BIOLOGY AND MANAGEMENT OF SOYBEAN CYST NEMATODE

SECOND EDITION

EDITED BY

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Agriculture is a production ecosystem in which the grower can produce food and fiber for sale so that goods can be purchased with the revenue. A certain investment of labor and capital is needed to produce the crop or crops. Once these investments have been made, the producer has the incentive to protect this investment from various elements, including pests (Headley, 1972).

One of the most serious pests of soybean is soybean cyst nematode (Wrather *et al.*, 2001a). Producers can protect their crop from this pathogen through the wise selection of management strategies. They must consider the costs of each management strategy, including labor and capital, within the framework of their long term financial goals (Khan, 1972; Mumford and Norton, 1984). This chapter will focus mainly on farm level direct and indirect costs associated with the management of soybean cyst nematode. Some of the environmental and social impacts associated with this pathogen will be addressed since they are affected by decisions to manage soybean cyst nematode but are not often considered.

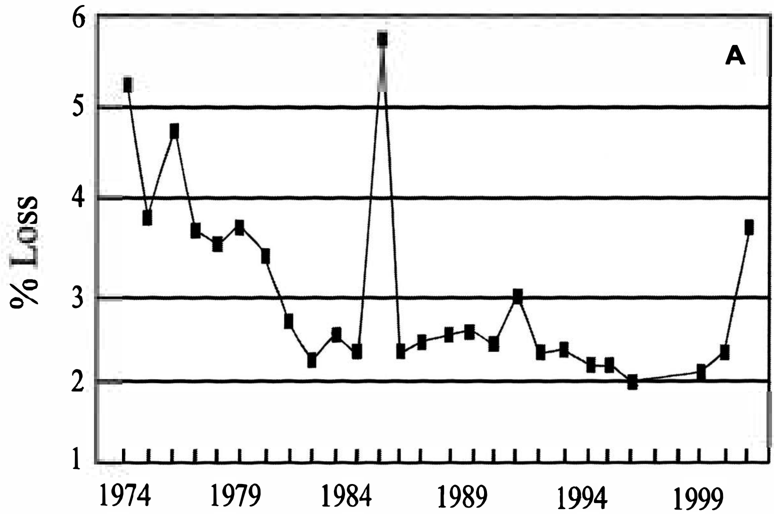
DIRECT COSTS ASSOCIATED WITH SOYBEAN CYST NEMATODE YIELD LOSSES

Yield losses

Most estimates of soybean yield losses from soybean cyst nematode are subjectively-based on observations, field surveys, field research plots and questionnaires. These estimates are indicators of direct yield loss. Eventually, it will be beneficial to develop crop loss data for soybean cyst nematode damaged soybean crops using crop surveys and crop loss models. Soybean cyst nematode suppresses soybean seed yield more than any other disease (Koenning, 1999; Pratt and Wrather, 1998; Wrather *et al.*, 1995; Wrather *et al.*, 2001a; Wrather *et al.*, 2001b; Wrather *et al.*, 2003).

In the USA, losses caused by soybean cyst nematode fluctuate annually (Fig. 1). Average losses are less in the southern USA (Fig. 1A) than the average losses for the entire USA (Fig. 1B). These losses vary considerably by state. The average soybean yield losses for 1999-2001 in the 11 states that produce nearly 90% of the crop in the USA ranged from 0.5% in Nebraska to 13.0% in Iowa (Fig. 2A). Most of the state losses ranged from 2% to 5%. Prevention of these losses should have enabled growers to achieve a higher potential yield (Fig. 2B).

According to the reported crop loss statistics, losses attributed to soybean cyst nematode are generally declining. This decline is assumed to be a result of increased producer awareness of soybean cyst nematode, better use of methods for detecting it and more implementation of soybean cyst nematode management tactics. For example, in the southern USA, the trend of less loss began in 1980, two years after the registration of 'Bedford' soybean. Bedford was resistant to the predominate HG Types (races) in the region. This cultivar became widely grown in several southern states.



