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ROOT-KNOT NEMATODE MANAGEMENT GUIDE

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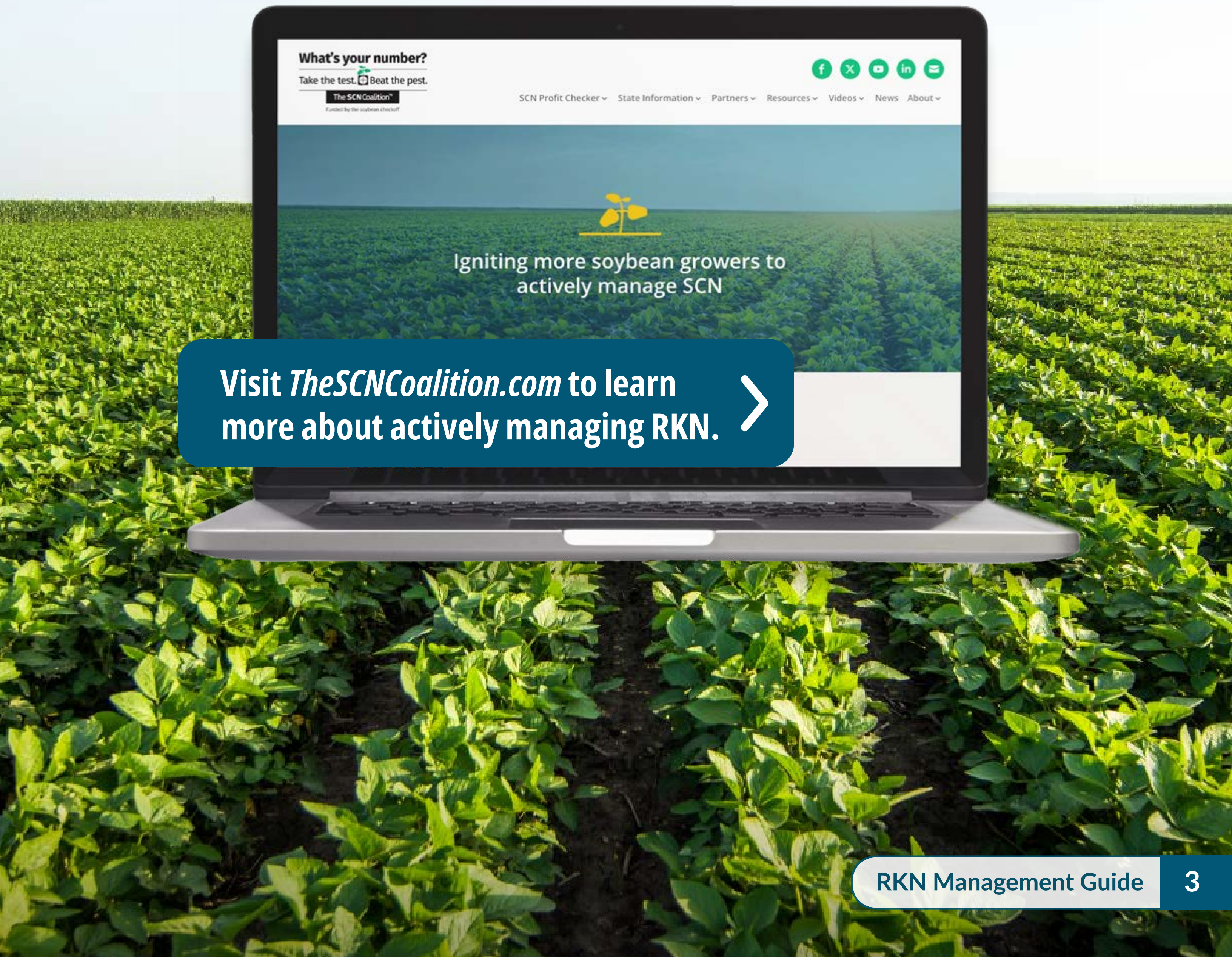
Proven Strategies Soybean Farmers Can Implement to Battle Root-Knot Nematode

Found in most soybean production regions in the U.S., root-knot nematode (RKN) causes up to 25% yield loss in individual fields, costing farmers millions in revenue. Although root-knot nematodes (especially *M. hapla*) occur in Canada, they are not a major threat to soybean.

The bad news? Once a field is infested with RKN, it's impossible to eliminate it.

The good news? Whether you want quick tips or a scientific deep dive, this guide will help you determine whether you have RKN infestations, tailor a management strategy for your farm and recover lost yield.



Visit *TheSCNCoalition.com* to learn more about actively managing RKN.

Is RKN Really a Problem?

The impact of root-knot nematodes on soybean can vary widely because several RKN species can infect the crop.

