

IMA 5801B2RF, insect-resistant and glyphosate-tolerant cotton cultivar, with resistance to root-knot nematode

Jean-Louis Belot^{1*}, Patricia Vilela¹, Rafael Galbieri¹, Leonardo Scoz¹, Alberto Souza Boldt¹, Rodrigo Chimenez-Franzon¹, Idimar Leoni¹, Ueverton Rizzi¹ and Marcio Souza¹

Abstract: IMA 5801B2RF is a medium to short season cultivar with high fiber yield potential. The genes *Bt cry1Ac* and *cry2Ab* confer resistance to Lepidoptera and *cp4-epsps* confers tolerance to the herbicide glyphosate. The key feature of this new cultivar is resistance to ramularia leaf spot and root-knot nematode.

Keywords: *Gossypium hirsutum*, fiber yield, *Meloidogyne incognita*, *Ramularia areola*

INTRODUCTION

In the 2019 growing season, Brazil became the world's fourth largest cotton fiber producer and the second largest exporter behind only the United States (OECD-FAO 2019). Cotton is produced mainly in the dryland farming system, producing upland cotton (*Gossypium hirsutum* L.) for the cotton market of medium-length fiber (27-30 mm). The production areas lie in the "Cerrado" biome, where the vegetation is shrubby savanna, the topography flat, suitable for agricultural mechanization, and the rain seasons are clearly defined (Santos et al. 2020). In these regions, cotton can be an option for soybean+maize intercropping systems. It can be cultivated after soybean, as cotton in the late or second growing season, when the relative air humidity and rainfall (600-800 mm) are high, during at least the first 100 days of the cycle.

High moisture environments favor the occurrence of phytosanitary problems, including high pressure of weeds, pests (insects, mites), and different pathogen groups, e.g., fungi, viruses, bacteria, and nematodes (Belot and Vilela 2019). In particular, both the incidence and population of *Meloidogyne incognita* have increased remarkably in agricultural production areas in the last years. This nematode occurs in 25% of the cotton-producing area of the state of Mato Grosso (Galbieri et al. 2016) and in 37% of that of the state of Bahia (Perina et al. 2018). The estimated production loss due to this nematode ranges from 35% to 65% in Mato Grosso (Galbieri et al. 2009, Silva et al. 2014). There are some areas in the Cerrado where the nematode pressure is currently so high that cotton production has become unviable.

The use of transgenic plants in cotton cultivation has been widely exploited in Brazil since 2005 (ISAAA 2017), by the application of mainly the following technologies: Bollgard II RR Flex™ (B2RF) and Bollgard III RR Flex™ (B3RF) by Bayer Crop Science, Glytol™ (GL), Glytol Twinlink™ (GLT) and Glytol Twinlink

Crop Breeding and Applied Biotechnology
20(4): e322920412, 2020
Brazilian Society of Plant Breeding.
Printed in Brazil
<http://dx.doi.org/10.1590/1984-70332020v20n4c65>

*Corresponding author:

E-mail: jeanbelot@imamt.org.br

 ORCID: 0000-0002-2950-9500

Received: 07 May 2020

Accepted: 01 July 2020

Published: 13 November 2020

¹ Instituto Mato-Grossense do Algodão, Rua Engenheiro Edgard Prado Arze, 1777, Edifício Cloves Vettorato, Bairro CPA, 78.049-015, Cuiabá, MT, Brazil

Vipcot™ (GLTP) by Basf, or WideStrike™ (WS) and WideStrike 3™ (WS3) of Corteva. BAYER, IMAmt, TMG and EMBRAPA (Suassuna et al. 2018, Morello et al. 2020) released cultivars with B2RF technology in Brazil.

