Boll Weevil in South America

Clayton Campanhola [1]

Gilberto José de Moraes [1]

Abstract

Cotton production gears a major business in South America. The boll weevil is one of the fiercest cotton pests in the American continent. Its introduction into Brazil in 1983 represented a major impact on the stability of cotton growing activities in the whole region. It has driven many traditional growers to produce alternative crops or to leave the rural areas. Mostly affected were growers who produced perennial cotton in northeastern Brazil, where the crop was important not only for the production of lint and seed oil, but also as forage to beef cattle at the end of each production cycle. The introduction of the boll weevil into Brazil has also caused already a significant impact in the surrounding countries, which had to establish task forces to prepare the local cotton growing sector for an inevitable invasion by the pest. Brazilian growers have already adopted efficient control measures which are economically viable for the control of the boll weevil in annual cotton. New basic and applied information should continue to be produced in Brazil to feed the development of new control strategies, which take into consideration particularities of the pest in the new home. Important neighboring cotton producers in South America should focus on delaying the dispersal of the pest and prepare growers for the eventual introduction of the pest.

[1] Centro Nacional de Pesquisa de Monitoramento e Avaliação de Impacto Ambiental - CNPMA/EMBRAPA
Address: C.P. 69, 13820-000 Jaguariúna, SP - Brasil
Phone: (0192) 671721 Fax: (0192) 672202 E.Mail: clayton@cnpda.embrapa.ansp.br

Introduction

Agriculture is the main economic activity in South America, despite the recent significant industrial development of some countries in the region. The importance of agriculture is reflected in the significant proportion of the rural population of each country, which ranges from about 14% of the total population in Argentina to about 53% in Paraguay.

Together with coffee, corn, wheat, soybean, sugarcane and fruits, cotton is one of the main types of cash crops in South America. Brazil and Argentina are the largest cotton producers in the region. Brazil is the sixth cotton producer in the world, with 661 thousand tons of cotton lint produced in the 1991/92 growing season. Argentina is the ninth largest cotton producer, with 250 thousand tons of cotton lint produced in that same period (Table 1).

Area harvested to cotton in Brazil is also ranked sixth in the world, with an estimated total of 1,672 thousand ha planted in 1992/93 (Table 2). This represents the sixth most extensively grown crop in that country, despite the considerable decline experienced since the mid-1980's. The reduction in cotton acreage has been attributed to the increased pest problems on perennial cotton (*Gossypium hirsutum* marie galante Hutch) in parts of Brazil and, lately, to the regional market prices policy that has stimulated imports by the cotton gins.

In the last six years, Brazil has considerably increased the importation of cotton. Until 1963, the amount of cotton lint imported did not exceed 100 thousand tons per year, while in 1992 almost 200 thousand tons were imported. In 1993, the increase was even more expressive, with imports amounting to 325 thousand tons until August (Soares 1993). Cotton production is expected to increase in Brazil in the 1993/94 growing season because of high international prices, what should contribute to a 30% reduction in the imports, according to official estimates.

Argentina is the eighth largest cotton producer in terms of acreage. The area planted to cotton in that country has remained practically the same from mid 1980's to early 1990's, with an average of 500 thousand ha per year (Table 2). However, low international prices have contributed to reduce the area planted to cotton in the 1992/93 growing season to 367 thousand ha.

Cotton production in Paraguay has increased considerably lately. In the last six years, cotton production in Paraguay has been almost as high as in Argentina, and a considerable part of what is produced is exported. The total area harvested to cotton in 1991/92 was 630 thousand ha, mostly composed of fields smaller than 2 ha (Cavalcante et al. 1993a).

A tendency to increased yields has been observed in Brazil and Argentina in the last decade, whereas in Paraguay yields have remained stable. The average for the last four seasons was 484, 439 and 341 kg of cotton lint per ha in Argentina, Paraguay and Brazil, respectively (Cavalcante et al. 1993a). The lower average in Brazil is related to the area cultivated to perennial cotton in that country, which has a much lower yield capacity than annual cotton (Gossypium hirsutum L.).

The boll weevil (*Anthonomus grandis* Boh. 1843) has been considered a very destructive pest of cotton in the United States and in other countries. From 1909 to 1971, the average annual losses in the United States due to that pest amounted to US$ 175 million, even though drastic variations were observed from year to year (Warren 1978). Current annual losses in that country are estimated to range from US$ 200 to US$ 300 million.

Despite the fact that everyone involved in cotton production and processing in the South America considers the boll weevil a major pest, losses caused by it have not been routinely assessed.

