Worldwide Distribution of Soybean-Cyst Nematode and Its Economic Importance[1]

R. D. RIGGS[2]

Abstract: Soybean-cyst nematode *(Heterodera glycines)* was first reported from Japan in 1915. It has since been reported from Korea (1936), Manchuria (1938), the United States (USA) (1954), and Egypt (1968). It is of major concern to soybean producers only in Japan and the USA. Soybean was a major crop in the Orient by 1915 but it was grown very little elsewhere. Since that time its cultivation has spread, and in 1974 there were 37.6 million ha with a production of 51.7 billion kg. As soybean cultivation has spread, the soybean-cyst nematode has been more widely found. Soybean is one of the major food sources for feeding the increasing world population. Soybean-cyst nematodes have been spreading rapidly in recent years and are a major threat to this very important crop. *Key Words: Heterodera glycines, Glycine max,* soybean.

SOYBEAN-CYST NEMATODE DISTRIBUTION

Soybean-cyst nematode (SCN), *Heterodera glycines* Ichinohe, was first reported in 1915 (20). At that time, the disease caused by this nematode had been observed for several years. A later report indicated that the disease had been noted since 1881 and the cause attributed to *H. schachtii* (3). Subsequently, SCN was reported from Korea in 1936 (35) and Manchuria in 1938 (23) (Fig. 1). In 1954, it was detected in the United States (34). A 1958 publication (21) reported the occurrence of SCN in Taiwan, but this infestation has not been confirmed. SCN was reported on cowpea in the Republic of Egypt in 1968 (7). Cowpea is not a host of U.S. collections of SCN, and a later report (1) indicated that *Heterodera cajani* accounted for at least part of the cyst populations on cowpea in Egypt. Oteifa (personal communication) has indicated that SCN does occur on soybean on some islands in the Nile River.

SCN was first discovered in the U.S. in a bulb-growing area of North Carolina (34). The theory proposed at the time was that cysts were brought to North Carolina on bulbs from Japan (29). This hypothesis was supported by the fact that symptoms of the disease were similar in Japan and North Carolina. Golden (17), however, indicates that nematodes from Japan and North Carolina are slightly different morpholog-

[1] Symposium paper presented at the joint annual meetings of the Society of Nematologists and American Phytopathological Society, Houston, Texas, U.S.A., 10-14 August 1975. Published with the approval of the Director of the Arkansas Agricultural Experiment Station.

[2] Professor, Department of Plant Pathology, University of Arkansas, Fayetteville 72701.