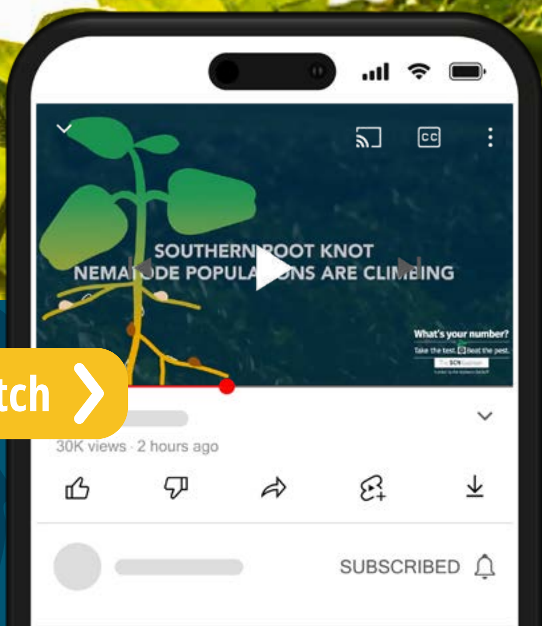
The level of damage depends on several factors, including:

- The specific RKN species present
- Abiotic environmental stresses (such as drought or soil conditions)
- The presence of other plant pathogens
- Nematode population density
- Soil type
- Soybean variety

Some RKN species can reduce soybean yields by 10%-25% and may become established in new fields over time. When high RKN pressure coincides with stressful environmental conditions such as drought, yield reductions can become even more severe.

Adopting an active management plan with the strategies outlined in this guide can help you protect your yield and stay one step ahead of this pest.

Root galling caused by root-knot nematode. (Travis Faske; University of Arkansas)



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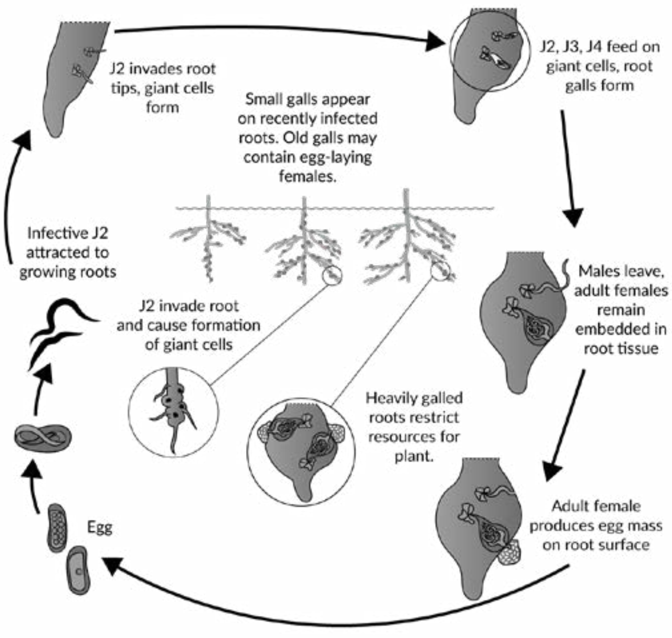
RKN 101: Biology and Reproduction

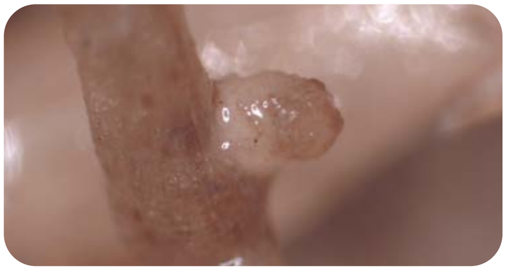
Found in the genus *Meloidogyne*, RKN are soilborne, microscopic, unsegmented roundworms that feed on and damage roots of soybean and other susceptible plants. These plant-parasitic nematodes require a living plant to complete their life cycle, which typically lasts 21 to 30 days, depending on factors like environmental conditions and host plant susceptibility. RKN has a broad host range, and even low levels of RKN can cause yield loss depending on the susceptible host and RKN species present.

RKN begin their life cycle as an egg, and the first molt occurs from the first-stage juvenile (J1) to the second-stage juvenile (J2) within the egg. The J2 then hatches and serves as the only infective stage for all *Meloidogyne* species. These juveniles are attracted to chemicals released by growing soybean roots, migrate toward the root tips and penetrate near the elongation zone. Once inside, they establish specialized feeding sites, known as giant cells, adjacent to the vascular tissue to withdraw nutrients. Nearby cells enlarge and divide, forming the characteristic root galls. The nematode molts three additional times within the root, completing four molts in total and progressing through four juvenile stages before reaching adulthood.



Juvenile root-knot nematode penetrating a root. (USDA)

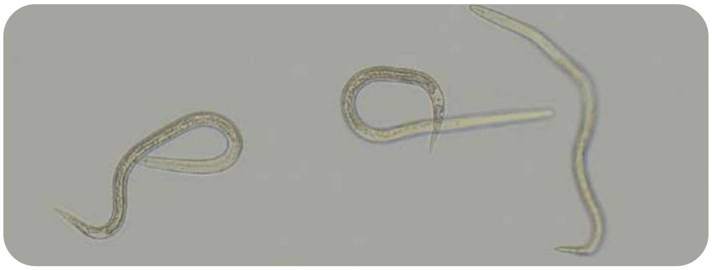
Adult females remain swollen and sedentary within the galls, where they feed and produce hundreds of eggs in a gelatinous mass on or near the root surface. Adult males regain their vermiform shape and motility and leave the roots to locate females for mating in species that require males. Under favorable conditions, eggs hatch quickly, supporting multiple generations per growing season, while the gelatinous mass protects eggs under less favorable conditions.



