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The soybean cyst nematode

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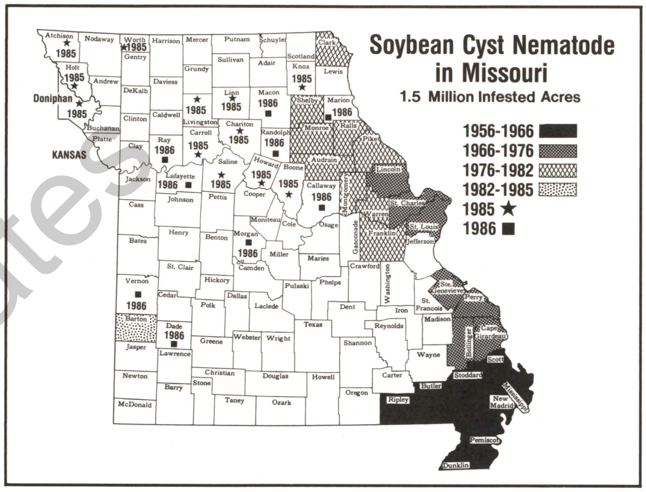
The soybean cyst nematode, *Heterodera glycines* Ichinohe, attacks soybean roots and is a serious threat to the crop in many soybean growing areas. This tiny, parasitic roundworm is so named because the female body, when filled with eggs, is known as a cyst. Cysts may remain in and infest soil for several years. The nematodes' persistence and rapid production, along with the severe injuries they cause to host-plant roots, make the nematodes a serious agricultural threat.

The soybean cyst nematode (SCN) is believed to have been imported from Asia. It has been present in soybean producing areas of Japan, Korea and Manchuria for 50 or more years. First discovered in the United States in 1954 in North Carolina, it has since been found in 22 additional Southeast and Midwest states: Alabama, Arkansas, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Minnesota, Mississippi, Missouri, Ohio, Oklahoma, South Carolina, Tennessee, Texas, Virginia and Wisconsin. About 20 percent of the total soybean acreage in the United States is now affected, and the outer boundaries are enlarging.

The soybean cyst nematode was first discovered in the Missouri Delta in 1956 in Pemiscot County. About 1.5 million acres are now infested in Missouri. Spread of the nematode has been persistent and has become a serious economic problem to many Missouri farmers.

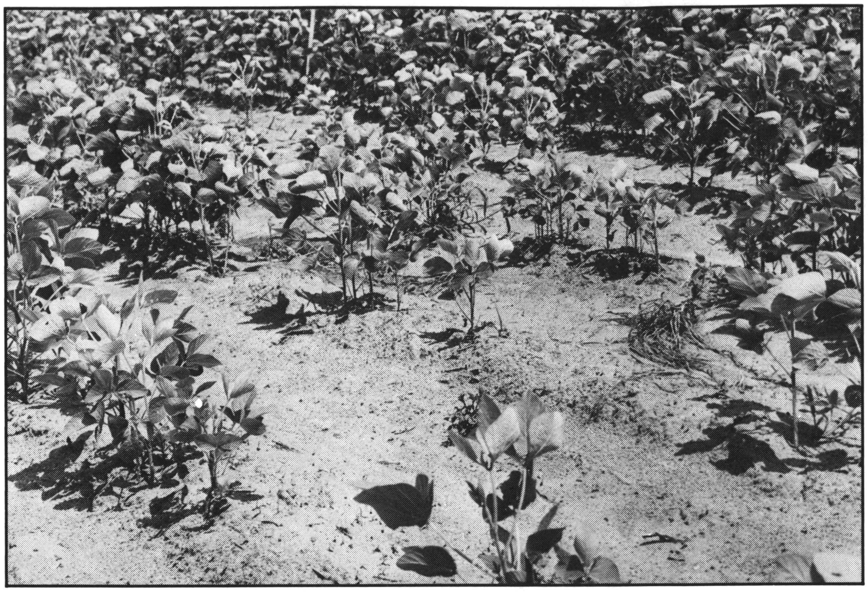
Infestations are widely distributed in all counties of the Delta area. In 1971, infestations were found in east-central Missouri in St. Louis, St. Charles and Lincoln counties. In 1977, new locations in southeast Missouri were discovered in Bollinger, Perry and Ste. Genevieve counties; and in east-central Missouri, new infestations were found in Audrain, Franklin



The soybean cyst nematode is spreading through Missouri.

