Reaction of Soybean Cyst Nematode Resistant Plant Introductions to Root-Knot and Reniform Nematodes

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ABSTRACT Soybean cyst [SCN, *Heterodera glycines* Ichinohe], southern root-knot [RKN, *Meloidogyne incognita* (Kofoid and White) Chitwood] and reniform nematodes [RN, *Rotylenchlus reniformis* (Linford and Oliveria)] are common plant-parasitic nematode species in southern US fields. Each nematode individually or collectively causes significant economic losses to field grown soybean. A subset of 120 soybean plant introductions (PIs) selected from the USDA Soybean Germplasm Collection have been shown to be resistant to one or more SCN populations (HG Types); however, many of these PIs have not been screened for resistance to either RKN or RN. The objective of this research was to evaluate these germplasm accessions for resistance to RKN and RN. The evaluation for RKN resistance was conducted in RKN infested field plantings after potatoes near Charleston, MO in 2006 and 2007. The evaluation for RN resistance was performed in a greenhouse at Fayetteville, AR, in 2007. Out of these accessions, 64 PIs were identified with high or moderate resistance to RKN. Of these 64 lines, 24 accessions showed good resistance to both RKN and RN. These new sources of resistance to multiple nematodes will be valuable materials for soybean breeding programs to develop new resistant cultivars that can overcome yield losses caused by one or more of these nematode species.

Keywords Soybean, Cyst nematode, Root-knot nematode, Reniform nematode

INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] cyst nematode (SCN, *Heterodera glycines* Ichinohe), southern root-knot nematode [RKN, *Meloidogyne incognita* (Kofoid and White) Chitwood], and reniform nematode (RN, *Rotylenchlus reniformis* Linford and Oliveria) are significant pathogens in southern U.S. soybean fields (Wrather and Koenning 2009). They cause approximately 157 billion U.S. dollars in damage worldwide (Klink *et al.* 2009).

SCN generally has caused more yield reduction than any other soybean disease. Estimated yield losses was 3.3 million tons in 2009 in 28 U.S. states (Wrather and Koenning 2010). RKN often occurs in soybean fields, but to a lesser extent than SCN (Wrather *et al.* 2003) with

losses estimated at 1.9 million tons over 28 U.S. states in 2009 (Wrather and Koenning 2010). If RKN interacts with other disease pathogens, damage is greater than would occur with RKN alone (Goswami and Agrawal 1978). Another nematode species, RN causes root decay, poor growth, reduced pod set, and significant yield reduction in susceptible soybean cultivars (Niblack *et al.* 2004).

Nematicide applications were once a cost-effective manner and widely used as an option to manage nematode infestation (Niblack *et al.* 2004). However, growers were reluctant to use chemical control due to high costs, environmental toxicity and human health concerns. Thus, breeding for new soybean cultivars with resistance to one or more species is a cost effective and environmentally friendly measure to reduce soybean yield losses to nematodes.

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The use of SCN-resistant soybean cultivars, such as Forrest, prevented approximately \$401 million in soybean yield losses at a cost of only about \$1 million for the variety development (Bradley and Duffy 1982). However, continuous cultivation of SCN resistant soybean cultivars may accelerate selection pressure for other nematode species, particularly RKN and RN that also damage soybeans (Schmitt and Barker 1988). Stetina *et al.* (1997) reported that RKN resistant soybean likely results in an increase of RN over time. Therefore, cultivars with resistance to multiple nematode species are essential in preventing losses from these pests which can occur in the same field. Several sources of resistance to RKN have been identified in soybean, which were being used in soybean breeding programs to develop soybean germplasm lines resistant to both SCN and RKN (Boerma *et al.* 1991; Luzzi *et al.* 1997). SCN-resistant soybean genotypes derived from cultivars Custer, Hartwig, Peking, PI437654, and PI 90763 are potentially also resistant to RN (Robbins *et al.* 1994a, 1994b; Davis *et al.* 1996).

Soybean plant introductions (PIs) selected from the USDA Soybean Germplasm Collection were screened in several studies and it was reported that about 120 accessions have shown to be resistant to one or more SCN populations or HG types (Shannon *et al.* 2004). However, many of these PI lines have not been screened for resistance to either RKN or RN. The purpose of this study was to collectively evaluate this subset of SCN resistant accessions for resistance to RKN and RN to identify sources resistant to all three nematode species.

