



Texas Rice

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Resistance to Rice Stem Borers

Stem borers are caterpillars that live inside the stem of their host such as rice, sugarcane, corn, and sorghum. In rice, there are several species that are destructive and they vary by region and country. The most destructive stem borers in Asia are the yellow stem borer (*Scirpophaga incertulas*), white stem borer (*Scirpophaga innotata*), striped stem borer (*Chilo suppressalis*), dark headed stem borer (*Chilo polychysus*), and pink stem borer (*Sesamia inferens*), while the white stem borer (*Maliarpha separattella*) and purple lined stem borer (*Chilo agamemnon*) are common in Africa. In Central and South America, the South American white stem borer (*Rupela albinella*) is a serious pest of rice. In U.S., the Mexican rice borer (*Eoreuma loftini*), sugarcane borer (*Diatraea saccharalis*), and occasionally the rice stalk borer (*Chilo plejadellus*) are found damaging rice (Way et al., 2006; Reay-Jones et al., 2007; Lv et al., 2008). These borers can cause damage to all stages of the rice crop, from seedling to maturity. The eggs of stem borers are usually laid on the leaves or leaf sheaths. Upon hatching, the larvae crawl to locate a tiller into which it rapidly enters and gains protection from natural enemies and insecticides. Rice is generally resistant to stem borer damage when very young, at mid-growth, and after panicle exertion (Bandong and Litsinger, 2005), while critical stages are active tillering and booting to heading. At the vegetative stage, the larva can damage the tillers causing deadhearts (DH), in which the young tiller and leaves of the tiller turn brown and die. However, deadhearts at the early vegetative stage may not be sufficient to affect grain yield. During the reproductive stage, injury to tillers can destroy the panicles resulting

in whiteheads. Plants injured by stem borers can partially recover by producing more tillers (Bandong and Litsinger, 2005; Lv et al., 2008), and at lower levels of damage the injury does not cause yield loss. However, tillers that are lost at the reproductive stage are not replaced causing yield loss. In Asia, monitoring and insecticide application are not recommended from panicle initiation to pre-booting on early maturing varieties and from late vegetative to booting in medium maturing varieties to save cost and labor in controlling stem borers.

Grain yield losses of 3 to 95% due to yellow stem borer (YSB) damage have been reported in India. In Ganado, Texas, yield losses of up to 60%, due predominantly to sugarcane borers, were reported in untreated fields (Way et al., 2006). From a large dataset in India obtained from 28 years of experiments, 1% deadhearts cause 2.5% yield loss, 1% whiteheads cause 4.0% yield loss, and 1% deadhearts and whiteheads cause 6.4% yield loss (Muralidharan and Pasalu, 2006). High levels of damage in hybrid rice (28 to 36%) have been reported in China (Chieng, 1985), with hybrid having 107 to 110% more egg masses and higher larval and pupal survival than found in inbreds. However, the reverse was observed at Ganado, Texas, where hybrid rice had fewer whiteheads than conventional inbred varieties (Way et al., 2006).

Methods for controlling stem borers include cultural practices, insecticides, biological, and varietal resistance. Insecticide control is the most popular method and accounts for the majority of insecticide use on rice in Asia. Insecticides are effective at

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From the Editor ...



A Linkage Between Plant Breeding and Insect Management

Welcome to the field day issue of *Texas Rice*. The Eagle Lake Field Day will be held Tuesday June 28 at the David R. Wintermann Rice Research Station, with field tours beginning at 4 PM. Garry McCauley will provide an overview of his weed management research, Rodante Tabien will discuss varietal development, Mo Way will describe his entomology research, and Shane Zhou will provide an overview of his disease management research. The field tour will be followed by an evening program and dinner that will be held at the Eagle Lake convention center. Joe Outlaw will provide an update on national farm policy, while Steve Balas will discuss water issues. Research that is currently being conducted by our scientists will be on display.

The Beaumont Field Day will be held Thursday July 14 at the Beaumont Center. Field tours will begin at 8 AM. The field tour will have 4 stops. Dante Tabien, Shannon Pinson, and Ming Chen will cover inbred rice breeding, genetics of grain quality and disease resistance, and health benefits associated with grain characteristics. Ted Wilson and Omar Samonte will describe the development of hybrid rice varieties and the physiological basis for improved yields of hybrids. Lee Tarpley and Fugen Dou will describe research on rice's response to environmental stresses, and carbon and nitrogen cycling in the soil, and how nitrogen cycling affects fertilizer use efficiency. Mo Way and Shane Zhou will provide overviews of their insect and disease management research.

