Charcoal Rot

Charcoal rot of soybean (Figure 1) is caused by the soilborne fungus *Macrophomina phaseolina* (Figure 2), which can infect more than 500 agricultural crop and weed species. This disease had been considered primarily a southern soybean problem, but recently has emerged as a threat in the North Central region of the U.S. and Ontario, Canada, where weather trends favorable for disease development — such as warmer summer and winter temperatures and reduced rainfall — have likely contributed to its presence. Yield loss from charcoal rot is highly variable, but farmers can reduce crop injury by implementing best management practices based on a better understanding of this disease.

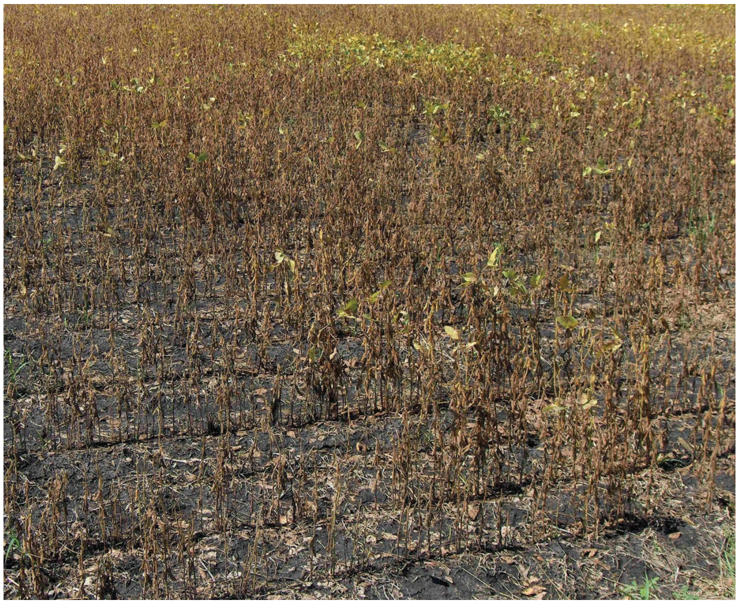


Figure 1. Severe charcoal rot in a soybean field.

Figure 2. *Macrophomina phaseolina* colonizing a soybean stem.

Disease Development

The charcoal rot fungus survives in soil and plant residue as very small, hard black structures known as **microsclerotia** (Figure 3). Many agronomic plants are host to this disease, which means that pathogen inoculum can be present in residues of several crops including corn, soybean, grain sorghum, sunflowers, and many weed hosts.