MATERIALS AND METHODS

Soybean cyst nematode resistant genotypes

A total of 120 soybean PIs in maturity groups (MGs) I to VII from the USDA Soybean Germplasm Collection (Shannon *et al.* 2004), previously identified as having SCN resistance to one or more SCN HG Types were evaluated to both RKN and RN to determine which of these SCN sources carried resistant to one or both of these species.

Root-knot nematode evaluation

One hundred twenty soybean PIs were evaluated for resistance to RKN in highly infested fields following potatoes near Charleston, MO on a Dundee sandy loam (Aeric Ochraqualfs). Levels of RKN at each site were not determined but, sandy soils following spring potatoes in Missouri often have high levels of RKN after harvest in late June and July. Ten seeds of each soybean accession were planted in hill plots spaced 61 cm apart in rows 76 cm wide at two sites in 2006 and one site in 2007. Planting dates were June 26, 2006 and June 30, 2007. The experimental design was a randomized complete block design (RCBD) with two replications. Six weeks after planting, soybean plants in each hill were dug with a shovel to expose root systems for determining reaction to RKN. Reaction to RKN damage was measured by root-knot galling and scored using a 1-5 scale (Luzzi *et al.* 1997) where 1=no galls and 5=very severe galling. A score of 3 or less was considered as resistance reaction. Cultivar 5601T (Pantalone *et al.* 2003) was used as the resistant check, and cultivar Anand (Anand *et al.* 2001) was used as the susceptible check.

Reniform nematode evaluation

After RKN evaluations, 64 PI lines that showed consistent resistance to RKN with galling scores ≤ 3 were phenotyped for resistance to RN in a greenhouse facility of the University of Arkansas, Fayetteville, AR, in 2007. Seeds were germinated in vermiculite. Seedlings at the cotyledon stage or VC growth stage (Fehr and Caviness 1977) were then transplanted into 10-cm-diameter clay pots (one seedling per pot) containing 500 cm³ of pasteurized fine sandy loam soil (ca. 91% sand, 5% silt, 4% clay, and < 1% organic matter). Each pot was inoculated into three, 2.5 cm-deep holes made in the soil with approximately 2,000 vermiform RN using an auto pipette. The experimental design was an RCBD with ten replications. For resistant checks, cultivars Anand (Robbins *et al.* 2006; Stetina *et al.* 2014) and Forrest (Williams *et al.* 1981; Stetina *et al.* 2014) and for susceptible checks, cultivars Braxton (Robbins and Rakes 1996) and Hutcheson (Buss *et al.* 1988) were included. A reproductive index (RI %) was estimated to evaluate the response of each pot of RN using the following

formula (Robbins *et al.* 1999), $RI (\%) = (\text{Number of eggs} + \text{vermiform nematodes at test termination} / \text{Initial infestation level}) \times 100$.

Statistical analysis

All statistical analyses were conducted using PROC GLM scripts of SAS version 8 program (SAS Institute 2004). The differences among mean values were tested by Duncan's Multiple Range Test at $P \leq 0.05$. The statistical analysis and tests were performed for only the 64 selected accessions that showed resistance to RKN.

RESULTS

Root-knot nematode resistance

The RKN and RN reaction of SCN resistant germplasm accessions for resistance to RKN are presented in Table 1. Among the 120 SCN resistant PI lines studied, 64 accessions (Table 1) showed galling scores of 3.0 or less over two years of evaluation at three sites. Their means were not significantly different ($P=0.95$) and not different from the moderately resistant RKN check 5601T which had a score of 3.0. The root galling score of 64 accessions ranged from 1.3 to 3.0 with an average score of 2.3, indicating that these accessions were resistant or moderately resistant to RKN based on their performance relative to the resistant check, cv. 5601T. Among these, three accessions, PI404198B, PI438342, and PI532444A showed the lowest root galling scores with an average score of 1.3, indicating these three accessions possessed the highest level of resistance to RKN. According to a previous report (Shannon *et al.* 2004) PI404198B was reported to be highly resistant to SCN races 1, 3, and 5 (HG Types 2.5.7, 0, and 2.5.7, respectively) and moderately resistant to race 14 (HG Type 1.3.5.6.7), while PI438342 was resistant to SCN race 5 (HG Type 2.5.7) and PI532444A was moderately resistant to SCN races 2, 3, 5, and 14 (HG Types 1.2.5.7, 0, 2.5.7, and 1.3.5.6.7) as shown in Table 1.

