Genetically Modified Rice: A Potential Leap Forward in Pest Management Technology

Rice pest management technology in the southern rice-producing states has advanced tremendously in the past 2 decades. Prior to 1998, the only pest management tool available to control rice water weevil, *Lissorhoptrus oryzophilus*, was granular carbofuran (Furadan 3G) applied at the rate of 0.5 lb active ingredient (a.i.) per acre (Way and Espino, 2010). This insecticide proved to be highly toxic to birds and was banned by the United States Environmental Protection Agency (Flickinger et al., 1980; U.S. Environmental Protection Agency, 1989). After the loss of granular carbofuran, university, USDA, private industry and regulatory scientists worked in concert to register the following host of novel chemicals approved for rice water weevil control: 1) Karate Z, a.i. is lambda-cyhalothrin and was approved for use in 1998; 2) Dimilin 2L, a.i. is diflubenzuron and was approved for use in 1999; 3) Mustang Max, a.i. is zeta-cypermethrin and was approved for use in 2003; 4) Prolex, a.i. is gamma-cyhalothrin and was approved for use in 2004; 5) Dermacor X-100, a.i. is rynaxypyr and was approved for use in 2008; 6) Trebon 3G, a.i. is etofenprox and was approved for use in 2009; 7) CruiserMaxx, a.i. is thiamethoxam and was approved for use in 2010; and (8) Nipsit INSIDE, a.i. is clothianidin and is pending approval for an experimental use permit approval for 2011 (Way and Espino, 2010). Many of these insecticides provide excellent control of other rice pests, in addition to the rice water weevil. Effective application rates of these novel insecticides are several times lower than granular carbofuran and are much less toxic to non-target organisms. For instance, the seed treatment Dermacor X-100 is applied at the rate of approximately 0.06 lb a.i. per acre, which is about 10 times less active ingredient per acre compared to granular carbofuran. Thus, the amount of insecticide applied to the rice agroecosystem is much less compared to 20 years ago. In addition, the availability of more options for insect control, in terms of multiple classes of active ingredients, logically translates to less chance for the development of resistance in target pest organisms. Thus, current pest management tactics are good for the farmer and better than insecticides of the past for the environment.

A relatively new pest management technology exists in GM rice. GM is the abbreviation for “genetically modified”. Traditional plant breeding methods, whereby individuals of the same species are crossed and progeny selected to create better adapted offspring, clearly results in modification of the offspring’s genome, which in a broad sense is a form of genetic modification. Even Mother Nature modifies the genome of a species or strain by providing the selection pressure to produce more vigorous or individuals with greater fitness that are better able to cope with a given environment. However, the current usage of GM is narrower in definition and refers to genes introduced into an organism obtained from another species by genetic engineering. In terms of GM rice, a gene from a bacterium is inserted via genetic engineering techniques into rice to produce an insect pest-resistant strain of rice. Describing and
Welcome to the 100th issue of Texas Rice! Since its inception, 10 issues of Texas Rice have been scheduled for production each year, comprised of an issue from March through October, a winter issue, and a highlights in research issue, the latter of which is distributed both as a hard copy and electronically to those who attend our field days in Eagle Lake and Beaumont. March 2011 was supposed to be our 101st issue, but a small problem back in 2005 resulted in our producing one fewer issues that year than was suppose to have been produced. Regardless, we are proud that we have been able to create a tradition of using Texas Rice to provide growers with up-to-date information on rice research and management both from Texas and from other states, and about Texas and other rice producing regions of the U.S. and the world.

Producing Texas Rice is a never-ending process. Each year during early spring, Omar Samonte and I meet, normally over a two-day period, to discuss possible articles to produce during the year and potential authors for each article. We assemble the 30 or so article titles and proposed authors and then one after the other we reach a decision on which articles to go forward with, matching each article with the time of year we think would have the greatest impact. For 2011, we have commitments for 26 articles, with the first two appearing in this issue. These articles are largely written by our project leaders, but in at least a few cases, our research technicians, post-docs, research associates, and colleagues from other states also contributed to the writing. Nor does this count the couple of dozen abstracts that we provide in our field day insert each year that summarize the individual research projects, or the editorials and crop updates that are both produced almost every issue.