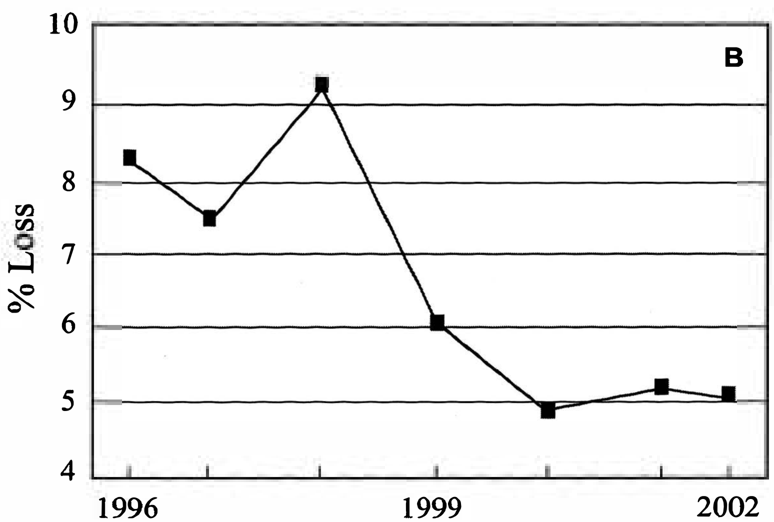


Figure 1. Average estimated percent loss in soybean yields attributed to soybean cyst nematode. A) Southern USA states, 1974-1996 and 1999-2001. B) USA, 1996-2002. (Sources: Koenning, 1999; Pratt and Wrather, 1998; Wrather *et al.*, 1995; Wrather *et al.*, 2003).