Cultivar IMA 5801B2RF is an upland cotton carrying the transgenic technology of Bollgard II RR Flex™ (CTNBio 2020). This technology involves two types of traits. The first type consisted of the introgression of two genes for the event MON15985 (Bollgard II™), responsible for resistance to several Lepidoptera insects, producing the proteins Cry1AC and Cry2Ab2 from *Bacillus thuringiensis*. The second trait involves a gene of the event MON88913 (Roundup Ready Flex™), which produces protein CP4-EPSPS of *Agrobacterium tumefaciens*, providing the plant with tolerance to the herbicide glyphosate at any stage of plant development. These two Bt genes (cry1Ac and cry2Ab2) allow the control of *Alabama argillacea*, *Pectinophora gossypiella*, *Heliothis virescens*, *Chrysodeixis includens*, and suppression of *Helicoverpa* spp. and *Spodoptera* spp.

Nematode control with chemical or biological nematicides is no guarantee for an efficient control of *Meloidogyne incognita* (Kofoid and White) Chitwood. The best possible option is the development of a new cultivar with introgressed genetic resistance, when available, to ensure an efficient nematode control (Davis and Stetina 2016). Two main sources of genetic resistance for cotton cultivars are available: one from *G. hirsutum*, and the other from *G. barbadense* (Lopes et al. 2020). We used the *G. hirsutum* source for the development of cv. IMA 5801B2RF. The resistant parents used were the lines M-315 RNR and M-240 RNR, which are part of a group obtained by introgressing resistance genes from cv. Auburn 623 RNR into an elite genetic background (Shepherd 1982). Cultivar Auburn 623 RNR inherited nematode resistance from the cross between cvs. Cleve wilt 6 and Mexico Wild Jack Jones.

Over the years, several authors have shown that a considerable part of the resistance of these lines can be ascribed to at least two major genes present in the chromosomes 11 and 14. Gene c11 (*qMi-C11*) is closely linked to the microsatellite marker CIR316 C07 (Shen et al. 2006), and Gutiérrez et al. (2010) demonstrated that this gene mainly prevents root gall formation. Gene c14 (*qMi-C14*), linked to markers BNL3545-118 and BNL3661-185, has a significant effect on nematode reproduction. These results were confirmed in the studies of Shen et al. (2010) and He et al. (2014), and even identified more precisely positioned markers, namely markers CIR069 - E14M27-375 for gene *qMi-C11* and markers CIR381b - UTG0045 for gene *qMi-C14*. According to Silva et al. (2018), *qMi-C11* and *qMi-C14* act at different times and have different effects on *M. incognita* development. Since the genes have different modes of action, their combination is a useful tool for root-knot nematode resistance in breeding programs.

The Mato Grosso Institute of Cotton (IMAmt) is the technological branch of the Cotton Producers' Association of Mato Grosso (AMPA). The cotton breeding program of this institute was initiated in 2008. A cooperative created by the members of AMPA, the Mixed Cooperative for the Development of Agribusiness (Comdeagro), is in charge of seed production and commercialization. Cultivar IMA 5801B2RF is the result of this program and expands the options of integrated pest and nematode management available to cotton producers in the Brazilian Cerrado.

GENETIC ORIGIN AND DEVELOPMENT

The objective of this research was marker-assisted introgression of both genes of the technology Bollgard II RR Flex™ and of nematode resistance into a genetic background of IMAmt with high agronomic value (line IMA1 08-3869). All developmental phases of the cultivar took place at the experimental station of IMAmt, in Primavera do Leste, Mato Grosso.

We used the genes *qMi-C11* and *qMi-C14* from the lines M-315 RNR and M-240 RNR for introgression. After biparental crossing, three backcrosses were made, using the aforementioned molecular markers to identify the two genes at all stages of the process (IMA1 08-3869/4 * M-315 RNR). The BC₃F₂ plants were established and line IMA1 08-3869 RNR was selected.

The three Bollgard II RR Flex™ genes were introgressed from donor DP 164 B2RF {DP 565/3*[DP 565 x (Cocker 312 RF x DP 50 B2)]}, provided by Monsanto, after the two institutions had signed a research agreement. This donor is a high-yielding cultivar but with a relatively low lint percentage. After crossing the parents IMA1 08-3869 RNR and DP 164 B2RF, three other backcrosses were made, using molecular markers linked to the three transgenes. The BC₃F₂ plants were denominated lines IMA1 08-3869 B2RF. The crosses and backcrosses performed made in a greenhouse between October 2011 and September 2013, while the molecular analyses were carried out at the IMAmt laboratory of molecular biology.

