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Plant Patent Systems for Equity and Sustainability

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Abstract: One domain of innovation in agriculture is patents for uniquely produced plants by plant breeding tools. Sometimes the researchers don't go for patents, missing the opportunity of earning profit from their novel innovative research. A pressing issue for the small-scale breeders is the financial and legal challenges during the patenting process. Hence, small breeders cannot compete in the international global seed markets while big giants are grabbing the capital and make trends with their own will and for their own benefits. Buyers should purchase from the original researchers and the researchers must be acknowledged by the international community to provide rights to the original researchers. The availability of better plant breeds will promote sustainable agriculture, secure biodiversity and improve the health and wellbeing of the people.

Keywords: inclusive patent system; plant intellectual property; equity; sustainability; genetic resources; small scale breeders

1. Introduction

Automation, artificial intelligence, and sophisticated manufacturing promise economic prosperity, but their unregulated expansion runs the risk of escalating global crises. This paradoxical dilemma has been highlighted by the increasing acceleration of technological innovation, especially within Industry 4.0 and its successors. Industrial paradigms need to be critically reevaluated in light of climate change, biodiversity loss, and freshwater depletion, all of which are exacerbated by human-caused greenhouse gas emissions. The Sustainable Development Goals (SDGs) of the UN today make clear how traditional industry cannot coexist with ecological limits, especially as the world's population continues to grow and water scarcity poses a threat to 3.2 billion people by 2050. In this regard, regenerative resource management and energy-circular systems must be given top priority during the shift to Industry 6.0 and 7.0 (Costa et al. 2025; Majeed, and Iftikhar 2024; Majeed, Iftikhar, and Abbas 2025). However, without systemic changes to intellectual property (IP) regimes, technological efficiency alone is insufficient. This imbalance is best illustrated by patent systems, especially those that control agricultural biotechnology and plant genetics. Four agrochemical companies own 63% of modern plant patents, which frequently limits access to climate-resilient agricultural varieties and threatens biodiversity conservation directly at odds with SDGs 2 (zero hunger) and 13 (climate action). Recent advancements in genetic engineering to produce genetically modified crops have changed the patenting trends. The patents' trends include high yield crop production, sustainability, reduction in landfills, utilization of agricultural waste and sustainable agriculture system patents. Patented plant varieties address food security challenges (SDG 1) by incorporating cutting-edge genetic engineering techniques to improve crop resilience, controlled water and nutrients uptake, pest resistance, and climate change adaptability (Otero et al. 2022). Plant patents encourage investment in green technologies, promoting sustainable farming practices. There is now a de facto monopoly by big multinational seed companies over genetic resources, posing serious challenges to agricultural systems' resilience and food security.

2. Existing Plant Patent Systems

Along other life forms, the US Congress has also permitted intellectual property protection for plants. While utility patents protect genetically modified and innovative varieties, plant variety protection certificates focus on unique plant characteristics. Despite their benefits, the existing system of plant patents has always been debated (Vallone and Lambin 2023).

2.1 Traditional Exclusionary Patent Model

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The first challenge with the current patent system is fragmentation. Concerns have been raised about patent proliferation as "patent thickets" thus hindering innovation. Patent thickets are a dense web of intellectual property rights that hampers innovation by companies. Apart from fragmentation, accessibility to critical patents threatens innovation. Some tools like patent pools and clearinghouses, such as the Syngenta e-licensing platform, Enza Zaden platform, and ILP Vegetable aim to make these patents accessible but the high fees and the potential for patent holdups is a major challenge with these platforms. Patent systems were introduced to encourage competition and promote innovation. Contrarily, the current patent system has allowed large corporations patent plant varieties and traits, thus locking up genetic resources. These patents have transformed seeds from a shared resource to a private commodity. By dominating the seed markets, current patent regimes have limited farmers' autonomy consolidating the hegemony of a few large corporations over genetic resources. By using cutting-edge methods like genetic use restriction technologies, also referred to as terminator technology, these companies ensure that the seeds stay their sole property by making them infertile following the first harvest. This terminator technology ensures that the seeds produced by plants are sterile and won't grow in new plants. By reducing crops' resistance to biotic and abiotic stresses, the implementation of such intellectual property rights narrows the genetic pool and increases their susceptibility to pests, diseases, and unfavorable weather conditions (Bostyn 2024; Portuese 2024; Panagopoulos and Sideri 2021).