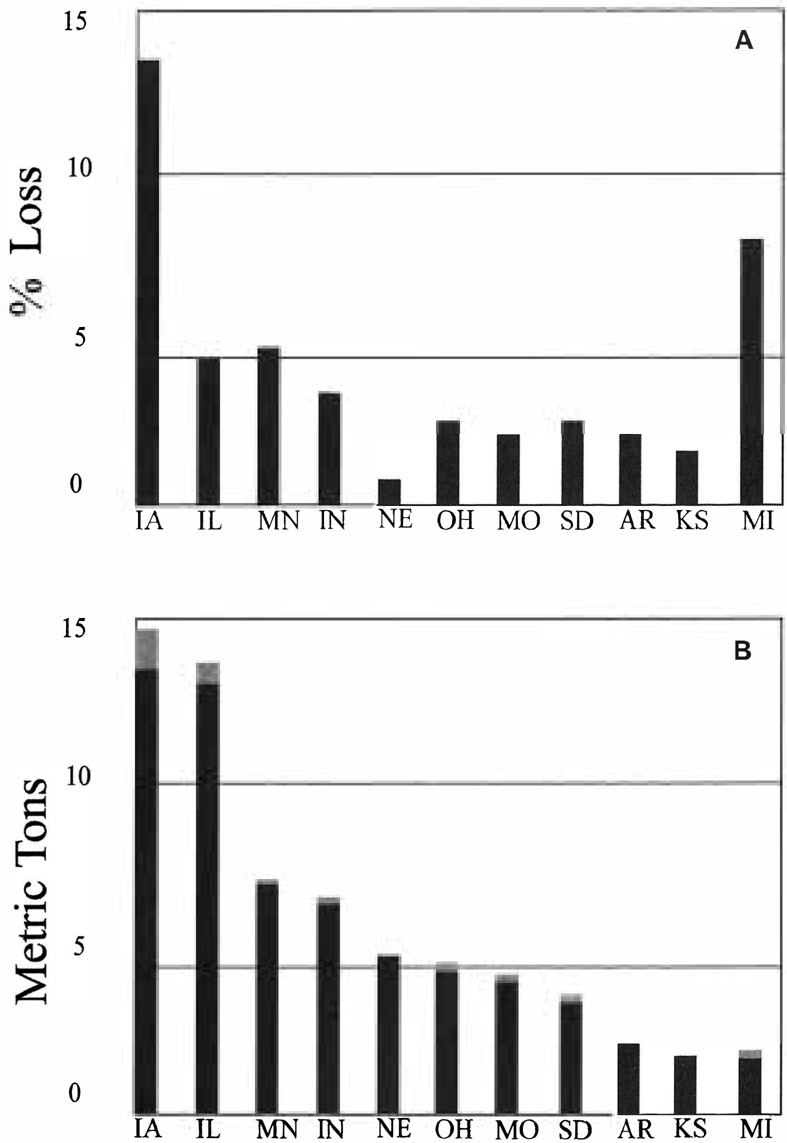


Figure 2. Average of three years production and crop losses attributed to soybean cyst nematode in the top 11 soybean producing states in the USA, 1999-2001. A) Percent loss, B) Production (solid black bars) and theoretical potential production (grey shade bars) without soybean cyst nematode. (Note: data for Minnesota was only available for 2001). (Source: United Soybean Board, 2002).

Profitability

The economic impact of any yield reduction, whether from soybean cyst nematode or other causes, has major implications for the profitability of the producer (Grainger, 1967). In the economic long run, the price per unit received by the producer must cover the cost per unit. The cost per unit of production can be calculated by dividing the total cost of production by the total units produced. Assuming that the producer has a yield of 42 bushels per acre (2780 kg per hectare) and a total production cost of $250 per acre ($615 per hectare), then the per unit cost of production is $5.95 per bushel ($0.22 per kg). If the yield loss from soybean cyst nematode damage was 5% or 2 bushels per acre (54 kg per hectare), then the price per unit needed to cover costs rises to $6.25 per bushel ($229 per hectare). There may be minor cost savings associated with reduced yield, such as time and fuel needed to harvest and to transport the crop, but these savings will be negligible within the overall production budget. For soybean production to be viable, especially at low prices, yield losses from soybean cyst nematode must be minimized to very low levels to achieve the highest possible yields.

Cost of management

A control or management practice should be adopted when the returns from the practice, less costs, exceed the returns from inaction or the current practice (Carlson and Headley, 1987; Pedigo, 1996). This establishes an economic threshold defined by Stern *et al.* (1959) as "the amount of injury which will justify the cost of artificial control measures." Southwood and Norton (1973) presented a practical mathematical expression that has been widely used. That expression is

$$C(a) = Y[s(a)] \times P[s(a)] - Y(s) \times P(s)$$

where: Y = yield, P = price per unit of yield, s = level of pest injury, a = control action, $[s(a)]$ = level of injury as modified by the control action and C = cost of the control action. This equation simply states that the cost of a control tactic equals yield times price when the tactic is applied minus yield times price without the tactic. Consequently, economic damage begins at the point when the cost of damage equals the cost of damage suppression.

Host plant resistance is one of the two tactics commonly employed by growers to manage soybean cyst nematode. Typically, seed of cultivars with resistance cost the same as those without resistance. However, it is important to recognize that the high cost of cultivar development must be absorbed. Most likely, the sales of all seed are adjusted so that research and development costs are covered.

In more practical terms, the cost associated with soybean cyst nematode control using a resistant cultivar is any reduction in yield associated with a susceptible cultivar compared to that of a resistant cultivar. Therefore, the economic threshold for planting a resistant cultivar is the level of infestation that would reduce yield of a susceptible cultivar to the yield of the resistant cultivar, plus costs associated with determining the infestation level and any additional costs that may be associated with planting a resistant cultivar.

Significant cost differences may arise if the soybean cyst nematode resistant cultivar is not compatible with current management practices, particularly herbicide tolerance. The producer may be reluctant to spend capital on alternatives to current practices.

