2254 An overwiew of cotton breeding in Brazil

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Abstract

Cotton, *Gossypium hirsutum*, breeding in Brazil can be divided into two distinct eras. The first era occurred before the 1990s when cotton production was wide spread across the country and was produced with few inputs and hand harvested. The second era began in the 1990s when cotton production moved to the 'cerrado' with high chemical input and a completely mechanized production practices. Major breeding objectives are for disease tolerance along with fiber yield and fiber quality. Farmers are demanding tolerance to fungal diseases, nematodes, and earliness of maturity. Selection progress during the second era has been 1.58% $year^{-1}$ as indicated by recent releases and those used in the beginning of the era. Breeding programs are located all over the growing areas, from 7º until 24º south latatude. Breeding methods include selection within existing cultivars, hybridization followed by selection, and recurrent selection. Programs have large variations in the quantity of plants selected in each season, and plot sizes and intensity of evaluation increases as the lines get closer to the market.

Introduction

The first cotton breeding program was started in the 1920s, when one public institution, belonging to the São Paulo state, named Instituto Agronomico de Campinas, began a breeding program located in Campinas, State São Paulo. Cotton breeding and seed production in Sao Paulo later became a state monopoly and soon the neighbouring state of Paraná adopted a similar strategy. Those were the main breeding programs for cotton in Brazil until the 1970s when Embrapa initiated a breeding program directed to improved cotton's potentioal for the north-eastern, semi arid part of the country. That program continues today. Before the early 1990s, cotton was mostly produced by small farmers and hand picked, a system that lead to the historical lowest area devoted to cottom production by the early 1990s.

During the early nineties, one agricultural company started to evaluate cotton in the "cerrado" area of the country and under contract with Embrapa, selected a strain of Deltapine Acala 90 that was named ITA 90. This cultivar requires special production techniques as it is susceptible to prevailing diseases and especially to viruses, which therefore demands rigorous vector control. It has good fiber qualities, is full season and is largely responsible for a renewal of cotton production in the country. After production moved from the small farms to the "cerrado" area, breeding programs had to adapt to the newer traits demanded by the market, including machine planting and harvesting, increased use of growth regulators, and improved fiber quality.

Present status of cotton in Brazil

Since the mid 1990s, the area devoted to cotton production has increased to the present day level of slightly over one million ha. Cotton is produced country wide but is more concentrated between latitudes 22° and 10° S. Elevations above 500 m are preferred as moderate temperatures will result in higher yields but cotton can be found in areas lower than a 100m. Rainfall is characterized by wet summers and dry winters with total rainfall of 2000 mm from October until April in most areas. Soils vary from clay to sand and have low natural fertility. Planting occurs primarily during December, at the mid of the rainy season, with harvest at its peak during the month of July when dry weather prevails. In the regions with a longer rainy season, producers tend to practice double cropping, soybeans followed by cotton. Crop rotation is seldom used as soil fertility recquirements by cotton are much higher than for other rotational crops, especially on the deeper soil horizons. For mechanized production, fiber yields are in the range of 1000 to 1800 kg ha^{-1}. When irrigation is used, yields may go as high as 2200 kg ha^{-1} of fiber. The majority of the fiber produced is exported while seed are mainly used for cattle feed.

One of the major requirements for sustainable cotton production in Brazil is the complete destruction of plants after harvest, which demands a large amount of energy. Not destroying stalks will result in increased boll weevil pressure, as well as that of other insects and diseases in the next growing season.

Breeding objetives

Fiber yield and and fiber quality are priorities in all breeding programs. A survey of cotton growers conducted by the Cotton Grower Association of Mato Grosso has identified the following breeding priorities (unpublished data):

Tolerance to nematodes
Tolerance to *Ramularia areola*
Tolerance to *Fusarium oxysporum*
Earliness.

Farmers on average spray the cotton crop around 20 times during the growing season, many times with mixtures of products. Sprays including fungicides amount from three to six times during the growing season. Growth regulators are used an average of four times per season and insecticides may be use up to 15 times per season. Where cotton is grown in Brazil, precipitation, temperature, and air humidity are ideal for fungal development. Viruses were a large problem, demanding 5-6 sprays for rigorous aphid control until recent years. The newest locally bred cultivars are resistant to most viruses, which allows for a more relaxed aphid control regime. A significant amount of resources is spent on disease controll, consequently disease resistance is one of the priorities in breeding.

