We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900
Open access books available

186,000
International authors and editors

200M
Downloads

154
Countries delivered to

Our authors are among the

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS
BOOK CITATION INDEX
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Cotton in Brazil:
Importance and Chemical Control of Bolls Rot

Willian Luis Antonio Zancan, Luiz Gonzaga Chitarra and Gilma Silva Chitarra

Additional information is available at the end of the chapter

1. Introduction

Currently, cotton (*Gossypium hirsutum* L. var. *latifolium* Hutch.) is one of the oldest plant fibers cultivated in the world, and it has been used not only for producing natural raw materials for the textile industry, but also by the use of its products for other important purposes, such as edible oil, pharmaceutical and animal feed oil (Chitarra, 2008).

The current world production of cotton is approximately 25.10 million tons and it has being produced by more than 60 countries on five continents. Among the major world producers, China, India, United States, Brazil and Pakistan stand out (United States Department of Agriculture - USDA, 2012). The expansion of areas under cultivation, the monoculture cropping system and especially the use of susceptible cultivars cause a significant increase in the inoculum potential of various pathogens, consequently causing a higher incidence of diseases.

The cotton boll rot can be caused by various pathogens, especially the fungi *Colletotrichum gossypii* South var. *cephalosporioides* Costa, *Colletotrichum gossypii* South, *Botryodiplodia theobromae* Pat, *Diplodia gossypina* Cke, *Fusarium* sp, *Ramularia areola* Atk. and the bacterium *Xanthomonas axonopodis* pv. *malvacearum* Smith Dye. These pathogens can directly affect the crop by reducing the productivity, the fiber quality and also by increasing the costs of production. Based on these facts, the knowledge of symptoms of the disease, morphology, physiology and epidemiology of pathogens are critical factors for defining the best control strategy to be adopted, in order to achieve high yield and quality of cotton fiber.

Among the methods of management and control of cotton boll rot, the following are used: crop rotation, tolerant varieties, chemically treated seeds, cultivar specific, spacing and plant population, insecticides (for pests and disease vectors) and fungicides. Fungicides that are belonging to different chemical groups are the most commonly used in commercial fields of cotton.

2. Cotton crop

Cotton is a plant of the malvaceae family, which originated from tropical and subtropical conditions, currently cultivated in all continents. Among the major producing countries, China is responsible for a production of approximately 6.53 million tons, followed by India with 5.53 million tons, the United States with 3.93 million tons, Brazil with 1.96 and Pakistan, with 1.91 million tons (United States Department of Agriculture - USDA, 2012).

In Brazil, the cotton cultivation began in the 90s, however, at that time, there wasn't adequate technology, i.e., operational infrastructure at the field level, fiber processing, lack of genetic material potentially suitable for the producing regions and non-fulfillment of the international consumer market (Guerra, 2006). Cotton production was mainly concentrated in the South, Southeast and Northeast of the country. The shift of cotton production to the states of the Midwest, known as producers of upland cotton, such as Mato Grosso, Goiás and Mato Grosso do Sul, in the region called "Cerrado", was the result of favorable conditions for crop development and, also, the use of varieties adapted to local conditions, disease tolerant and more productive potential. All these factors were combined with modern cultivation techniques, plus the increased use of growth regulators (Beltrão, 1999), what are used to maintain the balance between the vegetative and reproductive growth, which are essential to ensure adequate fiber production. These significant changes meant that Brazil would compete with countries with high technology, such as Australia and the United States. Other Brazilian states that are also cultivating cotton are Bahia, Maranhão and Piauí in the northeast, whose production systems have similar characteristics to the Midwest (Beltrão, 1999).

Cotton is one of the most important economic products of the group of fibers due to volume and value of production. Its cultivation is also of great social importance, due to the number of jobs generated directly or indirectly. The fiber, the main product of cotton, has many industrial applications. Examples are manufacturing of yarn for weaving of various kinds of fabrics, cotton batting for hospital use, felt clothing, blankets and upholstery, photographic films, plates for radiography among others (Richetti & Melo Filho, 2001).

The cottonseed is rich in oil, with approximately 18 to 25%, and contains 20 to 25% of crude protein. The cottonseed meal is a byproduct of oil extraction, and is used in animal feed because of its high protein content, approximately 40 to 45%. The seed coat is used to make certain types of plastics and synthetic rubber (Carvalho, 1996). The cottonseed, after the removal of the plume, is commonly used as ruminant feed. It is considered a palatable food, with characteristics of dietary fiber with high levels of energy and protein (Savastano, 1999).

The cotton plant is one of the most complex phytosystems found in nature (Oosterhuis, 1999). During most of the cycle of plant, various processes are occurring at the same time, such as vegetative growth, budding, flowering, growth and maturation. It has at least two types of branches (monopodials and sympodial), two types of true leaves (of the branches and fruit) and at least two gem (axillary and extra-axillary) located at the base of each sheet.

The cotton life cycle can be divided into five phases. The first phase covers the period between sowing and emergence, where watering and seed germination occurs as well as

establishment of the cotyledons, with an average of four to ten days. In this stage, in Brazil, usually occurs "damping off", due to the intensive period of rainfall. In the second phase, the first flower bud comes out, which usually occurs 30 days after emergence (DAE) and the main cotton diseases start to appear, such as, ramularia and ramulosis. The third phase is characterized by the appearance of the first flower and it occurs at 45 to 60 days after emergence, with an increase of cotton diseases severity. The fourth step is the opening of the first cotton boll, between 90-120 DAE and, depending on the environmental conditions, treatment to control bolls rot has to be done. The fifth phase includes the harvest period, when the cotton bolls are completely open, which occurs after 120 days after emergence on average, depending on the variety and environmental conditions (Beltrão & Souza, 2001). Therefore, the knowledge of the physiological stages of the plant is of fundamental importance in carrying out the cultural practices.

In cotton crops, for the plant to show its productivity potential, it is necessary to maintain healthy conditions (no disease) in all phenophases. The cotton life cycle, in certain regions, reaches approximately 200 to 220 days and it is considered a long cycle when compared with other crops, such as soybeans and corn, that have a life cycle of around 120 days. For this reason, it is necessary to monitor the crop properly during the whole cycle, so the cotton plants can obtain high productivity. Fungicides are responsible, in Mato Grosso, for about 7% of the cost of production, a similar percentage is destined in the control of aphids, vector of the virus causing blue disease (or Virose Vein Mosaic) (Mehta & Menten, 2006).

The expansion of cultivated area, the monoculture cultivation system and especially the use of susceptible cultivars cause a significant increase in the inoculum potential of various pathogens, and, consequently, a higher incidence of diseases. The disease can affect the production of cotton fiber and the seeds. Of course, the damage is proportional to the destructive power of each pathogen and the severity of each disease.

3. Cotton boll rot

In the main producing regions of the world, especially in Brazil, the losses in cotton crops caused by cotton bolls rot has increased in recent years. This disease is considerably affecting the production chain, either by production losses and/or fiber quality.

According to Hillocks (1992) a great number of microorganisms were isolated from cotton bolls rot, and these pathogens can be divided into three groups: those capable of penetrating intact bolls; those which are introduced by insects; and those are introduced after the boll are damaged by insects or after the suture of the boll lobes are broken. Most of the agents that cause cotton bolls rot penetrate through wounds from insect or pests and / or rupture of the division through the lobes of the bolls. However, primary infection of boll, when the pathogen penetrates directly into the healthy boll, is common in areas with high humidity or in those where the crop has dense vegetative growth.

According to Belot & Zambiasi (2007) there are many pathogens that can cause boll rot, such as *Alternaria* spp., *Ascochyta gossypii*, *Aspergillus flavus*, *Bacillus pumilus*, *Colletotrichum* spp.,

Diplodia gossypina, *Erwinia aroideae*, *Fusarium* spp., *Lasiodiplodia theobromae*, *Myrothecium roridum*, *Pantoea agglomerans*, *Phoma exigua*, *Phomopsis* sp., *Phytophthora* spp., *Rhizoctonia solani* and *Xanthomonas axonopodis* pv. *malvacearum*. Various symptoms may be due to the existence of a complex of pathogens. Commonly, the bolls are soft and blackened, and in some cases, arise from lesions in both the apex and at its base. Fructifications in various colors, from white to purple are also verified.

