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BIOTECHNOLOGICAL PROSPECTING FOR SCIENTIFIC ADVANCEMENTS: REGISTER, PROTECTION, AND INNOVATION SUGARCANE CULTIVARS

PROSPEÇÃO BIOTECNOLÓGICA PARA AVANÇOS CIENTÍFICOS: REGISTRO, PROTEÇÃO E INOVAÇÃO DE CULTIVARES DE CANA-DE-AÇÚCAR

PROSPECTIVA BIOTECNOLÓGICA DE AVANCES CIENTÍFICOS: REGISTRO, PROTECCIÓN E INNOVACIÓN DE CULTIVARES DE CAÑA DE AZÚCAR

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ABSTRACT

Biotechnology has become a prominent field in sugarcane research and the sugarcane industry, with a focus on registering, protecting, and innovating sugarcane cultivars. This article provides an overview of the registration and protection processes for sugarcane cultivars, as well as the biotechnological advancements in this area. The study conducted a systematic review of articles published between 2017 and 2022. The research also analyzed the registration of cultivars in the National Registry of Cultivars. Additionally, a search for patents related to sugarcane varieties was performed. The results highlight the importance of genetic improvement and selection of sugarcane varieties, understanding the physiology and biochemistry of sugarcane, and the role of intellectual property rights in protecting and promoting innovation in the sugarcane industry. The analysis of registered cultivars and patents provides insights into the most sought-after traits and technological domains in sugarcane research. This study contributes to the advancement of scientific knowledge and the development of sustainable and productive sugarcane cultivars.

KEYWORDS: Biotechnology. Innovation. Patents.

RESUMO

A biotecnologia tornou-se um campo de destaque na pesquisa canavieira e na indústria canavieira, com foco no registro, proteção e inovação de cultivares de cana-de-açúcar. Este artigo traz um panorama dos processos de registro e proteção de cultivares de cana-de-açúcar, bem como os avanços biotecnológicos nessa área. O estudo realizou uma revisão sistemática de artigos publicados entre 2017 e 2022. A pesquisa também analisou o registro de cultivares no Cadastro Nacional de Cultivares. Adicionalmente, foi realizada uma busca por patentes relacionadas a variedades de cana-de-açúcar. Os resultados destacam a importância do melhoramento genético e da seleção de variedades de cana-de-açúcar, da compreensão da fisiologia e da bioquímica da cana-de-açúcar e do papel dos direitos de propriedade intelectual na proteção e promoção da inovação na indústria canavieira. A análise de cultivares registradas e patentes fornece *insights* sobre as características e domínios tecnológicos mais procurados na pesquisa canavieira. Este estudo contribui para o avanço do conhecimento científico e para o desenvolvimento de cultivares de cana-de-açúcar sustentáveis e produtivas.

PALAVRAS-CHAVE: Biotecnologia. Inovação. Patentes.

RESUMEN

La biotecnología se ha convertido en un campo destacado en la investigación de la caña de azúcar y en la industria de la caña de azúcar, con enfoque en el registro, protección e innovación de cultivares de caña de azúcar. Este artículo presenta una visión general de los procesos de registro y protección de cultivares de caña de azúcar, así como de los avances biotecnológicos en esta área. El estudio realizó una revisión sistemática de artículos publicados entre 2017 y 2022. La investigación también analizó el registro de cultivares en el Registro Nacional de Cultivares. Además, se realizó una

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búsqueda de patentes relacionadas con variedades de caña de azúcar. Los resultados resaltan la importancia del mejoramiento genético y la selección de variedades de caña de azúcar, la comprensión de la fisiología y bioquímica de la caña de azúcar y el papel de los derechos de propiedad intelectual en la protección y promoción de la innovación en la industria de la caña de azúcar. El análisis de cultivares registrados y patentes proporciona información sobre las características y dominios tecnológicos más buscados en la investigación de la caña de azúcar. Este estudio contribuye al avance del conocimiento científico y al desarrollo de cultivares de caña de azúcar sostenibles y productivos.

