Postprint: Patent Landscape Analysis in Agricultural Biotechnology

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Abstract

Patents serve as effective vehicles for technology. Through patent landscape analysis, one can effectively grasp the development trajectory and trends of technology to a certain extent. Based on patent information, this study employs a methodology that organically integrates quantitative data, qualitative investigation, and expert wisdom to conduct patent technology landscape analysis in the agricultural biotechnology domain from multi-dimensional analytical perspectives, encompassing application trends, protected markets, field distribution, and key patent holders. Through such analysis, the overall landscape of global agricultural biotechnology patent protection is comprehended and key directions are identified. Building upon this foundation, and in conjunction with an examination of patent legal status and patent transfer and licensing conditions within China' s agricultural biotechnology sector, the current status and existing challenges of patent protection for agricultural biotechnology in China are investigated, with the objective of supporting innovation decision-making in China' s agricultural biotechnology field.

Full Text

Preamble

Patent Situation Analysis in Agricultural Biotechnology Field

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Abstract

Patents serve as effective carriers of technology, and patent situation analysis can effectively reveal technological development trajectories and trends. Based on patent information, this study employs an integrated methodology combining quantitative data analysis, qualitative research, and expert insights to analyze

the patent landscape in agricultural biotechnology from multiple dimensions, including application trends, protected markets, field distribution, and key patent holders. Through this analysis, we present a comprehensive overview of global patent protection in agricultural biotechnology and identify key development directions. Furthermore, by examining the legal status and transfer/licensing conditions of Chinese patents in this field, we discuss the current state and existing challenges of patent protection in China, aiming to support innovation decision-making in China' s agricultural biotechnology sector.

Keywords: Agricultural Biotechnology; Patent; Patent Layout; Situation Analysis

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Biotechnology has built a bridge from traditional to modern agriculture, with modern biotechnological advances triggering a new industrial revolution in the agricultural sector. In recent years, governments worldwide have attached great importance to agricultural biotechnology, leading to rapid global growth of the agricultural bio-industry. Many countries have formulated relevant policies to support innovation in agricultural biotechnology, striving to gain a voice in future international competition. Patents serve as effective carriers of technology, and industry giants have monopolized markets through intellectual property strategies. This paper presents a comprehensive overview of intellectual property protection in agricultural biotechnology both domestically and internationally through patent situation analysis, aiming to identify challenges in China' s patent protection and provide support for future technological innovation layout directions, while leveraging intelligence to guide industrial transformation and development driven by innovation.

1 Data Sources

This study focuses on agricultural biotechnology, referencing the International Patent Classification (IPC) scope for biotechnology defined in OECD reports and collaborating with field experts to select relevant IPC codes: A01H1/00, A01H4/00, A01N, A61K38/00, A61K39/00, A61K48/00, C05F11/08, C05F15/00, C12N, A23K, C07K14/415, C07K14/195, and C07K14/37. The logical combination rules for these IPC codes were also established. Using the Incopat database, we constructed our dataset through multi-layered logical combination retrieval strategies based on these IPC codes. The analytical approach integrates quantitative data with qualitative research, supplemented by expert insights. Analysis tools include Incopat' s patent analysis platform and data processing tools such as EXCEL and ACCESS to present a panoramic view of global and Chinese patent protection and layout in agricultural biotechnology.

2 Agricultural Biotechnology Patent Analysis

As of February 2018, the Incopat database contained 157,871 patents related to agricultural biotechnology, including 30,778 patents filed with the China National Intellectual Property Administration (CNIPA). This paper considers only invention patents for statistical analysis, using patent application numbers as the statistical unit; "Chinese patents" herein refer to patents filed with CNIPA.

