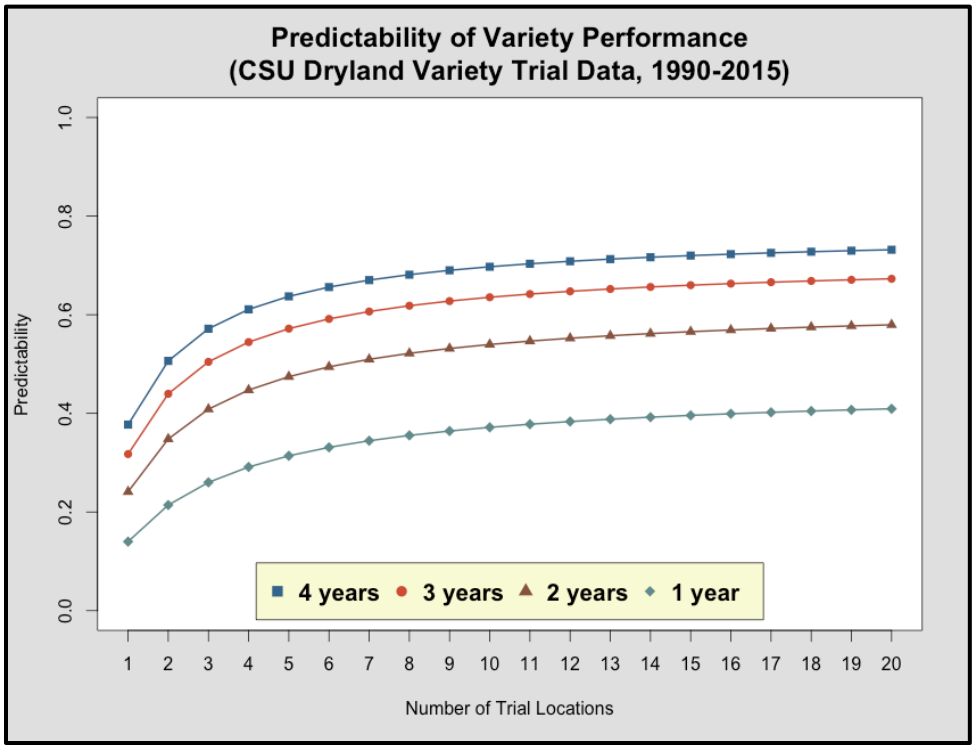

Figure 2 – Predictability of variety performance for grain yield estimated from CSU Dryland Variety Trial data (1990-2015).

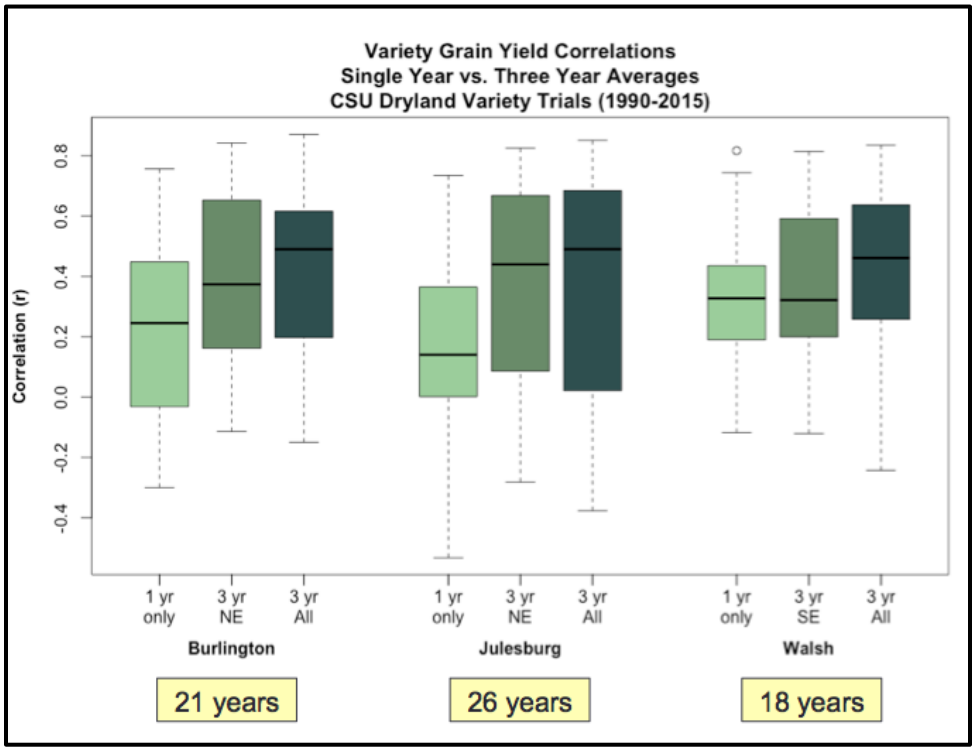

Figure 3 – "Box-plot" graph depicting the correlation of variety performance between years at three locations in Colorado. The horizontal line within each colored box shows the average of all the correlations.

One interesting observation was that zero or even negative correlations were quite common. The lowest correlation observed (-0.53 for 1990 vs. 1992 at Julesburg) showed that the top variety in 1990 ('Yuma') was 17th out of 19 in 1992 and the lowest variety in 1990 ('Jules') was 1st out of 19 in 1992. While this specific example may have been easily explained, it does reinforce that extreme year-to-year variability is common and variety predictability is imperfect.

The last part of the analysis involved calculating the correlation of yields from one year at one location with each of the next three years at the same location. This is shown in **Figure 3**. In each case, the lowest average correlation was observed when a single location-year of data (*light green* box) was used as the predictor. For Burlington and Julesburg, a higher correlation was observed when the current region-wide average ("3 yr NE"; *medium green* box) was used as the predictor, though at Walsh ("3 yr SE") this was equivalent to using a single year of data as the predictor. Most importantly, in each case, the current statewide three-year average (*dark green* box) was the best predictor of yields of the same varieties in subsequent years.

Summary and Conclusions

- Crop breeding and variety testing programs virtually everywhere must deal with the confounding effects of genotype-by-environment interaction (GxE). The presence of GxE reduces progress ("genetic gains") in breeding and complicates variety recommendations.
- The majority of the trial variation for grain yield was variation that did not involve the varieties in any way – and thus is not controllable. Year-to-year variation and GxE variation involving years are the most significant source of variation in these experiments.
- Predictability did improve with increased years of testing and locations but predictability is still imperfect due to extreme year-to-year climatic variability in Colorado. Producers should plant multiple varieties to hedge risks from unpredictable climatic conditions.
- The **worst** predictor of what will happen in a following year at a given trial location was what happened this year at that same location. A **better** predictor was generally the current region-wide three-year average. The **best** predictor was the current statewide three-year average.
- Producers should strive to use all available data to assist with the variety selection process. A handy and powerful database resource is available for desktop or handheld computers to enable generation of custom data summaries. This is available at – ramwheatdb.com.

Acknowledgements

The generous support of the Colorado Wheat Administrative Committee (CWAC) and Colorado Wheat Research Foundation (CWRF) is gratefully acknowledged.