Evaluation of Weed Species from the Northern Great Plains as Hosts of Soybean Cyst Nematode

Susilo H. Poromarto, Department of Plant Pathology, **Greta G. Gramig,** Department of Plant Sciences, **Berlin D. Nelson Jr.** and **Shalu Jain,** Department of Plant Pathology, North Dakota State University, Fargo 58108. Current address of first author: Agrotechnology Department, Sebelas Maret University, Surakarta, Indonesia

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ABSTRACT

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Weeds can be alternate hosts of soybean cyst nematode (SCN), a major pathogen of soybean in the United States. Weed species from the northern soybean production area of North Dakota-northern Minnesota have not been evaluated for host suitability. Fifty-one weed species with multiple collections from different locations, representing 13 families were evaluated as hosts of SCN. Weeds were inoculated with SCN HG type 0 and a female index (FI) was calculated by comparing reproduction to that on Barnes, a susceptible soybean cultivar. Thirty-three weed species had not previously been tested. For 20 weed species, no reproduction on roots was observed on any collection. For 31 weed species, SCN females developed on roots of one or more collection, but only two weeds, henbit and field pennycress, allowed substantial reproduction with average FI's of 30.5 to 38, respectively; the other 29 species had average FI's of less than 10 and thus were defined as poor hosts. Twenty-six of the weed species from 11 plant families were newly identified hosts of SCN. Collections of species varied in host suitability. Although most weeds were non-hosts or poor hosts, the number of weeds that supported limited SCN reproduction indicates that weed hosts could influence SCN survival and reproduction in the upper Great Plains. Few weed species, however, are major hosts of SCN in this region.

INTRODUCTION

Soybean cyst nematode (SCN), *Heterodera glycines* Ichinohe, is a major pathogen of soybean that occurs throughout the principal soybean production areas of the United States (Niblack 2005; Wrather and Koening 2006). The northernmost production area is North Dakota and northern Minnesota, where 1.6 million ha of soybean are grown. SCN was first reported in North Dakota in 2003 (Bradley et al. 2004) in the southeast corner of the state. Since then the nematode has been reported in at least 12 counties in the eastern half of the state all the way from the border with South Dakota to the border with Canada. In Minnesota, SCN has been present in the southern part of the state since 1978 (MacDonald et al. 1980), but within the last ten years it has spread into the northern part of the state where soybeans are produced. SCN is now considered a major problem for soybean growers in this northern two state area. Although concern about SCN has been primarily directed at the soybean crop, recent research has shown that SCN reproduces on dry bean cultivars and can cause a yield loss (Poromarto and Nelson 2009; Poromarto et al. 2010). The North Dakota-northern Minnesota region is a major dry bean production area with 300,000 ha of a variety of bean classes (Anonymous 2010). Therefore, SCN is a threat to two major crops in this northern crop production area.

Weeds are known to play a role in the biology of plant parasitic nematodes (Norton 1978). Weeds can serve as alternative hosts and therefore impact nematode management strategies (Duncan and Noling 1998; Thomas et al. 2005). Crop rotation to non-hosts is a common management practice to reduce SCN levels in soybean fields (Hartman et al. 1999). Weed hosts could reduce the effectiveness of crop rotation if weeds proliferate and SCN completes the life cycle on weed roots. Furthermore, when nonhost crops such as corn or wheat are grown for extended periods of five to six years, growers often expect SCN levels to be reduced to low levels or non-detectable levels. However, weed hosts that support high reproduction of SCN could decrease the effectiveness of crop rotation.