After establishing the two parents IMA1 08-3869 B2RF and IMA1 08-3869 RNR, they were crossed in a greenhouse in March 2014. The F₁ seeds were planted and self-pollinated to obtain F₂ plants in the same greenhouse. Homozygous F₂ plants for the five genes were identified and multiplied in the greenhouse. A total of 1895 F_{3:4} lines were planted in the field, under irrigation, between February 2016 and August 2016. The lines IMA 3869 B2RF RNR were evaluated phenotypically during the season. There was little morphologic variation among the lines, but remarkable differences in terms of yield, lint percent (LP) and fiber quality.

The best lines were evaluated for gall index and nematode reproduction factor in the greenhouse, while the yield potential and fiber quality of these lines were evaluated in the field, all in the 2016/2017 growing season. All greenhouse trials were arranged in a randomized block design, with 10 plots, each consisting of one 2.5 L pot with one plant. A mixture of two populations of *M. incognita* race 3 (*Mi*), one from Campo Verde (Mato Grosso) and the other from Primavera do Leste (Mato Grosso), was multiplied on tomato (*Lycopersicon esculentum* "Rutgers") roots for 60 days before using it as inoculum on the cotton plants. Inoculation was applied eight days after sowing, at an initial inoculum level (Pi) of 8.000 eggs or second-stage juveniles (J2) of *Mi* per plant. At 70 days after inoculation, the plant roots were washed and the gall index was evaluated on a 0 - 10 scale. The reproduction factor (RF) was calculated by adding the number of *M. incognita* eggs + specimens found on the roots, processed as described by Coolen and D'Herdt 1972, and by dividing the sum by the initial inoculum concentration (Pi=8.000).

Six lines, very similar from an agronomic point of view, with regard to fiber quality and nematode resistance, were grouped to form the genetic core of cv. IMA 5801B2RF, while other lines continued to be tested for possible cultivar release. The genetic core was multiplied in Mato Grosso in the growing season of 2016/17 and in Rio Grande do Norte in the late season of 2017. The then denominated cultivar IMA 5801B2RF was tested in six official field trials at five locations in Mato Grosso in the growing season of 2017/18 and in seven trials in 2018/19. During these two evaluation periods, a total of 25 specific field and greenhouse trials were carried out to investigate the resistance and tolerance of this cultivar against diseases and nematodes.

PERFORMANCE CHARACTERISTICS

Cultivar IMA 5801B2RF is medium to tall, has a cylindrical morphology and fruit branches with usually less than two bolls. This may result in a higher demand for growth regulators in the vegetative phase and beginning of flowering. The cultivar is also fertilizer demanding but responsive to fertilization.

Cultivar IMA 5801B2RF has a relatively aerated foliage, with medium-sized and clear-cut leaves. This plant architecture ensures good aeration and light penetration, which is an advantage in white-mold infested fields (*Sclerotinia sclerotiorum*).

Table 1. Agronomic traits and HVI fiber quality of IMA 5801B2RF, TMG 44B2RF, and FM 954GLT (check varieties) in 13 field performance trials in the growing seasons of 2017/2018 and 2018/2019

Trait	IMA 5801B2RF	TMG 44B2RF	FM 954GLT
Plant height (cm)	110	97	102
Storm resistance *	2.0	1.4	1.7
Maturity rating **	2.9	2.9	2.5
Boll weight (g)	6.59	5.32	5.06
Fiber length (UHML) (mm)	30.4	30.8	31.7
Uniformity index (ML/ UHML) (%)	84.4	83.4	84.1
HVI fiber quality (gf tex ⁻¹)	31.4	31.0	32.1
Elongation (%)	6.6	6.4	6.5
Micronaire reading	4.79	4.26	4.32
Reflectance- Rd (%)	80.5	81.3	80.9
Yellowness (+b)	7.9	7.4	7.8
Short fiber index (%)	6.31	7.08	5.90
Spinning Consistency Index (SCI)	146	146	154