PALABRAS CLAVE: Biotecnología. Innovación. Patentes.

1. INTRODUCTION

Biotechnology applied to sugarcane has been an area of great interest in agricultural research and the sugarcane industry. Issues related to the registration, protection, and biotechnological inventions of sugarcane cultivars stand out in this context.

The registration of sugarcane cultivars is essential for the protection of plant varieties that have distinct characteristics, such as higher productivity, resistance to diseases and pests, or superior quality. Brazilian legislation requires the registration of cultivars in the National Registry of Cultivars (RNC) of the Ministry of Agriculture, Livestock, and Supply (Ministry of Agriculture Ordinance No. 502 of October 19, 2022, 2022).

The protection of sugarcane cultivars can be done through intellectual property rights, such as patents, breeders' rights, and plant variety protection certificates (PVPs). The PVP is a specific form of protection for plant varieties, which grants its holder the exclusive right to exploit the protected variety commercially (Costa *et al.*, 2010). Developing new cultivars can be protected through patents or protection under plant breeders' rights. In both cases, there is a need for registration, identification, and proof of novelty and added value (Miranda *et al.*, 2010).

Biotechnology has been widely used in the genetic improvement of sugarcane, whether to increase productivity, resistance to diseases and pests, or to improve the quality of raw material for sugar and ethanol production. Some of the most relevant biotechnological inventions for sugarcane include transgenesis, mutagenesis, and genome editing.

Scientific and technological prospecting consists of identifying trends and opportunities in a particular research area (Ribeiro, 2020). In the field of biotechnology applied to sugarcane, some of the trends and opportunities include the identification of genes responsible for environmental stress tolerance, the development of varieties more resistant to diseases and pests, the optimization of the fermentation process for ethanol production, and the use of ethanol production waste for energy generation (Souza *et al.*, 2020).

Thus, this work aims to search for the intellectual property of sugarcane varieties to identify registered and protected cultivars, parameters, and existing technologies related to registered cultivars.



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2. MATERIALS AND METHODS

A systematic review was conducted to prospect data related to the scientific production of sugarcane. Articles published between 2017 and 2022 were searched in the scientific databases Scopus (<http://www.scopus.com>) and Web of Science (<http://www.webofknowledge.com>) in February 2022 using the following terms and Boolean operators: "(variety AND *Saccharum*)" prospecting in title or abstract of scientific articles. The metadata of the scientific publications obtained in the two databases was imported in BibTex format, duplicate files were removed, combined into a single dataset, and analyzed using R software version 4.0.2 (R core Team, 2020).

Next, prospecting was carried out in the database of the Ministry of Agriculture, Livestock, and Food Supply (MAPA) in the National System for Protection of Plant Varieties (SNPC) and National Registry of Cultivars (RNC), and the data obtained were recorded in a spreadsheet. The protected and registered sugarcane cultivars retrieved were analyzed. The search for protected sugarcane cultivars in the SNPC and registered in the RNC was exclusively performed using the MAPA's query database: the SNPC CULTIVAR WEB (<https://sistemas.agricultura.gov.br/snpc/cultivarweb/index.php>), limiting the study to protected cultivars in the Brazilian territory.

In the third stage, a search for patents related to sugarcane varieties was conducted using the Lens (LENS.ORG, 2022). The search protocol was based on the following keywords and descriptors: (variety AND *Saccharum*). The methodology employed in this study was based on information collection from the titles and abstracts of patent documents, without spatial delimitation.

The analysis of patent documents was carried out in an exploratory and quantitative manner based on information such as year of filing, Cooperative Patent Classification (CPC), and main inventors. It is worth noting that only valid patents were considered. For the compilation and analysis of patents, the data were exported in CSV format.