The most comprehensive host list for SCN was compiled by Riggs (1992) and included 22 plant families and 286 species, of which 164 species were listed as poor hosts. Numerous weeds and wild plants are included in this host list. Riggs and colleagues (Riggs and Hamblen 1962; Riggs and Hamblen 1966a and b) evaluated many of the species included in the host list. A plant was considered a host if at least one female with eggs was produced on roots (Riggs and Hamblen 1966a). A review of the literature found one additional plant family and eleven additional species identified as hosts since 1992 or reported earlier but not included in the Riggs host list (Miller 1967; Poromarto and Nelson 2010; Riggs 1987; Smart 1964; Venkatesh et al. 2000). The eleven species are the following: *Capsella bursa-pastoris* (shepherd's purse), *Cicer arietinum* (chickpea), *Crambe maritime* (crambe), *Cuphea viscosissima* (cuphea), *Guizotia abyssinica* (nyjer), *Lamium purpureum* (purple deadnettle), *Macroptilium atropurpurea* (purple bush-bean), *Macroptilium lathyroides* (wild bushbean), *Penstemon nitidus* var. *polyphyllus* (waxleaf penstemon), *Thlaspi arvense* (field pennycress) and *Trifolium hydridum* (alsike clover).

An important aspect regarding host range is that, within a species, host genotype is an important factor influencing

Corresponding author: B. D. Nelson Jr. Email: Berlin.Nelson@ndsu.edu

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reproduction of the nematode. For example, Riggs and Hamblen (1962), in their extensive study of host range, showed that when multiple collections of a species were evaluated, some species showed a range of reaction among the collections that varied from no SCN reproduction to slight reproduction (9 or fewer cysts per plant) to reproduction they considered a susceptible reaction (10 or more cysts per plant). Thus, testing multiple collections of a host species, when possible, is a more desirable method to determine if the species is a potential host of SCN. Host species can also react differently to the race or HG type of SCN. Venkatesh et al. (2000) showed that purple deadnettle (*Lamium purpurem*) was a strong host for races 1 and 3 of SCN but a weak host for race 6 whereas race 3 but not races 1and 6 reproduced well on henbit (*Lamium amplexicaule*).

Although numerous weed species have been previously identified as SCN hosts, host suitability has not been assessed for collections of these species that occur in North Dakota and northern Minnesota. Furthermore, many weed species that are common in this area have not been previously assessed for SCN host suitability. Therefore, the objective of this research was to determine the SCN host suitability of 51 weed species using multiple collections originating from the North Dakota and northern Minnesota area. A plant species was considered a host if at least one SCN female with eggs was produced in the roots as originally proposed by Riggs and Hamblen (1966a). The results from this research may be helpful for developing or modifying weed management tactics that will limit the survival and proliferation of SCN in the soybean production areas of North Dakota and northern Minnesota.

WEED SOURCE AND GROWTH ENVIRONMENT

Five of the weed species were collected in the seedling stage directly from the field in 2012. Those species were *Ambrosia artemisiifolia*, *Cirsium arvense*, *Polygonum persicaria*, *Senecio vulgaris*, and *Xanthium strumarium*. Seedlings were approximately 7 to 14 days old when collected. These five species were collected in shelterbelts or ditches bordering crop fields within a 40-km radius of Fargo, ND. There was no evidence that these areas were infested with SCN. The other 46 species were grown from seeds maintained by weed scientists at North Dakota State University, Fargo. These seed sources were collected from weed populations from different areas in North Dakota and northwestern Minnesota. At least two collections of each species were evaluated.

Plants from the field were extracted with soil on the roots and transported to the greenhouse where the soil was gently removed. Individual plants were then placed in "Cone-tainers" (type SC10 super cell, 164-ml volume; Stuewe & Sons, Inc., Corvallis, OR) containing autoclaved La Prairie silt loam and SCN was added to the soil around the roots as they were covered with soil (inoculation method described in following section). For plants grown from seed, all seeds were pre-germinated to obtain a small seedling and then planted directly into Cone-tainers filled with the silt loam. The Cone-tainers were placed on a lab bench under high pressure sodium lamps (1,000 $\mu E/m^2/s$) for 16 h/day. The ambient air temperature when lamps were on was approximately 25 ± 2°C and when lamps were off was approximately 20 ± 2°C. After seedlings reached 2 to 4 true leaves, SCN was placed around the plant roots. All plants with SCN in the Cone-tainers were placed in autoclaved sand in 30.5-cm diameter × 30.5-cm depth plastic pots (Cambro, Huntington Beach, CA) immersed in a water bath at 27 ± 2°C in the greenhouse. Plants were grown for 40 days under natural and supplemental light from high pressure sodium lamps (1,000 $\mu E/m^2/s$) for 16 h/day. Plants were fertilized 15 and 21 days after planting with 3 ml of a solution of Peters Hydro-Sol 5-11-26 (W.R. Grace & Co., Fogelsville, PA) at the rate of 20 ml of Peters in 980 ml of water.

