IMPACT OF THE INTRODUCTION OF THE COTTON BOLL WEEVIL IN BRAZIL

F. S. RAMALHO[1] & R. F. SANTOS[2]

1 - Biological Control Unit, CNPA/EMBRAPA, P.O. Box 174 - 58.107-720 - Campina Grande, Paraíba, BRAZIL
2 - Agricultural Economics, CNPA/EMBRAPA, P.O. Box 174 - 58.107-720 - Campina Grande, Paraíba, BRAZIL

Abstract

The populations of *Anthonomus grandis* Boheman that were first reported in Brazil in the state of São Paulo in February 1983, and in the state of the Paraíba in the northeastern region in August 1983, are morphologically similar to the southeastern boll weevil of the United States. All of the principal cotton-growing states in the southern region (São Paulo, Paraná, Minas Gerais, Mato Grosso and Mato Grosso do Sul) and in the northern region (Paraíba, Pernambuco, Rio Grande do Norte, Ceará, Bahia, Piauí, Maranhão and Alagoas) are now infested by the boll weevil.

The losses caused by the boll weevil in the northern region are both direct and indirect, and extend throughout the entire social, financial and economic structure of the region. It is impossible to estimate the losses due to depreciated land value, closing down of cotton gins and oil mills, and other indirect results of the boll weevil introduction.

An estimate of the magnitude of yield loss is afforded by the gains which have been recorded from recent field studies in which boll weevil injury has been eliminated. In the states of the Paraíba and Pernambuco where the boll weevil originally caused yield losses of 54 to 87%, increases in yield of seed-cotton over control (untreated plots) varied from 116 to 657% in tests. We believe that Integrated Pest Management technology using selective insecticides, natural mortality (high temperatures and low humidity and soil moisture, predators, parasitoids and pathogens), short season cotton and stalk destruction will collectively constitute the best management approach for production of a profitable cotton crop.

Introduction

Brazil is the sixth largest world producer of cotton, following China, the Commonwealth of Independent States (CIS, formerly USSR), United States of America, India and Pakistan (Cotton: World statistics, 1990).

In Brazil, cotton is grown in two large regions: the southern, including the states of São Paulo, Rio de Janeiro, Minas Gerais, Mato Grosso do Sul, Mato Grosso, Paraná and Goiás, and the northern, comprising all of the states where cotton is grown from Pará to Bahia. In the southern region only upland cotton (*Gossypium hirsutum* L. race *latifolium* Hutch.) is grown, while in the northern region perennial types (*Gossypium hirsutum* race *marie galante* Hutch.) and upland cottons are cultivated, with the area planted to perennial cotton larger than the area with upland cotton.

The southern region is the major cotton-seed producer of the country, producing 81% of the national seed output in approximately 37% of the cultivated area, from 1983 to 1990. This region, in addition to having excellent soil and climatic conditions for cotton production, the producer utilizes insecticides, fungicides, herbicides and fertilizers, and employs a rational approach to the control of pest and diseases.

In the northern region, in spite of cotton being an important agricultural crop and essential to the textile industry, the area accounts for only approximately 19% of the national production of seed cotton, despite occupying 63% of the planted area.

Although, cotton is one of the major crops of northeastern Brazil, productivity is lower than in other areas of the country. Several factors, including poor quality seed, lack of thinning practices, severe weed problems, and irregular rainfall contribute to low yields. Moreover, soil erosion and the absence of conservation and manuring practices deplete the soil and limit future technological advances. Because, the government provides few incentives for improved production, there is low grower income and lack of bank credit. As a result, northern cotton farmers fail to adopt technological innovations and changes.

One of the factors responsible for the low productivity of the cotton crop, mainly in the northern region of Brazil, is inadequate control of pests. Lamb (1974) cited 61 species of insects as pests of cotton in the various cotton-growing countries of the world. In Brazil, there are 16 species of insects and three species of mites considered as major pests of upland cotton (Gallo *et al.*, 1970). Davidson (1968) stated that eight species of insects and three species of mites are pests of perennial cotton, in northeastern region.

In spite of this large number of pests, Brazil until January 1983, could be considered a fortunate country, in that the boll weevil, *Anthonomus grandis* Boheman had not yet been reported in its cotton fields. In February 1983, the boll weevil was first found in Brazil.