2.1 Domestic and International Application Trends

The earliest global agricultural biotechnology patent appeared in 1908, when an individual in Switzerland filed for protection of a plant regeneration fertilizer technology (CH41006A). Over time, global agricultural biotechnology patent applications have experienced embryonic, growth, peak, and fluctuation phases, currently trending toward steady growth [Figure 1: see original paper]. From 1908 to 1961, annual global applications did not exceed 10; from 1962 to 1972, annual applications ranged between 10-100; beginning in 1973, annual applications increased rapidly (100-1,000 per year), entering a peak growth period in 1990. China' s first agricultural biotechnology patent emerged in 1985, filed by the Hebei Academy of Microbiology for a technique using raw cottonseed hulls to cultivate shiitake mushrooms (CN85101598A). China' s application trends are not fully synchronized with global patterns. Although showing an overall upward trend, China' s peak application period occurred later than the global peak. From 1985 to 1993, annual Chinese applications did not exceed 50; beginning in 1993, annual applications increased rapidly (50-1,000 per year), entering a peak growth period in 2008 with over 1,000 applications annually. Affected by the economic crisis, global annual applications experienced a slight decline from 2008-2012 before recovering; growth is expected to continue, though the rate of increase will not expand further (data from the most recent two years are subject to publication delays and are for reference only). Based on these trends, while R&D continues, the surge phase has passed, entering a period of steady growth, suggesting that agricultural biotechnology has entered a stage of large-scale industrialization.

2.2 Patent Receiving Countries/Regions Analysis

Agricultural biotechnology patents are widely distributed globally, covering over twenty countries/regions/organizations [Figure 2: see original paper]. China is the primary target country, followed by Japan and the United States. Australia and Canada rank among the top five, while South Korea, Brazil, Mexico, the United Kingdom, and India are among the top ten (World Intellectual Property Organization (WIPO) and European Patent Office (EPO) data are included as reference, as they represent effective pathways for patent protection). Patent receiving countries/regions reflect potential markets of interest to applicants. The analysis reveals that China, Japan, and the United States are key markets of interest for agricultural biotechnology R&D institutions, closely related to each country' s support for the agricultural biotechnology industry. Currently,

many countries regard biotechnology industry development as an important component of their national economies. The U.S. and European governments support agricultural biotechnology through research funding, while Asia-Pacific countries leverage government support for high-tech industries to capture commanding positions in agricultural biotechnology. Analysis of application trends in major patent receiving countries/regions shows that Japan' s patent applications are relatively evenly distributed over time, while China and the U.S. show more concentrated distributions: the U.S. concentrated between 2000-2010, and China concentrated from 2010 to present. China' s agricultural biotechnology industry started relatively late, but after years of development, R&D centered on genetic engineering has shown significant results.

2.3 Field Distribution Overview

IPC classification analysis reveals that agricultural biotechnology patents involve multiple technical fields, concentrated primarily in Human Necessities (Class A) and Chemistry & Metallurgy (Class C). They also involve Physics (Class G), Performing Operations & Transporting (Class B), Textiles & Paper (Class D), Mechanical Engineering (Class F), and Electricity (Class H), demonstrating extensive technological cross-pollination [Figure 3: see original paper]. Detailed IPC analysis shows the highest concentration in Microorganisms or Enzymes and Compositions Thereof (C12N), followed by Preparations for Medical, Dental, or Toilet Purposes (A61K) and New Plants or Methods for Obtaining Them/Plant Regeneration by Tissue Culture (A01H).

Analysis of IPC layouts in major countries/regions reveals slightly different technological priorities [Figure 4: see original paper]. U.S. and Australian patents concentrate on Microorganisms or Enzymes (C12N) and Medical Preparations (A61K); Japan shows greater focus on Medical Preparations (A61K); while China and Canada emphasize Microorganisms or Enzymes (C12N) and New Plants/Plant Regeneration (A01H).

Through expert analysis, agricultural biotechnology patents were categorized into sub-technologies including biotechnology breeding, applied chemistry, agriculture/dairy and animal science, protein pharmaceuticals, and microorganisms/enzymes or compositions thereof. By delimiting relevant IPC codes, the patent distribution across these sub-technologies was analyzed. Microorganisms/enzymes or compositions thereof represents the most concentrated subtechnology direction, followed by protein pharmaceuticals and applied chemistry, with biotechnology breeding close behind, while agriculture/dairy and animal science shows sparse patent distribution [Figure 5: see original paper].