The field tours will be followed by keynote

presentations on the future of agricultural production and management. John Greenplate, who is a Monsanto Research Fellow, will trace improvements made to *Bt* cotton efficacy and the potential for improved product durability relative to insect resistance management. While John's presentation will focus on cotton, it has major implications for rice. As you will read below, *Bt* rice is already a reality in some countries, and will become a reality for us as the political aversion to transgenic food crops in the U.S. sufficiently lessens. Johnny Saichuk with LSU will follow by discussing the adoption and implementation of new technologies in rice production. Cliff Mock, who is an independent crop consultant, will follow-up by providing an overview of the importance and adoption of new technologies from a crop consultants perspective. The Beaumont field day will have displays by our scientists and by local industry and will end with a luncheon.

The first article in this issue is by Dante Tabien, who is the Beaumont Center inbred rice breeder. Dante describes stem boring insects that attack rice across the world and makes a strong case for why rice varieties that are resistant to stem borer injury would be a strong selling point. Dante also points out that stem borer resistance in rice, while found in a number of wild rice species, is largely lacking and is very difficult to breed for in cultivated rice. The best that can be hoped for with most current varieties is a relatively low levels of tolerance, where either fewer eggs are laid on the plants or larval survival is somewhat lower, as Mo Way recently reported as part of his research. While it is possible to cross the largely stem borer susceptible cultivated rice with stem borer resistant wild rice species, the "trashy" nature of the offspring plants and the problems with the large genetic distances of the wild rice species from cultivated rice causing sterility problems means

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Farming Rice

A monthly guide for Texas growers

Providing useful and timely information to Texas rice growers, so they may increase productivity and profitability on their farms.

Disease Severity of Organic Rice as Affected by Host Resistance, Fertility and Tillage

Organic rice production has increased significantly in the U. S., with approximately 35,000 acres currently under production, with Texas and California having the most acreage. Texas organic rice acreage has increased steadily over the past decade, with acreage in 2009 reaching 16,000 acres, which accounted for 10% of the total Texas rice acreage. This is driven by an increased market demand for organically produced rice and the unique position that Texas organic farmers have to utilize large tracts of fallow lands that have been used in cattle operations. There are a wide range of organic rice products on the market, including long and medium grain rice, aromatic or scented rice, rice with colored bran, and rice flour.

Organic rice is produced using methods that differ from conventional rice cropping systems. Organic rice production must follow the USDA national standards for the production and handling of foods labeled as “organic”. Organic production systems avoid the use of synthetic chemicals, including most fertilizers and pesticides that can be used in conventional rice production. Instead, organic production relies on animal manures, crop residues, green manures, and tillage to supply plant nutrients.

Organic rice production can result in significant changes in the incidence and severity of diseases and their management. Due to the prohibition of the use of synthetic fungicides, the control of diseases is a particular challenge. However, there has been essentially no research in this area to support organic rice production. We conducted a series of studies at Beaumont, TX, to evaluate the effects of host resistance, fertility, and tillage on disease severity and grain yield of rice grown using organic and conventional cropping systems. Part of the results of

this study have been published in Zhou and McClung (2010).

Comparison of Disease Severity in Organic and Conventional Rice

More than 20 rice genotypes were grown in 2009 and 2010 using recommended organic production practices (Fig. 1.) and conventional management systems. The following diseases were most common in both production systems: seedling diseases (caused by *Rhizoctonia solani*, *Fusarium* spp. *Sclerotium rolfsii*, *Pythium* spp. and other fungi), narrow brown leaf spot (*Cercospora janseana*), brown spot (*Cochiobolus miyabeanus*), and leaf smut (*Entyloma oryzae*). Bacterial panicle blight caused by *Burkholderia glumae* or *B. gladioli* was observed only in 2010. Minor or occasional diseases included sheath blight (*Rhizoctonia solani*), stackburn (*Alternaria padwickii*), black kernel (*Curvularia lunata*), false

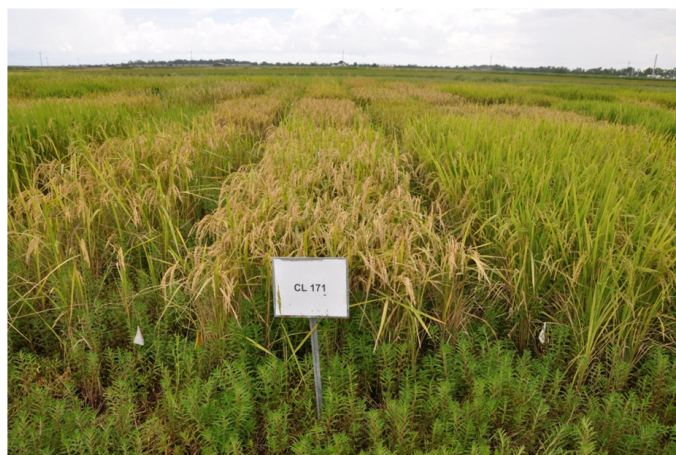


Fig.1. Organic rice plots at Beaumont, TX, in 2010.