* Storm resistance: visual evaluation of cottonseed in the open boll. 1: tightly retained- 5: cotton on the ground;

** Maturity rating: visual evaluation. 1: late season cultivar- 5: early season cultivar.

In favorable cultivation environments, the variety can grow productive vegetative branches, providing some flexibility for plant population recommendations. The oval-shaped bolls have a high average weight. Although the fruits of the middle third weigh around 6.6 g (Table 1), an average boll weight between 5.0 and 5.6 g was considered here. The seed is generally fully formed and has a high seed index (10.5 - 11.0 g) and high germination and vigor indices. The cultivar is stormproof and seedcotton is tightly retained in the slightly open bolls.

The fiber quality of 30 boll-samples picked from the middle third of random plants of each experimental plot was measured by HVI. This approach minimizes the variability within samples but may result in differences in the fiber quality across the whole field. The lint samples have good fiber properties (UHML = 30.4 mm, UI = 84.4%, SFI = 6.31%, fiber strength 31.4 g tex⁻¹. The micronaire is relatively high (4.79), but still below the threshold of 4.9, associated with a lower price per bale (Table 1).

Cultivar IMA 5801B2RF is resistant to root-knot nematode [*Meloidogyne incognita*], cotton blue disease [*Cotton leafroll dwarf virus-CLRDV*] and ramularia leaf spot [*Ramulariopsis pseudoglycines* (synonyms: *Ramularia areola* Atk)]. It is susceptible to ramulosis [*Colletotrichum gossypii* var. *cephalosporioides*], bacterial blight [*Xanthomonas citri* subs. *malvacearum*], target spot [*Corynespora cassiicola*], and reniform nematode [*Rotylenchulus reniformis*].

In all greenhouse and field tests, cv. IMA 5801B2RF proved resistant to all *Ramularia areola* Atk strains of Mato Grosso tested to date (2020). This is an advantage over the most frequently planted cv. TMG 44B2RF in the state, which is susceptible to infection by some strains of this pathogen. Cultivar IMA 5801B2RF has an extremely high nematode resistance; a reduction of over 90% in the gall index and nematode population were observed in comparison with susceptible genotypes, in greenhouse trials with artificial inoculation as well as under natural field infestation (Figure 1). This remarkable resistance can have huge impacts on the cotton agrosystem in the Cerrado region, with economic and environmental benefits for the farmers. This cultivar may even recover the suitability of areas with high nematode populations for cotton cultivation again.