2.4 Analysis of Important Applicants

Frequent mergers and acquisitions occur in the biotechnology sector, with multinational groups viewing integration of external advantageous resources as crucial for meeting industry challenges. To analyze patent portfolios of key R&D

institutions, we first traced the merger history of leading enterprises.

The global agrochemical industry has long featured a "Big Six" structure: Syngenta, Monsanto, Bayer, Dow, DuPont, and BASF. However, against the backdrop of sharply declining global agricultural product prices and resulting profit declines, a new wave of consolidation began. First, Dow Chemical and DuPont completed their merger in 2015, making DowDuPont the second-largest chemical enterprise after BASF. Second, ChemChina acquired seed giant Syngenta for $43 billion, becoming the world' s largest pesticide and agricultural supplier. Third, Bayer acquired Monsanto for $66 billion, becoming the world' s largest seed and fertilizer company. These three mergers formed the "Big Three" consolidations, creating four major agrochemical companies: Dow+DuPont, ChemChina+Syngenta, Bayer+Monsanto, and BASF. These companies also optimized their portfolios through acquisitions, such as BASF' s €5.9 billion purchase of Bayer' s seed and non-selective herbicide businesses in October 2017, which complemented BASF' s crop protection business, strengthened its herbicide portfolio, and enabled market entry through key agricultural patents. Meanwhile, specialized companies entered agricultural biotechnology through M&A, such as Novozymes (the world' s largest industrial enzyme and microbial preparation producer) strengthening its microbial solutions through acquisitions including Germany' s Organobalance, and Roche (a global pharmaceutical and diagnostics leader) expanding its biosequencing and vaccine businesses.

After thoroughly understanding these M&A histories and cleaning patent assignee data, DowDuPont (U.S.), Bayer (Germany), BASF (Germany), ChemChina (which acquired Syngenta in 2016; most patents now belonging to ChemChina were originally filed by Syngenta), and the Chinese Academy of Sciences emerged as the top five patent holders, each with over 1,500 patents. DowDuPont leads with over 5,000 patents, followed by Bayer and BASF (each with over 3,000). Among the top 20 applicants, eight are enterprises, eight are universities, and four are research institutions, with the top four positions all held by enterprises. Geographically, seven institutions are from the U.S., seven from China, three from Germany, two from Japan, and one from Switzerland. Among the seven U.S. institutions are multinationals like DowDuPont and Roche, as well as renowned universities like the University of California [Figure 6: see original paper].

Chinese patent applicants include enterprises, universities, research institutions, individuals, and government organizations, with enterprises filing the most patents (over 10,000), followed by universities and research institutions. The Chinese Academy of Sciences, Chinese Academy of Agricultural Sciences, China Agricultural University, Nanjing Agricultural University, Huazhong Agricultural University, Zhejiang University, BASF, DowDuPont, South China Agricultural University, Shanghai Jiao Tong University, Bayer, Fujian Agriculture and Forestry University, Jiangsu Academy of Agricultural Sciences, and ChemChina are the main applicants in China' s agricultural biotechnology field. The Chinese Academy of Sciences leads with 1,824 patent applications, followed by

the Chinese Academy of Agricultural Sciences with 1,230 patents—significantly higher than other institutions. Among China' s top 16 applicants, universities are most numerous (8), followed by enterprises (5) and research institutions (3), though research institutions rank higher in application volume [Figure 7: see original paper].

2.5 Current State of Patent Protection in China

As of the search date, among Chinese agricultural biotechnology patents, 26.39% are granted and effective, 30.87% are under substantive examination, 3.27% are published, 18.34% have been withdrawn, 13.43% have expired, and 7.16% have been rejected [Figure 8: see original paper]. In terms of validity, 26.39% of Chinese agricultural biotechnology patents are effective, 34.14% are pending examination, and 39.46% have lapsed. Overall, nearly 40% of Chinese agricultural biotechnology patents have lapsed, with a notable proportion withdrawn, warranting serious attention from relevant institutions to improve application quality and ensure genuine protection for developed technologies.