Southern RKN on soybean. (Travis Faske; University of Arkansas)

RKN can exist in diverse soil types, and soil conditions can affect reproduction. Warmer soil temperatures (above 64-65 F/17-18 C) accelerate the RKN life cycle. In contrast, cooler soils around 50 F (10 C) or lower can greatly slow development and reduce survival, depending on the species' cold tolerance.

Coarse-textured, sandy soil contributes to higher yield losses. Larger soil pore spaces have low water-holding capacity, resulting in water stress in plants, and at the same time allowing RKN easy mobility through the soil, which allows greater infection levels and eventually higher yield losses.



Infective second-stage juveniles (J2) of root-knot nematode. (Travis Faske; University of Arkansas)

Important to Determine Your Species

Several species of RKN can reduce soybean yields, so identifying which species are present in your field is critical for effective management.

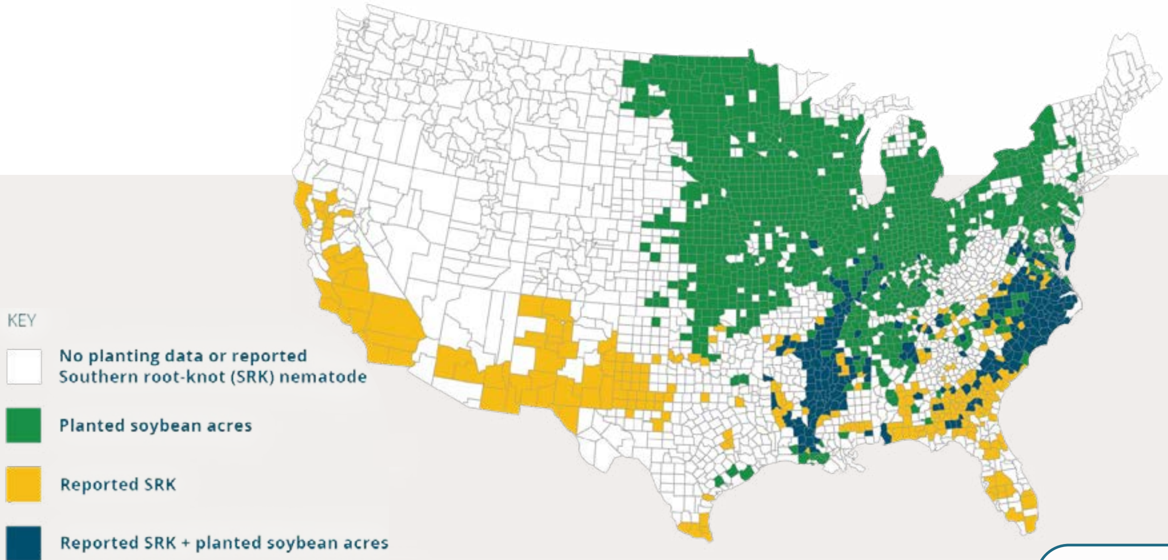
Four RKN species are commonly found across most soybean production regions in the U.S., and there is one species in Canada. Additional species may occur in more limited areas:

- **Southern RKN** *(Meloidogyne incognita)* is the most damaging and widespread of the species and is found predominantly in Southern states. It ranges as far north as southern Indiana and Illinois and into Mid-Atlantic states such as Delaware and Pennsylvania (see map). Poor cold tolerance limits its ability to overwinter in the north.
- **Peanut RKN** *(Meloidogyne arenaria)* is present in states where large acreages of peanut or tobacco are grown frequently, including Alabama, Georgia, Florida, North Carolina, South Carolina, Texas and Virginia.
- **Javanese RKN** *(Meloidogyne javanica)* thrives in warmer climates, commonly infecting plants within Gulf Coast states.

Click to watch

- **Northern RKN** *(Meloidogyne hapla)* can survive colder winters, making it the most prevalent species in northern states and Canada, but severe yield loss is uncommon.
- **Guava RKN** *(Meloidogyne enterolobii)* is an emerging species that has been detected in North Carolina, South Carolina, Florida and Georgia.

Southern Root-Knot Distribution



How to Spot RKN: Signs and Symptoms

A unique and diagnostic symptom, RKN causes knot-like swellings or galls on infected plant roots. While size and number vary depending on soil population density and species of RKN involved, these root galls limit water uptake along with absorption and translocation of nutrients in the plant.

On susceptible soybean varieties grown in soils with high nematode populations, root galls are visible as early as 30-35 days after plant emergence but appear smaller than *Rhizobium* nodules at that time. Closer inspection can help differentiate root galls from these nodules. *Rhizobium* nodules are attached to the root and are easily removable, while root galls are part of the root itself and cannot be detached.