Zancan et al. (2011) worked with three cotton cultivars BRS Araçá, Delta Opal and FMT 701, using two spaces between the rows of cotton, 0.80 and 0.90 m, two treatments, with and without surface disinfection of cotton bolls with (1%) sodium hypochlorite, and three levels of bolls rot (Figure 1), initial, intermediate and final. Nine fungi associated with the cotton bolls rot were detected in the spacing of 0,80 m and seven, in the spacing of 0.90. Among them, *Alternaria* spp., *Aspergillus* sp, *Botryodiplodia* sp, *Colletotrichum* spp., *Fusarium* spp., *Myrothecium roridum* and *Penicillium* sp. were associated with the cotton bolls rot in different percentages in both row spacings. The fungi *Diplodia* sp. and *Stemphylium* sp. were found only in the spacing of 0.80 m, both with 1.7% of occurrence.

In this study, saprophytic and/or opportunistic fungi detected and associated with cotton bolls rot were *Botrytis* spp, *Cephalosporium* sp, *Cercospora* spp., *Cladosporium* sp, *Curvularia* sp, *Epicoccum* sp, *Graphium* spp, *Mucor* sp, *Nigrospora* sp., *Periconia* sp., *Trichotecium* sp and *Rhizoctonia* sp. Among the cotton cultivars, the NUOPAL had the highest occurrence (%) of fungi associated with cotton bolls rot.

The results obtained by Zancan et al. (2011) confirm reports from Belot & Zambiasi (2007) and Silva et al. (1995), who found fungi associated with cotton bolls rot to be *Alternaria* spp., *Colletotrichum* spp., *Fusarium* spp., *Botryodiplodia theobromae*, *Myrothecium roridum* and *Aspergillus* spp.

Ranney et al. (1971) classified four factors that favor infection of cotton bolls rot: long wet periods (5 to 7 days), long periods with relative humidity above 75%, low light intensity, i.e., long overcast periods and high temperatures. According to Hillocks (1992) long periods with high atmospheric humidity is the main factor favoring the development of an epidemic of cotton bolls rot. Araujo & Goulart (2004) stated that the main predisposing factor for bolls rot is an excess of moisture. In the rainy season or under conditions of high relative humidity, the bolls remain with moisture on their surface for long periods, causing the gradual tissue flooding, and, in this case, promoting the penetration of the primary agents that cause the disease followed by secondary action of saprophytes. The excessive vegetative growth, high planting density and unbalanced fertilization are also factors that can increase the incidence of cotton bolls rot.

In Georgia, in 1968, Ranney et al. (1971) observed yield losses in the order of 1.5% caused by cotton bolls rot, in a particularly dry year, while in the next year, these losses increased to 14%, due to higher humidity and temperature. The same authors concluded that with the cotton plant has vigorous vegetative growth, the moisture retained in the canopy may be sufficient to promote boll rot, even if the relative humidity is lower. This effect was observed
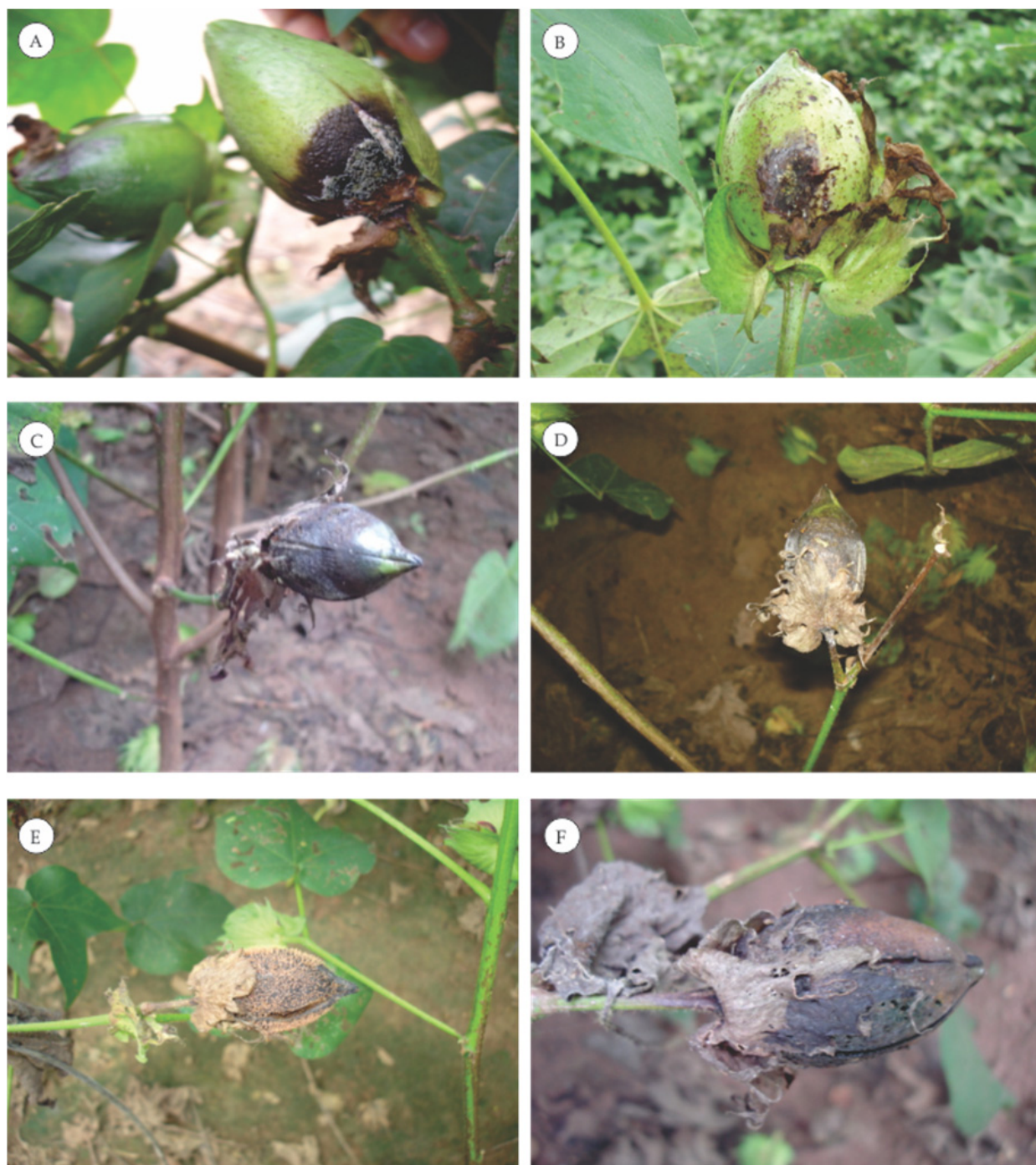
Figure 1. Cotton bolls with symptoms at different stages of decay. A and B) Early Stage, C and D) Intermediate Stage, E and F) Final Stage. IMA - Primavera do Leste - MT, 2011.

in the United States during the 70s, where cotton farmers experienced great productivity losses related to the bolls rot due to the use of high doses of nitrogen fertilize, that favored plant growth and provided a favorable environment conditions for the disease.

Cotton bolls rot can cause 20-30% losses in productivity, (Iamamoto, 2007). In general, affected plants losses the first bolls positions, where the plants produce the best quality of cotton fiber.

The presence of aphids and insects in cotton fields has favored the penetration of various microorganisms mainly due to the damage they cause on the earliest bolls. Moreira et al. (1994) found that the main causes of bolls rot in regions of the state of São Paulo were the attacks of the boll weevil (*Anthonomus grandis*), yellowstriped bugs (*Horcias nobilellus*) and cotton-stainer (*Dysdercus* spp). These insects favor the penetration of fungi and bacteria. The damage related to the attack of these pathogens was between 12.6% and 15.2% of bolls rot.

