Chapter 71

Application of instrumentation in cotton cultivation: systematic literature review

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ABSTRACT
In order to analyze the publications on the use of instrumentation in agriculture, the objective of this paper is to present a set of works published between 2017 and 2021 on the subject so that an analysis of the technologies developed during this period can be carried out. For this, a search was carried out in the IEEE, Science Direct and Scopus databases, where 1490 published articles were found using a search string to select papers considering theme, year of publication. In view of this result, the Start software was used to apply selection criteria to choose the articles to be used in the review. After performing all the steps of selection of works in the software, the result was 33 papers carrying out the Systematic Review. Of the 33 articles, the work methods and the result obtained by the author are presented, thus enabling an analysis of the technologies researched during the study period.

Keywords: Agriculture, Precision Agriculture, Agricultural Instrumentation, Agricultural machinery.

1 INTRODUCTION

The domestication of cotton occurred many years ago. Some ancient writings suggest that more than 4,000 years ago in southern Arabia, there were already some historical references to its use in the Manu Code (17th century). VII BC), considered the oldest legislation in India. In America, the Incas and other civilizations have used cotton since 4,500 BC, the indigenous peoples already knew cotton and dominated its planting even before the discovery of Brazil by Europeans. Since that time, they were able to harvest, either, weave and dye fabrics made with their fibers, being used in the making of nets, and blankets, in addition to the use of the plant in the plantation, and the use of its leaves for wound healing (AMPA).

Currently, Brazil is the fourth largest producer of cotton in the world, and despite the pandemic, Brazilian plume production reached a record 3 million tons in the 2019/2020 harvest (Coelho, 2021). Despite the lack of rainfall and frost between the first and second half of 2021, suffering some crop losses, the state of Bahia still performed well in cotton production (Podestà, 2021). The estimates for the 2021/2022 crop are an expected increase of 10.2 % in the planted area of the crop, totaling 1.51 million hectares cultivated, with the production of the plume tending to have 2.67 million tons (CONAB, 2021).

Currently, the world's largest producers are India, China, the United States, Brazil and Pakistan, with a representative ness of about 74% of the total fiber produced on the planet (Coêlho, 2021). The largest national producers are the states of Mato Grosso, Bahia, Minas Gerais, Goiás and Mato Grosso do Sul, with Mato Grosso maintaining its position in first place since 2020 (Coêlho, 2021; IBGE, 2021). In the foreign market, Brazil is the world's second largest exporter of fiber, maintaining high inventories since the 2018/2019 crop (USDA, 2021).

In the national territory, the diseases most observed in cotton crops are usually caused by fungi, nematodes, bacteria or viruses that develop and multiply in the tissues of plants causing a decrease in their productivity and may lead to the death of the plant. As for example the Fusarium Wilt caused by the fungus Fusarium oxysporum f. sp. Vasinfectum, which can affect the umd in all stages of the crop, causing necrosis, yellowing on the leaf surface, and even causing the death of the plant (Suassuna, Silva and Bettiol, 2019).

In the studies recovered by the research, it was observed the use of several technologies used in cotton production, as observed in Gaikwad (et al, 2021), which used Internet of Things (IoT) technology to monitor culture data. In addition to the use of sensors as in the works of Thompson (et al, 2019) with the use of culture sensing and Pelletier, Wanjura and Holt (2019) with the implementation of an electronic system for calibration of cotton production. The use of instrumentation, automation and IoT has been increasing in recent years, especially in the treatment of farming and specialization of machines, in order to optimize processes and provide higher quality and productivity in the field.

Given the great importance of culture in the national and world economy and the constant need for technological development in agriculture, the present work proposed the preparation of a Systematic Bibliographic Review (RBS) in scientific articles published since 2017, in order to understand the uses of technologies in cotton production. To this end, a search was performed in databases such as IEEE, Scielo, Science Direct, Scopus and Web of Science, with the aid of a free software for StArt bibliographic management. In addition, the work is aligned with the Sustainable Development Goals (SDGs), more specifically the SDGs of numbers 4 that concerns the promotion of Quality Education, since in this RBS will have access to various works, serving as a basis for the development of future research. In addition, it is also related to The SDS number 9 – Industry, Innovation and Infrastructure, thus having strong justifications for being carried out.

