1315 Reniform Nematode Management in Brazil

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The reniform nematode (*Rotylenchulus reniformis*) has become a significant pathogen in Brazilian cotton production. Studies on cotton as grown currently in the cerrado production region (Brazilian savanna) indicate that crop losses caused by the nematode will increase. The growing of cotton after a soybean crop in the same season and the absence of resistant cotton cultivars, limit the use of tolerant cultivars and nematicides for managing areas infested by the reniform nematode. Research on identification and introduction of *R. reniformis* resistance genes into cultivars adapted to conditions of the cerrado production region (Brazilian savanna) is highly recommended.

Keywords: *Gossypium hirsutum*, chemical control, crop rotation, resistance, tolerance, no-tillage cropping system, *Rotylenchulus reniformis*

INTRODUCTION

Cotton plantations in Brazil have changed a great deal in the last 15 years due to two innovative events: 1) an increase in cultivation in large, new areas referred to as the cerrado region (Brazilian wooded savanna); and 2) significant technological improvements in cotton production (in the cerrado sector (Fuzatto, 2006). The total number of hectares planted to cotton in Brazil (currently 1,066,679 ha) remains practically unchanged since 1992. However, productivity has increased approximately 55%. Cotton production has been moved from traditional cultivation areas (in the states of São Paulo and Paraná) to the country's central region (in the states of Mato Grosso, Bahia, Goiás, Mato Grosso do Sul, and Minas Gerais) (IBGE, 2007). About 88% of the areas have been planted to cotton for up to 15 years.

In the beginning, crop losses caused by plant-parasitic nematodes were insignificant in the new areas (Inomoto and Asmus, 2006) mainly due to low ability of nematodes to spread. However, the current agricultural production system in the cerrado has favored the selection, spread, and population build-up of nematodes. The primary causes are the monocropping of large areas for many consecutive years, and heavy traffic of machinery. As a result, economic production of plantations in the cerrado region has become jeopardized with time. That's probably why plant-parasitic nematodes have again become an important concern to Brazilian cotton producers during the last 4 or 5 years. The possible exceptions are producers from São Paulo and Paraná states, who have been aware of nematode problems since the end of the fifties (Inomoto and Asmus, 2006).

PLANT-PARASITIC NEMATODES ON COTTON IN BRAZIL

Very little is known about nematode distributions within the cerrado regions. However, systematic surveys of occurrence in cotton production areas have been conducted in Goiás (Gielfi et al., 2003), Mato Grosso do Sul (Asmus, 2004), and Mato Grosso (Silva et al., 2003) states. Among the various cotton-pathogenic species, root-knot (*Meloidogyne incognita)*, reniform (*Rotylenchulus reniformis*), and lesion (*Pratylenchus brachyurus)* nematodes were found in varied amounts in all states surveyed. There are also reports on the occurrence of plant-parasitic nematodes in cotton plantations in Minas Gerais (Silva and Santos, 1997) and in the western region of Bahia (Inomoto and Asmus, 2006). Nematodes have been observed to reduce cotton yields in most of the main production areas in the cerrado. Other significant nematode species which cause damage to cotton, such as *Hoplolaimus columbus, H. galeatus*, and *Belonolaimus longicaudatum*, have not been detected in Brazil yet.

RENIFORM NEMATODE IN BRAZIL

The reniform nematode is considered worldwide to be one of the main phytosanitary problems in cotton production (Robinson et al., 1997). *Rotylenchulus reniformis* is widely distributed in Brazil and is reported to be a parasite in many crops, such as pineapple, banana, coffee, papaya, passion fruit, soybean, tomato, and especially cotton (Monteiro and Ferraz, 1987; Lordello, 1981; Curi and Bona, 1972). Although this nematode has been detected in many cotton fields in Brazil, it often has not been considered to cause significant damages.

In contrast to the root-knot nematode, *R. reniformis* does not cause the obvious visible symptoms in roots nor the aboveground symptoms typical of root-knot nematodes in infested fields. Moreover, the population damage threshold is higher than the one established for the root-knot nematode.

Symptoms of reniform nematode parasitism in Brazilian cotton plantations do not differ from those in cotton fields in other areas of the world. Infected plants are typically underdeveloped and smaller than normal plants. Leaf chlorosis is not common, but other symptoms are similar to those caused by nutrition deficiency or soil compaction. In most cases, infected areas are bigger than those observed for other nematodes. In highly susceptible cultivars, or where nematode population levels are high, symptoms of intervenal chlorosis or necrosis may occur (Asmus et al., 2003). *R. reniformis* does not cause marked visible changes in roots. There is a reduction in root volume; in addition, after the roots are extracted and washed in running water, they retain a dirty appearance, due to clay particles adhering to nematode eggmasses.