The Cooperative Patent Classification (CPC) was used for patent classification, and the verification of patent codes was performed using the Classification Explorer, which is a patent database that allows for exploration of the code description based on trees.

3. RESULTS AND DISCUSSION

A total of 266 articles were identified and reviewed. After refinement, which involved excluding duplicate works and articles outside the research topic, 120 studies were found and thoroughly read. An average citation per document of 5.7 was observed, with a total of 23,375 references and 2,324 authors listed. The percentage of international co-authorships was 13.1%.

The use of bibliometric techniques is commonly employed in research in applied social sciences, allowing for the mapping and analysis of information within a specific field of knowledge. Additionally, these techniques enable the evaluation of productivity and quality of scientific research, as well as the identification of gaps to be explored in future studies (Pinheiro; Almeida, 2020). The first



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part of this study is to analyze the main relevant journals and their H-index regarding the subject under investigation.

The most relevant journals identified were Sugar Tech, Journal of Plant Registrations, Australian Journal of Crop Science, Frontiers in Plant Science, Revista Brasileira Agrícola Ambiental, Revista Caatinga, Industrial Crops in Products, Journal of Crop Improvement, Scientific Reports, and BMC Genomics. Among these journals, BMC Genomics, Industrial Crops in Products, Scientific Reports, Sugar Tech, and Frontiers in Plant Science stand out for having the highest impact factors (H-index) among the journals publishing works in the field.

Sugar Tech is profiled for publishing the most innovative developments in research and industry in the area of interdisciplinary studies of fundamental issues on which the subject is given high priority. Thus, corroborating as the most relevant journal and a significant impact factor among the scientific journals analyzed in the bibliometric review.

Figure 1 displays the most cited countries, where the color intensity is directly related to the number of articles produced in different regions of the world. The most cited countries in the manuscripts were Brazil with 544 citations, China with 283, the United States of America with 206, and India with 163.

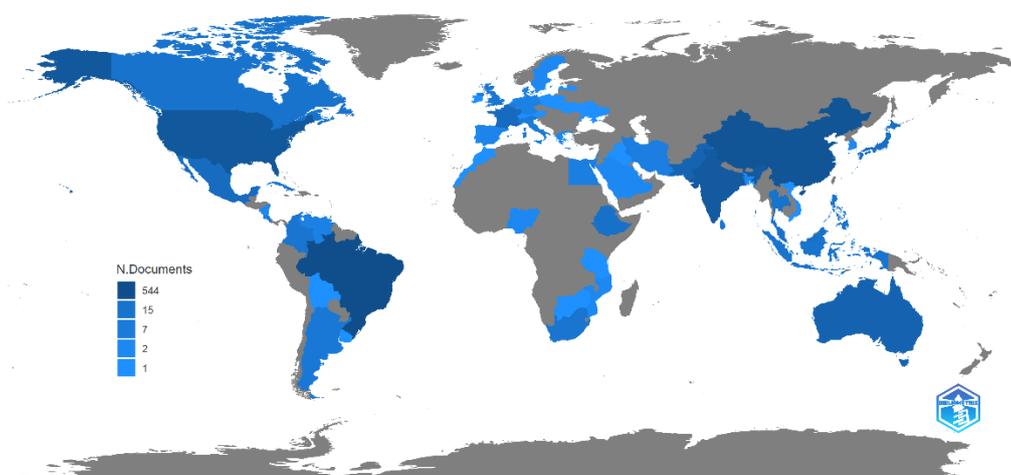


Figure 1 - Geographical distribution of countries based on scientific production in systematic research related to sugarcane
Source: Authors (2023)

The sugarcane sector plays an extremely important role in both the global economy and sustainable development. Sugarcane is a versatile crop that provides a variety of essential products, ranging from white sugar to renewable ethanol. Furthermore, it plays a crucial role in job creation and socio-economic stability in various producing regions. The commercial behavior of sugarcane by-products (such as paper, cosmetics, glass, mouth antiseptics, and perfumes) in both domestic and



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international markets is advantageous for the development of marketing projects and decision-making in scientific research (Nunes; Abud, 2022).

