Differential Response of a Rice Inbred Variety and a Hybrid to High Night Temperature

High temperatures are one of the major abiotic stresses that affect mid-south U.S. rice productivity. Periods of high temperature often coincide with the reproductive stage of rice grown in the mid-south (Mohammed and Tarpley, 2009a). This area also experiences periods of high night temperatures (HNT) because of high relatively humidity. Previous research has shown decreased rice yields due to HNT (Mohammed and Tarpley, 2009b). High night temperatures are known to increase respiration rates (Mohammed and Tarpley, 2009a, Cheng et al., 2009) and can lead to production of reactive oxygen species (ROS), which can increase membrane injury (destruction of cell membranes) (Liu and Huang, 2000). Leaky membranes, a result of ROS production, decrease cellular integrity and can affect production, consumption, and transfer of photosynthates. Moreover, HNT (>84°F) decreases spikelet fertility of rice, with a subsequent reduction in seed set and grain yield (Ziska et al., 1986). There is a strong negative linear relationship between number of fertile spikelets per acre and nighttime temperature (Peng et al., 2004).

We screened two rice varieties, ‘Cocodrie’ (inbred) and ‘XL723’ (hybrid), for variation in tolerance to elevated night temperature with respect to morphological, phenological, and physiological parameters. Plants were grown under ambient night temperature (ANT) (25°C or 77°F) or HNT (30°C or 86°F) in the greenhouse. HNT treated plants were subjected to daily HNT from 2000 to 0600 h through the use of continuously controlled (+/- 0.5°C or 0.9°F) infrared heaters starting at 30 days after emergence.

Fig. 1. Differential response of inbred variety ‘Cocodrie’ and hybrid ‘XL723’ to high night temperature.
Welcome to the July issue of Texas Rice. Earlier this month, the Texas rice industry mourned the loss of Bill Dishman Sr., a long time rice grower and a tireless promoter of the Texas A&M rice research programs at the Beaumont Center and the David R. Wintermann Rice Station in Eagle Lake. Bill Sr. was a quiet person and when he spoke people inevitably would find the information he provided to be useful. For a number of years, Bill Sr. served on the Texas Rice Producers Board, the Texas Rice Research Foundation, and the Texas Rice Improvement Association. The Texas rice industry was blessed to have had such a kind and thoughtful person working for them for so many years. Bill Sr. will be sorely missed. Please keep Martha and her family in your thoughts and prayers.

In late-June, we celebrated the 37th annual field day at the David R. Wintermann Rice Station in Eagle Lake. Overall, our Eagle Lake and Beaumont support staff and faculty worked extra hard to make the Eagle Lake field tour a success. The weather could not have been better as visitors toured the field plots and listened to Garry McCauley, Dante Tabien, Mo Way, Shane Zhou, Scott Senseman, and Edinalvo Camargo provide updates on their field research. For those who do now know Edinalvo, Edge as he is known by his friends, is a graduate student who works on weed management with Garry McCauley and Scott Senseman to determine how to get the best control out of new herbicides.

The Eagle Lake civic center was packed as we enjoyed a meal sponsored by BU Growers, and as we listened to the evening program presentations by Steve Balas and Joe Outlaw. Garry McCauley, who MC’ed the evening program, provided a long list of companies who provided funding that allowed us to hold this year’s program. Coleen Meitzen and the Colorado County Field Day Committee had everything in order, while Lee Tarpley, Dante Tabien, and their display committee developed posters that highlighted much of our research.