Ribeiro et al. (2000) found in samples of cotton bolls from Mato Grosso, Mato Grosso do Sul and Bahia showed no visible external symptoms, but all had symptoms of internal decay. Some samples detected external damage caused by stink bugs (migrant populations of *Euschistus heros* and *Piezodorus guildinii* from soybean and striped-bugs from cotton), but internally infected by pathogens. In a study conducted by the same authors, they observed mixed infection among the eleven samples of the variety Ita-90, where the incidence of *Fusarium* sp. was the highest, followed by *Aspergillus* sp. and *Colletotrichum* spp.. With respect to bacteria, *Erwinia* was identified in 2 samples.

Bagga & Laster (1968) reported a simple technique for evaluating the role of insects in cotton bolls rot development and reported that, the tarnished plant bug (*Lygus lineolaris* (Palisot de Beauvois) and fruit fly (*Drosophila melanogaster* Meigen) could cause the infection of cotton bolls rot after their feeding.

Bagga (1970) observed in both laboratory and field that *Bacillus subtilis*, *Diplodia gossypina*, *Glomerella. gossypii*, *M. roridum*, and *Xanthomonas malvacearum* can penetrated the boll valve directly from contact inoculation, and the internal rot was similar to that resulting from injection inoculation. This shows that these organisms are primary pathogens of the cotton bolls rot. The remaining 31 organisms tested in this study did not penetrate the endocarp when applied by contact, but all caused a complete internal rot when the infection method of inoculation was used.

According to Suassuna & Coutinho (2007), symptoms of *Colletotrichum* spp. in cotton bolls are depressed reddish-brown spots that expand and darken over time. In the central part of the lesion, a spore mass may be observed with a pink coloration. The infection causes the bolls to only partially open, leaving the fiber darkened and difficult to remove.

The fungus *D. gossypina* forms small brown lesions on the bolls and cotton bracts, and in high humidity conditions, the spots may expand, affecting the whole cotton boll. With the evolution of lesions, sporulation of the pathogen occurs, and a black coloration to the boll is observed (Paiva et al., 2001). Under these conditions, the boll dries and opens prematurely, exposing blackened fibers and seeds.

In the rot caused by *Fusarium* spp., small necrotic spots ranging in color from dark blue to brown occur in the bracts and in the bolls, and after sporulation of the pathogen, the lesions are covered by a pink color mass (Paiva et al., 2001). In these cases, the capsule does not open (Suassuna & Coutinho, 2007).

Myrothecium leaf spot, caused by the fungus *Myrothecium roridum* Tode, was responsible for losses of 50% in the town of Balsas in Maranhão (crop season 2003/04) and, since then, it has

also been reported in the state of Mato Grosso. The symptoms of the disease can appear on the leaves and cotton bolls (Suassuna et al., 2006). According to Belot & Zambiasi (2007) the first symptoms appear on the bottom leaves, spreading then to the bracts, bolls, petioles and stems. In the cotton bolls, petioles and stems, the lesions are irregularly shaped and have a dark color, surrounded by a violet and red color.

The fungus *Sclerotinia sclerotiorum* was observed infesting cotton plants in areas under central pivot, with symptoms of wilting, necrosis and wet rot of the stem, the petiole of the leaf and the bolls. Inside the capsule was observed a white, cottony mycelium and black and irregular sclerotia, that is, resistance structures of the pathogen (Charchar et al., 1999).

The angular leaf spot (bacterial blight) caused by *Xanthomonas axonopodis* pv. *malvacearum* occurs widely in all cotton producing regions. The wide dissemination and high variability of the pathogen are serious problems for the Brazilian cotton crop. Usually, the bacteria focuses on leaf blades, where we can observe angular lesions, initially green in color with an oily appearance and then brown in color with a necrotic appearance. Commonly, coalescence of the damaged area occurs and over time, tearing of the leaf. According to Belot & Zambiasi (2007) lesions of bacterial blight in bolls are rounded, oily and dark, later becoming black with a small depression on the site. Depending on the phenological stage of the plant, the disease causes fruit drop and premature opening of the new cotton bolls. When the bacterium is installed inside the capsule, infection may reach the seeds, causing yellowing of the fibers and allowing the entry of other pathogens.

3.1. Management of cotton bolls rot

The monitoring of the cotton crop should be performed periodically in order to diagnose early symptoms of diseases, so control measures can be undertaken with the aim of preventing the diseases progress.

Among the tactics of handling the cotton bolls rot can be used crop rotation, tolerant varieties, high quality seeds, adequate spacing and plant population, chemical control with insecticides (pests which are disease vectors that cause damage in cotton bolls) and fungicides. There is no specific recommendation for chemical control; however, the integrated management of diseases, as recommended for foliar diseases, should also reduce the incidence and severity of bolls rot. According to Hillocks (1992), using delinted seeds treated with fungicides is also a practice that reduces the primary inoculum in cultivated areas. The delinting consists in making a chemical reaction using sulphuric acid, which removes partially or totally the lint, which is the residue of the cotton fibers on the seeds. This method improves the performance of cottonseeds by eliminating the superficial microorganisms and, consequently, improving seed germination.

3.1.1. Chemical control of cotton bolls rot

In the integrated management of diseases, the use of fungicides is a major method to control plant diseases to be an effective method against pathogens, the facility of

implementation and the immediate results of this method, which makes it useful in many cultures.

The chemical control of plant diseases is practiced with greater intensity in economically developed countries, where agriculture is more technologically advanced with expected higher yields. Alviter & Nita (2011) states that the abusive uses of fungicides can cost not only growers budget, but it also can cost the society and the environment. Therefore, fungicide usages need to be carefully planned with a good understanding of plant disease epidemics, their components (host, environment and pathogen), fungicide mode of action (biochemical, biological, physical), risk of resistance development, and host physiology, among others aspects. Disease risk assessment tools can be very useful to reduce the costs of disease control and increase safety of the producers by helping growers to use fungicides in a timely and more efficient manner (Harwick 2006; Madden et al., 2007).

In the mid-1980s, developing countries accounted for about one-fifth of global consumption of pesticides. Their share in world use of insecticides is relatively high at 50 percent, while this share is 20 percent for fungicides and 10 percent for herbicides. East Asia (including China) accounts for 38 percent of developing countries' use of pesticides, Latin America for 30 percent, Near East/North Africa for 15 percent, South Asia for 13 percent, and sub-Saharan Africa for only 4 percent. Pesticide use is high on deciduous fruits, vegetables, cotton and cereals, and more moderate on citrus fruits, tropical fruits, cocoa, coffee and tea (FAO, 1995).

Currently, there has been an increase in the practice of using fungicides for controlling plant diseases. Major crops such as soybeans, cotton, corn and beans have already adopted this practice to reduce the progress of leaf spots, reducing the losses in yield and grain quality (Juliatti et al., 2001).

The use of fungicides to control boll rot does not prove effective because it is difficult to reach the bolls, due to the dense foliage of cotton, rainy periods are responsible for washing the fungicides from the leaves and the bolls of cotton (Hillocks , 1992).

Baird (1998) states that due to difficulty in controlling bolls rot, the efficiency of fungicides in Georgia has not justified the cost of control, with no increase in production. Numerous tests have been conducted and the results obtained are not accurate or verify no effective control.

Juliatti et al. (2001) evaluated the effectiveness of the inductor resistance acilbenzolar-S-methyl (Bion) at doses of 5, 15 and 25 g of commercial product, in combination with the fungicide azoxystrobin and copper oxychloride to control Ramularia spot, rust and boll rot. The authors observed no difference among treatments in relation to disease severity, but there was a reduced incidence of boll rot, and they acknowledged the potential use of induced resistance as a strategy for controlling this disease.