This paper focuses on the impact of the boll weevil to cotton production in the southern countries of South America and on recommendations for research to maintain cotton production a profitable and stable activity. Information on cotton production systems, on infested areas with boll weevil and on measures adopted for boll weevil control are also examined.

Cotton Production Systems

Cotton production systems are quite variable in South America, because of variable range of soil types, rainfall pattern, varieties, different pest compositions, availability of modern inputs, and growers' experience with the crop, among others.

Argentina. There are about 30,000 cotton growers in Argentina. Cotton fields are mostly small; about 50% are smaller than 15 ha, and about 73% are smaller than 55 ha. Chaco, Formosa, Santa Fé, Santiago del Estero and Corrientes are the cotton producing Provinces, all located in the northern region of the country and close to the borders with Brazil and Paraguay. About 66% of the total acreage is located in the Chaco Province (Brun R. 1993a).

Planting is normally done between September and January, coinciding with the rainy season, whereas harvesting is done from March to June. Over 90% of the Argentinean cotton area is grown without irrigation (upland cotton). Early sown fields are subject to dry periods and to low soil temperatures, frequently requiring replanting. Because of the increasing costs of labor, 35% of the cotton area is mechanically harvested (Brun R. 1993a).

Brazil. There are two large cotton growing regions in Brazil. The so called Meridional Region is composed of the States of São Paulo, Paraná, Minas Gerais, Goiás, Mato Grosso do Sul and Rio de Janeiro, whereas the Septentrional Region comprises the States of Bahia, Alagoas, Sergipe, Pernambuco, Paraíba, Rio Grande do Norte, Ceará, Piauí and Maranhão. The main cotton producing states in the Meridional Region are São Paulo and Paraná, while the main cotton producing states in the Septentrional Region are Rio Grande do Norte, Paraíba, Pernambuco and Ceará.

Exclusively annual cotton is planted in the Meridional Region, whereas both annual and perennial cotton are planted in the Septentrional Region. Perennial cotton has normally a long, good quality fiber. The yield however is low, reaching a gross average of 111 kg of seed cotton per ha in

the last ten years. A field of perennial cotton is normally maintained under commercial production for up to 5 years. The production of the second and third years amounts to 50-80% of the total. After the fourth year, yield declines sharply and becomes almost null in the sixth year (Beltrão et al. 1986).

Cotton yield has undergone considerable variation in the last decade. In the 1980's it increased in the Meridional Region, but declined drastically in the Septentrional Region (Table 3).

The annual cotton production system is similar in both regions. The main difference refers to the planting period, which is restricted to September and October in the Meridional Region and varies from October to June in different parts of the Septentrional Region, depending on the beginning of the rainy season in different places.

The peculiarities of growers seem to limit the adoption of new management techniques of perennial cotton. In the arid zone ('sertão') of the Septentrional Region, where perennial cotton is mostly grown, the production structure is based on beef cattle raising by sharecroppers, who take care of this activity for the landowner and explore the land with subsistence crops (cowpea and corn) and cotton for their own living. Cotton normally serves as forage to cattle at the end of each growing cycle. As a consequence of this structure, farmers are reluctant to adopt newly developed techniques. They utilize land and labor extensively and use little or no external inputs such as fertilizers and pesticides.

The agrarian structure, the level of technology adopted, the year around presence of cotton in the field and favorable climatic conditions contribute to increase the number of generations of the weevil per year and to maintain it always active.

Paraguay. The economy of Paraguay has always been dependent on the agricultural sector. Cotton has been very important as an export crop in this country, where the revenues from cotton lint exports represent today 20-30% of the total exportation of Paraguay.

The production system is very different from other Latin American countries. Over 99% of the cotton growing areas are located east of the Paraguay River (East Region) (Brun R. 1993b), where

cotton is grown on over 135,000 small farms. The farms are mostly owner-operated with non-mechanized activities that depend on oxen, horses, or mules for energy. Farmers have little capital, use almost no fertilizer, and spend less than US$ 50 per year on pesticides (Whitcomb & Marengo 1986).

In addition to the low level of technology adopted, other factors that contribute to low yield in Paraguay are the inefficient soil conservation practices, the use of low quality seeds, and the late cotton planting due to common delay in the availability of credits to growers.

