501 THE SOYBEAN CYST NEMATODE PROBLEM

The soybean cyst nematode (SCN), *Heterodera glycines*, is the number one yield reducer for soybean growers throughout the United States. Estimated yield losses due to SCN are more than $1 billion annually. In Soybean fields that are severely infested with SCN, symptoms of stunting and yellowing, or chlorosis, may be evident. However, significant yield loss frequently occurs without the appearance of obvious symptoms. The yield loss is usually most severe on lighter, sandy soils, but drastic losses have been observed even in the heavy clay-loam soils typical of much of the soybean acreage in Illinois. Symptoms observed in heavier soils are often limited, ranging from none, to some stunting or uneven growth not associated with yellowing.

The severity of yield loss can vary from year to year depending on prevailing environmental factors, such as rainfall amount, soil fertility, and host susceptibility. Complete yield losses have been observed in sandy soils. In addition, the damage caused by SCN can be greatly accentuated if infected soybean plants are stressed by other abiotic or biotic factors, such as drought or infection by root-rotting fungi. Rotation with non-host plants such as corn or small grains, elimination of weed hosts, and use of SCN-resistant soybean varieties are used to delay or perhaps prevent soybean cyst nematode populations from increasing to damaging levels. The soybean cyst nematode has been detected in every county in Illinois. An awareness of the problem will help in efforts to promote identification of undetected infestations.

SYMPTOMS AND IDENTIFICATION

Symptoms of soybean cyst nematode infestation are not reliable indicators of the presence of SCN in a soybean field. Depending on the level of infestation and field conditions, symptoms

can range from visible symptoms such as patchy areas of stunted and chlorotic, or yellowed, plants to no obvious visible symptoms even at somewhat high infestation levels. In addition, the aboveground symptoms observed may resemble abiotic disorders or other diseases. Yield loss is probably the most prevalent symptom of SCN infestation and frequently occurs with no visible symptoms. Because SCN-associated yield loss can be asymptomatic, proactive detection and quantification of the nematode in fields suspected to be infested is recommended and is necessary to determine most appropriate control measures.

When SCN is suspected, an initial field diagnosis is possible through direct observation of the roots. Plants dug up on the margins of damaged areas can be gently washed or tapped to dislodge the soil from the roots, and observed for lemon-shaped cysts; if present, cysts will be white, yellow, or brown and about the size of the head of a pin. Observation of these signs of the nematode can provide confirmation of a suspected SCN infestation in the field, however, the absence of visible cysts, does not mean that the soybean cyst nematode is not present. Cysts on roots are not always readily visible, especially when brown, or when roots are prematurely killed by root-rotting organisms. In addition, SCN infestations are typically patchy, and selected plants may not be representative of the field. For conclusive diagnosis, soil samples should be submitted for positive identification and to determine the extent of the infestation with an SCN egg count.

Collecting soil samples for SCN identification and egg counts must follow a highly random pattern in order to obtain a good representative of the population present. Sampling in a zig-zag pattern is an effective method to obtain samples since SCN population can widely vary throughout a field (Figure 1). Collect 12-24 soil cores 6-8 inches deep from a 10 to 20 acre area and place into a bucket. Mix cores thoroughly and submit a one pint sub-sample of this soil

mixture to the University of Illinois Plant Clinic located at S-417 Turner Hall, 1102 S. Goodwin Ave., Urbana, IL 61801 for diagnosis, quantification, and, if needed, SCN Type determination. The SCN Type test is typically performed when SCN levels are high, or when the egg count has increased after growing soybean. Growers can contact the University of Illinois Plant Clinic with any questions about taking and submitting samples, about any conditions observed and about the potential for SCN infestation in their soybean fields. Contact information and Nematode sample form can be found at this site http://web.extension.illinois.edu/plantclinic

