

PHY499WRF: AN IMPROVEMENT IN YIELD POTENTIAL AND STABILITY OF YIELD**Mustafa McPherson****Joe Johnson****Phytogen Seed Company, LLC****Leland, MS****Joel Mahill****David Anderson****Phytogen Seed Company, LLC****Corcoran, CA****Dru Rush****Phytogen Seed Company, LLC****Brewton, AL****Introduction**

Cotton breeders strive to develop new, value-added varieties with significant improvements over existing varieties. There are many varietal characteristics that can be improved to provide value to the grower in producing a crop and to the cotton industry in utilizing the harvested lint and seed. The emergence and broad acceptance of herbicide tolerance and insect resistance traits expressed by transgenic varieties has conveyed significant value to the grower primarily through ease of management and reduced production costs. Consequently, growers often first decide which transgenic trait package(s) then look for the best varieties with those traits. The primary determinant for what defines 'best' is most often lint yield potential in the immediate growing area. Since the emergence of transgenic varieties, there have been concerns about 'yield stagnation' due to a perceived reduction in breeding efforts directed toward germplasm improvement as opposed to trait introgression and possible negative linkage drag associated with the transgenic traits. Addressing these concerns, the release of PHY499WRF marks a significant improvement in the yield potential of transgenic cotton varieties.

PHY499WRF was developed by backcrossing the WideStrike® and Roundup Ready® Flex traits into the proprietary, conventional germplasm line P04X.3074. Line P04X.3074 was developed from a cross in 1999 between two high yielding lines. Performance testing in the Mid-South and Southeast since 2005 showed that P04X.3074 has exceptional yield potential and stability of yield across a broad range of environments. Subsequent testing of PHY499WRF since 2009 has shown very similar performance to its recurrent parent except for higher percent lint, smaller seed and lower micronaire.

Analysis of university performance data from 2010 and 2011 indicated that PHY499WRF was the highest yielding and most broadly adapted cotton variety. The 'Which-Won-Where' view of GGEbiplot placed PHY499WRF at the apex of the sector containing a preponderance of test locations. To better understand the area of adaptation, test locations were grouped into seven regions and head-to-head comparisons were made between PHY499WRF and all other varieties. PHY499WRF placed within the top four varieties in six of these seven regions. Head-to-head comparisons using university data indicated that PHY499WRF was higher yielding than all other varieties and that this advantage was significant for most varieties. PHY499WRF numerically won 26% of these university trials and placed within the top 25% of entries in 64% of trials. Recognizing the superior performance of PHY499WRF, growers purchased more seed of this variety in 2012 than any other variety.

Materials & Methods

Lint yield data were compiled from reports in 2010 and 2011 by all universities east of New Mexico. Whenever the list of entries was split into early and late groups at the same test site, the data were combined into one 'location' by multiplying the fraction a variety was of PHY499WRF in the late trial times the mean of PHY499WRF in the early trial, thus resulting in uniform, normalized, 'mean equivalent' data. Test locations that evaluated entries under both dryland and irrigated management regimes were treated as separate environments for the present study. Also, for purposes of this study the year and location columns were combined for unique 'environments'. These data were used for GGEbiplot, head-to-head, and Eberhart-Russell regression analyses. The GGEbiplot analysis was run using software licensed from Dr. Weikai Yan at <http://ggebiplot.com/biplot>. The head-to-head comparisons were run using Agrobases 99 over all environments and then over environments within the seven regions: Plains, South Texas, South Delta, North Delta, Tennessee Valley, South Coastal, and North Coastal. The Eberhart-Russell regression analysis

was run using Microsoft Office Excel 2007 by applying the linear trendline option to plots of varietal means versus the location means. The yield data were converted to ranks and subjected to analysis for frequency distribution with different rank groups.

Results & Discussion

Comparison with Recurrent Parent

From 2009 to 2012, PHY499WRF was tested in Phytogen trials along with its recurrent parent, P04X.3074. The GGEbiplot of data from trials from 2009 to 2011 with these entries as well as other check and experimental entries with less than 40% missing data indicated that PHY499WRF was equal in yield to P04X.3074 as indicated by equal distance from the origin along the Average Tester Coordinate (ATC) (Fig. 1). The biplot also placed P04X.3074 very close to the ATC to indicate high stability of yield; however, PHY499WRF was not quite as stable as indicated by falling a short distance below the ATC. Generally, the Southeastern locations from AL to VA were plotted on the same side of the ATC as PHY499WRF to indicate that PHY499WRF was slightly more adapted to these states than states on the opposite side of the ATC. Head-to-head comparisons were made between PHY499WRF and P04X.3074 across all available internal trials through 2012 (Table 1). PHY499WRF yielded about 50 pounds of lint/acre more than P04X.3074 in each year of testing, but the t-test was significant only over all years and in 2012. A likely explanation for this yield advantage is that PHY499WRF had significantly higher lint percent than P04X.3074. As often occurs with improvements in lint percentage, the seed size of PHY499WRF was significantly smaller. Smaller seed can be a point of concern for growers from the perspective of getting a stand after planting and seedling vigor. Widespread feedback from growers has indicated that emergence and seedling vigor of PHY499WRF are excellent. Another significant improvement in PHY499WRF over its parent is significantly lower micronaire that translates into grades falling more often in the premium range. Not only was there no significant negative linkage drag associated with the introgression of the transgenic traits, PHY499WRF was significantly better than its recurrent parent in lint yield and fiber micronaire.