The objective of this paper is to contribute to the knowledge of distribution and impact of the introduction of boll weevil into Brazil.

Distribution of the boll weevil in the New World and its introduction into Brazil

Information on the early distribution and subsequent movement of *Anthonomus grandis* is provided by Burke *et al*. (1986) (Fig. 1). The introduction of boll weevil into Paraguay was reported by Morengo and Whitcomb (1991). The present paper reports on the introduction and movement of the boll weevil in Brazil.

As a background for discussion of the introduction and movement of the boll weevil in Brazil, it is necessary to understand something of its taxonomy. Research on intraspecific variations in *A. grandis* were conducted by Werner (1960), Warner (1966), Burke (1968) and Burke *et al.* (1986). Studies developed by Burke (1968) and Burke *et al.* (1986) showed that three more less distinct forms of the boll weevil are recognizable: (1) the Mexican boll weevil occurring in Arizona, California, Mexico, Central America and Cuba; (2) the southeastern boll weevil in Texas, the southeastern United States, Haiti, Dominican Republic, Venezuela, Colombia and Brazil; and (3) the thurberia boll weevil which occurs in Arizona and Sonora, Mexico. There is a broad area of intergradation between the Mexican boll weevil and southeastern boll weevil in northeastern and northcentral Mexico (Fig. 1).

The populations of *A. grandis* that were first reported in Brazil, in the state of São Paulo, in February 1983 and in the state of the Paraíba, in northeastern Brazil, in August 1983 (Barbosa *et al.,* 1983) are morphologically similar to the southeastern boll weevil. The boll weevil may have originated from either the United States, northeastern Mexico, Haiti, the Dominican Republic, Venezuela or Colombia (Burke *et al.,* 1986). However, available evidences indicate that the infestations in São Paulo originated from southeastern United States. The introduction was possibly by airplane from somewhere in the southern United States. The first infestation was located near the International Airport of Cumbica, Campinas, São Paulo.

Because of the distance involved, the infestations of the boll weevil in northeastern Brazil, in August 1983, was probably the result of an accidental importation, through the activities of man, from the São Paulo infested area (Fig. 1), rather than a natural range extension. Burke *et al.* (1986) concluded that the infestation in Paraíba in northeastern Brazil was possibly due to shipment of raw cotton from São Paulo, but because of slight morphological differences, may have resulted from an independent introduction.

Movement of the boll weevil in the southern region of Brazil

The territory in the southern region in which *A. grandis* spread from February 1983 to the year 1993 is shown in Figure 2.

The first cotton fields infested by the boll weevil in Brazil were found in the counties of Campinas, Jaguariuna, Santo Antônio da Posse, Americana, Piracicaba, Tietê and Tatuí, in the state of São Paulo, in February, 1983 (Barbosa *et al.*, 1983). In March, 1983, the area infested by the pest was 3,600 ha. By the end season in June, over 45,000 ha of cotton distributed in 43 counties had been infested by the boll weevil. The first infestations occurred in isolated areas; in the meantime, at the end of the 1983/84 season, it was verified that the pest was distributed throughout the state, in spite of the large amount of insecticides applied against it. At the beginning of 1984/85 cotton season, cotton fields in 83 counties were infested by the weevil, comprising an infested area of ca. 100,000 ha (Martin *et al.*, 1987). In the 1988/87 season, practically 100% of the cotton-growing counties of the state were infested by the boll weevil.

In Minas Gerais, the first infestations of the boll weevil were detected at the end of 1984/85 in all countries bordering the state of São Paulo. This infestation originated from the São Paulo area and damaged small cotton bolls. However, the insect had not yet reached numbers sufficient to appreciably reduce the cotton yield. In the season of 1985/86, the government of the state of Minas prohibited planting of cotton in all of its counties bordering São Paulo. As a result of this decision the pest did not migrate from infested areas to the south, north and northeast of Minas Gerais. Personal information from Mr. C.E. Figueiredo, Head of the Plant Protection Service, Ministry of Agriculture, Minas Gerais, indicates that in May, 1991 infestations of the boll weevil were found in an area of 23,850 ha of cotton, located in the counties of Conquista, Uberaba, Conceição das Alagoas, Planura, Fronteira and Iturama, in the south of the state.