In work done by Zancan et al. (2011), the authors evaluated the chemical control of cotton bolls rot with the use of fungicides on cotton cultivars NUOPAL, BRS Araça and FMT 701, in two rows spaced at (0.80 and 0.90 m), and found that there was a variation of

approximately 2 to 15% of bolls rot on the cotton cultivars planted in spacing of 0.80 m and a variation of about 7 to 23% with 0.90 m spacing in the three cultivars when submitted to different chemical treatments. The lower incidence of bolls rot was observed in BRS Araça (Figure 2). These results showed that there are variations in bolls rot among cultivars in the southeastern region of Mato Grosso. The incidence of cotton bolls rot was higher in a larger spacing (0.90 m) due to the further crop development, favoring vegetative growth, with higher number of leaves, which favored the retention of moisture inside the plant canopy. The development of the pathogens was also favorable due to the environmental conditions. In this case, the fungicides were difficult to penetrate the leaf canopy, with lower retention of the products and, consequently, reducing the effect of them.
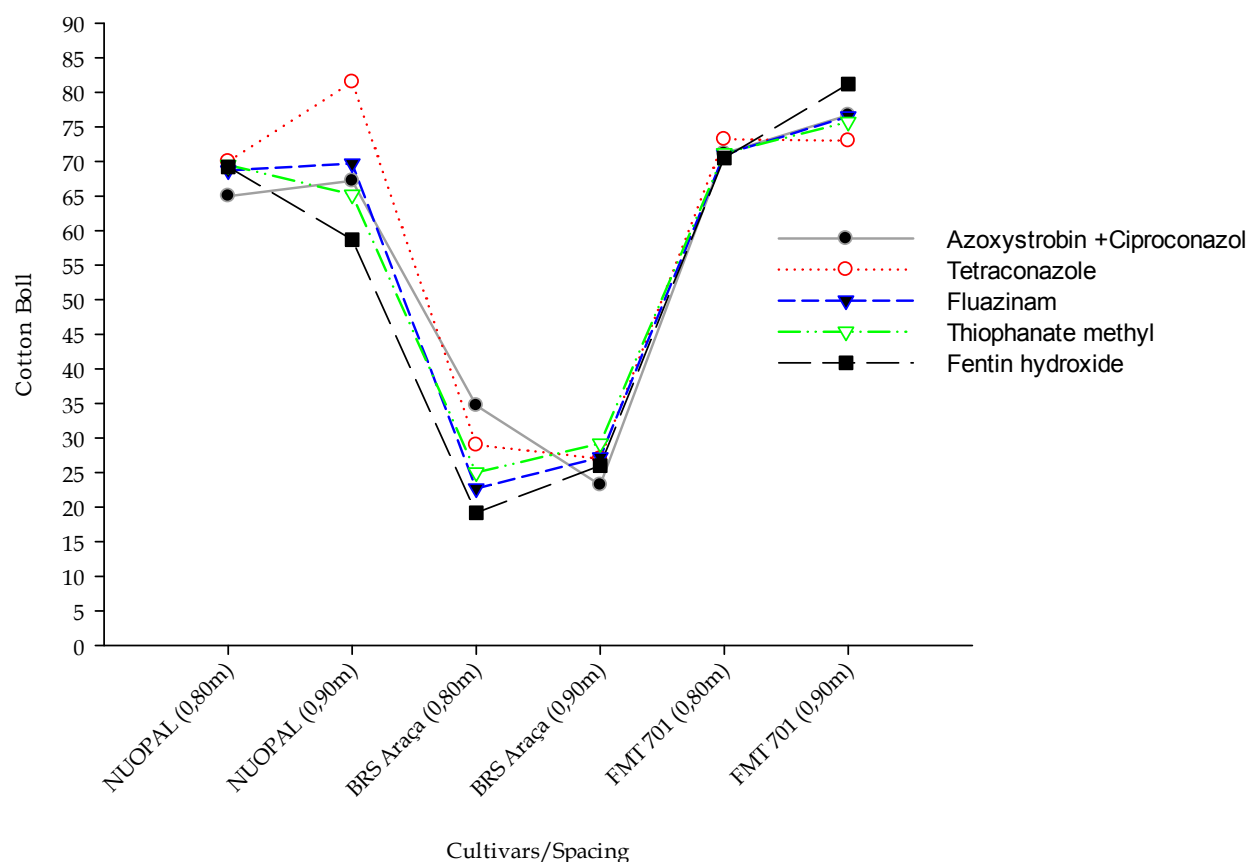

Figure 2. Number of cotton bolls rot in the cultivars NUOPAL, BRS Araçá and FMT 701 treated with fungicides at different spacing between cotton rows (0.80 e 0,90 m). IMA - Primavera do Leste - MT, 2011.

In relation to the fungicides, there were variations in the number of cotton bolls rot. The fungicide Azoxystrobin (strobilurin) + cyproconazole (triazole) reduced the cotton bolls rot in the cultivar NUOPAL (0.80 m) and BRS Araça (0.90 m). Both act differently on the fungi: strobilurins, with mesostemic action, inhibit mitochondrial respiration, while triazoles, with systemic action are related to the inhibition of sterol biosynthesis, and their function is related to the maintenance of the membrane integrity, which is preset in all eukaryotes (Reis et al., 2010).

The fungicide belonging to the strobilurin (Figure 3), groups of chemicals extracted from the mold *Strobilurus tenacellus* are used in agriculture as fungicides. These compounds belong to the group of the quinone outside inhibitors (QoI) or group 11 fungicides, whose toxicity arises from the inhibition of the mitochondrial respiratory chain at Complex III level, preventing the biochemical chain of electron transfer at the site of mitochondria, interfering with respiration of the pathogen (Ghini & Kimati 2000). They are typically absorbed by the cuticle of the fungus, acting as protectant fungicides (Vincelli & Dixon, 2002).

The active ingredient cyproconazole, which acts systematically, belongs to the group of triazoles, inhibitors of sterol synthesis, which are important structural components of fungal cell membranes. Triazoles are referred to as "DMI" (Demethylation Inhibitors) or group 3 fungicides, which is a reference to their unique mode of action (C14-demethylation is sterol biosynthesis), and all triazoles have the same mode of action (Tenuta et al., 2008). The fungicide tetraconazole belongs to the triazole group, which is inhibitor of ergosterol. When this fungicide was used it was observed a great number of bolls rot in NUOPAL cultivars spaced at 0.80 and 0.90 m and FMT 701 spaced at 0.90 m (Zancan et al. 2011). Probably, this fungicide was not efficient enough to control the pathogens associated with bolls rot in these cultivars.

According to Ghini & Kimati (2000) the fungicide fluazinam or group 29, acts as a potent uncoupler of oxidative phosphorylation and this proved to be an intermediary between other fungicides in the control of bolls rot, along with thiophanate methyl. The latter (Figure 3) specifically affects cell division, as it has selective activity for tubulin fungi, and binds to the protein, preventing the occurrence of polymerization of microtubules forming the mitotic spindle (Kendall et al., 1994; Wheeler et al., 1995).

In relation to organostannic compounds or group 30 fungicides, a common example is the fentin hydroxide based fungicide, that when used in controlling bolls rot, observed a reduction in the number of bolls rot in the cultivars NUOPAL (0.90 m), BRS Araça (0.80 m) and FMT701 (0.80 m). This fungicide acts as a multi-site inhibitors, prevents spore germination and inhibits the metabolism of fungi, particularly respiration, inhibits oxidative phosphorylation in mitochondria and induces lipid peroxidation. Low concentrations of organostannic compounds inhibit the translocation of H + bound to the membrane, H +ATPase and ions such as Na + and K + (Papa et al., 1982; Powers & Beavis, 1991).

Lawrence et al. (2007a) while testing the fungicides Quadris ® and 2.08SC Topsin M ® to control bolls rot found that foliar spraying of fungicide 2-4 times during flowering increased the cotton yield.