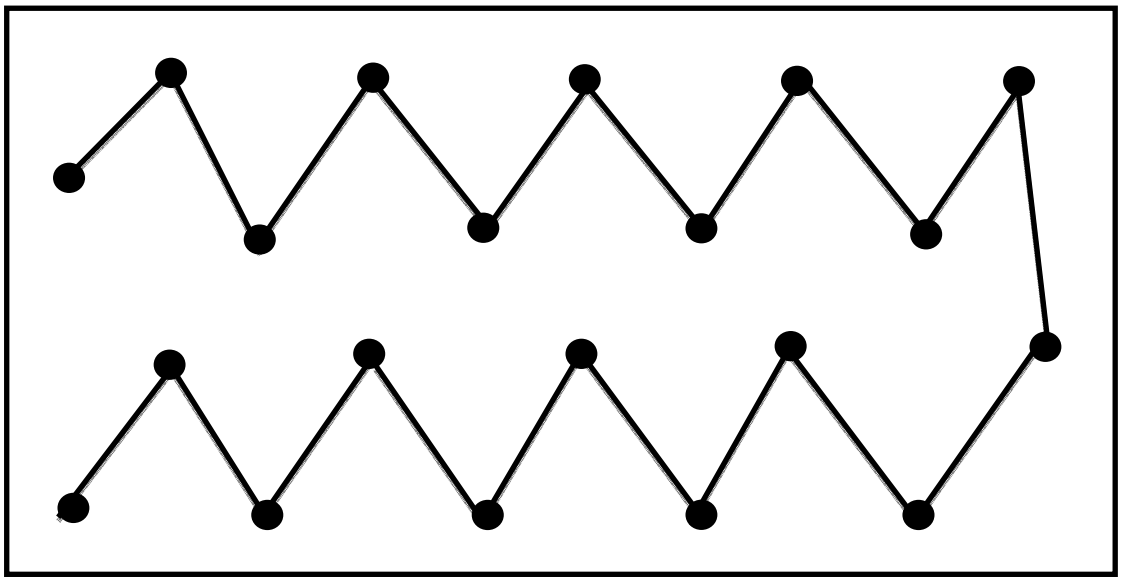

Figure 1. Example of zig-zag pattern that would be appropriate for soil sample collection for SCN egg counts and identification

THE NEMATODE AND ITS LIFE HISTORY

The diagnostic cyst found on soybean roots is in fact an egg-filled female cyst nematode's body. When mature, the egg-filled female generally contains around 250 eggs, but actual numbers can range from 50 to 500 eggs. The dead female body, now darkened and hardened, protects the eggs inside. Viable eggs can survive in cysts for many years after soybeans were last grown.

The soybean cyst nematode life cycle begins inside the SCN egg. Curled up inside each egg is a developing, approximately 1/60th-inch-long, juvenile nematode that is ready to hatch from the egg as a second-stage juvenile, or J2 (Figure 2). At this infective stage, the hatched J2 migrates through the soil towards a root and penetrates it by puncturing plant cells with a hollow, spear-like feeding structure called the stylet that protrudes from its mouth region. Once inside the root, J2 migrate toward food-conducting tissues, and there inject secretions that induce development of a feeding site called a syncytium, where they will feed on the plant's photosynthates and mature to adults. The formation of the syncytium alters the internal root structure and thereby interferes with normal root functions and ultimately causes plant damage. It takes approximately 4 weeks, under optimum conditions (soil temperatures at 80° to 84°F or 27° to 29°C), for egg-bearing females to reach maturity. The females enlarge greatly as they develop to about 1/32 of an inch long, and become lemon-shaped. Their enlarged bodies break through the root surface while remaining attached to the root by the head. Males also develop and when mature exit the root to fertilize females as they begin to protrude from the root. Eggs develop within females, some are exuded into a jellylike mass attached to their posterior end, but most are retained within their swollen bodies. If an infected plant is dug up at this stage, the attached females can be seen on roots with the unaided eye as shiny, white to yellow, lemon-shaped bodies slightly larger than the size of the period at the end of this sentence.

