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Agriculture Practice

Needle in a haystack: Patents that inspire agricultural innovation

An enhanced patent-review strategy could boost innovation capabilities for agricultural-input companies.

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Patent documents are underexploited resources—not only for understanding the evolution of agricultural technology but also for assisting governments, companies, and academic institutions in the inventive process.[1] More than 40,000 patents related to agricultural inputs have been granted in the past ten years. We find that a rigorous patent-review process could aid agricultural-input companies in their pursuit of innovation.

Agricultural innovation is increasingly important given the need to feed a growing global population—ten billion people by 2050, two billion more than today.[2] Worldwide, agricultural production will face challenges, such as skyrocketing demand for crop calories[3] and constraints on crop yields.[4] In addition to addressing global challenges, enhanced patenting may also lead to better corporate financial performance. Research has shown a positive correlation between granted patents and financial performance.[5] We find similar indications within the agricultural-input sector, with high-patenting firms leading their low-patenting counterparts in three-year average earnings before interest, taxes, depreciation, and amortization (EBITDA) margins by two percentage points.[6]

Most agricultural innovation has been geographically concentrated. In 2019, for instance, five regions accounted for 77 percent of the granted patents worldwide: China (45 percent), the United States (11 percent), European Patent Organization member states, Russia, and South Korea (7 percent each). While the United States holds the top spot in the relevance of innovation, China is expected to continue its dominance in the raw quantity of patents published. Moreover, 88 percent of agricultural-input patenting in the United States was associated with corporations, both foreign and domestic (Exhibit 1).

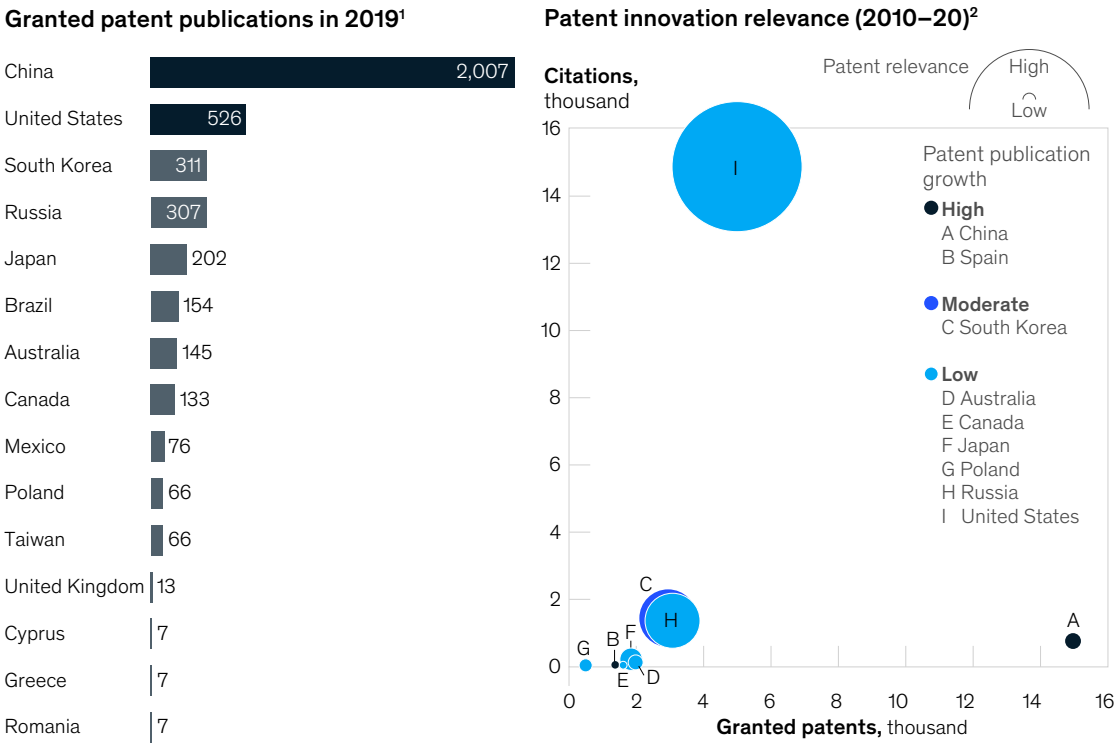
Examples of patent analytics to inspire future innovation in agriculture include monitoring highly productive academic groups or start-ups to identify potential targets for collaboration; automatically scanning publicly available data on competitor portfolios and patent applications[7]; extracting features from patents (such as chemical formulae) to reveal movements in global product development; and identifying emerging trends—which may be counterintuitive—to inform research and development (Exhibit 2).