The articles focused their research on several themes, which are depicted in Figure 2. The most significant theme was Genetic improvement and selection of sugarcane varieties, followed by Physiology and biochemistry of sugarcane, and Agronomic management, including planting practices, irrigation, fertilization, and pest and disease control. These three themes accounted for more than 50% of the published studies on sugarcane cultivars.

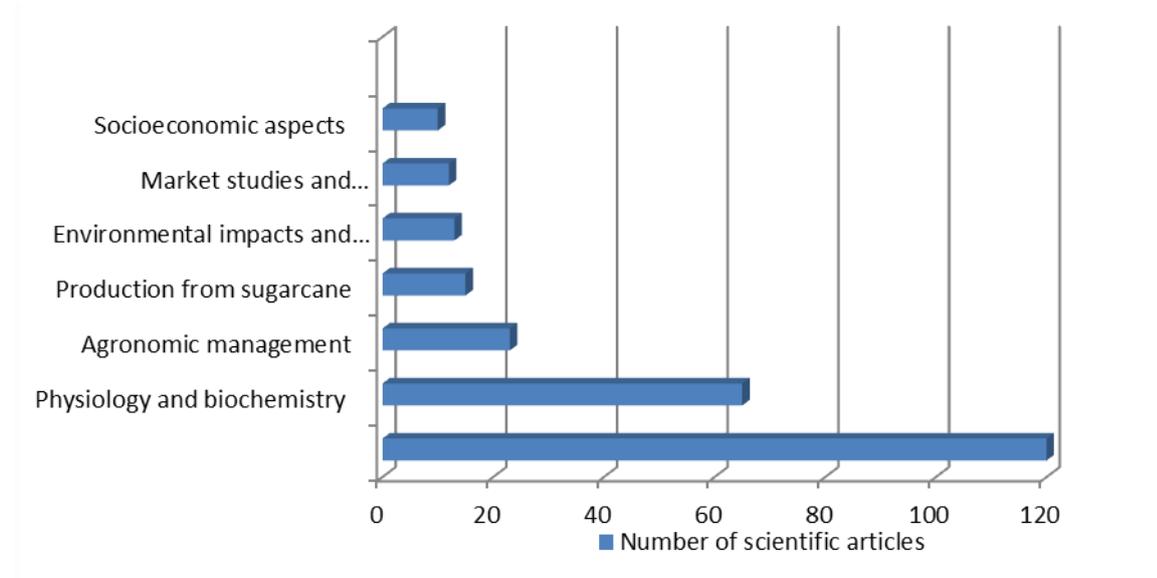


Figure 2 – Main topics of articles related to sugarcane
Source: Authors (2023)

A robust genetic improvement program is essential for the development and selection of superior sugarcane varieties. Through diligent research and selection, geneticists and breeders have made significant advancements in enhancing important agronomic traits such as yield, disease resistance, and sugar content. Their efforts have greatly contributed to the continuous improvement of sugarcane cultivars, ensuring the sustainability and productivity of this vital crop.

Studies focused on genetic improvement and selection of sugarcane varieties are essential for the development of new cultivars. These studies play a crucial role in advancing the field of sugarcane breeding and contribute to the improvement of key traits, such as yield, disease resistance, and quality of sugarcane products. Through the application of modern biotechnological tools and breeding techniques, researchers can identify and select superior genetic traits, leading to the development of high-performing and sustainable sugarcane cultivars.

The continuous effort in genetic improvement and selection ensures the availability of improved cultivars that are adapted to different environmental conditions, increasing productivity and contributing to the growth and success of the sugarcane industry (Cunha *et al.*, 2019; Grativol *et al.*, 2014; Mahadevaiah *et al.*, 2021; Menezes; Carvalho, 2015).