Sometimes, it is too easy to forget about all of the help we receive that makes it possible for our scientists to conduct research at Beaumont, Eagle Lake, Ganado, and elsewhere. While Texas A&M AgriLife Research and the USDA-Agricultural Research Service provide critical funding that enables the Center to hire most of our state and federal research scientists, funding from the Texas Rice Producers Board, the Texas Rice Research Foundation, and federal, state, and industry grants allow us to hire many of our support staff and to build upon this foundation. For example, for every dollar the Texas A&M system spends for research, about $0.55 comes from AgriLife Research while $0.45 is provided through grants. Funding from our growers is an important part of the non-state base support. Two things are sure about rice research in Texas. When times have gotten tough, such as in 2003 and again this year, the rice industry has stepped to the plate to help our researchers. Also, unbeknownst to many, every year our researchers work harder and harder to generate local, state, and federal funding. Without their efforts, much of the research in Beaumont, Eagle Lake, and elsewhere would not exist otherwise.

Earlier this month, we also held the 64th Beaumont Field Day. By all accounts the Beaumont Field Day...
Rice is a staple food for about half the world’s population, and the increasing demand for rice due to the increasing population size requires higher grain yield productivity. Rice ratooning may be a good choice for regions where the duration of the growing season is not long enough for a second main crop. A ratoon crop’s yield potential is about 50% of its main crop, and because it requires less input than a main crop in terms of seed, fertilizer, and water management, it can contribute greatly to profitability. Currently, rice ratooning is used in the southern U.S., Japan, China, and India. Aside from studying the effects of cutting height on rice ratooning, which has been well explored (Harrell et al., 2009; Prashar, 1970), few studies have been conducted to explore the effects of other management practices on ratoon crop grain yield.

**Varietal Effects on Ratoon Crop**

Varieties can play an important role in ratoon crop productivity. The geography and climate in a given area may allow only some varieties to be suitable for ratooning. For example, early-maturing varieties, such as Presidio, CL 152, Bowman, and Cocodrie perform well as ratoon crops in Texas and Louisiana because they allow time for the ratoon crop to mature before the cold weather of fall sets in. In India, intermediate-to late-maturing varieties are required to produce a good ratoon crop in the tropical hills and valleys (Krishnamurthy, 1988). In China, hybrid varieties (Zaishengyou and Aiyou 2) have been reported to have better performance in weight of mature panicles and percentage of filled grain than inbreds, such as...
Luke 2 and Zaishengai (Zhang et al., 2009). Greater ratoon yield of hybrids is attributed to better regeneration, planting height, and disease resistance. In the U.S., varieties with good tillering potential and vegetative vigor are preferred for ratoon cropping.

**Nutrient Management Effects on Ratoon Crop**

Nitrogen fertility is one of the most important factors influencing ratoon crop grain yield (Turner and McIlrath, 1988) and, in general, N application increases rice ratoon yield. The ratoon crop requires a lower amount of N fertilizer to achieve its potential yield than required for the main crop. Application to the ratoon crop of about 75% of the main crop nitrogen fertilization rate is sufficient to obtain high ratoon yield (Evatt and Beachell, 1960). Although this proportion varies with variety and other management options, the lesser N requirement for the ratoon crop may be due to its short developmental duration. In addition to N rate, the application timing affects ratoon rice yield. Turner and McIlrath (1988) reported that N applied at or near main crop heading tends to increase ratoon crop yields but decreases main crop yields, resulting in little effect on total (main crop + ratoon crop) yield. The effects of application timing also vary with variety. With some modern U.S. hybrids, an application from boot stage to 5% heading can increase main and ratoon crop yields. Turner and McIlrath (1988) also observed that N application following main crop harvest consistently increases ratoon crop yield.

Phosphorus (P) and potassium (K) are also essential to rice development and growth. However, P and K have smaller effects than N on ratoon yield when the main crop is supplied with adequate amounts of P and K (Evatt and Beachell, 1960; Ganguli and Ralwani, 1954).