Each article generally takes from a minimum of 4 hours to as much as a week or longer to produce. The willingness of our scientists to expend the effort to provide information to our readers is in itself a testament to their willingness to help our rice industry by continuing to provide useful rice production and management information.

The titles of articles that are proposed for Texas Rice this year are briefly summarized below. With hardly an exception, all of our project leaders and many of our lead technicians have agreed to help write articles covering this diverse set of topics.

- The potential of GMO rice to manage insect pests
- Rice Water Conservation Analyzer - Conservation Analysis
- Response of rice to nitrogen application
- Rice narrow brown leaf spot and its management
- Effects of drying and wetting on C and N transformations in rice soil
- Cultural and cultivar management methods for the control of false smut and kernel smuts.
- Rice sheath blight and its management
- Breeding for stem borer resistance
- Rice diseases in organic production systems
- Effects of management practices on rice ratoon production
- Differential response of an inbred cultivar and a hybrid to high night temperatures

Continued on page 8
Urban population growth and expansion in many metropolitan areas of the U.S. is adding increasing pressure to agricultural water supplies and forcing the agricultural sector to seek innovative approaches to conserve water. On-farm water conservation measures that could reduce water use for rice farming include precision leveling, multiple inlet system, conservation tillage, lateral improvement, tailwater recovery, and the use of a production system based on growing high-yielding water efficient varieties. This article provides an analysis of the potential water savings associated with each of these conservation measures using the Rice Water Conservation Analyzer (RiceWCA), which was developed through a project jointly sponsored by the Lower Colorado River Authority (LCRA) and the San Antonio Water System (SAWS).

**Overview of RiceWCA**

RiceWCA incorporates a web interface, and models to predict crop phenology and field water balance, and an economic component into an integrated analysis system that can rapidly evaluate field- and regional-level costs, water savings, and yield benefits associated with implementing different on-farm conservation measures for the three LCRA irrigation districts of Lakeside, Gulf Coast, and Garwood. The water balance model was verified and calibrated using 2000 and 2002 weekly irrigation records provided by LCRA for the Lakeside and Gulf Coast irrigation districts, and validated using weekly irrigation records for 2001, 2003, and 2004 for Lakeside and Gulf Coast.

**Irrigation Water Savings vs. Water Conservation Measures**

The conservation status of all fields (in production and fallow) for 2004 were provided by Parsons Engineering in Austin, Texas, and were used as the baseline for analysis of water savings associated with each water conservation measure. We estimated the potential water savings from implementing each conservation measure. The analysis was done using 59 years of historic weather data (1940-1998) and examined both District Level Water Savings and Field Level Water Savings. Field Level Water Savings refer to average water savings involving only those fields that implemented specific conservation measures. District Water Savings refers to water savings associated with implementing conservation improvements in any of the fields within an irrigation district.

Table 1 presents predicted irrigation water savings associated with the adoption of different conservation measures for Lakeside, Gulf Coast, and Garwood at both the field and district levels, with 2004 conservation practices as the baseline. District level irrigation water savings for Lakeside are 2.2, 0.9, and 1.7 ac-in/ac for improvement from contour laser leveling to bench grade leveling, contour to constant grade slope leveling, and constant to bench, respectively, while corresponding field level water savings are 6.6, 2.8, and 3.8 ac-in/ac (Table 1). For all three districts, improvement from contour to bench grade saves the most water since it results in the greatest reduction in elevation change, thus requiring less water to flush and flood rice fields.
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Table 1. Field and district level irrigation water savings from conservation improvements.