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Diseases of Organic Rice ...

smut (*Ustilaginoidea virens*), and pecky rice (various fungi and bacteria and insect injury). In general, the severity of seedling diseases, narrow brown leaf spot, and brown spot was significantly higher in organic than conventional plots. For example, when disease severity was evaluated in 2010 using a scale of 0 to 9, where 0 = no symptoms and 9 = most severe, narrow brown leaf spot severity on Cocodrie, Jazzman, Presidio and Sierra was 6.3, 8.3, 5.0, and 7.3 under organic management and 3.8, 4.0, 2.3, and 3.0 under conventional management, respectively. In contrast, bacterial panicle blight and sheath blight were significantly less severe in organic plots than in conventional plots. For example, bacterial panicle blight on Bengal and MCR02-1572 was respectively rated 1.0 and 1.3 in organic plots and 4.5 and 9.0 in conventional plots. For other diseases, including false smut, there were no apparent differences between these two cropping systems due to the low levels of these diseases.

Effects of Host Resistance

Resistance of 20 genotypes to narrow brown leaf spot, bacterial panicle blight (in 2010 only), brown spot, and leaf smut were assessed visually in organically managed plots at maturity in 2009

Table 1. Severity of diseases in 20 rice varieties and elite lines in organic production system at Beaumont, TX, in 2010.

Variety or Line	Narrow Brown Leaf Spot (0-9)	Bacterial Panicle Blight (0-9)	Brown Spot (0-9)	Leaf Smut (0-9)	Grain Yield (lb/ac)
Bengal	0.0 h†	1.0 b	4.0 bcd	0.0 e	5648 ef
Charleston Gold	0.3 gh	0.0 c	4.5 ab	0.0 e	6060 def
Cocodrie	6.3 c	0.3 c	4.0 bcd	0.5 de	5660 ef
Cybonnet	5.3 bcd	0.3 c	4.0 bcd	1.5 bc	5778 ef
GP2	0.0 h	0.0 c	1.3 ij	0.0 e	8356 b
Jasmine 85	0.5 fgh	0.0 c	2.5 fgh	0.0 e	5672 ef
Jazzman	8.3 a	0.0 c	2.5 fgh	1.0 cd	5586 fg
RU093150	4.5 e	2.3 a	0.8 j	0.0 e	6193 c-f
JES	1.0 fg	0.0 c	3.3 c-f	0.0 e	5727 ef
Jupiter	1.3 f	0.0 c	3.8 b-e	0.0 e	6839 cd
MCR02-1572	0.3 gh	1.3 b	4.3 abc	2.0 b	6163 def
PI312777	0.3 gh	0.0 c	3.5 b-f	0.0 e	7013 cd
PI338046	0.8 fgh	0.0 c	2.0 ghi	0.0 e	6569 c-f
Presidio	5.0 de	0.0 c	1.5 hij	3.0 a	6358 c-f
Rondo	1.0 fg	0.0 c	5.3 a	0.0 e	6670 cde
RU0703144	5.3 de	0.0 c	0.8 j	0.0 e	4554 gh
RU0703190	5.5 cd	0.3 c	2.8 efg	0.0 e	4564 gh
Sierra	7.3 b	0.0 c	3.0 d-g	0.0 e	4282 h
Tesanai 2	0.5 fgh	0.0 c	1.0 ij	0.0 e	9940 a
Wells	0.8 fgh	0.0 c	2.0 ghi	0.5 de	7228 c
LSD (0.05)	0.9	0.4	1.2	0.9	1039
P > F	0.0001	0.0001	0.0001	0.0001	0.0001

† Means in a column followed by the same letter are not significantly different (P = 0.05) based on Fisher's protected LSD test.

and 2010 (Table 1). Severity varied with genotype. Narrow brown leaf spot was highest on Cocodrie, Cybonnet, Jazzman, RU0903150 (Jeff/*O. rufipogon*), Presidio, RU0703144 (Cypress/Cocodrie), RU0703190 (Cocodrie/L202), and Sierra, and was low or non-existent on the remaining genotypes. Bacterial panicle blight was observed on Bengal, Charleston Gold, RU0903150, MCR02-1572, and RU0703190, with Bengal, RU0903150, and MCR02-

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1572 having a significantly higher level of disease. Brown spot was present in all genotypes, with severity the lowest on GP2, RU0903150, RU0703144, and Tesanai 2, and moderate on all other varieties. In general, leaf smut was minor, except on Presidio. Tesanai 2 and GP2, both of which are from China, had the highest grain yields under organic management. Wells was the highest yielding conventional long grain, whereas Jupiter had the highest grain yield of the medium grain genotypes. Charleston Gold was the highest yielding aromatic. Similar results for severity of narrow brown leaf spot, brown spot and leaf smut and grain yield were observed each year (Zhou et al., 2010b).