**Disease and Insect Management Effects on Ratoon Crop**

Sheath blight, bacterial panicle blight, *Cercospora*, and blast are four of the most important diseases affecting rice production (Groth et al., 2008). A review of the relationship between main and ratoon crop diseases indicates that responses to diseases are consistent in both crops (Mew and Fabellar, 1988).
other words, diseases that are prevalent in the main crop of a variety are also found in its ratoon crop. However, exceptions have been observed for some diseases. For example, yellow dwarf, a disease caused by a mycoplasma-like organism, is often observed in ratoon crops in tropical Asia, probably because of its long latency in the plant (Mew and Fabellar, 1988). Therefore, it is strongly recommended to apply disease control to the main crop for this disease. Even for diseases that are common to both main and ratoon crops, the carryover effect onto the ratoon crop is mitigated through the application of fungicides to the main crop. A similar carryover effect has been reported in insect control (Way et al., 2006) for the rice water weevil (Lissorhoptrus oryzophilus).

**Rice Ratoon Crop Studies at Texas A&M AgriLife Research**

In the past decade, new varieties, especially hybrids, have been planted broadly in the U.S., but few studies have been conducted to evaluate ratoon crop productivity. Our studies at the Texas AgriLife Research and Extension Center at Beaumont have indicated that ratoon yield is affected by variety, planting location and date (Fig. 1), and nutrient and disease management. Tested hybrids averaged 12% higher ratoon crop yield than inbreds. Within inbreds, ratoon yield was affected by variety. For example, Presidio had greater ratoon yield than Bowman and Cocodrie at Beaumont and Eagle Lake (Fig. 1). Eagle Lake trials usually have greater ratoon crop yields than trials at Beaumont. Early planting dates usually result in greater ratoon crop yield, especially for inbreds.

The effects of nitrogen on ratoon crop yield varies with rate (100, 135, and 165 lb/acre) and timing (single application prior to ratoon crop flooding vs. split application at pre-flooding, and 14 and 28 days after flooding) (Fig. 2). Generally, increased N rates increase ratoon crop yield. Split applications, with the first application prior to ratoon crop flooding and the second within 14 days after flooding, compared to a single application prior to flooding, both increase ratoon yield. In contrast, a second split application later than 28 days after ratoon crop flooding did not contribute to increased ratoon yield. Nitrogen applied to the main crop has a positive carryover effect on ratoon crop yield (Fig. 3). Similarly, fungicide treatment for sheath blight control during the main crop has a positive carryover effect with ratoon crop yield.
yield increased 6% (Fig. 4).

Our studies indicated that, similar to the main crop, ratoon crop yield is affected by varietal selection, planting date, and nutrient and disease management. However, to further improve ratoon crop yield, more comprehensive studies on the optimization of management practices are required.

For more information, please consult the following references:


* Article by Drs. Fugen Dou (f-dou@aesrg.tamu.edu) and Lee Tarpley, Texas A&M AgriLife Research and Extension Center, Beaumont, TX.
High Night Temperature ...

Table 1. Differential response of inbred variety ‘Cocodrie’ and hybrid ‘XL723’ to high night temperature (HNT) and ambient night temperature (ANT).

<table>
<thead>
<tr>
<th>Trait Parameters</th>
<th>Cocodrie</th>
<th>XL-723</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HNT †</td>
<td>ANT †</td>
</tr>
<tr>
<td>Panicle dry mass (g/plant)</td>
<td>15.0 ± 0.2 b</td>
<td>16.7 ± 0.2 a</td>
</tr>
<tr>
<td>Total grain (no./panicle)</td>
<td>80.0 ± 9.1 b</td>
<td>101.3 ± 3.5 a</td>
</tr>
<tr>
<td>Filled grain (no./panicle)</td>
<td>47.4 ± 7.5 b</td>
<td>62.9 ± 4.4 a</td>
</tr>
<tr>
<td>Unfilled grain (no./panicle)</td>
<td>32.6 ± 8.7 a</td>
<td>37.6 ± 5.4 a</td>
</tr>
<tr>
<td>Grain mass (g/panicle)</td>
<td>0.9 ± 0.1 b</td>
<td>1.3 ± 0.1 a</td>
</tr>
<tr>
<td>Grain width (mm)</td>
<td>2.25 ± 0.01 b</td>
<td>2.29 ± 0.01 a</td>
</tr>
<tr>
<td>Grain surface area (mm²)</td>
<td>15.2 ± 0.17 b</td>
<td>15.6 ± 0.15 a</td>
</tr>
</tbody>
</table>

† Each value is the mean with standard error (±S.E.). Means within a row for a variety followed by a different letter differed significantly (P < 0.05). NS = not significant.