Reniform nematode resistance

There was a significant difference ($P < 0.01$) among the 64 RKN resistance PI accessions for reaction to RN as

shown in Table 1. The average reproductive index (RI %) for RN was 13.1%. A minimum RI of 0.1% was estimated for PI507471 and a maximum RI of 45.8% was estimated for PI438496B. Among the four check genotypes, cv. Anand had the lowest RI of 0.8% and cv. Braxton had the highest index of 308.1%. Nine accessions, PI404198A, PI438498, PI467327, PI468915, PI494182, PI507470, PI507471, PI507476, and PI567516C showed similar or less RI (%) than a resistant check, cv. Anand. Thus, these nine accessions had high levels of resistance to RN. Among these accessions, PI404198A showed an RI of 0.5% for RN and a score of 2.8 for RKN. PI408198A had been reported to be resistant to SCN races 1, 2, 3, and 5 (HG Types 2.5.7, 1.2.5.7, 0, and 2.5.7, respectively). PI438489B with resistance to SCN races 1, 2, 3, 5, and 14 (HG Types 2.5.7, 1.2.5.7, 0, 2.5.7, and 1.3.5.6.7, respectively) showed RI of 0.9% for RN and a score of 2.2 for RKN. PI467327 was reported to be resistant to SCN races 1 and 3 (HG Types 2.5.7 and 0, respectively) with RI of 0.2% for RN and a RKN score of 2.8. A wild soybean (*G. soja*) accession PI468915 with SCN resistance to races 1, 3 and 5 (HG Types 2.5.7, 0, and 2.5.7) showed 0.4% of RI for RN, and a score of 2.3 for RKN. PI494182 with resistance to races 1, 3, and 5 (HG Types 2.5.7, 0, 2.5.7, respectively) and moderately resistant to race 2 (HG Type 1.2.5.7) of SCN, had an RI of 0.4% for RN and a score of 2.8 for RKN. PI507470 with resistance to SCN race 1 (HG Type 2.5.7) and moderate resistant to race 5 (HG Type 2.5.7) had an RI of 0.7% for RN and a score of 2.7 for RKN. PI507471 with resistance to races 2 and 5 and moderately resistant to race 1 and 14 had a very low RI of 0.1% for RN and a score of 2.7 score for RKN. PI507476 with resistance to races 3 and 5 and moderate resistant to race 1 of SCN had an RI of 0.5% for RN, and a score of 2.2 score for RKN. PI567516C with SCN resistance to races 1 and 3 and moderate resistance to race 2 in addition to resistance to the Hartwig SCN HG type had an RI of 0.8% for RN, and a RKN score of 2.2. The resistant check cultivar, Forrest with resistance to races 1 (HG type 2.5.7) and 3 (HG type 0) and resistance to RKN (Hartwig and Epps 1973) showed an RI of 5.0% for RN. Among the 64 remaining RKN resistant accessions, 15 accessions, PI089772, PI303652, PI404198B, PI417091, PI424137B, PI437690, PI438342, PI438489B, PI468903,

Table 1. Response of SCN resistance sources (Shannon *et al.* 2004) to root-knot nematode (RKN) and reniform nematode (RN).