Root galling caused by root-knot nematode. (Travis Faske; University of Arkansas)

RKN-induced yellowing in an Alabama soybean field. (Edward Sikora; Auburn University)

Initial yellowing foliar symptoms of RKN. (Edward Sikora; Auburn University)

Yellowing is an aboveground symptom of RKN. (Edward Sikora; Auburn University)

At early- to mid-reproductive growth stages of soybean (R1-R4), root galls are often large enough to coalesce into what appears to be an oversized root. As females die, the tissue around galls deteriorates and rots. At harvest, these decaying galls are not easy to recognize. Therefore, scouting fields during the season to diagnose an RKN problem is key.

As galls disrupt the root's vascular system, aboveground symptoms such as stunted, yellow plants often appear in patches or "hot spots," typically in areas with sandy soil. These patches are irregular and tend to expand as nematodes spread with soil movement caused by cultivation or water flow. Infected plants may show nutrient deficiency symptoms, wilt even when adequate soil moisture is available and die prematurely.

RKN's Common Yield-Loss Partners

Several yield-limiting fungal pathogens are frequently detected in soybean fields infested with RKN. Among these, *Agroathelia rolfsii*, the causal agent of southern blight, is the most common. Although planting resistant soybean varieties is an important management strategy for many diseases, no known resistance is available for southern blight, making RKN management a critical component of disease suppression. In addition, other soilborne pathogens may be present in RKN-infested fields and can contribute to further root damage and yield loss.

Additionally, if RKN is present, there's a strong chance other harmful nematodes like lance, lesion, sting and stubby root are present. Seed treatments can help protect young seedlings from early-season nematode damage and soilborne fungal pathogens.

Plant expressing both RKN and southern blight symptoms. (Edward Sikora; Auburn University)

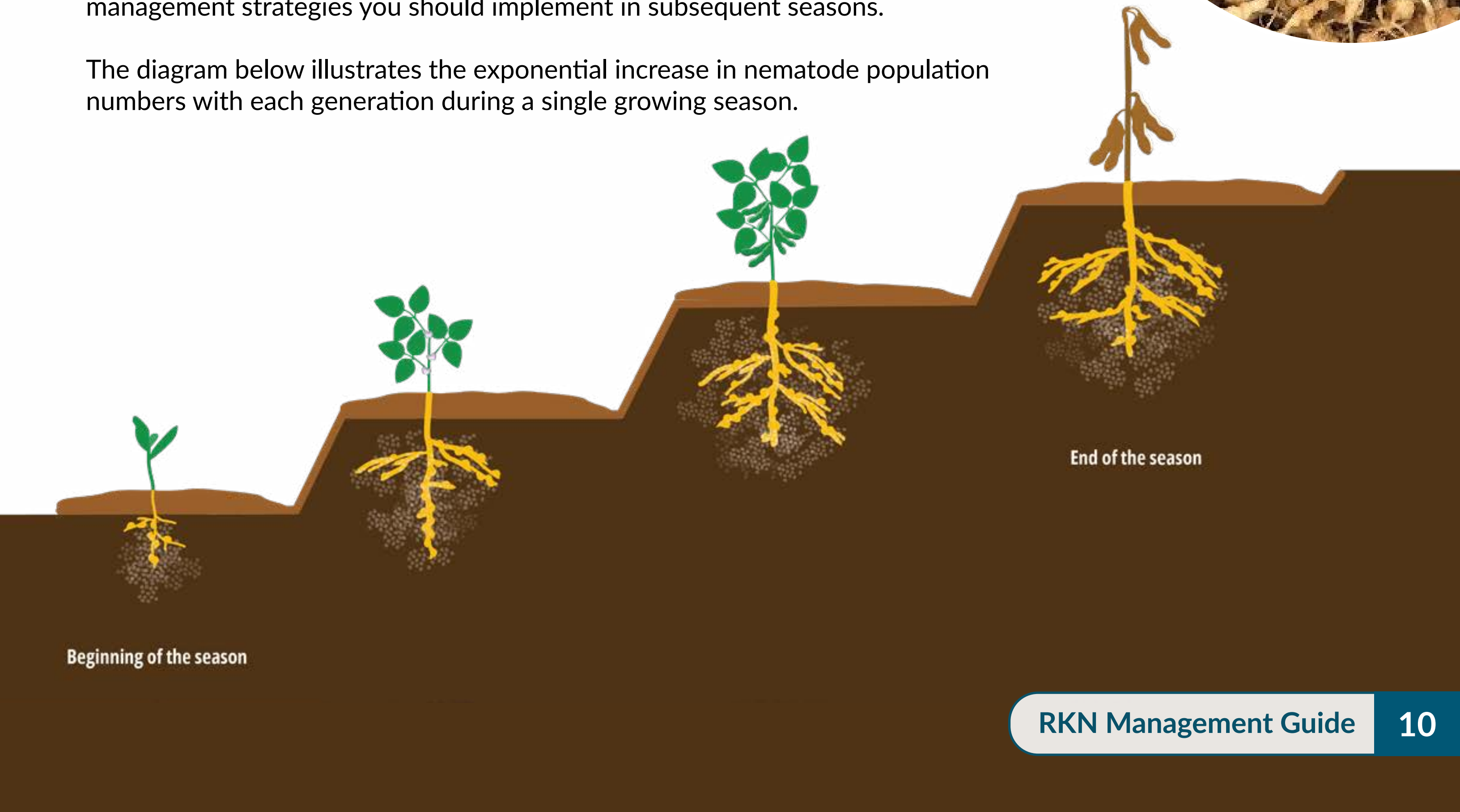
You've Heard About RKN. What's Next?

