Effect of Rice Blast and Sheath Blight on Physical Properties of Selected Rice Cultivars[1]

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ABSTRACT

Observations in 1997 indicated a significant reduction in kernel bulk density and head rice yield of rice cultivar LaGrue due to blast (*Pyricularia grisea*). A more detailed study on rice cultivar M202 in 1998 confirmed such observations but it also showed negative effects of blast on other physical properties of rice. Rough rice from blast-infected panicles was drier by 7–10 percentage points and 10% thinner than rough rice from blast-free panicles. Blast also caused incidences of chalky, unfilled, and fissured kernels that were 21, 30, and 7 percentage points higher, respectively. The effects of sheath blight (*Rhizoctonia solani*) on kernel thickness and moisture content of rice cultivars Cocodrie, Cypress, Drew, and LaGrue were similar to the effect of blast on M202. Sheath blight generally reduced kernel bulk density but did not significantly affect head rice yield of the cultivars in 1997 and 1998 (except in one sample of Drew). There was a general trend toward higher incidences of unfilled, chalky, and fissured kernels in sheath-blight-infected samples. The data indicated that blast could be a significant preharvest factor in causing high variability in physical properties as well as in reducing the milling quality of rice. Sheath blight is also a potentially significant preharvest factor in affecting these properties in situations where sheath blight pressure is high.

Rice blast and sheath blight are considered to be the most economically significant fungal rice diseases in the world (Groth et al 1988, Cu et al 1996). Rice blast is caused by *Pyricularia grisea* (Cooke) Sacc., while sheath blight is caused by a soilborne fungus, *Rhizoctonia solani* Kuhn.

Blast is destructive under favorable conditions in both tropical and temperate areas (Ou 1985). Reliable estimates and exact figures of grain yield losses caused by blast are very few (Ou 1985, Hwang et al 1987). Of the two major forms of blast, panicle blast has a stronger negative effect on panicle biomass than leaf blast (Torres and Teng 1993). Heavy infections of the panicles are often detrimental to rice yields (Ou 1985) because panicle blast constricts the main node of the panicle to reduce translocation (Torres and Teng 1993). Leaf blast has an indirect effect on panicle biomass by reducing the photosynthetic activity in infected rice plants due to a reduction in the green leaf area (Burrel and Rees 1974, Padhi et al 1978). There is little information on the effect of blast on the physical properties of rough rice. It has been reported that for every 10% of neck blast incidence, there was ≈6% yield reduction and 5% increase in chalky kernels which lowered the rice quality by one or two classes (Katsube and Koshimizu 1970).

Sheath blight is considered a major constraint to rice production where rice is grown under intense production systems in both temperate and tropical production areas (Cu et al 1996). Sheath blight is a serious disease of rice in the southern United States, especially in fields of long-grain rice (Marchetti 1983, Marchetti and Bollich 1991). In 1988, annual damage due to sheath blight was estimated by the U.S. Rice Foundation to be $67 million (Groth et al 1988). Yield loss can occur at any stage but is higher when infection occurs at panicle initiation, booting, and flowering (Sharma et al 1990, Cu et al 1996). Sheath blight infection from panicle initiation to flowering resulted in yield loss by reducing the mean grain weight and the number of filled grains (Cu et al 1996). Sheath blight also interferes with grain filling (Marchetti 1983) and can reduce rough rice yield by 39%, but that loss can increase to 50% in terms of kg/ha of milled whole grain rice because grains can be weakened and subsequently break during milling. A possible 46% yield loss in milled rice has been estimated if sheath blight lesions reach 90% of the plant height (Ahn and Mew 1986). Like blast, the effect of sheath blight on the physical properties of rice is not well documented.

Damage due to blast and sheath blight could be more extensive than what is already known. Previous research data have already indicated the effect of these diseases on photosynthesis, translocation of photosynthates, grain filling, and respiration (Roy 1982, Marchetti 1983, Baastians 1991). The objective of this study was to determine the effect of these two diseases on 1) rough rice kernel uniformity in terms of kernel physical properties such as individual kernel moisture content and individual kernel thickness distributions; and 2) kernel bulk density, head rice yield, and incidences of unfilled, chalky, and fissured kernels. Information from this study could be used to explain whether part of the variability in processing qualities of rice that are often experienced by end-use processors even within a cultivar, harvest lot, and location could be due to blast or sheath blight.

