PPA-42

COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF KENTUCKY • COLLEGE OF AGRICULTURE

Soybean Cyst Nematode: Soybean Thief and Public Enemy Number One

Donald E. Hershman
Extension Plant Pathologist

Importance

The soybean cyst nematode (SCN) is a microscopic roundworm that feeds on the roots of soybean plants. Depending on the level of infestation, SCN can cause yield losses ranging from 0 to 80 percent. SCN occurs in all major soybean-producing countries throughout the world and is considered the most serious pest facing soybean producers. In the United States, SCN is widespread in the midwest, southeast, and midsouth. The pest was first discovered in Kentucky in 1957 in Fulton County. SCN has since been detected in 40 counties throughout the Commonwealth (Figure 1). Annual yield losses due to SCN are estimated at 2.3 to 4.5 percent, worth $6-12 million.

SCN Life Cycle

The SCN life cycle begins with eggs inside a pear-shaped, golden brown cyst (Figures 2 and 3). A wormlike juvenile, approximately 1/64 inch in length and the diameter of a human hair, is inside each egg. Juveniles hatch in the spring about the same time soybeans are planted. Not all eggs hatch, however, and some remain dormant in cysts for many years. Prolonged dormancy of eggs ensures the survival of the species and is the main reason that SCN cannot be eliminated from infested fields.

As they move through soil, some hatched juveniles encounter soybean roots and penetrate them; this process is aided by soybean root exudates that attract juveniles. The vast majority of juveniles fail to find a soybean root and die of starvation. Juveniles that find a root enter it and begin feeding using a hypodermic needle-like structure called a stylet. Juveniles eventually develop into either adult males or females. Males mate with females, leave the root, and die. Fertilized females remain in the root, and their bodies begin to swell.

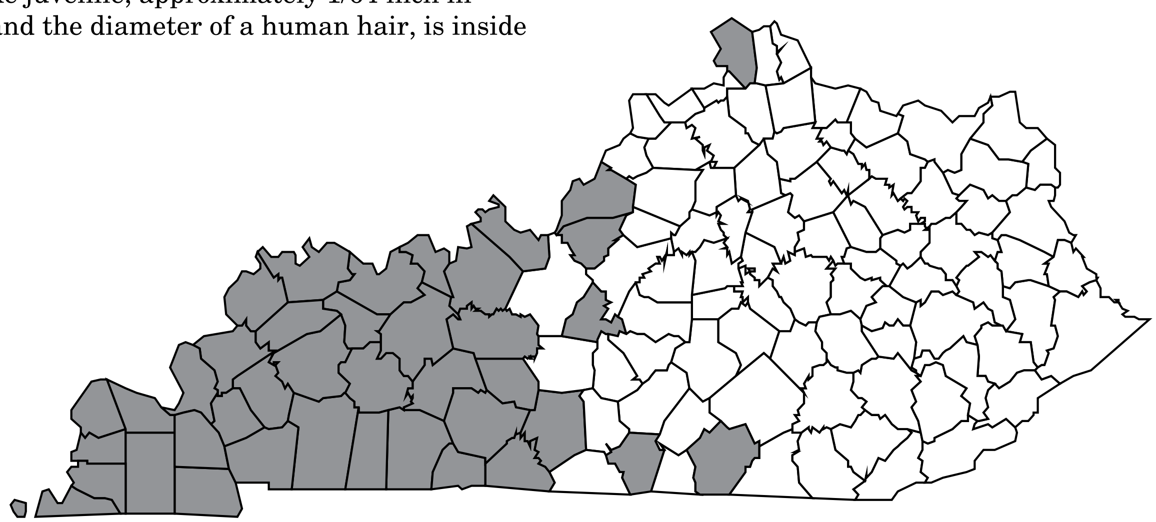

Figure 1. Counties infested with SCN as of 1997.