2 METHODOLOGY

To perform the work, it was divided into seven major main stages, each of which was subdivided into tasks. The steps were: a) Determination of the research question; b) Definition of the search strategy through the created string; c) Search the selected databases; d) Selection of studies recovered in the research; (e) data extraction; f) Synthesis of the selected studies and g) Elaboration of the text. Each of these steps is detailed below.

2.1 QUESTION DAND SEARCH

For preparation of the research question, based on the PICOS anagram, where P would be the population; I intervention (or exposure in case of clinical or experimental studies); C for comparison; The for outcome (output), and S for study types. Table 1 illustrates the components of the research question that was elaborated as the general objective of the study.

Table 1 - Components of the research question according to the PICOS anagram.

Description	Abbreviation	Question components
Population	P	Scientific productions on instrumentation used in cotton culture
Intervention	I	Reading and Separation of use of sensors in cotton crop.
Comparison	C	Articles with effective use of instrumentation in cotton culture.
The outcome	Or	Sensors being used in cotton culture.
Type of study	S	Scientific Articles.

Source: Authors (2022)

The question elaborated as the basis for the research was "How is instrumentation being the plied in cotton crop?" Based on the research question, the search string used as a search strategy in the databases was cotton AND instrumentation.

2.2 STRATEGY DAND SEARCH

The databases obtained through the CAPES Periodic Portal were searched. The selected areas of knowledge were, agrarian, exact and land sciences, for this we used the VPN connection (Virtual Private Network) provided by UNESP. Thus, it was possible to analyze the search string established in the previous stage to obtain complete texts, enabling the selection of databases to perform the searches.

2.3 SEARCH FOR LITERATURE

The bases used for the search were those that are arranged in Chart 2. In each of these bases, the same string was used on the same date, and the results obtained were inserted from spreadsheets. Data from papers were collected since 2017, and these original articles, in English or Portuguese, were collected and the information retrieved from these works, such as title, abstract and keywords were extracted in RIS (Research Information Systems) and BibTEX (and then downloaded) format. Which are extension formats accepted by the program that was used.

Table 2 - Databases used for searches

Source	Address	Kind
IEEE Xplore	https://ieeexplore-ieee-org.ez87.periodicos.capes.gov.br/Xplore/guesthome.jsp	Full Texts
Scopus	https://www-sciencedirect.ez87.periodicos.capes.gov.br/	Full Texts
Web of Science	https://www.webofknowledge.com/?authCode=null&app=wos&locale=pt-BR	Full Texts
Science Direct	https://www.sciencedirect.com/	Full Texts

Source: Authors (2022)

2.4 SELECTION OF STUDIES

The selection stage of the studies was performed through the Software StArt Tool (State of the Art Through Systematic Review) where the research protocol was created containing the definition of the different inclusion, exclusion and keywords criteria to start the data extraction process. Also in the protocol were defined the criteria for evaluating the quality of the selected articles, as well as the objectives of the research. Each stage of the selection of studies will be detailed in the next topics based on the eligibility criteria set out in the protocol defined by the authors based on the research question.

2.5 CRITERIAD AND ELIGIBILITY

The eligibility criteria were established and attached to the research protocol even before the production process of the systematic review in order to understand the ways of applying the sensors in cotton crops. The inclusion criteria (IC) and exclusion criteria (EC) are set out in Tables 3 and Table 4 we have the fields of extraction criteria that assist in the elaboration of quality criteria.

Table 3 - Inclusion and exclusion criteria used in research

Criterion	Description of the Inclusion or Exclusion Criteria
CI1	Studies using sensors in cotton culture were included.
CI2	Published and fully available papers in the scientific databases sought were included.
CI3	Works that are written in English and/or Portuguese.
CI4	Works containing complete abstract were included.
Ce1	Studies that do not make use of sensors in cotton crops were excluded.
CE2	Studies that do not have application in cotton production were excluded.
Ce3	Papers that do not present abstract/abstract were excluded.

