SOYBEAN CYST NEMATODE

Douglas J. Jardine
Extension Specialist, Plant Pathology

Timothy C. Todd
Nematologist, Plant Pathology

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

The soybean cyst nematode (SCN) or *Heterodera glycines*, is the most serious disease threat to soybeans in the United States. In the north central United States, it has been estimated that the nematode causes an annual loss of 48 million bushels. Losses may be as high as 40 percent in individual fields, making soybean production uneconomical without effective control measures. In Kansas, SCN was first reported in 1985 in Doniphan County. Since then, the range of the nematode has continued to expand. Through 2001, 42 counties from all but the three western crop reporting districts were infested (Fig. 1).

THE NEMATODE

The soybean cyst nematode is a microscopic, worm-like organism ranging in length from 1/64 to 1/16 inch. Upon hatching, juveniles (Fig. 2B) migrate short distances through the soil and enter plant roots near the tips. They burrow into the roots and begin feeding on young root cells. Females become immobile as they continue to feed and mature. The adult female's body swells, and the rear portion breaks through the surface of the root (Fig. 2C).

A female produces an average of 100 to 200 eggs (Fig. 2A) in about 30 days. A few eggs are deposited into the soil in a jelly-like mass, but the majority are retained within the body. The swollen body starts out white, but turns yellow, then brown, forming cysts as the female ages and dies. At maturity and death, the cysts become dislodged from the roots.

Unlike females, males do not become sedentary nor do they form cysts. Adult males do not feed, but move into the root where they remain for a few days, during which time they may or may not fertilize the females that have begun egg production. Eggs do not develop without fertilization by the male. Following mating, the males return to the soil and soon die.

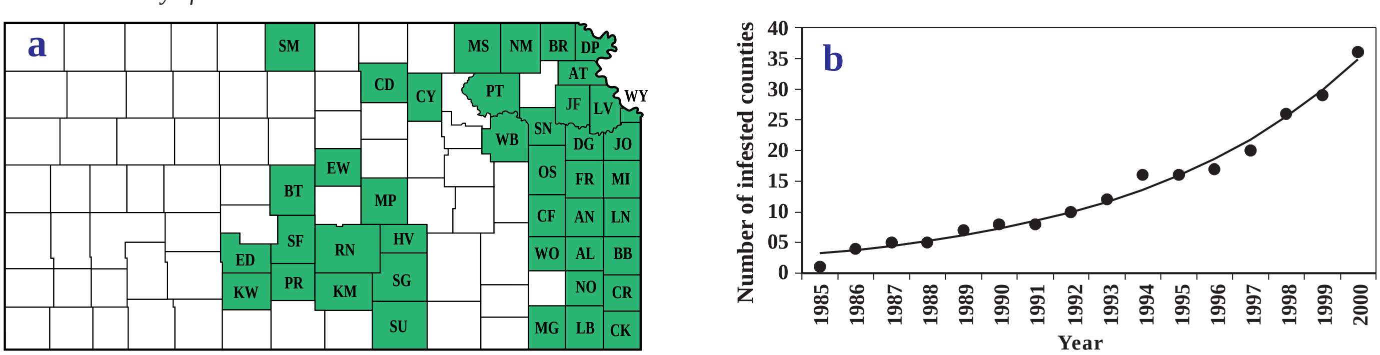
FIELD SYMPTOMS

The most commonly observed symptom associated with SCN is reduced yield. Identifiable symptoms of plant damage are often difficult to see, especially in high yielding environments such as irrigated soybeans. The visible symptoms of SCN injury that do occur can easily be confused with other soybean production problems including potash deficiency, herbicide injury, seedling blight damage, iron chlorosis, charcoal rot, drought, Phytophthora root rot, and soil compaction.

Yield loss may occur for several years before visible symptoms appear. The first noticeable symptoms are roughly circular spots in the field in which soybean plants may show signs of stunting, yellowing or nutrient deficiency (Fig. 2D). Roots have fewer feeder roots and nitrogen-fixing root nodules.

Heavily infested plants may die directly from nematode feeding or from the combination of nematodes plus

Fig. 1. Distribution and spread of SCN in Kansas. a) Current distribution. b) Increase in number of infested counties since the initial discovery of SCN in 1985.



nutrient deficiencies or other diseases. In heavy infestations, symptoms are most evident by the time plants are 6 to 12 inches tall. In lighter infestations, symptoms may not appear until the beginning of podding.