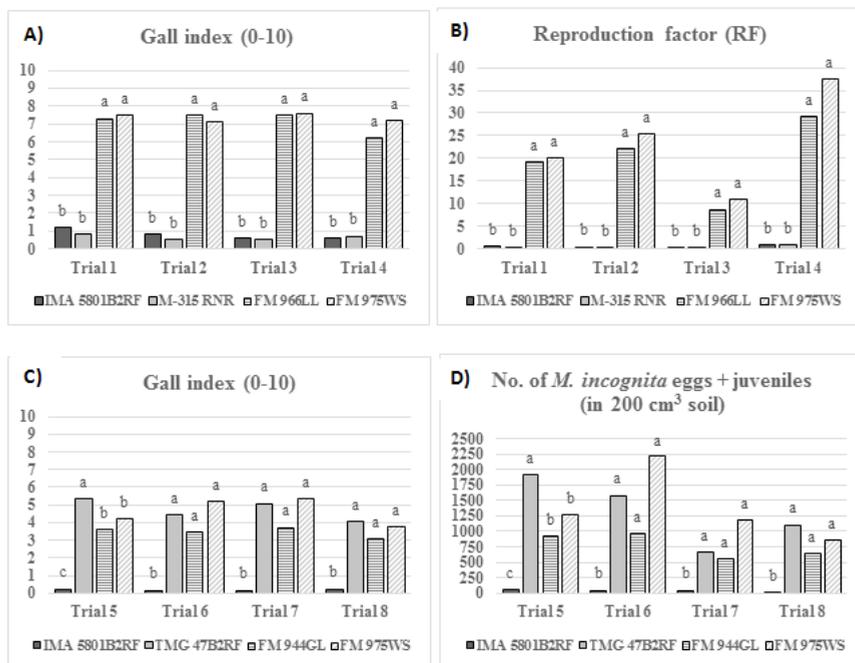


Figure 1. Response of different cotton varieties to *Meloidogyne incognita* race 3. **A** and **B**: greenhouse trials for: Gall index (0-10): 0 = no galling; 1 = 1-10% of root system galled; 2 = 11-20% galled, etc; 10 = 91-100% galled; RF: Pot with 2,500 cm³, *M. incognita* inoculum: 8.000 (eggs + juveniles J2)/pot. Soil and roots were processed 70 days after nematode inoculation. **C** and **D**: Field trials naturally infested with *M. incognita* at different locations in Mato Grosso. Soil samples to quantify nematode population levels were collected 100-120 days after planting. Nematodes were extracted from 200 cm³ soil by centrifugal flotation. Bars of the same trial followed by the same letter are not significantly different by the Scott-Knott test at 5% probability.

Table 2. Mean and coefficient of variation of cottonseed yield (CY, CV), lint percentage (LP), lint yield (LY) and percentage in comparison to the mean of the two controls (PCC) of cultivar IMA 5801B2RF, and the controls TMG 44B2RF and FM 954GLT. Growing seasons of 2017/2018 and 2018/2019

County/State	IMA 5801B2RF			TMG 44B2RF			FM 954GLT			PCC		
	CY (kg ha ⁻¹)	LP (%)	LY (kg ha ⁻¹)	CY (kg ha ⁻¹)	LP (%)	LY (kg ha ⁻¹)	CY (kg ha ⁻¹)	LP (%)	LY (kg ha ⁻¹)	CY	LY	CV
Primavera do Leste/MT (2017/18)	6128	39.5	2422	4788	42.1	2016	4996	42.9	2141	25.3	16.5	12.4
Campo Verde/MT ¹ (2017/18)	5853	38.6	2262	7128	38.6	2751	6590	38.9	2564	-14.7	-14.9	9.2
Campo Verde/MT ² (2017/18)	6178	38.1	2356	6747	42.4	2861	5931	41.2	2442	-2.5	-11.1	10.3
Sorriso/MT (2017/18)	6389	36.5	2332	7357	40.0	2944	6963	40.3	2804	-10.8	-18.9	13.1
Campo Novo Parecis/MT (2017/18)	6909	35.3	2442	6550	37.2	2433	5487	41.7	2289	14.8	3.4	10.0
Sapezal/MT (2017/18)	5468	35.4	1934	7989	38.7	3092	6686	39.5	2639	-25.5	-32.5	15.3
Mean 2017/2018	6154	37.3	2291	6760	39.8	2683	6109	40.7	2480	-4.4	-11.2	
Primavera do Leste/MT ¹ (2018/19)	6241	37.9	2366	4744	41.9	1988	5842	42.4	2478	17.9	5.9	13.1
Primavera do Leste/MT ² (2018/19)	5424	38.3	2075	4550	42.5	1935	3815	42.2	1611	29.7	17.0	13.4
Campo Verde/MT ¹ (2018/19)	5578	39.4	2198	6169	41.7	2571	4459	43.7	1949	5.0	-2.7	11.5
Campo Verde/MT ² (2018/19)	6859	40.1	2748	6060	42.2	2555	6196	43.4	2690	11.9	4.8	13.3
Sorriso/MT (2018/19)	5506	37.2	2048	5228	41.2	2152	5503	41.2	2267	2.6	-7.3	12.4
Campo Novo Parecis/MT (2018/19)	6628	38.9	2580	5838	41.4	2419	6128	42.8	2621	10.8	2.4	13.0
Sapezal/MT (2018/19)	7272	36.7	2665	6764	40.8	2760	7104	40.8	2898	4.9	-5.8	12.7
Mean 2018/2019	6215	38.3	2383	5622	41.7	2340	5578	42.4	2359	11.0	1.4	