An analysis of emerging trends in agricultural patenting in 2019 revealed terms such as "slag"[8] (Exhibit 3). This highlighted the presence of counterintuitive innovation that simultaneously addresses multiple challenges in sustainability (for instance, both industrial-waste recycling and crop-nutrition challenges). Recent studies have also shown that steel slag can be used as an accelerant in anaerobic digestion for better utilization of

[1] Leonidas Aristodemou and Frank Tietze, "Citations as a measure of technological impact: A review of forward citation-based measures," *World Patent Information,* June 2018, Volume 53, pp. 39–44.
[2] Craig Hanson et al., *Creating a sustainable food future: A menu of solutions to feed nearly 10 billion people by 2050,* World Resources Institute, July 2019, wri.org.
[3] *The future of food and agriculture—Alternative pathways to 2050,* Food and Agriculture Organization of the United Nations, 2018, fao.org.
[4] Elizabeth Ainsworth et al., "Genetic strategies for improving crop yields," *Nature,* November 2019, Volume 575, pp. 109–18; "Science breakthroughs to advance food and agricultural research by 2030," National Academies of Sciences, Engineering, and Medicine, Washington, DC: The National Academies Press, 2019, nap.edu.
[5] Kendall W. Artz et al., "A longitudinal study of the impact of R&D, patents, and product innovation on firm performance," *Journal of Product Innovation Management* Volume 27, Number 5, pp. 725–40; Knut Blind et al., *Patents and the financial performance of firms—An analysis based on stock market data,* Fraunhofer Institute for Systems and Innovation Research ISI discussion paper, Innovation Systems and Policy Analysis series, Number 28, February 2011, isi.fraunhofer.de.
[6] Based on historical three-year EBITDA margins of the top and bottom ten corporations in the top 100 patenting entities.
[7] Note that these use cases are based solely on publicly available information for the sake of inspiring novel innovation.
[8] Steel slag, a by-product of the conversion of iron ore to steel, can be used as either a fertilizer or a soil-acidity corrective, a corrective of soil acidity, as it contains compounds such as calcium oxide, magnesium oxide, silicon dioxide, phosphorus pentoxide, ferrous oxide, and manganese oxide. For more, see Leonardo Büll et al., "Effects of lime and steel slag application on soil fertility and soybean yield under a no till-system," *Soil and Tillage Research,* 2020, Volume 196, Number 104422.

Exhibit 1

While US innovation remains more relevant, China has dominated agricultural patenting in recent years.



[1]Data based on approximately 40,000 patents granted from January 1, 2010 to May 1, 2020, related to agricultural inputs, which were retrieved from a global database containing 117 million patents covering 95 different jurisdictions through keyword search terms such as "fertilizer," "herbicide," "fungicide," "insecticide," and variants thereof.
[2]Patent-forward citations (the number of citations that a patent has garnered from other patents) have historically been used as a simple but effective indicator of the economic and technological impact and relevance of a patent.

Note: The names shown here do not imply official endorsement or acceptance by McKinsey & Company.

digestate fertilizer,[9] for application to subtropical rice fields to reduce greenhouse gas emissions,[10] and as a mineral fertilizer for bok choy.[11]

To harness the wealth of information that patent documents can offer, agricultural-input companies should prioritize the following areas:

— *Establish a clear target and purpose for patent analytics.* To maximize the effectiveness of custom-built pipelines, agricultural-input firms should decide whether patent analytics are being used to inspire invention, track competitor activity, identify new partnerships, or predict future market developments. A clearly defined vision for patent analytics can help to avoid building impractical in-house tools or licensing expensive commercial intellectual-property-analytics software.

[9] Feng Han et al., "Steel slag as accelerant in anaerobic digestion for nonhazardous treatment and digestate fertilizer utilization," June 2019, *Bioresource Technology,* Volume 282, pp. 331–38.
[10] Shahar Baram et al., "Industrial wastes: Fly ash, steel slag and phosphogypsum—potential candidates to mitigate greenhouse gas emissions from paddy fields," *Chemosphere,* February 2020, Volume 241, Number 124824.
[11] Dong Chen, Yi-Ping Chen, and Zhong-Wen Meng, "Toxicity assessment of molybdenum slag as a mineral fertilizer: A case study with pakchoi (Brassica chinensis L.)," *Chemosphere,* February 2019, Volume 217, pp. 816–24.

Exhibit 2

Patent analytics can aid companies through the inventive process from multiple angles.

Portfolio analysis
Assess active patent portfolios of firms and institutions by jurisdiction, patent strength, and filing growth rate

Technology analysis
Evaluate concentration, filing growth rate, innovation quality, established trends, and inventor demographics

Innovation hub analysis
Discern innovation hubs (countries, states, counties, cities) to ascertain hotspots in excellence, and institutions or individuals propelling innovation

Network analysis
Identify innovation clusters and how they relate to each other, inventor networks, and technologies inspiring innovation (even in potentially unrelated areas)

Early trend analysis
Identify early trends in innovation, leading institutions, and overlapping themes using patent analytics combined with scientific text and news article analytics

— *Choose a data-collection strategy.* Patent databases such as Espacenet, Google Patents Public Data, The Lens, and PatentsView have made it easier for companies to access tens of millions of patents across dozens of jurisdictions. As these databases expand, it is important to keep abreast of which services offer convenient access to patents through callable application programming interfaces, which can be embedded into customized pipelines with on-request patent downloads.