Genotype	Maturity group	Nematode reaction						RKN ^{y)} (1-5)	RN ^{x)} RI (%)
		SCN ^{z)}							
		Race 1 (HG Type 2.5.7)	Race 2 (HG Type 1.2.5.7)	Race 3 (HG Type 0)	Race 5 (HG Type 2.5.7)	Race 14 (HG Type 1.3.5.6.7)			
Peking	IV	R		R	R	MR	1.5 a	5.3 p-z	
PI079693	III	MR		MR	MR	MR	2.0 a	23.8 e-m	
PI088788	III			R		R	2.0 a	17.8 f-p	
PI089008	II			MR	MR	MR	2.3 a	19.1 f-p	
PI089014	II	MS		MS	MS	MS	3.0 a	15.0 h-t	
PI089772	IV	R	R	R	R	MR	2.5 a	3.4 r-z	
PI090763	IV	R	R	R	R		1.5 a	6.3 p-z	
PI209332	IV			R	R	R	2.0 a	31.5 b-g	
PI303652	V	R		R	R	MR	2.2 a	1.8 s-z	
PI398680	IV			MR			2.7 a	38.4 b-e	
PI398682	IV			MR			2.2 a	27.6 d-i	
PI404198A	IV	R	R	R	R		2.8 a	0.5 xyz	
PI404198B	IV	R		R	R	MR	1.3 a	1.1 u-z	
PI407729	IV	MR					2.2 a	8.7 n-z	
PI416762	II	MR		R	R	R	1.7 a	13.6 h-y	
PI417091	II	MR		R	R	R	2.0 a	4.4 q-z	
PI417094	III			MR	MR	MR	2.5 a	14.5 h-u	
PI424137B	IV				MR	MR	3.0 a	1.3 t-z	
PI437090	0				MS	MS	2.5 a	12.1 j-z	
PI437655	III	R		R	R	MR	3.0 a	12.3 j-z	
PI437690	III	R	R	R	R	MR	2.8 a	2.4 r-z	
PI437725	IV	R		R	R		2.7 a	17.8 f-p	
PI437770	III			R		MR	2.8 a	25.3 d-k	
PI437908	II			MR			2.5 a	16.3 g-r	
PI438183	II			MR			2.8 a	9.6 m-z	
PI438342	VI				R		1.3 a	1.1 u-z	
PI438489B	IV	R	R	R	R	R	2.2 a	0.9 u-z	
PI438496B	III	MR		R			2.7 a	45.8 b	
PI438498	IV	R	MR	R	R		2.3 a	0.5 xyz	
PI438503A	II			R	MR	R	2.0 a	14.5 h-u	
PI458175B	IV				MR		2.0 a	6.6 o-z	
PI458199	IV		MR		MR		2.0 a	14.4 h-w	
PI458519A	II	MR	MR	MR	MR	MR	2.3 a	19.0 f-p	
PI458520	II			R	R	MR	1.5 a	20.9 f-o	
PI461509	I		MR	R	MR	MR	1.8 a	7.4 n-z	

Means followed by the same letter are not significantly different at $P=0.05$ by Duncan's Multiple Range Test.

^{z)}SCN reaction based on Niblack *et al.* 2004 and Shannon *et al.* 2004 and given as R, resistant or MR, moderately resistant to races 1 (HG Type 2.5.7), 2 (HG Type 1.2.5.7), 3 (HG Type 0), 5 (HG Type 2.5.7), and 14 (HG Type 1.3.5.6.7).

^{y)}RKN data: mean value averaged data from three locations with two reps across 2006 and 2007. Scored from 1=no root galls and 5=severe root galling, a score of 3.0 or less is considered showing some resistance.

^{x)}RN reaction is reproductive index (RI), calculated by dividing the average number of eggs + vermiform nematodes on each PI at test termination by the number of eggs and vermiform nematodes on cultivars Anand and Forrest (resistant checks).

Table 1. Continued.

Genotype	Maturity group	Nematode reaction					RKN ^{y)}	RN ^{x)}
		SCN ^{z)}						
		Race 1 (HG Type 2.5.7)	Race 2 (HG Type 1.2.5.7)	Race 3 (HG Type 0)	Race 5 (HG Type 2.5.7)	Race 14 (HG Type 1.3.5.6.7)		
PI467312	II		MR	R	R	R	2.7 a	7.7 n-z
PI467327	II		R		R		2.8 a	0.2 z
PI468903	II	MR	R	R	R		3.0 a	1.5 t-z
PI468915	II	R	MR	R	R		2.3 a	0.4 yz
PI475810	II				MR	MR	2.0 a	45.4 bc
PI490769	III		MR	MR	MR	MR	2.7 a	24.7 d-l
PI494182	0	R	MR	R	R		2.8 a	0.4 yz
PI495017C	IV		MR	R		MR	2.2 a	3.2 r-z
PI506862	IV		MR		R		2.0 a	4.0 q-z
PI507354	I	R	MR	R	R		1.5 a	1.0 u-z
PI507422	VI	R		R			2.0 a	2.3 s-z
PI507423	VI	MR		R			1.8 a	3.9 q-z
PI507470	VI	R			MR		2.7 a	0.7 xyz
PI507471	III	MR	R		R	MR	2.7 a	0.1 z
PI507476	VI	MR		R	R		2.2 a	0.5 xyz
PI509095	VII	MR		R	MR		2.7 a	1.4 t-z
PI532434	II		MR	MR		MR	3.0 a	40.6 bcd
PI532444A	I		MR	MR	MR	MR	1.3 a	21.3 f-n
PI548316	III			MR			2.2 a	13.9 h-x
PI567285	IV			R			2.0 a	16.2 g-r
PI567415A	IV	MR			MR	R	2.7 a	11.1 k-z
PI567421	IV					R	3.0 a	15.8 h-s
PI567492	IV					R	3.0 a	15.9 g-s
PI567510A	III					R	2.8 a	33.6 b-f
PI567512B	II					R	1.5 a	13.3 i-z
PI567516C	IV	R	MR	R			2.2 a	0.8 w-z
PI567535A	IV					R	1.7 a	40.1 b-e
PI567581	IV					R	2.5 a	27.7 c-i
PI567636	IV			R			2.3 a	28.1 b-h
5601T	Check						3.0 a	
Anand	Check						4.0 a	0.8 w-z
Forrest	Check							5.0 q-z
Hutcheson	Check							25.8 d-j
Braxton	Check							308.1 a
<i>P</i>							0.95	<0.01

