The Economic Impact of Hybrid Rice in the Mid-South

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Abstract
This study quantified the economic impact of the introduction of RiceTec® hybrid rice in the mid-south (Arkansas, Louisiana and Mississippi). Third party data were collected from The University of Arkansas and Mississippi State University for yield, head rice yield, and milled rice yield for 23 locations throughout the Mississippi and Arkansas Delta from 2003-2013. Weather data (temperature, relative humidity and solar radiation) were compiled daily for each station so that yield estimates could account for genetic differences in responses to various climatic anomalies. As such, credible yield estimates could be obtained by year, location and variety (hybrid, conventional, Clearfield and Clearfield hybrids) to estimate premiums or discounts relative to a base (in this study the base is conventional and Clearfield lines). Using existing publically available data on percentage of acreage planted to hybrids and Clearfield hybrids a total state "hybrid and Clearfield hybrid premium" in bushels per acre could be estimated. These premiums were multiplied by 2014 USD rice prices to obtain a "total gain" associated to the RiceTec® breeding program. Given that yields were estimated for each "type" of rice an associated standard deviation of yield could also be obtained to illustrate yield variability across these types. From this a simulation was run to simulate 10,000 rice varieties associated with each "type" of rice. University Extension production budgets were then used to estimate cost of production (which included different seed herbicide costs) for each type of rice to obtain a profit function. As such, head-to-head comparisons could be made in terms of profitability between two sets of variety substitutes: (1) hybrid vs conventional and (2) Clearfield vs Clearfield hybrid. Lastly, IMPLAN was used to estimate the "value added" defined as "the sum of employee compensation, proprietary income, other property-type income and indirect business taxes" associated with the additional rice produced attributed to the RiceTec® hybrid program. The major findings of the study were:

- **On average RiceTec® Hybrids were associated with a yield increase of 32.43 bu/ac over conventional (inbred) lines**

- **On average RiceTec® Clearfield Hybrids were associated with a yield increase of 33.94 bu/ac over inbred Clearfield lines**

- **The estimated increase in production from adoption of RiceTec® Hybrids in AR, LA and MS was 154.41 million bushels from 2003-2013**

- **The estimated total revenue gain from adoption of RiceTec® Hybrids in AR, LA and MS in terms of additional bushels was 915.34 million (2014 USD) from 2003-2013**

- **The total estimated value added in AR, LA and MS attributed to the adoption of RiceTec® varieties was 16.36 million (2014 USD).**

- **Under average weather conditions, hybrid rice was found to be more profitable than conventional rice 100% of the time in Mississippi and Arkansas, even when accounting for higher seed costs and differences in head rice yields**

- **Under average weather conditions, Clearfield Hybrid lines were estimated to be more profitable than Clearfield lines 100% of the time in AR and 99.96% of the time in MS, even when accounting for higher seed costs and differences in head rice yields**

The Economic Impact of Hybrid Rice in the Mid-South

Introduction

This study quantifies advances of the RiceTec® hybrid rice breeding program from 2003-2013 in terms of increased producer revenue in Arkansas, Louisiana and Mississippi. Given the fact that hybrids are associated with higher seed costs a profitability comparison was made for hybrid vs conventional and Clearfield hybrid vs Clearfield in order to determine if the yield premium associated with hybrids is enough to offset higher seed costs. Data were collected by third party scientists in the form of University (Mississippi State University and the University of Arkansas) test plots and included yield, head rice yield, milled rice yield, planting dates, days to heading, and harvest dates. 2003 was chosen as a starting point for this study to coincide with the first release of a commercialized hybrid XL8 by RiceTec®. The study looks at the adoption of hybrid lines and the associated estimated yield gains attributed to hybrid and Clearfield hybrid lines and proposes the counterfactual question "what if RiceTec® never released their hybrid rice lines?" Specific objectives include: (1) estimate yield gains associated with adopting hybrid and Clearfield hybrids over conventional and Clearfield lines, respectively; (2) estimate total revenue gains for Arkansas, Louisiana and Mississippi from the adoption of RiceTec® hybrids; (3) use IMPLAN to estimate the total value added from the additional rice produced from the adoption of RiceTec® lines; and (4) estimate the profitability between hybrid and non-hybrid varieties in a head-to-head comparison under average weather conditions.

In 2000 RiceTec® released XL6 which was the first hybrid grown commercially in the Mid-South of the United States and in 2002 accounted for approximately 12,000 acres in Arkansas (0.8% of total acreage). XL6 was associated with a 20% yield premium but suffered from lodging and poor milling rates and thus never gained widespread adoption (Virmani, Mao and Lardy, 2003). In 2002 RiceTec® released XL7 and XL8, neither of which had the yield potential of XL6 but had better milling rates and were more widely adopted in the Mid-South. In 2003 XL8 had a small market share in Arkansas at 1.1% of total acres but with additional hybrid releases RiceTec® lines accounted for 19.7% by 2007. Figure 1

illustrates adoption patterns in terms of acreage of hybrid lines in AR, MS and LA from 2003-2013. Arkansas represents the highest *relative* and *absolute* acreage with 40.80% of 2013 acres being sown to hybrids totaling 439,000 acres.

Data

Yield data measured in bushels per acre (bu/ac) was obtained from the University of Arkansas Division of Agriculture Arkansas Rice Performance Trials (ARPT) and Mississippi State Agriculture and Forestry Experiment Station rice variety trials from 2003-2013. A total of 65 variety/cultivars were analyzed, with 18 hybrids (seven of which were Clearfield hybrids), 10 Clearfield varieties and 47 conventional (inbred) varieties. Appendix 1 highlights each variety in the study and the associated number of observations in the sample data. The inbred lines were released by LSU, University of Arkansas, Mississippi State and Texas A&M/The Agricultural Research Service (ARS). The test plot locations were spread out across 23 sites in the Arkansas/Mississippi Delta with 7 locations in Arkansas and 16 in Mississippi (Figure 2).

In addition to (paddy) yield data, we collected information on days to heading, planting date, harvest date, head rice yield and milled rice yield at the variety-location-year level. Although a gap between experimental and actual yields exists, Brennan (1984) notes that, "the only reliable sources of relative yields are cultivar trials" (p. 182). While yields are higher on experimental test plots than on producers' fields, the relative yield and yield variance differential are assumed to be equivalent.