Roncadori et al. (1975) proposed that the fungicides applied at the flowering stage may be important in controlling *Fusarium*, one of the pathogens of bolls rot. The protection of flowers with fungicides more efficiently reduced bolls rot in relation to fungicide application at the opening bolls. These authors analyzed different methods to control the cotton bolls rot in Georgia, among these, the protectant fungicides captan and none, and found that they were ineffective in controlling this disease, becoming necessary to associate management combinations, such as reduce nitrogen rates and larger plant spacing.
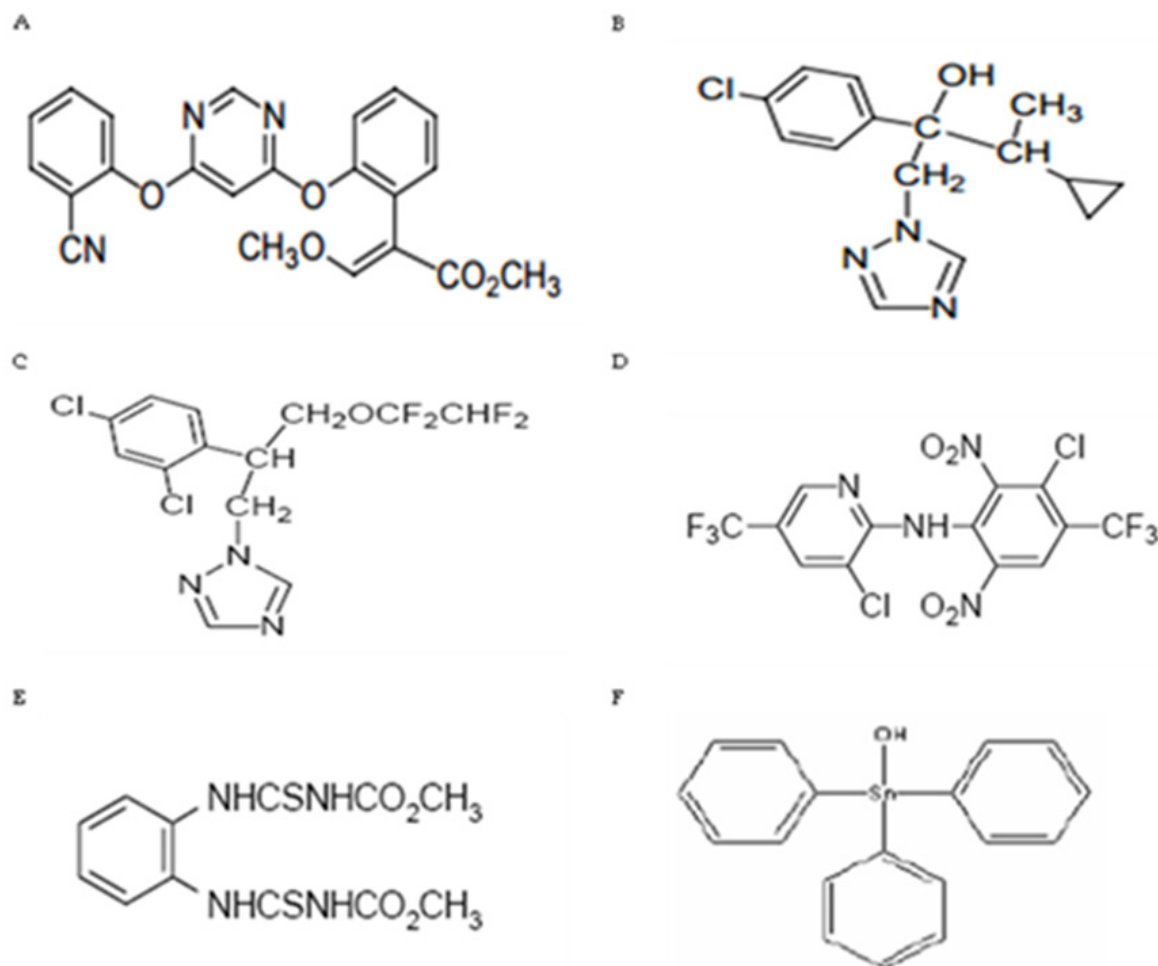
Figure 3. Structural Formula: A) Azoxystrobin, B) Cyproconazole, C) Tetraconazole, D) Fluazinam, E) Thiophanate Methyl F) Fentin hydroxide (Tomlin, 2011).

In a study conducted in western Bahia by Barbosa et al. (2007), the authors found a reduction of bolls rot with the use of two applications of copper tribasic (1.5 kg/ha), obtaining an increase of 330kg of raw cotton by hectare when compared to the control.

In relation to cotton yield in function of spacing, cultivars and fungicides, Zancan et al. (2011) found that the highest yield at the 0.80 m spacing in cotton cultivars were obtained using the fungicide tetraconazole, followed by thiophanate methyl. In the 0.90 m spacing, the fungicides tetraconazole and fentin hydroxide proved effective when compared with other treatments, obtaining higher yields (Figure 4). These authors observed that among the cotton cultivars studied, the highest yield was obtained by the cultivar NUOPAL in both row spacing of 0,80 and 0,90 m when subjected to chemical treatments, followed by FMT 701 and BRS Araça, in the conditions that the experiment was conducted (Figure 4).

More studies are needed to determine the timing and rates of fungicides to control diseases. In the southeastern United States cotton flowers and capsule production reach maturation between 6 to 10 weeks, and it is necessary to protect these flowers over a long period against infection by pathogens. Therefore, the best strategy may be the systemic application of compounds or compounds that induce systemic acquired resistance (Jenkins, et al, 1990).
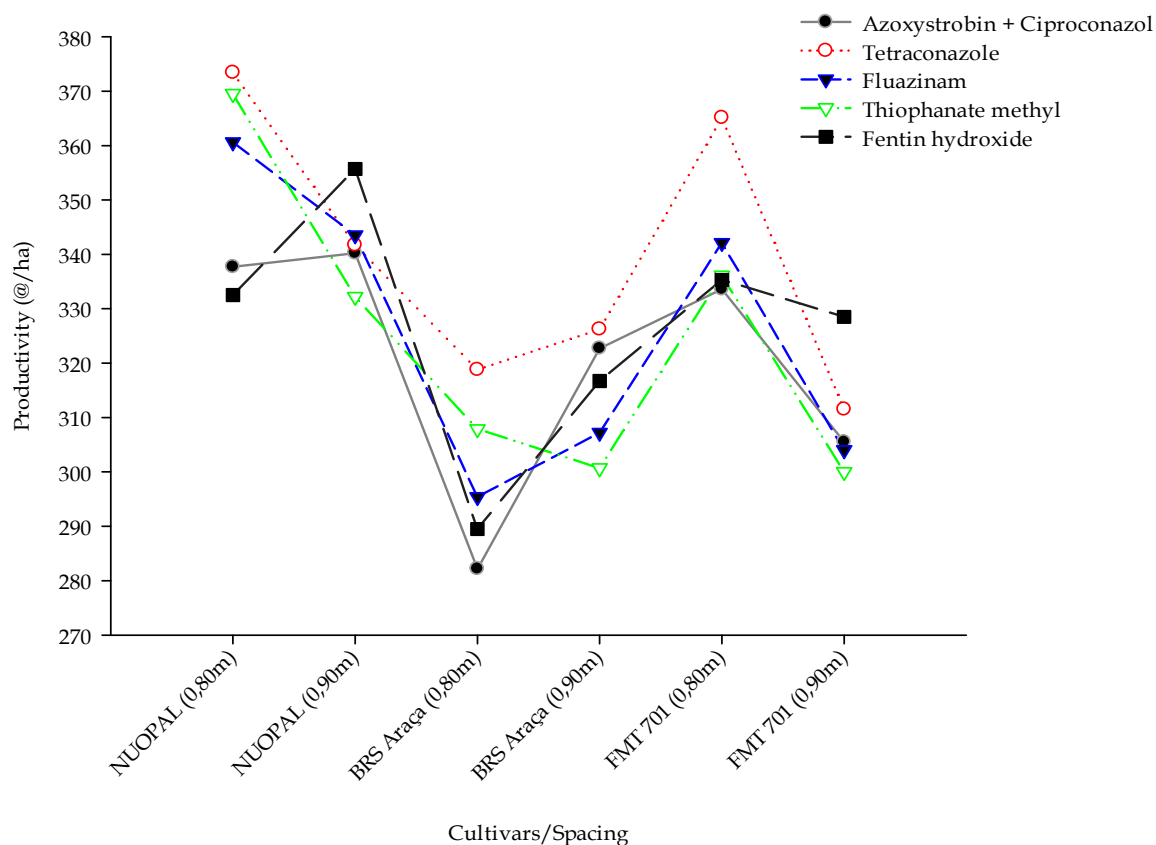
Figure 4. Average cotton yield (@ per ha) in cotton cultivars NUOPAL, BRS Araçá and FMT 701 with row spacing of 0.80 and 0.90 m, submitted to different chemical treatments to control cotton bolls rot. IMA - Primavera do Leste - MT, 2011.

