Rice Plant Types and Ideotypes

The Ideotype Concept

Before the release of the semi-dwarf variety IR8 in 1967, there were already semi-dwarfs varieties, but most of the rice grown in Asia were the tall and lodging-susceptible traditional rice plant types. Examples of some of the semi-dwarf varieties during that time are ADT 27 and Mahsuri, which were selections produced from *japonica x indica* crosses and planted across the Indian subcontinent in the 1960s (Hargrove and Coffman, 2006), and Dee-geo-woo-gen, which is a semi-dwarf from Taiwan and one of the parents of IR8. In the 1960s, Southeast Asia, which is relatively near the evolutionary origin of rice, was producing very low rice grain yields of 1 to 1.5 t/ha (892 to 1,338 lb/acre). In comparison, countries where rice was introduced, such as the United States, Australia, and the Mediterranean region, were producing grain yields of about 3 to 5 t/ha (2,676 to 4,461 lb/acre) (Jennings, 1964). To answer the question of what would be a successful plant type for tropical rice areas, Jennings (1964) indicated specific morphological traits that would interact most effectively to produce high yield. Jennings suggested that for tropical rice areas, the most successful plant type would be an *indica* rice having a plant type characterized by small, dark-green, erect leaves, and short, sturdy, narrow culms bearing compact, heavy panicles. He also suggested making *indica x japonica* crosses and then selecting for a plant type similar to *japonica* rice in appearance (leaves are short, narrow, erect, thick, and dark green; culms are thin, short, and sturdy; and panicles are short and dense) and growth patterns, but with improvements in cooking quality, longer dormancy, and threshability. The traditional varieties, in contrast, had tall, weak, thick culms, bearing long, broad, drooping, thin, pale-green leaves and relatively large, lax panicles (Jennings, 1964).

Donald (1968) introduced the term ideotype to specifically denote a model plant that is expected to yield a greater quantity or quality of grain, oil or other useful product when developed as a variety (1968). Jennings’ semi-dwarf plant type was an ideotype for a rice plant type that would yield higher than the traditional *indica* varieties.

The Semi-Dwarf Plant Type

In Asia, the International Rice Research Institute (IRRI) released its first variety IR8 in 1967, and this started the shift from the tall to the semi-dwarf plant types. IR8 is a selection from lines produced from a cross made in 1962 between Peta (a tall Indonesian variety with high vigor, seed dormancy, resistance to several insects and diseases and widely grown in the Philippines) and Dee-geo-woo-gen (a high-yielding, heavy-tillering, short-statured variety from Taiwan) (Chandler, 1992). IR8 and succeeding varieties represent the semi-dwarf plant type, which was short (semi-dwarf) and high tillering, and having sturdy stems, and dark green and erect leaves (Khush, 1995). Some of the trait parameter values of IR8, when compared to Peta are as follows (De Datta et al., 1968):

- Maximum grain yields were 9,477 kg/ha at 120 kg/ha of N fertilization (8,455 lb/acre yield at 107 lb/acre of N fertilization) for IR8, and 5,100 kg/ha at 30 kg/ha of N fertilization (4,550 lb/acre yield at 26 lb/acre of N fertilization) for Peta.

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Welcome to the September issue of *Texas Rice*. The lead article by Omar Samonte and me provides an overview of the history of semi-dwarf rice varieties in Asia and in the U.S., and research behind the development of high yielding plant types. Rice varieties that were grown 50 or more years ago were tall and produced relatively small panicles. As plant breeders developed higher yielding varieties, they selected for larger panicles that the tall weak culms were not able to support, which in turn introduced the problem of culms increasingly falling down (lodging). The newer semi-dwarf varieties with shortened internodes were able to better handle the increased weight of the panicles and tended to lodge to a lesser degree. As plant breeders continued to increase the yield potential of new varieties, and as agronomists, pest management scientists, producers and crop consultants increasingly push varietal performance closer and closer to each new variety’s yield potential, plant types able to support the increased weight of the panicles had to follow suite to make sure the grain did not end up on the ground. As the yield potential of each successive generation of new varieties has increased, so has the ability of each new plant type to take up nutrients at an unprecedented rate.