Weather data in the form of daily temperature, relative humidity and solar radiation was obtained from aWhere for each location and each year. Because the literature is rich on climatic (namely nighttime temperature) effects on paddy and head rice yield this study set out to hold as much climatic variation across stations and within stations (as some varieties mature quicker than others) constant. Given the fact that weather affects rice productivity differently at different stages of the rice plants, two life cycle "widows" were created. Window one (vegetative stage) started at emergence and ended at heading and

window two (grain filling stage) started at heading and ended when the rice was harvested. As such, weather data was classified for each variety by its specific windows.

Model

The data covers 2003-2013 and includes observations on 65 varieties across 23 locations in Arkansas and Mississippi. We include location fixed effects in the model to control for time-invariant features at each site that affect yield, such as soil type, etc. We did not include these as random effects because using fixed effects allows these sources of variation to be correlated with the other variables in the model.

We include several weather measures within each growth phase: cumulative hours of temperature exposure above 22°C in the nighttime (NH22), cumulative hours of temperature exposure above 33°C in the daytime (DH33), solar radiation (SRAD), and vapor pressure deficit (VPD). The NH22 and DH33 variables are constructed at the daily level using a sinusoidal approximation of temperature exposure between observed minimum and maximum temperatures, and then summed across days within windows one and two. SRAD and VPD are observed daily, and then averaged across all days within each window. Although the weather data are specific to each location, the variation in the days to flowering for each variety induces variation in weather outcomes within each season-location.

We used multiple regression to estimate the following statistical model:

$$y_{it} = \alpha + \alpha_l + \alpha_t + \alpha_{ht} I_{it}^h + \alpha_{ct} I_{it}^c + \alpha_{cht} I_{it}^{ch} + \mathbf{w}_{it}\beta + u_{it},$$

where y_{it} is yield for variety *i* in season-year *t* and α_l and α_t are fixed effects for location *l* and year *t*, respectively. α is the overall constant in the model, and I_{it}^h, I_{it}^c, and I_{it}^{ch} are dummy variables that correspond to hybrid, Clearfield, and Clearfield-hybrid varieties. As such, the parameters α_{ht}, α_{ct}, and α_{cht} capture the yield advantage of these varieties relative to the baseline (conventional) variety. Note that these advantages vary across years in order to allow for an evolution of advantages across time. $\mathbf{w}_{it}$ is a $1\times k$ vector of weather variables where *k* is the number of variables, β is a $k\times 1$ vector of

parameters that capture the impact of weather, and u_{it} is a random error term that represents other unobservable drivers of yield. We pool the Arkansas and Mississippi data and estimate the model using ordinary least squares. Standard errors are clustered at the year level to allow for spatially correlated residuals.

Results

Actual vs perceived hybrid benefits

According to RiceTec's website and their claims of yield advantage for hybrids (http://www.RiceTec.com/Products/Hybrids/conventional) and Clearfield hybrids (http://www.RiceTec.com/Products/Hybrids/clearfield) they propose that hybrids will on average yield 37.1 bu/ac more than conventionals and Clearfield hybrids will yield 35.2 bu/ac more than Clearfield lines.[1] Table 1 illustrates that on average from 2003-2013 hybrids yielded 32.43 bu/ac more than conventionals. However; when you look at the last five years, 2009-2013 (when the comparison varieties were released) hybrids are estimated to yield 38.85 bu/ac more than conventionals. Clearfield hybrids are estimated to yield 34.05 bu/ac more than Clearfield lines from 2003-2013 and from 2009-2013 (when the comparison varieties were released) Clearfield hybrids are estimated to yield 37.95 bu/ac more than Clearfield lines. Thus, the estimates in this study are in line with the claims that RiceTec makes on their website as far as increased yield due to hybrid adoption.[2]

[1] The website claims that CLXL 729 will yield 31 bushels more than CL 151, that CLXL 745 will yield 36 bushels more than CL 151, CLXP 756 will yield 31 bushels more than CL 151 and CLXP 4534 will yield 43 bushels more than CL 151 for an average of 35.25 bu/ac for Clearfield hybrids over the popular CL 151. The hybrid website claims that XL 723 yields 42 bushels more than Roy J and 30 bushels more than Cheniere; XL 753 yields 47 bushels more than Roy J and 57 more than Cheniere; XP 754 yields 31 bushels more than Cheniere and 20 bushels more than Roy J; XP760 yields 30 bushels more than Roy J and XP 4523 yields 47 bushels more than Cheniere and 30 bushels more than Roy J for an average yield advantage of 37.1 bu/ac more than conventionals.

[2] These are conservative estimates given the fact that the estimated yields used in this study are adjusted for milling differences.

Hybrids in Arkansas

Tables 1, 3 and 5 illustrate that on average (across years, locations and varieties) hybrid lines yielded 32.43 bushels more than conventional varieties. In Arkansas the average conventional variety was estimated to yield 179.39 bu/ac and thus on average a hybrid would represent an 18% increase.[3] Table 1 shows the adoption rate of hybrids in terms of percentage and total acres. From this we can estimate the gains obtained by producers in Arkansas by multiplying (percent acreage in hybrids)*(total rice acres)*(increased yield associated with hybrids) to estimate the total number of additional bushels that were produced via hybrid adoption. By simply multiplying the number of additional bushels by that years rice price we can measure the associated revenue gain. Table 1 shows the time series (2003-2013) yield advantages which are not constant but specific to each year. This can be attributed to several factors; mix of hybrids planted at the test plots (a few hybrids associated with a poor growing season could lessen the hybrid increase); the introduction of new high yielding hybrid one year could increase the yield premium and the departure of a high yield (but possibly low milling) hybrid such as XL8 could lower the overall hybrid premium. In this sense, Tables 1-6 provide the year-specific hybrid premium which likely mimics realistic growing conditions rather than using one static premium for the entire 11 year data. While we do control for time-invariant factors that affect yield at each location (e.g. soil type) using the location fixed effect, we assume that the yield advantage is constant across locations.

Given the fact that head rice yield data was available for each paddy yield observation a test for differences in HRY could also be estimated between rice types. This is important for two reasons: (1) producers are paid on HRY and paddy yield not paddy yield alone, and (2) early hybrids (notably XL8) had a poor milling reputation and as such many in the rice industry still view hybrids as being of poor milling quality compared to conventionals. Again, given the deep literature in the effects of temperature (namely high night time temperature) on HRY the model in equation 1 was rerun using HRY instead of paddy yield. Table 8 estimates the differences in HRY between: (1) hybrids and conventional, and (2)

[3] 179.39 is higher than reported state average but is well grounded for a test plot. Again, here the relative difference between rice types is important not the absolute yield amount per acre.