— *Explore the use of open-source packages to build customized pipelines.* The growth in packages for open-source software such as Python and R helps researchers customize patent analysis workflows to specific needs. A proliferation of open-source implementations of algorithms related to natural language processing (NLP), geospatial analytics, and deep learning is decreasing the costs of building customized patent analytics applications. Furthermore, the latest implementations of such algorithms tend to be more readily available in open-source ecosystems compared with popular commercial software.

— *Apply both bibliometric metadata and text data.* Patent analytics have historically focused on examining metadata (for example, patent authors, technology classifications, publication date, citations, country, and instutition). However, analyzing large volumes of text such as titles, abstracts, and claims can make the search more granular.

— *Use entire patent texts to avoid being misled by patent information.* When conducting such text analyses, NLP-based approaches should aim to work with full patent texts.[12] Patent titles and abstracts, while used in patent analyses, can be obscure and, as a result, present inadequate visibility into patent landscapes.[13] Full texts, however, offer a better representation of what is actually described in the patent, leading to deeper insight into how agricultural technology is advancing.

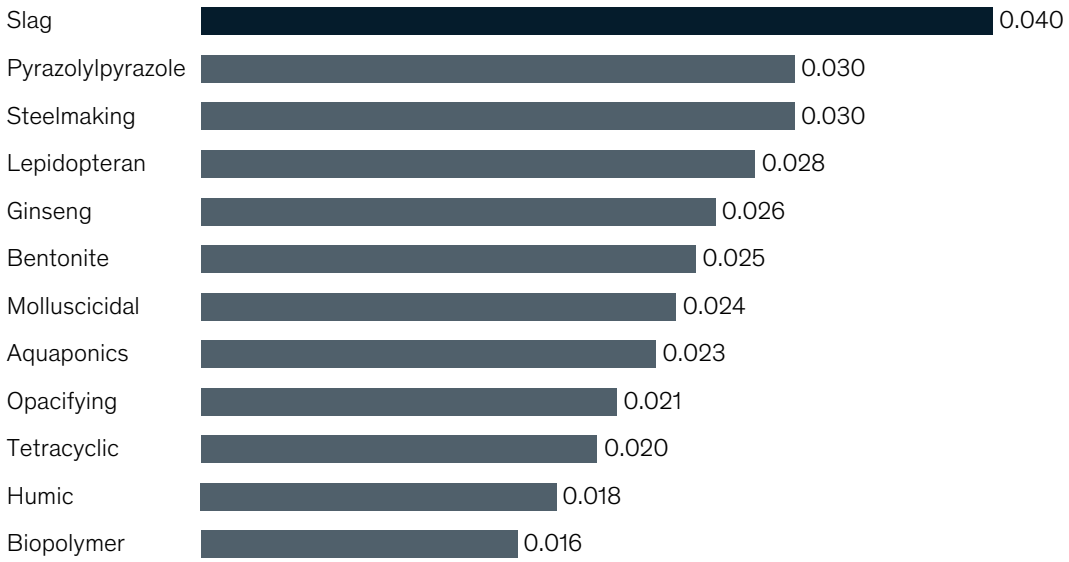
— *Combine patent analytics with additional data sources and the latest tools in AI.* Patents can be used in combination with other data sources (such as scientific papers, news articles, and clinical trial records) for an even broader view on the direction of innovation. Moreover, companies

[12] Full patent texts include claims and summaries.
[13] Marko Seppänen, Arho Suominen, and Hannes Toivanen, "Firms' knowledge profiles: Mapping patent data with unsupervised learning," *Technological Forecasting and Social Change,* February 2017, Volume 115, pp. 131–42.

Exhibit 3

Early trend analysis may reveal counterintuitive innovation that inspires future agriculture-related R&D.

Emergence among a sample of agricultural patents, 2019, tf–idf score[1]



[1]The term frequency–inverse document frequency (tf–idf) score is a numerical metric that reflects how important a word is to a document in a collection of documents. The higher the tf–idf score, the more important the word. For instance, the word "slag" was more important in 2019 relative to other years, indicating that the word is novel or emerging.

using machine learning and semantic artificial-intelligence engines can rapidly parse these combined sources of text data to determine impactful trends in global agricultural innovation and adapt their portfolios accordingly.

Agricultural innovation has included steady growth in parallel to mounting pressures on global agricultural production. Patents contain valuable information and can guide targeted investments in research and development while revealing unexpected examples of emerging agricultural technologies.

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