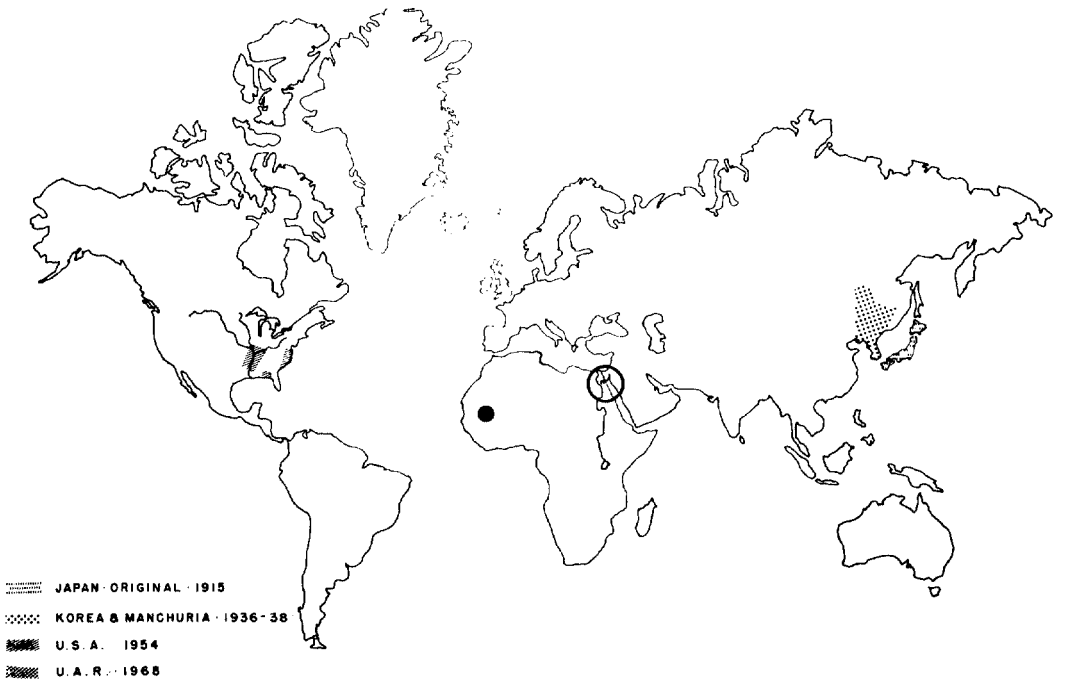

FIG. 1. World distribution of SCN.

ically. SCN was found in Missouri (19) and Tennessee in 1956 (9); in Arkansas, Kentucky, and Mississippi in 1957 (31); and in Virginia in 1958 (4) (Fig. 2-A). It was speculated that cysts were introduced into the Mississippi Delta on bagging from Japan. Epps' results might support this idea (11); but wild hosts, such as coffeebean *(Sesbania exaltata)* (13), sicklepod *(Aeschynomene virginica)* (25), *Penstemon digitalis* (28), old field toadflax *(Linaria canadensis)* (25), common lespedeza *(Lespedeza striata)*, and henbit *(Lamium amplexicanle)* (13) are common in the area. One of these plants might have carried an endemic population which served as an inoculum source. SCN was later found in Illinois, Indiana, Lousiana, Florida, Alabama, South Carolina, and (as recently as 1975) in Oklahoma.

SCN can spread rapidly, as examples from Arkansas illustrate (Fig. 2-B). In 1957, SCN was found only in a small part of one county. By 1960, three full counties were infested; by 1964, five more counties; and by 1969, 24 counties, including all the Mississippi Delta and the lower White and Arkansas River deltas, had infestations. In 1972, extensive infestations were found in five counties in the Arkansas River Valley but, since that time, only scattered new infestations have been found.

The increase in reported incidences of the nematode may have been due to more extensive sampling, but infestations were defined by spot sampling 44-88 km around known infestations (24). SCN may actually have spread, and if so, the manner in which this rapid spread occurred is a matter of conjecture. Several means, including the movement of farm machinery, use of contaminated seed, birds, wind, and flood waters, are possible. Modern farming practices include the movement of heavy machinery over wide areas because of large, centrally controlled farming enterprises, loan of equipment between neighbors, or custom operations such as land levelling or combining. Seed contamination results when small balls of soil called "peds" are included with harvested seed. Although special cleaning procedures remove a high percentage of the peds (information from Ark. State Plant Board), growers often obtain seed from neighbors that has been subjected to little or no cleaning and thus will carry peds containing cysts of SCN.