(DAE). Leaf photosynthesis and respiration were measured using a Licor LI-6400. The injury to the membrane was measured 40 DAE using the procedure described by Mohammed and Tarpley (2009a). Destructive sampling were conducted at 100 DAE. Plants were dissected, plant height was measured, numbers of tillers, leaves and panicles were counted, and dry weights were determined. Main stem panicles were harvested separately from the rest of the panicles, and length and number of primary branches, number of grain, and numbers of filled and unfilled grain per panicle were determined. Pollen germination and spikelet fertility were estimated using the procedures of Mohammed and Tarpley (2011). The paddy rice was dehulled manually and the length (mm), width (mm), surface area (mm²), volume (mm³), and chalkiness (%) of the brown rice grain were determined using a Winseedle (Regent Instruments, Inc. Quebec, Canada). Grain nitrogen concentration (GNC, %, w/w) was measured using a FP-528 Nitrogen/Protein analyzer (LECO Corporation, St. Joseph, Michigan, USA).

The results indicated that the two varieties responded differently to HNT with respect to respiration rates, relative injury to the membrane, pollen germination, spikelet fertility, grain yield per plant, and grain width, surface area, and weight (Fig. 1, 2; Table 1). XL723 was more tolerant to HNT than Cocodrie. Under HNT, both Cocodrie and XL723 showed increased respiration and membrane injury (Fig. 1), and decreased pollen germination, spikelet fertility (Fig. 2), panicle weight per plant, and grain width, surface area, and weight (Table 1). Similar results for high daytime (Prasad et al., 2006) and nighttime temperature (Ziska et al., 1986) have been reported for rice. Based on our previous work, the decrease in spikelet fertility under HNT is related to decreased pollen germination (Mohammed and Tarpley 2009b). The decreases in rice grain dimensions under HNT are associated with a reduction in average endosperm cell area (Morita et al., 2005) and a decrease in the capacity of the endosperm to accumulate dry matter (Bingham, 1969). In addition, cereals generally respond to high temperatures through an increase in the rate of kernel growth, which can lead to a decrease...
in the duration of dry matter accumulation (Zakaria et al., 2002) and a reduction in final grain size.

In conclusion, plant grain yield decreased with HNT, and this was highly associated with increased respiration and membrane injury, and decreased pollen germination. This study provides evidence that plant respiration, relative injury, and pollen germination can be used individually or in combination as screening tools or as a basis for the development of screening tools for HNT tolerance. The study also indicated that genetic diversity exists in US rice germplasm with regard to HNT tolerance.

For more information, please consult the following references:


Fig. 2. Differential response of inbred cultivar ‘Cocodrie’ and hybrid “XL723” to high night temperature with respect to pollen germination and spikelet fertility.
Variation in Yield-Related Traits within Variety in Large Rice Yield Trials

Variety Evaluation

The development of a new rice variety requires selecting from among thousands of genotypes, starting from the F2 populations to the breeding nurseries, local yield trials, and statewide multi-location and multi-state yield trials. Genotypes are compared against each other and against one or more control or check variety. High yield and stability of traits across environments (locations or years) are desirable in a variety for use in commercial production and as a check in yield trials.

The Uniform Regional Rice Nursery (URRN) is a large yield trial conducted in five states (Arkansas, Louisiana, Mississippi, Missouri, and Texas), and within each test site, 200 genotypes (composed of test entries and check varieties) are evaluated in replicated plots grown in several blocks. In the URRN at the Texas AgriLife Research and Extension Center at Beaumont, 80 genotypes (replicated four times) constitute the advanced entries and are grown in four field blocks, while 120 genotypes (replicated twice) constitute the preliminary entries and are grown in blocks 5 to 7. Genotypes that perform well in the preliminary group are usually selected for evaluation in the advanced group in the succeeding year.