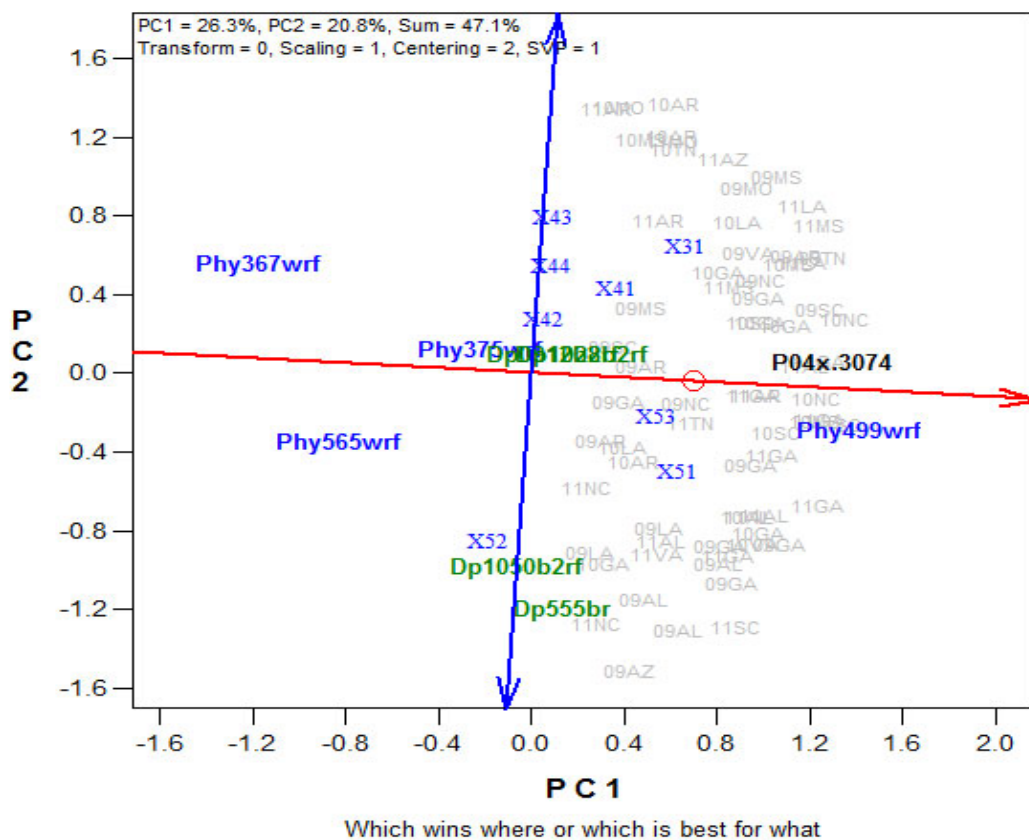


Figure 1. Mean vs. Stability view of GGEbiplot of Phytogen data from 2009 to 2011 across 70 environments.

Table 1. Head-to-head comparisons between PHY499WRF and its recurrent parent, P04X.3074.

Name	Season	Lint Yld		Seed			Strength	Unif Index	Rd
		Lbs/A	% Lint	Index	Mic	Length			
PHY499WRF	Overall	1375 *	44.6 *	9.6 *	4.9 *	1.13	32.9	84.4	74.7 *
P04X.3074	Overall	1326	43.6	10.0	5.2	1.13	33.1	84.5	74.3
PHY499WRF	12E	1438 *	44.6 *	9.2	4.7 *	1.16	31.3	85.2	74.4
P04X.3074	12E	1367	43.5	9.9	5.1	1.16	30.5	85.2	74.9
PHY499WRF	11E	1349	44.6 *	9.5 *	4.9 *	1.13	33.6	84.3	74.6
P04X.3074	11E	1313	43.5	9.8	5.2	1.13	33.8	84.3	74.2
PHY499WRF	10E	1393	44.9 *	9.5 *	4.9 *	1.12	33.1	84.1	74.5
P04X.3074	10E	1322	43.8	10.0	5.3	1.12	33.0	84.2	73.9
PHY499WRF	09E	1350	44.4 *	10.4 *	4.6 *	1.16	31.1 *	84.8 *	75.2
P04X.3074	09E	1305	43.7	10.8	5.0	1.16	31.9	85.3	74.6

Significantly different *

University Data

A comprehensive dataset of lint yield data from university variety trials from 2010 and 2011 was used for the remaining analyses. There were only eighteen varieties that had less than 40% missing data in the overall combined

dataset used for GGEbiplot analysis (Fig. 2). PHY499WRF was indicated as being the best variety by plotting on the apex of the sector with a preponderance of environments. Notably, there were fewer locations within the respective sectors having DP1252B2RF, DP0912B2RF or ST5458B2RF at the apex. The large number of environments on this biplot complicated the categorization of locations where PHY499WRF was not superior.