Clearfield hybrids and Clearfield lines. For instance, for 2013 in Table 8 the adjustment for hybrid yield is 96.55%. This number was calculated by estimating the average HRY for conventionals (62.59%) and hybrids (60.42%) in 2013, which results in an adjustment factor of 96.55% (= 100*60.42/62.59). This factor can be interpreted as a reduction of 3.45% per standardized unit of paddy yield to reflect differences in HRY. As such, the actual estimated hybrid yield premium in 2013 was 41.98 bu/ac but given that hybrid HRY was estimated at 96.55% of conventionals that year the premium (41.98) was multiplied by 0.9655 to produce the new premium of 40.58 bu/ac. This is how the adjusted hybrid and Clearfield hybrid premiums were calculated in Tables 1-6 from the estimated adjustment factors in Table 8.

From these new "adjusted" hybrid paddy premiums a statewide increase in revenue can be estimated. By putting all rice prices (2003-2013) in 2014 USD we can compare the increase in producer revenue from hybrid adoption in Arkansas. Several things determine this revenue increase: (1) hybrid yield premiums, (2) rice price, and (3) the percentage total rice acreage under hybrids at the state-level. Yearly revenue increases attributed to hybrid adoption in Arkansas range from $560,000 in 2008 to $31,742,536 in 2013. Again it should be noted that the hybrid premium changes from year to year and is the reason why 2008 had the lowest revenue increase, due to its low hybrid premium that year. Overall, RiceTec® hybrids have added over 100.3 million (2014 USD) in revenue to Arkansas producers which equates to an average of 9.1 million dollars per year. An alternative way of looking at this is that, if RiceTec® did not release hybrid rice in Arkansas from 2003-20013 producers would have been 100.3 million dollars worse off.

Clearfield Hybrids in Arkansas

Using the same methodology as above for "Hybrids in Arkansas," revenue increases could be calculated for the adoption of Clearfield hybrids in Arkansas. As with hybrids an "adjustment factor" was created to account for milling differences between Clearfield hybrids and Clearfield lines. This adjustment factor

ranged from 89% to 103.94%, implying that in some years Clearfield hybrids milled better than traditional Clearfield lines (Table 8). The average yield premium for Clearfield hybrids vs. Clearfield was larger than hybrids vs. conventionals at 34.05 bu/ac to 32.48 bu/ac, respectively. Table 2 highlights that between 2003 and 2013 the adoption of Clearfield hybrids produced an additional $619,518,455 in producer revenue. This results in an average yearly contribution of 56.32 million dollars. The larger magnitude of these numbers compared to hybrids in Arkansas is due to the higher adoption rates of Clearfield hybrids.

Hybrids in Louisiana

Unlike Arkansas (University of Arkansas) and Mississippi (Mississippi State University), who conduct University test plot trials on RiceTec® hybrids, LSU does not. Thus, there is no third party data specific to Louisiana available. As such, it was assumed that the hybrid and Clearfield hybrid premiums experienced in Arkansas and Mississippi would be equivalent to Louisiana. This is most likely a conservative estimate given the high percentage of rice acreage in Louisiana that is ratooned and the proven track record of hybrids being an excellent ratoon variety given their quick vegetative state. Table 3 illustrates the increased revenue from hybrid production in Louisiana. Total gains over the 11 year period were estimated at 12.2 million dollars. This is relatively small compared to Arkansas for two reasons: (1) adoption rate of hybrids in Louisiana is smaller than in Arkansas, and (2) rice acreage in Arkansas is twice that of Louisiana.

Clearfield Hybrids in Louisiana

Although Clearfield hybrid adoption was greater than hybrid adoption the gains associated with them are still considerably smaller than Arkansas given the relatively small number of rice acres in Louisiana. Over the 11 year period the adoption of Clearfield hybrids in Louisiana amounted to a producer revenue increase of 113.06 million dollars. Again, this is a conservative estimate given the fact this study did not

account for ratooning, and the fact that some Clearfield hybrids (namely CLXL 729) excel during a ratoon crop.

Hybrids in Mississippi

Total revenue gain from hybrid adoption in Mississippi is estimated at $9,754,419, which is smaller than both Arkansas and Louisiana and driven by the lower percentage adoption in Mississippi relative to the other two states.

Clearfield Hybrids in Mississippi

Total revenue gain from Clearfield hybrid adoption in Mississippi is estimated at $60,430,057 over the study's time period.

Total Gains in the Mid-South

Summing the hybrid and Clearfield hybrid benefits across all states and years results in a net revenue gain of $915,337,828 million 2014 USD. This ranges from a low of 1.66 million in 2003 to a high of 207.77 million in 2011. Again, these figures are driven by hybrid adoption, hybrid yield premiums for each year, and the price of rice. These cumulative numbers would increase if the other two mid-south states were included (Texas and Missouri), assuming that the yield advantages calculated here are consistent with the advantages in those states. Figure 3 illustrates the total gains for each state over time.

Value Added

From the total additional bushels attributed to hybrid adoption, IMPLAN was used to estimate the total value added to local economies. Value added as described by IMPLAN is the sum of employee compensation, proprietary income, other property-type income and indirect business taxes. In Arkansas it was estimated using IMPLAN that for every cwt of rice produced $0.2355 ($0.1059 per bushel) of value

added was created within the Arkansas economy. Table 9 illustrates that across Arkansas, Louisiana and Mississippi from 2003-2013 RiceTec® created 16.39 million dollars in value added to local economies. This is in addition to the increase in producer revenue experienced on-farm. Arkansas alone experienced a value added of 12.88 million dollars from the introduction of RiceTec® hybrids into the state.

Profitability

While it is apparent that hybrid rice adoption has increased producer revenue the obvious question is how hybrid adoption has affected producer profits. Given that hybrid seed is more expensive that its conventional counterpart, yields must be sufficiently higher to offset higher seed costs. From the estimated yield equations for each rice type a mean and standard error could be obtained and from that simulated yields could be generated. As such, 10,000 simulated yields were generated for hybrids, conventionals, Clearfield hybrids and Clearfield lines for Arkansas and Mississippi under average weather conditions. As such, these provide a measure of dispersion across individual cultivars within each rice type around average yield for that type, holding weather at its sample average (i.e. normal growing conditions). 2014 cost of production data was obtained from the University of Arkansas and Mississippi State University for each type of rice. In Arkansas an acre of hybrid rice was estimated to cost a producer $767.90, an acre of conventional rice $720.42, an acre of Clearfield hybrid $778.80 and an acre of Clearfield rice $752.90. In Mississippi an acre of hybrid rice was estimated to cost a producer $770.52, an acre of conventional rice $723.04, an acre of hybrid $776.66 and an acre of Clearfield hybrid $849.12.[4] Given a rice price of $6.25 per bushel a per-acre profit function (price times yield, minus cost) was constructed for each of the 10,000 simulated yields and compared. Table 10 and Figure 4 highlight these results. In Arkansas hybrids and Clearfield hybrids were found to be more profitable than conventionals and Clearfield lines 100% of the time. That is under none of the 10,000 simulated yields did conventional