Main Cotton Pests

Worldwide cotton is usually severely attacked by pest arthropods. It is traditionally one of the crops on which the largest amounts of pesticides have been applied. Until recently, up to 40 yearly applications of pesticides were done in Brazil for the control of key cotton pests (C. Campanhola, G.J. de Moraes & L.A.N. de Sá, unpublished). In other countries in the southern region of South America, pest problems are not nearly as severe. Much lower levels of pesticide applications have normally been necessary both in Argentina and Paraguay.

Cotton pest species include both insects and mites, and the most important species regionwide were the insects *Pectinophora gossypiella*, *Alabama argillacea* and *Eutinobothrus brasiliensis*. The insects *Aphis gossypii* and *Heliothis virescens* and the mites *Tetranychus urticae* and *Polyphagotarsonemus latus* were also as important in most of the cotton growing areas of Brazil. Boll weevil represents a new component to the list of important cotton pest species in southern South America.

Spread of the Boll Weevil

Argentina. Anticipating the socioeconomic impact the introduction of the boll weevil may cause, the government created in 1984 an Interinstitutional Committee for Prevention and Control of the boll weevil. The objective of that Committee is to develop monitoring procedures and to train growers on aspects related to boll weevil control. In April 1993 the boll weevil was first trapped in Argentina, in the National Park of Iguazú, near cotton producing areas in Brazil, and not far from important cotton producing areas of Argentina.

Between January and August 1993 the IASCAV (Argentinean Institute of Plant Quality and Sanitation) installed 2,600 traps in risk areas involving boundary zones with Brazil, cotton gins, main roads and strategic cotton planted areas. They are now concentrating on training growers to allow them to implement IPM techniques appropriate to boll weevil control, in anticipation to its eventual invasion.

Brazil. The boll weevil was first found in Campinas, State of São Paulo, in 1983, from where it quickly spread to over 100 thousand ha by the end of 1984 (Barbosa et al. 1986), an area that corresponded to about 40% of the area then planted to cotton in that State (Table 4).

In 1985 the boll weevil was captured in pheromone traps in the south of the State of Minas Gerais, where cotton is not grown commercially. The explanation to that is the presence of extensive cotton producing areas in the State of São Paulo, close to the region. A year later, it was found in cotton gins in the State of Paraná, probably coming with cotton from infested areas or with used packing sacks.

The infested area in Paraná state in the 1988/89 season surpassed 20% of its total cotton producing area of 400,000 hectares. As in other states, boll weevil spread was very rapid, with 70% of the 550,000 hectares of cotton being infested until 1991 (Santos 1989).

In February 1990 boll weevil was detected in the state of Mato Grosso do Sul. In August of the same year the pest was found in plants of *Gossypium anomalo* in the city of Uberaba, Minas Gerais state. In May 1991 infested fields were observed in the Municipalities of Uberaba, Campo Florido, Iturama, Conquista e Conceição das Alagoas, all located in the "Triângulo Mineiro" area of the State of Minas Gerais. In 1991, the total infested area in that state was 1,500 ha of cotton (Laca-Buendia & Brandão 1991).

In the Septentrional Region, the boll weevil was first found in the States of Paraiba and Pernambuco, almost 2,000 km north of Campinas already in 1983. The most accepted hypothesis is that the insect was carried to those States with seeds collected from cotton gins in São Paulo. Those seeds are frequently used for direct planting in the Septentrional Region. Spread of the boll weevil in the Septentrional Region was also very rapid. At the end of 1984, 150 thousand ha of cotton in Paraiba (52% of total area) and 30 thousand ha in Pernambuco (35% of total area) were infested (Table 4). In 1984 it was found in the State of Rio Grande do Norte, where 70 thousand ha (25% of total area) were infested by the end of that year. In 1985 it was detected in the State of Ceará, and in 1986 it was found infesting cotton fields in the neighboring States of Piaui, Alagoas, Maranhão, Sergipe and Bahia (Silva Neto 1987).

In summary, 12 Brazilian states were infested by 1985/86, representing an area of 1,585,200 ha of cotton fields, or almost 50% of the countrywide cotton growing area (Silva Neto 1987). About 65% of the infested area corresponded to perennial and 35% to annual cotton. Also, 78% of the total acreage with perennial cotton and 28% of the total acreage with annual cotton were infested by the boll weevil by the end of 1986.

The level of boll weevil infestation has varied from season to season, with a consequent variation in yield losses. The variations are normally due to irregular climate and irregular availability of credit to allow the adoption of adequate pest control procedures.