Source: Authors (2022)

Table 4 - Fields of extraction criteria

Field	Kind	Content
Used sensors to increase cotton production	Pick on list	{Yes, No}
Addresses use of sensors	Pick on list	{Significant, Constructivist, Both}
Cotton production	Pick on Many	[before the gate, inside gate, outside the gate]
Electronic system	Pick on Many	[sensor types, types of applications, evaluation methods, use of multiple sensors or one, sensor set, calibration]
Methodology	Text	
Used some efficiency assessment metric	Pick on list	{Yes, No}
Data were collected	Pick on list	{Yes, No}
There was data analysis	Pick on list	{Yes, No}

Source: Authors (2022)

2.6 EXECUTION STEP

To perform this step in the StArt program, the execution is divided into three stages, being the analysis of keywords, insertion of the articles retrieved in each of the databases in RIS format, as well as their selection of the works according to the eligibility criteria, and the extraction of the papers for full reading.

The first step within the program is the completion of the search protocol, after this first step, the databases used for the search are added within the program, being assigned the names of SEARCH0, SEARCH1, SEARCH2 and SEARCH3, respectively according to Chart 2.

In each of these databases, the downloaded data were inserted in RIS format, so the software analyzes the works and based on titles, abstracts and keywords, the program lists the keywords used by all the works. However, still during the protocol completion step, the keywords that are related to the search question are inserted, as well as their respective synonyms, all in English. Table 5 shows the keywords used within the search protocol.

Table 5 - Terms used for search (keywords)

Terms	Synonyms	Translation
Cotton Field	*Cotton Production*	Cotton fields
Cotton culture	*Cotton Plant*	Cotton culture
Instrumentation	*Industry 4.0*	Instrumentation
Sensor	*Sensoring*	Sensor
Arduino	*Microcontroller*	Arduino

Source: Authors (2022)

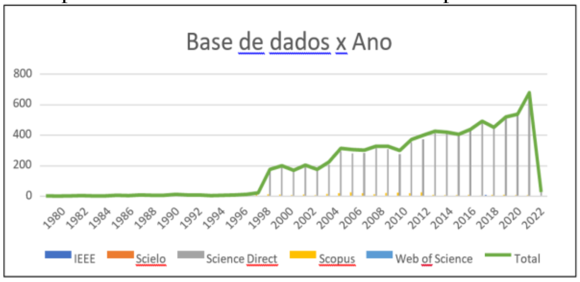
With the data already entered in the program, it generates points for jobs that have the same keywords added within the protocol, according to the number of times they appear. This score generated helps when selecting the papers that are related to the research theme. Therefore, there was a need to insert 63 new terms after an analysis in all the words of the work recovered and inserted in the program, with this, new scores could be generated. The analyses were carried out in a total of 1,914 studies in the program.

After this change and the generation of new scores, the "SCAS - Auto Classify Papers" method was also used, which generates a type of score based on the number of citations of the works, subdividing them into quadrants. The extraction slap of the studies was performed in a paired and independent way in order to avoid selection bias. From the total, 37 studies were extracted, of which 30 were selected for full reading based on quality criteria.

3 RESULTS AND DISCUSSIONS

The research in the databases managed to recover a total of 8,369 titles, of which 2,713 were works from 2017, and within these, only 1,914 were original works inserted in the StArt software. Graph 1 illustrates the work retrieved from the databases from 1980 to 2022.

Figure 1 - Papers recovers from databases in the period 1980 to 2022



Source: Authors (2022)

Table 6 is related in order to the proposals and applications of all the works selected for the systematic review.