Means followed by the same letter are not significantly different at $P=0.05$ by Duncan's Multiple Range Test.

^{z)}SCN reaction based on Niblack et al. 2004 and Shannon et al. 2004 and given as R, resistant or MR, moderately resistant to races 1 (HG Type 2.5.7), 2 (HG Type 1.2.5.7), 3 (HG Type 0), 5 (HG Type 2.5.7), and 14 (HG Type 1.3.5.6.7).

^{y)}RKN data: mean value averaged data from three locations with two reps across 2006 and 2007. Scored from 1=no root galls and 5=severe root galling, a score of 3.0 or less is considered showing some resistance.

^{x)}RN reaction is reproductive index (RI), calculated by dividing the average number of eggs + vermiform nematodes on each PI at test termination by the number of eggs and vermiform nematodes on cultivars Anand and Forrest (resistant checks).

PI495017C, PI506862, PI507354, PI507422, PI507423, and PI50909 showed an RI for RN equal to or less than the Forrest but higher than the Anand indicating that these 15 accessions are resistant to RN.

DISCUSSION

Among 120 cultivated soybean germplasm accessions from the USDA Soybean Germplasm Collection, previously reported to be resistant to single or multiple SCN HG Types, 64 accessions showed resistant to RKN (Table 1). Greg *et al.* (2008) reported that cultivars JGL934014XRJ and JGL937014XRJ were resistant to SCN, but were highly susceptible to RKN. About half of the SCN resistant accessions evaluated showed susceptibility to RKN. Out of 64 accessions showing different levels of resistance to both SCN and RKN, 24 accessions showed high resistant to RN. Therefore, these 24 accessions have resistance to SCN, RKN, and RN.

Efforts have been made to develop new soybean varieties resistant to SCN, RKN, and RN. For SCN resistance, the cultivar Hartwig was utilized as a resistance source in different soybean breeding programs to develop superior soybean cultivar with broad resistance to SCN (Anand 1992; Faghihi *et al.* 1995). Vierling *et al.* (1996) identified and mapped a QTL region on Chromosome (Chr. 11) for resistance to SCN race 3 (HG Type 0) in a mapping population derived from cv. Hartwig that explained 91% of the total phenotypic variation for resistance to SCN. This QTL region showed the highest effect ever reported for a single SCN resistance QTL. Genetic studies reported five major genes, *Rhg1* to *Rhg5*, underlying resistance to different SCN races (Rao-Arelli 1994). The QTL conferring a high level of resistance to SCN in many sources was mapped to the regions containing *rhg1* and *Rhg4* on Chrs. 8 and 18, respectively (Concibido *et al.* 2004; Wu *et al.* 2009; Vuong *et al.* 2011). Multiple resistance to SCN races 1, 2, 3, 5, 14, and LY1 QTL were identified and mapped on Chrs. 10 and 18 from PI567516C (Vuong *et al.* 2010). Recently, Jiao *et al.* (2015) reported that three significant QTLs associated with resistance to RKN were mapped on Chrs. 10, 13, and 17, and also two QTLs associated with

resistance to RN were detected on Chrs. 11 and 18 from PI 567516C. For RKN resistance, Luzzi *et al.* (1987) identified partial resistance in cultivar Forest (Luzzi *et al.* 1994). Recently, Pham *et al.* (2013) identified four candidate genes on Chr. 10 that carry a high level of resistance to RKN from PI96354 previously identified as having a high level of resistance to RKN. Three QTLs underlying RKN resistance in PI438489B, were identified on Chrs. 8, 10, and 13 (Xu *et al.* 2013).