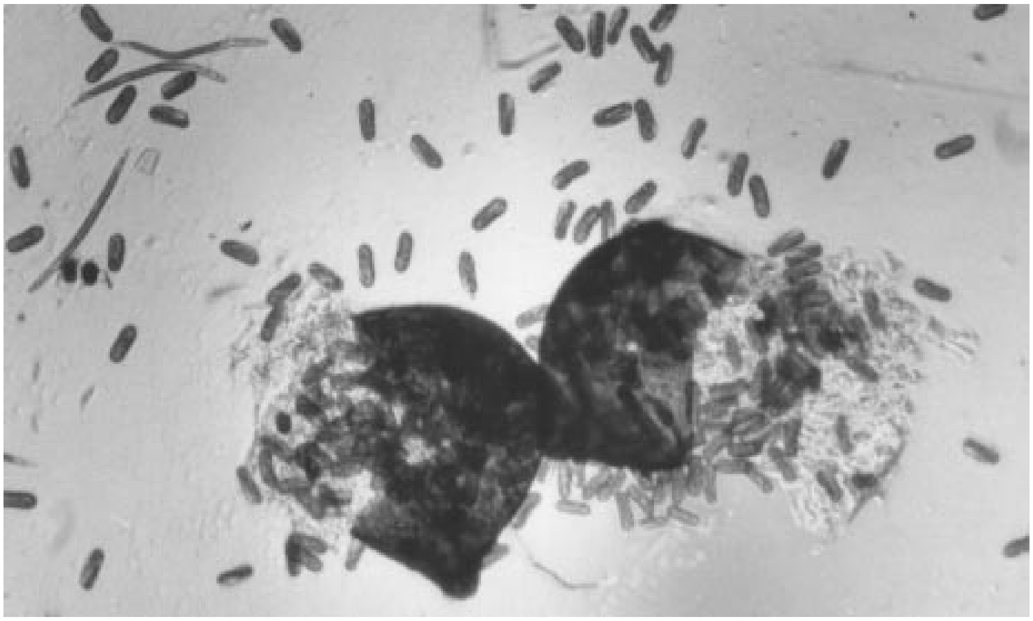

Figure 2. Eggs and hatched juveniles are visible after breaking open two cysts.

About 28 days after hatching, the swollen bodies of SCN females break through the root surface and are visible to the naked eye. This stage is referred to as the "white female" stage. As white females age, they begin to turn yellow and eventually golden brown. The brown stage marks the death of the female, which is now referred to as a **cyst**. Each cyst is about the size of a period at the end of a sentence and 25 to 50 times **smaller** than nitrogen-fixing nodules (see Figure 4).

The brown shell of each cyst protects the 50 to 500 eggs inside from adverse soil conditions. Cysts and their eggs are spread any time infested soil is moved. The production of cysts concludes the SCN life cycle. In Kentucky, two to three generations of SCN occur each year.

How SCN Damages Soybean

SCN damages plants both directly and indirectly. Direct damage results from the feeding and growth of female nematodes in roots. Damage is caused by the removal of essential plant nutrients from root cells and the disruption of nutrient and water transport systems in the root. Indirectly, SCN damages soybeans by reducing the production of nitrogen-fixing nodules and by encouraging other diseases that affect root systems. Examples of these diseases are Rhizoctonia seeding blight, sudden death syndrome, and charcoal rot.

SCN Populations and Soybean Yield Loss

The extent of yield loss due to SCN in a soybean crop can be estimated by determining the number of SCN eggs present in soil **at the time of planting**. A "threshold" level of SCN is the highest population of eggs at which a SCN-susceptible variety can be grown with little or no yield loss. This threshold, as well as damage estimates at specific SCN levels, varies by state. The variation is caused by the many factors which influence SCN and soybean growth. Damage estimates and the threshold for Kentucky are listed in Table 1.

Table 1. SCN damage estimates and threshold for Kentucky.

Eggs per 100 cc soil		Potential yield loss*
0		0%
1-500	Threshold	0-5%
501-1500		5-15%
1501-3000		15-20%
3001-5000		20-40%
5000+		25-60%

***** Range of potential yield loss if a SCN-susceptible variety is grown within the specified population range. Less yield loss will occur with better growing conditions.