Another management tactic to reduce the rate of cotton bolls rot, especially at the end of the cotton season's is to control pest, with pesticides, in bolls that cause injuries, such as bedbugs. Among them can be cited the brindle (*Horcias nobilellus*), the cotton stainer (*Dysdercus* sp.) and the migratory aphids such as the brown stinkbug (*Euschistus heros*), small stinkbug (*Piezodorus guildinii*), green stinkbug (*Nezara viridula*) and, in addition, *Edessa meditabunda* and *Dichelops melacanthus*, among others. The migratory bugs are so named because in the production systems, cotton remains in the field for long periods of time, longer than other crops such as soya, becoming it the last host in the food chain for these insects. When the soybean crops enter the maturation phase, the migration process of the bugs begins and progresses through the days. Infestations are proportional to the extension of areas planted with soybeans. Attacks occur from advancing into the borders of the blocks (Santos, 2007).

3.1.2. Influency of chemical control on the quality of cotton fiber

According to Zancan et al. (2011) analysis of the results of the High Volume Instrument (HVI), performed to verify the technological characteristics of cotton fibers, showed no variation in the percentages of fiber, fiber length, uniformity, strength and micronaire (fineness of the fiber), among the chemical treatments used to control bolls rot in cotton cultivars, according to data presented in Table 1. These results demonstrate the uniformity

of the fiber characteristics of each cultivar, regardless of fungicides used in the experiment of cotton bolls rot. The results of the technological characteristics of the NUOPAL cultivar obtained in this study are similar to the results reported by MDM (2006), except for the parameter micronaire with values from 4.5 to 5.0, higher than the MDM ranging from 3.8 to 4.5 (cotton fiber thinner), which is more interesting for the industry, because the too low micronaire (<3.8) may mean that fibers are immature, leading to breakages in fibers within the yarn and poor dye uptake during textile processing.

Regarding to BRS Araçá, the values of HVI analyzes obtained for the parameters the percentage of fiber and micronaire ranged from 41.5 to 46.2% and 4.5 to 5.0 respectively, but differ from the values reported by Embrapa (2005), where the BRS Araçá has fiber yield from 37.5 to 38.3% (less percentage of fiber) and micronaire from 3.8 to 4.2. The results regarding the percentage of fiber of FMT 701 subjected to different chemical treatments ranged from 43.5 to 46.2%, higher than the values reported by the Foundation MT (2007), with a yield of 42.5% fiber. For the parameter micronaire, the results obtained in this study for the FMT 701 ranged from 4.8 to 5.1, higher than the value obtained by the Foundation

Treatments	High Volume Instruments/Spacing (m)									
	Fiber		Length		Uniformity		Resistance		Micronaire	
	0,80	0,90	0,80	0,90	0,80	0,90	0,80	0,90	0,80	0,90
Cultivar NUOPAL										
Cyproconazole + Azoxystrobin	43,7	43,2	30,3	31,0	85,5	85,5	30,0	29,2	4,5	5,0
Tetraconazole	44,3	43,2	31,8	32,0	85,5	85,5	29,3	29,2	4,7	4,7
Fluazinam	43,8	43,0	32,5	32,5	86,2	86,0	29,8	30,5	4,6	5,0
Thiophanate Methyl	43,2	43,0	32,4	31,5	86,0	86,2	28,2	30,0	4,5	5,0
Fentin hydroxide	43,9	43,0	31,6	31,7	85,6	85,7	29,5	30,0	4,6	5,0
Cultivar BRS Araça										
Cyproconazole + Azoxystrobin	41,5	46,2	31,2	31,5	84,2	85,0	30,0	28,0	4,6	5,0
Tetraconazole	43,2	45,2	31,6	31,2	85,1	85,2	29,7	29,2	4,7	5,0
Fluazinam	42,3	44,7	31,4	31,5	84,9	85,0	30,7	29,5	4,7	5,0
Thiophanate Methyl	42,5	42,5	31,1	31,5	84,5	85,2	29,2	29,0	4,7	4,5
Fentin hydroxide	42,8	45,0	31,9	32,2	85,5	86,0	30,0	29,0	4,6	4,7
Cultivar FMT 701										
Cyproconazole + Azoxystrobin	45,1	45,7	30,9	30,2	85,8	86,2	30,5	30,2	5,0	5,0
Tetraconazole	45,0	43,5	30,7	31,0	86,0	86,2	31,6	30,5	5,1	5,0
Fluazinam	45,1	45,5	30,7	31,5	86,1	85,7	31,6	31,2	5,0	4,9
Thiophanate Methyl	45,2	45,7	30,5	30,2	85,4	85,7	32,0	30,0	5,1	5,0
Fentin hydroxide	45,3	46,2	30,8	30,7	85,9	85,7	31,4	30,0	5,0	4,8

Table 1. Technological characteristics of cotton fiber from the cultivars NUOPAL, BRS Araçá and FMT 701, submitted to different chemical treatments to control cotton bolls rot with row spacing of 0.80 and 0.90 m. Primavera do Leste - MT, 2011.

MT (2007) of 4.2. Other evaluated parameters such as length, uniformity and strength were similar to those obtained by the Foundation MT (Zancan et al. 2011).

Work done by Meneses (2007), related to physiological seed quality of cotton under water stress induced by polyethylene glycol-600 in the region of Paraíba, found that moisture can or may not improve the quality of the cotton fiber, and water deficit, particularly in stages after flowering can reduce the development of bolls, the strength of the fibers and enhance existing micronaire in the bolls. Moreover, the work done by Rodrigues et al. (2005) to check the quality of cotton fibers soaked in the vegetative phase, it was found that besides the change in resistance, the temporary flooding affect the yield and rate of fiber micronaire, a period of flooding also found in experiments carried out by Zancan et al, (2011).

According to Araújo et al. (2005), the processing is the last stage of cotton production, is the phase that precedes industrialization and consists of cleaning processes, drying, extraction of fiber from the seed and packaging, typically, these operations have a major influence on yield and quality commercial and industrial fiber, a fact that may have caused an increase in the parameter in yield and micronaire cotton cultivars NUOPAL, BRS 701 and FMT Araçá obtained by Zancan et al. (2011).

3.1.3. Resistance of cotton cultivars against bolls rot

The management of bolls rot with the use of resistant cultivars has been considered a strategy to be followed. Ballaminut (2008) states that different cultivars show differences in the incidence of bolls rot, strong interaction with the environment, crop management and the cultivar itself in relation to disease. Lawrence et al. (2007b) evaluated the response of 35 cotton cultivars to bolls rot in Alabama and found a variation from 0.0% to 10.3% among cultivars. The incidence of rot was similar between the flex transgenic cultivars and conventional cultivars. The earliest cultivars had a lower incidence of the disease when compared to those late and were similar to flex transgenic cultivars.

Soomro et al. (2000) observed a lower incidence of cotton bolls rot in Pakistan in Okra leaf cultivars with different cultivars of normal leaves. The percentage of cotton bolls rot varied between 6.0 and 6.9% in cultivars with normal leaves and between 0.5% and 2.2% in cultivars that have Okra leaf. The authors attribute this reduction in the percentage of rot in the resistance of these cultivars. Andries et al. (1972) and Jones (1982) also found that cotton cultivars with Okra leaf type have a lower incidence of cotton bolls rot, probably by promoting greater aeration and penetration of sunlight in the canopy.