Infested areas may increase in size annually and become oval shaped, expanding in the direction of tillage. Damage is usually most severe in the center of infested areas, becoming less severe toward the margins. Effects are worse in sandy soil where water and nutrient levels are more variable; however, serious SCN damage also occurs in heavier soils.

DIAGNOSIS

Accurate diagnosis of the problem may be delayed several years because of the similarity of symptoms to other production problems. Frequently, SCN is suspected only after eliminating all other possibilities. **The only sure way to identify SCN damage is by a soil test.**

For detection in a field planted to soybeans, collect suspected plants with roots and surrounding soil attached. Use a shovel to carefully lift the plants from the soil. Pulling the plants out will often dislodge cysts and may result in an inaccurate diagnosis.

Soil samples can be collected throughout the year, but immediately following soybean harvest is the optimum time since SCN numbers tend to be highest when the plants are almost mature to shortly after harvest. When sampling, it is best to use a cylindrical soil probe. Many county extension offices have soil probes available to loan if you do not own your own. Collect 10 to 20 soil cores in a zig-zag pattern across the entire area to be sampled. Collect cores to a depth of 6 to 8 inches. Ideally, a sample should be taken from no more than a 10- to 20-acre area of the field. Separate samples should be submitted when several areas of a large field are to be sampled. When soybean plants or stubble is present, probing directly in the row will maximize the chances of detecting the nematode. Bulk the cores in a container (bucket) and mix thoroughly. Place about 1 pint of mixed soil in a plastic bag or a standard wax-lined soil sample bag and label the outside of the bag with a waterproof marker with your name and field identification information. Whenever possible, a completed *Plant Disease Checksheet*, available at local K-State Research and Extension offices, should accompany the sample. Store the sample away from sunlight in a cool (not frozen) area until it is shipped to the laboratory to protect the nematodes from dying and to ensure an accurate diagnosis.

The samples should be submitted through the local K-State Research and Extension offices whenever possible, but they can be forwarded directly if it is more convenient. Send to: *Plant Disease Diagnostic Clinic, Department of Plant Pathology, Kansas State University, 4024 Throckmorton Hall, Manhattan, KS 66506-5502.*

The glossy, enlarged bodies of female cyst nematodes can often be seen attached to roots (Fig. 2E). Mature cysts are more difficult to see because they are only the size of a pinhead and their color changes from white to a golden yellow to dark brown as it matures. They also dislodge easily from the roots unless the soil is carefully broken away. Early in the season, white females are most common, but as the season progresses, all stages of cyst colors are present. Attached cysts may be easier to find on roots near the perimeter of a severely affected area, rather than on the most severely damaged plants. **Do not rely upon visual inspection of attached cysts for diagnosis.**

GENETIC DIVERSITY

Populations of SCN are genetically diverse, varying in their ability to reproduce on different plant species and

Fig. 3. Female indices for representative SCN populations on the two most common sources of resistance. Indices are calculated as the % cyst production on each line compared to that on the standard susceptible cultivar Lee.

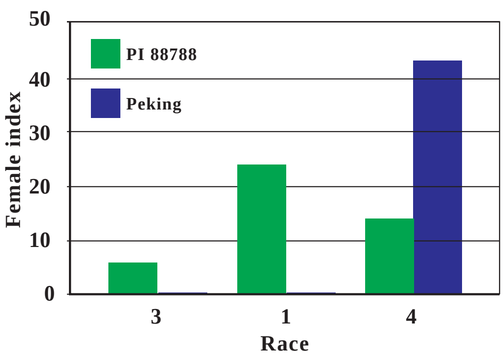
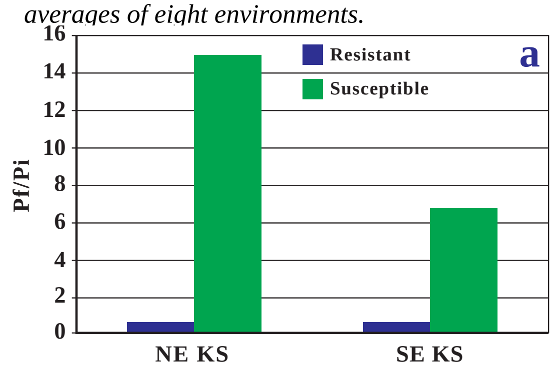