It is believed that if the government of Minas Gerais maintains its boll weevil suppression program as determined in the First State Meeting on Boll Weevil held at Montes Claros, Minas Gerais on August 21 and 22, 1985 which included the prohibition of interstate and intrastate movement of seed and/or seed-cotton from the infested region to uninfested area, the spread of the pest from the south to north and north-east of Minas Gerais will be retarded.

In May, 1987, the boll weevil was first found in the state of the Paraná, and the first infestations occurred in the counties of Barra do Jacaré and Maringá. At the end of 1990/91 cotton season over 432,000 ha of the cotton-planting area of the state had been infested by the pest, leaving only about 48,000 ha uninfested by the weevil.

The first counties of the state of Mato Grosso do Sul to be infested by the boll weevil were Taquarussú and Bataipora, in February, 1990, from infested area of the state of São Paulo. In June, 1991, the pest occurred in cotton fields of the counties of Jateí, Naviraí, Nova Andradina, Brasilândia and Santa Rita do Pardo. In December 1992, the boll weevil was distributed throughout all of the important cotton-producing areas of the state.

In Mato Grosso, cotton fields infested by boll weevils were detected on June 1993, in the counties of Mirassol D'Oeste and Cáceres (Arantes *et al.*, 1993).

The boll weevil has now spread over almost all of the cotton-producing states of the southern region, with exception of Goiás. From 1983 to 1993, more than 90% of the southern region became infested by the pest, and the area now infested produced over 95% of the seed-cotton of this region.

Movement of the boll weevil in the northern region of Brazil

The spread of the boll weevil in the northern region of Brazil, from 1983 to 1993 is seen in Figure 2. The records of Braga Sobrinho *et al.* (1983), Barbosa *et al.* (1983) and Menezes Neto and Ramalho (1984) indicate that the first infestations of cotton fields by the boll weevil, in northern region, were detected in small cotton-producing areas of the counties of Ingá, Paraíba, on July 4, 1983. A preliminary examination, made during July, 1983, under the direction of agents of the Extension Service and National Center of Cotton Research -

CNPA/EMBRAPA showed that the cotton area infested by the pest was constituted of the counties of Ingá, Gurinhém, Itatuba, Juarez Távora and Mogeiro, and that 80% of the cotton fields were smaller than five hectares. These counties are located in the "Agreste" region of the state, and included farms with areas over 50 ha, managed mostly by the partnership system. This system of land exploitation favors the development of polyculture, i.e., the intercropping of upland cotton with corn and beans, with the cotton crop consisting of the major component of the system.

In December, 1983, over 90% of the cotton fields of the "Agreste" region of Paraíba were infested, and in June, 1984, the boll weevil was found in the "Carirí" region (counties: Soledade and Taperoá) of the state, damaging both perennial and upland cottons. At the end June, 1984, the pest was detected in the "Seridó" region, i.e., the principal producer region of perennial cotton of the Paraíba, and also in the "Sertão" region (county: Brejo do Cruz) which was planted to both upland and perennial cottons. In 1985, all the cotton-producing regions of the Paraíba were infested by the pest.

The first cotton fields of the state of Pernambuco infested by the boll weevil were recorded in July 1983, in the county of Toritama. The infestations originated as a natural range extension from the "Agreste" region of the Paraíba. At the end of 1985 season, the pest was spread throughout the state of Pernambuco, reaching cotton fields at the border of the "São Francisco" River, in the county of Petrolina.

On July 23, 1984, the boll weevil was first discovered in the state of Rio Grande do Norte. It was found in the fields of irrigated upland cotton, in the "Itans-Sabugí" Irrigated Perimeter/DNOCS, in the county of Caicó. This record indicated that weevils from "Seridó" region of the Paraíba reached the "Seridó" region of the state of the Rio Grande do Norte. In this region, perennial cotton is the major crop. At the beginning the 1985 season, the boll weevil was detected in the "Agreste" region of the state, in the counties of Passifica and Nova Cruz. These infestations were the result of the emigration of weevil populations from the "Agreste" region of the Paraíba. At the end of 1985, all areas of the state were infested by the insect.

In the 1985 season, boll weevil populations which probably originated from the "Sertão" regions of the states of the Paraíba and Rio Grande do Norte, arrived in the south region of the state of the Ceará. The first cotton fields infested by the pest in this state were found in the county of Pereiro. at the end of that year, all the cotton fields of the south region of the state, were infested by the boll weevil. In the 1986 middle season, the pest was detected in fields of perennial cotton in the semi-arid regions of the Ceará. At the beginning the 1987 season, the boll weevil had spread to all of the cotton-growing counties, from south to north of the state.