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Understanding the physiology and biochemistry of sugarcane is crucial for maximizing its productivity and sustainability in agricultural systems. Insights into the physiological processes involved in photosynthesis, carbon allocation, nutrient uptake, and stress responses can help optimize crop management practices and improve the overall performance of sugarcane varieties.

Furthermore, a deeper understanding of the biochemistry of sugarcane can contribute to the development of innovative approaches for enhancing the quality of sugarcane products, such as sucrose content and fiber composition. The impact of studying the physiology and biochemistry of sugarcane extends beyond the field of research, as it directly influences the development of strategies for efficient crop production, environmental conservation, and economic viability (Grativol *et al.*, 2014; Guo *et al.*, 2020).

The continuous search for more productive and adapted sugarcane cultivars is essential for driving the sugarcane industry forward. The selection and development of new sugarcane varieties have the potential to improve agronomic efficiency, increase productivity, and enhance the quality of final products such as sugar and ethanol. Additionally, by developing cultivars that are more resistant to diseases and pests, it is possible to reduce reliance on agricultural pesticides, thereby promoting more sustainable production practices. Thus, research and breeding of sugarcane cultivars play a crucial role in advancing and developing this important agricultural crop (Graef; Schneider; Santoyo, 2022).

A total of 228 sugarcane cultivars were analyzed and registered in the RNC (National Cultivar Register). Among these, 39 cultivars were registered by COPERSUCAR, 39 by CTC - Centro de Tecnologia Canaveira S/A, 32 by Universidade Federal de São Carlos - UFSCAR, 28 by Instituto Agrônômico - IAC, 20 by Universidade Federal de Alagoas - UFAL, and 20 by Monsanto do Brasil LTDA.

Regarding the registration history, it can be observed that in 1999, 43 cultivar registrations were made in the National System for Protection of Plant Varieties (SNPC). From the year 2000, this number was reduced and maintained an average of 5 registrations. In 2007, the number of registrations increased to 18 (Figure 3).



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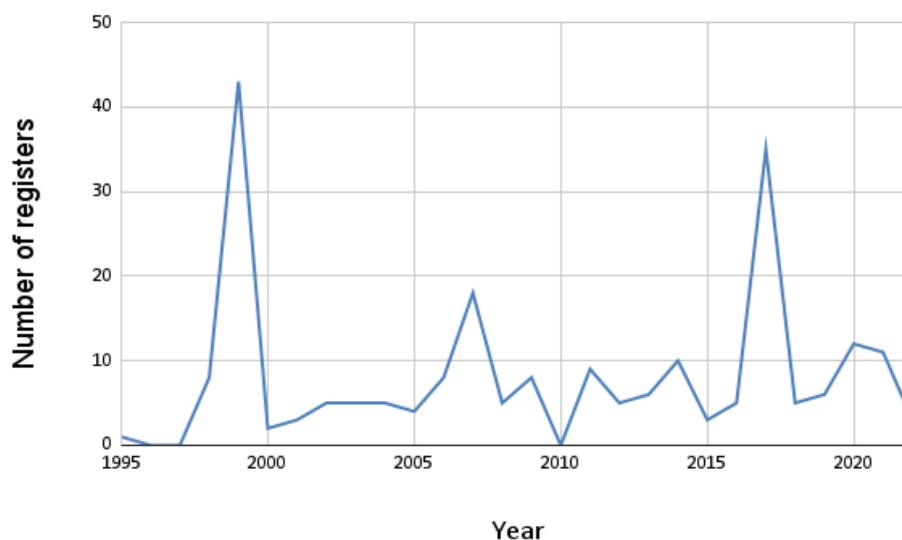


Figure 3 – Number of cultivar registrations were made in the National System for Protection of Plant Varieties (SNPC)
Source: Authors (2023)

In 2017, there was a significant increase in the number of registrations of sugarcane cultivars, driven by the active participation of the Federal University of Alagoas (UFAL) in the RIDESA (Interuniversity Network for the Development of the Sugarcane Industry) program. In that year, UFAL was responsible for registering 13 out of the 35 sugarcane cultivars, highlighting its prominent role in the development and genetic improvement of this important agricultural crop. The contribution of UFAL in expanding the number of registered cultivars reflects its commitment to research and innovation, aiming to enhance the productivity, quality, and adaptability of sugarcane varieties in Brazil.