Fig. 4. Effect of resistance on a) SCN reproduction. Pf/Pi = number of eggs and juveniles per 100 cm3 soil at harvest/number of eggs and juveniles per 100 cm3 soil at planting. Data are averages of eight environments.



rotation option. The benefits associated with including a susceptible soybean crop in a rotation include greater variety selection and a break from the selection pressure that occurs on resistant varieties. There are also risks associated with planting a susceptible soybean variety, even when low levels of SCN are present, and these must be considered carefully. Nematode populations can increase rapidly on susceptible cultivars. Several years' worth of population reductions can be erased in a single growing season (Fig. 6). Additionally, yield losses as great as 30 percent have occurred on a susceptible soybean crop following 3 years of rotation with nonhost crops and resistant soybean varieties.

The ability of some additional Kansas crops to serve as a host for SCN is shown in Fig. 7. In some cases, the level of nematode reproduction on a given plant species will vary from one SCN population to another. This fact has resulted in confusion about the host status of a number of crop and weed plants, making general recommendations difficult.

Planting Date and Cultivar Maturity. Delaying planting, such as in a wheat-soybean double-cropping rotation, can result in lower SCN egg numbers at the time of planting compared to nematode numbers for an earlier planted, full-season soybean crop. This difference in nematode numbers generally has little influence on soybean yields, with nearly identical levels of yield loss occurring in both cropping systems in Kansas (Fig. 8a).

In southeastern Kansas, maturity group V varieties usually exhibit less yield loss due to SCN than earlier-maturing cultivars (Fig. 8b). A similar relationship has been documented for charcoal rot severity in this region of the state. In the case of SCN, differences in yield loss among varieties from maturity groups III through V are partly related to differences in growth development type (determinant vs. indeterminant). The same pattern is not expected for areas of the state where the adapted soybean varieties are all of the indeterminate growth type (e.g. maturity groups II through IV).

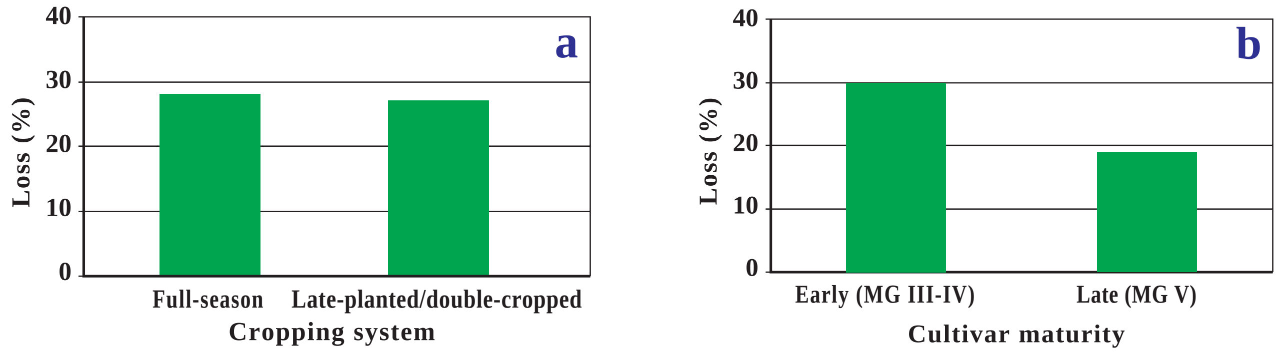
Tillage. Recent research at Iowa State University has documented lower SCN population numbers in no-till compared to tilled soybean fields across the north central United States. This relationship is dependent upon soil texture, however, with the largest differences observed in clay soils and no differences observed in sandy soils. Other research suggests that producers that double-crop soybean following wheat may experience the greatest management benefit from no-till.

Fertility and Weed Management. Good soil fertility and water management are necessary to achieve the yield potential of any soybean variety. This relationship can be magnified in fields infested with SCN because the nematode interferes with water and nutrient uptake by the plant.