MATERIALS AND METHODS

Blast

Initial studies to determine the effect of panicle blast on the physical properties of rice were performed during the 1997 cropping season. Rice samples from naturally infected panicles, as well as samples from blast-free panicles of rice cultivar LaGrue were collected by hand from three producers' fields in Lodge Corner (two sites) and Ulm, AR. The samples were analyzed for bulk density (mass per unit volume) and head rice yield.

Environmental conditions during the 1998 cropping season were not favorable for blast development in the state of Arkansas. Hence, only one cultivar and one location were available for sampling. Rough rice samples from blast-free and naturally infected panicles of rice cultivar M202 were collected from varietal performance trial plots in Pocahontas, AR, on September 12, 1998. The design structure for this varietal performance trial was a randomized complete block design with four replicates. Blast-free and blast-infected panicles of M202 were collected by hand and hand-threshed individually. Four samples (or replicates) of rough rice each weighing ≈300 g from blast-free and blast-infected panicles were collected. Additionally, 20 blast-free and 20 blast-infected panicles per replicate were collected. From these panicles, the number of unfilled kernels was counted to determine the percentage of unfilled kernels per panicle.

Data for bulk density and head rice yield of LaGrue were analyzed as a location × disease level factorial experiment by using the PROC GLM procedure of SAS (version 6.12, SAS Institute, Cary, NC).

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The effect of location × disease level interaction on bulk density and head rice yield of LaGrue was not significant. Hence, the data were presented as averages of the three locations, and contrasts were made between blast-free (control) and blast-infected (blast) samples. Mean separation between blast-free and blast-infected samples was performed by least significant difference ($P < 0.05$).

Sheath Blight

Initial sampling for sheath blight was done during harvest of the 1997 rice cropping season. Rough rice samples were collected from the 1997 Arkansas Rice Fungicide Field Testing Program plots at the Pine Tree Experiment Station, Colt, AR. Treatments (untreated and disease-free checks) were arranged in a randomized complete block design with four replicates. Untreated checks were inoculated with *R. solani* at panicle differentiation (PD) and did not receive any fungicide treatment while the disease-free checks were treated with fungicides at PD, 14 days after PD, and 28 days after PD. Disease-free samples of rice cultivar Cypress were treated with either Quadris (Zeneca Ag Products) for the Novartis, Zeneca, and Tank Mix fungicide trials or Moncut 50WP (AgrEvo) for the Moncut fungicide trial at the rate of 910 mL/ha or 0.32 kg/ha of formulated products, respectively. On the other hand, disease-free samples of rice cultivar Lemont were treated with either Elexa (IGG International) for the Elexa fungicide trial or RH0753 2SC (Rohm & Haas Co.) for the Rohm & Haas fungicide trial at the rate of 10% v/v of the formulated product or 0.23 kg/ha of active ingredient, respectively. Samples of Cypress and Lemont were collected from four and two fungicide trials, respectively. Plots were harvested individually by a miniplot combine (Yanmar). A subsample weighing 500 g from a bulk sample was used in the study. The samples were analyzed for bulk density and head rice yield. Sheath blight severity was determined and expressed as sheath blight index which was calculated by the formula:

$$\text{Sheath blight index} = (\text{sheath blight lesion height}/\text{tiller height}) \times \%\ \text{infected tillers}$$

where sheath blight lesion height is the distance of the lesion from the ground surface and tiller height is the distance from the ground surface to the flag leaf.

Sheath blight index in untreated checks ranged from 58–81 and 27–64 for Lemont and Cypress, respectively. On the other hand, the sheath blight index for the disease-free checks ranged from 1–16 and 0–1 for Lemont and Cypress, respectively.

Data were analyzed as an unbalanced fungicide trial × cultivar × sheath blight severity level factorial experiment by using the PROC GLM procedure of SAS. The effect of fungicide trial × disease level interaction on bulk density and head rice yield for each cultivar was not significant. Therefore, the data for each cultivar were presented as averages for each sheath blight level across all fungicide trials. Contrasts or mean separations between sheath-blight-free (control) and sheath-blight-infected (sheath blight) samples were performed by least significant difference ($P < 0.05$).

