DISEASES

Microorganisms such as fungi, bacteria and viruses are known to cause plant diseases and limit the health, quality and production potential of crop plants. There are many factors that determine the incidence and severity of a specific disease in the field, but there are three principal elements that must be present for the occurrence of a plant disease: a susceptible host, a pathogen, and favorable environmental conditions for disease development. Disease pressure in California is relatively low when compared to tropical and subtropical production areas. The lack of precipitation and low humidity during the growing season limit the development of severe epidemics; however, diseases can become a limiting production factor when the three elements are present.

All of the diseases affecting rice in California are fungal diseases; no bacteria or viruses are known to cause diseases in California. The following discussion is meant to provide you with the tools needed to identify rice diseases and understand the interaction among the rice plant, pathogen and environment. With this information, you will be able to make informed disease management decisions based on biology. Remember that the best tools you have are your eyes so be sure to scout your fields regularly so you may make the most educated decision.

Seed Rot and Seedling Disease

Seed rot and rice seedling diseases may be-caused by *Achlya klebsiana* and *Pythium* species. These diseases are widespread throughout the rice growing areas of California and may occur wherever rice is water seeded. Seed rot and seedling disease often result in poor stand establishment.

Symptoms of seed rot and seedling disease appear shortly after seeding. The most common sign of the pathogen is whitish fungal hyphae growing over the surface of the seed and young seedling (fig. 1). Algae often colonize the mycelium, turning it green. A dark circular spot may also occur on the soil surface around infected seed due to the growth of algae and bacteria on the fungal hyphae and infected seed. Seeds that are infected shortly after seeding often don't germinate because the endosperm or embryo is rapidly destroyed. Growth of seedlings may be greatly impeded when seeds are infected following germination. Symptoms of seedling disease may include stunting, yellowing or rotting of the seedlings.

Unfavorable conditions for seed germination and seedling growth favor the development of these diseases. Cool weather at planting is the most common factor that predisposes seed and seedlings to these diseases because of decreased germination and seedling development rates. Once seedlings are established, they will often outgrow the disease under environmental conditions favorable for seedling growth with little effect on plant growth and survival.

The seed rot and seedling disease fungi survive in the soil and produce zoospores (swimming spores) in response to flooding of the soil. Zoospores are attracted to cracks in the seed coat where the endosperm is exposed or to the germinating seedlings. Feeding by rice seed midge or tadpole shrimp may predispose seed or seedlings to seed rot and seedling disease.

Laser leveling and maintaining a flood of 4 inches promotes rapid germination and stand establishment without the loss of weed control often associated with draining for stand establishment. Planting high quality seed with 85% germination or more when water temperatures are favorable for seed germination and growth (> 70°F) is an important cultural management practice for these diseases. Higher seeding rates can compensate for losses due to seed rot and seedling disease.

Bakanae

Bakanae disease of rice is widely distributed in Asia and was first recognized in Japan in 1828. The word bakanae in Japanese means "foolish seedling" and describes the excessive elongation often seen in infected plants. Symptoms of elongated seedlings led to the identification of bakanae in California rice fields in 1999. The disease has now become widespread throughout the rice growing areas of California.

Bakanae is caused by the fungus *Gibberella fujikuroi* (anamorph *Fusarium fujikuroi*). The fungus infects plants through the roots or crowns and grows systemically within the plant where it produces the growth hormones gibberellin, which causes plant elongation, and fusaric acid, which causes stunting. The types of symptoms produced by an infected plant may be dependent upon the strain of the fungus and nutritional conditions. The most visually striking symptoms of the disease are chlorotic, elongated, thin seedlings that are often several inches taller than healthy seedlings (fig. 2 and 3). Infected seedling may also be stunted and chlorotic, exhibiting a rot and crown rot. Infected seedlings usually die. Older plants infected with the fungus may exhibit abnormal elongation, stunting or normal growth, yellowing, crown rot (fig. 4) and if they survive to maturity produce no panicle or empty panicles. As death approaches infected plants, leaf sheaths are usually covered with a mass of white or pinkish growth and sporulation of the fungus near the waterline (fig. 5). Leaves sheaths of infected plants may also turn a blue-black color with the production of sexual reproduction structures called perithecia.