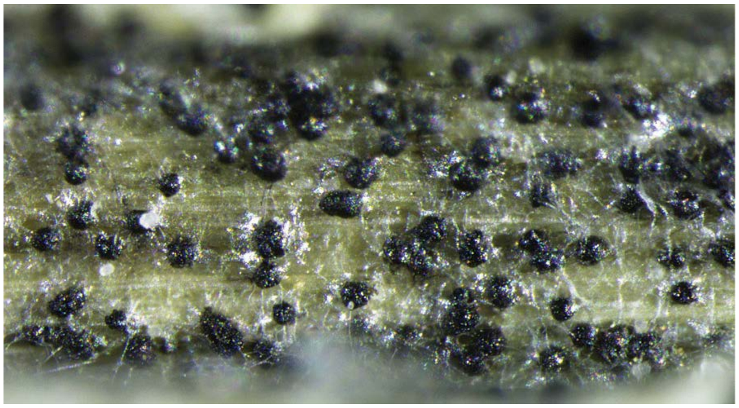
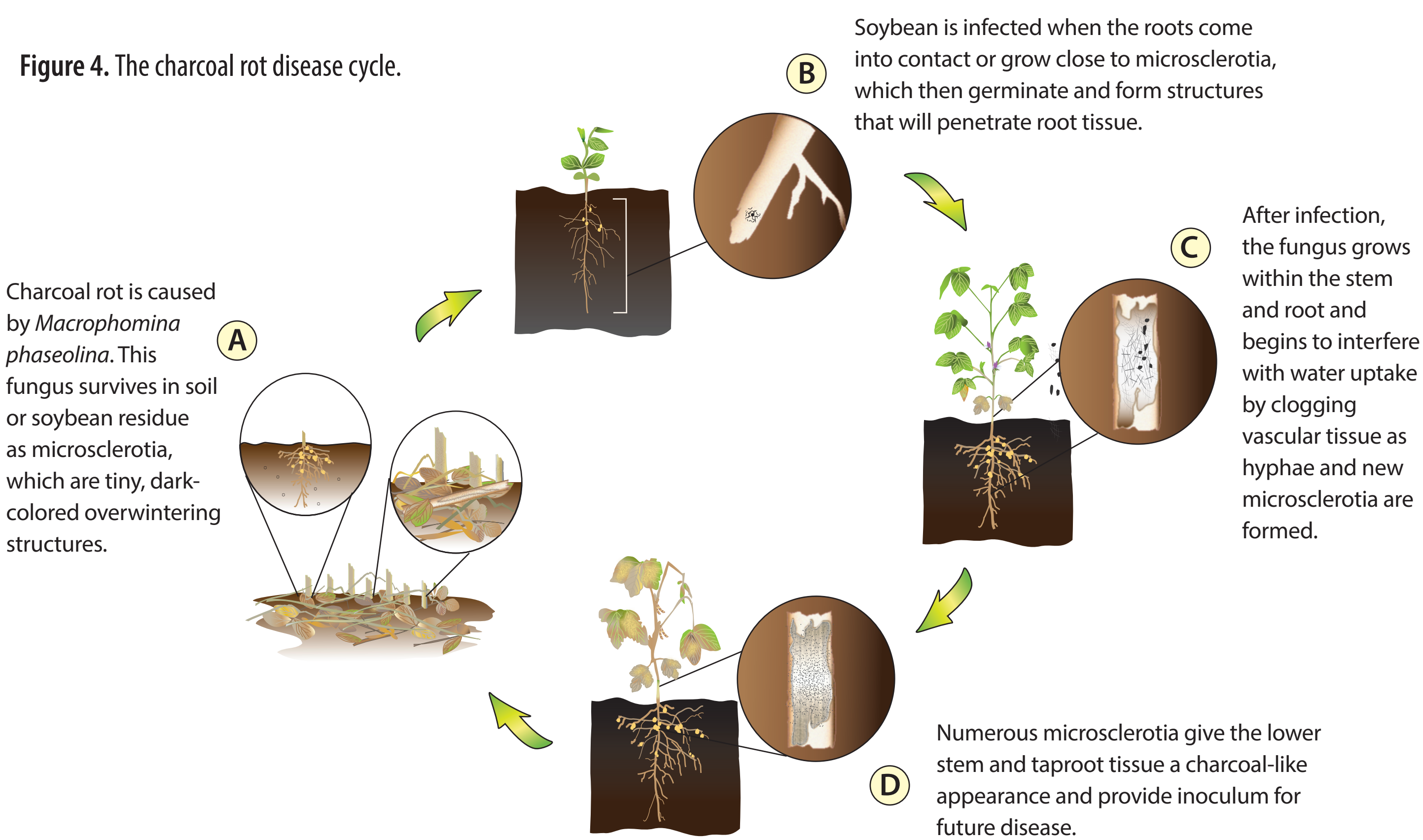


Figure 3. Close-up of charcoal rot fungus microsclerotia.

Infected soybean seed can also be a source of inoculum, although seed infection may not always be apparent, with microsclerotia embedded in cracks in the seed coat or on the seed surface. When soybean roots come into contact with or grow very close to microsclerotia, the latter germinate and infect those roots (Figure 4). This can occur throughout the season, affecting even young seedlings when soils are wet. Once the roots are infected, the fungus will slowly colonize both root and stem tissue until soybeans reach the reproductive growth stages (flowering to full maturity).

After pod fill is complete, colonization rapidly increases as the plant fully matures. The fungus grows within the roots and stem and interferes with water uptake by clogging vascular tissue with fungal growth and newly formed microsclerotia (Figure 5).

Figure 4. The charcoal rot disease cycle.