In the west of Bahia, Pedroso et al. (2007) found that there are variations in cotton bolls rot among the cultivars in the region. These authors found, among eight cultivars, the cultivar Delta Opal had 50% more yield losses by cotton bolls rot than the cultivar Fibermax 966.

Cultivars 409 and CD 96 IPR have behaved more resistant, while IAN 338 has been the most susceptible with higher more cotton bolls rot. There is a need to develop more studies about this disease, since it is one of the most important occurrences in cotton crops in the state of Mato Grosso (Mehta & Mentem, 2006).

4. Conclusions

The cotton bolls rot causes direct loss in both productivity and quality of cotton fiber, and when the control is not performed properly, can make it impracticable to cultivate cotton in certain regions. Chemical control with fungicides is a rapid and effective tactic in the management of diseases, both through seed treatment and foliar sprays, and it can also be used to control the cotton bolls rot along with others techniques, such as row spacing. The cotton bolls rot can also is related with the region, the planting season and cultivars. Further work should be carried out regarding the use of fungicides to control this disease, since it is one of the most important in cotton crops.

Author details

Willian Luis Antonio Zancan
Department of Plant Pathology, Federal University of Lavras, Lavras, MG, Brasil

Luiz Gonzaga Chitarra
Brazilian Agricultural Research Corporation – Embrapa-Cotton, Campina Grande, PB, Brasil

Gilma Silva Chitarra
Federal Institute of Education, Science and Technology of Mato Grosso, Campus Sorriso, MT, Brasil

Acknowledgement

5. References

Alviter, A.R.; Nita, M. (2011). Optimizing fungicide applications for plant disease management: Case studies on strawberry and grape. Fungicides – Beneficial and harmful aspects, pp. 18, ISBN 978-953-307-451-1.

Andries, J.A.; Jones, J.E.; Sloane, L.W.; Marshal, J.G. (1972). Further studies on the effect of leaf shape incidence of boll rot and economic characters of cotton. Proceedings Beltwide Cotton Production Research Conference, pp. 147-158.

Araújo, A.E; Goulart, A.C.P. (2004) Doenças do algodoeiro. In: Beltrão, N.E. de M.; Araújo, A.E. (Ed.) Algodão: o produtor pergunta a Embrapa responde. Brasilia, DF: Embrapa informações tecnológicas, pp.69-81, ISBN 85-7383-278-9.

Araújo, E.R.; Silva, O.R.R.F.; Almeida, F.A.C.; Queiroga, V.P.; Jerônimo, J.F.; Barros, H.M.M. (2005). Características tecnológicas da fibra do algodão herbáceo cultivar CNPA 8H obtidas em diferentes descaroçadores. In: Congresso Brasileiro de Algodão, 5., 2005, Salvador. Anais... Campina Grande: Embrapa Algodão, pp. 5.

Bagga, H.S. (1970) Pathogenicity studies of organisms involved in the cotton boll-rot complex. Phytopathology, Vol. 60, pp.158-160.

Bagga, H.S. & Laster, M.L. (1968) A simple technique for evaluating the role of insects in cotton boll rot development. Phytopathology, Vol.58, pp. 1323-1324.

Baird, R.E. (1998). Cotton boll rot. The University of Georgia, Accessed March 03, 2012, Available from:

<http://plantpath.caes.uga.edu/extension/plants/fieldcrops/CottonBollRotpaper.html >

Ballaminut, C.E.C. (2008). A Podridão de Maçãs do Algodoeiro. Informativo eletrônico do Sistema de Informações Agroindustriais do Algodão Brasileiro, Accessed March, 03, 2012, Avaliable from: < http://www.portaldoalgodao.org.br/index.php?option =com_content&task=view&id=111>

Barbosa, C.A.S; Costa, R.V.; Rodrigues, J.; Evangelista, R.C.C., Oliveira, B.; Baumgratz, C.; Filho, J.A.C.; Alves, M.D. (2007). Avaliação da eficiência comparativa de produtos da linha Pzifer no manejo de podridão de maçãs na cultura do algodão. Comunicado Técnico, No. 1, Circulo Verde Consultoria Agronômica, Barreiras, Brasil, pp. 28.

Bélot, J.L. & Zambiasi, T.C. (2007). Manual de identificação das doenças, deficiências minerais e injúrias no cultivo do algodão. Boletim Técnico, No. 36, COODETEC/CIRAD-CA, Cascavel, pp. 95.

Beltrão, N.E.M. (1999). O Agronegócio do Algodão no Brasil. Brasília: Embrapa Comunicação para Transferência de Tecnologia, Vol. 2, pp. 1023, ISBN 85-7383-061-1.

Beltrão, N.E. de M. & Souza, J.G. (2001). Fisiologia e ecofisiologia do algodoeiro. In: Embrapa Agropecuária Oeste. Algodão: tecnologia de produção. Dourados: Embrapa Agropecuária Oeste; Campina Grande: Embrapa Algodão, pp. 54-75.

Carvalho, P.P. (1996). Manual do algodoeiro. Lisboa: IITC, pp. 282.

Charchar, M.J.D.; Anjos, J.R.N. & Ossipi, E. (1999). Ocorrência de nova doença do algodoeiro irrigado, no Brasil, causada por *Sclerotinia sclerotiorum*. Pesquisa Agropecuária Brasileira, Brasília, Vol. 34, No. 6, pp. 1101-1106.

Chitarra, L.G. (2008). Identificação e controle das principais doenças do algodoeiro. Cartilha Técnica, No. 2, Vol. 2, Embrapa Algodão, Campina Grande, pp. 65.

Empresa Brasileira de Pesquisa Agropecuária. (2005). BRS Araçá. Campina Grande: Embrapa CNPA, pp. 4.

Food and Agriculture Organization of the United Nations. (1995) World agriculture: Towards 2010, an FAO study. Chichester GB et FAO Rome, ISBN 92-5-203590-7.

Fundação Mato Grosso.(2007). FMT 701. Rondonópolis: Fundação MT, pp. 1-17.

Ghini, R. & Kimati, H. (2000). Resistência de fungos a fungicidas. Vol. 1, Jaguariúna: Embrapa Meio Ambiente, pp. 78, ISBN 85-85771-10-0.

Guerra, J. (2006). Algodão: Os caminhos do algodão no Brasil. Viçosa, pp. 60.

Hardwick, N. V. (2006). Disease Forecasting. The Epidemiology of Plant Diseases. B. M. Cooke, G. J. Jones and B. Kaye. Dordrecht, The Netherlands, Springer.

Hillocks, R.J. (1992). Fungal disease of the boll. In: Hillocks, R.J. (Ed.) Cotton Diseases. Wallington: CAB Internacional, Chap. 7, pp. 239-261.

Iamamoto, M.M. (2007). Doenças do algodoeiro. Fundação de Apoio a Pesquisa, Ensino e Extensão, Jaboticabal, Brasil, pp. 62.

Jenkins, J.N.; McCarty J.C. & Parrott, W.L. (1990). Effectiveness of fruiting sites in cotton: Yield. Crop Science, Vol. 30, No. 2, pp. 365-369, ISSN 0011-183X.

Jones, J.E. (1982). The present state of the art and science of cotton breeding for leaf morphological types. Proceedings Beltwide Cotton Production Research, pp. 92-99.

Juliatti, F.C.; Duarte, R.P. & Freitas, P.T. (2001). Acil benzolar (Bion) em combinação com fungicidas no controle da mancha de ramulária, ferrugem e podridão de maçãs, efeito na produtividade e qualidade das fibras do algodoeiro. In: Congresso Brasileiro de Algodão: Produzir sempre, o grande desafio, 2001, Goiânia: Anais. Campina Grande: Embrapa Algodão; Dourados: Embrapa Agropecuária Oeste, Vol. 3.

Kendall, S.; Hollomon, D.W.; Ishii, H.; Heaney, S.P. (1994). Characterization of benzimidazole-resistant strains of Rhynchosporium secalis. Pesticide Science, Vol. 40, No. 3, pp. 175-181, ISSN 0031-613X.