Paraguay. The boll weevil was detected in Paraguay in April 1991, near the Brazilian states of Mato Grosso do Sul and Parana, infesting an area of 35 thousand ha (Brun R. 1993b). In June 1992, the insect was found 70 km from west of the Brazilian border. In February 1993, it had advanced 220 km to the west.

Presently, the infested area corresponds to 50-60 thousand ha, which represent more than 10% of the total area planted to cotton in the country.

Impact of Boll Weevil

Argentina and Paraguay. Cotton pest problems in Argentina are not as important as in other South American countries, and only 3 to 5 pesticide applications are presently done per cotton season. The presence of the boll weevil should imply the need for 4 additional applications, according to Brun R. (1993a). In Paraguay, only 2 pesticide applications are necessary for pest control each year (Servian de Cardozo 1990). It is expected that the pest will impose economic difficulties to the small scale cotton growers, who are responsible for most of the national cotton production.

Brazil. Perennial cotton production, an exclusive activity of the Brazilian Septentrional Region, was the most affected by the presence of the boll weevil. The area harvested to perennial cotton in the season of 1983/84 was 1,441 thousand hectares and corresponded to 46.3% of the country harvested area. In the season of 1992/93 that area was 162 thousand hectares, representing only 11% of the total cotton acreage in the country (Tables 3 and 5). The production of perennial cotton corresponded to 12.5% of the total national cotton production in 1983/84, but to only 1.2% in 1991/92 (Tables 3 and 5). The introduction of the boll weevil put in check the fragility of the structure of production of perennial cotton and also affected the less capitalized sector involved in the production of annual cotton.

In the same way, the area planted to annual cotton in the Septentrional Region declined from 887 thousand ha in 1983/84 to only 236 thousand ha in 1992/93. At the same time, yields decreased during that period, mostly because of the low cotton market prices, which limited the utilization of inputs (Cavalcante et al. 1993b). Other studies confirming this trend were conducted by Laca-Buendia & Brandão (1991) and Maia et al. (1986). An apparent paradox was registered in the areas not infested by the weevil in northeast Brazil between 1983/84 and 1985/86, when a 154% increase in production occurred with the concurrent increase of only 51.3% in acreage (Maia et al. 1986).

The Septentrional Region participated with 79% of the national cotton harvested area and with 35% of the total cotton production in the 1976/77 season. In the 1988/89 season the participation declined to 56% and 14%, respectively (Santos & Barros 1991). That trend continued further, and in 1991/92 cotton acreage in the Septentrional Region corresponded to only 34.4% of the nation's total, and the production in that region represented only 10.1% of the national cotton production.

Growers of the Septentrional Region generally attribute the drastic reduction in cotton acreage to drought, scarcity of credits and high interest rates. Actually, boll weevil contributed to expose the fragility of the cotton producing system, accelerating the process of poverty and inducing migration of considerable part of the rural population to urban areas, where growers often became part of a marginal labor force because of their low competitiveness with urban people, being exposed to all sorts of economic and social problems.

More than three million workers were directly or indirectly involved in cotton production in the Septentrional Region. It is estimated that the introduction of the boll weevil caused the dismissal of about 370 thousand workers, i.e., one third of the labor force directly involved in cotton production (Martins 1993). Of this total, 160 thousand (43%) were involved in perennial and 210 thousand (57%) in annual cotton production.

The textile industry of the Septentrional Region has not been affected in the same proportion because they routinely import cotton lint from the Meridional Region. In 1990, the factories of Ceará imported 80% of the lint they processed, the ones of Rio Grande do Norte imported 73% and those of Paraíba, 44%. This situation poses instability to those industries, because cost of long distance transportation may compromise the process in years of high cotton market prices.

In this Region, the number of insecticide applications in annual cotton jumps from 4 to 5 per season in areas without the boll weevil, to 6 to 7 per season in infested areas, which corresponds to a cost of control equivalent to 115-220 kg cotton lint per hectare (Silva 1988). These costs may certainly affect profitability in years of low yield or low cotton market prices.

A case study was conducted in an area known as "Compartimento da Borborema" in the State of Paraíba, to evaluate the impact of the boll weevil. This area comprises 57 municipalities and 43% of the total area of that state. It used to be the main cotton producing area in Paraíba (Santos & Barros 1989). Most of the cotton grown in that area is perennial. The introduction of the boll weevil resulted in severe difficulties to growers because they were used to a traditional cotton growing system where pests are not of major concern and because they did not have access to external inputs such as quality seeds and pesticides. Growers still insisted in growing cotton for a while, because of their long experience with the crop and because they were not prepared to adopt alternative crops. However, the new pest forced them out of cotton growing business by the end of 1986. That situation is still unsettled in that part of the country.