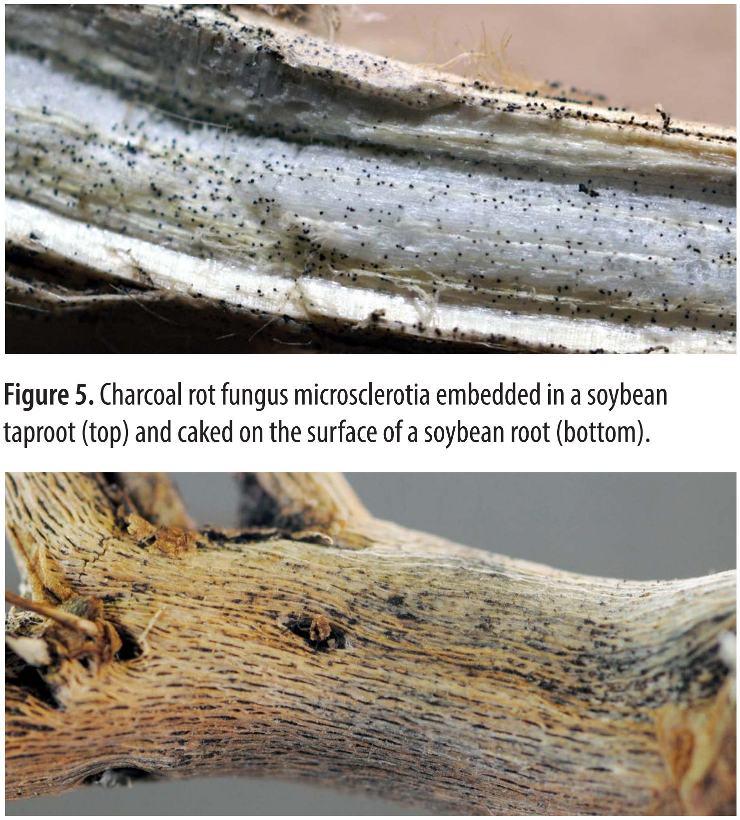


Figure 5. Charcoal rot fungus microsclerotia embedded in a soybean taproot (top) and caked on the surface of a soybean root (bottom).

Many environmental factors affect microsclerotia survival, root infection, and disease development. For example, microsclerotia can survive in dry soils for many years but cannot survive longer than a few weeks in saturated soils. Soil pH may not impact microsclerotia survival, but the abundance of microsclerotia (inoculum density) may be greater in soils at pH levels outside the range optimal for soybean production.

Although infection by the charcoal rot fungus can occur early in the season with colonization progressing throughout the season, symptoms may not develop unless the infected plants are stressed. These conditions typically involve extreme heat and drought, and the timing and duration of these conditions will influence the type and severity of symptoms that develop. Charcoal rot symptoms are most prevalent during hot, dry weather, especially when it occurs during the soybean reproductive growth stages. However, disease and subsequent yield loss have been observed in irrigated systems and in crops with no visible symptoms.

Symptoms/Signs of Charcoal Rot

In the North Central region, visible symptoms, when they occur, generally do not appear until the later stages of pod fill. The characteristic sign of charcoal rot is the microsclerotia in root and stem tissue, and these may not be visible until maturity or plant death.

In soybean, the charcoal rot fungus can infect seeds, seedlings, or mature plants. If infected at the seed or seedling stages, plants may not emerge or seedlings may become discolored and die. Plants that have been infected early in the season may not display symptoms until midseason or later. In more mature plants, the fungus can cause reduced vigor, yellowing, and wilting. Patches of these symptoms in a field are usually the first indication of a problem. Premature dying with leaves still attached to the plant is the most common symptom. Within a field, symptoms develop first in the driest parts of the field. Common areas affected include hillsides, sandy areas, terrace tops, compacted headlands, or along the edges of fields where trees may compete for moisture.

Plants affected by charcoal rot may initially have a gray discoloration on the lower woody portion of the stem (Figure 6). Microsclerotia also will be visible on the lower portion of the plant, often just under the outermost layer of stem tissue (Figure 7). Microsclerotia are less than 1/25 of an inch (1 mm) in size. To the naked eye, it will look as if the root or stem has been "peppered" with black spots. Upon closer inspection with a hand lens, individual microsclerotia can be seen within the plant tissue. In some instances, a fine line of stem decay and discoloration can be observed in root cross-sections of soybean plants (Figure 8).