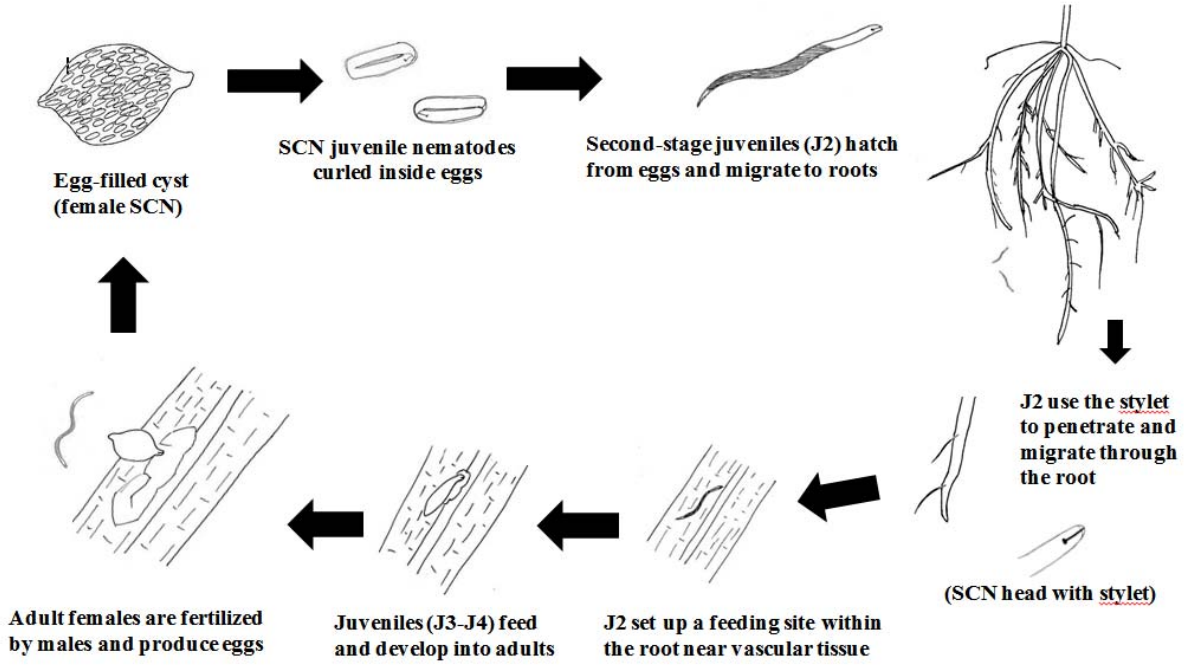

Figure 2. Life cycle of the soybean cyst nematode

At this stage, the female bodies begin to change from yellow to brown. The dead female body becomes a protective structure containing hundreds of eggs and are commonly referred to as cysts. The cyst wall protects the eggs from drying, chemical action, predators, and some parasites. Because of these properties, SCN cysts are well-suited for the spread of the nematode in soil to new locations. Because of the 30-day life cycle, several generations are possible each growing season. With optimum environmental conditions and susceptible hosts, including weed hosts, if one cyst containing 400 eggs is introduced into a soybean field in the spring, several thousand cysts could be produced in one growing season from that single cyst. In previously infested fields, the potential for high nematode population growth exists if appropriate management is not implemented.

HOW NEMATODES SPREAD

In infested soil, cysts can be found throughout the root zone in the soil. Some accumulate on the soil surface. From there, they can easily be transported alone or with soil by man and by natural agents. Cysts may be found in the soil adhering to farm implements, machines, vehicles, tools, shoes, or other soil-carrying items. Nursery stock, transplants, bulbs, corms, and root crops may carry cysts in adhering soil, even though the plants themselves are not being attacked by the nematodes. Hay, straw, grain, or seed crops that carry dust or soil peds may also serve as carriers. Basically, anything that moves through an infested field in contact with the soil is capable of picking up and transporting cysts. Equipment and contaminated soybean seed that have not been thoroughly cleaned may be an important means of spreading SCN.