In 1998, samples from sheath-blight-free and sheath-blight-infected tillers of rice cultivars Cocodrie, Cypress, Drew, and LaGrue were collected by hand on September 22, 1998, from fungicide trial experimental plots at the Rice Research and Extension Center in Stuttgart, AR. The design structure of this experiment was an RCBD with three replicates. Sheath-blight-free checks were treated with Quadris fungicide (Zeneca Ag Products) at the growth stages and rate of application described above. Untreated checks were inoculated with *R. solani* at PD and did not receive fungicide treatment. Another sample of Drew was collected from a producer's field in Keiser, AR, where separate samples also were collected by hand from sheath-blight-free and sheath-blight-infected tillers. Tillers with relative lesion height [(lesion height/ tiller height) × 100] of at least 20% were selected as the diseased samples for this study.

Panicles were hand-threshed individually. Three samples (or replicates) of rough rice each weighing ≈300 g from sheath-blight-free and sheath-blight-infected panicles were collected. Additionally, 20 sheath-blight-free and 20 sheath-blight-infected panicles per replicate were collected. From these panicles, the number of unfilled kernels was counted to determine the percentage of unfilled kernels per panicle.

Data were analyzed as a cultivar × sheath blight severity level factorial experiment in an RCBD by SAS. Mean separation was performed by least significant difference ($P < 0.05$) after a significant F test. Contrasts between sheath-blight-free (control) and sheath-blight-infected (sheath blight) samples per cultivar were made.

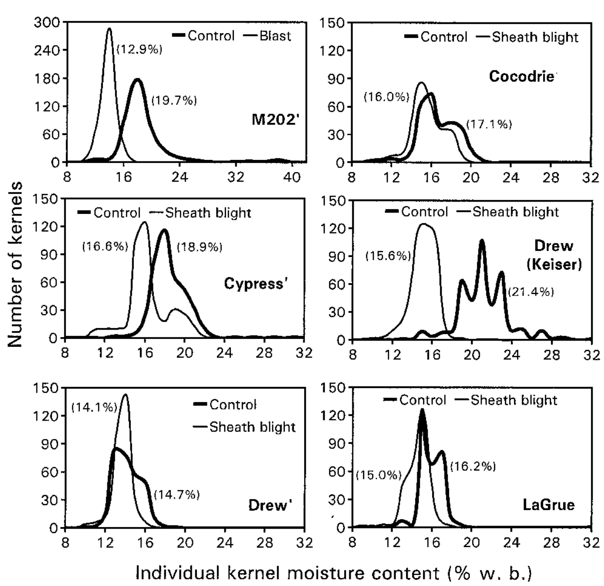

Fig. 1. Individual kernel moisture content distributions as affected by blast on cultivar M202 and sheath blight on four selected cultivars. Sample sizes were 400 kernels each from blast-free and blast-infected samples and 300 kernels each from sheath blight-free and sheath blight-infected samples of cultivars Cocodrie, Cypress, Drew, and LaGrue. Numbers in parentheses are average moisture contents.

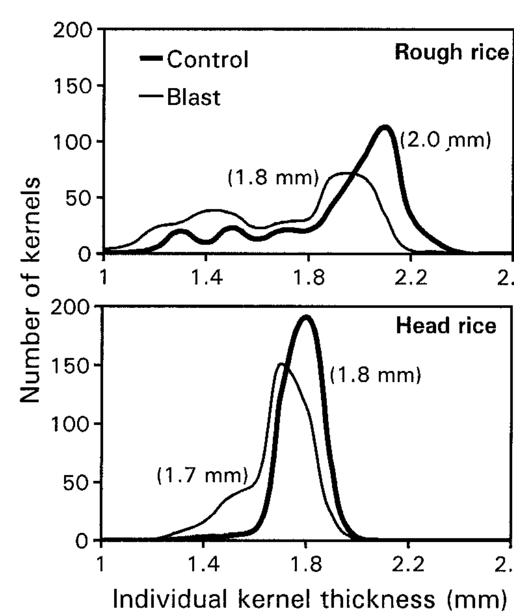

Fig. 2. Effect of blast on individual kernel thickness distribution of rough rice and head rice of cultivar M202. Sample size was 400 kernels each from blast-free and blast-infected sample. Numbers in parentheses are average kernel thicknesses.

Data on bulk density and head rice yield for Cypress from the 1997 and 1998 experiments were presented as two-year averages at each sheath blight level because the effects of year × sheath blight severity level interaction on these parameters for this cultivar were not significant.