Differently from what was observed in the Septentrional Region, the effect of the introduction of the boll weevil in the Meridional Region was not nearly as disastrous. Developed and adapted IPM techniques soon became available and were adopted in the Region, which actually had its absolute production increased after the introduction of that pest.

Normally 6 pesticide applications per season were required for pest control in the State of São Paulo. In the first year after the arrival of the boll weevil, up to 15 applications were recommended. As a result, the cost production increased by 25-35% (Assunção 1987) or up to 44% (Carvalho et al. 1984). Fields under IPM required only 1 or 2 insecticide applications per season in the early 1980's. After the introduction of the boll weevil, the number of applications in fields under IPM increased to 4 or 5 per season (C. Campanhola, G. J. de Moraes & L. A. N. de Sá, unpublished).

A study to evaluate the impact caused by boll weevil in the infested area of Campinas and Sorocaba in the State of São Paulo indicated reductions of 20 and 33% in cotton acreage, respectively, between 1982/83 and the next growing season (Campanhola et al. 1988). The average number of insecticide applications also increased from 2.8 to 4.1 in both areas in the same period. Estimated losses on farms with the highest boll weevil damage were 4.7% in Campinas region and 6.6% in Sorocaba, considering just damaged squares and bolls that remained on the plants. On the other hand, there was an increase in cotton yield of 27% Campinas and 30% in Sorocaba, because of the change in the pest control program adopted.

Uncertainties about yield and crop profitability induced many growers to quit growing cotton in the infested areas of São Paulo and Paraná. Even growers that used modern production systems quit growing cotton because of the damage due to the boll weevil (Moreira 1993).

Recommended Measures for Boll Weevil Control

When boll weevil was first found in Brazil, EMBRAPA's scientists proposed an eradication program which would involve airplane periodic applications of azinphosethyl late in the 1982/83 season, to prevent migration of weevils to non-infested areas (Barbosa et al. 1986). Fearing negative

impacts to the environment, it was then recommended that malathion rather than azinphosethyl should be used. The sprays should begin late in the season and proceed up to stalk destruction.

The program included the establishment of two concentric security belts, 20 km wide each: the first belt adjacent to the infested area, and the second 20 km away from the first. In both security belts and in the infested area cotton plants should be destroyed no later than April 15, i.e., 3 months earlier than the legal deadline for uprooting. Eventual cotton plants in house yards would be destroyed by the householders through an educational program. The program would rely on the absence of alternate hosts of the boll weevil in the area. The whole area would be constantly monitored with pheromone traps for adult weevils. Starting in the following season, cotton growing would be suspended for two years in the infested area and in the so-called first security zone. The infested area would be heavily sprayed with insecticides to reduce the number of boll weevils.

Many environmentalists and politicians did not agree on the implementation of the eradication program, arguing that it would expose the environment to undesirable doses of chemicals. Many scientists, aware of the potential risk that the boll weevil represented to cotton production in Brazil, insisted in recommending the eradication of the pest, but the previous position prevailed and at thus the program was not implemented.

An alternative program was proposed by a "Working Group for Boll Weevil Control" of the State of São Paulo Secretariat of Agriculture and Supply, to be implemented in the 1983/84 growing season. The objective of that program was to hold the boll weevil within the infested area, preventing its expansion to non-infested areas (Carvalho et al. 1984). This would be done by first applying three sets of sprays during the cotton growing season in the infected area. Each set was composed of three sprays spaced five days from each other. The beginning of each set should be at 40, 70 and 100 days after the emergence of plants. The third set was optional and should be considered only for late planted fields.

Next season, cotton growing in the infested area was not prohibited, but growers were discouraged to do so because they would not be covered by insurance normally provided by official banks. A 40-50 km wide cotton free isolation belt was established adjacent to the infested area, where subsidies for growing other crops and indemnification were applied to growers that had planted cotton in the area in the previous season. Even though much effort was dedicated to this program, it was not sufficient to hold the weevil within the infested area, although the massive use of insecticides recommended in the sets of sprays contributed to decrease the boll weevil population and to increase yields in more than 25% in that period (Campanhola et al. 1988).