Table 6 - Documents reviewed in full for review

No.	Author(s)	Title	Local	Proposal	Application
1	Thorp, K. R. et al. (2017)	**Cotton Irrigation Scheduling Using a Crop Growth Model and FAO- 56 Methods: Field and Simulation Studies**	USA	Use of Cultivation System Model (CSM-CROPGRO- Cotton) compared to FAO-56 methods for irrigation management in cotton crop, making it possible to estimate crop growth and production effects for decision making.	Irrigation
2	Baio, F. H. R. et al. (2017)	**Financial Analysis of the investment in Precision Agriculture Techniques on Cotton Crop**	Brazil	Use of precision agriculture techniques to reduce production costs in cotton cultivation compared to conventional agriculture.	Cotton Crop Productivity
3	Martin, D. E. et al. (2017)	**Remote Sensing Evaluation of Two- spotted Spider Mite Damage on Greenhouse Cotton**	USA	Use of multispectral sensor to identify damage to cotton grown in an artificially infested greenhouse with different population densities of spider mites. It is a remote sensing technique that allows evaluating possible treatments with insecticides.	Evaluation of insecticide treatments in cotton
4	Souza, H. B. et al. (2017)	**Using Passive and Active Multispectral Sensors on The Correlation With The Phenological Indices of Cotton**	Brazil	Use of multispectral sensors to identify phenological parameters indicators of growth of the umdotree using NDVI (Normalized Difference Vegetation Index).	Growth of The Odoeiro
5	Martin, D. E. et al. (2018)	**Active Optical Sensor Assessment of Spider Mite Damage on Greenhouse Beans and Cotton**	USA	Evaluation of the application of remote sensing using active optical sensor to identify damage caused by spider mite in cotton and bean cups using as indication the NDVI (vegetation index by normalized difference).	Identification of damage by spider mite in cotton
6	Rozenstein, O. et al. (2018)	***Estimating Cotton Water Consumption Using a Time Series of Sentinel-2 Imaginary***	Israel	Estimation of the water consumption of cotton crop using time series of sentinel-2 satellite images in obtaining vegetation indices for spectral modeling of the crop crop coefficient (Kc) which is an important parameter for irrigation management enabling decision making.	Estimate Cotton Crop Water Consumption
7	Trevisan, R. G. et al. (2018)	***Management of Plant Growth Regulators in Cotton Using Active Crop Canopy Sensors***	Brazil	Application of Plant Growth Regulators (PGR) using optical and ultrasonic sensors to detect spatial variability of the crop in cotton crops in order to predict the harvest height and biomass accumulation in cotton.	Height of cotton feet
8	Cao, L. et al. (2018)	***Potential Dermal and Inhalation Exposure to Imidacloprid and Risk Assessment Among Applicators During Treatment in Cotton Field in China***	China	Quantification of the potential for skin exposure and inhalation of operators responsible for the application of pesticides in cotton crop.	Job safety
9	Baio, F. H. R. et al. (2018)	***Relationship Between Cotton Productivity and Variability of NDVI Obtained By Landsat***	Brazil	Use of multispectral satellite images to correlate ndvi yield and variability in cotton fields	Remote Sensing and Harvest Yield
10	Uddin, J. et al. (2018)	***Smart Automated Furrow Irrigation of Cotton***	Australia	Development of a prototype of intelligent commercial automation for groove irrigation. The prototype was tested and evaluated at a cotton farm in Australia.	Irrigation