Natural agents may also be important in the spread of the soybean cyst nematode. Wind, runoff water, and wildlife can carry cysts into clean areas. Even waterfowl and other birds feeding in infested fields may ingest cysts and carry them considerable distances.

HOST PLANTS

The host range of the soybean cyst nematode includes leguminous field crops plus some ornamental plants and certain weed species that are susceptible and will increase nematode populations. Multi-year crop rotations with non-host crops and management of weed hosts are important measures to take in attempts to reduce SCN populations. In most cases, a short corn-soybean rotation is not long enough to effectively reduce SCN populations in soybean fields. See table below for a short list of some alternative weed and crop hosts of the soybean cyst nematode.

Weed hosts	Crop hosts
Birdsfoot treefoil	Edible beans
Clovers (crimson, scarlet, aslike, white)	Vetch (common, hairy, or winter)
Chickweed (common and mouse-ear)	Cow pea or black eyed pea
Henbit	Lespedezas
Wild mustard	Soybean
Foxglove	Sweet clover

Table 1. List of some additional weed and crop hosts to SCN

DETECTION

Identifying the problem is the first step in controlling SCN. Soybean producers should be familiar with symptoms and should suspect SCN where yields are reduced or hit an unexplained plateau. Because of the asymptomatic yield reduction associated with SCN, the so-called “silent killer”, and the finding of SCN in every county in Illinois, every soybean producer should consider testing for SCN. The best way to determine if SCN is present and to measure population densities is to collect a soil sample and submit it for analysis. The ideal time to sample is in the fall, after harvest. Because the overwinter survival of SCN in Illinois is typically very high, the fall SCN egg count will very closely approximate the spring SCN population. This will also allow ample time for planning for the next growing season based on the results of the egg count, and in addition will allow time for completion of an SCN Type test if warranted due to moderate to high SCN egg counts. However, samples collected any time during the growing season can be processed to detect the presence of SCN.

SCN Egg Count per 100cc of soil	SCN Level	Overall management plan
0	Not detected	Monitor with periodic SCN egg counts, at least every 3rd year soybean is grown
Up to 500	Very low	Plant SCN resistant variety (can focus on higher yielding varieties) and incorporate rotation to a non-host crop into your management plan, monitor SCN egg counts
500 to 2000	Low to moderate	Plant SCN resistant variety with greater resistance and include rotation to a non-host crop into your management plan, monitor SCN egg counts after growing soybean
2000 to 5000	Moderate to high	Plant and rotate with SCN resistant varieties (most effective using resistance matched with identified SCN Type test results) and rotate to a non-host crop (each year after soybean is grown until high count decreases)
5000 and higher	High	Rotate to a non-host crop, sample for SCN egg count before returning to soybean

Table 2. Management guidelines based on fall SCN Egg Count

Soil samples should be collected as described above and sent to the University of Illinois Plant Clinic. In addition to the Plant Clinic, there are several private labs that are also capable of processing soil samples.

CONTROL: AND INTEGRATED APPROACH

Ideal programs to manage SCN infestations have successfully integrated the following: detection through scouting and sampling procedures, and crop rotations utilizing non-host crops and SCN-resistant soybean varieties. Maintaining proper soil fertility and pH, managing other soybean diseases and pests, and proper planting methods also help to keep plants vigorous and better able

to buffer the effects of SCN. The most effective management system has and will continue to involve integrated approaches.

CROP ROTATION

The value of crop rotation should not be underestimated. A grower will achieve higher yields on all crops involved in the rotation than on any crop that is planted continuously. Crop rotation has proven to be a powerful tool for controlling SCN as well as other diseases. The goal of crop rotations in the presence of SCN are to: improve soybean health and yield; reduce SCN numbers; and to preserve yield potential of SCN-resistant varieties. Rotations with non-host crops such as corn, small grains, red clover, alfalfa, and sunflower and with SCN resistant soybeans are effective because SCN juveniles hatch from eggs as long as soils are between 60° to 90°F (16° to 32°C). The second-stage juveniles have food reserves to last seven to fourteen days, depending on soil temperature, after which time they must establish a feeding site in a host plant. In fact, SCN juveniles have been observed to enter non-host roots such as corn and die after a failed attempt to feed within the root. Thus, if no host plant is available, data indicate that 50 percent or more of the SCN population is eliminated by starvation each year. Even greater reductions may occur where eggs or juveniles are attacked by parasites and predators such as fungi, predacious nematodes, and bacteria. Many soybean producers have found that following a consistent rotation of corn-resistant soybean in fields where SCN is present adequately manages the SCN population, and keeps it to a low level without additional effort required.