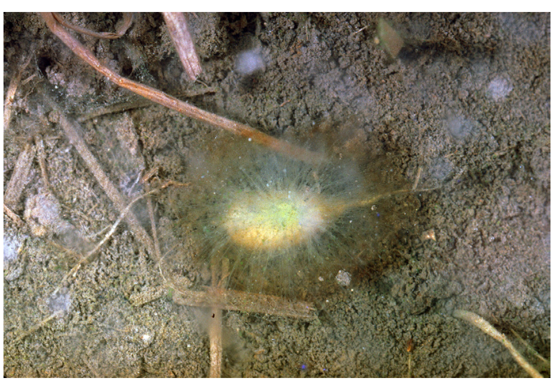

Figure 1. Seeds infected by seed rot show white fungal hyphae growing on the surface of the seed. Photo Credit: UC IPM

Bakanae is primarily a seedborne disease and

Figure 2. Seedlings infected with bakanae are elongated with thin leaf blades.

Figure 3. Healthy (left) and bakanae infected (right).

Figure 4. The crown of bakanae infected plants rots, resulting in premature plant death. Crown of infected plant (left) compared to a healthy crown (right).

Figure 5. Bakane Sporulation in infected mature plants can be white or pink, developing above the water level.

may be moved from one location to another on infested seed. Airborne spores of the fungus may contaminate seed after heading or during harvest. The fungus does not appear to infect the seed internally but rather contaminate the outside of the seed coat. Survival of the fungus in crop residue or the soil is thought to play a minor role in the disease cycle of bakanae.

Planting clean seed is the most effective management method for bakanae. Destruction of crop residue in fields infested with the pathogen may provide some benefits by limiting the amount of inoculum that may carry over to the next crop. Soaking seed in a sodium hypochlorite soak solution is effective in reducing bakanae incidence. Since 2003, Ultra Clorox Germicidal Bleach has been labeled for bakanae control. The product label specifies using a thoroughly premixed solution of five gallons of product to 100 gallons of water, seed is soaked for two hours, then drained and soaked in fresh water for the remaining time. Alternatively, the label specifies using a thoroughly premixed solution of 2.5 gallons of product to 100 gallons of water; seed is soaked for 24 hours, then drained and planted within 12-24 hours. In some cases, bakanae can be observed in fields seeded with treated seed. When seed is held for more than 24 h because seeding is delayed, the temperature increase of the seed due to its physiological activity may result in growth and sporulation of surviving bakane inoculum, resulting in increased incidence of the disease in the field.

Stem Rot

Stem rot disease occurs in most rice growing regions of the world and is caused by the fungus *Magnaporthe salvinii*. The stem rot pathogen is most often found in its sclerotial state, *Sclerotium oryzae*, in the field. The initial symptoms of stem rot appear after mid-tillering as very small irregular black lesions on the outer leaf sheath of the tiller at the waterline (fig. 6). As the season progresses, the lesions enlarge and the fungus moves inward, infecting interior leaf sheaths (fig. 7). Infected leaf sheaths often die and slough off throughout the season. In severe cases, the fungus will penetrate and rot the culm killing the entire tiller (fig. 8). Tiny black sclerotia (hard resting structures) often form within diseased leaf sheaths or culms (fig. 9). Sclerotia and white fungal mycelium may also be found inside the culm of severely infected plants near maturity (fig. 10). Disease incidence and severity is positively correlated with the number of sclerotia present in the upper layer of soil prior to planting (fig 11).

The fungus overwinters mostly as sclerotia associated with diseased crop residue. When the field is flooded for the following season, the sclerotia float to the surface and infect developing seedlings at the waterline. When young plants are infected, tillers are often killed or fail to produce panicles. Moderate infections result in chlorotic leaves. In severe cases where the culm is infected, plants lodge and senesce prematurely (fig. 12), and panicle blanking increases. Yield and quality may be significantly reduced.

Cultural control methods play a key part in the management of stem rot. Since sclerotia overwinter in crop residue, one of the most valuable management tools is limiting the amount of inoculum that carries over from one season to the next. Burning of crop residue in the fall is a very effective method of reducing sclerotial inoculum levels in a field and reducing the amount of crop residue available for sclerotia to form on while overwintering. Swathing at ground level and removing the straw from the field may be nearly as effective as burning. Incorporation of straw and winter flooding has also proven helpful in reducing carry over of sclerotia to the following season (fig. 13).

