RESISTANCE TO SOYBEAN CYST NEMATODE: GENETICS AND BREEDING IN BRAZIL

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Abstract The soybean cyst nematode (SCN), *Heterodera glycines* Ichinohe, is one of the most important diseases in Brazil that causes losses in practically all Brazilian growing regions. Breeding for SCN resistance has become a priority for all soybean breeding programs, since genetic resistance is probably the only practical SCN control method. The oligogenic basis of resistance in soybean and the genetic diversity of nematode populations that can suffer selection pressure from resistant varieties are the challenges to be managed by researchers. The most common strategy to introduce SCN resistance in Brazil has been the selection of lines derived from populations resulting from crosses including adapted genotypes and North-American cultivars with resistance derived from 'Peking' ('Pickett', 'Sharkey', 'Centennial', 'Padre', 'Forrest', 'Gordon', among others) and/or from PIs 88788 ('Bedford', 'Linford', 'Fayette', 'Leflore', etc), 90763 ('Cordell') and 437654 ('Hartwig'). Resistance of more than 60 Brazilian soybean cultivars was developed from few sources that normally provide resistance to race 3 or to races 1 and 3. A few varieties adapted to Central Brazil, the savannah area, have resistance to most races, except races 4^+ and 14^+ which are specific to Brazil and broke the resistance from 'Hartwig'. There are very few resistant varieties adapted to the Southern Region, where the demand for new resistant varieties is likely to increase in the near future. Selection assisted by molecular markers for SCN resistance is already a routine in some breeding programs and will become absolutely necessary to improve the selection efficiency and increase the genetic gains for this trait.

Keywords *Glycine max*, SCN, resistant variety, resistance management

Introduction

The soybean cyst nematode (SCN - *Heterodera glycines* Ichinohe) was found for the first time in Brazil in 1992 in soil samples from the States of Mato Grosso, Minas Gerais and Mato Grosso do Sul, collected after the 1991/92 growing season (Mendes and Dickson, 1993). Nowadays it is one of the most important diseases in Brazil that causes losses in practically all Brazilian growing regions. The objective of this paper is to give an overview on SCN incidence and race distribution in Brazil and try to show some of the research on genetics and breeding for SCN resistance developed in Brazil.

Current state of SCN in Brazil

After its first report in Brazil in the season 1991/92, the disease expanded to other soybean regions. Currently it is distributed in around 150 cities including 10 States, including Mato Grosso, Mato Grosso do Sul, Minas Gerais, Goiás, São Paulo, Paraná, Rio Grande do Sul, Bahia, Tocantins and Maranhão (Figure 1). In fields with SCN, the growers must live with the problem, since its eradication is practically impossible. Yield losses can reach 100% and it can be minimized by procedures like crop rotation with non-host plant species and the use of resistant cultivars.

Breeding for SCN resistance has become a priority for all soybean breeding programs, since genetic resistance is probably the only practical SCN control method. The oligogenic basis of resistance in soybean and the genetic diversity of nematode populations that can suffer selection pressure from resistant varieties are the challenges to be managed by researchers. Genetic resistance must not be the unique control option once the pathogen can easily develop new races under high selection pressure. The SCN genetic variability is larger in Brazil (Figure 1), where 11 races have already been found (1, 2, 3, 4, 4^+, 5, 6, 9, 10, 14 and 14^+, Silva et al., 2007). Dias et al. (1998) reported a field population collected from a field with the cv. 'EMGOPA-313' in February 1997 at Sorriso county, Mato Grosso State, which was classified in the greenhouse as race 4 and had the capacity to infect soybean cv. Hartwig, a North-American soybean cultivar which was until that time resistant to all SCN races. This isolate was referred to as race 4^+. Thus, the races 4^+ and 14^+ arise only in Brazil and differ from the classical 4 and 14 races, respectively, for their ability to parasite 'Hartwig'. However, the same authors showed that one of Hartwig's ancestors, the PI 437654 (Anand, 1992), remain resistant to all races of *H. glycines* including this SCN population. Abdelnoor et al (2001), using RAPD technique, characterized molecularly the race 4^+ SCN population

and showed that this population differs from others classified as races 4 and 9.
The possibility to arise a new SCN population able to defeat the 'PI 437654' resistance was proved by Arelli et al (2009) with the LY1 nematode population derived from a mass mating of races 2 and 5, which infects all currently known sources of resistance except PI 567516C. Analyzing the distribution of SCN races in Brazil (Figure 1), it is possible that a SCN population like LY1 can arise in the State of Mato Grosso (near Sorriso county) where there are both races 2 and 5.