Figure 6. Gray discoloration of the lower portion of a soybean stem caused by charcoal rot.

Figure 7. Microsclerotia of the charcoal rot fungus on the lower portion of a soybean stem.

Figure 8. Internal soybean stem discoloration due to charcoal rot.

Charcoal rot is hard to diagnose in dry years, since it is difficult to distinguish between the symptoms of the disease and those of general drought stress. However, plants with charcoal rot die more quickly during periods of drought stress than those without the disease. To accurately identify charcoal rot, pull symptomatic plants and split the lower stems and taproot to confirm discoloration as light gray or silver (Figure 6) and the presence of black streaks (Figure 8) and microsclerotia (Figure 7).

Diseases With Similar Symptoms

Charcoal rot has microsclerotia in the lower stem and roots that can help differentiate it from other diseases. However, some charcoal rot symptoms can be confused with other diseases.

Pod and Stem Blight (*Diaporthe/Phomopsis* spp.)

Pod and stem blight can occur during warm, humid weather, especially when soybean plants are maturing. Infection results in the production of small, black specks, called **pycnidia**, which can be confused with microsclerotia. Pycnidia can form on stems, petioles, pods, and seeds.

How to distinguish pod and stem blight from charcoal rot:
Pycnidia are generally larger than microsclerotia and are present in linear rows on the outside of stems, whereas charcoal rot microsclerotia form throughout (inside) the taproot and lower stem; leaves do not remain attached as they do when charcoal rot affects soybeans.

Figure 9. Pod and stem blight infection results in pycnidia, which are different than the microsclerotia charcoal rot produces.

Phytophthora Root and Stem Rot (PRR — *Phytophthora sojae*)

Phytophthora root and stem rot (PRR) occurs in wet, waterlogged, compacted soils. Symptoms of this disease generally occur during or shortly after the occurrence of waterlogged soil conditions.

How to distinguish PRR from charcoal rot:
Stems of Phytophthora-infected plants have characteristic dark brown lesions visible on the outer stem tissue that are continuous from the roots and up the lower stem.

Figure 10. Phytophthora-infected plants have dark brown lesions on the outer stem tissue that are continuous from the roots and up the lower stem.

Saprophytic Fungi

Once soybeans have senesced, many fungal organisms will use dead plant tissue as a food source. These fungi, called **saprophytes**, do not infect the plant during the season, but survive by colonizing dead tissue. Black fungal structures produced by these organisms may be mistaken for charcoal rot microsclerotia.

How to distinguish saprophytic fungi from charcoal rot:
Soybeans that senesce early will be more heavily colonized by saprophytic fungi, giving stems a dark appearance. In these situations, be sure to examine the inner plant tissue of the stem and root to determine if microsclerotia are present.

Figure 11. Plants infected with saprohytic fungi do not have microsclerotia in the inner stem and root tissue like plants infected with charcoal rot do.

White Mold (Sclerotinia stem rot — *Sclerotinia sclerotiorum*)

White mold (Sclerotinia stem rot) is typically more of a problem in years with rainy and cool environmental conditions that occur at flowering. Lesions develop on the nodes and expand up the stems.

How to distinguish white mold from charcoal rot:
Sclerotinia-infected plants can be identified by the presence of a fluffy white growth on the outside of stems. In addition, the sclerotia produced by the sclerotinia stem rot fungus, which are also hard and black, are much larger than charcoal rot microsclerotia.

Figure 12. Plants with white mold have fluffy white growth on the outside of stems.

Soybean Cyst Nematode (SCN — *Heterodera glycines*)

Subtle symptoms of soybean cyst nematode (SCN) infection include uneven plant height, a delay in canopy closure, or early maturity. Severely infected plants may be stunted with yellow foliage.

How to distinguish SCN from charcoal rot:
White SCN females are most readily observed on soybean roots starting about six weeks after crop emergence.

Figure 13. Plants infected with soybean cyst nematode can be distinguished by white cysts on the roots.

Stem Canker (*Diaporthe* spp.)

Stem canker is problematic when prolonged wet weather early in the season is followed by dry conditions.