Each block of the advance group corresponds to a maturity group. Genotypes are compared within each block and across blocks. Since the URRN is a large yield trial, is there significant variation in yield and yield-related traits within a genotype across blocks? Our study attempts to answer these questions.

Field Experiments

In 2009 and 2010, 8 plots were added to each of the seven blocks of the URRN at the Beaumont Center. The added plots consisted of four rice varieties with two replications each. The varieties were ‘Francis’ (Moldenhauer et al., 2007b), ‘Spring’ (Moldenhauer et al., 2007a), ‘Trenasse’ (Linscombe et al. 2008), and ‘Wells’ (Moldenhauer et al., 2007c). These are or recently were check varieties and collectively provide a wide range of yield-related traits, such as tiller density, flowering duration, number of spikelets and mass per main culm panicle, heading, plant height, grain yield, and whole and total milled rice percentages (Samonte et al., 2009). Francis was a check variety of Groups 2 and 6 in 2008, and of Groups 2 and 7 in 2009 and 2010. Spring was a check variety of Group 1 in 2008 and 2009. Trenasse was a check variety in Group 1 in 2008 and Group 5 in 2009. Wells was a check variety of Group 4 in 2008 and 2009, and of Group 2 in 2010. Grain yield and yield-related traits were determined from each plot, while soil samples were taken from each block for soil analyses.

Soil and Varietal Evaluation

Soil analyses revealed that there were no significant differences among the blocks in terms of pH, and concentrations of N, P, K, Ca, Mg, S, Na, Fe, Zn, Mn, and Cu based on soil sampling on three dates in 2009 (pre-planting, heading, and maturity).
Variation in Traits ...

Table 1. Significance of variation of traits within variety when planted in seven blocks of the URRN at Beaumont in 2009 and 2010.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Means ± Standard Deviations and Significance of Variation among URRN Blocks</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>2009</td>
</tr>
<tr>
<td></td>
<td>Francis</td>
</tr>
<tr>
<td>Tiller Density (no./m row)</td>
<td>107 ±</td>
</tr>
<tr>
<td></td>
<td>13.6</td>
</tr>
<tr>
<td>Panicle Density (no./m row)</td>
<td>79 ±</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
</tr>
<tr>
<td>Days to Heading (d)</td>
<td>79.1 ±</td>
</tr>
<tr>
<td></td>
<td>1.2 **</td>
</tr>
<tr>
<td>Plant Height (cm)</td>
<td>96.4 ±</td>
</tr>
<tr>
<td></td>
<td>4.7</td>
</tr>
<tr>
<td>Grain Yield (lb/acre)</td>
<td>8,864 ±</td>
</tr>
<tr>
<td></td>
<td>1,045</td>
</tr>
<tr>
<td>Whole Milled Rice %</td>
<td>55.4 ±</td>
</tr>
<tr>
<td></td>
<td>1.7</td>
</tr>
<tr>
<td>Total Milled Rice %</td>
<td>71.6 ±</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
</tr>
<tr>
<td>Panicle Mass (g)</td>
<td>3.6 ±</td>
</tr>
<tr>
<td></td>
<td>0.93</td>
</tr>
<tr>
<td>Panicle Length (cm)</td>
<td>20.8 ±</td>
</tr>
<tr>
<td></td>
<td>2.2</td>
</tr>
<tr>
<td>SPAD Reading at Heading</td>
<td>44.3 ±</td>
</tr>
<tr>
<td></td>
<td>1.9</td>
</tr>
</tbody>
</table>

*, ** – significant differences at the 5 and 1% level, respectively.

and two dates in 2010 (pre-planting and heading). The non-significant differences among blocks for pH and soil fertility levels is a preferred condition in field experiments, indicating that the URRN field at Beaumont had no significant gradients that may affect results.