The industry press contains many stories of producers experiencing a significant increase in soybean yields after switching to a resistant cultivar. Unfortunately, this is a clear indication that they went well beyond the economic threshold and incurred significant yield losses in the past that could have been avoided.

The second commonly used tactic to manage soybean cyst nematode is crop rotation with nonhosts (Beron, 1984). Planting a crop other than soybean may also involve costs greater than that associated with growing soybean. Even though many crops are nonhosts of the soybean cyst nematode, growers generally select crops that are marketable and profitable to justify their production. For example, corn as a nonhost is normally grown in rotation with soybean because it is a marketable and profitable crop. The decision is much easier if net returns from the nonhost crop are equal to or greater than that from soybean. In much of the midwestern USA, corn is an example of an economically viable nonhost crop. Producers in some other regions of the world do not have economically viable nonhost crops that can be planted on large land areas.

The concept of an economic threshold for action against soybean cyst nematode is complicated by the time required to provide some measure of control. For example, a 6-year cropping system is recommended in Iowa (Tylka, 1997). The suggested order of crops in the cropping sequence is: nonhost crop, resistant soybean cultivar, nonhost crop, a resistant cultivar with a source of resistance different from that used in the second year, nonhost crop, susceptible soybean cultivar and then repeat the cycle. The costs or lost revenues must be computed for this six year period. Thus, the cost of the strategy must be compared to the losses expected in the current year within the cropping sequence if no action is taken. This requires a net present value analysis wherein the income stream (in this case, expected returns) in each year is discounted up to the current time period.

Mathematically,

$$NPV = \sum_{t=1}^{n} (FV_t)/(1 + d)^t$$

where NPV = net present value, n = the number of time periods considered, FV_t = the cost or loss in time period t and d = the discount rate reflecting the opportunity cost of money. If considered as part of a typical corn-soybean rotation and assigning no economic loss to the nonhost crop (corn) and a loss of \$10 per acre (\$24 per hectare) in the years when a resistant cultivar is planted, the present value of these losses discounted at 5% over thirty years, as compared to a corn-soybean rotation with no losses to soybean cyst nematode, is $52 per acre ($128 per hectare). Applying the same approach to a corn-soybean rotation and letting the value of the losses remain at $10 per acre in each year when soybeans are grown (assuming that the nonhost crop prevents soybean cyst nematode infestation from increasing), the discounted value of losses is $79 per acre ($195 per hectare). A more complete understanding of soybean cyst nematode population response and predictive yield loss models are needed to better evaluate the economic consequences of such strategies.

Ultimately, the level of soybean cyst nematode infestation should be a critical factor in land values and the level of cash rent paid. Prospective buyers and tenants should require a soybean cyst nematode egg count before bidding on a piece of land. During the lease period, landlords should require tenants to use soybean cyst nematode management protocols developed by extension specialists or crop consultants.

In summary, the decision to adopt any type of control depends on many factors in addition to the level of soybean cyst nematode infestation. The profitability of soybeans and alternate crops as determined by prices and costs is critical. Interest rates and the opportunity cost of money changes the net present value of anticipated costs and returns. These are all variable factors, which add risk to any management strategy.

Practical strategies for determining control action

The cost of determining the level of soybean cyst nematode infestation is reasonable, especially considering that cost effective prescriptions can be developed for implementation of a management strategy. The most precise approach is to assay fields for nematodes. An assay to obtain soybean cyst nematode egg counts typically costs $15-$25. Additional costs in time and management are required for sampling fields, submitting the samples and evaluating test results. Another relatively reliable method of assessing economic losses attributable to this nematode is to plant an appropriate complement of resistant cultivars in small representative portions of selected fields. This side-by-side trial minimizes variable effects of weather, soil and time; however, variation is still a factor because populations of soybean cyst nematode are highly clustered within fields. Alternately, on-board yield monitors provide data that can be used to determine areas of fields with low yields. These areas can then be evaluated for the presence of the nematode. If specific fields are known to be infested with soybean cyst nematode, then low yielding areas may be correlated with high population densities of this nematode. All of these methods provide evidence needed to determine whether soybean cyst nematode is a management concern.