How to distinguish stem canker from charcoal rot:
Stem canker is distinguished by the production of brown to black, slightly sunken lesions or "cankers" that start at the nodes and grow completely around the stem. These will typically not be at the soil line extending upward like Phytophthora root and stem rot.

Figure 14. Stem canker produces brown to black, slightly sunken lesions.

Sudden Death Syndrome (SDS — *Fusarium virguliforme*)

Symptoms of sudden death syndrome (SDS) are expressed as yellowing and necrosis between the veins of leaflets. Veins of symptomatic leaves will remain green. Leaflets will eventually curl or shrivel and drop off with only the petiole remaining.

How to distinguish SDS from charcoal rot:
Symptoms of SDS occur between the veins rather than causing generally brown, crinkled leaves.

Figure 14. Sudden death syndrome symptoms occur between the veins.

Management

Management of charcoal rot includes the use of resistant varieties and certain cultural practices, including those that conserve soil moisture. No fungicide seed treatments have been identified that offer consistent control of charcoal rot.

Resistant Varieties

Efforts to identify resistance to charcoal rot have focused largely on soybean varieties adapted to the southern U.S. (maturity group IV and later). Although partial resistance has been identified, the level of resistance is moderate at best and must be combined with other management strategies. To date, our knowledge of resistance to charcoal rot in northern varieties (maturity groups 0–III) is limited. Evaluation of commercial varieties and breeding lines for partial resistance to charcoal rot is underway and varieties suitable for production in the North Central region will be available.

Tillage

Soybeans direct-seeded in no-till systems typically have lower levels of charcoal rot compared to soybeans under conventional tillage. This is because no-till systems often result in higher soil microbial activity, in some cases greater available soil nutrients, and generally healthier plants. In addition, no-till systems can aid in soil moisture conservation, which may also reduce the severity of charcoal rot.

Irrigation Management

Colonization of roots by *M. phaseolina* can be lower in irrigated soybeans compared to nonirrigated soybeans. However, root colonization still occurs in irrigated production systems. Although supplemental irrigation can reduce the damage caused by charcoal rot when soil moisture is predominantly low (e.g., under drought conditions), colonization by *M. phaseolina* can result in the production of microsclerotia, which will increase the level of inoculum for subsequent host crops.

Rotation

Rotation to nonhost crops such as wheat for one or two years should be considered part of a charcoal rot management plan in problematic fields. Also, although corn, sunflowers, and other crops are hosts, research has shown that there are strains of the fungus that have host preferences. For instance, some strains prefer soybeans while others prefer corn or sunflowers. Therefore, rotation with any other crop can be beneficial and the longer the rotation, the better.

Seeding Rate

Like irrigation management, avoiding excessive seeding rates will not prevent root colonization. However, reducing seeding rates will reduce crop stress that helps minimize loss to charcoal rot.

Best Management Practices

Management of charcoal rot of soybean can include one or all of the following strategies:

Use varieties with the highest level of resistance available in a maturity group appropriate for your region.

Use no-till systems to increase soil microbial activity and conserve soil moisture, which can reduce charcoal rot.

Use supplemental irrigation to slow colonization of the plant by the charcoal rot pathogen and reduce symptom severity during drought conditions.

Rotate to nonhost crops (such as wheat) for one to two years in fields with a history of charcoal rot.

Avoid excessive seeding rates to reduce crop stress and minimize loss to charcoal rot.

Conclusion

Our understanding of charcoal rot and its management comes mostly from studies conducted in the southern U.S. In the North Central region and Canada, producers and consultants know very little about charcoal rot due to its sporadic nature and symptoms, which could be confused with other diseases or problems. With predictions of drier growing seasons in the future, we expect that the incidence and severity of charcoal rot will continue to increase in the North Central region and Canada. It is crucial, therefore, for agribusiness personnel and producers to be aware of and understand how the disease develops and the available management options.

Find Out More

To learn more about charcoal rot, visit the visit the NCSRP Soybean Research Information and Initiatve (SRII) website (www.soybeanresearchinfo.com) or consult your land-grant institution. Other publications in the *Soybean Disease Management* series are available by visiting the SRII website or your land-grant institution's website.

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