Effects of Fertilization

An organic fertilizer trial was conducted to evaluate the effect of different application rates of AgriCycle (4-2-3, N-P-K), Nature Safe (13-0-0), Rhizogen (7-2-1), Top Organic Fertilizer (4-2-2), and True Organic Fertilizer (12-3-0) on narrow brown leaf spot severity and grain yield at Beaumont, TX, in 2009 and 2010 (Zhou et al., 2010a, 2011a). Presidio was used as a test variety, which is moderately susceptible to narrow brown leaf spot.

All fertilizer treatments significantly reduced narrow brown leaf spot severity compared to the unfertilized control (Table 2). For AgriCycle, disease severity tended to decrease as the rate of the fertilizer increased. When the total nitrogen (N) applied using AgriCycle was increased to 130 lb/ac, narrow brown leaf spot disease severity decreased to the lowest level. Similar disease response patterns were observed with the applications of all other fertilizers. Disease severity was not significantly different among fertilizers at the same or similar N application rates. When disease severity was regressed against total N amount, narrow brown

Table 2. Effects of organic fertilizers on severity of narrow brown leaf spot in organic rice at Beaumont, TX, in 2010.

Fertilizer (N-P-K)	Fertilizer Rate (lb/ac)	Total N Rate (lb/ac)	Narrow Brown Leaf Spot (% flag leaf blade affected)	Grain Yield (lb/ac)
Untreated control	0	0	27.3 a †	2065 k
AgriCycle (4-2-3)	1000	40	20.3 bc	2472 hij
	1500	60	17.7 dc	2547 ghi
	3250	130	8.0 fgh	2823 d-g
Nature Safe (13-0-0)	500	65	10.7 e-h	3277 bc
	1000	130	11.3 efg	3248 bc
	1500	195	5.3 h	3963 a
Rhizogen (7-2-1)	1000	70	18.3 dc	2348 ijk
	1500	105	15.3 cde	2795 e-h
	1857	130	10.3 e-h	3147 cd
Top Organic Fertilizer (4-2-2)	1000	40	25.0 ab	2151 jk
	1500	60	15.0 cde	2593 ghi
	3250	130	11.7 efg	2683 fgh
True Organic Fertilizer (12-3-0)	1000	120	13.3 def	3055 cde
	1084	130	11.0 e-h	2948 c-f
	1500	180	6.7 gh	3572 b
LSD (0.05)	-	-	5.9	334
P > F	-	-	0.0001	0.0001

† Means in a column followed by the same letter are not significantly different (P = 0.05) based on Fisher's protected LSD.

leaf spot severity linearly decreased with the increase of total amount of N applied ($R^2 = 0.82$, $P < 0.0001$) (Fig. 2). Applications of all fertilizers increased grain yield compared to the untreated control, with the trend pattern of increasing yield with the increase of total amount of N applied. The results of this study suggested that N deficiency causes more severe narrow brown leaf spot in organic rice, which is in agreement with the previous research results in conventional rice (Hollier, 1992).

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Effects of Tillage

Organic rice production is frequently associated with the use of crop residues such as legume cover crops to supply nitrogen and maintain soil productivity. Tillage plays a role in the process of converting crop residues to N and other elements in forms available to plants. However, tillage also may affect disease severity. In this study, we evaluated the effects of tillage on disease severity and yield potential on 20 rice varieties. Two field trials were established in 2010 at Beaumont, TX (Zhou et al., 2011b, 2011c). One trial was tilled prior to seeding while the other was not. For the first trial, Durana white clover was planted in fall 2009, plowed down in spring 2010, followed by tillage, and water-seeding of the varieties. For the second trial, Durana white clover was planted then mowed prior to planting rice. Without tilling the soil, the varieties were direct-seeded using a drill into the mowed clover. Diseases were monitored throughout the cropping season.

In the no-till plots, straighthead, which is a physiological disorder, occurred in all varieties, with Cocodrie, RU0703144, and RU0703190, having the most severe symptoms (Fig. 3). In contrast, straighthead was not observed in any of the varieties using conventional tillage and water-seeding. Severity of narrow brown leaf spot, bacterial panicle blight (2010 only), and brown spot and leaf smut, was similar between the tilled treatments (Zhou et al., 2011b, 2011c). Tesanai 2, GP2, and Jasmine 85, all *indica* varieties from Asia, had the highest yields, although Jasmine 85 was ranked relatively high for straighthead (Fig. 3).