Epps (12) in Tennessee has shown that

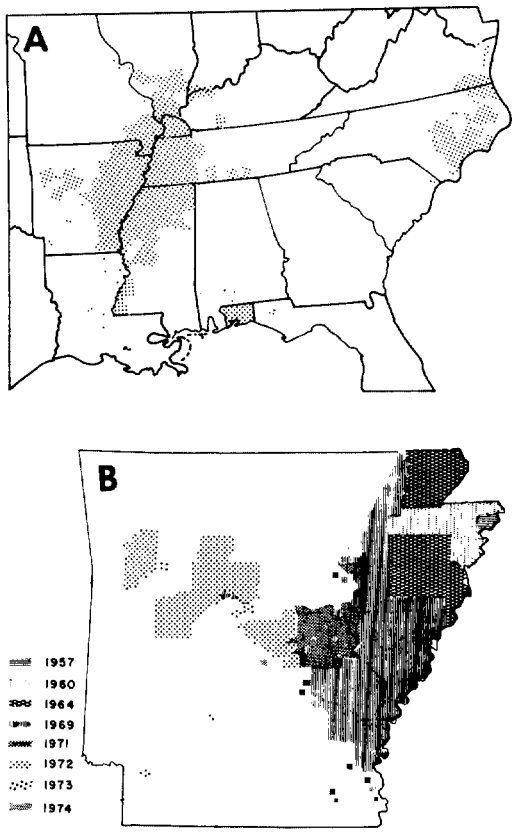

FIG. 2. *A)* Distribution of SCN in the U.S.A. *B)* Progressive distribution of SCN in Arkansas.

birds may also carry cysts of SCN. The eggs inside the cysts will pass through the digestive tract and remain viable. The three species of slackbird (brown-headed cowbird, *Molothrus ater;* grackle, *Quiscalus quiscula;* and starling, *Sturnis vulgaris*) which were tested are very common in Arkansas and could spread the cysts over considerable distances. Since cysts can withstand desiccation (10), they may also be transferred by the wind. County agents have reported that, in many fields, the first place SCN was found was on the lee side of a high area in the field. Water may also be a means by which cysts spread (27, 30). Streams or drainage canals traverse much of the infested area and these flood periodically. In addition, most of the infested area is flat and, at times, surface water may build up enough to carry floating cysts from one field to another.

SOYBEAN AS A WORLD CROP

Soybean was an important crop in the Orient long before it was grown to any extent in other parts of the world. Production records in Japan go back to 1878 (statistics from Ministry of Agriculture of Japan). In 1921, Manchuria produced more soybeans than all other countries combined. In 1915, when SCN was first reported, soybean was grown in the U.S. primarily as a hay crop or mixed with corn for silage. The first U.S. production records, in 1924, showed 181,300 ha with a production of 133.3 million kg (2). When SCN was found in the U.S., the hectarage had increased to 6.9 million and, in 1974, the U.S. total was 21.3 million ha harvested for seed. Records of world soybean production were not available until 1935 but, in the 1935-39 period, world figures showed 11.7 million ha with a production of 12.6 billion kg. By 1954, the hectarage had climbed to 17 million and, in 1974, had more than doubled again to 37.6 million ha (Table 1). The U.S., where the largest infestation of SCN was found, had 56% of the hectarage and 66% of the production. In the U.S., soybeans had grown from the 6th ranked crop on 5.5% of the cultivated hectargae in 1954 to the 4th ranked on 15% of the cultivated hectarage in 1971.

ECONOMIC ASPECTS OF SCN ON SOYBEAN

In 1956, quarantines were initiated to limit SCN to the known infestation (6). The quarantine program included extensive sampling to delineate infestations, cleaning of machinery before movement from infested to noninfested areas, and strict cleaning procedures for seed beans from infested fields. It also included restrictions on the movement of any material which might carry the nematodes from infested to noninfested fields. The effectiveness of the quarantine cannot be judged as there are no data to compare in the absence of a quarantine. The effectiveness of the quarantine program was probably reduced by attitudes in local areas. In North Carolina, SCN was found in an area where bulbs were the major crop and soybean was a cover or in-between crop (29, 33). The main concern there was the effect the nematode would have on movement of the bulbs. In Arkansas, no serious damage was seen for

TABLE 1. Soybean production over the past 50 Years (2).

Year	Arkansas		U.S.		World	
	Hectares (1,000's)	Production Kg (1,000's)	Hectares (1,000's)	Production Kg (1,000's)	Hectares (1,000's)	Production Kg (1,000's)
1924	1.2	40.9	181.3	10,121.6		
1935					11,736.1	948,771.1
1954	387.7	22,540.8	6,898.8	699,885.5	16,997.2	1,469,427.0
1974	1,740.2	175,956.0	21,254.6	2,545,062.4	37,562.9	3,870,369.1

two or three years, and SCN did not produce the typical yellow dwarf symptoms reported in Japan. The potential destructive ability of this pest became evident during subsequent seasons with different weather conditions. In Mississippi, growers discouraged public recognition of SCN because of restrictions which might have been imposed and thus diluted efforts to keep the pest under control.