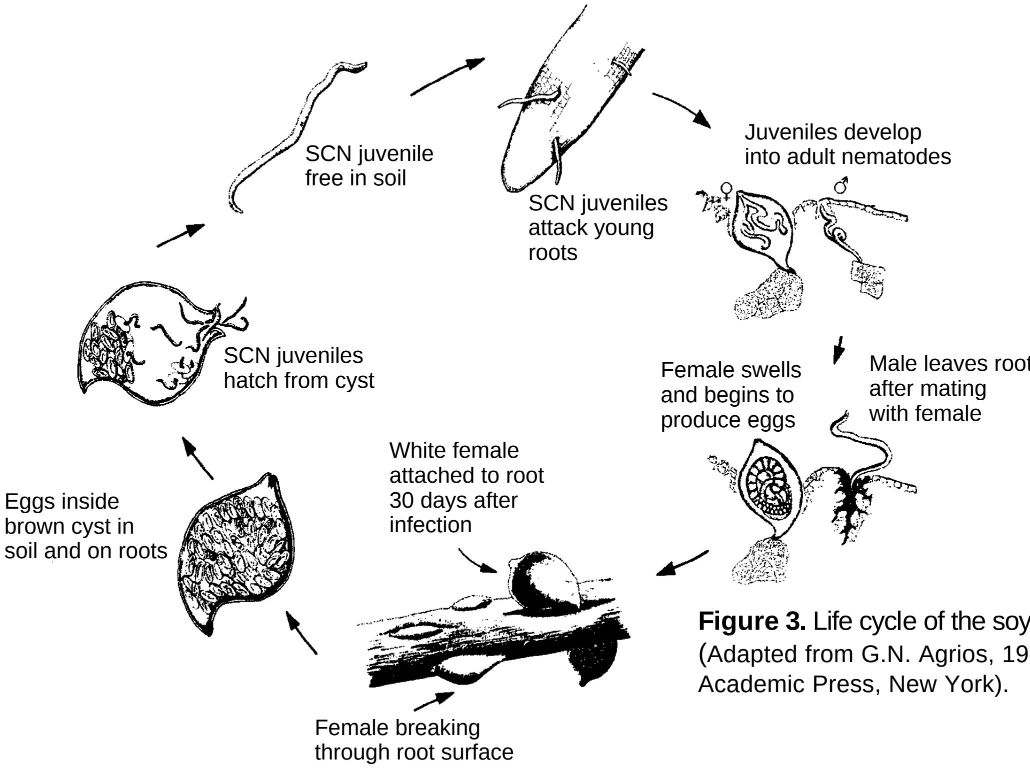

Figure 3. Life cycle of the soybean cyst nematode (SCN). (Adapted from G.N. Agrios, 1978, *Plant Pathology,* 2nd ed., Academic Press, New York).

The SCN Symptom Dilemma

In most situations, SCN can be economically managed by rotating crops and growing SCN-resistant and -susceptible soybean varieties at appropriate times. With this being the case, one might reasonably ask, “Why does SCN cause so much damage in Kentucky each year?” The answer to this question is based upon a simple fact: serious yield loss due to SCN is rarely associated with obvious disease symptoms. **In other words, farmers cannot tell when SCN is reducing yields until crop harvest.** At that time, low yields are frequently blamed on problems other than SCN. Consistent, moderate damage by SCN may not even be noticed by producers, since acceptable yields may be obtained even though higher yields may be possible.