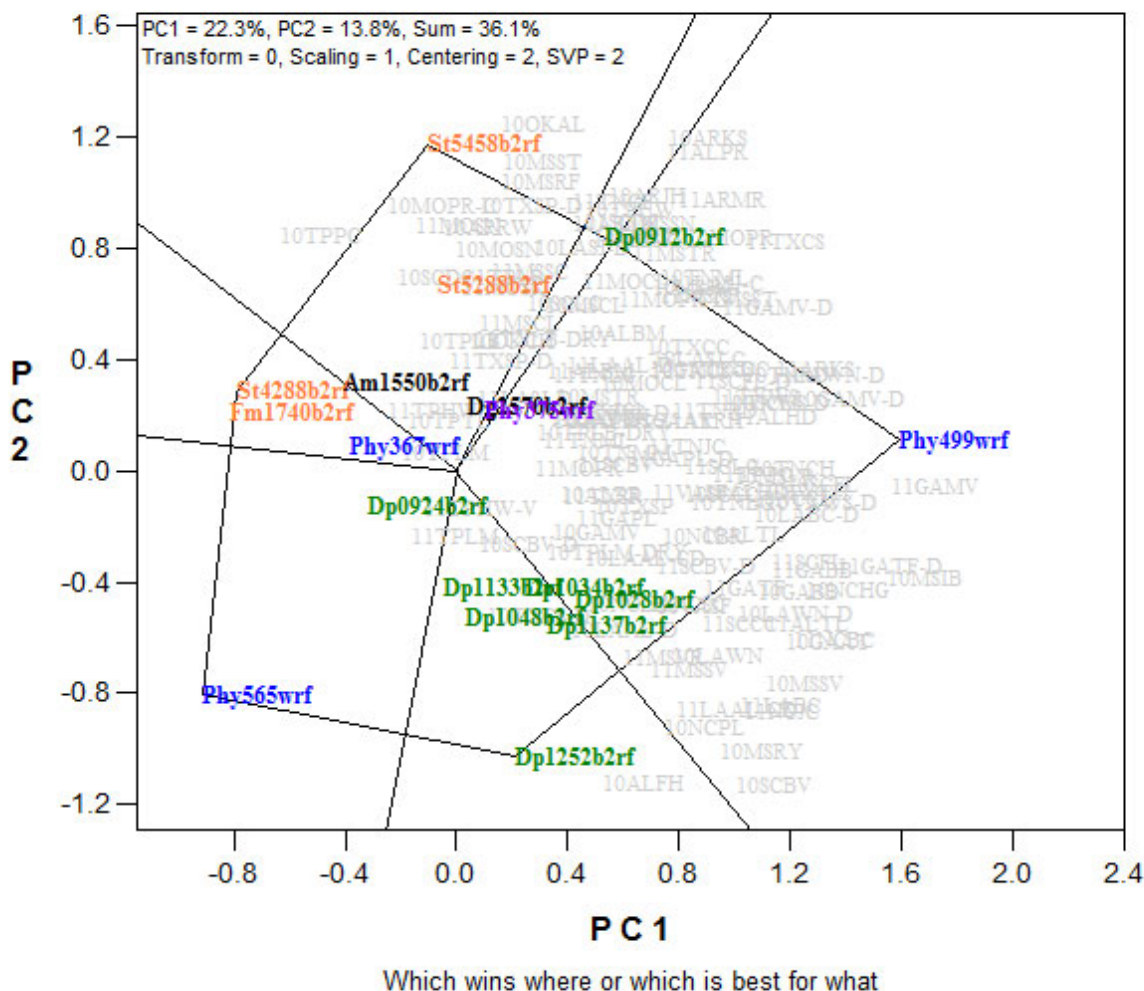


Figure 2. Which-Won-Where view of GGEbiplot of university data from 2010 and 2011 with all varieties having less than 40% missing data among 137 environments.

Head-to-head comparisons were made to PHY499WRF over years and by each state with Texas being split. These results were used for the GGEbiplots in Figures 3 and 4 with 33 varieties having less than 40% missing data. The Which-Won-Where view in Fig. 3 again shows that PHY499WRF was the best overall variety by plotting at the apex of the sector containing 10 of the 13 state environments. ST5458B2RF was indicated as the best variety in the North Delta states of Mississippi, Arkansas and Missouri. To better understand varietal performance in this secondary sector, the data were evaluated relative to Arkansas in Fig. 4. Again, ST5458B2RF was indicated as being the best variety there by being farthest from the origin along the red line, but PHY499WRF was indicated as being next best since its projection line intersected the red line behind only ST5458B2RF. Although PHY499WRF is better adapted to other regions, it still performed very well in the North Delta due to its exceptional yield potential. Since the maturity of PHY499WRF falls more in the mid-maturity range, in the North Delta and other short-season environments it should be planted earlier than early maturity varieties.