Although all California rice varieties are susceptible to the stem rot pathogen, slight differences between varieties exist. Varieties with shorter developmental periods tend to have higher stem rot severity when compared to varieties with

Figure 6. Initial symptoms of stem rot appear as small black lesions on the outer leaf sheath of the tiller at the water level. Photo Credit: UC IPM

Figure 7. As stem rot develops, black lesions enlarge, affecting the leaf sheath and affecting leaves. Sometimes while sporulation can be observed at the water level.

Figure 8. In severe cases, stem rot penetrates and rots the culm, killing the tiller.

Figure 9. Stem rot sclerotia can develop on leaf sheaths and culms.

longer developmental periods (fig. 14). Stem rot is more severe in dense stands of rice and with excessive levels of nitrogen fertilization. Low potassium levels in the soil can increase the susceptibility of plants to stem rot. To minimize the severity of stem rot, use seeding rates to establish 20-25 plants per square foot and fertilize fields to maintain soil nutrient levels required for optimum productivity.

The fungicide azoxystrobin (Quadris, QuiltXcel) is registered for stem rot control. Application of azoxystrobin between the late boot stage (when the panicle has not yet emerged) and early heading (when 10 to 20% of panicles have emerged from the boot and can be seen over the canopy) can reduce the severity of stem rot. In trials, treatment with azoxystrobin has resulted in stem rot severity reductions of 20 to 30%.

Figure 10. At maturity, severely infected plants will show large number of sclerotia inside infected culms. These sclerotia survive in the straw residue and become the inoculum for next season.

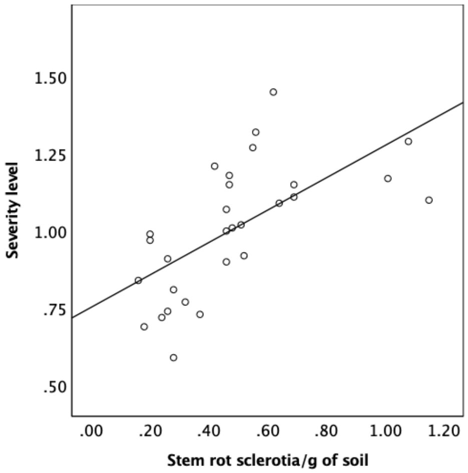

Figure 11. Disease severity (0=healthy, 4=culm rotted through) is positively correlated with the number of sclerotia present in the upper layer of soil prior to planting. From Webster et al., Hilgardia 49 (3), 1981.

Figure 12. Stem rot infection can cause premature plant senescence and lodging.

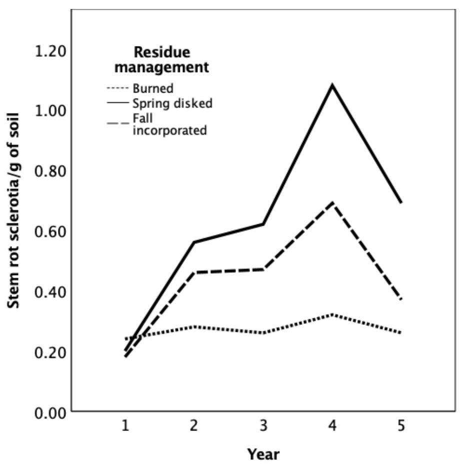

Figure 13. Residue management plays a key role in the management of stem rot. Burning or decomposing straw during wintertime can reduce the number of sclerotia in the soil, resulting in lower disease levels during the season. From Webster et al., Hilgardia 49(3), 1981.