The specific rotation plan for SCN management should depend on the initial SCN egg count (Table 2) and on the history of the SCN management in the field. With a new infestation and low

egg count, the population could be managed with rotation and resistance and monitored with SCN egg counts every 2-3 years that soybean is grown, or anytime an unexpected yield decrease is observed or any other evidence of SCN, such as cysts on roots, is observed. The SCN egg count is an inexpensive test ($20 in most labs) that can help to ensure that your management practices are working effectively. If the SCN egg count of a field is not at a low level, is increasing or already high, the management plan should include a greater number of years of non-host crops between soybean, and the selection of an effective resistant soybean variety based on the SCN or HG Type test.

HG or SCN TYPE TEST

When SCN egg counts are moderate to high, or are increasing in a field despite the use of a resistant variety and/or rotation with a non-host, an SCN or HG Type test is often recommended. The SCN or HG Type tests are greenhouse bioassays that test the SCN field population against known resistant indicator lines in order to identify on which types of resistance the field population can develop. With the 30 day greenhouse bioassay, the development of the field population is measured on resistant lines and compared to development on a standard susceptible soybean line (Lee 74), and a percentage value called the Female Index (FI) is calculated. When the percentage of a field population that can develop on a resistant line, or FI, is high (10 or greater), that source of resistance should not be used in that field. When the percentage or FI is less than 10, that source of resistance is considered effective against the field population.

For Illinois producers interested in a greenhouse bioassay, the SCN Type test is recommended. It includes three resistant indicator lines, PI 548402 (Peking), PI 88788 and PI437654 (Hartwig-

type). These three indicator lines represent the SCN resistance incorporated into soybean varieties that are available to Illinois producers. The HG Type test is a larger (more expensive) test that includes seven sources of resistance and is typically used by researchers that study SCN field populations (HG stands for the scientific name of SCN, *Heterodera glycines*). The SCN Type test is simply a shortened version of the HG Type test and contains only the resistant lines important to them.

When results of the SCN Type test are obtained, an Illinois producer will know which source of resistance to look for when selecting a resistant soybean variety. If the test result is "SCN Type 0" this means that the field population did not develop well on any of the resistant varieties, indicating that any resistant line will be effective. If the test result is an SCN Type 1, SCN Type 2, or SCN Type 4, then 10% of the population was able to develop on the corresponding numbered line (Table 3). If the test result contains more than one number, for example SCN Type 1.2, this means that the SCN population developed well on more than one type of resistance, in this example on Peking and PI 88788 (see table 3). A more detailed explanation of the SCN Type test results is sent with the actual test result when performed at the University of Illinois Plant Clinic. For additional information, contact the Plant Clinic (contact information at the end of this document).

SCN Type test resistant indicator line name	SCN Type test resistant indicator line number	SCN Type number/name if FI $\geq$ 10 on indicator line in greenhouse bioassay	Prevalence of this SCN Type in Illinois
PI 548402 (Peking)	1	1	Increasing in prevalence in Illinois
PI 88788	2	2	Common in Illinois
PI 437654 (Hartwig)	4	4	Rare in Illinois

Table 3. SCN Type Test indicator lines used and their relevant use in Illinois

The use of an effective resistant soybean variety in the rotation scheme can be a critical component of SCN management. Anytime a host is provided to SCN, the population will increase, including on a soybean variety labeled as resistant but with resistance that is not effective against the field population. The SCN field population can develop on the deployed resistant variety, shifting the field population to one that can develop on that type of resistance as if it were a susceptible soybean. If a rotation regimen that includes a resistant variety is not managing your SCN population, it is important to identify the SCN population type and match it to an effective resistant soybean variety for the specific soybean field tested. Although the use of resistant varieties is a key factor in managing SCN, resistant varieties should not be planted consecutively for several years because of the possibility of developing a population capable of reproducing on a given genetic source of resistance. While rotation with non-hosts should be incorporated in every management plan, incorporating rotation with different resistant varieties can be an important and effective way to prevent this type of population adaptation to specific sources of resistance. Use them wisely!