As subsequent generations of root-knot nematode eggs hatch, more roots are infected, leading to higher levels of galling, which results in decreased water and nutrient uptake and eventually greater yield losses. Even low initial levels of RKN and root galling can reduce yield potential.

With each female capable of producing hundreds of eggs and subsequent generations of females also producing eggs, the populations of RKN can increase dramatically in one year even if only a small percentage survive.

Once the crop is planted, there are no in-season options to reduce yield loss from nematodes. However, a postharvest soil test can guide which long-term management strategies you should implement in subsequent seasons.

The diagram below illustrates the exponential increase in nematode population numbers with each generation during a single growing season.



Start With a Soil Test

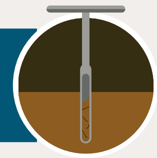
Soil samples can be collected at any time, but postharvest testing is ideal because nematode densities are typically highest from harvest through the following six weeks. To effectively monitor populations and guide management decisions, it's important to remember that RKN pressure is not evenly distributed across a field and often occurs in pockets or "hot spots."

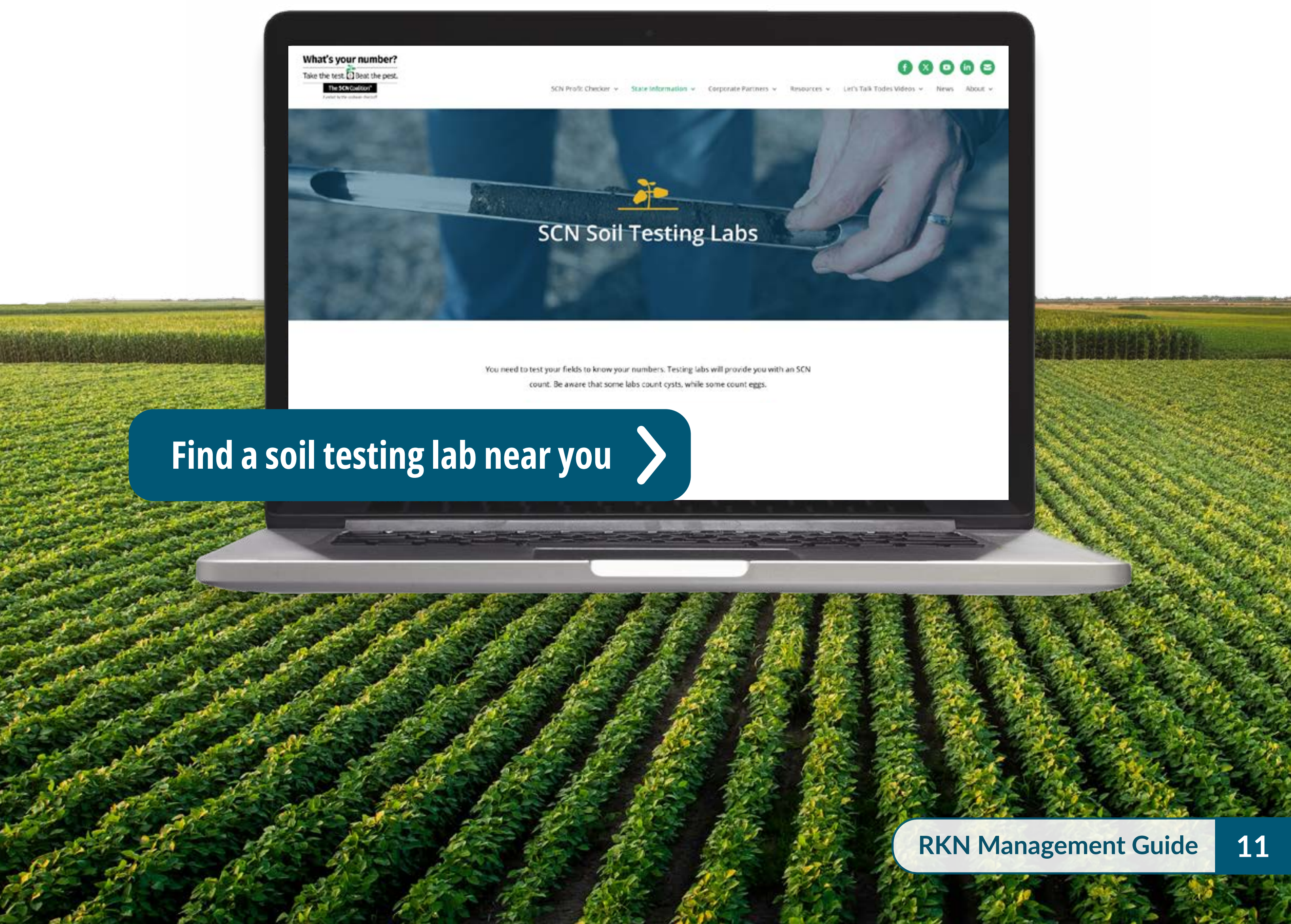
More intensive sampling provides the most accurate results. Sample fields separately based on natural divisions such as soil type, drainage, cropping history or areas that differ in yield potential. Sections with poor yields, unusually high yields or premature plant death should also be sampled separately.