<table>
<thead>
<tr>
<th>Conservation Measure</th>
<th>District Level Water Savings (ac-in/ac)</th>
<th>Field Level Water Savings (ac-in/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lakeside</td>
<td>Gulf Coast</td>
</tr>
<tr>
<td>Contour to Bench</td>
<td>2.2</td>
<td>3.6</td>
</tr>
<tr>
<td>Contour to Constant</td>
<td>0.9</td>
<td>1.7</td>
</tr>
<tr>
<td>Constant to Bench</td>
<td>1.7</td>
<td>1.1</td>
</tr>
<tr>
<td>Multiple Inlet</td>
<td>3.7</td>
<td>3.2</td>
</tr>
<tr>
<td>Conservation Tillage</td>
<td>2.3</td>
<td>2.5</td>
</tr>
<tr>
<td>Underground Pipe</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Tailwater Recovery(^1)</td>
<td>10.5</td>
<td>21.8</td>
</tr>
<tr>
<td>High Yield Variety</td>
<td>10.1</td>
<td>11.6</td>
</tr>
</tbody>
</table>

\(^1\) Water savings for Gulf Coast for improvements other than tailwater recovery system excludes potential savings from eliminating maintenance stream, which is a common practice in this district.

\(^2\) Water savings for tailwater recovery system are based on the best saving/cost ratio, higher water savings are achievable at greater costs.

For precision leveling, the district level water savings are much less than that for field level mainly because some fields have already been improved, with water savings only from those fields that can be further improved. Precision leveling can reduce the levee area within a field by reducing the number of levees, thereby increasing the amount of land within a field that can be planted to rice. For example, for fields with a contour grade in the Lakeside district, levees account for 18.4% of total field area, but for fields with a bench grade, levees account for only 3.3% of total field area. This means the rice production area (i.e., paddy area) is increased by 15.1% when a field is converted from contour leveling to bench grade leveling. Since the paddy area uses more water than do the levees, the water savings are offset by the increased irrigation demand due to the increase in the paddy area.

District-level irrigation water savings for Lakeside are 3.7, 2.3, and 0.7 ac-in/ac for improvement with multiple inlets, conservation tillage, and underground pipe, respectively (Table 1). The reduction in irrigation demand with multiple inlets results from improved irrigation efficiency with the installation of inlet gates. Inlet gates help farmers to better time cutoff for irrigation inflows to minimize tailwater loss, because each inlet gate controls irrigation of a smaller section of a field as compared to a single inflow point for an entire field. The reduction in irrigation demand with conservation tillage results from the increased soil moisture and decreased evaporation due to residue cover on the soil surface. The reduction in irrigation demand with underground pipe results from the elimination of water loss via seepage, percolation, and evapotranspiration from laterals. The water savings from underground pipes are very small for Lakeside and Gulf Coast mainly because only a small proportion of the fields have laterals, while water savings for Garwood are much larger because of the presence of many laterals in the district.

Tailwater recovery system can save 10.5, 21.8, and 11.4 ac-in/ac of irrigation water for Lakeside, Gulf Coast, and Garwood, respectively (Table 1). Tailwater recovery savings are based on the assumption that for every field in rice, there are approximately two fallow fields supplying runoff to the tailwater recovery system for Lakeside and Garwood (one-in-two-out rotation), and three fallow fields for Gulf Coast (one-in-three-out rotation). The capture of runoff from fallow fields and capture of maintenance stream from irrigated fields is a main reason for the greatest projected water savings...
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occurring with the Gulf Coast district. Growing a high-yielding main crop variety can save 10.1, 11.6 and 15.3 ac-in/ac of irrigation water for Lakeside, Gulf Coast, and Garwood, respectively, with the water savings from this method being solely from not growing the ratoon crop. However, we are very much aware that smart growers know low to speed up the