Ibrahim *et al.* (2011) identified that silencing of tyrosine phosphatase (TP) and mitochondrial stress-70 protein precursor (MSP) genes can decrease gall formation of RKN. Charlton *et al.* (2010) mentioned that suppression of dual oxidase and a subunit of a signal peptidase reduced RKN numbers in roots. For RN resistance, six soybean lines, PI656647, PI659348, PI567516C, DS97-84-1, 02011-126-1-1-2-1, and 02011-126-1-1-5-1 were identified as having resistance to RN (Stetina *et al.* 2014). Melo *et al.* (2013) evaluated 199 genotypes for RN resistance. Among them Custer, PI437654, Fayette, BRSGO Ipameri, BRSMT Pintado, and BRS262 showed high levels of resistance to RN. Asmus (2008) evaluated 31 soybean genotypes for resistance to RN. Among them BRSMG250, TMG115RR, TMG121RR, MGBR015849, TMG113RR, BRS Jiripoca, and M-SOY833RR were not significantly different from the resistant cultivar 'Custer' (Rebois *et al.* 1970). Cardoso *et al.* (2014) reported that soybean resistance to RN is inherited quantitatively based on lines evaluated from two populations of Forrest (resistant) x BR96-25619 (susceptible) and Custer (resistance) x BR96-25619 (susceptible) normal distribution from highly resistant to highly susceptible. Ha *et al.* (2007) identified three QTLs conditioning RN resistant on Chrs. 11, 18, and 19 that explained 16, 8, and 21% of phenotypic variation, respectively from accession PI437654. This PI was also reported to be resistant to all known SCN HG Types and several resistance QTLs have been mapped from this source (Concibido *et al.* 2004). Iatsenko *et al.* (2014) reported that *Bacillus thuringiensis* DB27 produces two protoxins, Cry21Fa1 and Cry21Ha1, which act synergistically against nematodes.

Studham *et al.* (2009) conducted a study to identify whether *Rag1*, a single dominant gene for aphid resistance

also confers resistance to both SCN and RKN similar to *Mi-1.2*, a tomato gene that confers resistance to both aphid and RKN. They reported that the gene *Rag1* does not confer resistance to SCN and RKN. Davis *et al.* (1998) identified N87539 and N91245 from the breeding program in North Carolina and G801515, G83559, G939106, and G939223 from the University of Georgia with resistance to both SCN and RKN. Kruger *et al.* (2008) reported that LS94-3207 and LNX97164-35-5 were resistant to SCN and RKN. Youssef *et al.* (2013) identified expression of cloned *AtPAD4* (Phytoalexin-deficient4) gene in soybean roots, showing broadened resistance to SCN and RKN. Two soybean genotypes, Jake (PI643912) and S99-2281 developed by the University of Missouri Agricultural Experiment Station showed broad resistance to three nematode species, SCN, RKN, and RN (Shannon *et al.* 2007, 2009).

Kim *et al.* (2011) reported that stacking SCN resistance alleles of two QTL regions, *cqSCN-006* and *cqSCN-007*, significantly increased resistance level compared to each allele separately. Thus, stacking resistance genes or QTL could result in high levels of resistance to SCN. Meksem *et al.* (2001) identified and mapped two genomic regions of *rhg1* and *Rhg4* that together explained over 98% of the phenotypic variation associated with resistance to SCN race 3 (HG Type 0).

The identification of new genetic sources with broad spectrum resistance to multiple SCN HG types, RKN and RN would be beneficial for the development of germplasm and varieties to reduce losses from these nematode species. In this study, 24 accessions were identified as sources of resistance to three nematode species in soybeans. Some of the resistance accessions to the three nematode species or were studied to understand genetics of nematode resistance. However, many of these sources have not been studied for inheritance of resistance to these different nematode species. These sources may possess unique and previously unidentified resistance genes that could be incorporated into new varieties with higher levels of resistance. This information will be useful to soybean breeders and other researchers who want to study genotypes or develop soybean cultivars with cross resistance to multiple nematodes species.

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