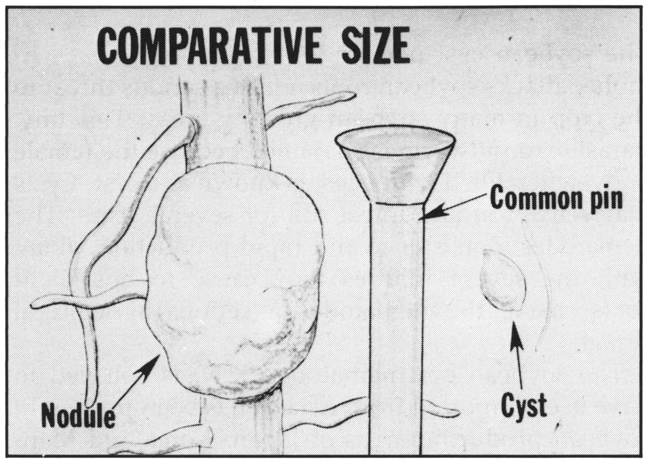
Numerous cysts, shown here magnified, are attached to the roots of heavily infested soybean plants.

Stunted plants in circular spots in fields may indicate soybean cyst nematode injury.



and Warren counties. In 1978, the nematode was found in Ralls County. Since then, Clark, Shelby, Marion, Monroe, Montgomery and Pike were added to the list of infested counties. Barton County in southwest Missouri was added in 1982. In 1985, Atchison, Holt and Worth counties in northwest Missouri were added. In north-central Missouri, infestations were found in Livingston, Linn, Carroll, Saline, Chariton, Howard and Boone counties. Knox County was a new county in northeast Missouri. Morgan, Ray, Lafayette, Callaway, Dade, Vernon, Macon and Randolph counties were added to the list in 1986.

Although estimating losses resulting from the soybean cyst nematode is difficult, the relentless increase in the number of infested acres and the steady buildup in infested soils make the pest a multimillion-dollar problem every year in Missouri. At least $30,000,000 and perhaps more than double that amount may be lost annually by farmers in the Missouri Delta. Yield losses on individual farms may vary from slight to 90 percent, depending upon the extent of SCN infestation; soil types and fertility; soil moisture; variety susceptibility; age and vigor of soybean plants; races of the nematode present; presence of other parasitic nematodes, such as the root knot nematode; other fungus root diseases; and many other environmental conditions.



The cyst is smaller than the head of a common stick pin.