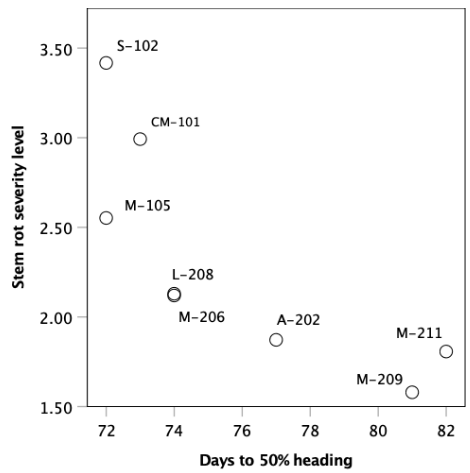

Figure 14. Stem rot severity (0=healthy, 4=culm rotted through) at the end of the season among selected varieties. Varieties with longer periods of development tend to have lower stem rot severity. Richvale, Butte County, 2021.

Aggregate Sheath Spot

The fungus *Rhizoctonia oryzae-sativae* causes aggregate sheath spot disease of rice. Lesions of the disease first appear at the waterline during the tillering stage as oval lesions with gray-green to straw-colored centers surrounded by a brown margin (fig. 15). Additional margins often appear around the initial lesion forming concentric bands. As the season progresses, aggregate sheath spot lesions move upward and form lesions on the upper leaf sheaths (fig. 16). Lesions often coalesce and cover the entire leaf sheath. Leaves of infected leaf sheaths turn bright yellow (fig. 17) and eventually die. Under favorable conditions, the disease may spread to the flag leaf or panicle rachis and result in partially filled panicles (fig. 18).

Rhizoctonia oryzae-sativae produces irregular brown sclerotia that are larger than stem rot sclerotia on the surface of infected leaf sheaths and cylindrical sclerotia inside the cells of infected tissue (fig. 19). Potassium deficiency has been associated with more severe disease symptoms. Excess nitrogen fertilization does not increase the severity of aggregate sheath spot as it does for stem rot. The same cultural management methods used for stem rot may be used for aggregate sheath spot. The disease cycles of the two diseases are very similar so reducing the carry over of sclerotia to the following season is key. Just as with stem rot, the fungicide azoxystrobin (Quadris, QuiltXcel) is effective in reducing the severity of the disease when applied between the late boot and early heading stage. Reductions of up to 80% in disease severity have been observed.

Figure 15. Initial symptoms of aggregate sheath spot develop on leaf sheaths at the water level as oval lesions with gray-green to straw-colored centers surrounded by a brown margin.

Figure 16. As the season progresses, aggregate sheath spot lesions move upward and form lesions on the upper leaf sheaths.

Figure 17. Leaves of leaf sheaths infected with aggregate sheath spot turn bright yellow and eventually die.

Figure 18. Under favorable disease conditions, aggregate sheath spot lesions can infect the flag leaf sheath or panicle rachis, potentially producing panicle blanking.

Figure 19. Aggregate sheath spot sclerotia are cylindrical and develop inside infected tissue

Rice Blast

Rice blast disease is caused by the fungus *Pyricularia grisea* and is widely distributed throughout the rice growing regions of the world but was only identified in California in 1996. The incidence of rice blast is relatively low most years, but severe epidemics have occured. Blast is considered to be the most important disease of rice worldwide and may cause crop losses of up to 50% when conditions are favorable for disease development. *Pyricularia grisea* may infect most aboveground parts of a rice plant including leaves, leaf collars, nodes, panicles and grains. Rice blast disease may be called by different names depending on the part of the plant infected.

Symptoms of leaf blast typically consist of elongated diamond-shaped lesions with gray or whitish centers and brown or reddish brown margins. Lesions can coalesce and result in large, irregular, affected areas on leaves (fig. 20). Leaf collars may also be infected by the fungus and produce a brown or reddish-brown necrotic area at the junction of the leaf blade with the sheath creating a "collar rot" symptom (fig. 21). Collar rot may lead to death of the entire leaf, which may have a significant effect on yield when occurring on the flag leaf. Stem node infections result in a blackened node and may result in complete death of the tiller above the infection point . "Neck blast" is considered to be the most destructive phase of the disease and occurs when the fungus infects the node just below the panicle resulting in a brown or black lesion that encircles the entire node (fig. 22). Depending on the time of infection and progress of the pathogen, neck blast may result in blanking of the panicle or incomplete grain filling. In addition, panicle branches and spiklet pedicles may also be infected resulting in reduced yield and/or milling quality.