The direction taken to increase grain yields has in some ways been similar in China, the Philippines, and the U.S. However, a big difference remains that is intrinsic to the way rice is produced in most of Asia, compared to how it is produced in the U.S. In Asia, most rice is first grown in seedbeds or flats then transplanted by either hand or using mechanical transplanting equipment. For both planting methods, small clumps of rice plants are placed into “hills” that are typically 8 to 12 inches apart. As the transplanted rice plants grow, they rapidly produce tillers filling in the space between the plants. Varieties that are better able to fill in the space, compete with weeds, and produce reproductive tillers have been selected. In contrast, rice varieties in the U.S. are machine-planted as seeds at a much higher density than used in an Asian transplanted production system. As a result, less open space is available for tiller production. As a result, rice varieties that have been developed in the U.S. tend to tiller much less than Asian varieties, even in controlled experiments when varieties from both continents are grown side-by-side at the same density. While modern U.S. hybrid varieties are typically planted at $\frac{1}{2}$ to $\frac{1}{4}$ the seeding rate of U.S. inbred varieties, due to both their higher potential to tiller and the higher cost of seed, they nevertheless tend to tiller less than their Asian counterparts.

The second article in this issue of *Texas Rice* describes the Ganado Field Day that has been lead by Mo Way and Gene Reagan each of the last several years. The authors of this article, which also include Julien Buezelin, Waseem Akbar, and Shane Zhou, who is the Center’s new plant pathologist, discuss the sugarcane and rice stem borer management program and some of their results from the 2009 season, and the rather major loss in yield and profit ($200/acre) in areas were damage by the Mexican rice borer and sugarcane borer are the worst.

I hope you enjoy this issue of *Texas Rice*. Please keep on sending up your suggestions.

Sincerely,

L.T. Wilson
Professor & Center Director
Jack B. Wendt Endowed Chair in Rice Research
Ganado Site Visit: Stalk Borer Management in Sugarcane and Rice

Areas of high incidence or variation in pest populations are ideal to conduct research on plant and pest interactions. The Mexican rice borer (MRB) (*Eoreuma loftini*) and sugarcane borer (SCB) (*Diatraea saccharalis*) (Fig. 1) attack both rice and sugarcane, and the Texas AgriLife Research Site, which is located about 5 miles east of Ganado off FM 1957 in Jackson County historically suffers from high stalk borer populations. Thus, this site is an excellent location to conduct rice and sugarcane stalk borer research. This year, the Ganado Site Visit, which is an annual “turn-row” meeting, was held on September 8, 2009, and emphasized stalk borer management in both sugarcane and rice. A diverse range of participants attended the meeting. Participants included farmers, agrichemical representatives, county extension agents from Texas and Louisiana, sugarcane and rice scientists from both states, and commodity officials.

**Sugarcane**

During the meeting, the participants were shown how to distinguish MRB and SCB larvae and the damage each causes. MRB larvae possess discontinuous stripes running the length of the body, while SCB larvae have dark, sclerotized round plates on the back and sides of the body (Hummel et al., 2008). Damage to sugarcane causes a decrease in sugar production and possible stunting and/or lodging of stalks. This damage is due to the boring and feeding activity of the larvae within the stalks. Severe stalk borer damage can cause 20% or more bored internodes resulting in over $200/acre in losses (Reay-Jones et al., 2008).