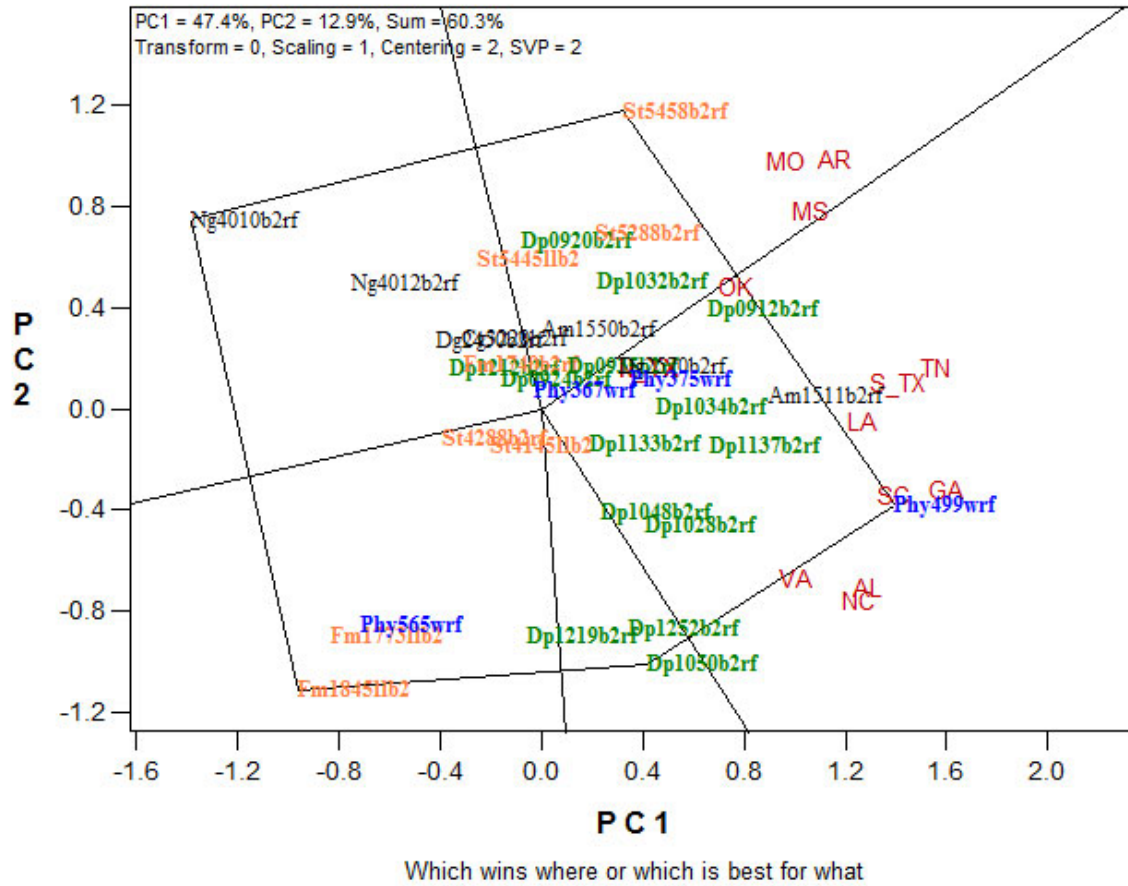


Figure 3. Which-Won-Where view of GGEbiplot head-to-head comparisons with university data for all varieties having less than 40% missing data among 12 states.