[4] Mississippi did not have a hybrid rice budget so the cost of production was found by adding the difference of hybrid and conventional in Arkansas to the conventional rice cost of production in Mississippi. It was also assumed that in Mississippi that straight levees were used.

or Clearfield lines exhibit a higher profit than their hybrid counterparts. This implies that the lowest performing hybrids outperform their highest performing counterparts among the conventional and Clearfield lines. In Mississippi, hybrids were more profitable than conventionals 100% of the time and Clearfield hybrids were more profitable than Clearfield lines 99.96% of the time. In Arkansas, hybrids are 20% more profitable than conventionals 97.38% of the time and Clearfield hybrids are 20% more profitable 100% of the time. In Mississippi those numbers are slightly lower at 74.82% and 89.51%. What appears to be evident is that hybrids/Clearfield hybrids are more profitable than conventionals/Clearfield lines under normal growing conditions, and in the case of this study the additional revenue offsets the higher seed costs.

Conclusions

This study set out to estimate the economic impact in terms of increased producer revenue and amount of value added to local economies from the adoption of RiceTec® varieties from 2003-2013. As such, data was collected from Arkansas, Louisiana and Mississippi on percent of total acreage planted under hybrid and Clearfield hybrid rice. Paddy yield, HRY, DTH, MRY, planting and harvest dates were collected for 3,500 University test plot run variety trials conducted by University of Arkansas and Mississippi State University. Data from 23 site locations throughout the Arkansas and Mississippi Delta were used to estimate what/if any hybrid and Clearfield hybrid premium existed. Daily weather observations for temperature, relative humidity, and solar radiation were collected from aWhere for each location-year combination. We used a multiple regression model to estimate: (1) the average yield difference between hybrid and conventional varieties across locations and years, and (2) the average yield difference between Clearfield hybrids and Clearfield varieties across locations and years. Two direct comparisons were made under the assumption that hybrids compete with conventionals for acreage and Clearfield hybrids compete with Clearfield lines for acreage.

Results indicate that on average (across time and locations) hybrid varieties were estimated to yield 32.43 bu/ac more than their conventional counterparts. Clearfield hybrids were estimated to yield 34.05 bu/ac more than their Clearfield counterparts. Because yield is dynamic overtime this study measured a "hybrid premium" for each year. The theory being that given the mix of hybrids/conventionals and Clearfield hybrids/Clearfield varieties which constantly rotate in and out of production the premium associated with hybrids should be dynamic as well. To reference this to existing literature on RiceTec's website they state that in their head-to-head comparisons the hybrids XL 723 (released in 2005), XL 753 (2011), XP 754 (2011) and XP 761 (2011) had an average yield premium of 37.1 bu/ac compared to two common conventionals; Cheniere (released in 2003 by LSU) and Roy J (released in 2010 by Arkansas). Analyzing the 2011 (given that the majority of hybrid lines made in the claim were released in 2011) to 2013 data the estimated hybrid increase in this study is 37.63, or nearly identical to the claim put forth by RiceTec®. RiceTec's website also states that in their head-to-head comparisons the hybrids CLXL 729 (2007) and CLXL 745 (2008), CLXP 756 (2011) and CLXP 751 (2011) had an average yield premium of 35.25 bu/ac compared to the popular Clearfield variety CL 151 (2008). Analyzing the same 2011-2013 time series the estimated Clearfield hybrid increase in this study is 37.66, slightly higher than the claim put forth by RiceTec®.

From these estimated yearly hybrid and Clearfield hybrid yield increases an increase in bushels produced per state could be obtained by analyzing the portion of a state under hybrid/Clearfield hybrid production. These additional bushels are simply multiplied by the rice price (in 2014 USD) for each year to measure revenue gains associated with adoption. Total gains in Arkansas, Louisiana and Mississippi attributed to RiceTec® from the adoption of their hybrid/Clearfield hybrid varieties is estimated at 915.34 million dollars from 2003-2013. The value added, as defined by IMPLAN as "the sum of employee compensation, proprietary income, other property-type income and indirect business taxes" of the additional rice attributed to the adoption of hybrid/Clearfield hybrid varieties is estimated at 16.36 million dollars across the same states in the same time frame.

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Tables

Table 1. Revenue Gain (2014 USD) associated with Hybrid Adoption in Arkansas: 2003-2014.

Year	Hybrid Premium (bu/ac)	% State Acreage Planted to Hybrids	Total State Acres Harvested	Additional Bushels From Hybrids	Long Grain Price ($/bu)	Long Grain Price (2014$/bu)	State Gain (2014 USD)
2003	35.12	1.30%	1,466,000	669,250	$1.87	$2.42	$1,619,585
2004	32.08	1.80%	1,561,000	901,469	$3.42	$4.31	$3,885,330
2005	29.27	2.00%	1,643,000	961,650	$3.30	$4.02	$3,865,832
2006	44.59	3.10%	1,406,000	1,943,584	$3.29	$3.88	$7,541,106
2007	19.88	8.50%	1,331,000	2,249,434	$4.26	$4.89	$10,999,734
2008	1.51	4.30%	1,401,000	90,837	$5.58	$6.17	$560,461
2009	36.17	2.70%	1,448,550	1,414,515	$6.71	$7.44	$10,523,994
2010	45.19	1.50%	1,785,000	1,210,069	$5.81	$6.34	$7,671,837
2011	61.39	3.60%	1,155,000	2,552,552	$4.95	$5.24	$13,375,374
2012	10.93	9.80%	1,280,000	1,371,606	$6.03	$6.25	$8,572,535
2013	40.58	10.90%	1,076,000	4,759,001	$6.53	$6.67	$31,742,536
						Total	$100,358,324

Table 2. Revenue Gain (2014 USD) associated with Clearfield Hybrid Adoption in Arkansas: 2003-2014.