MRB is a relatively new insect pest in Texas and Louisiana. MRB moths were detected for the first time in Louisiana in pheromone traps near a rice field northwest of Vinton in December 2008, raising concerns by Louisiana sugarcane and rice farmers. MRB pheromone trap collections in Texas in selected counties east of Harris county from 2003 to 2008 are shown in Table 1. No MRB moths were collected in Liberty, Chambers, or Jefferson counties in 2003. However, MRB moths were collected in Liberty and Chambers in 2004 and 2005, and all three counties had MRBs by 2006 (Way et al., 2009). Trap collections showed dramatic increases following detection in a given county. Figure 2

![Fig. 1. Mexican rice borer larva (left) and sugarcane borer larva (right). (Photos by Mo Way)](image)

<table>
<thead>
<tr>
<th>Texas Counties</th>
<th>No. of Mexican Rice Borer Moths Trapped from 2003 to 2008</th>
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<tbody>
<tr>
<td></td>
<td>2003</td>
</tr>
<tr>
<td>Liberty</td>
<td>0</td>
</tr>
<tr>
<td>Chambers</td>
<td>0</td>
</tr>
<tr>
<td>Jefferson</td>
<td>0</td>
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Table 1. Number of Mexican rice borer (*E. loftini*) moths collected in pheromone traps in Southeast Texas from 2003 to 2008 (Way et al., 2009).

Continued on next page
also shows the movement of MRB across the Texas Rice Belt towards Louisiana prior to 2000 to 2005. SCB and MRB respond differently depending on variety (Reagan et al., 2009). For instance, Figure 3 shows sugarcane variety L 03-371 was the most susceptible with 88% bored internodes, while HoCP 05-961 was least susceptible with 55% bored internodes. Four other sugarcane varieties (HoCP 04-838, Ho 95-988, HoCP 85-845, and HoCP05-902) had significantly less damage than L 03-371. However, all 6 varieties suffered heavy damage at Ganado, which illustrates the potential for damage in Louisiana.

Research at Ganado clearly shows stressed sugarcane, caused by drought, soil salt imbalances, and nutrient deficiencies, is very susceptible to MRB. Insecticide evaluations revealed control of MRB (measured by percentage of bored internodes) through foliar applications of Diamond, Baythroid XL, Rynaxypyr, Confirm, or Belt. The results of these experiments and prior studies will form the foundation of an Integrated Pest Management (IPM) program for MRB attacking sugarcane in Louisiana and Southeast Texas, given a future industry in this region of Texas. This IPM program will rely on host plant resistance, cultural management, and chemical controls. Current research suggests weed hosts are crucial to population build-up of stalk borers. Thus, manipulating these hosts on an area-wide basis may serve to reduce overall damaging populations of stalk borers.

**Rice**

Participants were shown stalk borer damage and...
instructed how to identify the damage. Stalk borer damage results in deadhearts (dead tillers) and whiteheads (unfilled, erect, white panicles) (Fig. 4). Also, unpublished data suggest less grain filling in affected panicles. Participants were instructed to inspect for culm lesions (yellow-tan discoloration on the outside of sheaths) (Fig. 4) followed by observing the space between sheaths and culms for larvae, frass, and entrance holes. They were also shown results of research conducted at Ganado in 2008, during which stalk borers reduced main crop grain yield by an average of 1,254 and 1,667 lb/acre for Cocodrie and XL723, respectively, and reduced ratoon crop grain yield by an average of 900 and 378 lb/acre for Cocodrie and XL723, respectively (Reagan and Way, 2009) (Table 2). When left untreated (Karate Z not applied), stalk borer incidence, as measured by whitehead density, was higher in Cocodrie (18,669 and 50,172 whiteheads/acre in the main and ratoon crops, respectively) than in XL723 (8,168 and 3,500 whiteheads/acre in the main and ratoon crops, respectively). Treatment with Karate Z at 0.03 lb ai/A (2 applications on main crop; 1 application on ratoon crop) reduced stalk borer damage to 1,167 and 9,361 whiteheads/acre for Cocodrie main and ratoon crops, respectively, and 0 and 4,667 whiteheads/acre for XL 723 main and ratoon crops, respectively.