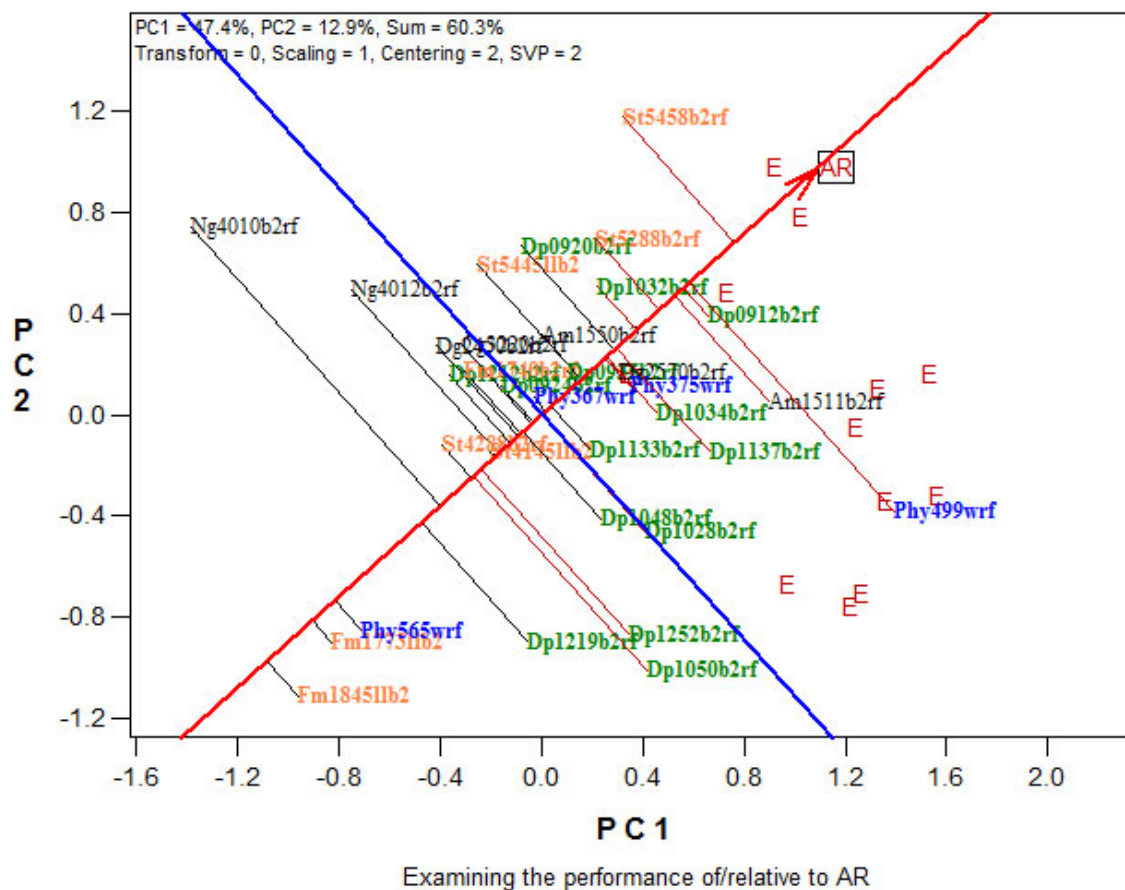


Figure 4. GGEbiplot of performance relative to AR using head-to-head comparisons with university data for all varieties having less than 40% missing.

The various university test locations were grouped into seven regions and subjected to head-to-head analysis by region. Results for the top 20 of 34 entries based on the combined head-to-head analysis are presented in Table 2. PHY499WRF was numerically superior to all other entries in the South Texas, Tennessee Valley, South Coastal, and North Coastal regions. It ranked fourth in the South Delta and North Delta and it ranked 15 of 66 entries in the Plains region. The GGEbiplot of these head-to-head results by region indicated that PHY499WRF was the highest yielding variety overall and that it was highly stable across regions (Fig. 5).

Table 2. Results for best 20 of 34 varieties from head-to-head comparisons with PHY499WRF within 7 regions.

Variety	Plains	South Texas	South Delta	North Delta	TN Valley	South Coastal	North Coastal	Overall
PHY499WRF	1143	1325	1295	1314	1382	1608	1353	1368
AM1511B2RF		1283	1293	1384	1346	1582	1266	1345
DP0912B2RF	1080	1173	1222	1319	1328	1532	1265	1303
DP1137B2RF	1133	1294	1249	1196	1254	1485	1315	1285
DP1028B2RF	1007	1129	1286	1224	1277	1521	1296	1275
ST5458B2RF	1221	1155	1243	1338	1290	1336	1197	1270
DP1034B2RF		1158	1227	1197	1341	1471	1248	1266
PHY375WRF	1161	1203	1201	1245	1303	1432	1200	1264
DG2570B2RF	1131	1076	1115	1270	1297	1403	1269	1262
DP1050B2RF	1189	1114	1252	919	1252	1511	1313	1258
DP1252B2RF	1110	1196	1245	1104	1292	1460	1279	1258
ST5288B2RF	1126	1129	1300	1289	1241	1375	1210	1255
DP1133B2RF	1062	1145	1301	1192	1235	1392	1224	1238
CG3787B2RF	901	1112	1332	1138	1335	1481		1236
DP1048B2RF	1065	1146	1216	1092	1297	1445	1235	1232
DP1032B2RF	1029	1106	1229	1276	1271	1331	1231	1229
DP1219B2RF	1248	1131		1055	1178	1547	1256	1226
DP0935B2RF	1128	1188	1078	1147	1281	1384	1250	1222
PHY367WRF	1133	1131	1163	1205	1253	1365	1196	1221
AM1550B2RF		1162	1106	1271	1213	1379	1185	1217

The GGEbiplot in Fig. 6 placed PHY499WRF at the apex of the sector containing 5 of the 7 regions. Although ST5445LLB2 was only average in yield as indicated by falling near the blue line at the origin, it had a strong positive interaction with environments in the Plains and North Delta regions as indicated by placing at the apex of the sector including these regions. Despite ST5445LLB2 being better adapted to the North Delta and Plains regions, reorientation of the biplot relative to the North Delta (Fig. 6) indicates that PHY499WRF still competed favorably due to its high yield potential.