SCN SOURCE, INOCULATION, AND EVALUATION

SCN HG Type 0, the prevalent HG type in infested fields in the area, was used in all inoculations and originated from an infested soybean field in Richland Co., ND. The general methods described by Niblack et al. (2002) for inoculation of soybean with SCN were followed. Females of SCN were produced on Barnes soybean, a susceptible cultivar grown under the same conditions as described for the weeds species. Barnes is equally susceptible as Lee 74, a standard susceptible cultivar used in many studies on resistance in soybean to SCN (Niblack et al. 2002). Females were washed off the roots of Barnes soybean and eggs were extracted as described by Poromarto and Nelson (2010). To treat weed seedlings transplanted from the field, a suspension of eggs in distilled water was prepared and adjusted to 1,000 eggs/ml. As seedlings were transplanted into Cone-tainers, a suspension containing approximately 2,000 eggs was pipetted around the roots as they were covered with the soil. To treat weed seedlings grown from seed, the same rate of eggs was pipetted onto the sand directly around the plant when the weed seedlings had reached 2 to 4 true leaf stage. The temperature of the soil in the Cone-tainers was monitored using Watchdog 450 Data loggers with soil temperature sensors (Spectrum Technologies, Inc., Plainfield, IL).

To evaluate host suitability of weed plants, females of SCN were collected from the roots of individual weeds after 40 days growth in the water bath. Plants were extracted from the Cone-tainers and the root-soil masses were soaked in water for 5 minutes. The females were then washed off the roots with a forceful stream of water and sieved from the water/soil mix of the root soakings using the methods described by Poromarto and Nelson (2010). Females collected from each plant were viewed with a dissecting microscope, evaluated for presence of eggs, and counted. Roots were also examined with the dissecting microscope to insure all mature females were removed.

Weed species were tested at different times because plants in the field were collected at different dates and weeds grown from seed were available at different times due to seed germination rates and plant growth. Furthermore, the water bath for the Cone-tainers had limited space. Therefore, 14 separate experiments were conducted to test all weed species. At least two or more collections of each species were tested in separate experiments. For each weed collection, four plants were tested (each plant was considered as one replication). In each separate experiment there were four plants of Barnes soybean, the susceptible check. For each experiment, a randomized complete block design was used within the plastic pots immersed in the water bath. Only when Barnes soybean had an average of 100 or greater females per plant in an experiment was the test considered valid. For each experiment, the average number of females per weed collection was recorded and a female index (FI = average number of females on the test plant divided by the average numbers of females on the susceptible Barnes soybean times 100) (Niblack 2005) was determined for each weed collection.

REPRODUCTION OF SCN ON WEEDS

In each separate experiment the average number of females on the Barnes soybean control was greater than 100 females per plant (overall mean of 313; range 127 to 495), thus all tests for SCN reproduction in each experiment were considered valid. Fifty-one weed species from 13 families were evaluated as hosts

of SCN (Table 1) and on 20 species there was no evidence of reproduction with FI's of 0 on each collection. Females developed on the roots of 31 species in one or more collections, but only two species, henbit and field pennycress, had substantial reproduction with average FI's of 30.5 and 38, respectively. Of those 31 species, 19 had females on one or more collections, but not all collections. When averaged over the collections tested, 29 species had FI's of less than 10, and 15 of those had FI's of one or less. Therefore, based on these results, reproduction of SCN on those 29 species would likely be limited under field conditions. Twenty six of the weed species tested from 11 plant families are newly reported hosts of SCN and are indicated by a double asterisk in Table 1.