By 1986 the boll weevil was detected in the state of Alagoas infesting solid cotton fields (county of Santana do Ipanema) and cotton fields interplanted with tobacco (county of Arapiraca) in the "Agreste" region of the state. Preliminary examinations, made throughout the season by agents of the Extension Service of the state, indicated the enormous capacity of the pest to do damage.

In August, 1986, the boll weevil was found in fields of irrigated cotton, Acala Del Cerro cultivar, in the county of Juazeiro, state of the Bahia, and at the end of 1991, the boll weevil was found in the Yuyu Valley, damaging upland cotton. It seems likely that boll weevil spread to areas far outside of its present territory, can be explained through the shipment of seed, seed-cotton or certain other cotton products.

The first fields of cotton infested by the boll weevil in the state of Piauí, were recorded in the south and north regions of the state, in the counties of São Raimundo Nonato and Burití dos Lopes, respectively, during the 1986 cotton season. These infestations possibly originated from Ceará and Pernambuco areas. In the 1987 season, it reached all the cotton-growing areas of the Piauí.

In September, 1986, the boll weevil was detected damaging squares and bolls in cotton fields of the state of the Maranhão, in the county of São Bernardo (Mr. A. P. Angelim, Head

of the DFARA/MA, personal communication). They may have been originated from north region of the state of the Piauí. At which time, the pest has spread through the all the state.

At the present time, 1993, the boll weevil has been found in more than 95% of the cotton growing states in the northern region, except in the states of Sergipe and Pará. However, it has been impossible to verify the rumors that the pest has been found in the state of Sergipe. The area now infested by the boll weevil produces over 95% of the seed-cotton of the northern region.

The fast spread of the boll weevil in the northern region is explained by the following factors: (1) in this region, cotton is grown from January to December, due to the irregular distribution of rainfall; (2) the cotton is grown almost everywhere in the region at different stages of development; and (3) at any time the pest may be carried far outside of the infested area through the frequent shipments of seed, seed-cotton or other cotton products.

Destructiveness of the boll weevil in the cotton-production regions of Brazil

The Brazilian modernization of agriculture was significantly intensified in the middle of the 1960s, when, under state direction, a dynamic development program in the sector was established. The term "agricultural modernization" should be herein considered an industrialized agriculture process, i.e., the intensive use of fertilizers, insecticides, tractors and other industrial products in agriculture. This process, given its peculiarities, reached with higher effects agricultural products with a greater technology need. For these products at the international level, the utilization of available technologies implies the use of industrial products. This is the case of the cotton-production.

In the system of cotton-production of Brazil, a clear technological difference exists between the southern and northern regions at the farm level. In the first region, the work developed by the "Instituto Agronômico de Campinas", since the beginning of this century and the efforts made by the textile industry have facilitated the modernization of cotton technology. In the northern region, this modernization did not occur. This lack of progress can be explained by the lack of interest of the textile industries as well by the adhering to the traditional structure of production and by the climate risk associated with the system of exploitation of the cotton crop.

Commenting about the structure of cotton production that prevails in the northeastern Brazil, Andrade, quoted by Santos and Barros (1989), commented that one of the greater advantages of the cotton crop was "to share it with subsistence crops all the land to be utilized for planting, allowing to the small farmer produces, in the same area, with only a work of land preparation, the food and the commercial products". He also mentioned "...after the harvest, done in the dryer period of the year, the cotton and corn foliages should feed the cattle, ... justly when he did not have pasturage in the field. This fact was an advantage to the big cattle-rearing of the region, once that they using this practice, increased their profits without giving up completely their cattle-rearing activities ... ".

The major liability of this cotton-production system is its aversion to utilizing innovation. This system wastes land and labor on a large scale, and incorporates few innovations (i.e. the inputs of fertilizers, insecticides, and other industrial products are limited).

The introduction of the boll weevil into the northern region of Brazil accelerated the already existent cotton-production system crisis. In order to produce a profitable cotton crop in the presence of the boll weevil, a certain level of technology is required with higher associated production costs. In the "Seridó" region of the states of Paraíba and Rio Grande do Norte, where cotton grown on small farms is one of the few commercial crops produced, significant reductions in seed-cotton have occurred (Figs. 3, 4).