Procedures presently recommended for boll weevil control in the State of São Paulo include use of rapid fruiting and early-maturing varieties, chemical suppression of pre-diapausing weevils, stalk destruction immediately after harvesting, use of trap crops early in the season and after harvest, area-wide uniform planting period (September 20 to October 20), use of low plant density (to expose fallen squares to sunlight to kill boll weevil larvae), and adoption of chemical control only at action level of 10% oviposited squares with the following insecticides: endosulfan, carbaryl, methamidophos, methyl parathion, azinphosethyl, malathion, phosmet, monocrotophos, fenitrothion, fenvalerate, demeton-s-methyl, disulfoton, cypermethrin and deltamethrin (Cruz 1988; Cruz et al. 1987; Assunção 1987). Although a recommended practice, the real effect of the use of trap crops has not been confirmed.

Similar approaches are recommended in the State of Paraná. However, differently from São Paulo, the action level for insecticide treatment of 10% oviposited squares is adopted only for early infestations on field borders, while 5% is recommended for later treatments. The recommended insecticides are only cypermethrin and deltamethrin, which showed best efficiency in field trials. Azinphosmethyl and methyl parathion are not listed for showing low efficiency (Santos 1989).

No eradication program was tried in the Septentrional Region though a proposal had been presented by Braga Sobrinho et al. (1983). Indemnification of growers in the infested areas was proposed but never really implemented, because of the lack of a real commitment of governmental institutions and insufficient motivation of growers. The severe losses imposed by the weevil to growers of perennial cotton resulted in the expansion of the acreage with the most yielding annual cotton, and the concurrent adoption of IPM practices similar to those used in other parts of the country, with emphasis on the use of early maturing varieties and chemical control (Ramalho et al. 1990; Beltrão & Azevedo 1992).

Despite some promising results obtained in studies about the biological control of the boll weevil with *Beauveria bassiana* and *Metarhizium anisopliae* in Brazil, use of those organisms has been restricted to experimental purposes (Camargo et al. 1985, Coutinho & Cavalcanti 1988). Laboratory studies involving the parasitoids *Catolaccus grandis* (Pteromalidae) and *C. hunteri*, have indicated levels of parasitism of up to 70 and 100%, respectively (Araújo et al. 1991). Field evaluations conducted in northeastern Brazil have shown natural parasitism of 8.5% in squares and 11.0% en bolls, inflicted jointly by *C. grandis*, *C. hunteri* and *Bracon mellitor*. Studies conducted in Brazil in this regard are scarce and non-conclusive.

Strategic Recommendations for Argentina and Paraguay

It seems probable that the boll weevil will eventually spread to all cotton growing areas in South America, especially in those countries which maintain more intensive commerce with Brazil, that is with Argentina and Paraguay. Delaying that process is of utmost importance to cotton growers. Previous experiences of other countries where that pest is already present should help to curtail the speed at which it is spreading. In this sense, the following strategies are recommended:

- control of the transit of all modality of raw material derived from cotton plants (lint, seed cotton, cotton seed) as well as instruments and equipment used in cotton growing and processing from infested to non-infested areas;

- establishment of monitoring system with pheromone traps and scouts in cotton fields near infested areas in Brazil (give special attention to most critical areas such as country boundaries, cotton gins, airports, etc.);

- establishment of legislative measures, including restriction of planting periods and deadlines for stalk destruction, of known efficiency in other countries;

- development, importation or adaptation of short-season, early-maturing varieties;

- training of agronomists/technicians/extension agents/growers on general behavior and management of boll weevil;

- development of systematic campaigns to deliver information related to boll weevil recognition, scouting procedures, management tactics, etc.;

Research Recommendations for Brazil

After more than ten years of its introduction, the presence of the boll weevil in all cotton growing areas in Brazil is a fact. Research emphasis at this point in time should be placed on the actual management of the pest. To properly do so, research should be oriented so as to turn available basic information on the biology and ecology of the pest and of other organisms directly related to it. Applied investigation should also be conducted to readily offer to growers technologies that can be immediately put into practice, programming their periodic upgrading, as more information becomes available. As the boll weevil is now present also in Paraguay, although still spreading, the comments presented in this section are also pertinent to that country. The following studies are suggested:

- management of cotton production systems, to prevent occurrence of pests, including the boll weevil;

- characterization of population dynamics (diapause, migration, dispersion, natural mortality), including modeling and development of expert systems for population/infestation prediction;

- development and validation of alternative cultural practices, such as hand picking, planting period, intercropping, crop rotation, and trap crops;

- development of resistant cotton varieties, including short season, early maturing varieties;

- conclusive studies on biological control, including not only laboratory evaluations but also real field work, to consider the efficiency of native natural enemies, the perspective of their practical use and the convenience of the introduction of more efficient exotic natural enemies;

- determination of control or action thresholds for different ecologies;

- determination of baseline data on insecticide resistance and monitoring of resistance development;

- development of tactics to prevent and to manage insecticide resistance;

- adaptation of control tactics to different social, cultural and economic characteristics of growers;

- improvement of application technology of insecticides;

- assessment of environmental impacts caused by insecticides used for boll weevil control;

- evaluation of socioeconomic impact caused by the boll weevil.