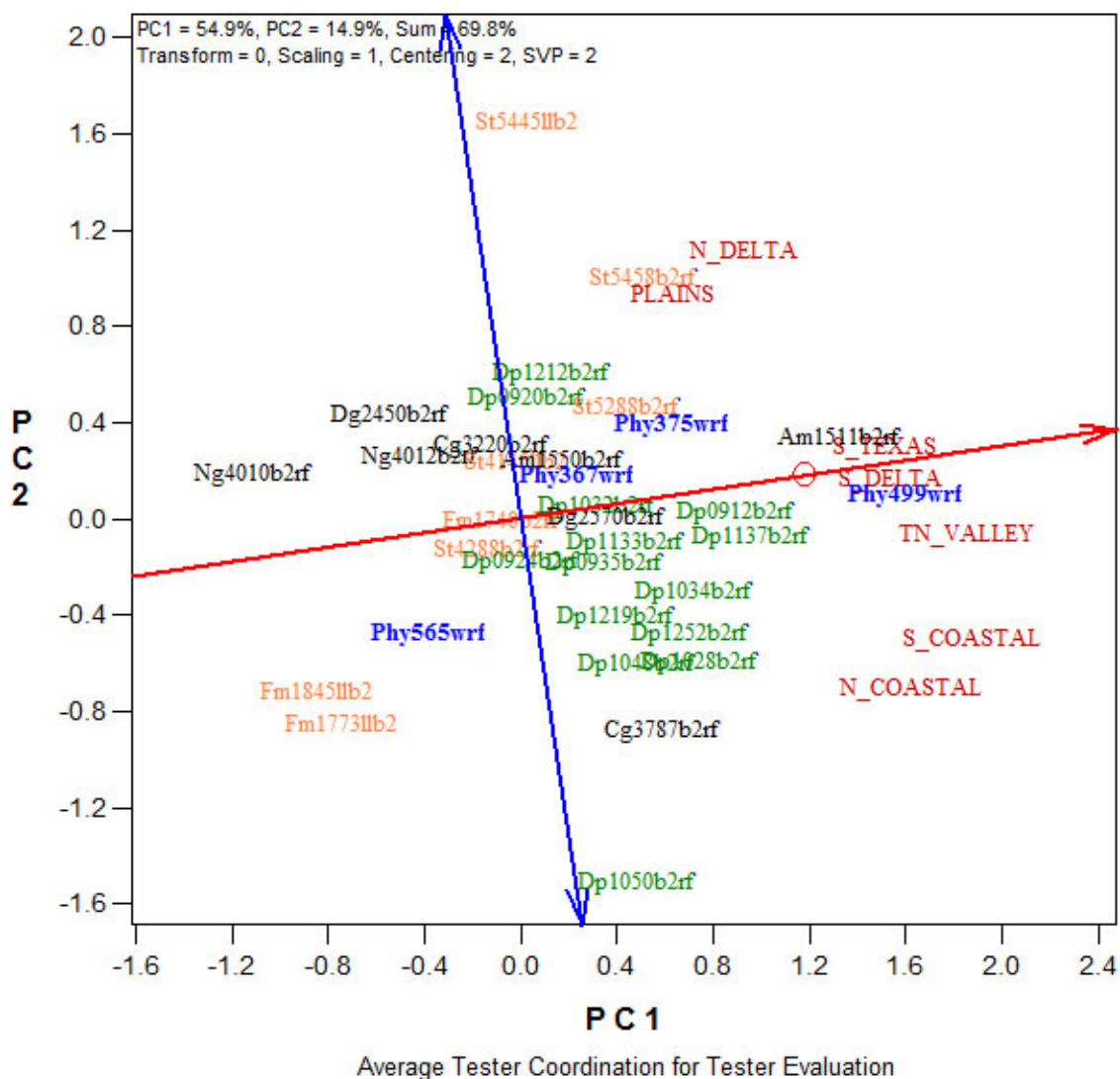


Figure 5. Mean vs. Stability view of GGEbiplot using university data from 2010 and 2011 combined over years and over states within 7 regions with all varieties having less than 30% missing data.

The Eberhart-Russell regression of PHY499WRF (Fig. 6) yielded an equation with an intercept of 95 pounds to reflect that its yield is consistently above the location mean. In addition to this advantage, the slope of this line was 1.056 to indicate PHY499WRF had a relatively greater yield advantage at the highest yielding locations. The regression of PHY499WRF was compared to that for four other varieties in Fig. 7. The slope for AM1511B2RF at 1.034 was slightly lower than PHY499WRF to indicate that PHY499WRF had a slight advantage at the higher yielding locations. The slope for DP0912B2RF was slightly higher than PHY499WRF, but its intercept was much lower to indicate it had disproportionately lower yield at the lower yielding locations. Both the slope and intercept for DP1028B2RF was lower than PHY499WRF to indicate that the difference between these two varieties became more pronounced at higher yielding locations. Although this model provides a simplistic analysis of stability by only considering the relative productivity of environments, the regression R^2 and nearness of the slope to 1.0 have been used to indicate stability. Using these parameters and PHY499WRF appears to be less stable than AM1511B2RF and DP0912B2RF; however, GGEbiplot indicate similar stability across regions.