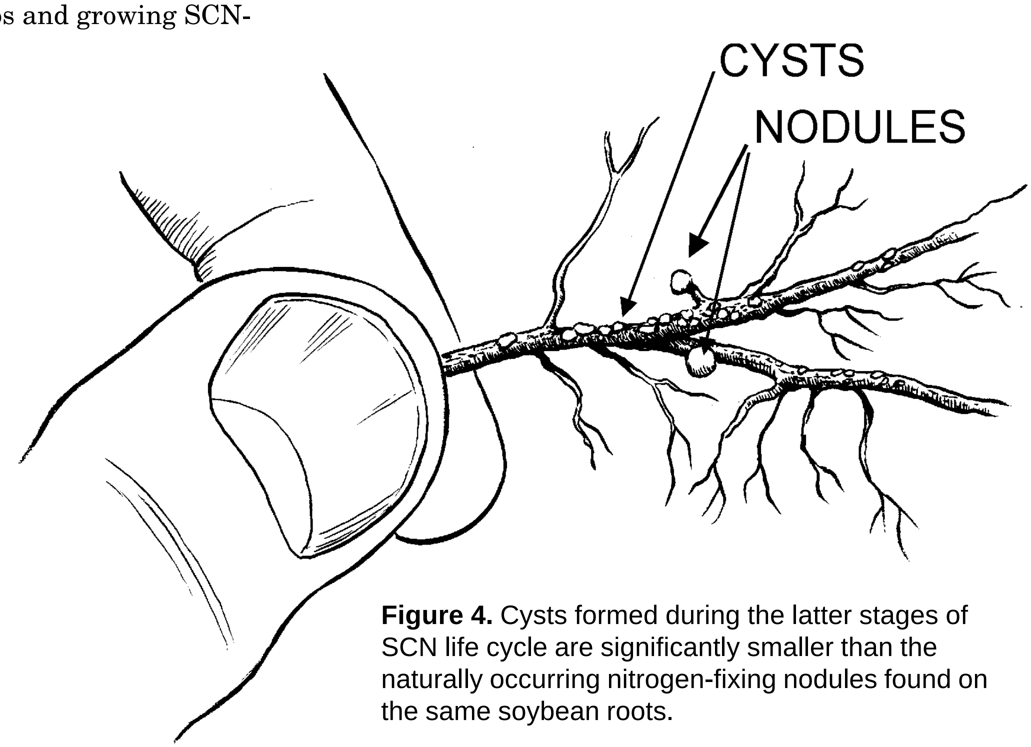

Figure 4. Cysts formed during the latter stages of SCN life cycle are significantly smaller than the naturally occurring nitrogen-fixing nodules found on the same soybean roots.

When Symptoms Are Visible

Occasionally, nonspecific aboveground symptoms are associated with SCN damage. These symptoms are most common in sandy soil types and are frequently associated with other plant stresses. Symptoms are easily confused with those caused by other factors, such as herbicide injury, soil fertility problems, soil compaction, drought, excess soil moisture, etc. Aboveground symptoms include general plant yellowing, stunting, wilting in the heat of the day, and, rarely, plant death. A potassium deficiency symptom, evident as a bright yellowing of the margins of leaves, is the most common aboveground symptom of SCN infection. SCN-induced potassium deficiency symptoms are not caused by soil deficiencies. Rather, they are the result of the plant's inability to pick up sufficient potassium due to nematode feeding.

Root symptoms in plants heavily damaged by SCN are more common than aboveground symptoms. These symptoms include reduced root growth, a "bottle brush" appearance to the root systems, root browning (i.e., necrosis), and poor nodulation. These symptoms, however, are obscured by the fact that they occur belowground. As a result, root symptoms are seldom seen by producers.

What Are Races of SCN?

Just like humans and all other animals, SCN is genetically diverse. Each population of SCN is made up of many individuals. Individual nematodes have most of their genes in common with their fellow nematodes, but unique genes also occur. A race of SCN is defined as the **average** genetic makeup of a SCN population. The race is determined by exposing the SCN population to four differential SCN-resistant soybean varieties or lines (Pickett, Peking, PI88788, and PI90763) and to Lee 74 (which is susceptible to SCN). Each race has different abilities to reproduce on the soybean differentials in relation to the susceptible Lee 74. Because there are four differential lines, 16 races are possible. However, not all 16 races are known to occur in nature. In Kentucky, for example, most fields are infested with SCN race 3; races 1, 6, 9, and 14 also occur in localized fields.

Race Identification

Race identification is of primary importance to nematologists wishing to characterize the SCN populations they are studying; it is primarily a matter of communication among scientists. Producers need to know which SCN-resistant variety to grow in a field, not which race is present. Race testing can provide this information, but the results of tests frequently lead more to confusion than to answers. For example, a race test might indicate that a field is infested with SCN race 6. As it turns out, most varieties resistant to race 14 will also work against race 6. However, because few seed companies test their varieties against race 6, this information will **not** be on the seed tag. This leads to confusion among farmers and seed salesmen. This confusion is the main reason race testing is not recommended for nonresearch samples.

In most cases, producers will have success in using SCN-resistant varieties without a race test being done. This is because most fields are infested with SCN race 3, and all resistant varieties resist race 3. Planting a variety resistant to races 3 and 14 will be effective in all but the most unusual situations.

SCN Race Shifts

Because a race is defined as the average genetic make-up of nematodes in a field, each field can be infested with only one race; **mixtures of races in a field are not possible**. Races, however, can change over time. This is known as a race shift.