Conclusion and Disease Management

The results of these studies suggest that organically produced rice is more vulnerable to infection of narrow brown leaf spot and brown spot. This is partially due to nitrogen deficiency as a result of using slow release organic fertilizers. This conclusion is supported by the organic fertility study in which there was a clear association of increased severity of narrow brown leaf spot with decreased total N applied. However, some of the diseases, such as bacterial panicle blight, were less severe in organic rice compared to

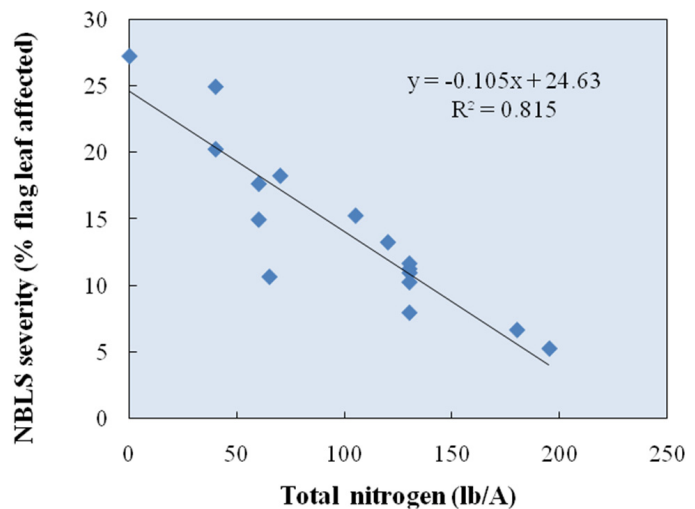


Fig. 2. Relationship between total nitrogen applied and severity of narrow brown leaf spot (NBLS) in organic rice at Beaumont, TX, in 2010.

conventional rice. Therefore, developing cropping systems that enhance soil nutrient quality is a means of improving foliar disease control and yield under organic management.

The results of this study clearly indicate the impact of tillage on the severity of straighthead, a physiological disease in rice. Severe straighthead is most likely to occur in no-till organic production systems involved with the direct seeding of rice into a cover crop. These results suggest that straighthead may be related to decomposition of organic residues in flooded (anaerobic) soils. These results also suggest that to prevent straighthead, highly susceptible varieties should be avoided and the rice crop should not be directly planted into fields with an abundance of decaying crop residues.

Host resistance significantly affects disease severity, especially straighthead. In this study, several varieties, such as Tesanai 2, GP2, Wells, Jupiter, and Rondo, demonstrate resistance to multiple diseases including narrow brown leaf spot, straighthead and bacterial panicle blight. These varieties consistently produced the highest grain yields in these trials. Selection for disease-resistance with high yield potential is the most effective method to minimize damages caused by diseases in organic rice production

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systems.

For more information, please read the following references:

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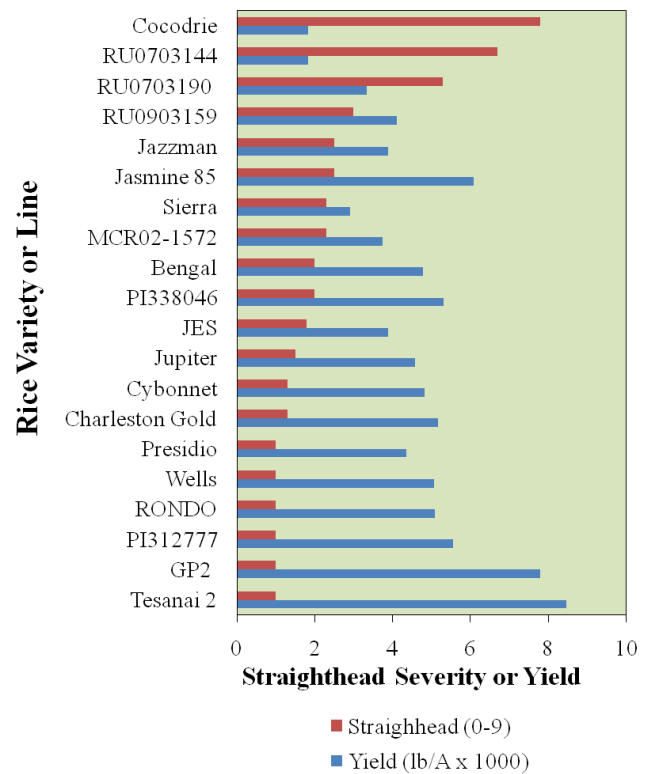


Fig. 3. Straighthead severity and grain yield in 20 rice varieties and elite lines in an organic production system at Beaumont, TX, in 2010.