Rotylenchulus reniformis populations were monitored monthly in a cotton plantation in Mato Grosso do Sul for two years (Asmus et al., 2005b). Build-up of the nematode population was strongly dependent on the presence of a cotton crop in the field. At any time of the year, population density differed with soil depth: the amount of nematodes between 0.2 – 0.4 m was always higher than between 0.0 – 0.2m. In Brazil, nematode population growth seems to be affected less by soil moisture and temperature than by the presence of a host plant. In a long-term study (Sereia and Asmus, 2006), the monocroping of a highly susceptible plant species led to a great increase in the *R. reniformis* population. Monoculture of a susceptible crop significantly increased nematode populations compared to areas where crop rotation with non-host plants or a crop-livestock integrated system was used.

The damage threshold of *R. reniformis* to cotton has not been measured rigorously under Brazilian conditions. Preliminary studies in Mato Grosso do Sul indicate that a population density between 500 and 1000 nematodes/200cc in the spring (at sowing) is likely to damage a cotton crop (Asmus et al., 2005b).

So far, all *Rotylenchulus* populations studied in Brazil belong to the *R. reniformis* species. An analysis of 48 populations from different regions of Brazil indicated that the range of morphometric features, such as stylet length, V%, and tail shape, was greater than among populations of *R. reniformis* in other parts of the globe (Soares et al., 2003). Two Brazilian populations, from cotton and from soybean, were similar to various populations from different cotton fields in the USA (Agudelo et al., 2005).

In relation to the variability of the species in Brazil, it is important to stress the occurrence of pathogenic populations in sugarcane in Pernambuco (Rosa et al, 2003).

MANAGEMENT

Some specific aspects of Brazilian cotton cultivation must be analyzed to better understand reniform nematode management.

Cotton production areas in Brazil are quite large. It is common for the main producers to plant cotton crops which are larger than 5,000 ha, sometimes more than 10,000 ha. High investments into soil preparation and crop establishment, as well as sale contracts made two or more years prior to the product's harvest, limit the producer's options for using integrated production systems, mainly through crop rotation.

Rotylenchulus reniformis reproduces prolifically on soybean, raising serious concerns (Asmus, 2005a). In most cotton production areas in Brazil, cotton has been introduced after many years of soybean production. Because soybean is a more tolerant crop than cotton, soybean cultivation leads to a nematode population build-up before the potential for damage to cotton becomes evident. In addition, in many regions of Mato Grosso state, rainfall allows double cropping of soybean and cotton in the same year. Early-maturing soybean is planted in September and harvested in January, while cotton is planted in January to be harvested in July or August (Aguiar, et al., 2006). In infected areas, after susceptible soybean, cotton crops are being established in the field at a point in time when the nematode population has achieved its peak, thus increasing the probability of great losses. Currently, this type of cropping system accounts for 25% of total cultivated area of cotton in Mato Grosso (Aguiar et al., 2006).

Another aspect to be considered is the increased use of no-till or minimum- till production systems, which require a cover crop for straw production. No-till is a significant tool for managing nematode-infected areas because threre is little dispersal of infested soil. On the other hand, if the cover crop is a good host for the nematode, the nematode population level will be maintained or elevated during the intercrop period.

Without a doubt, the ideal strategy is to employ agricultural practices that are implemented sequentially to avoid the introduction, spread, and population growth of the reniform nematode. It is important to emphasize that *R. reniformis* lives in spatial aggregations, so simple prophylactic measures, such as machinery traffic control, can limit the spread of *R. reniformis* from infested to uninfested areas. Infested areas should be treated differently during all phases of crop production. Unfortunately, prophylactic measures that could avoid the need for other forms of control usually are not taken.

Once high reniform nematode population levels are achieved, it is more difficult to manage infected areas. It is unlikely that only one nematode control measure in these areas will be sufficient to effectively bring back to the soil the same productivity as before the nematode was introduced. As a result, all actions that protect production areas from the introduction, spread, and population build-up of nematodes are essential. Diversified production through integrated crop–livestock systems or crop rotation between cotton and non-susceptible crops, as well as good choice of cover crops for straw production, is very important. Once the nematode has been introduced to a plantation, management strategies need to be changed to include resistant crops, crop rotation, or chemical nematicides.

When nematode populations have reached damage levels, specific measures are needed to control them. The cheapest, most effective measure among those is the use of resistant cultivars. Unfortunately, Brazilian commercial cultivars with the ability to suppress populations of *R. reniformis* are limited to IAC 23 and IAC 24 (Inomoto, 2006; Asmus, 2005b) and those cultivars are not recommended for cerrado conditions. As an alternative to resistant cultivars, tolerant cultivars (that support reproduction but are less damaged by *R. reniformis*) have been identified (Inomoto, 2006). Among them, FMT 701, BRS Cedro, Delta Opal and Makina are not only tolerant to the reniform nematode but also well adapted to the cerrado. However, it is necessary to point out that: a) tolerance decreases as nematode population density increases and b) tolerant crops do not avoid nematode multiplication; that is, their use does not decrease nematode soil population levels. At the moment, the Brazilian Agricultural Research Corporation - EMBRAPA is developing a research program to evaluate sources of resistance to the reniform nematode in *Gossypium barbadense* lines. *Gossypium barbadense* has great phenotypical variability and is widespread in Brazil (Barroso et al., 2006).