¹ Trial with cotton as main crop; ² Trial with cotton as 2nd crop, after soybean

The yield of this new cultivar is not very different from that of cvs. TMG 44 B2RF and FM 954 GLT, the two best commercial varieties currently used in Mato Grosso. In the 13 field trials with four replications in areas without root-knot nematode incidence, cv IMA 5801B2RF had a 4.4% lower seedcotton yield in the 2017/2018 growing season and 11% higher in that of 2018/2019 (Table 2). This is a remarkable result for a cultivar with resistance to *M. incognita* and ramularia leaf spot. Even though the lint percentage of this variety is around 3% lower than that of the two standard varieties, it is between 37% and 39%, which is acceptable for producers. In fields with the presence of *M. incognita*, the fiber yield potential of cv. IMA 5801 B2RF was far higher than that of the other commercialized varieties.

SEED MAINTENANCE AND DISTRIBUTION

'IMA 5801B2RF' was protected as commercial cultivar by IMAmt at SNPC/ MAPA (CPC No. 20190185) under registration number RNC No. 38257 of RNC/MAPA. The genetic seed of this cultivar is maintained by IMAmt. The cooperative *Comdeagro* holds the license for seed production and commercialization of cv. IMA 5801B2RF in Brazil. More than 80.000 20-kg seed bags were made available for marketing for the 2019/2020 growing season. Seeds of cv. IMA 5801B2RF can be provided for research purposes upon written request to the corresponding author. The traits B2RF are patented technologies of Bayer/Monsanto, and permission must be legally required from Bayer/Monsanto for their use, be it for research or commercialization.

ACKNOWLEDGEMENTS

The authors thank Drs. Jenkins JN and Mc. Carthy JC (USDA, Mississippi) for guidance and advice for the use of parent M-315 RNR in the IMAmt breeding program for resistance to root-knot nematode. We also thank Dr. Giband of CIRAD for his help with the inclusion of marker CIR316 in the routine analyses of this study, and Dr. João Paulo S. Moraes of EMBRAPA for proofreading the final version of the manuscript.

REFERENCES

- Belot JL and Vilela PMCA (2019) *Compêndio de identificação: problemas agronômicos em algodoeiro e ferramentas de controle*. IMAmt, Cuiabá, 304p.
- Coolen WA and D'Herde CJ (1972) *A method for the quantitative extraction of nematodes from plant tissue*. State Agricultural Research Centre, Ghent, 77p.
- CTNBio - Comissão Técnica Nacional de Biossegurança (2020) *Aprovações comerciais. Parecer técnico nº 3365/2012*. Available at <<http://ctnbio.gov.br>>