Plant Disease Management Reports 5:FC011. *

* Article by Drs. Xin-Gen Zhou (Texas A&M AgriLife Research and Extension Center at Beaumont, TX), and Anna McClung (USDA ARS, Dale Bumpers National Rice Research Center at Stuttgart, AR). For more information, please contact Dr. Xin-Gen (Shane) Zhou at xzhou@aesrg.tamu.edu. USDA is an equal opportunity provider and employer.

Rice Stem Borers ...

reducing stem borer infestations and yield losses in rice in Texas (Reay-Jones et al., 2007). However, the price of chemicals is generally high, and excessive applications are not economical. Moreover, because the larvae feed inside the stem, they are protected from non-systemic insecticides. Biocontrol agents such as *Tetrasticus schoenobii*, *Telenomus rowani*, *Telenomus*

dignus, and *Trichogramma japonicum* are effective in parasitizing eggs of stem borers in tropical areas (Litsinger et al., 2006), while *Cotesia flavipes* can be effective in parasitizing larvae in tropical climates (Mailafiya et al., 2010). Unfortunately none of these parasitoids have proven effective at controlling stem

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borers in rice in temperate climates, such as in Texas (Lv et al., 2011).

Sources of Varietal Resistance

There is hope that plant varietal resistance can be used to control stem borers. Varietal resistance for stem borers originates from two sources: 1) natural variations present in cultivated rice and their non-cultivated relatives, and 2) resistance from other organisms or plants, e.g. bacteria or non-related plants that are inserted into rice using genetic transformation, which is commonly referred to as GMO or GM rice.

Cultivated Forms and their Relatives

Screening for stem borer resistance in rice has been conducted in several countries and the results vary depending on the stem borer species. Large-scale field and laboratory screening of 10,000 varieties from the gene bank at the International Rice Research Institute (IRRI) identified 20 varieties that are resistant to YSB (Pathak, 1969). In an evaluation of 257 rice lines, significant variation in infestation percentage was observed for pink stem borer (PSB) resistance (Ntanos and Koutroubas, 2000). Infestation ranged from 0 to 89%, and resistance was correlated with heading date, plant height, and stem diameter. This study indicated that for mid-season rice varieties (80-85 days to heading), short plant height (<100 cm), narrow stem diameter (<5 mm), and high tillering ability are preferred in reducing infestations. Further screening has identified IR75288-38-3-1 as an important donor for stem borer resistance, with more than 86% larvae mortality both on detached leaf and with field screening (Li et al., 2010).

In a screen for PSB and YSB resistance in India, a number of varieties were reported with reduced deadhearts and whiteheads (Kalode et al., 1989). In a screen of 88 rice varieties, five were resistant to YSB (Padhi, 2002). Among 118 released varieties from India, 12 were resistant to YSB (Subudhi et al., 2007). Sudha was identified as a common donor of resistance to stem borer. Field screening of U.S. rice varieties and gene bank collections identified several resistant genotypes. Oliver et al. (1973) identified entries that were better than the stalk borer resistant varieties TKM6 and PI 245717. Some of the resistant entries included material from the world collection.

Recently, Way et al. (2006) reported reduced injury in CLXL8, Wells, Cheniere, XP723, XP710, and CL161, as part of a 4-year study that aimed at assessing the resistance of rice to sugarcane borer and Mexican rice borer.

Wild relatives of rice are important donors for disease and insect resistance, including stem borers (Jena, 2010). In 25 wild rice species evaluated for YSB, stem borers were not found in three species and very low infestation in three additional species (Padhi and Sen, 2002). In another study, *O. coarctata* was immune to YSB, and four additional rice species were highly resistant (Panigrahi and Rajamani, 2008). Recently, resistance to YSB was confirmed in *O. coarctata*, *O. brachyantha*, *O. officinalis*, and *O. ridleyi*, and these are being transferred to desirable plant material using large-scale backcrossing (Behura et al., 2011). Cultivated rice germplasm and wild relatives are potential donors in breeding for stem borer resistance in the U.S., but these have to be evaluated in our environment using sugarcane borer and Mexican rice borer.

Genetically Modified Plants

Resistant genes such as *Bt* (from *Bacillus thuringiensis*) and *pin2* (potato proteinase inhibitor 2) have been transferred into rice. *Bt* genes are the most popular, and their toxin (also referred to as δ -endotoxin, cry gene proteins, or *Bt* toxin) are lethal to Lepidoptera, but not most other insects. The first *Bt* gene was cloned in 1981, and the first transgenic rice was developed in 1988 (Deka and Barthakur, 2010). The first field evaluation of *Bt* rice was conducted in 2000 and the first commercial *Bt* rice variety was released in Iran in 2004. Among the *Bt* genes, *cry1A* is the most popular and well-studied, but transgenic rice with *cry2A*, *cry1C* and *cry9C* genes for resistance have also been studied.