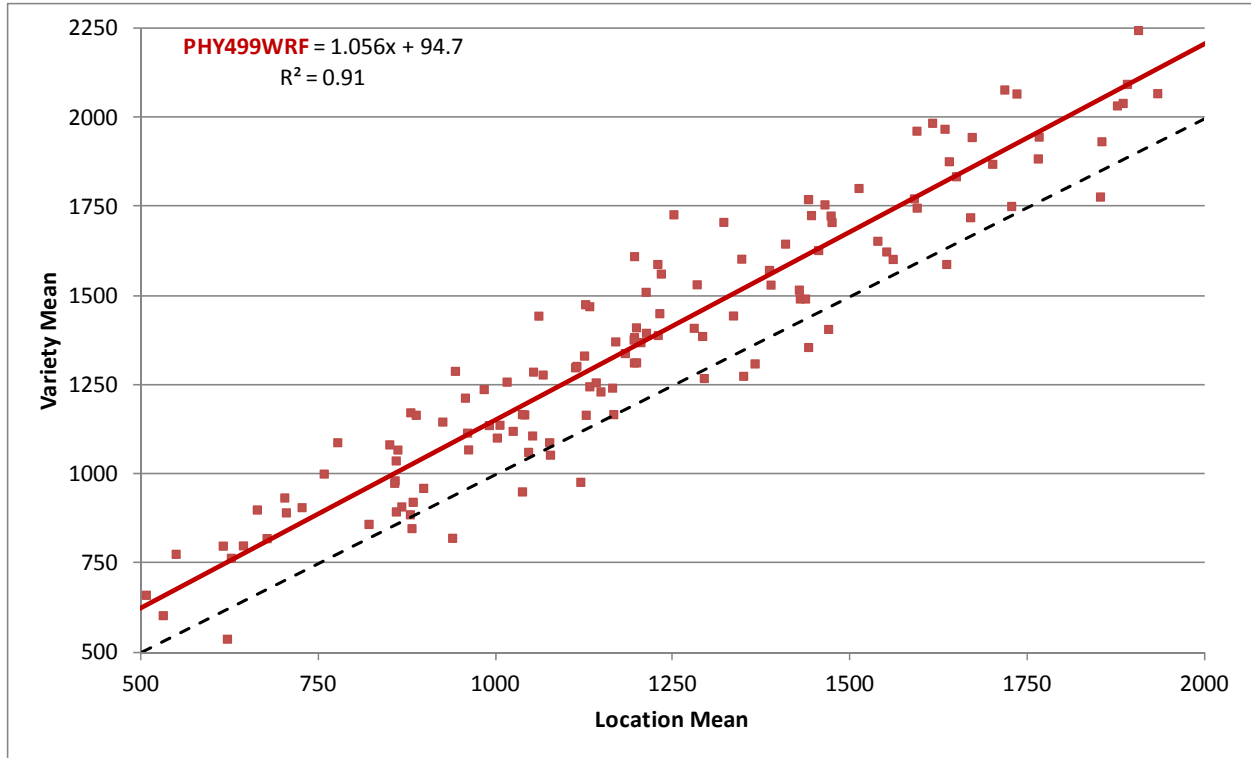


Figure 6. Eberhart-Russell regression of PHY499WRF yield vs. the location mean.