Numerous weed hosts have been described for SCN. As noted earlier, however, the host status of individual plant species can vary among SCN populations. Recent studies in Ohio have demonstrated that purple deadnettle and henbit can serve as alternate hosts, raising new concerns about control of winter annuals in soybean fields. As a rule, effective weed control is necessary to ensure optimum SCN management.

Nematicides. Nematicides are not recommended for SCN control in Kansas. Susceptible varieties treated with nematicides produce yields comparable to, but no better than, those of resistant varieties. The reduction in nematode numbers immediately following nematicide application is usually short-lived, and numbers return to their preseason levels by harvest.

Fig. 8. Effect of a) cropping system and b) cultivar maturity on yield loss to SCN in southeastern Kansas. Data are averages of six (a) and four (b) environments.



on soybean varieties with different resistance genes. Field populations traditionally have been classified as **races** based on an index of the number of females that develop on a set of four differential soybean cultivars compared to the standard susceptible cultivar Lee.

$$\text{Female index} = \frac{\text{\# of cysts on the resistant variety}}{\text{\# of cysts on the susceptible variety}} \times 100$$

Two of these differentials, Peking and PI 88788, are especially important because nearly all (99 percent) commercial, SCN-resistant soybean varieties adapted for Kansas currently derive their resistance from one (primarily PI 88788) or both of these sources. Female indices on Peking and PI 88788 are shown for representative SCN populations in Fig. 3. Most SCN populations in Kansas can be classified as Race 3, and do not reproduce well on either resistance source. A few populations, however, do have the ability to reproduce on one or both resistance sources. Race classification of SCN populations is available through the Plant Disease Diagnostic Laboratory at Kansas State University, but generally is recommended only for new infestations. **Populations within a designated race can, and do, vary in their response to soybean lines other than those used in the differential test, including varieties developed from the standard resistance sources.**

Broad resistance to diverse SCN populations is being incorporated into adapted soybean varieties by breeders. These resistant varieties, derived from the soybean variety Hartwig (originally from its resistant parent PI 437654) are limited, but should be more readily available in the future. Information on sources of resistance in adapted soybean varieties is available at K-State Research and Extension offices in the publication *Kansas Performance Tests with Soybean Varieties* and through local seed dealers.

POPULATION INCREASE AND SPREAD

Both local and long distance spread of SCN occurs by any means of soil movement. Local spread of SCN occurs primarily through movement of cyst-infested soil by wind, water (such as when streams or creeks overflow their banks onto cultivated fields), and farm equipment (including tractors, tillage implements, spray applicators, and combines). Cysts also may be transported long distances by migratory birds, seed sources contaminated with soil peds, and custom applicators and harvesters. Soybean growers can reduce the risk of spreading SCN to additional fields by working noninfested fields first and washing adhering soil from equipment after leaving infested fields. Seed should be completely free of soil when produced in or purchased from infested areas.

Once introduced, the length of time required for a damaging population to develop depends on the frequency of susceptible soybean crops and environmental conditions, especially soil texture. The rate at which populations increase starting from low egg densities is significantly greater in coarse-textured soils. Generally, SCN infestations precede noticeable damage by several years so that by the time a problem is detected, the nematode has already spread throughout the field.

DAMAGE THRESHOLDS

The amount of yield loss in a soybean crop is usually related to the SCN egg density at planting. The damage threshold is the population level at which measurable yield loss occurs. Threshold levels vary with environment, but are lowest under conditions that favor large population increases such as coarse-textured soils, long growing seasons, and warm temperatures. In Kansas, economic damage in coarse textured soils can occur with as few as 300 eggs per 100 cubic centimeters (cc) of soil at planting or 1,000 eggs per 100 cc of soil in fine textured soils. When SCN egg counts exceed 5,000 eggs

Fig. 4. Effect of resistance on b) seed yields in soybean variety trials at nematode infested locations in Kansas. Pf/Pi = number of eggs and juveniles per 100 cm3 at harvest/number of eggs and juveniles per 100 cm3 soil at planting. Data are averages of eight environments.