Currently, crop rotation using non-host crops is considered to be the best measure to control *R. reniformis*. Adequate choices are corn, sorghum, rice, and resistant soybean. Some soybean cultivars have been identified as reniform nematode resistant, including: M-Soy 8001, BRSMT Pintado, BRS Jiripoca, BRS Invernada, BRSMG 250 [Nobreza], M-Soy 8300, M-Soy 8500, M-Soy 8336, TMG 113, TMG 115, TMG 121 and FMT Tucunaré (Asmus and Schirmann, 2004). Planting cotton after susceptible soybean cultivars is never recommended due to the nematode's high reproduction level on susceptible soybean. Ongoing research by the author has shown that cotton - grass (*Brachiaria ruziziensis*) crop rotation can significantly reduce the nematode population in the soil. That means that integrated crop-livestock systems are a technical possibility for management of areas infested by *R. reniformis*. One significant aspect in crop rotation systems is related to *R. reniformis*' high persistance in soil. Two or more years of a non-host crop could be necessary before the nematode population level is appropriate for cotton planting. As a result, monitoring nematode population changes through soil sampling and soil analysis are highly recommended.

Spread of the reniform nematode results primarily from machinery movement and strong winds across fallow soil. No-till systems (NTS) can exert considerable pressure against *R. reniformis* populations, since they keep the soil covered permanently. The straw on the surface and less soil moving minimize nematode spread. However, nematode-susceptible cover crops planted in the beginning of October, or during Spring, are likely to maintain or even increase the nematode population density in soil rather than decrease it. Thus, it is essential to use resistant cover crops in plantation areas using NTS. Among the various cover crops in Brazil proven to be resistant to the reniform nematode (pearl millet, forage sorghum, oil radish, oat, rye, finger millet, moa, and Mulato grass), Mulato grass and forage sorghum showed the greatest decrease in nematode population and greatest increases in cotton production (Asmus et al., 2005a). An alternative to reniform nematode control is the cultivation of sunn hemp (*Crotalaria* spp.). Sunn hemp crops are not very common in cerrado plantations, probably due to economic and/or practical reasons yet have been used in some cases where there is a high nematode population density. *Crotalaria* spp. have been known for years to suppress various phytoparasitic nematodes. Nine species (*Crotalaria spectabilis*, *C. juncea*, *C. paulina*, *C. striata*, *C. grantiana*, *C. mucronata*, *C. retusa*, *C. breviflora* e *C. lanceolata*) effectively reduce nematode populations (Silva et al., 1989). Sunn hemp can be sown in the fall as a cover crop, benefiting from the last rains; or it can be sown in the spring, as a rotation crop.

Chemical control with nematicides, though not used much in the cerrado nowadays, is a common measure to control the reniform nematode in other regions where cotton is produced. In Brazil, the main product recommended for *R. reniformis* control is the carbamate, aldicarb, applied as a granule to the seed furrow at 0.9 to 1.95 kg of active ingredient/ha. Sometimes, when the nematode population density is high,, aldicarb is also applied to the soil surface, which increases its application costs. Cotton fiber yield is increased in treated areas. However, nematode populations are not usually reduced at the end of the growing season. As a result, aldicarb application is less sustainable through time, especially due to its high cost (approximately US$ 80/ha). Other registered nematicides for *R. reniformis* control on Brazilian cotton plantations are terbufos (3.0 to 4.0 kg a.i./ha) and carbofuran (2.5 kg a.i./ha). There are no registered fumigant products for cotton in Brazil. Recently, abamectin cotton seed treatment has been evaluated. Studies have shown that abamectin interferes with hatching and mobility of second-stage *R. reniformis*. Some experiments are being carried out in the current growing season to assess the effectiveness of abamectin in naturally-infected areas in Brazil.

An alternative to reniform nematode management for producers who use traffic control of machinery is cotton seeding between the rows of the previous crop. This interesting and simple measure should not be the only control method, but rather be used along with other management techniques.

CONCLUSIONS

Cotton production systems currently in use in Brazil are highly likely to spread and increase the population density of plant-parasitic nematodes. In the short-term, nematode management via increased use of crop rotation with non-host crops is unlikely. Thus, the best possibilities for *R. reniformis* control rely on resistant or tolerant cultivars, and nematicides. The need for resistant cultivars still limits reniform nematode management. More studies are needed to identify *R. reniformis* resistance genes and introduce them to cultivars adapted to cerrado conditions. Considering that soybean and cotton crops can be planted alternatively in the same production area, the development of reniform nematode management methods are highly recommended for both crops.

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