3. Impact on Small Scale Breeders

3.1 Challenges Analysis Faced by Small Growers Due to Large Companies' Patents

Small farmers and plant breeders face significant challenges due to the dominance of multinational corporations in the patenting of genetic characteristics. Essential genetic resources are being monopolized due to patents on genetically modified crops, hybrid seeds, and private breeding methods, making it challenging for small-scale producers to obtain them. Less than ten multinational companies, including Bayer-Monsanto, Corteva (formerly Dow-DuPont), Syngenta, and BASF, control most of the world's seed patents. This impacts agricultural diversity, innovation, and food security and has legal, economic, and scientific ramifications (De Jonge, Salazar, and Visser 2022).

3.1.1 Economic Barriers and Licensing Costs

Every season, farmers must buy costly hybrid or genetically modified seeds or pay license fees, which increases their reliance on corporate seed systems. According to the International Assessment of Agricultural Knowledge, Science, and Technology for Development, smallholder farmers find it challenging to reinvest in farm innovation since they must spend their total income on patented seeds (Rosendal and Olesen 2022).

3.1.2 Reduction in Genetic Diversity and Innovation

The gene pool for breeding crops resistant to pests and climate change is declining by patenting the genetic resources. Due to the replacement of native landraces by hybrid and genetically modified seeds, worldwide crop variety decreased by 75% between 1980 and 2020. Independent breeding initiatives for drought-resistant rice and wheat were hindered by several years due to patents (Kock 2022; Rosendal and Olesen 2022).

3.1.3 Impact on Food Security and Developing Nations

In poor countries, where 70 to 80 % of the food supply is produced by smallholder farmers, the effects of restrictive patent laws are particularly pronounced and have harmful impact. Patented seeds push farmers into recurrent purchases and raise debts, combined with contractual prohibitions on seed saving. To lessen corporate monopolization, Brazil and Argentina have chosen state-sponsored seed production initiatives. However, the WTO's Trade-Related Aspects of Intellectual Property Rights and UPOV 1991 trade agreements constrain state policy options by promoting patent protections (Bezner Kerr 2013; Delmer et al. 2003).

3.2 Policy Reforms and Future Directions

Alternative intellectual property approaches include restricting the scope of patents for genetic features that occur naturally to avoid monopolizing vital crops. Putting into practice breeders' exemptions, which permit small farmers to conduct breeding and research using patented genetic material without paying license fees. Mandatory licensing procedures that compel patent owners to grant wider access at controlled prices. Maintaining access to a variety of genetic material free from corporate control by creating national and regional seed banks. Small farmers face financial, legal, and scientific obstacles because of large firms' monopolization of agricultural patents. This restricts their access to essential genetic resources, deters independent breeding, and lowers agricultural biodiversity. Small-scale growers' reliance on corporate-controlled seeds has increased due to costly licensing prices, stringent patent claims, and active litigation, which has increased expenses and financial risks. A more equitable patent system that combines open-source genetics, independent breeding powered by CRISPR, and blockchain-based traceability to guarantee both innovative incentives and equitable farmer access is the answer. As Industry 6.0 takes shape, the combination of CRISPR-engineered crops and AI-driven precision agriculture needs to be regulated by intellectual property laws that give distributive justice and carbon-negative innovation top priority. Technological advancement runs the risk of exacerbating the very crises it is intended to alleviate in the absence of such reforms. To ensure a resilient and food-secure future in line with SDGs 2 (zero hunger), 9 (industry, innovation, and infrastructure), and 12 (responsible consumption and production), governments and international organizations must amend intellectual property laws to safeguard small-scale agricultural producers (Jiang, Jakobsen, et al. 2022; Irfan, et al. 2024; Gupta, Mejia, and Kajikawa 2025).