Of the 51 species, 18 were previously evaluated for reproduction of SCN and 33 species had never been evaluated (Table 1; references listed in table). The results of this study are similar to what was reported for 12 of the 18 previously evaluated species. Black nightshade, common lambsquarters, eastern black nightshade, ground cherry, redroot pigweed, and wild sunflower were all non-hosts as previously reported (references in Table 1). However, for shepherd's purse there was no reproduction and for velvetleaf, black medic, catnip, yellow woodsorrel, ladysthumb smartweed, and common cocklebur there was a small amount of reproduction, in contrast to earlier reports (Table 1). Differences in the HG type or race used in various studies with these weed species might account for differences in the reported host suitability compared to this current research. Unfortunately, most studies with weeds have not reported HG types or races of SCN.

Riggs and Hamblen (1962; 1966a) showed that genotype of a plant species, even those that are not considered common hosts, was a critical factor in reproduction by SCN. For example, they tested 17 plant introductions of *Medicago hispida* (now *M. polymorpha*; burclover) and found accessions that had no reproduction, poor reproduction, or good reproduction by SCN. This is the principal reason that multiple collections of a weed species should be evaluated when possible to determine suitability

TABLE 1
Weed species evaluated as hosts of soybean cyst nematode HG type 0.

Scientific name	Family	Common name	Collection	Range of females/plant	Female Index[x]	Previously evaluated by: Reference/results[y]
Artemisia biennis Willd.**[z]	Asteraceae	biennial wormwood	1	10-17	10.6	
			2	5-13	7.8	
			3	—	0	
Abutilon theophrasti Medik.**	Malvaceae	velvetleaf	1	—	0	Wong & Tylka 1994/ non-host
			2	0-1	0.1	
Amaranthus blitoides S. Watson**	Amaranthaceae	prostrate pigweed	1	—	0	
			2	1-2	0.3	
Amaranthus retroflexus L.	Amaranthaceae	redroot pigweed	1	—	0	Sortland & Macdonald 1987;
			2	—	0	Wong and Tylka 1994/non-host
Amaranthus tuberculatus (Moq.) Sauer**	Amaranthaceae	common waterhemp	1	—	0	
			2	—	0	
			3	4-8	2	
Ambrosia artemisiifolia L.[#]	Asteraceae	common ragweed	1	—	0	
			2	—	0	
Arctium minus Bernh.**	Asteraceae	common burdock	1	3-10	2.9	
			2	—	0	
Capsella bursa-pastoris (L.) Medik.	Brassicaceae	shepherd's-purse	1	—	0	Venkatesh et al. 2000/ poor host
			2	—	0	
Chenopodium album L.	Chenopodiaceae	common lambsquarters	1	—	0	Riggs & Hamblen 1966a; Sortland & Macdonald 1987; Wong & Tylka 1994/ non-host
			2	—	0	
Cirsium arvense L.**[#]	Asteraceae	Canada thistle	1	—	0	Wong & Tylka 1994/ non-host
			2	4-6	1.5	
Conyza canadensis L.**	Asteraceae	horseweed	1	—	0	
			2	—	0	
			3	1-11	0.7	
Datura stramonium L.	Solanaceae	jimsonweed	1	—	0	
			2	—	0	
Descurainia pinnata (Walter) Britton**	Brassicaceae	tansy mustard	1	1-4	0.5	
			2	7-12	3	
Descurainia sophia (L.) Webb ex Prantl**	Brassicaceae	flixweed	1	3-4	1.4	
			2	2-15	3	
			3	0-1	0.1	
Euphorbia esula L.**	Euphorbiaceae	leafy spurge	1	1-1	0.3	
			2	—	0	
Helianthus annuus L.	Asteraceae	wild sunflower	1	—	0	Wong & Tylka 1994/ non-host
			2	—	0	
Hibiscus trionum L.**	Malvaceae	Venice mallow	1	—	0	
			2	0-1	0.1	
Ipomoea hederacea Jacq.	Convolvulaceae	ivyleaf morningglory	1	—	0	
			2	—	0	

(continued)

TABLE 1 (continued)
Weed species evaluated as hosts of soybean cyst nematode HG type 0.