- mctic.gov.br/liberacao-comercial#/liberacao-comercial/consultar-processo>. Accessed on January 6, 2020.
- Davis RF and Stetina SR (2016) Resistance and tolerance to nematodes in cotton. In Galbieri R and Belot JL (eds) **Nematoídes fitoparasitas do algodoeiro nos cerrados brasileiros: Biologia e medidas de controle**. Instituto Mato-Grossense do Algodão, Cuiabá, p. 166-242.
- Galbieri R, Fuzatto MG, Cia E, Lüders RR, Machado ACZ and Boldt AF (2009) Reação de cultivares de algodoeiro a *Meloidogyne incognita* em condições de campo e casa de vegetação no estado de Mato Grosso. **Tropical Plant Pathology** 34:018-023.
- Galbieri R, Vaz CMP, Silva JFV, Asmus GL, Crestana S, Matos ES and Magalhães CAS (2016) Influência dos parâmetros do solo na ocorrência de fitonematoides. In Galbieri R and Belot JL (eds) **Nematoídes fitoparasitas do algodoeiro nos cerrados brasileiros: Biologia e medidas de controle**. Instituto Mato-Grossense do Algodão, Cuiabá, p. 37-89.
- Gutiérrez, OA, Jenkins JN, McCarty JC, Wubben MJ, Hayes RW and Callahan FE (2010) SSR markers closely associated with genes for resistance to root-knot nematode on chromosomes 11 and 14 of Upland cotton. **Theoretical and Applied Genetics** 121: 1323-1337.
- He Y, Kumar P, Shen X, Davis RF, Van Becelaere G, May OL, Nichols RL and Chee PW (2014) Re-evaluation of the inheritance for root-knot nematode resistance in the Upland cotton germplasm line M-120 RNR revealed two epistatic QTLs conferring resistance. **Theoretical and Applied Genetics** 127: 1343-1351.
- ISAAA (2017) Global status of commercialized biotech/GM crops in 2017: Biotech crop adoption surges as economic benefits accumulate in 22 years. ISAAA, Ithaca, 153p. (ISAAA Brief, 53).
- Lopes CML, Suassuna ND, Cares JE, Gomes ACMM, Perina FJ, Nascimento GF, Mendonça JSF, Moita AW and Carneiro RMDG (2020) Marker-assisted selection in *Gossypium* spp. for *Meloidogyne incognita* resistance and histopathological characterization of a near immune line. **Euphytica** 216: 19.
- Morello CL, Suassuna ND, Pedrosa MB, Barroso PAV, Silva JL, Suassuna TMF, Perina FJ, Sofiatti V, Magalhães FOC and Lamas FM (2020) Cultivar BRS 433FL B2RF: upland cotton with high-quality fiber, insect resistance and glyphosate tolerance for the Brazilian Savanna. **Crop Breeding and Applied Biotechnology** 20: e29262039.
- OECD/FAO - Food and Agriculture Organization of the United Nations (2019) OECD-FAO Agricultural Outlook 2019-2028. In OECD Publishing, Paris, p. 217-226. Available at <https://doi.org/10.1787/agr_outlook-2019-en>. Accessed on February 5, 2020.
- Perina FJ, Fabris A, Pontel DPS, Santos IA, Brandão ZN, Araújo AC, Breda CE and Brugnera P (2018) Levantamento e manejo de fitonematoides em algodoeiro no Oeste da Bahia safra 2016/17 e 2017/18. Fundação BA, Luís Eduardo Magalhães, 14p. (Circular Técnica, 05).
- Santos LOF, Machado NG, Querino CAS, Pedreira Junior AL, Ivo IO, Lotufo Neto N and Biudes MS (2020) Hourly precipitation patterns in a Brazilian tropical city. **Revista Brasileira de Climatologia** 26: 411-424.
- Shen X, He Y, Lubbers EL, Davis RF, Nichols RL and Chee PW (2010) Fine mapping QMi-C11 a major QTL controlling root-knot nematodes resistance in Upland cotton. **Theoretical and Applied Genetics** 121: 1623-1631.
- Shen X, Van Becelaere G, Kumar P, Davis RF, May OL and Chee PW (2006) QTL mapping for resistance to root-knot nematodes in the M-120 RNR Upland cotton line (*Gossypium hirsutum* L.) of the Auburn 623 RNR source. **Theoretical and Applied Genetics** 113: 1539-1549.
- Shepherd RL (1982) Registration of 3 germplasm lines of cotton (Reg. Nos. GP 164 to GP 166). **Crop Science** 22: 692.
- Silva MB, Davis RF, Kumar P, Nichols RL and Chee PW (2018) Resistance quantitative trait loci *qMi-C11* and *qMi-C14* in cotton have different effects on the development of *Meloidogyne incognita*, the southern root-knot nematode. **Plant Disease** 103: 853-858.
- Silva RA, Rack VM, Vigolo F, Santos PS, Castro RD and Kobayashi L (2014) Correlação entre densidade populacional de nematoides e produtividade de algodoeiro. **Bioscience Journal** 3: 210-218.
- Suassuna ND, Morello CL, Pedrosa MB, Barroso PAV, Silva JL, Suassuna TMF, Perina FJ, Sofiatti V, Magalhães FOC and Farias FJC (2018) BRS 430 B2RF and BRS 432 B2RF: Insect-resistant and glyphosate-tolerant high-yielding cotton cultivars. **Crop Breeding and Applied Biotechnology** 18: 221-225.