3.3 Case Studies Illustrating the Effects on Biodiversity and Innovation

Monopolization of genetic traits has led to the decline of traditional and locally adapted varieties, threatening ecological balance. Such practices undermine agricultural resilience to environmental changes and pests, posing risks to food security. Currently, four major companies control over 60% of the seed market worldwide. Each patent owned by these companies has an extensive list of traits. Adaptive Seeds, an organic seed company that grows chemical-free seeds and does not use any kind of intellectual property rights, thus anyone can use these seed varieties without restriction. Andrew Still started Adaptive Seeds in 2009. In 2020, Adaptive

Seeds received a letter from the fourth-largest vegetable breeding company stating a list of traits and varieties patented by that company. This letter was a reminder of the control these big corporations have over the patent system (Kleeger and Still 2012; Kliem and Sievers-Glotzbach 2022).

4. Transition from Exclusivity to Inclusivity

4.1 Proposal for Inclusive Patents as Alternative Rights

Experts advocate for inclusive patent systems that balance innovation incentives with broader accessibility. Inclusive patents could involve open-access models, benefit-sharing agreements, or time-limited exclusivity periods to ensure that patented innovations eventually become widely available. To ensure accessibility private collaborative licensing mechanisms including patent pools and clearinghouses need to be encouraged. These mechanisms will help swift access to patents related to plant genetics. One such example is the Syngenta e-licensing platform providing breeders and researchers open access to patented traits and enabling technologies present in their commercial vegetable varieties. This platform offers royalty-free access to licensed traits during the development and breeding of new varieties. Payment must be made if a new variety contains patented traits. This provides access to patented subject matter. However, the effectiveness of this platform has yet to be seen. Enza Zaden, a Dutch-oriented vegetable breeding company, also provides breeders with an agricultural e-licensing platform. This platform deals with varieties, relating to lettuce, cucumber and melon. In 2014, another platform named International Licensing Platform for vegetable plant breeding was established. This platform provides access to crucial vegetable plant traits. However, one must become a member of the ILP platform to publish a patent and access other patents. This platform resembles a patent pool. In June 2023, the US Department of Agriculture and the US Patent and Trademark Office launched an online tool named Farmer Liaison that would provide breeders and companies with access to plant patents. This tool allows researchers to look up patented plant varieties (Lee, Ryu, and Kim 2025).

4.2 Potential Benefits of Inclusive Patents for Universal and Sustainable Openness

Transition to an inclusive open access patent system will enhance collaboration among stakeholders and ensure equitable access to genetic resources promoting sustainable agricultural practices. This open access model will provide accessibility and opportunities to all users. Inclusive patent system will strengthen collaboration among stakeholders to develop news plant varieties mitigating devastating impacts of changing climatic conditions. It will create a balanced and innovative agricultural ecosystem. These systems can incentivize the preservation of biodiversity by promoting the use of diverse genetic resources in breeding (Vasudevan et al. 2024).

4.3 Characteristics of an Inclusive Patent System with a High Tech Perspective

An inclusive patent system aims to promote equitable technology distribution, sustainability, and universal innovation. This inclusive model prioritizes the affordability, accessibility, and expedited patent processing than time-consuming traditional patent systems. This strategy maintains a balanced environment that promotes cooperation, knowledge-sharing, and technological equity while enabling inventors, especially those working on sustainable and open-source technologies to quickly and effectively secure intellectual property protection (Bagley 2024).