Crop loss assessment

Numerous factors are involved in making accurate crop loss assessments in fields infested with soybean cyst nematode. These assessments can be made to determine direct losses using density-dependent damage functions (Duncan and Noling, 1998; Schmitt *et al.*, 1987) (See Chapter 6). The changes in yield across a field and the causes (soil physical and chemical properties, pests, environmental factors, etc.) of these changes need to be carefully evaluated. All of these factors confound the interpretation involved in assessing damage caused by soybean cyst nematode. In fact, the lowest yields in a field will frequently occur in areas of lowest nematode population densities (Schmitt, unpublished). Plant growth is very poor in some areas of fields. These unthrifty plants support little or no development of soybean cyst nematode populations. This same phenomenon also occurs on cotton, cabbage (Schmitt, unpublished) and pineapple (Sipes and Schmitt, unpublished).

INDIRECT COSTS ASSOCIATED WITH SOYBEAN CYST NEMATODE

Loss to producer

Decisions about management of soybean cyst nematode must be made long before soybean or an alternate crop is planted. These management decisions include: monoculture or multiple cropping, planting resistant or susceptible cultivars, use of a nematicide, weed control and choice of cultural practices, such as planting date and tillage. These decisions may be complicated and confounded by a poor understanding of the biology and management of soybean cyst nematode by lending agents and farm advisors. Each decision can affect farm revenue because all have associated costs.

Soybean cyst nematode may also contribute to losses from other diseases (See Chapters 6 and 7). Soybean cyst nematode damage predisposes the plant to other pathogens and further suppresses yield. This potential synergy would lower the level of soybean cyst nematode population needed before some control action is justified.

Loss to the consumer

Consequences to society associated with managing the soybean cyst nematode are often indirect and intangible. Soybean provided two-thirds of the world protein meal consumption and 29% of world vegetable oil consumption in 2000 (United Soybean Board, 2002). An assessment of the gains resulting from improved soybean cyst nematode control requires a determination of the impacts of increased soybean production on the livestock and meat sector and on other plant-based meal and oil sectors.

As mentioned earlier in this chapter, there is not a differential cost between soybean cyst nematode resistant and susceptible seed. Nevertheless, tremendous resources at universities, federal research branches and commercial seed companies are required to bring a cultivar to commercial availability for sowing. This research can result in significant economic gain. For example, the cultivar Forrest [resistant to HG Types 2- and 0- (races 1 and 3)] cost about $1 million to develop and has returned in excess of $400 million in added revenues (Bradley and Duffy, 1982).

In addition, society spends money to control soybean cyst nematode movement across borders. Regulation and inspection is a concern even in countries that are not major soybean producers. Given the spread of soybean cyst nematode around the world, such monitoring may slow, but is unlikely to prevent the introduction of soybean cyst nematode to new uninfested locations.

New uses for soybean should increase demand for the commodity and result in an expansion of the hectareage. Some of these uses include added value products such as tofu, soymilk and cooking oil. Most soybean products are still used as livestock feed supplements. Thus, rising income and a growing population of people increase the demand for livestock products, which in turn stimulate the demand for soybean meal. Other uses such as soy ink are industrial but do require a portion of the soybean supply. The potential of biodiesel as a replacement for fossil fuels is an additional factor in the supply and demand curve.

The impacts on these uses as a consequence of soybean cyst nematode are complex. Increased production of soybean should lower the price and provide benefits to consumers and make other uses of soybean economically viable. However, with the continued spread of the nematode throughout the world, some fields may have to be abandoned or shifted to alternate crops because the nematode is likely to cause more damage and become more widespread.

Soybean production and utilization are global. Any gains from improved soybean cyst nematode control practices will accrue first to those producers. Since soybean cyst nematode has achieved a nearly global dispersal, the economics of soybean cyst nematode management must be considered on a global scale.

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