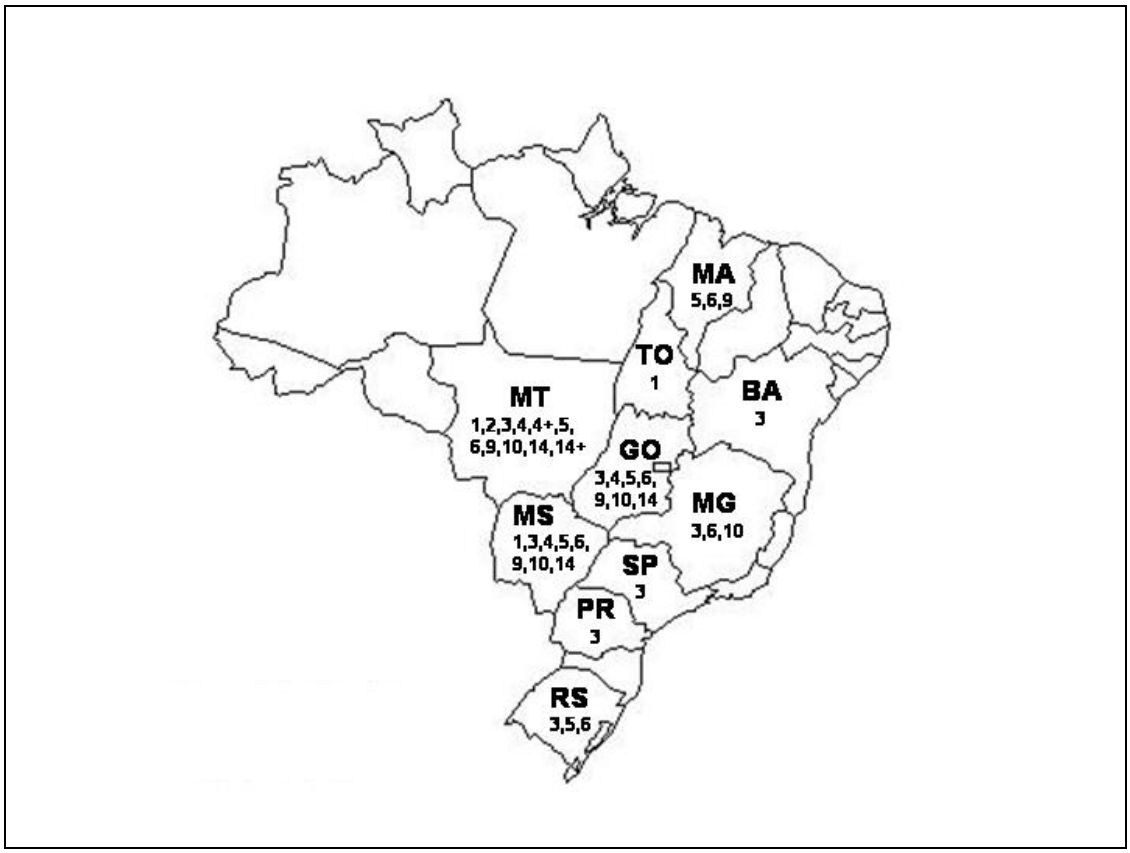

Fig. 1 Distribution of soybean cyst nematode races in Brazil: States of Rio Grande do Sul (RS), Paraná (PR), Sâo Paulo (SP), Mato Grosso do Sul (MS), Minas Gerais (MG), Goiás (GO), Mato Grosso (MT), Bahia (BA), Tocantins (TO) and Maranhão (MA).

In addition to the great number of races, the small number of resistant sources used by the Brazilian breeding programs is another difficulty to be overcome. The majority of cultivars available across the country are resistant only to races 1 and 3. Normally they are derived from 'Peking' and/or PI 437654 via 'Hartwig'. A few varieties adapted to Central Brazil, the savannah area, have resistance to most races, except races 4^+ and 14^+ which are specific to Brazil and broke the resistance of 'Hartwig' derived from a cross between PI 437654 and 'Forrest' (Anand, 1992).

Other important difficulty for the breeders is to obtain resistant varieties with good adaptation. The SCN resistant varieties normally have lower yield potential in relation to susceptible varieties in environments without or low SCN population. Other adverse effects like susceptibility to *Corinespora cassiicola*, late maturity or higher lodging scores were also observed among the resistant varieties restricting their employment by the farmers. This type of linkage between SCN resistance with undesirable agronomic traits was already reported by some authors (Noel, 1992; Chen et al, 2000; Mudge et al, 1996; Kopish-Obuch et al., 2005) and the same trend appears to be true for Brazilian resistant varieties. However, the breeders can always find exceptions to the general rule. The 'BRSMT Pintado' is a resistant SCN cultivar with adaptation to the State of Mato Grosso launched in 1998. Besides the resistance to races 1 and 3 and the moderate resistance to other SCN races, this cultivar has shown high yielding potential and yield stability reaching great commercial success until the current years.