During the meeting, there was discussion concerning the relative merits of Dermacor X-100, a recently labeled rice seed treatment with activity against stalk borers. Comments from participants were very favorable. Plans are underway to gain a full federal label for Dermacor X-100 for the 2010 field season.

Following discussions on stalk borer research, Dr. Shane Zhou spoke with participants about plans for rice pathology research, which include bacterial panicle blight and ratoon disease studies. Texas rice farmers have expressed the need for more research on these topics.

For more information on MRB and SCB, please consult the following references:


### Table 2. Whitehead incidence and grain yield of main and ratoon crops of treated and untreated rice cultivars at Ganado, TX, in 2008 (Reagan and Way, 2009).

<table>
<thead>
<tr>
<th>Rice Variety</th>
<th>Treatment</th>
<th>Whiteheads</th>
<th>Grain Yield</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>(no. /acre)</td>
<td>(lb/acre)</td>
</tr>
<tr>
<td></td>
<td>Main</td>
<td>Ratoon</td>
<td>Main</td>
</tr>
<tr>
<td>Cocodrie</td>
<td>T</td>
<td>T</td>
<td>1,167 b</td>
</tr>
<tr>
<td>Cocodrie</td>
<td>T</td>
<td>U</td>
<td>2,334 b</td>
</tr>
<tr>
<td>Cocodrie</td>
<td>U</td>
<td>T</td>
<td>22,169 a</td>
</tr>
<tr>
<td>Cocodrie</td>
<td>U</td>
<td>U</td>
<td>18,669 a</td>
</tr>
<tr>
<td>XL723</td>
<td>T</td>
<td>T</td>
<td>0 b</td>
</tr>
<tr>
<td>XL723</td>
<td>T</td>
<td>U</td>
<td>0 b</td>
</tr>
<tr>
<td>XL723</td>
<td>U</td>
<td>T</td>
<td>7,001 a</td>
</tr>
<tr>
<td>XL723</td>
<td>U</td>
<td>U</td>
<td>8,168 a</td>
</tr>
</tbody>
</table>

a T = treated with Karate Z at 0.03 lb ai/A (2 applications on main crop; 1 application on ratoon crop); U = untreated

b Within each variety, means within a column followed by the same or no letter are not significantly different at the 5% level using the Least Significant Difference Test.

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Ganado Site Visit ...


* Article by Dr. Mo Way, Dr. Gene Reagan, Mr. Julien Beuzelin, Mr. Waseem Akbar, and Dr. Shane Zhou. Drs. Way and Zhou work at the Texas AgriLife Research and Extension Center at Beaumont, TX. Dr. Reagan works at the LSU AgCenter. Mr. Beuzelin is a graduate assistant and Mr. Akbar is a graduate associate under Dr. Reagan.

Rice Plant Types ...

- Harvest indices (HI = grain mass/[grain + straw masses]) were 0.55 for IR8 and 0.38 for Peta
- No lodging was shown by IR8, while drooping leaves and lodging culms were shown by Peta.

Initial Semi-Dwarf Rice Varieties in the U.S.

In the U.S., semi-dwarf varieties were selections of lines produced from crosses that had at least one parent having the semi-dwarf (sd-I) gene. LA 110, which was released in 1976, was developed in Louisiana from a Taichung Native 1 (TN-1) x H4 cross, where TN 1 is a semi-dwarf (McIlrath et al., 1979). Bellemont, which was the first semi-dwarf variety developed in Texas in 1981, was produced from a cross between CI 9881 x PI 331581, where CI 9881 is a selection from a cross of Bluebelle//Belle Patna/Dawn and PI 331581 is a selection from the Backcross Bluebelle6/TN1 (Bollich et al., 1983). Cybonnet, which was the first long-grain semi-dwarf cultivar developed in Arkansas in 2004 (Gibbons et al., 2006b), was selected from a Cypress//Newbonnet/Katy cross (Gibbons et al., 2006a), where Cypress is a semi-dwarf variety. In contrast, the semi-dwarf variety Calrose 76 released in California in 1976, was selected from a single short-statured M2 generation plant grown from Calrose seed that were exposed to the mutagen Cobalt-60 gamma radiation (Rutger et al., 1976, Rutger and Peterson, 1976). Average height of Calrose 76 was 87 cm (34.2 in), which was about 25 cm (9.8 in) shorter than Calrose.