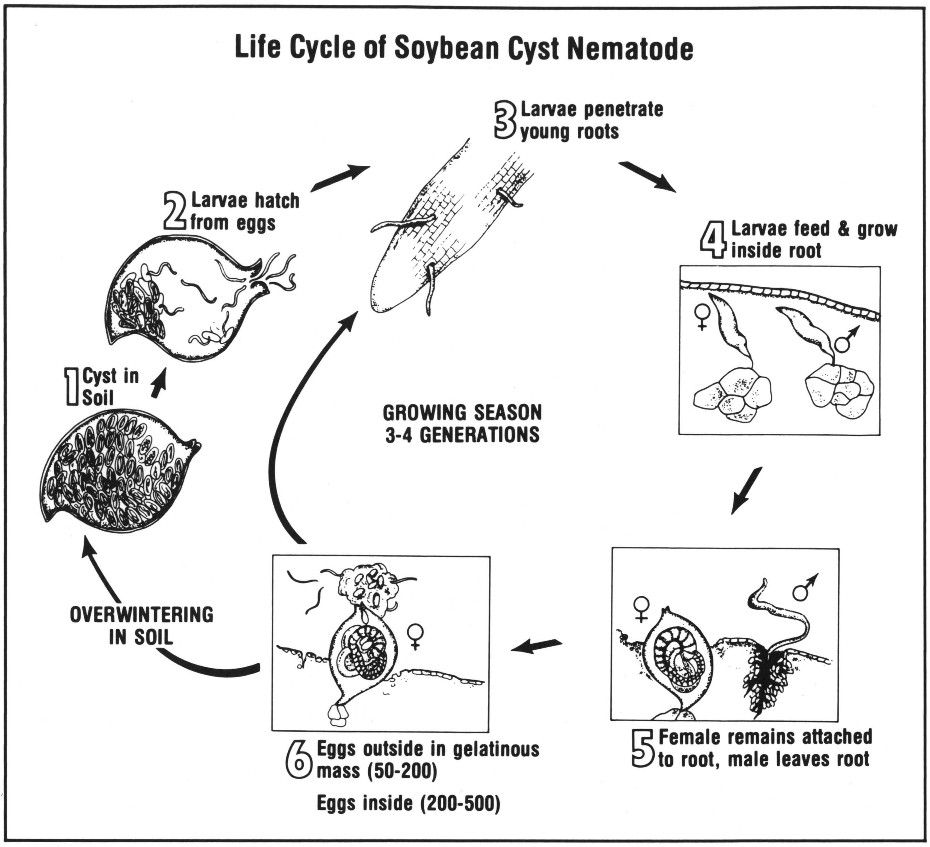
Field symptoms

The first symptom of cyst nematode injury in soybeans is a circular area of stunted, yellow plants. The Japanese call the disease "yellow dwarf" because of these characteristic symptoms. Yellowing is mainly due to nitrogen deficiency resulting from inhibition of *Rhizobium* nodule formation.

When an infestation of the nematode is high, the dwarfing and occasional yellowing are easily recognized. Early field detection may be difficult with light infestations, however, or in high-fertility soils because symptoms may be almost absent. Roots of normal-looking plants can support a nematode population that may cause serious injury to the following soybean crop. Light-to-moderate SCN infections stimulate over production of lateral roots. Root systems of heavily infected plants are drastically reduced, necrotic and devoid of nodules. Examination of the roots with a hand lens reveals minute white-to-yellow females and brown cysts attached to the roots. They are much smaller than nodules.

Most symptoms of SCN injury can be easily confused with other crop production problems—soil compaction, nutrient deficiencies, drainage, drought injury, herbicide injury and other soybean diseases and disorders.

Injury from SCN is more severe in light, sandy soils. It will also be found in heavier soils, though the symptoms are not as dramatic.



The soybean cyst nematode life cycle: 1. Cysts overwinter in soil. 2. Larvae hatch from eggs. 3. Larvae penetrate young roots in spring. 4. Larvae feed and grow inside the root. 5. Female nematodes remain attached to the root; males leave. 6. Eggs form inside the cyst and outside it in a gelatinous mass.

How the nematode lives

The soybean cyst nematode has a five-stage life cycle: egg, second, third, and fourth stage larvae, and adult. Under Missouri summer conditions, the nematode requires about 30 days to complete a life cycle. Thus, this pest may complete three to four generations in a single growing season from mid-May until late September. The tremendous increase in nematode population during one growing season can result in severe damage to the crop.

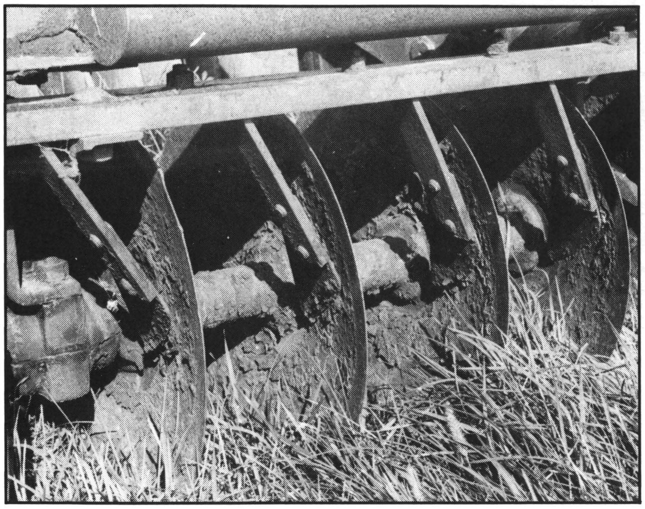
The nematode overwinters in the egg stage, enclosed inside the dark brown, lemon-shaped body of a dead adult female. This cyst is smaller than the head of a common pin or a small grain of sand. The cyst's tough, thick skin is highly resistant to decay, heat and desiccation. It can protect its 200-plus eggs or larvae for a long time under unfavorable conditions.