Race shifts occur when SCN populations are frequently exposed to SCN-resistant soybean varieties. Initially, most nematodes in a population are unable to feed when a resistant variety is grown. As a result, populations of the nematode decline. **In all instances, however, at least a few "resistant" nematodes will successfully feed and reproduce on the resistant variety**. Then, the next time the same or a similar resistant soybean variety is grown, the population of resistant nematodes increases even further. Once the resistant SCN type makes up the majority of the population, the race is said to have shifted. The process responsible for selecting resistant nematodes over others in the population is called selection pressure.

Principles of SCN Management

SCN is the only soybean disease for which a reliable preplanting prediction can be made about yield loss. This places soybean producers at a great advantage over SCN. Effective management of the nematode, however, requires that growers use a variety of tactics in an overall management program. To implement this program, growers need to understand how and why individual tactics work.

Manipulation of SCN populations

The key to managing SCN lies in the producer's ability to "outsmart" SCN. By planting nonhost crops and SCN-resistant or -susceptible soybean varieties at appropriate times, producers can grow high-yielding soybean crops in infested fields. Planting decisions have a tremendous impact on SCN levels in fields. The overall objective of reducing populations is accomplished by growing nonhost crops and SCN-resistant soybean varieties, then planting SCN-susceptible soybean when the SCN population is reduced below the damage threshold. The rationale for occasionally planting a susceptible variety will be discussed later.

Soil analysis to determine SCN population levels

To successfully manage SCN, growers must first determine the degree of infestation in fields by conducting a SCN soil analysis. The main use of analysis data is to aid in crop decisions. Without this information, these decisions would be based on guesswork.

In most cases, once a baseline SCN level is established for a field, retesting will only be necessary every three to four years. Retesting is necessary to determine when it is safe to plant a susceptible soybean variety. More frequent testing may be needed when additional information is required, such as an evaluation of a resistant soybean variety's effect on SCN levels.

Soil sampling for SCN analysis

Once a soil sample arrives at the SCN laboratory, analysis of that soil for SCN is very straightforward and reliable. Collecting a soil sample that reflects the SCN population in a field, on the other hand, is much more difficult. SCN is never uniformly distributed in fields. To account for this variability, samples must be comprised of multiple subsamples, collected in a specific way and at a specific time. **Nonrepresentative samples will yield nonrepresentative SCN analysis results.**

Detailed sampling instructions are outlined on the back of SCN Analysis Forms available at your local county Extension office. In most cases, SCN soil samples can be taken the same time soil fertility samples are collected. There are minor differences in how SCN and soil fertility samples should be handled, so pay special attention to your Extension office's instructions.

SCN samples may be collected in the fall, winter, or spring. The key is to have an analysis done **prior** to making critical cropping decisions. In this regard, fall may be the best time to take samples. This is because (1) soil conditions are usually more conducive for taking a uniform soil sample, (2) time constraints on the farm are not as demanding, and (3) sampling in the fall allows plenty of time for crop adjustments to be made if need is indicated by the analysis. Note that samples taken during the growing season are useful only to confirm a SCN problem in a field. The earliest a sample can be taken and have any predictive value at all is late September.

Using results of SCN analysis

The main result of a SCN analysis is a finding of the number of SCN eggs or cysts per volume of soil submitted. For a properly collected soil sample, this number represents the "average" SCN population in a field.

If SCN populations and damage potential are unacceptable, then steps must be taken to bring populations down to acceptable levels. This must be done within the context of maintaining farm profitability.

Specific Management Tactics — Primary Defenses

Nonhost crops

SCN is only capable of attacking a very small number of crop species. In Kentucky, for example, soybean is the only widely grown crop susceptible to SCN. Minor susceptible crops include black turtle and other edible beans; pea, sweet, crimson, and alsike clover; bird's-foot trefoil; common, crown, and hairy vetch; lupine; and lespedeza. Corn is the predominant nonhost crop grown in Kentucky. Other nonhosts include grain sorghum, small grains (with summer fallow, not doublecrop soybean), summer grasses, and alfalfa.

By definition, SCN is unable to complete its life cycle on a nonhost crop. As a result, SCN levels decline as eggs hatch and are not replaced. Studies have shown that SCN levels decline by 50 to 80 percent per year when exposed to a nonhost crop. Even at this rate of decline, at least two years of a nonhost crop are needed to reduce SCN below threshold if initial levels were in the moderate to high range. This is why SCN can remain at yield-reducing levels in fields where corn is grown every other year.