Two ways to scout for RKN:

1. Dig roots and look for galls. (Dig, don't pull.)

2. Collect soil samples for testing.





(Ambria Small, The Ohio State University)

What you need for RKN soil sampling:

- 1-inch-diameter cylindrical soil probe (or shovel)
- Bucket
- Cooler
- Plastic bags
- Permanent marker

1

Use a cylindrical soil probe at a slight angle to collect soil samples. Samples should be taken in the root zone near the base of the plant.

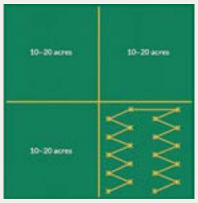
2

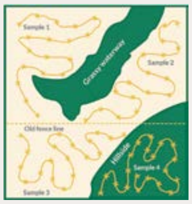
Collect soil cores to a depth of 6 to 8 inches.

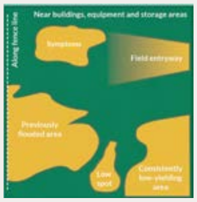
If a cylindrical probe is not available, use a shovel. First, clear the surface of the soil. Discard sides and keep the central part of the subsample.

3

Collect 10 to 20 soil cores that are 1 inch (2.5 cm) in diameter using a zigzag or "W" pattern across the entire area to be sampled. If you are soil sampling on a standard 2.4- or 2.5-acre grid and would like to collect a 20-acre sample, you can collect two extra cores from every eight or nine grid cells, respectively.







Get a closer look ❯

4

Combine those cores in a separate bucket, then place the soil from the multiple grid cells in a single bag and mix. This creates a single sample that will represent those 20 or so acres.

5

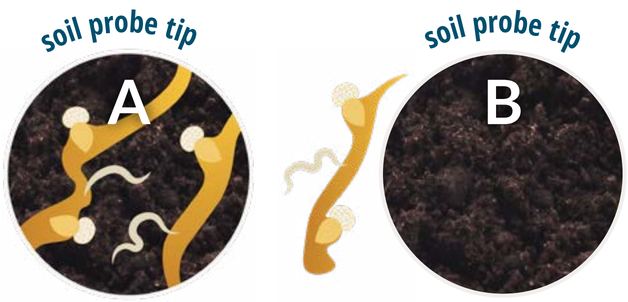
Place the homogenized composite soil sample (at least 2 cups or 500 ml in volume) in a plastic bag and label it with a unique field ID using a permanent marker.

6

High temperatures are the greatest threat to sample integrity. Store the sample away from direct sunlight in a cool area until it is shipped to the laboratory. Ship samples within a few days of sampling in order to obtain the most accurate results.

Why RKN soil test results are variable

It all depends on where you put the probe. A 1/2-inch difference can mean the difference between zero and 150 RKN.