Figure 1. Crop season rainfall (in) and predicted average irrigation (in) before and after improvement of fields from contour to bench grade for Lakeside (A), Gulf Coast (B), and Garwood (C); Corresponding irrigation water savings after improvement for Lakeside (D), Gulf Coast (E), and Garwood (F), using historic weather data from 1940 to 1998.
growth, development, and maturation of their ratoon crops by the timing of their first ratoon crop nitrogen application. As a result, it is possible to grow a ratoon crop from the longer season high yielding plant type, but it is harder to do so for later planted fields (By the way, two high-yielding plant varieties are scheduled for release by the Beaumont Center at the end of this March.) The Garwood district has a high ratoon crop percentage (85%), which results in greater water savings when the conventional main plus ratoon crop system is replaced with a high-yielding main crop variety.

Figure 1 presents the predicted irrigation demand and water savings for improvement from contour to bench grade for the three districts, along with total rainfall during the crop season. In general, wet years (high rainfall) require less irrigation while dry years (low rainfall) require more irrigation, since some of the water demand can be met by rainfall. Since water demand is closely tied to crop growth stages and management events, maximum use of rainfall by the crop will only be achieved if the rainfall amount and pattern closely matches crop water demand.

**Further Analysis**

Each conservation measure incurs certain implementation, operation, and maintenance costs. The measure or combinations of measures that best fit an irrigation district or its subdivisions can only be determined by fully analyzing associated benefits and costs. This article only addresses the water saving aspect of conservation improvements. A follow up article will address the economic aspect.

**Acknowledgements**

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explaining specific genetic engineering techniques are beyond the scope of this brief article, but if readers so desire, we can discuss this topic in a later issue of *Texas Rice*. So, in our case, GM rice possesses DNA from 2 widely genetically unrelated species – rice and a bacterium! Some skeptics have dubbed GM crops as “Frankenfood” taken from Mary Shelley’s famous novel *Frankenstein*. However, the monster in this novel is not a GMO (genetically modified organism), but is derived from body parts assembled from individuals of a single species – *Homo sapiens*!

One of the most damaging groups of insects attacking rice on a global scale belongs to the Order Lepidoptera (moths and butterflies), Family Crambidae (includes stalk borers) (Way and Bowling, 1991). In Texas, rice is attacked by 3 stalk borers – sugarcane borer (*Diatraea saccharalis*), Mexican rice borer (*Eoreuma loftini*), and rice stalk borer (*Chilo plejadellus*) – which can cause significant losses to our rice crop (Reay-Jones et al., 2008). The larval stages of all stalk borers infesting rice in all parts of the world bore into rice culms and feed on the inside of the culms to cause “whiteheads”, which are completely unfilled panicles, or to cause partial grain fill of panicles with resultant yield losses. These insects are very difficult to control with pesticides once larvae bore into culms where they are protected from exposure to insecticides and also to beneficial predators and parasitoids. No wonder stalk borers are some of the most difficult rice insects to control throughout the world! However, what if the rice plant manufactured its own toxin, which was specific to insects, and was produced in its culms? Although this sounds far-fetched, this is exactly the outcome of select strains of GM rice.

For a little background into this technology, certain bacteria, including a soil-dwelling bacterium, *Bacillus thuringiensis* (Bt), are able to transform themselves into endospores when exposed to unfavorable conditions – for instance, lack of essential elements such as carbon and oxygen (Tortora, 2005). So, a bacterial endospore is simply an environmentally-resistant form of a bacterium which enables the organism to survive in a resting
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state for an extended period of time, until favorable conditions return. Endospores produce crystal proteins called endotoxins (Cry proteins) which, when ingested, can be lethal to certain insects, such as stalk borers (Toenniessen, 1991). Upon ingestion of the endotoxin, the alkaline pH of the insect’s gut activates the toxic protein which binds to the gut membrane to cause cell rupture and eventual death of the insect. Genes from Bt were first inserted via genetic engineering into plants in the mid-1980s (Vaeck et al., 1987). These genes coded for the toxic Cry proteins which were produced by the plant. In 1989, Chinese scientists produced the first genetically modified rice possessing Bt genes (Yang et al., 1989). The first field test of Bt rice was conducted in China in 1998, and in 2009 China’s Ministry of Agriculture issued biosafety certificates for commercial production of Bt rice (Chen et al., 2011). Thus, GM rice is now produced on a commercial scale in China to help feed a population of 1.3 billion, which is expected to increase to 1.6 billion in the near future (Chen et al., 2011). The “Genie is out of the lamp”!