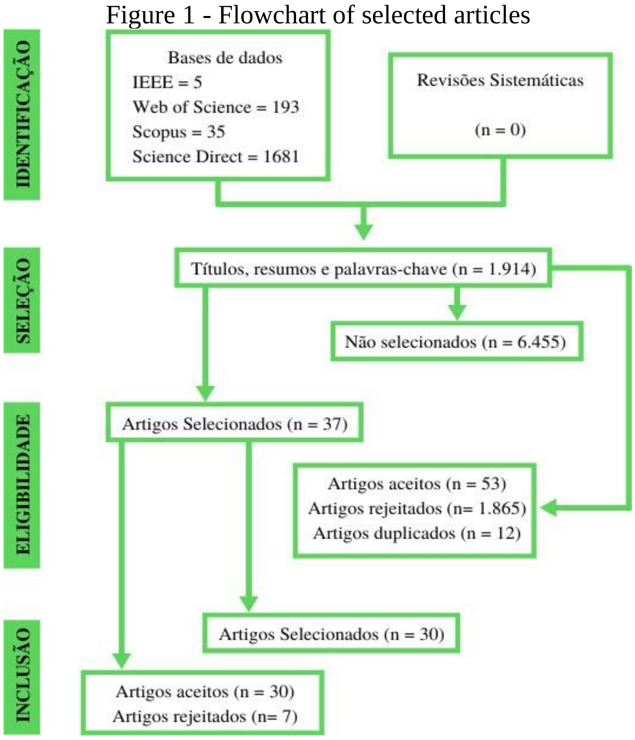
11	Papadopoulos, A. V. et al (2018)	***Weed Mapping in Cotton Using Ground-Based Sensors and GIS***	Greece	Use of two management systems in GIS environment for spectral detection for mapping weed spots grown in cotton fields.	Weeds
12	Thompson, A.L. et al. (2019)	***Comparing Nadir and Multi-Angle View Sensor Technologies for Measuring in-field Plant Height of Upland Cotton***	USA	Deployment of four Nadir ultrasonic vision transducers, two light detection and range (LiDAR) systems and an unmanned aerial system with color digital camera to characterize the height of cotton plants.	Height of cotton feet
13	Pelletier, M. G. et al. (2019)	***Electronic Design of a Cotton Harvester Yield Monitor Calibration System***	USA	Implementation of an electronic project for calibration of the cotton harvester yield monitor.	Harvest yield
14	Pelletier, M. G. et al. (2019)	***Embedded Micro- Controller Software Design of a Cotton Harvester Yield Monitor Calibration System***	USA	Implementation of a microcontroller software design incorporated into a cotton harvester yield monitor calibration system. The microcontroller software design has been tested in combination with electronic design.	Harvest yield
15	Baio, F. H. R. et al. (2019)	***In Situ Remote Sensing As a Strategy to Predict Cotton Seed Yield***	Brazil	Use of remote sensing to predict the yield of cotton seeds.	Remote Sensing and Harvest Yield
16	Thorp, K. R. et al. (2019)	***Novel methodology to evaluate and compare evapotranspiration algorithms in an agroecosystem model***	USA	Model based on algorithms for evaluation of evapotranspiration in cotton cultivation.	Evapotranspiratio n
17	Pelletier, M. G., Wanjura, J. D., & Holt, G. A. (2019)	***Man-Machine-Interface Software Design of a Cotton Harvester Yield Monitor Calibration System***	USA	Development of a softwarand with human machine interface for the control and evaluation of cotton harvesting conditions.	Harvest yield
18	Rozenstein, O. et al. (2019)	***Validation of the cotton crop coefficient estimation model based on Sentinel-2 imagery and eddy covariance measurements***	Israel	Estimation of harvest coefficient using satellite images of public domain with remote sensing.	Remote Sensing and Harvest Yield
19	Yu, J. et al. (2019)	***Nitrogen Consumption and Productivity of Cotton under Sensor- based Variable-rate Nitrogen Fertilization***	China	Determination of nitrogen consumption rate and cotton yield using optical sensor in a uniform application system fertilization with nitrogen.	Nitrogen consumption
20	Yan, L. et al. (2020)	***Cotton Appearance Grade Classification Based on Machine Learning***	China	Application of Machine Learning to measure the degree of appearance of cotton in order to improve the classification step of cotton that is done manually.	Cotton classification
21	Butler, S. et al. (2020)	***Making the Cotton Replant Decision: A Novel and Simplistic Method to Estimate Cotton Plant Population from UAS-calculated NDVI***	USA	Use of unmanned aerial systems to estimate cotton production to help replanting.	Harvest yield
22	Feng, A. et al. (2020)	***Yield estimation in cotton using UAV-based multi-sensor imagery***	USA and China	Creation of a remote sensing system with an unmanned aerial vehicle in order to measure the yield of cotton production. The use of the system was performed in two moments: in the growth phase and just before harvest.	Remote Sensing and Harvest Yield
23	Chen, X. et al. (2020)	***Evaluation of a new irrigation decision support system in improving cotton yield and water productivity in an arid climate***	USA and China	Creation of a decision support system for irrigation programming, in order to improve cotton productivity in arid climates.	Irrigation
24	Larson, J.A. et al. (2020)	***Effects of Landscape, Solids, and Weather on Yields, Nitrogen Use, and***	USA	Use of optical sensing to evaluate the effects on the soil and climate field landscape, using some variables such as nitrogen rates in cotton and net return yield of production.	Harvest yield