Spring was the most stable variety for the 10 measured traits in both 2009 and 2010 (Table 1). Spring showed no significant differences among the seven blocks in terms of tiller and panicle densities, number of days to heading, plant height, whole and total milled rice percentages, mass per main culm panicle, main culm panicle length, chlorophyll (SPAD) reading (Turner and Jund, 1984), and grain yield. Francis was the 2nd most stable, as it showed significant differences among blocks for number of days to heading in 2009 and whole milled rice percentage in 2010. Both Trenasse and Wells showed significant differences among blocks for number of days to heading in 2009. In 2010, Trenasse showed significant differences in whole grain and total milling yield, while Wells showed significant differences among blocks in tiller and panicle densities.

The trait that showed the most instances of significant differences among blocks was number
of days to heading, as shown in 2009 by Francis, Trenasse, and Wells, followed by whole grain milling yield in 2010 by Spring and Trenasse. The traits that showed no instance of significant differences among blocks for all varieties were mass per panicle, panicle length, chlorophyll reading, plant height, and grain yield.

Results show the importance of analyzing the soil fertility levels in each block and the importance of evaluating the stability of check varieties. Knowing this information enables the researchers to better interpret results from large yield trials.

For more information, please consult the following references:


* Article by Drs. Stanley Omar PB. Samonte, Rodante E. Tabien, and Lloyd T. Wilson, Texas A&M AgriLife Research and Extension Center at Beaumont, TX.

Editorial ...

was a success. The first field stop focused on inbred plant breeding, genetics, and grain quality, with presentations by Dante Tabien, Shannon Pinson, and Ming Chen. The second stop focused on hybrid rice physiology and plant breeding, with presentations by Ted Wilson and Omar Samonte. The third stop focused on rice physiology and plant nutrition with talks by Lee Tarpley and Fugen Dou. The fourth stop focused on insect and disease management with presentations by Mo Way, Shane Zhou, and Young-Ki Jo.

The keynote speakers at the morning program filled the auditorium was people. John Greenplate from Monsanto, Johnny Saichuk from LSU, and Cliff Mock an independent rice crop consultant each provided an overview of the future of research, extension outreach, and the rice industry as a whole. We could not have asked for better presentations. Joe Mike Crane with BU Growers deserves special thanks for providing our field day luncheon.

The afternoon program had 9 presentations. Anna McClung, Shane Zhou, and Fugen Dou discussed their organic rice research, Mo Way and Suhas Vyavhare described their soybean entomology research, and Lee Tarpley, Russell Jessup, Chuck Dowling, and Jiale Lv presented their bioenergy research. The afternoon tour was followed by an informal discussion on bioenergy crop production.

Mo Way deserves special thanks for his tireless planning of the field tour, Brandy Morace and Daun Humphrey deserve recognition for producing the Center research posters and for their major help with organizing the field day. Randy Eason, Agustin Castro, Joe Holden, and the large majority of staff and faculty literally whipped the weeds and ditches into shape, with this field day being the best organized of any of the field days I have experienced. Special thanks
Rice Crop Update

As of July 15, 2011, about 86% of the rice crop acreage in Texas were at panicle differentiation (PD) (Fig. 1). In comparison, about 95, 94, 93, 95, and 93% were at PD as of July 15 in 2006, 2007, 2008, 2009, and 2010, respectively.

About 68% of the rice acreage were at heading as of July 15, 2011 (Fig. 2). In comparison, about 86, 72, 65, 80, and 70% were at heading as of July 15 in 2006, 2007, 2008, 2009, and 2010, respectively.

Fig. 1. Percentage of main rice crop acreage in Texas at panicle differentiation (PD) by July 15 in 2006 to 2011.

Fig. 2. Percentage of main rice crop acreage in Texas at heading by July 15 in 2006 to 2011.