Conclusion

Of major concern to Brazilian cotton growers is the improvement of IPM techniques, through the better understanding of the pest ecology in its new home (where cotton varieties, soil types,

climate and competitors are different) and the development of control techniques (including biological, cultural and chemical control). Of major concern to neighboring countries is the adoption of adequate international quarantine, the implementation of suitable monitoring procedures and training of growers to cope with the new pest when it arrives. In Paraguay, activities should be directed both in reducing the speed of boll weevil spreading as well as in the actual management of the pest. Understanding previous experiences in other countries, adequate adaptation of available control techniques and development of basic research and local technologies has been demonstrated necessary for the maintenance of the cotton industry.

Table 1. Production of cotton lint (1,000 tons) in the main cotton producing countries, 1980/81 to 1992/93

Country	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93[1]
China	2,706	2,968	3,598	4,637	6,253	4,147	3,540	4,246	4,149	3,790	4,508	6,575	4,528
USA	2,422	3,405	2,605	1,692	2,826	2,924	2,119	3,214	3,356	2,655	3,376	3,835	3,540
Soviet Union	2,661	2,453	2,260	2,172	2,597	2,782	2,660	2,467	2,766	2,660	2,613	2,482	-
India	1,362	1,428	1,471	1,333	1,820	1,964	1,579	1,555	1,802	2,308	1,989	2,023	2,252
Pakistan	714	748	824	494	1,008	1,216	1,319	1,468	1,425	1,455	2,638	2,176	1,530
Brazil	623	640	648	745	965	793	633	864	709	676	717	661	565
Turkey	500	488	489	522	580	518	517	537	650	617	655	561	604
Egypt	529	499	460	409	399	435	403	352	311	289	296	293	305
Argentina	84	152	112	180	171	120	100	282	195	274	300	250	180
Greece	117	120	102	128	147	163	205	174	235	255	210	216	250
Mexico	353	314	183	226	242	220	139	223	308	167	175	181	30
Sudan	97	155	206	222	203	142	163	136	142	128	81	90	71

1. Estimates
Source: Cavalcante et al. 1993a.

Table 2. Area harvested to cotton (1,000 ha) in the main cotton producing countries, 1980/81 to 1992/93

Country	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93[1]
India	7,820	8,060	7,871	7,721	7,382	7,533	6,948	6,471	7,080	7,331	7,402	7,684	7,480
China	4,920	5,186	5,828	6,077	6,923	5,140	4,306	4,844	5,535	5,203	5,588	6,539	6,670
USA	5,348	5,601	3,939	2,974	4,201	4,140	3,427	4,061	4,833	3,860	4,748	5,244	4,514
Soviet Union	3,147	3,168	3,188	3,192	3,347	3,316	3,475	3,527	3,432	3,327	3,227	3,054	-
Pakistan	2,108	2,215	2,263	2,221	2,242	2,364	2,505	2,568	2,508	2,598	2,662	2,882	2,460
Brazil	2,998	2,779	3,030	3,107	3,707	3,325	2,161	2,577	2,230	1,964	1,939	2,121	1,672
Turkey	672	654	595	605	760	660	585	586	740	725	647	599	643
Argentina	282	399	343	470	447	339	273	492	490	540	634	535	367
Egypt	523	495	448	419	413	454	443	412	426	422	417	358	375
Greece	141	126	138	168	192	209	210	202	256	280	268	230	280
Sudan	387	355	392	400	360	326	346	318	313	297	209	147	151

1. Estimates
Source: Cavalcante et al. 1993a.

Table 3. Harvested area, production and yield of annual cotton (seed cotton) in different geographic regions of Brazil, 1980/81 to 1992/93