Resistant soybean varieties

The primary goal when growing a resistant variety is to achieve acceptable yields in spite of damaging levels of SCN. Most resistant varieties will, in fact, yield five to 20 bushels per acre higher than a susceptible variety when SCN is above damage threshold. Unlike older resistant varieties, most new public and private resistant varieties are high-yielding and have good agronomic characteristics.

Another goal when growing a resistant variety is to reduce levels of SCN. Depending on the type and level of resistance bred into a variety, SCN levels may increase slightly, remain static, or decrease. The best way to ensure that you get the resistance and yield qualities you desire is to select varieties with a history of good performance in your area. New resistant varieties can be selected based on the results of replicated field tests. In all instances, look at as much performance data as possible before committing to a particular resistant variety.

The key to effective, long-term use of resistant varieties is to not plant varieties with similar SCN resistance too often. Failure to heed this advice may lead to a SCN race shift. Once a race shift occurs, the resistance options available to a producer are greatly reduced or even eliminated. This is because most currently available resistant varieties resist SCN races 3 and 14. Once SCN can reproduce on any race 3 and 14 resistant variety, then all other varieties resistant to race 3 and 14 will be unusable. At that point, producers will have to make selections from a very small pool of varieties which represent an alternate source of resistance. Many of those varieties are hard to find and/or have less than desirable yield and agronomic characteristics.

There is a great deal of debate about what is "too often" when growing resistant soybean varieties. The frequency recommended by most nematologists is no more than once every three to four years. Planting resistant varieties every year is universally accepted as being too often. There is no consensus about the repercussions of planting a resistant variety every other year. It is generally believed that this frequency will encourage a race shift, but not to the same extent as growing a resistant variety every year. Until data suggest otherwise, growing a resistant variety every other year is not recommended.

There may be instances where it is necessary to plant a resistant soybean variety more often than is recommended. In these instances, SCN race shifts may be discouraged by planting varieties resistant to different races of SCN in alternate years. For example, the public variety Delsoy 4710, which is resistant to SCN races 3 and 14, could be alternated with Manokin, which is resistant to races 1 and 3. Your agricultural Extension agent or seed dealer can help you make the appropriate decisions on variety selection.

Susceptible soybean varieties

Even after a field becomes infested with SCN, susceptible varieties should still be an important part of your farm plan. Planting a susceptible variety every three to four years will greatly reduce the potential for a SCN race shift. When a susceptible variety is grown, there is no selection pressure placed on the SCN population. This is because all nematodes can feed and reproduce freely. As a result, a balance is maintained in the SCN population and a race shift is averted. This situation is the opposite of that which occurs when a resistant variety is grown.

Regardless of the merits of periodically growing a susceptible cultivar, many producers are fearful of this practice. Nonetheless, research has shown that susceptible varieties can be grown with little or no yield loss once SCN levels have been managed below threshold. SCN levels at the end of the season, however, **will** be high **regardless of the SCN level at planting**. For this reason, it is recommended that susceptible varieties not be grown more often than once every four years, and never in consecutive years.

Always have a SCN analysis done prior to planting a susceptible variety. In this way you can be certain that SCN is at or below threshold. Do not assume that SCN levels are sufficiently low even if you are following recommended crop rotations and management practices.

Specific Management Tactics — Secondary Defenses

Maintaining crop health

SCN damages plants by stressing essential plant functions. Additional plant stresses, such as those caused by adverse fertility or soil conditions or other pests, exacerbate damage caused by SCN. Under these conditions, yield losses will be greater than where the same SCN populations exist without the additional crop stresses. Maintenance of adequate soil fertility, breaking hardpans, and controlling other pests will improve crop health and reduce damage caused by SCN. None of these practices, however, will eliminate yield loss if SCN is above damage threshold.

Doublecrop soybeans and the "residue effect"

Planting doublecrop soybeans into wheat straw can help to keep SCN from building up to high levels on a susceptible variety. The mechanism by which this activity occurs is not known. Nonetheless, this "residue effect" is most active when soybeans are planted into wheat straw using no-tillage methods. Any amount of tillage tends to reduce the effect. The residue effect is not a replacement for primary SCN management tactics, such as planting resistant varieties, because wheat residue has no effect on SCN levels **at planting**. As indicated earlier, SCN levels at planting determine yield effects in soybean. The residue effect can, however, help in a long term SCN management program by limiting the number of nematodes that develop when soybean is produced. Lower levels of SCN can be managed with greater ease and flexibility than high SCN levels.