Some GM crops are currently grown in the US. For instance, 85% of soybeans grown in the US in 2007 were GM (GMO Compass, 2011). These GM soybeans, resistant to glyphosate herbicides, are primarily grown for livestock feed, but some are used for human consumption (cooking oil and food additives). Much controversy surrounds the commercialization of GM crops in the US, so GM rice in the US is far from becoming a reality. But, in my humble opinion, this technology, which is now available in China – the largest producer of rice in the world – should be available to US rice farmers. Bt rice will reduce the pesticide load in the environment, eliminate drift of insecticides into the fragile aquatic rice agroecosystem and reduce the detrimental effects of pesticides on non-target organisms, such as beneficial parasites and predators.

In 2003, my project was able to evaluate 2 strains of Bt rice in an experiment at Ganado, TX where stalk borers frequently cause severe damage. The Bt strains were provided by private industry; thus, my project conducted the experiment under a secrecy agreement, so I did not know the identity of the Cry proteins expressed by the Bt strains. In addition to the Bt strains, I was provided corresponding isolines of non-Bt strains.

Table 1. Efficacy and yield of 2 Bt strains. Ganado, TX. 2003.

<table>
<thead>
<tr>
<th>Strain</th>
<th>No. of live sugarcane larvae/plant</th>
<th>Yield (lb/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bt 1</td>
<td>0.1 b</td>
<td>4,612 b</td>
</tr>
<tr>
<td>Control 1</td>
<td>25.1 a</td>
<td>226 c</td>
</tr>
<tr>
<td>Bt 2</td>
<td>0.1 b</td>
<td>5,403 a</td>
</tr>
<tr>
<td>Control 2</td>
<td>25.3 a</td>
<td>190 c</td>
</tr>
</tbody>
</table>

Means in a column followed by the same letter are not significantly different (P = 0.05, ANOVA and LSD)

Fig. 1. In foreground left to right: 2 plots of sugarcane borer-damaged non-Bt isoline, 2 plots of Bt isoline. Ganado, TX. 2003.
None of the 4 strains was adapted to SE Texas conditions. My project, with help from Jack Vawter and his crew at Eagle Lake, adhered to the many rules required to conduct GM crop studies. The experiment was planted late to better coincide with the typical population build-up of stalk borers. This tactic worked to perfection, because tremendous populations of sugarcane borers developed in the experiment, there was no need to artificially infest experimental plants. The results were astounding (Table 1 and Fig. 1). Although only from a single experiment, these results show the tremendous potential of GM rice to the US rice industry. Again, speaking from a personal standpoint, I believe eventually the US will have to approve GM rice. If not, our industry will be at a competitive disadvantage with other rice-producing nations. In the meantime, US rice scientists, when called upon, must conduct the necessary efficacy and environmental studies to make GM rice a reality for a hungry world.

For more information, please consult the following references:


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From the Editor ...

- Stability of rice cultivars at large yield trials
- Rice phytonutrients
- Potential for/lessons learned on using wireless sensing networks for monitoring environmental conditions in rice fields
- Soybean research at the Beaumont Center
- Aerobic rice revisited
- Impact of climate on rice yields
- Predicting the value of parasitoids and pathogens as fire ant control agents
- Analyses of the growth, development, and yield
I like to start the first *Texas Rice* editorial of the year by saying something positive about the rice industry or the Texas A&M university system. I wish all of you success in your farming and I wish a rapid turn around for all who continue to suffer from an ongoing state and/or federal budget rescission. A simple little prayer for $16 to $22/cwt rice, a wish for a stopepage of the price gouging at the diesel and gasoline pumps, and a speedy economic recovery does not sounds like too much for us to ask.