Although efforts have been undertaken to introduce the principles of Integrated Pest Management, the success attained in adopting this technology by the cotton farmers in the northeast is yet very insignificant. Several reasons exist, the main one being the cotton-

production structure that prevails in the northeast farms: the traditional character of the farmers and their low educational level and the region economic inequality that has been reinforced by the government policy, including the dispensing of scientific and technological information.

The impact of the boll weevil in harvested area, production and yield of seed-cotton in the main states (São Paulo and Paraná) of the southern region infested by this pest is seen in Figure 3. These data show that there is a slight increase in harvested hectarage and production, indicating a 2% annual rate of growth in the period from 1981 to 1990. The situation is similar to the period after the introduction of the weevil, 1983 to 1990. From 1983 to 1990 the annual rate of yield of seed-cotton remained steady. The annual rate of growth from 1983 to 1990 was 1%. This increase in the yield of seed-cotton may be considered as a change in the cotton-production technological level. It may be interpreted as a positive effect of the boll weevil introduction in the southern region. In the northern region, a decline in the harvested area and production of upland cotton was 13 and 7%, respectively, in the period from 1981 to 1990 (Fig. 4). Between 1983 and 1986, an increase in the harvested area was observed. This increase corresponded with the period in which the weevil was present in the region. This fact may be explained, firstly by the end of the greater drought period occurred in the northeast between the years of 1979 and 1983, and secondly by the fact that the Brazilian government gave incentives to the cotton eradication in the northeast from 1983 to 1986. The government paid the cotton elimination and indemnified for the planted cotton areas. In this case, the intention of the farmer was not to increase his hectarage in expectation of a profitable cotton harvest, but to be compensated from the government indemnity. The yield of seed-cotton showed an annual rate of growth of 5%. Probably, it occurred due to climatical and biological factors which interfered directly or indirectly in the suppression of the boll weevil populations.

In the case of perennial cotton, reductions in harvested area, production and yield seed-cotton were expressed by annual rates of decline of 16; 18 and 1%, respectively (Fig. 5).

Therefore, the losses caused by the introduction of the boll weevil in the agroecosystem of the northern region of the Brazil are both direct and indirect, and extend throughout practically the entire social, financial and economic structure of the region. It is impossible to estimate the social and economic losses due to depreciated land values, closing down of cotton gins and oil mills, unemployment, emigration of rural workers to the big cities of the northeast and the southeast of Brazil, and other indirect results of the weevil introduction. The magnitude of losses due to boll weevil is dynamic, varying from year to year, and from area to area. The damage in individual fields is influenced by many factors, and varies widely, ranging from slight injury to complete destruction of the cotton. Generally, regions and seasons with the heaviest precipitation during the cotton-growing months will suffer the greatest damages.

An estimate of the yield loss can be extracted by confirm gains observed in field studies, where boll weevil injury has been eliminated. However, the information concerning yield losses (Table 1) must be used with caution. The losses were developed from field plots in which yield data from untreated plots were compared with yield from insecticide-treated plots. These losses do not reflect those that occur under the best agricultural practices. They reflect the potential of boll weevil populations to cause losses when no control is used and when the most effective chemical of those tested has been applied in research studies. The data are useful in that they provide information concerning the potential impact of the weevil on the cotton crop of the northeast.

In the states of the Paraíba and Pernambuco (Table 1), the boll weevil caused losses of cotton yield ranging from 54 to 87% in tests. Increases in the yield of seed-cotton over the control (untreated plots) varied from 116 to 657%. However, the losses caused by the boll weevil may also be minimized by the use of the Integrated Pest Management (IPM) which combines economically sound and environmentally safe pest management practices (Ramalho *et al.*, 1989).