Physical Properties

In addition to bulk density and head rice yield, the 1998 samples also were analyzed for individual kernel moisture content and thickness distributions, and incidences of unfilled, fissured, and chalky kernels. Immediately after sampling, 100 kernels of rough rice from each sample were selected to measure the individual kernel moisture content distribution using a single kernel moisture tester (CTR-800A, Shizuouka Seiki). Another 100 kernels of rough rice from each sample were measured for individual kernel dimensional distribution using a rice image analyzer (RIA1A, Satake). Data from the four and three replicates of each level of blast and sheath blight treatments, respectively, were combined and characterized for individual kernel moisture content and individual kernel dimensional distributions using JMPIN statistical discovery software from SAS (version 3).

All samples were dried in thin layers (2.54 cm) to 12.5% equilibrium moisture content (EMC) in an equilibration chamber set at 21°C and 52–53% rh. After drying to 12.5% MC, the bulk density of all rough rice samples was measured by obtaining the weight of rough rice in a 50-mL beaker and subsequently expressing the weight per unit volume as kg/hL. This procedure was repeated twice for each sample, and the bulk densities for the resulting three subsamples per replicate were averaged. Kernels from each dried sample were individually dehulled by hand until 100 dehulled kernels were obtained. From these 100 kernels, the number of kernels with fissures and the number of chalky kernels was determined. Chalkiness was based on the translucence of the kernel when held against a source of light plus the visible sign of chalk.

Milling

Rough rice at 12.5% MC from each sample (150 g) was dehulled by a Satake laboratory rice huller and then milled for 35 sec with a McGill No. 2 laboratory mill to determine head rice yield (weight percentage of rough rice that remains as head rice, or kernels that are ≥75% intact after milling). Head rice was analyzed for degree of milling (DOM) in a Satake MM1-B milling meter. The head rice weights were then expressed based on a DOM of 90 (Reid et al 1998).

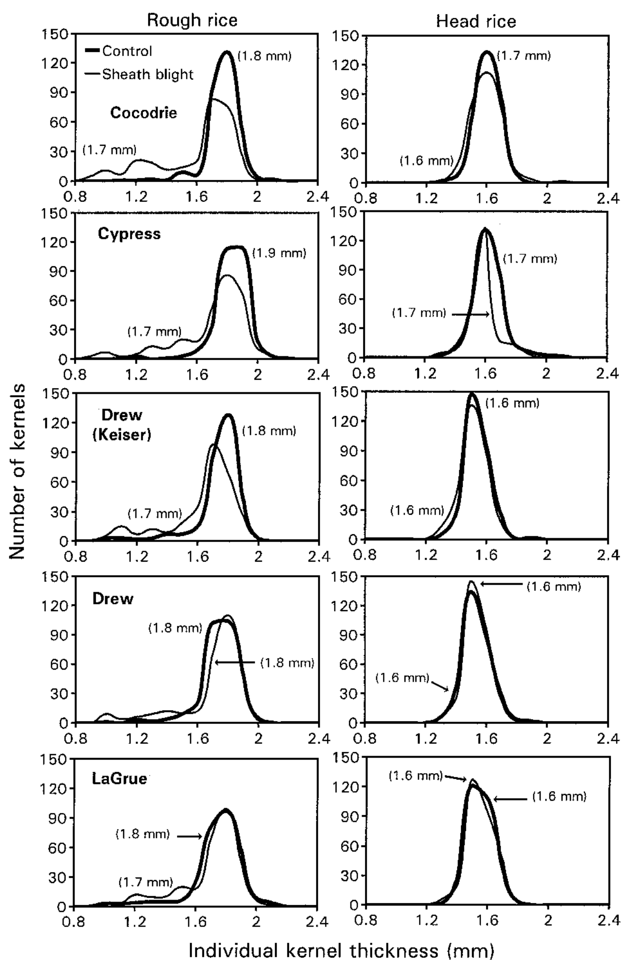

Fig. 3. Effect of sheath blight on individual kernel thickness distribution of rough and head rices of selected cultivars. Sample size was 300 kernels each from sheath blight-free and sheath blight-infected samples of each cultivar. Numbers in parentheses are average kernel thicknesses.