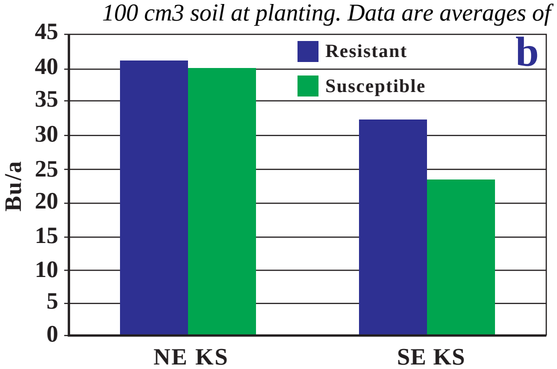
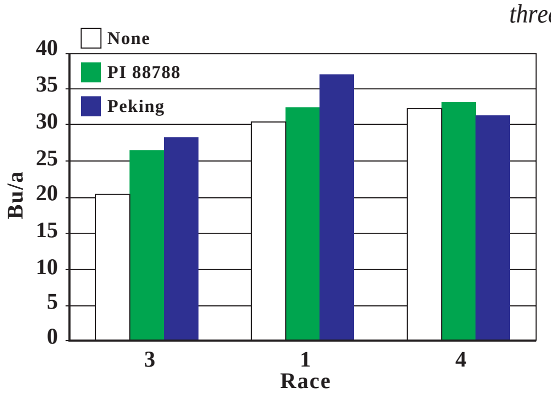


Fig. 5. Yield advantage of soybean varieties with SCN resistance derived from Peking or PI 88788 over a susceptible variety in the presence of three SCN populations.



Data are averages of eight environments.

per 100 cc in coarse textured soils or 10,000 eggs per 100 cc in fine textured soils, nonhost crops should be considered in place of even resistant varieties.

MANAGEMENT

The goal of SCN management is to minimize the risk of soybean yield loss by reducing and maintaining egg numbers below economic damage thresholds. This goal is best achieved with an integrated management program that emphasizes host resistance and rotation with nonhost crops. Periodic soil sampling is necessary to monitor SCN egg numbers and to evaluate the performance of selected management strategies.

Resistant Varieties. Resistant varieties work by limiting the reproduction of SCN on roots, which typically results in nematode population declining during the growing season. By comparison, high rates of nematode reproduction on susceptible varieties usually result in large population increases (Fig. 4a). A decline in nematode reproduction can provide a yield advantage to resistant varieties, although the comparative performance of resistant and susceptible varieties varies with environment and level of infestation. In northeastern Kansas, where deep soils and low to moderate levels of nematode stress (≤ 1,000 eggs/100 cm^3 soil) are common, yields of resistant and susceptible varieties may be similar. In southeastern Kansas, however, where shallow soils often contain large numbers of nematodes (≥ 4,000 eggs/100 cm^3 soil), the yield advantage from planting a resistant variety can approach 10 bushels per acre or 40 percent (Fig. 4b). Based on limited performance data from the south central Kansas, growers can expect an intermediate yield advantage (≈ 25 percent) from planting a resistant variety on moderately-infested, irrigated sands.

Adapted, high-yielding resistant varieties are available for most SCN populations in the state. To obtain the maximum benefit from planting a resistant variety, the source of SCN resistance must be matched with the ability of a given nematode population to reproduce on that source. This can be seen in the yield performance of soybean varieties with either Peking or PI 88788 as the source of resistance grown in the presence of three SCN populations (Fig. 5). While both sources of resistance provided similar yield advantage over the susceptible variety when a Race 3 population was present, Peking-derived resistance was clearly better when Race1 was present. Neither resistance source provided a significant yield improvement over the susceptible variety in the presence of a Race 4 population. The ability of SCN populations to adapt to resistant varieties is a major concern. Research suggests, however, that periodic soil sampling will detect any changes in the nematode population structure before yield loss on a resistant variety occurs. Rotation of resistant varieties, preferably with different resistance sources, may limit adaptation of SCN populations. This strategy, while often recommended, has not been proven to be effective.

Crop Rotation. All crops commonly planted in rotation with soybean in Kansas, including corn, grain sorghum, and wheat are nonhosts for SCN and, like resistant soybean varieties, will usually result in a decrease in nematode numbers. A rotation scheme that alternates resistant soybean varieties and nonhost crops will produce a steady decline in SCN egg numbers (Fig. 6). The actual rate of decline will depend on the initial number of eggs (survival is density-dependent, with survival rate increasing as population numbers decrease) and environment (overwinter survival is high in the north central United States and low in the southern United States).