		Profitability with Sensor-Based Variable Rate Nitrogen Management in Cotton			
25	Fue, K. et al. (2020)	***Autonomous Navigation of a Center-Articulated and Hydrostatic Transmission Rover Using a Modified Pure Pursuit Algorithm in a Cotton Field***	USA	Development of software based on Robot Operating System (ROS) in order to control the sensor that will acquire the field information. The study proposed the use of an algorithm capable of controlling an autonomous and multifunctional system to navigate along cotton cultivation lines.	Autonomous Vehicle
26	Zare, E. et al. (2020)	***Two-dimensional time-lapse imaging of soil wetting and drying cycle using EM38 data across a flood irrigation cotton filed***	Australia	Use of a sensor system using mathematical devices to maximize the use and efficiency of water in irrigated cotton agriculture.	Irrigation
27	Delhom, C. D. et al, (2020)	***Engineering and Ginning: The Classification of Cotton***	USA	Use of automated instrumentation in the classification and grating of cotton.	Cotton classification
28	Gaikwad, S.V. et al. (2021)	***An innovative IoT based system for precision farming***	India	Development of an Internet of Things-based system in order to monitor cotton production data in real time, using three components: Arduino, Smartphone Application and a Web server.	Harvest yield
29	Bronson, K. F. et al. (2021)	***Use of an ultrasonic sensor for plant height estimation in irrigated cotton***	USA	Use of ultrasonic sensor for estimation of the height of cotton plants, with the objective of comparing traditional measurement techniques with the use of these sensors.	Height of cotton feet
30	Ibragimov, N. et al, (2021)	***Cotton irrigation scheduling improvements using wetting front detectors in Uzbekistan***	Uzbekistan, UNITED STATES	Use of damping front detector to promote improvements in irrigation regime in cotton planting.	Irrigation

Source: Authors (2022)

Figure 1 shows the flowchart that summarizes the entire process of execution, selection, and extraction of the work recovered by the research.

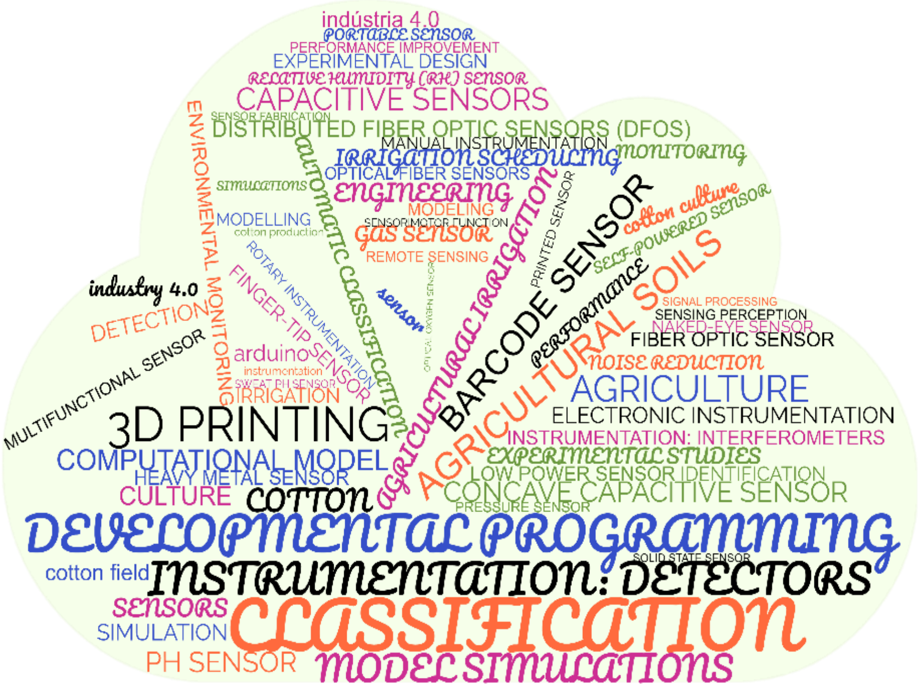
Figure 1 - Flowchart of selected articles



Source: Authors (2022).

And in Figure 2, the word cloud with the keywords used in the selection of works, highlighting some of them, such as Program Development, Classification, Agriculture and Instrumentation.