Research projects were established to obtain information on the control of SCN within infested areas. Resistance was discovered, and breeding programs were initiated to transfer the resistance to commercially acceptable varieties (5). Resistance was found to be controlled by at least three recessive genes and one dominant gene, linked to black seed coat (5, 22). Transfer of resistance to commercially acceptable varieties was accomplished with difficulty. Chemical treatments and rotation programs were tested and found to be successful though costly at times (8, 14). At that time, soybean was a low per-hectare-value crop and chemical treatments were too expensive. Often, resistant varieties were planted continuously while rotation recommendations were largely ignored. Growers felt that the available alternate crops were not acceptable. As a result, within a few years, physiological races which parasitized the "resistant" varieties became apparent (15, 26, 28). Resistance to the new races was found, but the resistance was on a lower level and appeared to be more difficult to transfer (16, 18, 32). Commercial varieties with resistance to the different races of SCN have not been forthcoming. Crop rotation has now been adopted by some growers, but others prefer to use chemical treatments which are now feasible because of the higher value/ha of the crop. Even so, the cost of treatment is $25-50/ha and treatments must be repeated each year. Whole fields are treated even though SCN infestations are spotty and serious damage is usually experienced on less than 50% of a field. Some growers who switched to a 3-year rotation, with 1 year in a nonhost, 1 year in a cyst-resistant variety, and 1 year in a cyst-susceptible variety, have found that they not only increased their overall income/ha but also helped their weed control program as well (unpublished data).

An accurate assessment of the cost of the SCN program in the U.S. cannot be obtained. We can obtain an estimate of the cost from a few figures which are available (Tables 2, 3). The cost of the quarantine

TABLE 2. Costs related to SCN regulation and control.[a]

Area	Agency	Cost U.S. $ (in 1,000's)
Arkansas	State Plant Board	$ 120[b]
	Dept. of Plant Pathology	410
	Dept. of Agronomy	100
Virginia	Va. Poly. & State Univ.	1,304
	Va. Dep. of Agric. & Comm.	3,167

[a]Personal communications.
[b]Cost since 1972 when federal quarantine was removed.

TABLE 3. Estimated loss to growers in various states as a result of SCN infestation.[a]

State	Year	Loss (U.S. $) (in 1,000's)
Arkansas	1972	$30,900[b]
Illinois	1974	1,500
Kentucky	1974	10,000
North Carolina	1974	3,500
Tennessee	1974	8,000

[a]Personal communications.
[b]This estimate was made when soybeans were $0.09 per kg; in 1974 this cost would have been doubled.

program from 1956 to 1972 has been set at $7.2 million for the federal government and $2.2 million for the state governments (personal communication). The estimated costs to various agencies in two states are shown in Table 2 but no figures were available from other states. Estimates of the value of the yield loss from SCN in some of the infested states are given in Table 3. The estimated losses for Arkansas were obtained from a survey of County Extension Agents in which they were asked to estimate the infested acreage and yield reduction in their counties. All such figures must be regarded as estimates, but they do give us some basis for deriving an economic value for the damage caused by this pest.

The magnitude of the SCN problem is illustrated in Tables 4 and 5. In 1974, the 13 states of the U.S. known to have infestations of SCN had 62% of the soybean hectarage and produced 61% of the total U.S. crop. If a projection on the 1975 estimated hectarage is made on the basis of these figures and Oklahoma is included, the total hectarage would be 14.1 million. If SCN could eventually infest the total hectarage in the states known to have infestations, this amount would include 64% of the U.S. hectarage or about 35% of the world soybean hectarage. All the countries known to have infestations of SCN, on the basis of 1974 figures, are included in Table 5. If all soybean hectarage in countries known to have infestations became infested, 79% of the world soybean hectarge, producing 80% of the world supply of soybeans, would be infested with SCN.