Lawrence, K.S.; Glass, K.; Lawrence , G. W.; Pegues, M.D.; (2007b). Evaluation of early season flex cotton varieties for response to boll rot disease in Alabama, 2006. Research Report, Auburn, Alabama, No. 30, pp. 11.

Lawrence, K.S.; Lawrence, G.W.; Pegues, M.D.; Monks, C.D. (2007a). Evaluation of Quadris 2.08SC for management of cotton boll rot disease in south Alabama, 2006. Research Report Series, Auburn, Alabama, No. 30, pp. 55.

Madden, L.V.; Hughes, G. and Bosch, F. van den. (2007). The study of plant disease epidemics. St. Paul, MN, APS press.

Maeda Deltapine Monsanto. (2006). Guia Técnico - Cultivares de Algodoeiro. Uberlândia: MDM, pp. 36.

Mehta, Y.R. & Menten, J.O.M. (2006). Doenças e seu controle. In: Fundo de Apoio a Cultura do Algodão. Algodão: Pesquisas e Resultados para o Campo. Cuiabá: Facual, Vol. 2, pp. 157-204, ISBN 85-60267-01-8.

Meneses, C.H.S.G. (2007). Potencial hídrico induzido por polietilenoglicol-6000 na qualidade fisiológica de sementes de algodão. Paraíba: UFPB, 2007. Dissertação (Mestrado em Agronomia), Universidade Federal da Paraíba, pp. 97.

Moreira, P.H.R.; Soares, J.J.; Busoli, S.A.; Cruz, V.R. da; Pimentel, M.H.L.; Pelinson, G.J.B. (1994). Causas do apodrecimento de maçãs do algodoeiro. Pesquisa Agropecuária Brasileira, Brasília, Vol. 29, No. 10, pp. 1503-1507.

Oosterhuis, D.M. (1999). Growth and development of a cotton plat. In: CIA, E.; FREIRE, E. C.; SANTOS, W. J. dos. (Ed.). Cultura do algodoeiro. Piracicaba: Potafos, pp. 35-55.

Paiva, F. de A.; Asmus, G.L. & Araújo, A.E.de. (2001). Doenças. In: Embrapa Agropecuária Oeste. Algodão: tecnologia de produção. Dourados: Embrapa CNPAO/Embrapa CNPA, pp. 245-267, ISBN 85-7540-001-0.

Papa, S.; Guerrieri, F.; Puyou, M.T.G; Barranco, J.; Puyou, A.G. (1982). Studies of the mechanism of action of triphenyltin on proton conduction by the H$^+$ ATPase of mitochondria. European Journal Biochemistry, Vol. 128, No. 1, pp. 1-7.

Pedroso, M.B.; Silva filho, J.L.; Santos, J.B.; Alencar, A.R.; Oliveira, W.P. (2007). Perdas causadas pelo apodrecimento de maçãs em cultivares de algodoeiro no oeste da Bahia, safra 2005/2006. In: Souza Filho, J. L. (Coord.). Pesquisas com algodoeiro no Estado da Bahia – Safra 2005/2006. Campina Grande: Embrapa Algodão, Vol. 164, pp. 53-58.

Powers, M.F. & Beavis, A.D. (1991). Triorganotins inhibit the mitochondrial inner membrane anion channel. Journal of Biological Chemistry, Vol. 266, No. 26, pp. 17250-17256.

Ranney, C.D.; Hurshe, J.S. & Newton, O.H. (1971). Effect of bottom defoliation on microclimate and the reduction of boll rot of cotton. Agronomy Journal, Madison, Wisconsin, Vol. 63, No. 2, pp. 259-263.

Reis, E.M.; Reis, A.C. & Carmona, M.A. (2010). Manual de fungicidas: guia para o controle químico de doenças de plantas. Passo Fundo, Vol. único, Ed. 6, pp. 225, ISBN 978-7515464-9.

Ribeiro, J.S.F.; Bacchi, L.M.A. & Degrande, P.E. (2000). Apodrecimento prematuro. Revista Cultivar Grandes Culturas, Pelotas, Vol. 2, No. 19, pp. 8-9.

Richetti, A. & Melo Filho, G.A. (2001). Aspectos Socioeconômicos do Algodoeiro. In: Embrapa Agropecuária Oeste. Algodão: tecnologia de produção. Dourados: Embrapa CNPAO/Embrapa CNPA, pp. 13-34, ISBN 85-7540-001-0.

Rodrigues, L.N.; Nery, A.R.; Fernandes, P.D.; Beltrão, N.E.M. (2005). Qualidade da fibra do algodoeiro encharcado na fase vegetativa. In: 5° Congresso Brasileiro de Algodão. Salvador, Anais, pp. 5.

Roncadori, R.W.; Carter, S.M.Mc. & Crawford, J.L. (1975). Evaluation of various control measures for cotton boll rot. Phytopathology, Vol. 65, No. 5, pp. 567-570.

Santos, W.J. (2007). Manejo das pragas do algodão com destaque para o cerrado brasileiro. In: FREIRE, E. C. (Ed.) Algodão no cerrado do Brasil. Brasília, ABRAPA, Vol. 1, pp. 403-478.

Savastano, S. (1999). Caroço de algodão na alimentação de ruminantes. Campinas: CATI, Folder.

Silva, N.M.; Carvalho, L. H.; Cia, E.; Fuzatto, M.G.; Chiavegato, E.J.; Alleoni, L.R.F. (1995). Seja o doutor do seu algodoeiro. Arquivo do Agrônomo, Piracicaba, SP: Potafos, Vol. 8, pp. 17.

Soomro, A.R.; Soomro, A.W.; Mallah, G.H. Memon, A.M.; Soomro, A.H.; Kalhoro, A.D. (2000). Okra leaf cotton, its commercial utilization in Sindh. Pakistan Journal of Biological Sciences, Vol. 3, No. 1, pp. 188-190, ISSN 1028-8880.

Suassuna, N.D.; Chitarra L.G.; Asmus, G.L.; Inomoto, M.M. (2006). Manejo de doenças do algodoeiro. Circular Técnica, Embrapa Algodão, Campina Grande, Vol. 97, pp. 24.

Suassuna, N.D. & Coutinho, W.M. (2007). Manejo das principais doenças do algodoeiro no Cerrado Brasileiro. In: Freire, E. C. (Ed.) Algodão no Cerrado do Brasil. Brasília, ABRAPA, Vol. 1, pp. 980.

Tenuta, A.; Hershman, D. & Draper, M. 2008. Fungicides basics. p.48-56. In: Using Foliar Fungicides to Manage Soybean Rust (2nd edition). Dorrance, A.E.; Draper, M.A. and Hershman, D.E. (Eds). Ohio State University Extension Bulletin SR-2008, pp. 111.

Tomlin, C.D.S. (2011). The pesticide manual: a world compendium. Surrey, UK: British Crop Protection Council. 15 ed., pp. 1457, ISBN 9781901396188

United States Departament of Agriculture (2012). World Agricultural Production. Accessed March 05, 2012, Available from: <http://www.fas.usda.gov/wap/current/default.asp>

Vincelli, P. & Dixon, E. (2002). Resistance to QoI (Strobilurin-like) fungicides in isolates of Pyricularia grisea from perennial ryegrass. Plant Disease, Vol. 86, No. 3, pp. 235-240, ISSN 0191-2917.

Wheeler, I.E.; Kendall, S.J.; Butters, J.; Hollomon, D.W.; Hall, L. (1995). Using allele-specific oligonucleotide probes to characterize benzimidazole resistance in Rhynchosporium secalis. Pesticide Science, Vol. 43, No. 3, pp. 201-209, ISSN 1526-4998.

Zancan, W.L.A.; Chitarra, L.G. & Chitarra, G.S. (2011). Fungos associados à podridão de maçãs do algodoeiro na região de Primavera do Leste, MT, Brasil: ocorrência, controle químico e influência na qualidade da Fibra. Bioscience Journal, Uberlândia, Vol. 27, No. 4, pp. 518-525, ISSN 1981-3163.