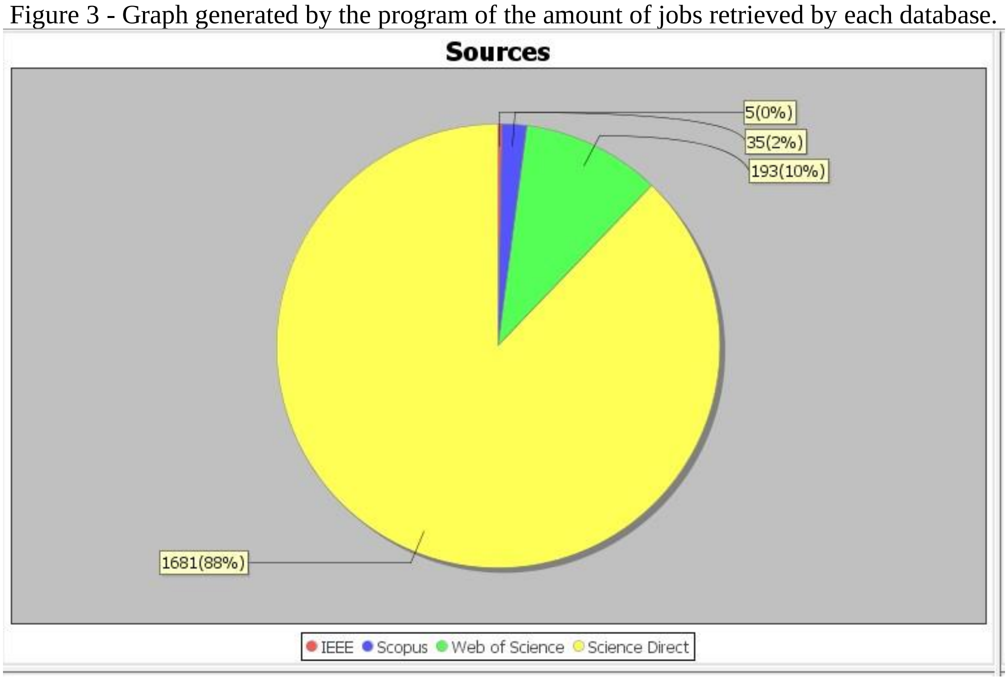
Figure 2 - Word cloud of selected articles



Source: Authors (2022).

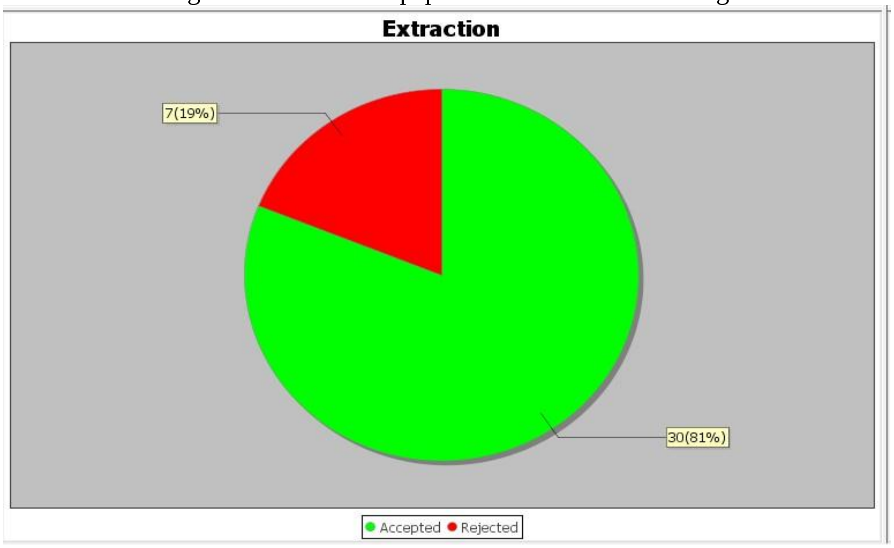
Figure 3 illustrates the graphs of the selected papers and their respective databases. These charts were plotted within the program.

Figure 3 - Graph generated by the program of the amount of jobs retrieved by each database.



Source: Authors (2022).