Some scientists are concerned the use of *Bt* rice will result in the development of *Bt*-resistant insects, negatively impact susceptible non-target insects, and possibly cause uncontrolled secondary insect pest outbreaks. However, in China, *Bt* rice efficiently controls a number of rice stem borers (*Chilo suppressalis*, *Scirpophaga incertulas*, and

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Sesamia inferens) and the leafhopper (*Cnaphalocrocis medinalis*) (Chen et al., 2006) without unintended effects on non-target insects. Moreover, insecticides were found to be more harmful to natural enemies of insect pests than was the *Bt* rice. *Bt* rice reduced yield losses particularly in areas with high insect pressure (Xia et al., 2010). However, yield losses under low insect pressure in the transgenic rice was attributed to reduced *Bt* rice fitness. The same phenomenon has been observed in other transgenic plants, including GM wheat and *Arabidopsis*.

Mechanism of Resistance

Stem borer resistance can be due to antibiosis (reduced longevity and reproduction, increased mortality of insect), antixenosis (reduced plant attractiveness), and tolerance (ability to withstand and recover from damage). Most resistant rice varieties cause increased larval mortality, slower larval growth, and smaller stem borer body size (Pathak, 1969). Compared to resistant IR36 and susceptible IR62 and IR72, IR40 exhibited the highest YSB larval mortality (Rubia-Sanchez et al., 2001). The same observation was noted in IRRI line IR75288-38-3-1 and the Chinese varieties Shan-you 63, Zhendao No. 2, and 92-109 (Fang et al., 2002; Li et al., 2010). Resistant varieties caused mortality or inhibited the growth of YSB, and resistance was highly correlated with smaller interval vascular bundles and larger width of the leaf sheath ridge. In a comparison between the new plant type (NPT) lines developed by IRRI and released varieties, the NPT was more attractive for oviposition and this contributed to higher YSB damage (Zhu et al., 2002). In wild rice, non-preference is attributed to very narrow pith, and slender, hard and tough stems (Padhi and Sen, 2002).

Inheritance and Use of DNA Markers

Although several stem borer resistance donors have been identified, few inheritance studies have been conducted. Reports indicate a polygenic inheritance (Kalode et al., 1989; Selvi et al., 2003) for YSB resistance, and this nature of trait inheritance makes breeding for resistance challenging. Moreover, the best donors are from wild relatives that are difficult to hybridize with cultivated rice (Jena, 2010). Sterility barriers, non-homologous chromosome pairing,

and linkage drags (transfer of both desirable and undesirable traits) have to be overcome to transfer stem borer resistance to modern varieties. Current technology can facilitate this trait transfer. Sterility can be avoided by selecting against plants that contain sterility DNA markers, while DNA markers closely linked to the desired resistance trait can identify plants with the desired trait. The need for mass rearing of insects for screening can be minimized using DNA marker-aided selection (MAS). Similar to inheritance studies, mapping studies for rice stem borer resistance are limited. Using the population derived from W1263 (resistant) and Co43 (susceptible) cross, four DNA markers linked to YSB resistance in chromosome 4 were identified (Selvi et al., 2002a; 2002b; 2003). However, identification of additional markers near this locus was recommended to fully use the DNA markers in MAS.

Progress has been made in the development of leafhopper and planthopper varietal resistance in rice, but major progress for stem borers is limited. Moreover, GMO approaches for stem borers control is limited to the *Bt* technology. Stem borer varietal resistance should include both conventional breeding and use of biotechnology. Natural variations in cultivated and wild relatives should be exploited to develop varieties with high resistance to stem borers. Mapping and development of DNA markers have to be expanded to facilitate varietal release. *Bt* technology has the potential to reduce yield losses and use of insecticides, but efficient deployment and management strategies have to be developed to prevent borers from developing resistance.

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* Article by Dr. Rodante E. Tabien, Texas AgriLife Research and Extension Center at Beaumont, TX.

From the Editor ...

it would take possibly a career's worth of effort to develop cultivated rice having high levels of stem borer resistance.