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Fig. 1. Plant height of rice varieties released in Texas from 1944 to 1992 (Graphed from data presented in Tabien et al., 2008).
Although the first semi-dwarf variety developed in Texas was not released until 1981, rice breeders in Texas had been selecting for shorter plant types, resulting in the gradual decrease in the plant height of released *japonica* rice varieties since the release of Texas Patna in 1942. By 1979, two years before the varietal release of semi-dwarf Bellemont, the plant height of the varietal release Newrex was down to 102 cm (40.2 in), which was already 40 cm (15.8 in) shorter than the 1944 release of Bluebonnet (Tabien et al., 2008) (Fig. 1).

**Rice Yield Plateau**

IR8 and succeeding semi-dwarf varieties produced grain yields at a level higher than that of traditional varieties. However, getting to the next level of grain yields was challenging. Peng et al. (1999) cited studies conducted in the 1960s and 1970s (Yoshida and Parao, 1972; De Datta et al., 1968) and in the 1990s (Peng et al., 1996; Kropff et al., 1993) to show that maximum yields under favorable irrigated conditions have ranged from 9 to 10 t/ha (8,030 to 8,922 lb/acre) and suggested that the yield potential of *indica* inbred varieties has not changed (Kropff et al., 1993) or has been on a plateau for 30 years.

**First-Generation New Plant Type**

To break through the yield plateau and further increase the yield potential, IRRI scientists proposed modifications to the plant architecture of the semi-dwarf rice varieties started by IR8, which were high tillering, but had unproductive tillers. Peng et al. (1993) listed the following traits of the new ideotype or new plant type (NPT) proposed by IRRI scientists and also cited research by Vergara (1988), Janoria (1989), and Dingkuhn et al. (1991) that contributed to the development of the NPT:

- Low tillering, with 3 to 4 panicles per plant when direct-seeded
- No unproductive tillers
- Sturdy stems
- Thick erect leaves
- 200 to 250 grain per panicle
- Plant height, 90 to 100 cm (35.4 to 39.4 in)

- Vigorous root system
- Multiple disease and insect resistance
- Growth duration, 110 to 130 days
- Harvest index, 60%
- Yield potential, 13 to 15 t/ha (11,598 to 13,383 lb/acre)

Breeding for this NPT from tropical *japonicas*, now referred to as first-generation NPT, resulted in rice lines that had large panicles, few unproductive tillers, and lodging resistance. However, its grain yield was not as high as expected, due to low biomass production and poor grain filling (Peng and Khush, 2003).

**Second-Generation NPT**

To improve on the shortcomings of the 1st generation NPT, IRRI started development on its 2nd generation NPT, which would have higher tillering ability than the 1st generation NPT. Higher tillering ability is needed to increase biomass production and improve compensation when tillers are lost due to abiotic or biotic factors. The 2nd generation NPT lines are based on crosses between 1st generation NPT lines and elite *indica* lines. The following are the trait parameters targeted for the 2nd generation NPT (Peng and Khush, 2003):

- Panicle density, 330 panicles/m²
- 150 spikelets per panicle
- Grain filling, 80%
- Grain weight, 25 mg grain weight
- Aboveground total biomass, 22 t/ha (19,628 lb/acre)
- Harvest index, 50%
- Grain yield, 11.0 t/ha (9,814 lb/acre)

**Super Rice Breeding**

In China, Yuan (2001) proposed the following morphological traits of a super rice hybrid ideotype, which combines heterosis (hybrid vigor) and improved plant morphology.