Year	Clearfield Hybrid Premium (bu/ac)	% State Acreage Planted to Clearfield Hybrids	Total State Acres Harvested	Additional Bushels from Clearfield Hybrids	Long Grain Price ($/bu)	Long Grain Price (2014$/bu)	State Gain (2014 USD)
2003	17.36	0.00%	1,466,000	0	$1.87	$2.42	$0
2004	46.45	2.50%	1,561,000	1,812,760	$3.42	$4.31	$7,812,993
2005	17.69	2.60%	1,643,000	755,821	$3.30	$4.02	$3,038,401
2006	34.25	5.60%	1,406,000	2,696,499	$3.29	$3.88	$10,462,417
2007	34.54a	11.20%	1,331,000	5,149,096	$4.26	$4.89	$25,179,079
2008	34.54a	24.10%	1,401,000	11,662,120	$5.58	$6.17	$71,955,281
2009	34.83	25.17%	1,448,550	12,698,978	$6.71	$7.44	$94,480,398
2010	41.96	26.60%	1,785,000	19,923,777	$5.81	$6.34	$126,316,748
2011	62.47	36.75%	1,155,000	26,517,701	$4.95	$5.24	$138,952,752
2012	30.15	40.50%	1,280,000	15,630,322	$6.03	$6.25	$97,689,511
2013	20.33	29.90%	1,076,000	6,541,360	$6.53	$6.67	$43,630,874
						Total	$619,518,455

Table 3. Revenue Gain (2014 USD) associated with Hybrid Adoption in Louisiana: 2003-2014.

Year	Hybrid Premium (bu/ac)	% State Acreage Planted to Hybrids	Total State Acres Harvested	Additional Bushels From Hybrids	Long Grain Price ($/bu)	Long Grain Price (2014$/bu)	State Gain (2014 USD)
2003	35.12	0.12%	427,015	17,994	$1.87	$2.42	$43,546
2004	32.08	0.76%	514,882	125,544	$3.42	$4.31	$541,095
2005	29.27	0.32%	514,328	48,166	$3.30	$4.02	$193,627
2006	44.59	0.27%	331,903	39,961	$3.29	$3.88	$155,047
2007	19.88	2.66%	347,969	184,034	$4.26	$4.89	$899,927
2008	1.51	1.35%	347,996	7,084	$5.58	$6.17	$43,707
2009	36.17	2.09%	404,823	306,000	$6.71	$7.44	$2,276,643
2010	45.19	0.38%	490,094	84,167	$5.81	$6.34	$533,621
2011	61.39	2.74%	357,021	600,530	$4.95	$5.24	$3,146,776
2012	10.93	2.10%	359,221	82,485	$6.03	$6.25	$515,530
2013	40.58	4.40%	324,206	578,830	$6.53	$6.67	$3,860,793
						Total	$12,210,312

Table 4. Revenue Gain (2014 USD) associated with Clearfield Hybrid Adoption in Louisiana: 2003-2014.

Year	Clearfield Hybrid Premium (bu/ac)	% State Acreage Planted to Clearfield Hybrids	Total State Acres Harvested	Additional Bushels from Clearfield Hybrids	Long Grain Price ($/bu)	Long Grain Price (2014$/bu)	State Gain (2014 USD)
2003	17.36	0.00%	427,015	0	$1.87	$2.42	$0
2004	46.45	0.89%	514,882	212,860	$3.42	$4.31	$917,429
2005	17.69	1.98%	514,328	180,183	$3.30	$4.02	$724,335
2006	34.25	2.24%	331,903	254,616	$3.29	$3.88	$987,911
2007	34.54a	10.90%	347,969	1,310,055	$4.26	$4.89	$6,406,167
2008	34.54a	9.56%	347,996	1,149,091	$5.58	$6.17	$7,089,892
2009	34.83	15.96%	404,823	2,250,351	$6.71	$7.44	$16,742,610
2010	41.96	21.24%	490,094	4,368,031	$5.81	$6.34	$27,693,317
2011	62.47	25.01%	357,021	5,578,327	$4.95	$5.24	$29,230,435
2012	30.15	17.17%	359,221	1,859,666	$6.03	$6.25	$11,622,912
2013	20.33	26.50%	324,206	1,746,834	$6.53	$6.67	$11,651,380
						Total	$113,066,389

Table 5. Revenue Gain (2014 USD) associated with Hybrid Adoption in Mississippi: 2003-2014.

Year	Hybrid Premium (bu/ac)	% State Acreage Planted to Hybrids	Total State Acres Harvested	Additional Bushels From Hybrids	Long Grain Price ($/bu)	Long Grain Price (2014$/bu)	State Gain (2014 USD)
2003	35.12		251,000	0	$1.87	$2.42	$0
2004	32.08		234,000	0	$3.42	$4.31	$0
2005	29.27		234,000	0	$3.30	$4.02	$0
2006	44.59	1.00%	263,000	117,277	$3.29	$3.88	$455,034
2007	19.88	7.50%	189,000	281,838	$4.26	$4.89	$1,378,187
2008	1.51	1.00%	189,000	2,850	$5.58	$6.17	$17,583
2009	36.17	1.00%	243,000	87,885	$6.71	$7.44	$653,867
2010	45.19	1.00%	303,000	136,938	$5.81	$6.34	$868,186
2011	61.39	7.00%	157,000	674,665	$4.95	$5.24	$3,535,242
2012	10.93	1.00%	129,000	14,105	$6.03	$6.25	$88,158
2013	40.58	7.90%	129,000	413,517	$6.53	$6.67	$2,758,161
						Total	$9,754,419

Table 6. Revenue Gain (2014 USD) associated with Clearfield Hybrid Adoption in Mississippi: 2003-2014.

Year	Clearfield Hybrid Premium (bu/ac)	% State Acreage Planted to Clearfield Hybrids	Total State Acres Harvested	Additional Bushels from Clearfield Hybrids	Long Grain Price ($/bu)	Long Grain Price (2014$/bu)	State Gain (2014 USD)
2003	17.36		1,466,000	0	$1.87	$2.42	$0
2004	46.45		1,561,000	0	$3.42	$4.31	$0
2005	17.69		1,643,000	0	$3.30	$4.02	$0
2006	34.25	1.00%	1,406,000	90,071	$3.29	$3.88	$349,474
2007	34.54a	7.50%	1,331,000	489,605	$4.26	$4.89	$2,394,166
2008	34.54a	2.00%	1,401,000	130,561	$5.58	$6.17	$805,563
2009	34.83	9.00%	1,448,550	761,730	$6.71	$7.44	$5,667,270
2010	41.96	20.00%	1,785,000	2,542,872	$5.81	$6.34	$16,121,806
2011	62.47	38.00%	1,155,000	3,727,175	$4.95	$5.24	$19,530,397
2012	30.15	43.00%	1,280,000	1,672,481	$6.03	$6.25	$10,453,004
2013	20.33	29.20%	1,076,000	765,874	$6.53	$6.67	$5,108,378
						Total	$60,430,057