There is a relatively quick work around the slow drawn out wide-crossing, repeated backcrossing, and massive selection required to develop conventional stem borer resistant rice. Instead, rice breeders could use transgenics or genetically modified rice breeding, which would result in the release of a stem borer resistant rice variety in as little as a few years. In Dante's paper, he reports that scientists in China have field-tested *Bt* rice and have shown that stem borer injury can be largely eliminated. The *Bt* toxins are produced by bacterial genes that have been inserted into a number of crops, are very selective in terms of the insects that are affected, and lack at least some of the negatives associated with insecticide-based stem borer management. Because the *Bt* toxins are inside of the plant, they also do not affect most natural enemies that attack stem borers. In contrast, most insecticides broadly kill a wide range of good and bad insects,

which can result in secondary outbreaks of pests that are normally often kept in check by natural enemies at sub-economic levels.

The transgenic solution to developing stem borer resistant rice is at hand and has proven exceedingly valuable for a number of crops including canola, corn, cotton, papaya, soybeans, and many others. However, rice as a major food crop is prone to a number of political barriers and transgenic rice is perceived by some as being a Franken-food that poses untold harm to humans and our environment. My perspective is somewhat different. It has been 30 years since the first transgenic crop was developed and so far the overwhelming evidence is that any negative impacts that might be associated with transgenic crops are far outweighed by the resulting yield benefits.

I have no doubt that a number of transgenically derived rice varieties will soon hit the market shelves. Unfortunately, the first commercial transgenic rice will be produced in Asia and not in the U.S. As discussed a few years back with Norman Borlaug, who was the father of the green revolution, transgenic rice has the potential to increase yields, particularly in the developing countries of the world, in the process saving over a billion acres of land from having to be used for agriculture. What could be more environmentally sustainable, assuming we take due precautions in rotating crops and varieties to minimize the likelihood of *Bt* resistant stem borers developing.

The second article in this issue is by Shane Zhou and Anna McClung and focuses on how fertilizer management in organic rice impacts the prevalence of different species of rice pathogens and how disease pressure is effected by tillage for different rice varieties. Organic rice production differs greatly from conventional rice production in that conventional fertilizers, insecticides, fungicides, and herbicides are not allowed. While organic rice receives a premium of sometimes double the price of conventional rice, organic rice is harder to produce and yields are often as low as 25% to 40% of conventional rice. In addition, organic rice is often planted later than conventional rice, at a higher seeding rate, and is seeded into water, all three of which allow the crop canopy to form more quickly providing more efficient weed control.

Shane's and Anna's research shows that some varieties yield more than other varieties under

Continued on the next page

From the Editor ...

organic production. Two varieties from China gave the best yields under organic production, possibly due to the Chinese varieties having been developed under a lower nitrogen input production system than normally found with U.S. varieties. Overall, most of the tested varieties yielded more than is typically observed for organic rice, suggesting that under proper management organic rice yields can be greatly increased. The issue, however, is always one of weighing the costs of applying higher levels of organically approved fertilizer and the benefits from higher yields and lesser disease levels.

Shane and Anna's research also shows that organic rice is more susceptible to narrow brown leaf spot and brown spot disease, particularly due to the greater level of nitrogen deficiency, and that organically produced rice is more sensitive to these diseases compared to conventionally produced rice. However, their research also shows that bacterial panicle blight was less severe in organic rice than in conventional rice. It is only through research such as

this that we can continue to improve the efficiency of agricultural production.

Please don't forget to read the field day inserts included with this issue of *Texas Rice*. Our researchers have provided a summary of about 40 research projects that are underway at Eagle Lake, Beaumont, and across the Texas rice belt.

I hope we see you in a few weeks at our Eagle Lake and Beaumont field days, where we will be shown some of the exciting research and research outreach being conducted on rice in Texas and where we will hear speakers bring us all up to speed with new developments.

Sincerely,



L.T. Wilson
Professor & Center Director
Jack B. Wendt Endowed
Chair in Rice Research

Rice Crop Update

As of June 10, 2011, about 59% of the rice crop acreage in Texas were at permanent flood. In comparison, about 93, 81, 85, 88, and 79% were at permanent flood as of June 10 in 2006, 2007, 2008, 2009, and 2010, respectively.

About 23% of the Texas rice acreage were at panicle differentiation (PD) as of June 10, 2011. In

comparison, about 69, 26, 39, 56, and 29% were at PD as of June 10 in 2006, 2007, 2008, 2009, and 2010, respectively.

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>.

Professor and Center Director: L.T. (Ted) Wilson

lt-wilson@aesrg.tamu.edu

Technical Editor: S.O.P.B. Samonte

sosamonte@aesrg.tamu.edu

Texas A&M University System

AgriLife Research and Extension Center

1509 Aggie Drive, Beaumont, TX 77713

(409)752-2741

Access back issues of *Texas Rice* at

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AgriLife Research and Extension Center
1509 Aggie Dr.
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