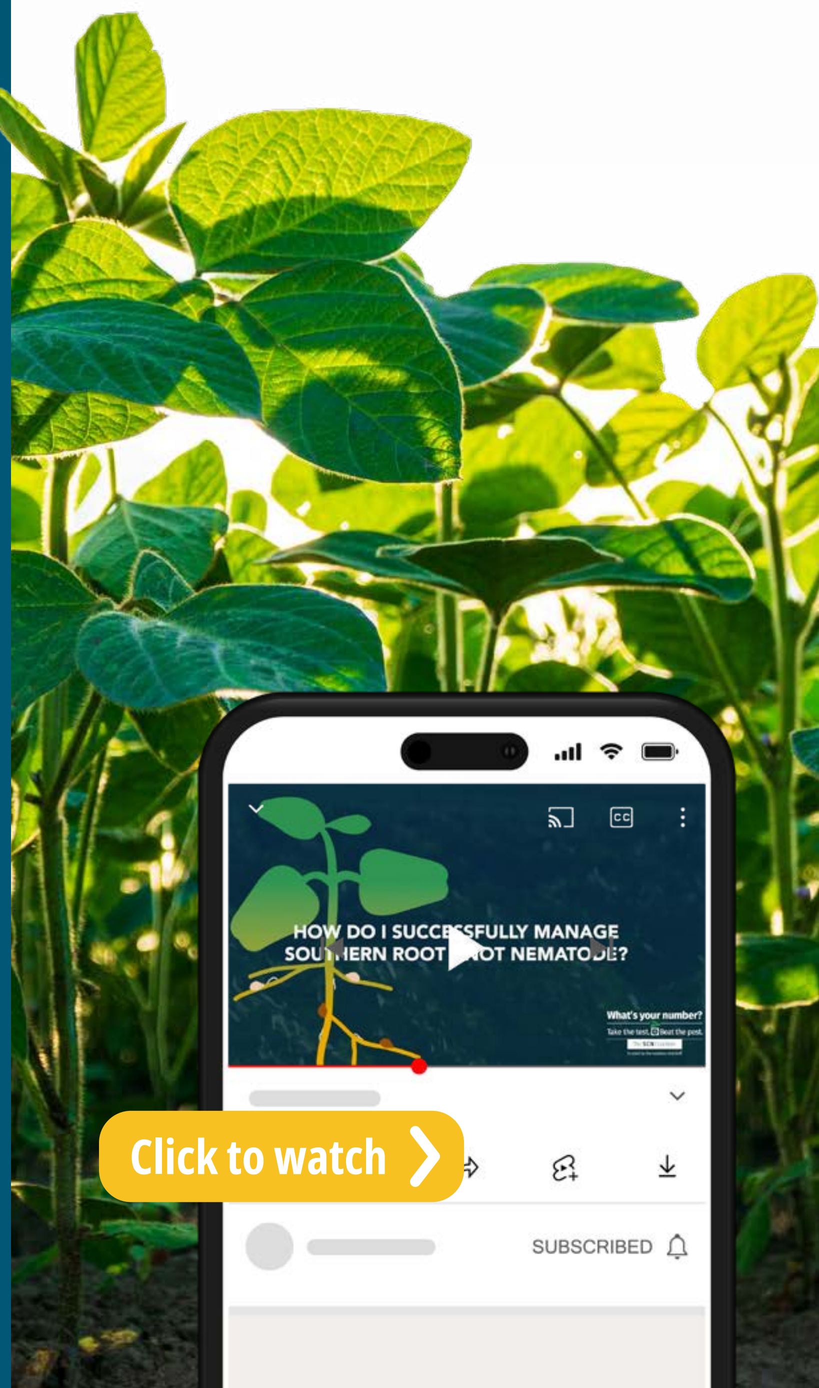


Interpreting YOUR RESULTS

Most labs will provide a report with a count for each nematode genus present in the sample. Soil samples often contain numerous different nematode genera, with some genera being more impactful on crop yields than others. The report should include either a damage threshold or management recommendations for your level of nematodes.

Nematode thresholds are reported as the number of nematodes per volume of soil measured in cubic centimeters (cm^3) or milliliters (ml), usually 100, 250 or 500 cm^3 or ml of soil. A good reference point for a damage threshold for RKN is 100 per 100 cm^3 of soil for samples taken 30 to 60 days after harvest, but thresholds will vary greatly in different areas, geographies, soil textures and environments. For example, the damage threshold for soybean for a sample taken in November is 60 RKN/100 cm^3 of soil in Arkansas. In South Carolina, the threshold is closer to 150 RKN. Be sure to consult with your local county Extension agent, crop consultant or Extension nematologist to help interpret nematode thresholds and develop a management plan.

Most nematode labs identify nematode samples to genus, not species. To refine RKN identification to the species level, consult your local nematode or plant pathology diagnostic labs on the availability of these molecular tests, and include healthy roots and roots that exhibit numerous galls.



Implement RKN Management Solutions

While it's impossible to eliminate RKN from an infested field, proper active management can help you reduce its impact. The goals of active management include:

- Improve soybean health and yield
- Keep RKN numbers low and prevent spread
- Preserve the yield potential of resistant varieties by delaying nematode adaptation

Because RKN populations are highly variable, no single management practice can achieve all three goals. An integrated approach that combines multiple strategies has been shown to effectively reduce RKN's impact on yield. By using a combination of resistant soybean varieties, crop rotation and soil- or seed-applied nematicides, you can select the practices that work best for your operation.

Resistant Soybean Varieties

RKN variety trial in an Alabama soybean field demonstrates the improvement that soybean resistance can offer. (Edward Sikora; Auburn University)

Host plant resistance limits RKN development and reproduction, allowing farmers to grow soybean profitably in infested fields. Because resistance to one RKN species does not imply it protects against other RKN species, determining which species is present in your field is key to managing population densities. For additional guidance, consult your local university or Cooperative Extension Service for region-specific recommendations on RKN-resistant varieties.

RKN-resistance levels vary among soybean varieties, with more options available in the later maturity groups (MG V to VII) than earlier maturity groups (MG III to IV). RKN reproduction can still occur on resistant varieties, but root galling and yield impact are significantly reduced compared to susceptible varieties. Herbicide programs may further restrict variety selection, particularly in areas with herbicide-resistant weeds.

Crop Rotation and Cover Crops

While no single cover crop will eliminate RKN, crop rotation produces several soil health benefits whether nematodes are present or not, and it may already be part of your farm plan.