From the analysis of the registrations, it was possible to identify the most sought-after traits, which include higher productivity, high sucrose content, and resistance to diseases.

A genetically modified seed has three components that can be protected by patents: the plant germplasm, i.e., the seed itself; the gene sequences or genetic traits that result in a specific change, and the processes, such as research tools, needed to incorporate the new genetic trait into the plant cell. Utility patents are created under regular patent law (Gray *et al.*, 2017).

A total of 75 patents were registered for technologies related to the development of sugarcane-related products (Figure 4).



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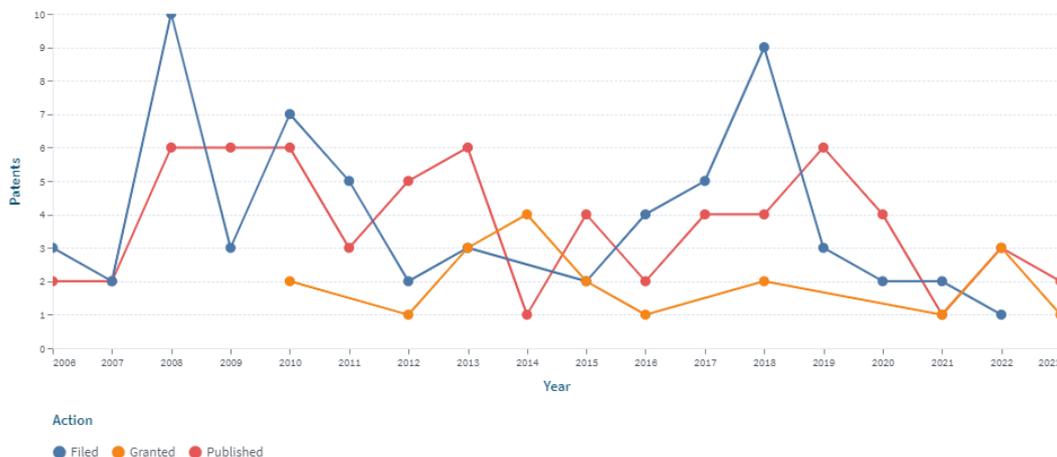


Figure 4 - Number of patents filed, granted, and published related to sugarcane
Source: Authors (2023)

Several years stood out for having a higher number of patent registrations, suggesting an increase in inventive activity during those periods. In 2009, a total of 6 patents were registered, while in 2012, 5 patents were recorded. The year 2018 saw 4 patents being registered, similar to the years 2013 and 2017. Additionally, in 2010, there were also 4 patents registered. These findings highlight these specific years as having a significant volume of patent registrations, indicating a potential surge in inventive endeavors during those timeframes.

Hummel Aaron emerged as the leading inventor with 6 registered patents, closely followed by Keith Bischoff, Marcos Buckeridge, Juliana Maria Felix, Gravois Kenneth, Mathias Labs, Satoru Nishimura, Amanda Pereira de Souza, and Naoko Tsurumaru, each having 5 registered patent documents.

The patent classification codes play a crucial role in organizing and categorizing patents based on their technological features and subject matter. These codes, such as the CPC (Cooperative Patent Classification), provide a standardized system for classifying patents into specific technology areas and subareas. By assigning unique codes to patents, the classification system enables efficient retrieval and analysis of patent data, allowing researchers, inventors, and industry professionals to navigate through the vast landscape of intellectual property.

In this context, Figure 5 presents an overview of the patent classification codes and their corresponding document counts, shedding light on the distribution of patents across various technological domains.