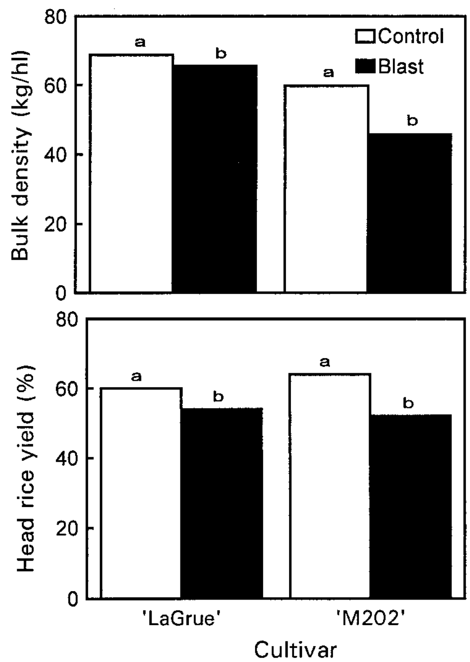

Fig. 4. Effect of blast on kernel bulk density and head rice yield of cultivars LaGrue and M202. Within a cultivar, means with the same letter are not significantly different ($P < 0.05$).

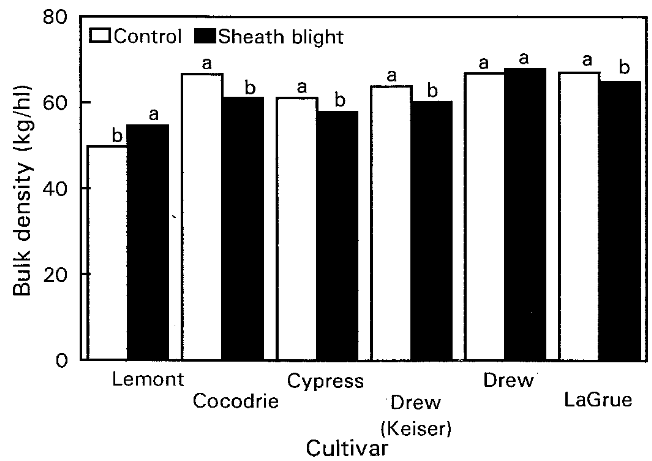

Fig. 5. Effect of sheath blight on bulk density of selected rice cultivars. Within a cultivar, means with the same letter are not significantly different ($P < 0.05$).

RESULTS AND DISCUSSION

Individual Kernel Moisture Content Distribution

All M202 kernels from blast-infected panicles had individual kernel moisture contents that were lower than the average kernel moisture content (19.7%) of the kernels from blast-free panicles (Fig. 1). Cultivars Cocodrie, Cypress, Drew (two sample locations), and LaGrue all had different individual kernel moisture content distribution patterns with respect to sheath blight infection. An average of 73–100% of the kernels from sheath-blight-infected tillers across all cultivars tested had individual kernel moisture contents that were lower than the average moisture content of the kernels from sheath-blight-free tillers. The individual kernel moisture content distributions of the sheath-blight-free and sheath-blight-infected samples indicate higher frequencies of drier kernels in the latter than in the former.

The results indicate a potential negative effect of blast and sheath blight on the individual kernel moisture content distribution of rough rice at harvest. Severe levels of blast and sheath blight can cause premature ripening and drying of rice (Marchetti 1983, Pinnschmidt et al 1994). At harvest time, a condition could exist where grains from the diseased portions of a field are overripe and too dry, while the grains from the disease-free portions of the field may be optimum for harvest (Marchetti 1983). Moreover, under actual field conditions, grains from these portions of the field are harvested together to comprise a harvest lot. Consequently, the result is a harvest lot with nonuniform individual kernel moisture contents. Aside from a potential significant reduction in head rice yield, this situation also provides a risk in income loss to producers due to higher cost of drying (Lu et al 1995).

