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Technology advances in sugarcane propagation: A patent citation study

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A B S T R A C T

Sugarcane propagation technologies have, in recent years, been the focus of interest of large corporations involved in the sugar and ethanol business. The objective of this study is to present the methodology used to identify the technology domain found in different sugarcane propagation technologies. The methodology was based on the bibliometric analysis of patents, including a meticulous selection of the most representative technologies used by the sugarcane market and the application of patent citation. The results report the process developed to identify a novel technology domain of high complexity involving different fields of science resulting in a set of sugar cane propagation technologies and show that the main technology advances have happened in the last decade (2005–2015), especially in seedling containers and the use of chemical compounds for seedling treatment. Further studies are recommended to help understand how these new technologies will impact the sugarcane production-chain in Brazil.

1. Introduction

The Brazilian sugarcane industry has undergone profound organizational, institutional and technology changes in the last two decades as a response to social and environmental pressure. Among these changes is the implementation of Law N.°11.241 in the State of São Paulo in 2002, providing for the gradual elimination of sugarcane straw burning, a common practice in the manual harvesting process. The resulting increase in mechanized harvesting is noteworthy: from 28% to 89% by 2013 [1]. On the down side, as described by Coimbra Manhães et al. [2], mechanized harvesting of sugarcane has led to perceptible losses, among them a loss in productivity as ratoons get damaged, thus affecting their sprouting capability. This legislation caused new agricultural frontiers in areas with lower soil slope to be sought out, and the development of new methods of propagation and planting of sugarcane as a way to increase productivity and reduce costs [1].

Since then, in this changing environment, what has been observed is the emergence of a new technological domain involving new developments in the field of sciences involving biology, genetics, chemistry and biotechnology, as well as agronomy and cultural techniques with enormous potential repercussion in the structure and organization of the sugarcane production chain in Brazil.

The sugarcane is a semi-perennial grass, belonging to the genus *Saccharum*, typical of tropical and subtropical climates. It has sexual reproduction and tillering capability. The spread in commercial crops is however performed by asexual reproduction or vegetative techniques which, according to Landell et al. [3], ensures uniformity of planting. The traditional propagation method used since the introduction of sugarcane in Brazil, in the sixteenth century, is done manually, using sugarcane stalks, cut into sections containing three or four nodes, which are then horizontally planted in the soil. Each node contains a bud which can develop a whole new plant. The volume of sugarcane required in traditional propagation varies from 11 to 14 t/ha [4]. This type of farming has the disadvantage of being time-consuming and expensive due to the high cost of growing sugarcane seed [5].

What will be shown in this study is that this secularly established pattern of preparation and propagation of sugarcane seedlings, central aspect for the supply of the raw material of one of the most important agroindustrial activities of Brazil, is being confronted by the profound changes that are announce from the new scientific and technological developments. Such developments are based on new investments by large global corporations that are redesigning the institutional environment of the sugarcane agroindustrial complex.

It is possible to identify at least two seedling production techniques:

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the aforementioned traditional one and techniques of plant tissue culture, known as micropropagation. According to Kaur and Sandhu [6], micropropagation has not been fully exploited as an agro-business in developing countries due to high cost of capital and the difficulties to commercialize high-priced tissue culture products. The same was observed by Nieves et al. [5], who reported the difficulty of commercially accepting artificial seeds, despite their many advantages as compared to traditional techniques, such as not needing much manpower or large nursery areas or logistics storage and transportation, irrigation and acclimatization.

Much of this difficulty lies in turning basic knowledge into innovation, i.e. the absorption of new technology by the market. However, researching scientific literature is not enough to be able to understand the interactions between basic knowledge and marketable innovation, or to study how the market behaves in the face of changing technologies in the production-chain. One of the solutions is the use of patent documents as a source of technology information, little explored in the academic environment due to the lack of knowledge of the researchers of the patent system itself [7,8]. A study on the utilization of this information in the Brazilian universities showed that only 16.4% of 586 thesis and Master's dissertations between 2000 and 2007 had cited patents [8]. Scientific papers are a means of disseminating scientific knowledge whereas patents are a means of disseminating technology knowledge, and consequently the structure of the texts differ from each other. Dias & Almeida [7] showed that the sequence of thoughts that dominate the text of a scientific papers and a patent application differs primarily by the greater degree of freedom presented by the publication in comparison to the greater objectivity of a patent. In addition, patent information is also typically more detailed and comprehensive than scientific papers [9]: patents have to clearly describe the current state of the art technologies within their field and report in detail the problem and the technical solution to overcome it. According to Alberts et al. [10], a further advantage of is that they are classified in databases, thus facilitating their retrieval. The system-based filing of patent documents is based on standard metadata structures: title, dates and document numbers for the application, publication and issuance, list of applicants and inventors, and domain of the patent knowledge (field and/or subfield), classified against a standard taxonomy, known as patent classification. Metadata are part of the patent document or can be added by patent offices, like the patent classification, being the key information for searching patents across nations.