Major diseases affecting cotton production in Brazil are:
Ramularia areola: the most important fungal disease; may reduce yields up to 35%; no resistant sources known; control is with fungicides.

Colletotrichum gossypii: fungal disease that may attack all parts of the plant; cultivars have been developed with acceptable field resistance; control with fungicides is possible.

Bacterial blight: caused by *Xanthomonas axonopodis;* disease is seed transmitted; seed treatment along with resistant cultivars (Delta Opal) result in good disease control.

Cotton mosaic vein virus: may cause complete loss; good aphid control and use of resistant cultivars are the best control; resistance is provided by two independent and dominant genes and most recent cultivars are tolerant.

Seedling diseases: caused by *Rhizoctonia solani*, *Colletotrichum gossypii*, *Fusarium spp.* *Macrophomina phaseolina*, *Pythium spp*, *Lasiodiplodia theobromae* alone or in combination; problems exacerbated in years of excess moisture at planting.

Boll rots: caused by *Colletotrichum gossypii, Alternaria spp., Lasiodiplodia theobromae, Diplodia sp., Fusarium spp.*, and *Cercospora sp*., among others: increased incidence after excess rainfall, especially on the bolls located on the lower part of the plant.

Other diseases that have variedd in importance over the years include: *Alternaria macrospora, Stemphylium sp., Cercospora gossypina, Fusarium oxysporum, Myrothecium roridum, Corynespora cassiicola, Phakopsora gossypii, Sclerotinia slerotiorum*, and other viruses. Presently, fusarium wilt is not listed among the most important diseases, although in the past though it has been responsible for moving cotton out of many important growing areas.

Three species of nematodes affect cotton production in Brazil, *Meloidogine incognita, Rotylenchulus reniformis* and *Pratylenchus brachyurus*. The last one is the most prevalent but usually in small populations. Races 3 and 4 of *M. incognita* have been isolated in Brazil, with race 3 prevalent. There have been no cultivars identified as completely resistant to *R. Reniformis* within *G. hirsutum* but some that have reduced reproduction factors under greenhouse production have been found. Testing for *M. incognita* race 3 has shown that BRS Sucupira was resistant as indicated by reduced nematode numbers.

Insects take another significant amount of resources and among the most important are boll weevil, white flies, a variety of caterpilars, aphids, thrips,

Selection progress

Moresco (2003) analyzed performance trial data produced by Embrapa over a period of 12 years and concluded that the average gain from selection was 3.8% year^{-1} within the state of Mato Grosso. A local organization that promotes cotton within the state of Mato Grosso, named Facual, conducts an annual cultivar evaluation trial at 12 locations. An extract of the trial results over these12 locations during the season 2005/06 is shown below (Farias et al. 2006):

Cultivar	Fiber yield	Year released
	- kg ha^{-1}-	
FMT 701	1747 a	2006
FM 993	1719 ab	2006

Acala 90	1348 gh	1992
CV(%)	12.7	

Using the above data, calculated gain from selection during the last 14 years is 27.5 kg ha^{-1} yr^{-1}, or 1.58% yr^{-1}. The fact that some of the newer cultivars have virus tolerance also makes their cost of production lower and therefore more cost efficient than the older cultivars.

Breeding programs

Cotton breeding is conducted by a variety of groups including research organizations controlled by public funds, private companies of international origin, and private organizations. Among the public programs, the largest is Embrapa, whose headquartes are located in Campina Grande, 7º 13’ 59” S. The group runs three full breeding programs, one at the headquarters, one in the middle of the cotton growing area in Santa Helena de Goiás, 17º 48’ 50” S, and the third one in Primavera do Leste, 15º 33’ 45” S. Coodetec is a private company that runs its largest program from Primavera do Leste and has testing sites located in the States of Goiás and Bahia. The company has a contract with CIRAD to breed cotton for Brazil and Paraguay with a second station in Palotina, 24º 17’ 02” S. Ongoing state programs are conducted by the Instituto Agronomico de Campinas, 22º 54’ 21’’ S, and the Instituto Agronomico do Parana located in Londrina, 23º 18’ 36” S. These two programs have a long tradition in breeding cotton. Private companies include Bayer, Delta and Pine Land (now Monsanto) and a local foundation, Fundação Mato Grosso, which is located in Rondonopolis, 16º 28’ 15” S.