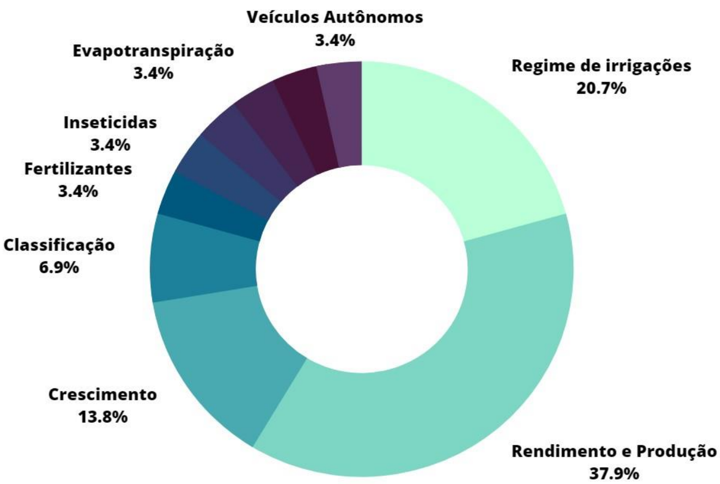
Figure 4 - Number of papers selected for full reading



Source: Authors (2022).

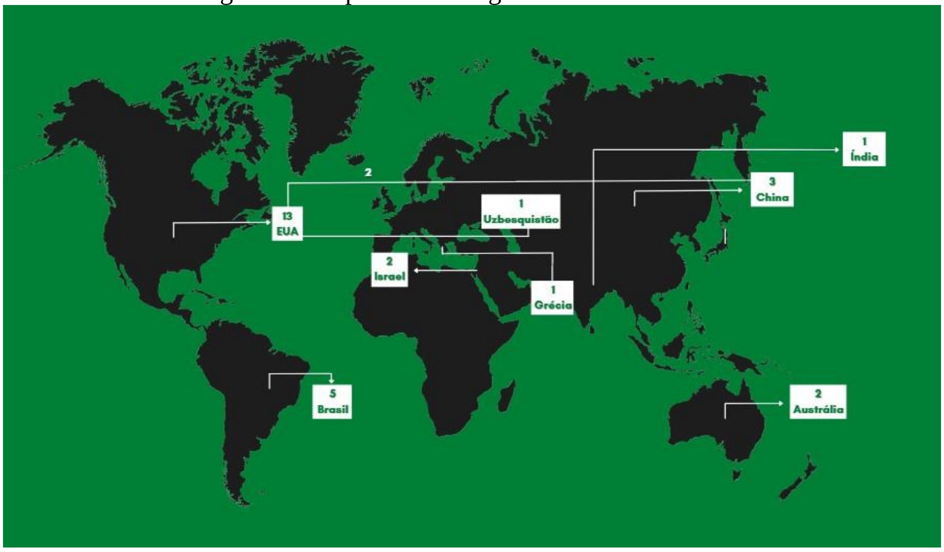
According to the initial objective of the work in relation to the understanding of the application of instrumentation in cotton cultivation, the studies recovered by the research presented several applications, drawing attention to some important points. About 20% of the studies report on the irrigation regime and water consumption in the plantations, 36.67% deal with the estimated yield and productivity of the harvest, 13.3% deal with the determination of the size of the cotton foot, that is, characteristics related to plant growth morphology, and 6.67% deal with improvements in the classification of cotton for the industry. While the other subjects revolve around 3% of each, related to fertilizer use, insecticide treatments, work safety, plant evapotranspiration, nitrogen consumption, and use of autonomous vehicles. In Figure 5, the graph summarizes all the applications found in the recovered studies, and in Figure 6, an illustrative map that presents the origin of these studies, illustrating a strong prevalence for studies carried out in the United States of America, Brazil and China.

Figure 5 - Applications of the found works



Source: Authors (2022).

Figure 6 - Map with the origin of the studies found.



Source: Authors (2022)

4 FINAL CONSIDERATIONS

Although the review was limited to some parameters of choice, it was still possible to identify great potential for the application of instrumentation in cotton cultivation. Serving as a basis for the application of technologies in the areas with greater lag of these application in future work. In addition, it was possible to notice evidence of some gaps in knowledge regarding some problems found, with most of the studies focused on production yield. Another notable point was the lack of work at the national level with proposals for the use of little debated topics. For the application of future work, it would be interesting to carry out work that is focused on solving these problems and a better methodological design, in order to present better refined results.

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