Scientific name	Family	Common name	Collection	Range of females/plant	Female Index[x]	Previously evaluated by: Reference/results[y]
Iva xanthifolia Nutt.	Asteraceae	marshelder	1	—	0	
			2	—	0	
			3	—	0	
			4	—	0	
			5	—	0	
			6	—	0	
Kochia scoparia L.	Chenopodiaceae	kochia	1	—	0	
			2	—	0	
			3	—	0	
Lamium amplexicaule L.	Lamiaceae	henbit	1	249–478	45.5	Epps & Chambers 1958; Riggs &
			2	19–48	15.5	Hamblen 1962; Riggs & Hamblen 1966a/ host
Leonurus cardiaca L.**	Lamiaceae	motherwort	1	1–19	2.7	
			2	6–19	3.7	
Lepidium densiflorum Schrad.**	Brassicaceae	greenflower pepperweed	1	—	0	
			2	0–1	0.1	
Lotus corniculatus L.	Fabaceae	birdsfoot trefoil	1	1–5	1	Riggs 1992/host
			2	5–15	3.5	
Malva neglecta Wallr.	Malvaceae	common mallow	1	—	0	
			2	—	0	
Medicago lupulina L.**	Fabaceae	black medic	1	—	0	Riggs & Hamblen 1962; Riggs &
			2	1–19	1.7	Hamblen 1966a/ non-host
Nepeta cataria L.**	Lamiaceae	catnip	1	1–3	0.7	Riggs & Hamblen 1966a/non-host
			2	5–13	2.9	
*Oxalis stricta L.***	Oxalidaceae	yellow woodsorrel	1	2–7	1.4	Riggs & Hamblen 1966a/ non-host
			2	2–15	2.3	
Physalis spp.	Solanaceae	ground cherry	1	—	0	Riggs & Hamblen 1966a/ non-
			2	—	0	hosts and hosts in genus
Plantago major L.	Plantaginaceae	broadleaf plantain	1	—	0	
			2	—	0	
Polygonum aviculare L.	Polygonaceae	prostate knotweed	1	—	0	
			2	3–10	2	
Polygonum convolvulus L.	Polygonaceae	wild buckwheat	1	—	0	
			2	—	0	
Polygonum persicaria L.**[#]	Polygonaceae	ladysthumb smartweed	1	—	0	Donald et al. 2007/ non-host
			2	1–3	0.6	
Portulaca oleracea L.	Portulacaceae	common purslane	1	—	0	Riggs 1992; Riggs & Hamblen
			2	2–4	1.6	1966b / host
Rumex crispus L.	Polygonaceae	curly dock	1	—	0	
			2	—	0	
Salvia reflexa Hornem.**	Lamiaceae	lanceleaf sage	1	2–17	5.5	
			2	7–15	8.5	
			3	3–11	4.9	
Senecio vulgaris L.[#]	Asteraceae	common groundsel	1	—	0	
			1	—	0	
Sida spinosa L.**	Malvaceae	prickly sida	1	1–10	0.6	
			2	0–1	0.2	
Silene noctiflora L.**	Caryophyllaceae	nightflowering catchfly	1	0–2	0.1	
			2	2–16	2.1	
*Sinapis arvensis L.***	Brassicaceae	wild mustard	1	—	0	
			2	0–1	0.1	
Sisymbrium altissimum L.**	Brassicaceae	tumble mustard	1	11–25	5.6	
			2	9–27	6.1	
Sisymbrium irio L.**	Brassicaceae	London rocket	1	1–5	0.3	
			2	—	0	
Solanum nigrum L.	Solanaceae	black nightshade	1	—	0	Riggs & Hamblen 1966a/ non-host
			2	—	0	
			3	—	0	

(continued)

TABLE 1 (continued)
Weed species evaluated as hosts of soybean cyst nematode HG type 0.