Other benefits described in literature is the ability to use and interpret the citations contained in patents to identify innovative paths [11], evaluate knowledge flows, monitor technologies and competitors [12] as well as to study technology trajectories [13]. According to Karki [14], citation studies based on patents, also known as patent citation analysis, seek to link patents in the same way that science citations link the references in scientific papers. According to the author, the main idea behind patent citation analysis is to find which patents are most often cited (i.e. cited in more than 5 patents), so “that highly cited patent is likely to contain an important technological advance, an advance that many later patents are built upon” (Karki, 1997 p. 269). Furthermore, patent citation studies can be used as an indicator of inventive quality on a patent level as well as an important indicator of the innovative output of a firm on a more aggregate level [14,15]. Patent citations include references to patent documents, also known as patent literature (PL) and scientific papers, also called non-patent literature (NPL), allowing the study of spillovers in technologies and scientific fields between distinct industrial sectors [13]. In addition, patent citation studies enable analysing the correlation between different actors, technology fields and inventors and, consequently, identifying overlapping technology areas and potential trajectory changes with the emergence of convergence and new science-based technologies [13].

In this context, this study aims to identify the technology domain found in different sugarcane propagation technologies as well as understand the technological advances associated with the propagation techniques of sugarcane seedlings in recent years using patent citation study. This study is divided into three parts: methodology, results and conclusion. The results are subdivided into 5 sections: 1) Profile of the Selected Patent Documents, 2) Citation Analysis: PL and NPL, 3) Relationship between citation documents, 4) Technology Domain Identification and 5) Geographic Distribution Analysis.

2. Material and method

The methodology is based on the study of patent citations, divided into four steps. In the first step, the patent documents to be studied were selected. To do so, patent documents related to seedlings or artificial sugarcane seed production technology were selected through bibliometric analysis carried out on Derwent Innovations Index of Thomson Reuteurs®, using various keywords such as: sugarcane, sugar and cane, saccharum, plant, vegetative, micropropagation, propagation, germination, shoots, propagules, plantlets, clone, seedling, artificial, synthetic, seed, somatic, callus, embryogenesis, apical, tissue culture, in conjunction with the international classification A01H (new plants or processes for obtaining them; plant reproduction by tissue culture techniques). The study made use of the Boolean operators “OR”, “AND”, “NOT” and word garbling with asterisk (*). All the recovered documents were treated in an Excel spreadsheet followed by a selection of documents that complied with the following criteria: i) Family size equal to or larger than 3; ii) number of citations equal to or larger than 2; iii) only one document per company as assignee. The tiebreaker was the number of citations. The objective is to analyse a representative number of various technologies with a diversity in global sugarcane market.

The second step was to extract the following information of the selected patent documents:

a) Description of the sugarcane vegetative propagation techniques in the specification and claims of the patent document;
b) The INPADOC Patent Family, defined as a set of documents with the same priority number (i.e., the first patent application of an invention);
c) International Search Report - ISR;
d) Written Opinion of the International Search Authority - WOSA;
e) Cited and Citing Documents available at the European Patent Office - EPO,
f) Patent Literature (PL) and Not Patent Literature (NPL) cited in the specification of patent documents (by the applicant);

The third step consisted in tabulating all the results from the second step into an Excel spreadsheet containing the patent number; the year of publication; the country of publication of the INPADOC patent family, the applicant's or Journal's name; the inventor or the author's name; the priority number and the International Patent Classification (IPC).

The last step was the data analysis itself, consisting of:

a) Making a graph of the evolution of PL and NPL citations over time and another according to their sources (ISR examiner or applicant) according to the publication date;
b) Analysing the relationship between the selected patent documents and the citations patent documents (PL), using only the priority number of cited and citing patent documents. The analysis was conducted using the NodeXL basic tool of social networks;
c) Identifying the process of a technology domain in the production of sugarcane seedlings by analysing all patent documents, i.e. cited and citing documents and the selected patent documents, taking into account the international classifications of the patent (IPC);

The geographical distribution study was done by analysing the country of publication of each patent family document and comparing