Data obtained in IPM programs (Fig. 6) conducted in the counties of Iguatú, state of the Ceará in 1985, and in Souza, state of the Paraíba in 1986, with and without the presence of the boll weevil, in upland cotton (cv CNPA 3H), showed that the number of insecticide applications (8 to 10 sprayings) necessary to keep the populations of cotton pests below the action level, from seedling emergence to the setting of the first open boll, was the same in both situations. This is due to the fact that the sprayings which should be done against cotton leafworm (*Alabama argillacea* Hübner) after the appearance of the first squares and pink bollworm (*Pectinophora gossypiella* Saunders) should be redirected against the boll weevil, being that the chemical product utilized must be effective against boll weevil, cotton leafworm and pink bollworm (i.e., the control cost of the cotton pests is not increased in the presence of the weevil) (Ramalho *et al.*, 1989; Ramalho and Jesus, 1989; Ramalho and Gonzaga, 1990a,b; Ramalho *et al.*, 1990; Ramalho and Gonzaga, 1991b).

The adoption of Integrated Pest Management technology using selective insecticides (Ramalho *et al.*, 1989; Ramalho and Jesus, 1989), natural factors of mortality (high temperatures and low humidity of the soil, predators, parasitoids and pathogens) (Ramalho and Gonzaga, 1990b,c; Ramalho and Gonzaga, 1991a; Gonzaga and Ramalho, 1991), short season cotton cultivars and stalk destructions will be the best tool for production of a profitable cotton crop.

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Table 1. Losses to seed-cotton and control cost attributed to the cotton boll weevil in Brazil.

Year	County/State	Yield losses (%)*	Control cost (US$/ha)	Yield increase (%)*	Reference
1986	Souza/PB	58	23.22	139	Ramalho and Jesus (1989)
1986	Queimadas/PB	87	32.44	657	Ramalho *et al.* (1990)
1986	Queimadas/PB	79	38.93	382	Ramalho *et al.* (1990)
1986	Queimadas/PB	84	25.95	526	Ramalho *et al.* (1990)
1986	Surubim/PE	77	9.85	329	Ramalho *et al.* (1990)
1986	Surubim/PE	84	28.85	538	Bleicher and Almeida (1988)
1986	Queimadas/PB	65	16.57	188	Ramalho and Gonzaga (1990a)
1986	Queimadas/PB	63	10.12	172	Ramalho and Gonzaga (1990a)†
1987	Queimadas/PB	68	16.57	217	Ramalho and Gonzaga (1990a)
1987	Queimadas/PB	68	8.67	209	Ramalho and Gonzaga (1990a)†
1987	Queimadas/PB	60	18.79	153	Ramalho and Gonzaga (1991b)
1989	Ingá/PB	54	15.05	116	Souza Filho *et al.* (1991a)
1989	Ingá/PB	56	35.20	128	Souza Filho *et al.* (1991b)
1990	Alagoinha/PB	74	18.94	252	F.S. Ramalho (unpublished data)

* Calculated using yield data from untreated plots compared with yield from insecticide treated plots.

† Cotton interplanted with corn.

Figure 1. Distribution of the three forms of *Anthonomus grandis*. Hypothesized routes of the southwestern boll weevil from United States to Brazil (dashed line) and from São Paulo to Paraíba (solid line). Distribution adapted from Burke *et al.* (1986). Routes of introduction hypothesized by the first author.

Figure 2. The territory in the southern and northern regions of Brazil in which *Anthonomus grandis* spread from February 1983 to the year 1993.

Figure 3. Harvested area (ha), production (t) and yield (kg/ha) of seed-upland cotton in states (São Paulo and Paraná) of the southern region of Brazil, from 1981 to 1990. **O——O** = harvest area (ha), Δ.-.-.-.Δ = production (t) and □ ----- □ = yield (kg/ha).

Figure 4. Harvested area, production and yield of seed-upland cotton in states (Paraíba, Pernambuco, Ceará, Rio Grande do Norte, Maranhão, Piauí and Alagoas) of the northern region of Brazil, from 1981 to 1990. **O——O** = harvested area (ha), Δ.-.-.-.Δ = production (t) and □ ----- □ = yield (kg/ka).

Figure 5. Harvested area, production and yield of seed-perennial cotton in states (Paraíba, Pernambuco, Ceará and Rio Grande do Norte) of the northern region of Brazil, from 1981 to 1990. **O——O** = harvested area (ha), Δ.-.-.-.Δ = production (t) and □ ----- □ = yield (kg/ha).

Figure 6. Integrated Pest Management of cotton in Brazil without and with boll weevil. E = seedling emergence, **S** = square, **F** = flower, **HB** = hard boll, **OB** = open boll and **H** = harvest. Source: Ramalho (1994).