Blends of resistant and susceptible varieties

Some farmers use blends of resistant and susceptible soybean varieties in SCN management programs. Blends will not perform well if SCN levels are high enough that a resistant variety is needed. In this case, the susceptible component of the blend will be damaged and the resistant component will not make up for the loss. The only case where a blend may be appropriate to plant is where SCN levels are generally low, but some problem areas exist, and **a susceptible variety would have been grown in place of a blend**. In this case, the resistant component may provide some benefit compared to expected results, had a susceptible variety had been used.

Planting date and maturity group

Planting date has no direct effect on SCN. That is, doublecrop soybeans are just as likely to be damaged by SCN as full season soybeans. There is some evidence, however, that very early maturing varieties (i.e., group 2 varieties in areas where group 4 and 5 varieties predominate) can escape serious damage due to their short season of growth. Current research has shown that this can be accomplished without a yield penalty due to early maturity. Research is ongoing to identify group 2 varieties best suited to Kentucky.

As with the residue effect and soybean blends (see above), early maturing varieties should not be used in situations where resistant varieties or nonhost crops are needed. The best use of early varieties may be to reduce the risk of yield loss when growing SCN-susceptible varieties in a rotation scheme.

Weed management

Good weed management will limit stress in crops caused by excessive weed competition. The result will be a healthier crop that is less susceptible to SCN-related yield loss. In addition, some weed species support at least some level of SCN reproduction. Examples are common mullen, hemp sesbania, hop clovers, milk and wood vetch, American and Carolina vetch, pokeweed, purslane, spotted geranium, and winged pigweed. Fortunately, few of these weed species are a serious problem in Kentucky row crops. Many of them, however, may be present in pasture/CRP fields. In fact, a survey of CRP fields conducted in 1995 demonstrated that high SCN populations existed in some fields that were in fescue and other pasture settings for as long as ten years. The maintenance of SCN populations on weed and pasture species is thought to be the main contributing factor.

SCN can also reproduce on the common winter annuals henbit and common and mouse-eared chickweed. These weeds develop after soybeans and corn are harvested in mid to late fall. They persist well into the spring where wheat is grown, primary tillage is delayed, or the next crop is produced without tillage (i.e., no-till). Although each of these weeds is know to be a host for SCN, it is unlikely that any will contribute much to higher SCN populations. The reason is that SCN eggs and juveniles are dormant during most or all of the winter annuals' life cycle — soil temperatures are just too cold to support significant SCN reproduction.

Continuous no-tillage of crops

Fields subject to long-term, continuous no-till crop production tend to have lower SCN levels than tilled fields. Unlike the residue effect, which is specific to wheat residue, the tillage effect has to do with soil conditions and their effect on SCN. The exact cause of the tillage effect is unknown, but several biotic and abiotic factors may be responsible. For example, natural biological control agents may be more active in long term, no-till soils. Changes in soil structure and organic matter associated with long-term, no-till may also come into play. Regardless of the cause, long-term management of SCN populations may be easier where crops are produced no-till. The influence of no-tillage will be lost, however, as soon as any tillage is applied to any crop in a rotation, not just soybeans. As with all secondary defense tactics, do not expect no-tillage of crops to replace primary defense tactics or reduce yield losses if SCN levels are above threshold at planting.

Specific Management Tactics — Last Resort

Nematicides

Several nematicides are available for achieving an acceptable yield of SCN-susceptible soybean varieties exposed to damaging levels of SCN. The cost of using nematicides, however, is high, and similar yield results can be obtained by planting a resistant variety without a nematicide.

Nematicides may be the only option in fields which cannot be successfully rotated to nonhost crops **and** in which resistant varieties cannot be grown because of the SCN race which exists. Note that SCN populations are frequently higher at the end of the season where nematicides are used. This is because more root tissue is available late in the season to support additional SCN reproduction. Thus, nematicides cannot be used to reduce SCN levels, unlike nonhost crops and most resistant soybean varieties.

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, C. Oran Little, Director of Cooperative Extension Service, University of Kentucky College of Agriculture, Lexington, and Kentucky State University, Frankfort.

Issued 5-97, 5000 copies to date.