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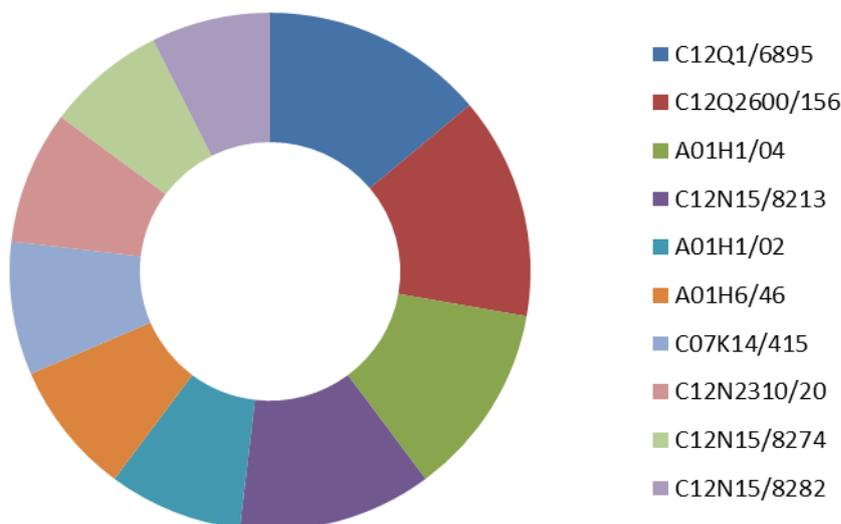


Figure 5 – Registered patents with the top patented Technologies
Source: Authors (2023)

Based on the provided data, interesting patent results were found. The most frequent patent codes based on the CPC classification were C12Q1/6895, which focuses on biochemistry and molecular biology, specifically diagnostic methods or processes involving nucleic acids. It has received the highest number of patents. Additionally, C12Q2600/156 is an area in biochemistry and molecular biology that specifically deals with diagnostic methods or processes involving specific sequences of nucleic acids, and it has also garnered significant patent activity with 15 associated documents. Following closely, A01H1/04 is a patent code related to the breeding or genetic manipulation of plants, with a particular focus on the selection or alteration of plant varieties. Similarly, C12N15/8213, within the field of biotechnology, is associated with the genetic engineering or modification of microorganisms. Both A01H1/04 and C12N15/8213 appeared in 13 documents each.

Other patent codes such as A01H1/02, which pertains to the breeding or genetic manipulation of plants primarily through hybridization, A01H6/46, which involves the genetic engineering or modification of plants, specifically in terms of introducing or expressing specific genes or traits, C07K14/415, a technology that relates to the isolation, purification, or modification of proteins or peptides, and C12N2310/20, which pertains to the identification, isolation, or manipulation of nucleic acids within the field of biotechnology, had nine documents each.

Finally, the patent codes C12N15/8274, which focuses on the genetic engineering or modification of plants or plant cells within the biotechnology field, and C12N15/8282, a technology that involves the genetic engineering or modification of microorganisms, particularly in terms of introducing or expressing specific genes or traits, were associated with eight patent documents.



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These patent results indicate areas of research and development that are receiving a significant number of patents. Such information can be valuable for identifying technological trends and innovative sectors within the industry.

4. CONCLUSION

The registration of new sugarcane cultivars in Brazil is essential for driving the sugarcane industry, increasing productivity, improving product quality, adapting varieties to different regions, and promoting agricultural sustainability. Furthermore, it offers protection for breeder's rights, encouraging research and development of new technologies for sugarcane improvement.

Through research in patent documents, it was possible to know and prospect the current state of technological systems related to the development of products related to sugarcane, characterizing the patent classification codes, playing a crucial role in the organization and categorization of patents based on its technological characteristics, building technological indicators to contribute to the advancement of innovation in sugarcane genetic improvement in the industry.

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