RESISTANT VARIETIES

Resistant varieties are the foundation for IPM approaches in managing SCN as well as other plant diseases. Some distinct advantages of using host resistance are that the pest control is purchased with the seed, it is compatible with other management practices, has few adverse effects on the environment, and in most cases the cost is minimal. The success story of managing SCN has been the use of resistant varieties. Three decades ago, only a small number of SCN-resistant varieties were available. Today, through the efforts of public and private soybean breeders, this list has expanded to a great variety of soybean lines adaptable to Illinois growing conditions. In previous years, the Illinois Soybean Association funded Varietal Information

Program for Soybeans (VIPS) tested hundreds of varieties annually for the level of resistance to SCN and other diseases. Although this program was discontinued in 2013, the data is still available for soybean varieties tested in 2013 and earlier at www.vipssoybeans.org. All varieties are listed by maturity group and disease ratings are given for each tested soybean variety. Information from the SCN Type test allows Illinois producers to directly determine which types of SCN resistance will be effective in their fields. This information is important to Illinois producers that need more intensive management when the SCN egg count is high. For more information on how to obtain this information, contact the University of Illinois Plant Clinic.

MAINTAINING PLANT HEALTH

Damage by SCN is greater on plants that are under stress from other factors. Damage may be reduced by providing plants with optimum growing conditions including adequate moisture (irrigation, if available), maintaining adequate soil fertility, breaking soil hardpans, improving soil aeration; and by controlling weeds, insects, and other plant diseases. These practices help plants compensate for damage by SCN but do not decrease nematode numbers. Research involving plant-parasitic nematodes has shown that resistant varieties and crop rotations do not increase yield to their full potential without the factors necessary for good plant growth and development.

SANITATION

Since SCN moves with infested soil, soybean producers with SCN-infested fields can reduce but not eliminate the spread to other fields by washing soil from equipment used in infested fields before moving the equipment to non-infested fields. Whereas SCN is often carried in soil peds,

seed produced on infested ground should be thoroughly cleaned to remove soil peds before planting. Another common source of SCN contamination is second-hand farm equipment. Such equipment should be washed free of as much of the adhering soil as possible before it is brought on a farm and used. Cleaning methods have involved the use of high-pressure water or steam. Certain fields on a farm may be infested with SCN. Working, planting, and cultivation of these fields should be done after uninfested fields have been worked. After working infested fields, equipment should be cleaned.

NEMATICIDES

There are a few nematicides that are registered for use against SCN. However, they are not generally recommended for control of SCN because resistant varieties are more cost effective than nematicides (nematicides increase the cost of production). Additionally, nematacides work only under proper environmental conditions. Environmental factors such as rainfall, soil pH, soil microbial activity, and moisture can reduce or increase the efficacy of nematacides. Using nematicides under some environmental conditions can actually increase the SCN population by allowing the soybean plant to develop a somewhat normal root system early in the growing season because of nematode control and later in the season, when the nematicide has degraded to a non-toxic form, remaining nematodes in the soil attack the root system and are able to reproduce rapidly because there is more root mass and consequently, more feeding sites. The end result is that population levels at the end of the growing season may be as high or even higher in treated fields than in untreated fields. In this example, and in general, nematacides are never completely effective in eliminating the SCN population or suppressing the SCN population below economic thresholds. The use of SCN-resistant varieties in rotations involving non-host crops is the most effective and economical approach in controlling the nematode.

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