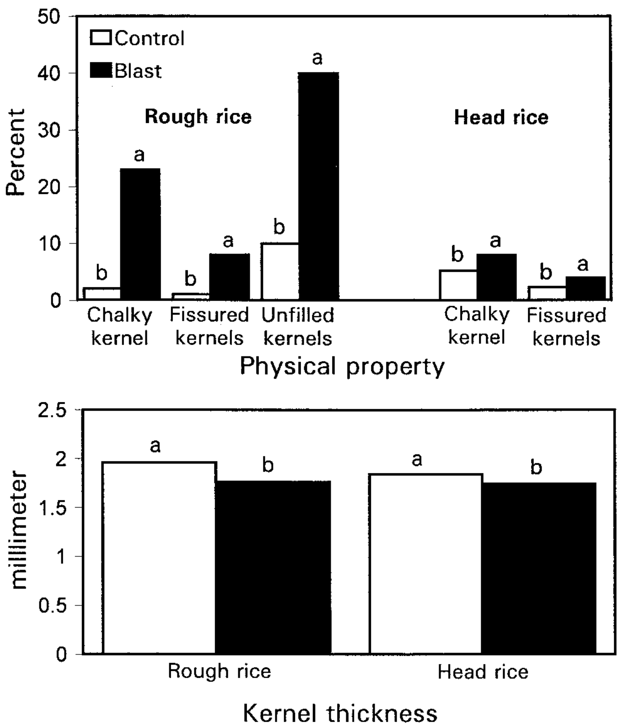

Fig. 6. Effect of blast on average kernel thickness and incidences of chalky, fissured, and unfilled kernels (per panicle) of cultivar M202. Within a physical property, means with the same letter are not significantly different ($P < 0.05$).

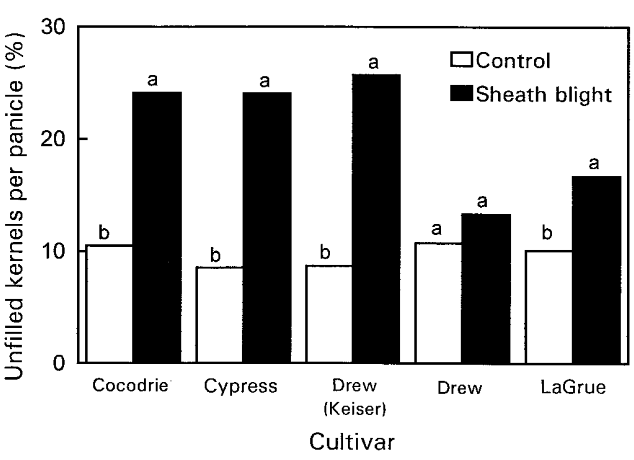

Fig. 7. Effect of sheath blight on the incidence of unfilled kernels per panicle in selected rice cultivars. Within a cultivar, means with the same letter are not significantly different ($P < 0.05$). Incidences of unfilled kernels were not measured in cultivars Lemont and Cypress in 1997.

Individual Kernel Thickness Distribution

Blast resulted in higher frequency of thin kernels of both the rough rice and head rice of M202; 65% of the kernels from blast-infected panicles had individual kernel thicknesses that were less than the average thicknesses of the rough and head rice kernels (2.0 and 1.8 mm, respectively) of blast-free samples (Fig. 2). Average thickness of the rough and head rice kernels from blast-free panicles was always significantly greater than the average kernel thickness of the kernels from blast-infected kernels.

The effects of sheath blight on the individual kernel thickness distributions of Cocodrie, Cypress, Drew (two sample locations), and LaGrue are presented in Fig. 3. For these cultivars, an average of 46–58% of the rough rice kernels from sheath-blight-infected tillers had individual kernel thicknesses lower than the average kernel thickness of rough rice kernels from sheath-blight-free tillers. Sheath blight appeared to have no effect on the individual kernel thickness distributions of head rices of all cultivars tested.

The data from the cultivars tested demonstrate that blast and, to a limited extent, sheath blight reduced rough rice kernel thickness. This would correspond to generally smaller kernels, which in turn would result in lower agronomic yields. The data also indicated that rough rice from diseased samples was more likely to have higher