Scientific name	Family	Common name	Collection	Range of females/plant	Female Index[x]	Previously evaluated by: Reference/results[y]
Solanum ptycanthum Dun.	Solanaceae	eastern black nightshade	1	—	0	Wong & Tylka 1994/ non-host
			2	—	0	
Solanum rostratum Dunal**	Solanaceae	buffalobur	1	—	0	
			2	4–8	3.1	
Solanum villosum (L.) Mill.	Solanaceae	hairy nightshade	1	—	0	
			2	—	0	
Sonchus arvensis L.**	Asteraceae	perennial sowthistle	1	—	0	
			2	4–8	1.7	
Taraxacum officinale F.H. Wigg.	Asteraceae	dandelion	1	—	0	
			2	—	0	
Thlaspi arvense L.	Brassicaceae	field pennycress	1	67–199	34	Venkatesh et al. 2000/ host
			2	91–180	42	
Tripleurospermum maritima (L.) W.D.J. Koch	Asteraceae	false chamomile	1	—	0	
			2	—	0	
Xanthium strumarium L.**#	Asteraceae	common cocklebur	1	—	0	Wong & Tylka 1994/non-host
			2	2–12	2.1	

[x] Female index = average number of females on the test plants (n = 4) divided by the average number of females on the susceptible soybean cultivar Barnes times 100. Average number of females on Barnes was 313; range 127–495.

[y] Publications listed are included in the literature cited. Non-host = no reproduction by SCN reported; host = one or more females on the roots reported. A blank space indicates no previous evaluation of the species.

[z] **Newly reported hosts of SCN. #Species were collected in the seedling stage from the field. All other species were grown directly from seed.

as a host. The extremely wide host range of SCN, the existence of different virulent types, and past research on weed hosts suggests that within weed populations it may not be unusual to find genotypes that allow some reproduction on roots.

HG type 0 (previously known as race 3), a SCN genotype determined on a set of soybean plant introductions with different resistance to SCN (Niblack et al. 2002), is the common SCN type in infested fields in North Dakota. However, in other areas, such as Illinois and Iowa with longer histories of soybean production and use of resistant varieties, there is greater diversity in virulence in the SCN population, thus there are more HG types (Niblack et al. 2002; Niblack et al 2008). A similar situation will likely occur in the North Dakota-northern Minnesota soybean production area in the future. Reproduction of SCN on weeds or other plants is affected by HG type. Venkatesh et al. (2000) showed that purple deadnettle (*Lamium purpurem* L.) was a good host for races 1 and 3 of SCN but a weak host for race 6. In *Phaseolus vulgaris*, some genotypes had high reproduction with race 2 but less reproduction with races 3 or 5 and even with one race there were significant differences between genotypes in the amount of reproduction (Smith and Young 2003). Therefore, as the HG type changes in this area, common weed species should be tested against those new prevalent HG types.

CONCLUSION

It is important to determine if a weed species is a host or non-host to the locally prevalent HG types of SCN since there is a potential effect on SCN biology or management even if it is a poor host. Weed collections that are poor hosts may indicate that within the population there are efficient hosts as demonstrated in the host range studies by Riggs and Hamblen (1962; 1966a). Furthermore, could weeds cause selection pressure in the SCN population that results in selecting types with biological characteristics affecting management for crops? This study does suggest that there are few weed species in North Dakota and northern Minnesota that could potentially return large amounts of eggs to the soil if they grew in sufficient numbers in SCN HG type 0 infested fields. However, 61% of the species evaluated did have some reproduction, albeit small amounts, on the roots. Those weeds could potentially maintain populations of the nematode especially in weedy areas within fields, and thus provide egg sources for dispersal to non-infested parts of fields where crop rotation and other management techniques had reduced egg numbers to non-detectable levels. Weeds therefore, should be considered as factors affecting management of SCN in this northern soybean production area. In particular, highly prevalent winter annual weeds such as field pennycress may require special attention (Johnson et al. 2008). Reduced tillage and decreased reliance on soil residual herbicides have led to an increase in winter annual weed populations. Such weeds can proliferate during warm and moist fall months. During September soil temperatures in eastern North Dakota average around 15.5°C, still high enough for SCN reproduction (Alston and Schmitt 1988). Control of winter annuals such as field pennycress that start growing in late summer into the fall may need consideration when managing SCN in this northern soybean production area.

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