2.6 Patent Transfer and Licensing Conditions in China

Chinese agricultural biotechnology patents have seen 1,724 transfers and 193 licenses. Figure 9 [Figure 9: see original paper] illustrates transfer and licensing conditions. Transfer volumes have increased annually since 2008, growing rapidly with minor fluctuations after 2012 (recent two years' data are subject to publication delays). Major transferors include the Chinese Academy of Sciences, Bayer, Shanghai Shangfang Horticulture Co., Novartis, and Weiming Wangsheng System Crop Design Frontier Laboratory (Beijing) Co., while major transferees include Bayer, State Grid Shanghai Municipal Electric Power, Sichuan Qicai Forestry Development, and Shanghai Shangfang Horticulture.

Regarding licensing, the earliest agricultural biotechnology patent license occurred in 2004, with licensed volumes showing a tortuous upward trend from 2009, peaking in 2012 before declining. Major licensors include the Chinese Academy of Agricultural Sciences, Nanjing Agricultural University, Academy of Military Medical Sciences, and Huazhong Agricultural University, while major licensees include Beijing Dabeinong Technology Group, Academy of Military Medical Sciences, Wuxi Xiangtianmu Biotechnology, and Wuhan Kenuo Biotechnology.

IPC analysis of transferred and licensed patents reveals they concentrate primarily in microorganisms or enzymes and compositions thereof, new plants or methods for obtaining them/plant regeneration, medical/dental/toilet preparations, and biochemistry-related microorganisms.

3 Conclusions and Development Recommendations

(1) China' s Development Trends Are Not Synchronized with Global Patterns

Global agricultural biotechnology patent applications exhibit two distinct phases: before 2010, growth was primarily driven by multinational corporations such as DuPont, BASF, Bayer, pre-acquisition Monsanto, and pre-acquisition Syngenta; after 2010, these companies' applications show a declining trend. Conversely, China' s agricultural biotechnology is currently in a rapid development phase, becoming the main contributor to global application growth after 2010.

(2) Chinese Institutions Are Gradually Challenging International Giants' Dominance

Currently, DowDuPont, Bayer, and BASF each hold over 3,000 patents, maintaining absolute advantages. However, after 2010, China' s research institutions and universities have become the main contributors to global application growth, with the Chinese Academy of Sciences, Chinese Academy of Agricultural Sciences, and China Agricultural University breaking the R&D monopoly previously held by multinational agrochemical giants. Additionally, Chinese chemical industry giant ChemChina has entered the R&D advantage ranks through its Syngenta acquisition. China should strategically utilize existing patents at the macro level, establishing patent alliances centered on core patent holders to form patent pools with high-quality patents, thereby strengthening control over advantageous technological points and striving for industry leadership.

(3) China Must Strengthen Patent Protection in Agricultural Biotechnology

China' s lapsed patent ratio approaches 40%, wasting research resources and directly affecting technology commercialization rates. Relevant applicants and agencies must attach greater importance to this issue, implementing effective measures to improve patent quality and ensure patents truly safeguard technologies.

(4) China' s Patent Transfer and Licensing Conditions Are Favorable

Institutions including the Chinese Academy of Sciences, Shanghai Shangfang Horticulture, State Grid Shanghai Municipal Electric Power, Sichuan Qicai Forestry Development, Chinese Academy of Agricultural Sciences, Nanjing Agricultural University, Beijing Dabeinong Technology Group, and Academy of Military Medical Sciences lead China' s agricultural biotechnology patent transfer and licensing, accelerating technology industrialization through these mechanisms. As China' s agricultural biotechnology industrialization further develops, more sophisticated intellectual property transaction and operation systems will be needed. China should strengthen its agricultural biotechnology intellectual property system construction to facilitate the transformation of patented tech-

nologies into products.

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Note: Figure translations are in progress. See original paper for figures.