TABLE 4. Production of soybean in 1974 in states known to have infestations of SCN (2).

State	Hectares (1,000's)	Production (Kg) (1,000's)
Alabama	412.8	50,086.1
Arkansas	1,740.2	175,956.0
Florida	111.7	12,988.0
Illinois	3,439.9	434,775.0
Indiana	1,582.4	199,996.5
Kentucky	481.6	65,738.0
Louisiana	712.3	86,423.0
Mississippi	1,032.0	99,128.7
Missouri	1,760.4	213,602.4
North Carolina	586.8	71,200.8
South Carolina	505.9	48,592.5
Tennessee	623.2	69,318.5
Virginia	172.0	19,999.7
Total	13,161.1	1,547,805.2
% of U.S. Total	62	61

TABLE 5. Production of soybeans in 1974 in countries known to have infestations of SCN.

Country	Hectares (1,000's)	Production (Kg) (1,000's)
China (Mainland)	8,053.4	507,448.9
Japan	92.7	10,148.2
Korea	382.8	24,281.9
UAR	not enough to report	
US	1,250.5	24,935,640.4
Total	29,779.4	25,477,519.4
% of World Total	79	80

Soybean is and will continue to be a vital part of the world food supply. Soybean-cyst nematode is an important parasite of this crop and remains as a constant threat to the crop in areas around the world. Research has made it possible to keep this pest in check, but continued efforts will be necessary to stay ahead of this dynamic and destructive parasite.

LITERATURE CITED

1. ABOUL-EID, H. Z., and A. I. GORAB. 1974. Pathological effects of Heterodera cajani on cowpea. Plant Dis. Rep. 58:1130-1133.
2. AMERICAN SOYBEAN ASSOCIATION. 1975. Soybean Digest Bluebook, 1975.
3. ANONYMOUS. 1922. Investigations on chlorosis of soybeans. J. Pl. Protect. (Tokyo) 9:101-105, Hokkaido Nat'l. Agric. Exp. Stn. (In Japanese).
4. ANONYMOUS. 1961. Soybean cyst nematode progress in research and control. ARS Special Report 22-72.
5. CALDWELL, B. E., C. A. BRIM, and J. P. ROSS. 1960. Inheritance of resistance of soybeans to the cyst nematode, Heterodera glycines. Agron. J. 52:635-636.
6. CLARKSON, M. R. 1957. Soybean cyst nematode disease domestic quarantine notices. Federal Register May 28, 1957:3725-3729.
7. DIAB, K. A. 1968. Occurrence of Heterodera glycines from the Golden Island, Giza, U.A.R. Nematologica 14:148.
8. ENDO, B. Y., and J. N. SASSER. 1958. Soil fumigation experiments for the control of the soybean cyst nematode, Heterodera glycines. Phytopathology 48:571-574.
9. EPPS, J. M. 1956. Soybean cyst nematode found in Tennessee. Plant Dis. Rep. 41:33.
10. EPPS, J. M. 1958. Viability of air-dried Heterodera glycines cysts. Plant Dis. Rep. 42: 594-595.
11. EPPS, J. M. 1968. Survival of soybean cyst