Eggs in cysts can remain viable for several years in field soils. Survival depends on soil temperature, soil moisture and other environmental factors. Survival decreases as soil temperatures increase. In dry soils, some eggs may survive in cysts for several years under cool conditions. Viability decreases more rapidly when dry soils are exposed to high temperatures or when soils are flooded. Dried but viable cysts are brought to the soil surface by soil preparation, which makes it easy to disseminate this parasite.

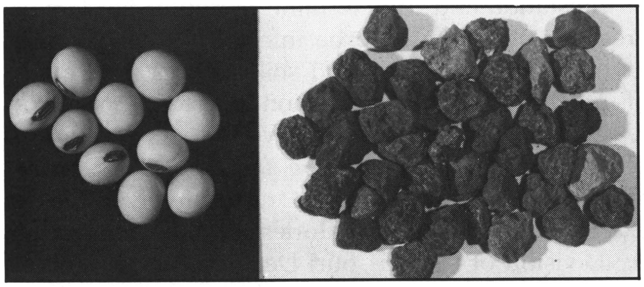
As with most plant-parasitic nematodes, the larvae of the SCN molt once while still in the egg. After some development, the second-stage larvae emerge from the eggs when the soil temperature reaches 60 degrees F. A "hatching factor" from the soybean roots may be involved. The larvae move through the soil and enter the soybean root tips. Once in the tips, they move between the root cells and become established in the root tissues. By secreting saliva into the root tissues, the larvae produce areas known as syncytia. The larvae become sedentary while their stylets are inserted in the developing syncytia, upon which they feed. The larvae then undergo a second molt, which is quickly followed by a third and fourth molt to the adult stage. The sex of the SCN can be determined in the third molt stage.

As the larvae feed, their bodies swell. Developing males and females become sausage-shaped and sessile. The bodies of the adult females continue to swell and eventually break through the root surface, with the heads and necks remaining inserted under the surface. The males change into a long, slender, worm-like shape at maturity. They leave the roots to move about in the soil.

The males and females mate, and 200-500 eggs develop inside the females. The females retain most eggs within their bodies, the walls of which become the protective cysts. They deposit some of the eggs (50-200) in gelatinous secretions outside the cyst. These eggs hatch within a few days, producing second-generation, second-stage larvae. They can reinfect soybean roots, thus repeating the cycle. The females die when egg-laying ceases.



Left: Farm machinery carrying infected soil may spread the soybean cyst nematode to other fields. **Below:** Small soil particles, known as soil peds, that are mixed in with poorly cleaned seed lots may be responsible for cyst spread.



Races of soybean cyst nematode

Originally, four races of cyst nematode were identified in 1970. Races 1 and 2 were predominant in North Carolina and Virginia; race 3 was present everywhere the nematode was isolated; and race 4 infestations were centered in southeast Missouri, southern Illinois, western Tennessee and northeastern Arkansas. With the continuous use of cultivars resistant to race 3, race 4 became more widespread. Recently, race 5 was identified in areas where race 4 resistant cultivars have been planted for a number of years. Usually, a field is infested with more than one race. The use of a cultivar resistant to one race and susceptible to another race tends to change the race pattern in a field.

In actuality, the SCN apparently is highly variable in its pathogenicity, with perhaps an infinite number of biotypes that can adapt to changes in soybean cultivars.

How the nematode spreads

The soybean cyst nematode can move through the soil only a few inches on its own. It can, however, be spread easily by soil moved with farm and construction equipment, root crops, nursery plants, containers, seed and other articles.

Farm machinery covered with particles of soil can spread the pest to other fields in which the equipment is used. Equipment used on a custom basis can distribute the SCN over a wide area.

Normal surface drainage, flood waters and wind movement can spread SCN. Man, domestic or wild animals and cars or trucks driven through fields also can spread it. Since the mature cysts float on water, flood waters probably account for much spread. Wind movement of infested soils also accounts for considerable local spread. Cysts have been found in windblown sand samples.

Long-range dissemination also may be brought about by migratory birds. Cysts, eggs and larvae can pass through the digestive tracts of blackbirds or water fowl and remain viable. Migrating birds may move nematodes north and south.