Table 7. Total Revenue Gain in 2014 USD for Arkansas, Louisiana and Mississippi from RiceTec® Adoption: 20013-2013

Year	Arkansas	Mississippi	Louisiana	Total (2014 USD)
2003	$1,619,585	$0	$43,546	$1,663,131
2004	$11,698,323	$0	$1,458,524	$13,156,847
2005	$6,904,232	$0	$917,962	$7,822,194
2006	$18,003,523	$804,508	$1,142,958	$19,950,989
2007	$36,178,813	$3,772,258	$7,306,094	$47,257,165
2008	$72,515,743	$823,114	$7,133,599	$80,472,455
2009	$105,004,392	$6,321,137	$19,019,253	$130,344,782
2010	$133,988,586	$16,989,992	$28,226,938	$179,205,516
2011	$152,328,127	$23,065,639	$32,377,211	$207,770,977
2012	$106,262,046	$10,541,162	$12,138,443	$128,941,651
2013	$75,373,409	$7,866,539	$15,512,174	$98,752,122
			Total	$915,337,828

Table 8. Percent Yield Adjustments from Estimated Hybrid and Clearfield Hybrid Yield Premiums due to differences in Estimated Head Rice Yields by Year.

Year	Hybrid vs Conventional Yield Adjustments	Clearfield Hybrid vs Clearfield Yield Adjustments
2003	96.74%	93.21%
2004	100.31%	89.91%
2005	100.29%	95.79%
2006	100.50%	97.43%
2007	98.19%	98.65%
2008	94.63%	103.94%
2009	96.80%	99.90%
2010	98.56%	97.87%
2011	97.98%	99.76%
2012	94.54%	95.54%
2013	96.55%	97.63%

Table 9. Total Value Added from the Release of Hybrid Rice by RiceTec®: 2003-2013[a]

Year	Arkansas Bushels	Mississippi Bushels	Louisiana Bushels	Value Added Per Bushel	Arkansas Value Added (2014 USD)	Mississippi Value Added (2014 USD)	Louisiana Value Added (2014 USD)	Total Value Added (2014 USD)
2003	669,250	0	17,994	$0.11	$70,924	$0.00	$1,907	$72,831
2004	2,714,228	0	338,405	$0.11	$287,640	$0.00	$35,862	$323,503
2005	1,717,471	0	228,349	$0.11	$182,009	$0.00	$24,199	$206,208
2006	4,640,083	207,347	294,577	$0.11	$491,733	$21,973	$31,218	$544,924
2007	7,398,530	771,442	1,494,089	$0.11	$784,059	$81,753	$158,336	$1,024,149
2008	11,752,957	133,411	1,156,175	$0.11	$1,245,520	$14,138	$122,526	$1,382,183
2009	14,113,493	849,615	2,556,351	$0.11	$1,495,677	$90,037	$270,909	$1,856,625
2010	21,133,846	2,679,809	4,452,198	$0.11	$2,239,659	$283,992	$471,822	$2,995,474
2011	29,070,253	4,401,840	6,178,857	$0.11	$3,080,720	$466,484	$654,804	$4,202,009
2012	17,001,927	1,686,586	1,942,151	$0.11	$1,801,779	$178,735	$205,819	$2,186,335
2013	11,300,361	1,179,391	2,325,663	$0.11	$1,197,556	$124,985	$246,462	$1,569,004
				Total	$12,877,277	$1,262,103	$2,223,865	$16,363,245

[a]Value added is defined as the sum of employee compensation, proprietary income, other property-type income and indirect business taxes.

Table 10. Estimated Percentage of Times that Hybrid/Clearfield Hybrids are more Profitable than Conventional/Clearfield varieties in Arkansas and Mississippi.

	Arkansas		Mississippi	
	Conventional	Clearfield	Conventional	Clearfield
Hybrid/Clearfield Hybrid				
More Profitable	100%	100%	100%	99.96%
10% more profitable	99.95%	100%	98.37%	99.02%
15% more profitable	99.56%	100%	91.60%	96.32%
20% more profitable	97.38%	100%	74.82%	89.51%
25% more profitable	90.19%	100%	49.03%	76.39%
30% more profitable	74.36%	99.99%	24.54%	57.88%
35% more profitable	50.23%	99.82%	9.64%	38.54%

Figures

Figure 1. Long Grain Hybrid Acreage in Arkansas, Louisiana and Mississippi: 2003-2013

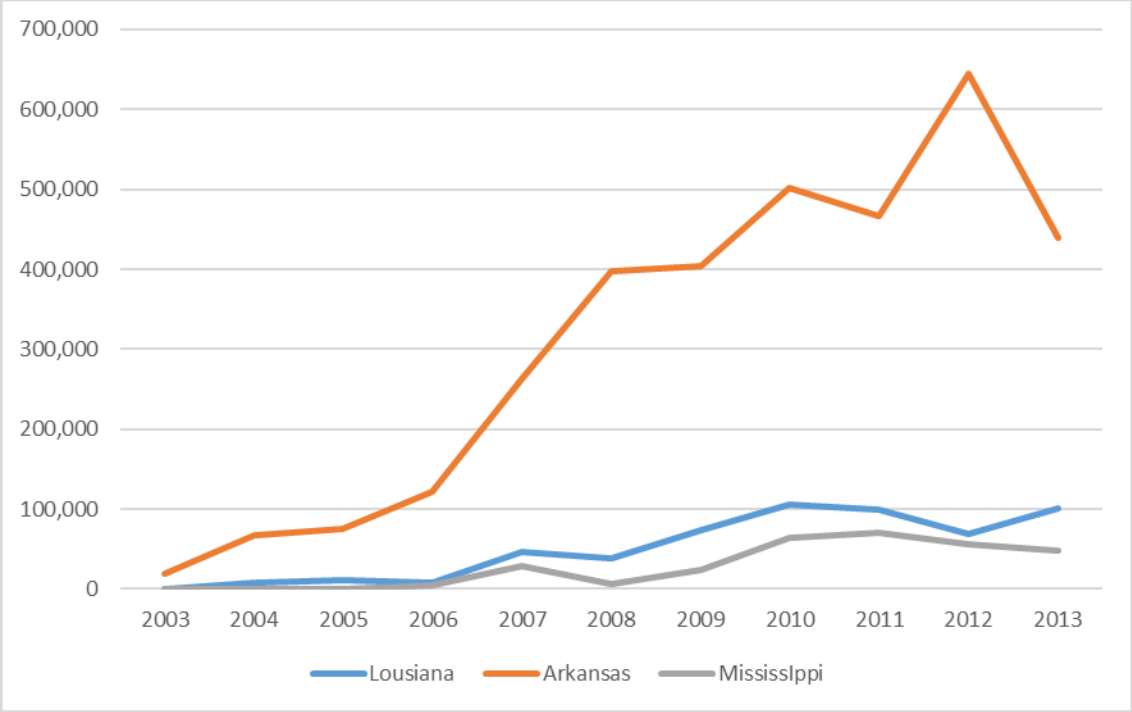


Figure 2. Test Plot Locations in Arkansas and Mississippi Used in Study.