Region (States)	Season	Harvested area (1,000 ha)	Production (1,000 tons)	Yield (kg / ha)
Northeast	80 / 81	575.85	154.78	269
(AL, BA, CE, MA,	81 / 82	674.97	203.75	302
PB, PE, PI, RN, SE)	82 / 83	426.03	102.44	244
	83 / 84	887.55	517.51	583
	84 / 85	1,012.66	454.82	449
	85 / 86	955.56	388.12	406
	86 / 87	346.53	129.45	374
	87 / 88	698.58	481.80	690
	88 / 89	556.59	200.45	360
	89 / 90	330.57	151.36	458
	90 / 91	335. 75	217.44	648
	91 / 92	359.93	167.35	465
	92 / 93	235.75	114.49	486
Northwest	80 / 81	55.93	81.86	1,464
(MS, MT, PA)	81 / 82	57.13	71.59	1,253
	82 / 83	57.26	67.42	1,177
	83 / 84	63.45	74.92	1,181
	84 / 85	88.55	130.14	1,476
	85 / 86	72.90	84.69	1,162
	86 / 87	70.67	87.95	1,245
	87 / 88	92.54	117.11	1,266
	88 / 89	98.79	141.04	1,428
	89 / 90	96.29	135.10	1,403
	90 / 91	125.29	166.93	1,332
	91 / 92	128.67	153.82	1,195
	92 / 93	119.34	155.75	1.305

Table 3. Cont.

Region (States)	Season	Harvested area (1,000 ha)	Production (1,000 tons)	Yield (kg / ha)
Midsouth	80 / 81	763.14	1,303.82	1,708
(GO, MG, PR, SP)	81 / 82	826.07	1,416.95	1,715
	82 / 83	869.72	1,350.92	1,553
	83 / 84	722.15	1,297.83	1,797
	84 / 85	1,142.42	2,062.86	1,806
	85 / 86	967.13	1,723.34	1,782
	86 / 87	868.06	1,396.93	1,609
	87 / 88	1,031.30	1,836.81	1,781
	88 / 89	839.09	1,455.51	1,735
	89 / 90	956.14	1,487.17	1,555
	90 / 91	1,023.04	1,653.34	1,616
	91 / 92	1,099.57	1,531.92	1,393
	92 / 93	632.90	893.87	1,412
Brazil	80 / 81	1,394.92	1,540.46	1,104
	81 / 82	1,558.17	1,692.29	1,086
	82 / 83	1,347.01	1,520.78	1,129
	83 / 84	1,673.15	1,890.26	1,130
	84 / 85	2,243.63	2,647.82	1,180
	85 / 86	1,995.59	2,196.15	1,101
	86 / 87	1,285.26	1,614.33	1,256
	87 / 88	1,822.42	2,435.72	1,337
	88 / 89	1,494.47	1,797.00	1,202
	89 / 90	1,383.00	1,773.63	1,282
	90 / 91	1,484.03	2,037.71	1,373
	91 / 92	1,588.17	1,853.09	1,167
	92 / 93	987.99	1,164.11	1,178

Source: Cavalcante et al. 1993b.

States: AL-Alagoas, BA-Bahia, CE-Ceará, MA-Maranhão, PB-Paraíba, PE-Pernambuco, PI-Piauí, RN-Rio Grande do Norte, SE-Sergipe, MS-Mato Grosso do Sul, MT-Mato Grosso, PA-Pará, GO-Goiás, MG-Minas Gerais, PR-Paraná, SP-São Paulo.

Table 4. Evolution of cotton area (1,000 ha) infested with boll weevil in Brazil

State	March 1983	July 1983	Dec 1983	July 1984	Dec 1984
São Paulo	3.6	40	40	100	100
Paraiba	-	10	40	100	150
Pernambuco	-	10	17.4	20	30
Rio Grande do Norte	-	-	-	13	70
Total	3.6	60	97.4	233	350

Source: Silva Neto 1987.

Table 5. Harvested area, production and yield of perennial cotton (seed cotton) in northeastern Brazil, 1980/81 to 1992/93

Season	Harvested area (1,000 ha)	Production (1,000 tons)	Yield (kg/ha)
80 / 81	2,114.36	189.56	90
81 / 82	1,975.92	233.32	118
82 / 83	1,579.26	77.30	49
83 / 84	1,440.68	270,59	188
84 / 85	1,337.79	188.10	141
85 / 86	1,163.88	116.07	100
86 / 87	697.03	61.10	88
87 / 88	734.41	99.33	135
88 / 89	618.37	47.14	76
89 / 90	508.24	38.44	76
90 / 91	345.67	38.73	112
91 / 92	283.63	22.31	79
92 / 93 [1]	162.04	18.29	113

[1] Estimates
Source: Cavalcante et al. 1993b.

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