How can each of us help get all of us through these rough times? The world’s increasingly global economy makes the old saying, “united we stand, divided we fall” resonates particularly well. Who would have thought that this saying would still hold such meaning, approximately 2600 years after Aesop is credited with initially saying it, or over 200 years ago in 1799 when Patrick Henry used similar words when he said “Let us trust God, and our better judgment to set us right hereafter. United we stand, divided we fall”. Or, the numerous songwriters or bands from John Dickinson in “The Liberty Song” to Pink Floyd in “Hey You”, who have used this phraseology in their writing. If as a group we keep pushing for the best, the likelihood of the best occurring for rice producers and those of us who are fortunate to be able to work with them will keep on getting better and better.

While I am talking about better, I decided that it was time for me to use an updated picture of myself for the editorial page of *Texas Rice*. Recently while reviewing past articles I and behold, it turned out that I had not updated my picture for 10 years. Maybe I will be able to wait another 10 years before having to do another update.

As a final comment, please plan to attend one of our post-harvest grain management workshops scheduled for the week of May 9, with the first workshop in Crowley Louisiana (May 10), followed by Beaumont Texas (May 11) and ending with Jonesboro Arkansas (May 13). These workshops are organized as part of a federal competitive grant obtained by scientists from Texas A&M (Ted Wilson and Yubin Yang), USDA-ARS Manhattan Kansas (Frank Arthur and Jim Campbell), University of Arkansas (Terry Siebenmorgen and Jean Meullenet), Oklahoma State University (Brian Adam), Arkansas State University (Tanja McKay), and Louisiana State University (Gene Reagan). At each workshop, 9 topics will be covered, with an update provided on the use of our post-harvest grain management program. Each workshop will begin at 9:30 AM and will continue to 3:00 PM, with an on-site luncheon for those who wish to attend. Details on who the speakers are and the location for each workshop will be provided via email next week. I hope we see you there.

Keep on sending us your suggestions!

Sincerely,

L.T. Wilson
Professor & Center Director
Jack B. Wendt Endowed Chair in Rice Research
As of March 18, 2011, about 18.0% of the main rice crop acreage in Texas had been planted. In comparison, about 39.0, 12.6, 9.4, 7.9, and 3.4% had been planted as of March 18 in 2006, 2007, 2008, 2009, and 2010, respectively (Fig. 1). In terms of germination, about 1.0% of the rice acreage had emerged seedlings as of March 18. In comparison, 9.9, 1.6, 0.6, 0.7, and 0.0% of the rice acreage had emerged seedlings as of March 18 in 2006 to 2010, respectively (Fig. 2).

Weekly updates on the acreage and percentage of rice grown in Texas that are in the various growth stages are available at our website at http://beaumont.tamu.edu/CropSurvey/CropSurveyReport.aspx.

The Texas Rice Production Guidelines, which is available online at http://beaumont.tamu.edu/eLibrary/ExtensionBulletins_default.htm, recommends planting dates for rice in Texas. It states that optimum planting dates vary with location, and these range from March 15 to April 21 in the western area and from March 21 to April 21 in the eastern area. It also states that planting after April 15 reduces ratoon crop potential. The guidelines also recommend not to plant when the 4-inch daily minimum soil temperature is less than 65°F. This temperature is important for normal seed germination and seedling growth. The 4-inch soil temperatures are available on-line at http://beaumont.tamu.edu/climaticdata/StateMap.aspx?index=2_14_0_44&name=TEXAS.

Fig. 1. Percentage of main rice crop acreage in Texas that had been planted as of March 18 in 2006 to 2011.

Fig. 2. Percentage of main rice crop acreage in Texas with emerged seedlings as of March 18 in 2006 to 2011.