Figure 20. Blast lesions on leaves are diamond-shaped, with gray or whitish centers and brown or reddish brown margins. Lesions can coalesce and result in large, irregular, affected areas on leaves.

Infected seed and crop residue are thought to be the most important sources of fungal inoculum in California. Only a small amount of starting inoculum is needed to produce a high incidence of rice blast disease as the pathogen may go through several reproductive cycles per season under favorable conditions. Each cycle consists of a spore of the fungus infecting a plant, producing a new lesion, and resulting in thousands of new spores that may infect other plants within a matter of 7-10 days under favorable conditions. With each spore capable of producing a new lesion, this disease may increase rapidly in a suitable environment. The fungal spores are dispersed by air and may be carried long distances, so it is possible to develop collar and neck rot in a field with no previous signs of leaf blast.

Rice blast development is favored by high nitrogen fertilization, extended periods of leaf wetness, high relative humidity, little or no wind and nighttime temperatures of 63-73°F. Spores are produced and released only under high relative humidity conditions and infection of the plant requires a lengthy period of free moisture on the plant tissue surface before the process is complete. Most years, environmental conditions appear to be permissive but not optimal for rice blast development in California rice fields.

Planting resistant cultivars is one of the primary methods of managing rice blast in many areas of the world. In California, M-210 is currently the only rice cultivar with resistance to rice blast; all other varieties are susceptible, with some differences in their degree of susceptibility. Several cultural practices are helpful in managing rice blast. Destruction of crop residue in infested fields, planting clean seed, water seeding, maintaining a continuous flood, and avoiding excessive nitrogen fertilization are recommended to limit the incidence and severity of rice blast. Azoxystrobin (Quadris, QuiltXcel) and trifloxystrobin (Stratego) fungicides are registered for use on rice in California as protectants against neck blast. Applications should be made at the late boot to early heading stage to protect panicles. During severe epidemics, a second application may be necessary. As panicles mature, they become less susceptible to the pathogen. Applications to control leaf blast are usually not necessary unless large areas of the field are affected.

Figure 21. Blast can produce a collar rot that may lead to leaf death.

Figure 22. “Neck blast” is considered to be the most destructive phase of the disease and occurs when the fungus infects the node just below the panicle resulting in a brown or black lesion that encircles the entire node and a empty or partially filled panicle.

Kernel Smut

Kernel smut, caused by the fungus *Tilletia barclayana*, is generally considered a minor disease of rice in California. Kernel smut is characterized by a black mass of spores (chlamydospores) that replace the endosperm of individual kernels near maturity (fig. 23). Generally, a panicle may only have a few smutted kernels at random locations. Kernel smut is most noticeable early in the morning when dew causes infected kernels to swell and erupt in a black ooze of spores. Severe epidemics have occurred in California, resulting in yield and quality losses. In severe cases, milled grain whiteness can be significantly reduced (fig. 24)

The disease cycle of kernel smut is rather complicated. The fungus may overwinter in or on

Figure 23. Kernel smut produces a black mass of spores that replace the endosperm of individual kernels near maturity.