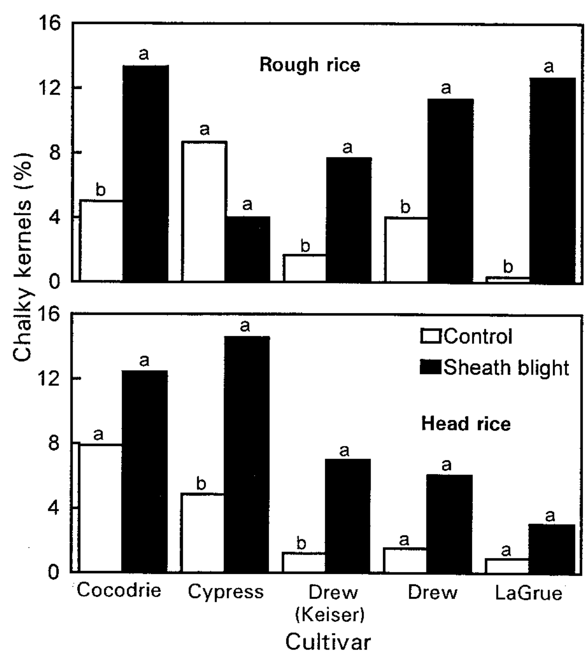

Fig. 8. Effect of sheath blight on incidence of chalky kernels in rough and head rices of selected rice cultivars. Within a cultivar, means with the same letter are not significantly different ($P < 0.05$). Incidences of chalky kernels were not measured in cultivars Lemont and Cypress in 1997.

incidences of thinner kernels ranging from unfilled to partially filled kernels. Rice harvested from diseased and disease-free portions of the field results in a harvest lot composed of kernels with great variability in individual kernel thicknesses. This situation could affect drying and milling quality.

The individual kernel thickness distribution patterns of the head rice of the disease-free and diseased samples, particularly in the sheath blight study, were almost identical (Figs. 2 and 3). This indicates that the differences in kernel thickness distributions due to diseases at the rough rice stage were reduced when the rice was milled. Kernels most affected by disease probably broke during the milling process, leaving the undamaged kernels for thickness measurement. There were slight differences in head rice thickness distributions resulting from blast. These two diseases probably interfere with the grain filling process in a different manner.

Bulk Density

Rough rice kernel bulk density of both LaGrue and M202 was significantly reduced by blast by 3.2 and 14 kg/hL, respectively (Fig. 4). Rough rice kernel bulk density of Cocodrie, Cypress, Drew (Keiser sample), and LaGrue was significantly reduced by sheath blight (Fig. 5). However, this relationship was not consistent in all cultivars. For example, the bulk density of Lemont was higher in sheath-blight-infected samples than in sheath-blight-free samples. The unusual trend in bulk density of Lemont could have been due to an unidentified soil problem in the experimental plots during the experiment, which could have been related to high pH associated with irrigation water in the area. Sheath blight did not significantly affect the bulk density of Drew collected from Stuttgart. The reduction in bulk density due to blast was probably due to the observations that samples from blast-infected panicles had 30 percentage points more unfilled kernels compared with samples from blast-free panicles (Fig. 6). In the case of sheath blight, the reduction in bulk density due to sheath blight was significant in cultivars where the incidence of unfilled kernels in sheath-blight-infected samples was, in general, also significantly higher (Fig. 7). Sheath blight has been demonstrated to reduce mean seed weight and lower the percentage of filled spikelets (Cu et al 1996). The incidence of chalky kernels was higher also in diseased plants than in sheath-blight-free plants (Fig. 8). This could be another contributing factor to the reduction of kernel bulk density in sheath-blight-infected samples.

Head Rice Yield

Blast significantly reduced the head rice yield of LaGrue and M202 by seven and 12 percentage points, respectively (Fig. 4). On the other hand, sheath blight caused no significant reduction in head rice yield except on Cypress (Fig. 9). Environmental conditions during the 1998 rice cropping season in Arkansas were not conducive to sheath blight development. In 1997, sheath blight development in inoculated plots developed late in the cropping season. Therefore, sheath blight may not have been sufficiently severe during the cropping season to cause a significant loss in head rice yield.

The reduction of head rice yield due to blast and sheath blight (in Cypress) may be due to the negative effect of these diseases on kernel moisture content and thickness distributions, as well as on higher incidences of unfilled, chalky, and fissured kernels in diseased samples. The results demonstrated that most kernels from diseased plants were drier and thinner than those from disease-free plants, and also were more likely to be unfilled, chalky, and, in the case of blast, fissured (Figs. 6 and 10). The differences in incidences of fissured kernels between sheath-blight-free and sheath-blight-infected samples were not significant except in the head rice of Drew (Keiser sample) and LaGrue, but there was a general trend toward higher incidences of fissured kernels in sheath-blight-infected samples of both the rough rice and the head rice (Fig. 10).