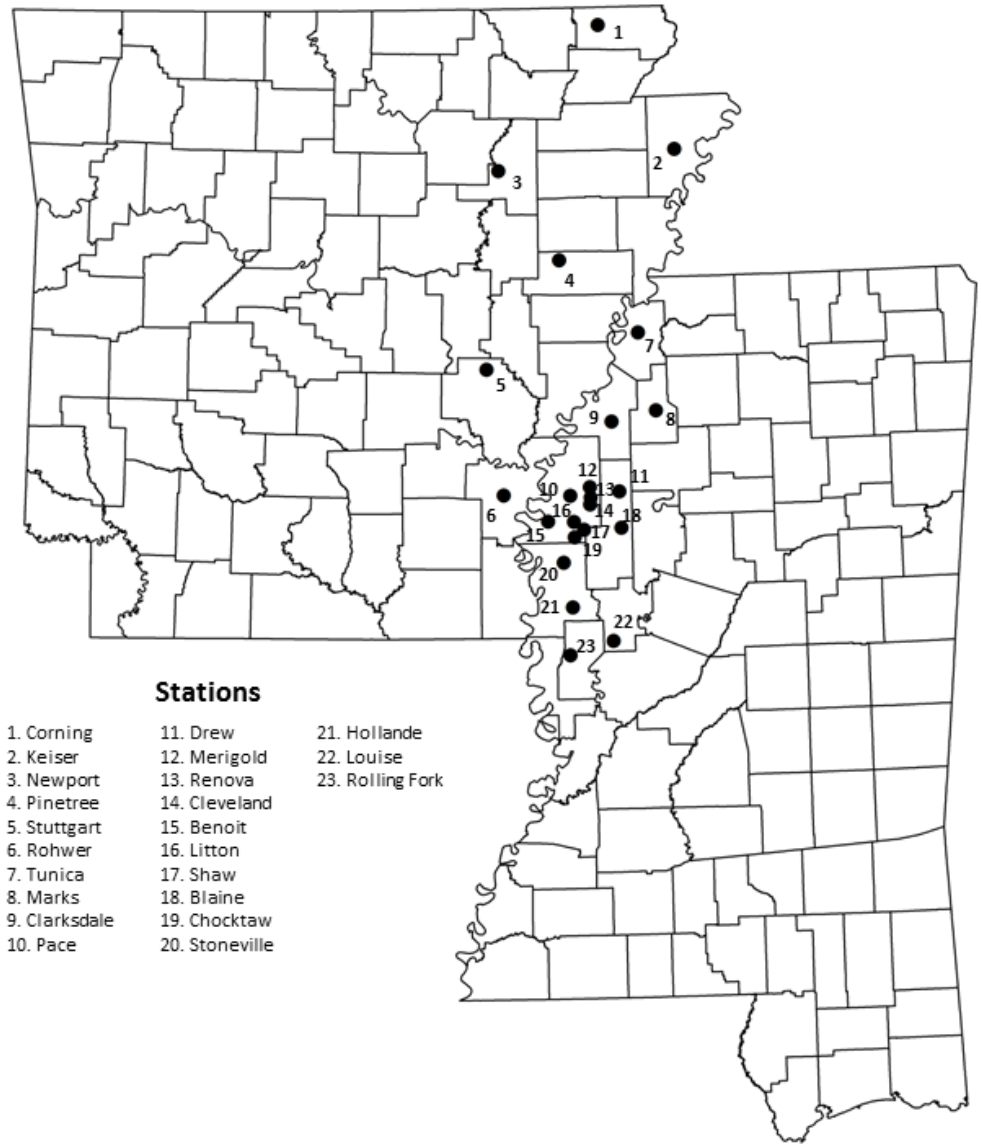


Figure 3. Total Revenue Gains by State and Year from Adoption of RiceTec® Varieties: 2003-2013