Once SCN numbers have been reduced below damage threshold levels, susceptible soybean varieties become a

Fig. 6. Decline in SCN egg levels during a rotation of nonhost crops and resistant soybean varieties (solid line). A single susceptible soybean crop increased nematode populations to levels equal to or greater than those found on continuous soybean (dashed line). Data are averages of four environments.

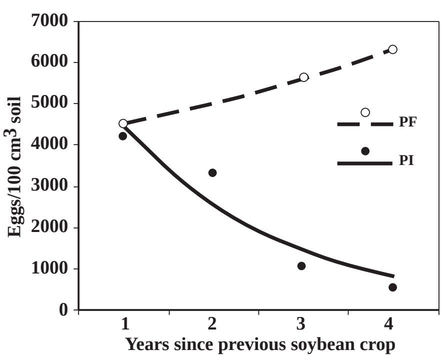


Fig. 7. Host status of four soybean varieties and seven other crops for two SCN populations. Indices are calculated as the % cyst production on each plant compared to that on the standard susceptible cultivar Lee. Error bars represent minimum and maximum values.

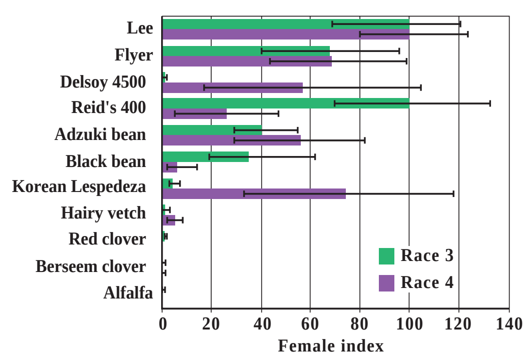
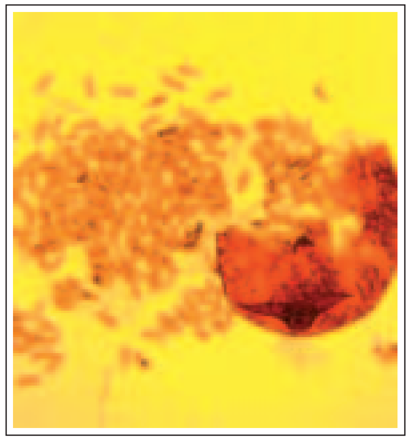
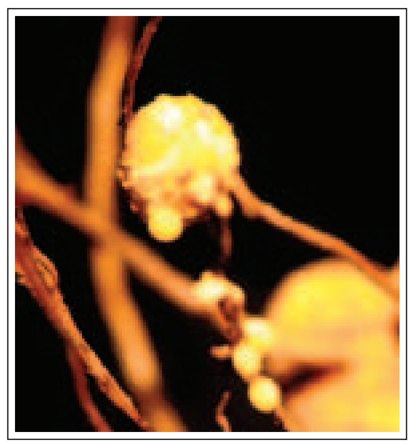


Fig. 2. Stages of development of a soybean cyst nematode infection.

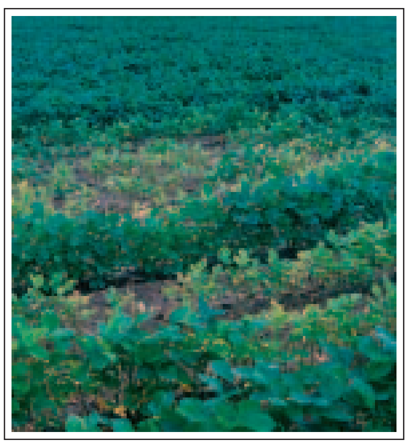


***A.** Eggs being released from a ruptured cyst*

***B.** Second stage juvenile. This is the stage that infects the roots.*



***C.** Immobile white females feeding on the roots. The larger nitrogen nodule can be used for size comparison.*



***D.** Aboveground symptoms associated with cyst nematode injury.*

***E.** A heavily infested root system. The cysts will slough off into the soil and remain there until a host plant is again available.*

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned.

Publications from Kansas State University are available on the World Wide Web at: http://www.oznet.ksu.edu

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

L-786 November 2001