Inheritance of resistance to *H. glycines*

The complexity of its inheritance and the huge task for selecting resistant individuals increase the difficulties to develop SCN resistant cultivars. Recessive and dominant genes were reported such as *rhg1*, *rhg2*, *rhg3*, *Rhg4* and *Rhg5* (Caldwell et al., 1960; Matson and Williams, 1965; Rao-Arelli et al., 1992; Qiu et al.,1997; Concibido et al., 2004; Meksem, 2001), besides different alleles for the same locus in different PI (Brucker et al., 2005).

In Brazil, the genetics of resistance of PI 437654 to race 4^+ involved expression of additive, dominant and additive x additive epistatic effects (Dias, et al., 2005), which suggests the presence of at least two genes and *i*-locus was associated with resistance. Obviously cv. 'Hartwig' did not receive at least one resistance allele next to *i*-locus derived from PI 437654.

Silva et al (2007a) found four genes conditioning resistance to race 14 and three genes involved on the resistance to races 3 and 9. The authors also found that the higher the number of resistance genes to SCN the higher the resulting resistance level. The *rhg1* gene has a great importance in the control of resistance to several races of SNC (Silva et al., 2007b).

Breeding Strategies Developed by the Companies in Brazil

The breeding strategy applied by each company depends on the region where the varieties will be launched and on the available structure to evaluate the developed genotypes. Once the SCN was detected in the Brazilian savannas where all SCN races were already detected, it is expected that the greater number of resistant varieties is available for those conditions. Infested environments are common in savannas and facilitate the assessments on field and the natural increase of resistant gene frequency into the plant populations. Some companies consider SCN resistance an obligate trait for savannas condition. In the South Region, the demand for SCN resistant varieties is still small but those varieties are already available for the growers.

The most common strategy to introduce SCN resistance in Brazil has been the selection of lines derived from populations resulting from crosses including adapted genotypes and North-American cultivars with resistance derived from 'Peking' ('Pickett', 'Sharkey', 'Centennial', 'Padre', 'Forrest', 'Gordon', among others) and/or from PIs 88788 ('Bedford', 'Linford', 'Fayette', 'Leflore', etc), 90763 ('Cordell') and 437654 ('Hartwig').

Resistance of more than 60 Brazilian soybean cultivars was developed from few sources that normally provide resistance to race 3 or to races 1 and 3. The resistant cultivars are being developed with the progress of the breeding and are beginning to replace with advantages the North-American resistant sources.

Soybean plant populations containing resistance sources in their genealogy are submitted to natural selection in field conditions along the generations of selfing until they reach higher levels of homozygosis. The environment used for this purpose is managed with susceptible cultivars to allow the presence of high SCN pressure.

Molecular markers assigned to the diverse *rhg* loci are available and private companies have applied molecular assisted selection (MAS) for SCN resistance in their routine. Selection can begin very early on individual plants from F2 generation or later on progeny lines before entering in the field trials to determine their yield potential. MAS technique has not been used by public companies in their routine activities.

To date, breeders can use SCN resistant and adapted Brazilian cultivars in their crosses. Some cultivars like 'BRSMT Pintado', BRS Jiripoca, BRSMG Liderança, FMT Matrinxã and M-Soy 8001 have shown stable resistance and are adapted to savannas region, becoming good options as resistance sources for breeding. Another cultivar, 'BRSGO Chapadões', is resistant to all SCN races except 4^+ and 14^+, and can be a good option for crossings. In Brazil, there are very few cultivars with resistance derived from 'PI 88788', one of them named 'BRSGO Ipameri' is adapted to Brazilian Central Region including BA, DF, GO, MG, MT and TO. The soybeans cvs. 'NK 412113' and 'NK 7059 RR' are adapted to Southern Brazilian region and probably have their resistance derived from 'PI 88788'. But in this case it is not possible to be sure about the resistance source as their genealogies are not available. Covering the genealogy has been a common procedure among some private companies.

Available cultivars and resistance management

Nowadays, there are around 60 soybean cultivars resistant to SCN in Brazil. However, for the States of GO, MT and MS, where there are several SCN races, the available resistant cultivars normally comprise only races 1 and 3 and they need resistant cultivars to other races. From these 60 resistant cultivars only 10 are tolerant to ghyphosate

herbicide, two of them adapted to the southern Brazilian region.

The ideal protocol for management of SCN resistance should include procedures like crop rotation with non-host plant species, the use of resistant and susceptible cultivars and practices of monitoring races. Crop rotation has had a very restricted use as a consequence of few options of economical non-host plant species. Monitoring races is not feasible in commercial scale for majority of the farmers. For infested environments, the farmers avoid the use of susceptible cultivars even in areas previously cultivated with non-host species or with low SCN population pressure. Therefore, among the indicated management practices, the use of SCN resistant cultivars has been the unique extensively applied by the Brazilian farmers.

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