nematodes in seed bags. Plant Dis. Rep. 52:45.
12. EPPS, J. M. 1971. Recovery of soybean cyst nematodes (Heterodera glycines) from the digestive tracts of blackbirds. J. Nematol. 3:417-419.
13. EPPS, J. M., and A. Y. CHAMBERS. 1958. New host records for Heterodera glycines; including one host in the Labiatae. Plant Dis. Rep. 42:194.
14. EPPS, J. M., and A. Y. CHAMBERS. 1962. Effects of seed inoculation, soil fumigation, and cropping sequences on soybean nodulation in soybean-cyst-nematode-infested soil. Plant Dis. Rep. 46:48-51.
15. EPPS, J. M., and L. A. DUCLOS. 1970. Races of the soybean cyst nematode in Missouri and Tennessee. Plant Dis. Rep. 54:319-320.
16. EPPS, J. M., and E. E. HARTWIG. 1972. Reaction of soybean varieties and strains to race 4 of the soybean cyst nematode. J. Nematol. 4:222(Abstr.).
17. GOLDEN, A. M., and J. M. EPPS. 1965. Morphological variations in the soybean-cyst nematode. Nematologica 11:38(Abstr.).
18. HARTWIG, E. E., and J. M. EPPS. 1970. An additional gene for resistance to the soybean-cyst nematode, Heterodera glycines. Phytopathology 60:584(Abstr.).
19. HEGGE, A. H. 1957. Soybean cyst nematode, Heterodera glycines, in Missouri. Plant Dis. Rep. 41:201.
20. HORI, S. 1916. Phytopathological notes. 5. Sick soil of soybean caused by nematodes. J. Plant Protect. (Tokyo) 2:927-930. (In Japanese).
21. HUNG, Y. 1958. A preliminary report on the plant-parasitic nematodes of soybean crop of the Pingtung District, Taiwan, China. Agric. Pest News 5(4):1-5.
22. MATSON, A. L., and L. F. WILLIAMS. 1965. Evidence of a fourth gene for resistance to the soybean-cyst nematode. Crop Sci. 5:477.
23. NAKATA, K., and H. ASUYANA. 1938. Survey of the principal diseases of crops in Manchuria. Bur. Indus. Rep. 32:166 (In Japanese).
24. POPHAM, W. L. 1955. Memorandum on soybean cyst nematode to state regulatory officials in important soybean growing areas. USDA, ARS, Plant Pest Control Branch, July 1, 1955.
25. RIGGS, R. D., and M. L. HAMBLEN. 1966. Further studies on the host range of the soybean-cyst nematode. Ark. Agric. Exp. Stn. Bull. 718-1-20.
26. RIGGS, R. D., D. A. SLACK, and M. L. HAMBLEN. 1968. New biotypes of soybean cyst nematode. Ark. Farm Res. 17(5):11.
27. SKOTLAND, C. B., N. N. WINSTEAD, and J. N. SASSER. 1956. The soybean cyst nematode disease. N. C. Agric. Ext. Folder 126.
28. SMART, G. C., JR. 1964. Physiological strains and one additional host of the soybean cyst nematode, Heterodera glycines. Plant Dis. Rep. 48:542-543.
29. SPEARS, J. R. 1955. Information regarding the soybean cyst nematode. An information sheet issued by Mr. Spears of the USDA, ARS, Plant Pest Control Branch, July 29, 1955.
30. SPEARS, J. F. 1956. The soybean cyst nematode —a threat to soybeans and information to cooperators. USDA, ARS, Plant Pest Control Branch issued July 16, 1956.
31. SPEARS, J. F. 1957. Review of soybean cyst nematode situation for presentation at public hearing on the need for a Federal Domestic Plant Quarantine, July 24, 1957.
32. THOMAS, J. D., C. E. CAVINESS, R. D. RIGGS, and E. E. HARTWIG. 1975. Inheritance of reaction to race 4 of soybean-cyst nematode. Crop Sci. 15:208-210.
33. WINSTEAD, N. N., and C. B. SKOTLAND. 1957. Eradicant treatments for narcissus bulbs and gladiolus corms harboring soybean nematode cysts. Phytopathology 47:67-69.
34. WINSTEAD, N. N., C. B. SKOTLAND, and J. N. SASSER. 1955. Soybean-cyst nematode in North Carolina. Plant Dis. Rep. 39:9-11.
35. YOKOO, T. 1936. Host plants of Heterodera schachtii Schmidt and some instructions. Korea Agric. Exp. Stn. Bull. 8(43):47-174.