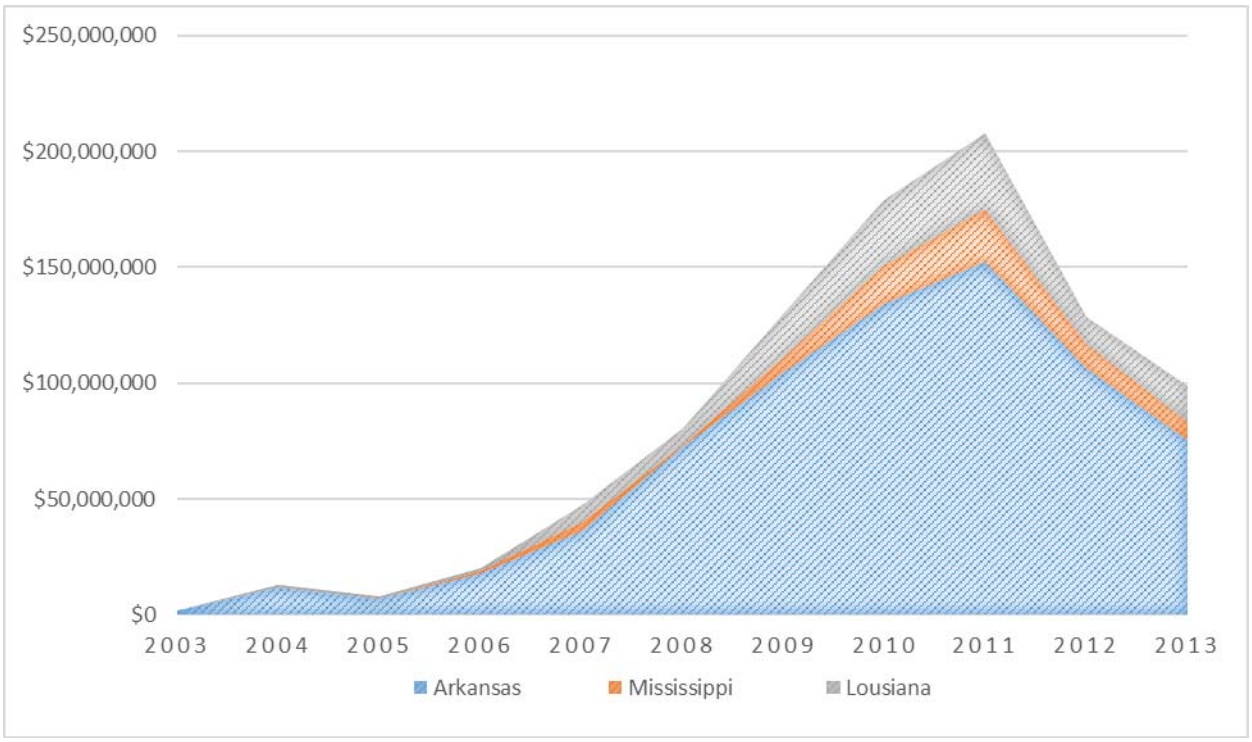
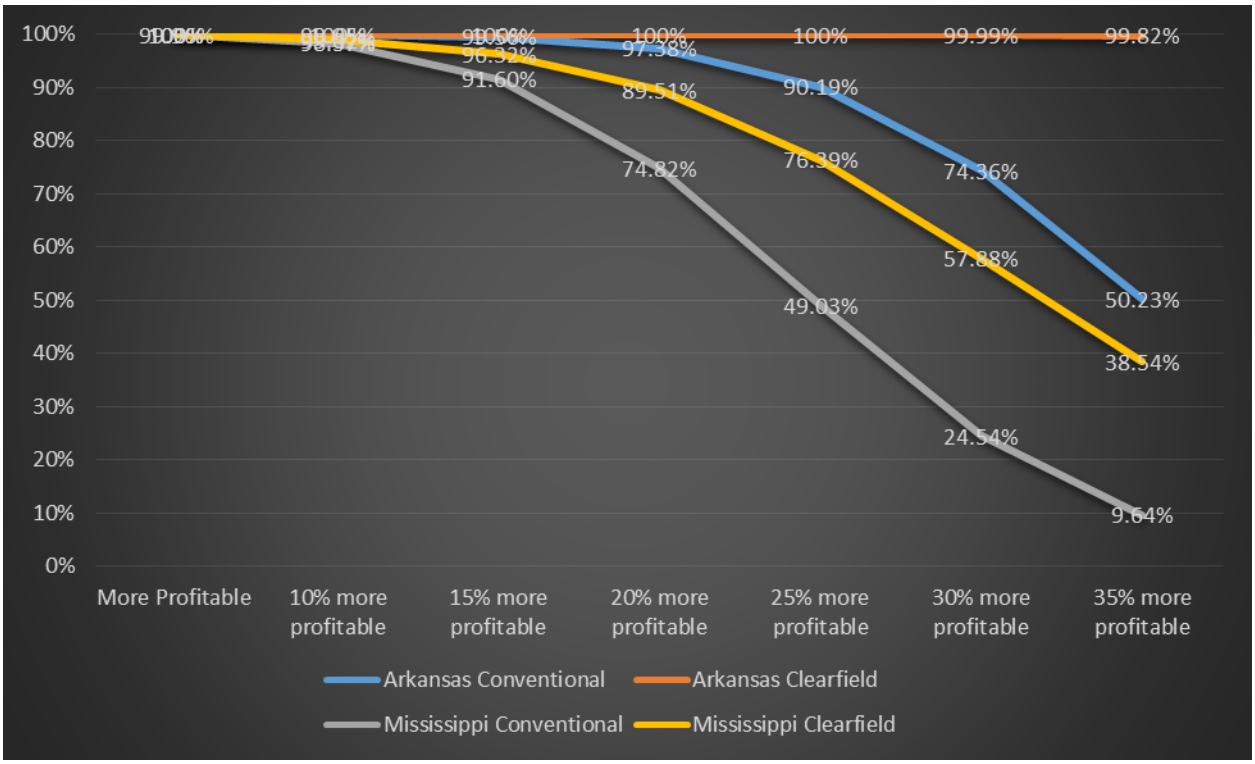


Figure 4. Estimated Percentage of Times that Hybrid/Clearfield Hybrids are more Profitable than Conventional/Clearfield varieties in Arkansas and Mississippi.



Appendix 1: Varieties and Number of Appearances in the University of Arkansas Division of Agriculture Arkansas Rice Performance Trials (ARPT) and Mississippi State Agriculture and Forestry Experiment Station rice variety trials from 2003-2013

Variety	NOBS	Variety	NOBS
Ahrent	58	Kaybonnet	21
Antonio	30	LaGrue	98
Arize1003	48	Maybelle	21
Banks	63	Medark	64
Bengal	104	Mermentau	30
Bowman	69	Neptune	43
Caffey	32	Pace	7
Catahoula	55	Pirogue	18
Cheniere	140	Presidio	67
CL111	71	Priscilla	32
CL131	96	Rex	51
CL142AR	66	Rondo	5
CL151	76	RoyJ	49
CL152	36	Saber	21
CL161	88	Sabine	41
CL162	41	Spring	59
CL171AR	38	Taggart	70
CL181AR	53	Templeton	65
CL261	45	Trenasse	81
CLXL729	63	Wells	149
CLXL730	14	XL723	91
CLXL745	61	CLXL729	1
CLXL8	67	XL744	2
CLXL751	5	XL753	25
CLXL729	15	XL8	15
CLXL730	26	XP761	5
CLXP751	15	XP710	52
CLXP756	6	XP712	21
Cocodrie	155	XP716	24
Colorado	30	XP721	18
Cybonnet	95	XL723	56
Cypress	21	XP744	16
Drew	77	XL753	11
Francis	124	XP754	6
Jefferson	58	XP761	15
Jupiter	109	Grand Count	3500

Observations by Location		Observations by State	
Benoit (MS)	31	Arkansas	2518
Blaine (MS)	73	Mississippi	982
Choctaw (MS)	44	Total	3500
Clarksdale (MS)	157		
Cleveland (MS)	41		
Corning (AR)	492		
Drew (MS)	16		
Hollandale (MS)	151		
Keiser (AR)	518		
Litton (MS)	24		
Louise (MS)	11		
Merigold (MS)	15		
Newport (AR)	525		
Pace (MS)	16		
PineTree (AR)	295		
Renova (MS)	24		
Rohwer (AR)	192		
Rolling Fork (MS)	35		
Shaw (MS)	23		
Stoneville (MS)	172		
Stuttgart (AR)	496		
Tunica (MS)	149		
Total	3500		