An important cause of spread has been contaminated soil particles in soybean seed. Cysts have been found in "soil peds" mixed in with poorly cleaned seed lots or stuck to seed bags. Soil peds may retain viable eggs for 22 months. Distribution of contaminated seed was probably responsible for the rapid and uniform spread of the soybean cyst nematode in the Delta area of Missouri.

Using Clipper-spiral seed cleaners and certified seed has greatly reduced the problem of soil-contaminated soybean seed. Uncleaned soybean seed, however, is still a potential threat.

Host plants

Although more than 1,100 species of plants have served as hosts under experimental conditions, the critical host species are relatively few. The soybean is by far the principal favored host. Certain other legumes may also be hosts, including lespedeza (annual and common), vetch (common and hairy), adzuki bean, garden bean (common and snap) and white lupine.

Some weed hosts may be involved, including low hop clover, common mullein and hemp sesbania (coffee weed). Although these other hosts may be a part of SCN survival mechanisms, rapid buildup of nematode populations has been almost exclusively associated with growing susceptible soybeans year after year.

What is being done?

Since the discovery of the soybean cyst nematode, the U.S. Department of Agriculture, the departments of agriculture in Missouri and other states, the University of Missouri-Columbia College of Agriculture and colleges of agriculture in other states have cooperated in efforts to combat the pest. Surveys to locate and evaluate infested areas, regulatory efforts to reduce spread, cultural and chemical measures and experiments to develop suitable nematode-resistant varieties are underway.

Surveys have been conducted to detect new areas of infestation and to determine the outer borders of areas already known to be infested. Other surveys involve collecting plant and soil samples from areas of intensive soybean production to determine severity of infestation and races involved. Roots of soybean plants are examined for live females. Greenhouse tests are used to determine races involved. State extension diagnostic laboratories and the Plant Industry Division of the Missouri Department of Agriculture have cooperated in these efforts.

Quarantine regulations on the federal and state level were implemented when the soybean cyst nematode became an imminent threat in 1954. They were designed to prevent accidental introduction of the pest into nematode-free areas.

The USDA's quarantine was withdrawn in 1972 because it was believed to be ineffective in preventing spread. Since discontinuation of the federal quarantine program, the Plant Industry Division has continued a modified regulatory program for interstate and international shipments of soybean seed, nursery stock and agricultural equipment from affected areas. Departments of agriculture in adjacent states have carried on similar programs.

Control measures

The SCN is controlled by trying to prevent its spread and by reducing and maintaining nematode numbers below the crop damage level. Integrated control measures include: sanitation, crop rotation, resistant varieties, fertility management, chemical control and biological control.

Sanitation. A good sanitation program on the farm helps prevent movement of nematodes by mechanical means. Producers should exercise caution to avoid introducing nematodes into non-infested fields. Thorough machinery and equipment cleaning is important. Producers should carefully wash equipment with a pressure hose or use steam cleaning equipment, which does a more thorough job because steam can penetrate hard-to-reach places. They should also exercise care in traveling over infested areas, and avoid working these areas before working non-infested fields.

Crop rotation. Rotation of soybeans with non-host crops (corn, cotton, sorghum, wheat) offers one of the most practical means of control. Planting a non-host crop for one or two years generally results in a decrease in SCN populations and an increase in

Prevent movement of nematodes by steam cleaning farm equipment.

yield of subsequent soybean crops. Nematode numbers in soil samples have been reduced up to 75 percent by one-year rotations and up to 92 percent by two-year rotations. Additional years usually add smaller reductions. Using a resistant variety has virtually the same effect.

Populations of SCN resurge rapidly when susceptible varieties are planted in a rotation program. Yields may not be affected the first year of soybeans, but losses may be significant in subsequent years. Therefore, crop rotation programs need to be coupled with resistant varieties to be most effective.

Resistant varieties. Soon after the discovery of the SCN in the United States, a search was made to isolate sources of resistance to this disease. At that time, race 3 of SCN was the most predominant biotype in the country. After several years of research, race 3 resistance from a black-seeded variety, Peking, was successfully transferred to yellow-seeded varieties.

A Lee background variety, Pickett, was the first race 3 resistant cultivar developed in the mid-1960s. The first set of cultivars—Custer, Dyer and Pickett in maturity groups IV, V and VI, respectively—all carried resistance from Peking. These cultivars were slightly less productive than the best commercial cultivars in non-infested land. However, they served as parental stocks for further improvement.