Germplasm Banks

The largest germplasm bank belongs to Embrapa and is located in Brasília. Other groups that are known for having a good history in germplasm maintenance are the Instituto Agronomico de Campinas, IAPAR, and EPAMIG, all public. The private companies of international origin have direct access to their private banks as well as all public germplasm banks.

Breeding methodology

Selection within existing cultivars is a common practice and was used to obtain IAC 21 as a resselection of IAC 19; IAC 23 was obtained as a selection from IAC 20 and IAC 24 was selected from IAC 20 RR. The cultivar ITA 90 was a selection from Deltapine Acala 90, which originated in the USA. The first brown lint cultivar released was a selection from native cottons grown in the north eastern part of the country.

Hybridization and selection is the most common practice used for breeding . Individual plant selection will start in the F_2 in some cases, with most programs use a bulk breeding method with individual plant selections starting in F_5 or F_6. Individual plant selection criteria are multiple with major importance to field disease resistence and fiber traits. The average number of parental combinations generated each year is between 50 and 100, in some exceptions a program may produce over 200 parental crosses a year.

Besides the hybridization to generate variability, Embrapa had a recurrent selection program ongoing, entitled CNPA-2001-01, which originated from intercrossing 35 lines. The isolated plot had approximately 10,000 plants with the best 300 plants field selected and then reselected on HVI data. The final set of selections were then recombined. Another population for superior fiber lenght has been synthesized by the same program. (Freire et al. 2004).

Fundação Mato Grosso, during the season 2004/05, made 683 parental combinations during both the rainy and dry seasons. During the rainy season 4126 bulks were increased while 1721 were planted during the dry season. A total of 90,519 individual plants were field selected. A total of 25,819 lines were field evaluated as reported by Aguiar et al., (2005). Embrapa had 100 F_1 populations, 145 F_2 populations, 233 F_3 populations, and 261 F_4 populations during the 2003/04 season. From those, 4500 plants were field selected and protocol was to eliminate 80% of those after individual plant fiber analysis. According to Penna (2006) Coodetec made 17,820 individual plant selections in the field during the season 2003/04, and 5,702 were identified with good fiber traits and planted in the following season.

Plot sizes

Fundação Mato Grosso, as informed by Aguiar (2005), uses the following plot sizes:

- F_1: one row, 15 m
- F_2 to F_4: four rows, 50 m
- F_5: eight rows, 50 m
- First field evaluation of progenies: one row, 6 m: checks at every 30 rows
- First year trials: 4 rows, 5 m, harvest 2 middle rows; checks at every 20 plots; 1 rep
- Second year trials: similar to first year with 2 reps
- Third to fifth year trials: 4 rows, 6 m; 4 reps; 4 locations
- Large plots: 10 rows, 50 m; replicated; 24 locations.

Offseason field work has been reduced as cotton production in Brazil requires a growing season of 180-200 days, and when combined with time required for laboratory analysis makes it difficult conduct two generations yr^{-1}. Primary off-season work includes hybridization and disease evaluation in the greenhouse.

Special Traits

One frego cultivar has been released with the objective of improved boll weevil control. Various programs have evaluated okra leaf types but so far no cultiavrs have been released. Low gossypol cultivars have been evaluated but failed to reach the market. Among the genes identified in other species and transfered to cotton, only one gene, Cry1Ac, has been approved for market release, cry@Ab, cry1F, Vip3A, CP4 epsps and Bar are being field tested and are under commercial release proposals.

Cultivar development

Private companies spend a lot of effort in developing the cultivars that have been released to the market while companies being finaced mostly by public resources spend a relative larger amount of time in trait breeding. Cultivars of public origin tend to have a lower market share than the one predicted by their performance in field trials. Farmers, although many have mange large farms, some over a thousand ha, fail to run on-farm comparitive tests and lag behind the technology created by research.

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