Rapid moisture adsorption of kernels with moisture contents <14% could have led to the higher frequency of fissured kernels in diseased samples that could easily break during milling (Banaszek and Siebenmorgen 1988). Furthermore, kernels with moisture contents <14% are susceptible to cracking when allowed to adsorb moisture when kernels are rewetted by rain (Kunze and Prasad 1978, Siebenmorgen and Jindal 1986). Results of this study show that 86% of the kernels from blast-infected panicles had moisture contents <14%. Only 2% of the rough rice kernels from blast-free panicles had moisture contents <14%. Of the sheath-blight-free kernels of Cocodrie, Cypress, and the Keiser sample of Drew, 1–3% had moisture contents <14%. The Stuttgart sample of Drew had 34% of kernels with moisture contents <14%. On the other hand, 8–39% of the kernels from the sheath-blight-infected samples of the above cultivars had moisture contents <14%.

The kernel thickness distribution also could have had an effect on head rice yield. Higher breakage was observed in the thinner fractions of milled rice (Matthews and Spadaro 1976, Sun and Siebenmorgen 1993). The high prevalence of thin kernels in diseased samples probably resulted in higher breakage and lower head rice

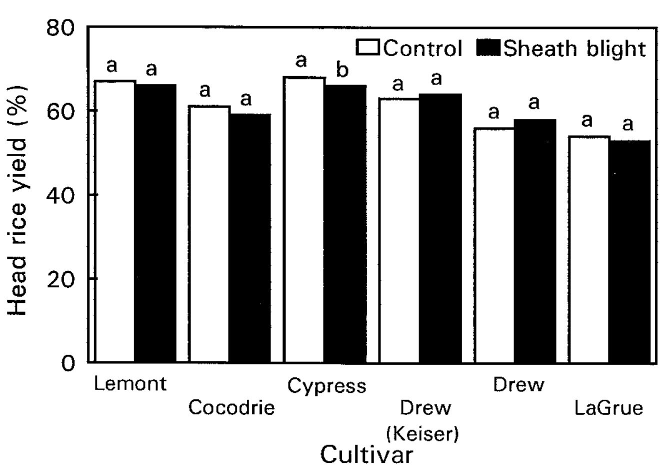

Fig. 9. Effect of sheath blight on head rice yield of selected rice cultivars. Within a cultivar, means with the same letter are not significantly different ($P < 0.05$).

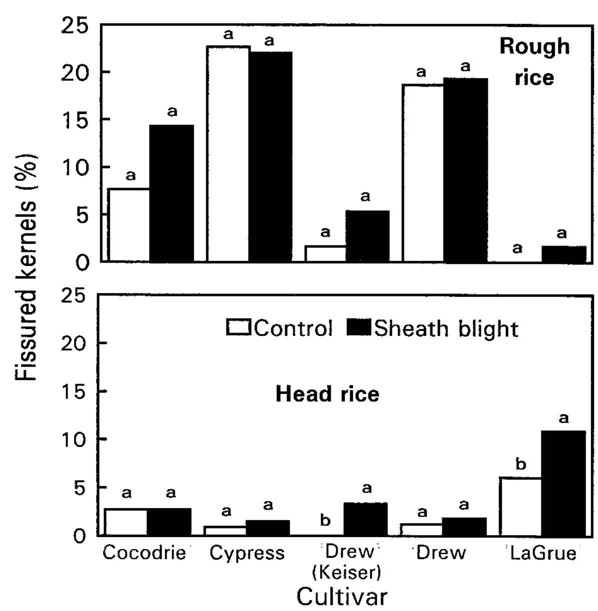

Fig. 10. Effect of sheath blight on incidence of fissured kernels in rough and head rices of selected rice cultivars. Within a cultivar, means with the same letter are not significantly different ($P < 0.05$). Incidences of fissured kernels were not measured in cultivars Lemont and Cypress in 1997.

yield. This study also confirmed previous results that demonstrated a reduction in milling quality due to blast and sheath blight (Katsube and Koshimizu 1970, Marchetti 1983).

CONCLUSIONS

The results demonstrated the negative effect of blast on the physical properties of rice kernels. Blast infection resulted in drier and thinner kernels; higher incidences of unfilled, fissured and chalky kernels; lower rough rice bulk density; and lower head rice yield. The effect of sheath blight on these properties of rice kernels was not as spectacular as that of blast, but the data did indicate that higher sheath blight pressure could potentially cause a substantial negative effect on these properties. Blast and sheath blight could be a significant preharvest factor affecting the physical properties of rice. The preceding conclusions were based on a limited number of genotypes and locations. Further studies with more cultivars from a larger number of locations are warranted.

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