A second cycle of cultivar development resulted in the release of Forrest and Mack in maturity group V, Franklin in group IV and Centennial in group VI. These cultivars combined high yielding abilities and SCN race 3 resistance. They have out performed the conventional cultivars not only in SCN infested land, but even without the presence of the nematode. Among these, Forrest became the most cultivated variety in the Missouri Delta and is still popular in areas that use group V varieties.

Widespread and continuous use of race 3 resistant cultivars resulted in the emergence of race 4 of SCN, which could attack all race 3 resistant cultivars. Using resistance from PI 88788, a black-seeded soybean line, several race 4 resistant cultivars have been developed and released. They include Bradley and Jeff in group VI, Bedford and Nathan in group V, Egyptian in group IV and Fayette in group III. Two group II cultivars, CN210 and CN290, with resistance to race 3 were released for cyst-infested areas of the north-central states.

In recent years, several cultivars resistant to one or more races have been released by private seed companies. To select cultivars, farmers should consider the maturity group and the race of SCN present in the field. Resistance or susceptibility to other diseases is also important in selecting a soybean variety.

All currently grown resistant cultivars derived their race 3 resistance from Peking and their race 4 resistance from PI 88788. A new race, classified as race 5 in Japan, has been observed in several areas in Missouri, Arkansas and Tennessee. Although all our cultivars are susceptible to race 5, the extent of damage caused by it has not been substantiated.

Nevertheless, there is a need to diversify the sources of SCN resistance to stabilize soybean yields. The work conducted at the Delta Center of the University of Missouri led to the discovery of 31 new soybean lines resistant to race 3 and several others resistant to races 4 and 5. One of these lines (PI 437654) is almost immune to all the SCN races present in the country. This soybean line is currently being incorporated in our soybean breeding programs.

Fertility management. Whenever soil fertility is deficient, SCN injury and losses can be more severe. The use of fertilizer doesn't control the SCN, but reduces plant stress, especially in nutrient-deficient soils. Fertilizer use, therefore, results in increased yields. Potash-deficient soils have shown increased vulnerability to SCN injury. Fertilizer should be added to soil according to soil test recommendations.

Chemical control. Research and field treatments have demonstrated how chemical soil treatments aid in the control of the SCN. Only a few non-fumigant nematicide chemicals are labeled for use on soybeans. Furadan (FMC), Nemacur (Mobay) and Temik (Union Carbide) are among those that can be used. They are most frequently applied as granules as a band with in-row applicators at planting time. Nematode larvae coming in contact with these chemicals may be killed or disoriented in movement in the soil and in root penetration. Fumigant nematicides are not commonly used. Use of DBCP was prohibited by the Environmental Protection Agency.

The efficacy of nematicides varies, depending on the chemical, method of application, soil type, rainfall, temperature and other environmental factors. Nematicides are useful when resistant cultivars are unavailable. They provide short term protection for susceptible cultivars and usually provide some yield increases. Results from their use are often erratic, and susceptible cultivars protected with nematicides may not perform as well as resistant cultivars. Additional costs and labor should be considered.

Biological control. There is evidence that several parasites of the SCN exist in nature. Fungi, such as *Fusarium oxysporum*, *F. solani*, *Exophiala pisciphila*, *Nematophthora gynophila* and *Catenona auxiliaris*, which are found commonly in agricultural soils, have been found to infect eggs and cysts. Further research into fungus-nematode relationships is needed.

What can producers do?

Report new infestations

Producers should contact the county extension office or plant pest control representative in their area if they have yellow, stunted soybean plants, reduced yields or other unexplained crop losses. They will refer specimens to state extension diagnostic laboratories. It is especially important to submit specimens to state extension laboratories for verification, especially if the SCN has not been previously reported in a county.

Follow recommended production practices

In fields with known infestations, producers should initiate a crop rotation program with non-host crops and use adapted, resistant varieties. Farmers should maintain optimum fertility programs and use nematicides only when planting a susceptible variety in a heavily infested field.

Guard against further spread

To reduce the possibilities of spread from infested to non-infested fields, producers should work the infested fields first and clean (steam cleaning is preferred) machinery before returning to non-infested fields.

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