Soybean yield can be reduced by several RKN species, each with its own host range. *Identifying the species present is key to choosing effective nonhost rotation crops*. For example, cotton is a great rotation crop to address peanut RKN pressure, but it's an excellent host for southern RKN; fortunately, southern RKN-resistant cotton varieties will reduce southern RKN populations. In contrast, peanut helps reduce southern RKN but promote peanut RKN development. Furthermore, corn and grain sorghum are hosts to southern RKN, which can increase the nematode population density for a subsequent soybean crop.

Common cover crops tested for their suitability as hosts of RKN. (Travis Faske; University of Arkansas)

Winter cover crops can serve as hosts for southern RKN. For example, southern RKN can reproduce on crimson clover, cereal rye, vetches and wheat, although other grasses are less suitable hosts. Terminating these crops in early spring, before soil temperatures reach 65 F/18 C, can help interrupt the southern RKN life cycle. In contrast, planting soybean into a green, actively growing cover crop may allow RKN reproduction to continue, increasing the risk of early-season infection.

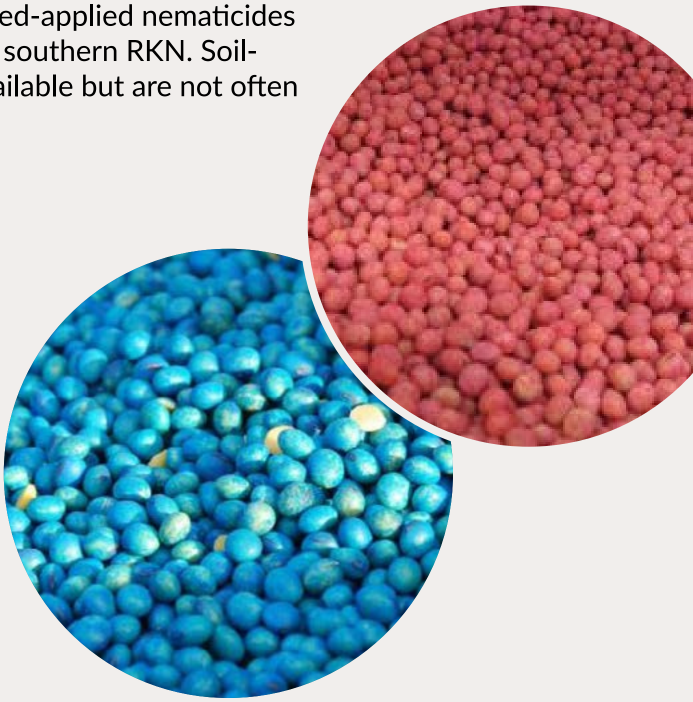
Weed Management

Because several weed species can serve as hosts for RKN, weed management is another important consideration. In infested fields, many weeds – both monocots and dicots – can support RKN reproduction. Some species, such as entireleaf morning glory, pink purslane and pitted morning glory, may allow nematode reproduction even when root galling is not visible. Additionally, soil temperatures in spring or fall may remain warm enough to permit RKN reproduction on winter annual weeds.

Nematode-Protectant Seed Treatments

While nematode-protectant seed treatments do not provide season-long protection, they are often used when host plant resistance is not available or when multiple species of nematodes that infect soybean are present. Yield protection by seed-applied nematicides is very low in fields with at least a moderate population density of southern RKN. Soil-applied nematicides, both liquid and granular formulations, are available but are not often used because they require some planter modifications.

Seed-applied nematicides can be grouped as chemical or biological control agents. Combining a seed-applied nematicide with an RKN-resistant variety can aid in the suppression of additional nematode species such as soybean cyst nematode, lance or reniform. Keep in mind that no seed-applied nematicide will enable a susceptible variety to yield well in heavily RKN-infested fields; host plant resistance is needed to provide season-long yield protection.



Soil-applied nematicides are available, but some are only registered in specific U.S. states. While soil-applied nematicides often provide better root protection than seed-applied products, consistent yield protection is not always observed. Consult your local Extension office for soil- and seed-applied nematicide registered in specific states and their recommended application practices.

Cultural Practices

Strong root systems are essential for maximizing soybean yield, but they can also create favorable conditions for increased nematode populations and reproduction. In compacted soils where root growth is limited, cultural practices such as tillage can help. Although tillage does not directly reduce RKN populations, alleviating soil compaction promotes deeper, healthier root systems, allowing soybean plants to better tolerate RKN feeding and other soilborne diseases.

Proper fertility management is equally important. Plants lacking adequate nutrients are more susceptible to nematode injury, and symptoms of nutrient stress can sometimes signal underlying RKN activity. RKN also tends to cause greater yield losses in nutrient-deficient plants compared with those growing under optimal fertility conditions.

For additional soil testing recommendations, or to learn more about actively managing RKN and other damaging nematodes to soybean, visit:

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How to Cite:

Faske, T., Sikora, E., Gorny, A., & Mueller, J. (2026). *Soybean Nematode Management Guides: Root-Knot Nematode Management Guide* (T. L. Niblack, D. Mangel, & H. D. Lopez-Nicora, Eds.). The SCN Coalition. https://www.thescncoalition.com/field-guides/root-knot-nematode-management-guide/

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