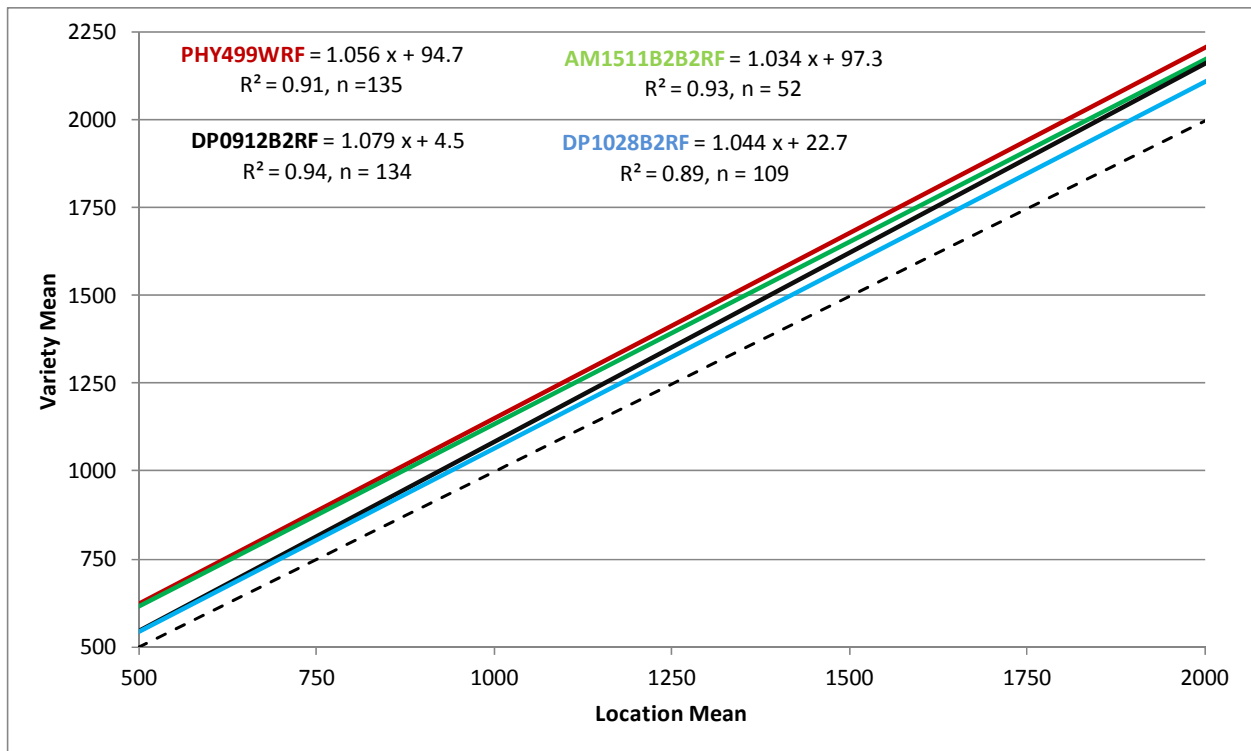


Figure 7. Eberhart-Russell regression of PHY499WRF, AM1511B2RF, DP0912B2RF and DP1028B2RF.

The frequency distributions of trial ranks in Fig. 8 reflect yield potential of several top varieties. PHY499WRF was the highest yielding variety in 26.3% of all trials and it finished in the top 2 entries 39.8% of the time. AM1511B2RF was the next best variety winning 15.4% of the trials and placing in the top 2 entries 25% of the time. DP0912B2RF was third using this rank parameter. Although this is a simplistic analysis, it does provide a very good indication of varietal performance across a broad range of environments. PHY499WRF stands head and shoulders above other varieties when one considers how often it won or placed second in university variety trials.

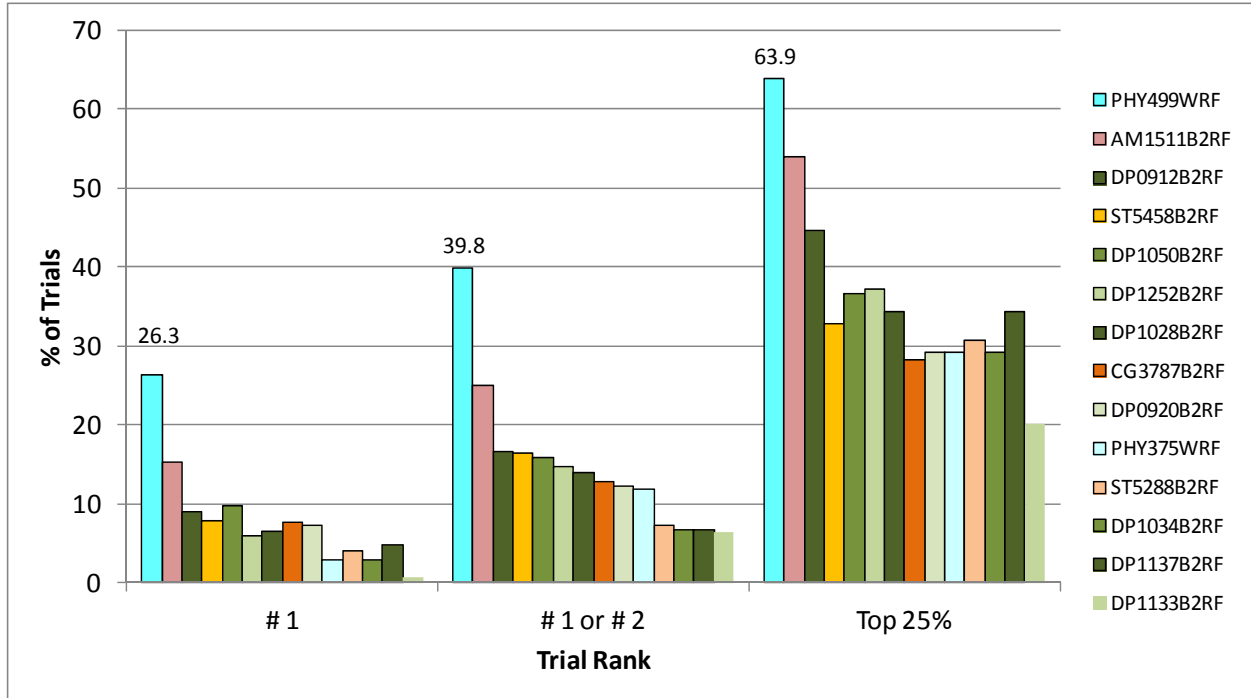


Figure 8. Frequency distributions of different trial rank groups within university trial environments.

Conclusion

From 2003 until 2010 DP555BG/RR was a dominant variety in the Southeast due to high yield and perceived stability of yield across a broad range of environments. Growers were concerned about finding a replacement for DP555BG/RR when seed production ceased in 2009. Other varieties such as DP1050B2RF and DP1252B2RF have been touted as being equivalent to DP555BG/RR, but the data presented above indicate that PHY499WRF is significantly higher yielding and more broadly adapted becoming the variety to beat across the lower Cotton Belt from South Texas to Georgia to Virginia.