- Plant height of about 100 cm (39.4 in), with a culm

Continued on next page
length of 70 cm (27.6 in)

- Erect leaf canopy before appearance of panicles
- Tillering capacity, moderate at 270 to 300 panicles per m²
- Panicles, heavy at 5 g per panicle, and drooping at maturity
- Panicle height, top of filled panicle is about 60 cm (23.6 in) from the ground
- Upper three leaves:
  - Flag leaf, length of 50 cm (19.7 in) long and located 20 cm (7.9 in) higher than the top of the panicle
  - 2nd leaf from the top, length is 55 cm (21.6 in) and is located higher than the top of the panicle
  - 3rd leaf from the top, location reaches the middle of the panicle
  - Leaf angles, remain erect until maturity. Leaf angles of the flag, 2nd, and 3rd leaves are about 5°, 10°, and 20°, respectively.
  - Leaf shape, looks narrow and V-shape, but is 2 cm wide when flattened
  - Leaf thickness, thick with specific leaf weight of top three leaves at 55 g/m²
  - Leaf area index, 6.0
  - Ratio of leaf area to grain weight, 100:2.2 to 2.3
- Harvest index, 55%.

**Plant Type and Varieties in Texas**

At Texas AgriLife Research and Extension Center at Beaumont, the best combination of parameters of four traits (maximum node production rate, main culm node number, and masses of individual leaves and grain) for an ultra high-yielding variety for the Gulf Coast Environment was identified through simulation and field studies. Using the physiologically-based Rice Population Simulation Model (RICEPSM) (Wu and Wilson, 1998; Wilson et al., 1998), these four traits were evaluated in 187,500 simulations involving 1,875 different plant types. Simulation results recommended that rice genotypes having fast node production rate, high main culm node number, and high potential leaf and grain masses relative to Lemont would yield better than those without these trait parameters. Results from the field study confirmed that 100% of the genotypes that had the four recommended trait parameters yielded better than Lemont, while 75% of the genotypes that did not have the four trait parameters yielded lower than Lemont (Wilson et al., 2001). These four trait parameters are currently included in the selection criteria used to breed for high yielding rice lines and varieties.

Currently, about 73% of the rice acreage in Texas are grown to inbred long-grain varieties, while 23% are grown to hybrids (Texas AgriLife Research and Extension Center, 2009). A list of rice varieties grown in Texas over the past years, as well as the acreage in which they were grown, is available at the Texas AgriLife Research and Extension Center’s website at http://beaumont.tamu.edu/CropSurvey/CropSurveyReport.aspx. It is interesting to note that IR8, which is locally known as Milagro, is still one of the varieties grown in Texas, covering 9% of the rice acreage.

In 2005, Khush summarized the challenge of feeding 5 billion rice consumers in 2030, when there will be an increased demand for rice and when these demands will have to be met by producing rice using less land, less water, less labor and fewer chemicals. Today, ideotype breeding is one of the strategies (along with conventional hybridization and selection procedures, hybrid breeding, wide hybridization, and genetic engineering) applied to increase rice yield potential and meet this demand (Khush, 2005).

For more information, please consult the following references:


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Rice Plant Types ...


Rice Crop Update

As of September 28, 2009, about 93% of the main crop rice acreage in Texas had been harvested (Fig. 1). In comparison, about 98% of the main crop rice acreage had been harvested by that date in 2006, 2007, and 2008.

Regarding the ratoon crop, about 4% of its acreage had been harvested by September 28, 2009. In comparison, less than 1% of the ratoon crop acreage had been harvested by that date in 2006, 2007, and 2008.

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.

Fig. 1. Percentage of Texas rice acreage, on a weekly basis, that had been harvested for their main crop grain yield in 2006 thru 2009.

Texas Rice Acreage Harvested for Main Crop


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