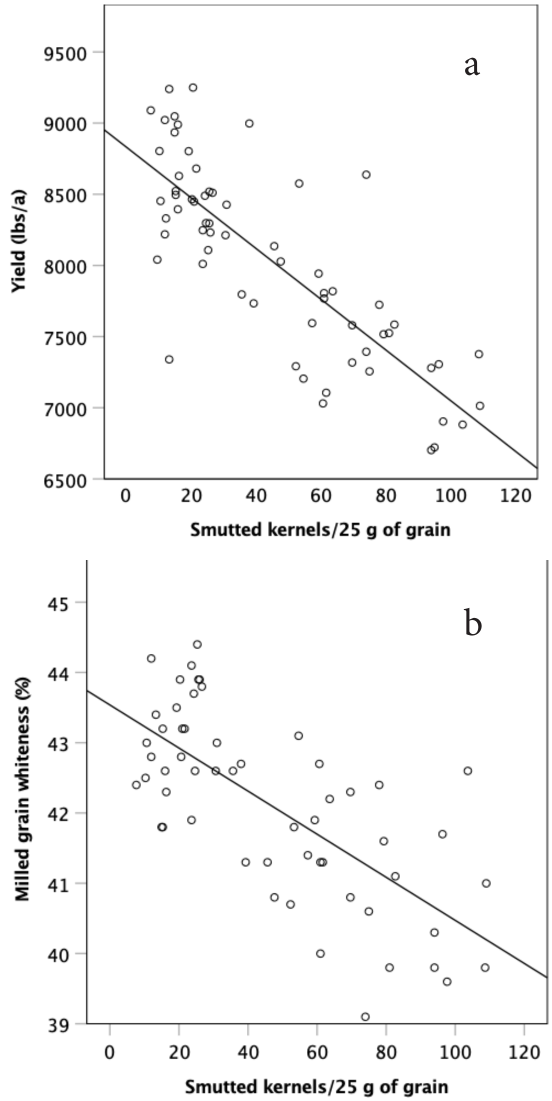

Figure 24. Relationship between kernel smut infection in a long grain variety with yield (a) and milled grain whiteness (b). As the number of smutted kernels increases, both parameters decrease. Richvale, Butte County, 2020.

seed or in the soil as chlamydospores dislodged during the harvest of infected grain. When fields are flooded the following spring, chlamydospores float to the surface and germinate to produce primary sporidia. Large numbers of secondary sporidia are produced from the primary sporidia and are forcibly discharged into the air where they may infect individual florets or kernels.

Short and medium grain rice varieties are less likely to have significant amounts of kernel smut compared to long grain varieties (fig. 25). This resistance is thought to be because long grain varieties have a longer duration of anthesis and a larger floret opening, resulting in a greater chance of spores entering the floret.

Kernel smut is a difficult disease to manage. Plant certified seed and avoid excessive nitrogen fertilization that may favor disease development. If a field has a history of kernel smut, avoid planting the more susceptible long grain varieties. Fungicides containing propiconazole (Tilt, QuiltXcel, Stratego) are registered for use on rice in California and provide protection against kernel smut. Applications should target the mid to late boot stage when panicles have not emerged yet. Applications made after panicle emergence have little effect on the disease.

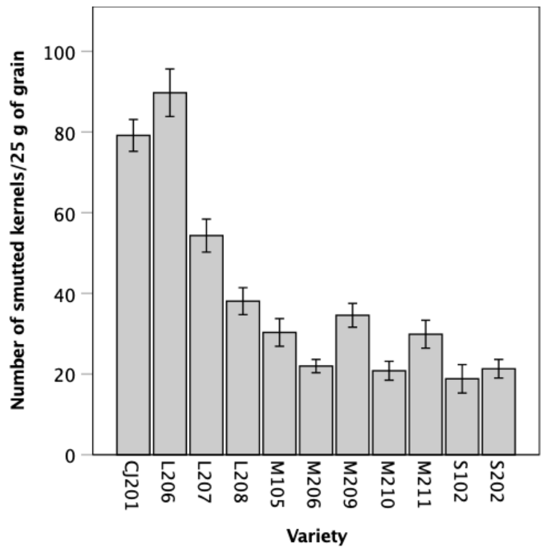

Figure 25. Response of common rice varieties to kernel smut. Short and medium grain varieties are considered less susceptible than long grain varieties. Glenn County, 2018.

False Smut

False smut disease, caused by the fungus *Ustilaginoidea virens*, was identified in a single Glenn County field in the fall of 2006 and subsequently in a couple of other Colusa and Glenn County fields. This pathogen replaces the rice kernels with globose, velvety spore balls up to 1 cm in diameter, which erupt from between the glumes. The spore balls consist of three spore-producing layers surrounding a hard core of fungal mycelium. The inner most and middle layers contain immature spores of yellow to orange coloration (fig. 26). The outermost layer consists of mature spores that are olive to black in color. One or more irregular, hard, black sclerotia are found at the center of the mature spore ball. Generally, only a few grains of a panicle are affected by this disease.

While this disease was reported to have occurred on rice in California many years ago the details of the extent of disease distribution are not well documented. No reports of negative effects on yield or quality exist from California.

Figure 26. False smut has only been identified in a few fields in Glenn and Butte counties. No reports of negative effects of the disease on yield or quality have been documented in California. Photo by Don Groth, LSU Ag Center.