4.3.1 Structure and Legal Framework of Inclusive Patents

The inclusive patent model will grant patent rights upon formal submission without the need for in-depth prior art research or novelty assessments. From an industry standard under an inclusive regime, administrative expenses will be lowered, and the patenting process could expedite. Post-grant oppositions, peer-review-based validation, and AI driven patent classification systems can be integrated to prevent patent thickets and low-quality submissions. The ability of this model to protect long-term innovation through an asymmetric IP protection strategy, which simultaneously promotes non-exclusive licensing, technology pools, and open-source collaborations is one of its key features. This strategy guarantees that patent holders maintain legal ownership and commercialization rights. Fair acknowledgment and benefit-sharing are ensured by the incorporation of blockchain-based patent registries, which further improve transparency, immutability, and worldwide accessibility. These blockchain-based patent registries will record and manage plant patents via blockchain technology which will ensure transparency about patent legal status. Once the data was added, it couldn't be edited, thus making it secure (Takenaka 2021; Miric, Jia, and Huang 2023).

4.3.2 Technological and Economic Benefits of an Inclusive Patent System

With AI assisted automation and streamlined procedural frameworks, an inclusive approach might save costs by many folds compared to traditional patent applications, which costs high including legal and administrative fees. Digital ledger monitoring and AI powered prior art analysis can speed up many times, allowing for real-time commercial scalability. Cross sector collaborations are easier by open-access licensing and technology-sharing agreements, which reduce R&D redundancy and increase the output of global innovation (Liu et al. 2021; Moro-Visconti 2024).

4.3.3 AI and Blockchain Enabled Patent Systems in Industry 6.0 and 7.0 (Futuristic approach)

Patenting techniques are changing because of the super hyper automation/ intelligent manufacturing technologies of Industry 6.0 and 7.0, which will integrate decentralized blockchain networks, artificial intelligence, and quantum computing. By recognizing innovative and non-obvious parts of inventions in milliseconds, AI driven predictive analytics may assess real time patentability, a process that often takes months or years. Blockchain based patent registries improve transparent licensing, safe timestamping, and IP integrity. This strategy ensures tamper-proof technology transfer arrangements between businesses, academic institutions, and governments while minimizing intellectual property issues and cutting down litigation expenses (Bui 2025; Akhtar et al 2025; Madanchian and Taherdoost 2024).

4.3.4 Sustainable Development and the Ethical Imperative

SDG 9 (industry, innovation, and infrastructure), and SDG 17 (partnerships for the goals) along with the integration of AI are in line with an inclusive patent system. This approach promotes green innovation by lowering administrative obstacles, guaranteeing climate-resilient crops (Biggi et al. 2025).

4.3.5 Challenges and Regulatory Adaptations

To handle issues with defensive patenting, licensing abuse, and technological misappropriation, legal frameworks should be changed. Such conflicts can be settled by smart contracts for automated royalties, guaranteeing fair revenue sharing for creators while spreading information worldwide (Akpobome 2024).

5. Future Directions for Policy and Practice in IPRs

To modernize patent systems that guarantee efficiency, equity, and transparency, an inclusive patent system should be adopted. This can be achieved by incorporating AI-driven automation, blockchain, big data analytics, and machine learning in patent systems. To ensure fair access and innovation for all scale breeders compulsory licensing should be integrated into national and international legislation. Furthermore, to preserve genetic diversity and provided open access to native varieties, national seed banks should be established and should be linked digitally to provide access across the globe. Government grants and subsidies should be provided to institutions that contribute to open-source initiatives focusing on plant innovations thus fostering collaboration and equal access. To resolve licensing disputes, blockchain and smart contracts should be improved within an inclusive patent system. Moreover, to support independent farmers, financial and infrastructural support should be provided to them. To observe, how changes in patent law frameworks will affect innovation, competition and accessibility for small-scale breeders, policymakers can use digital twin, a virtual model that simulates real time behaviors (Salle and Rini 2025; Mihus, Zahorskyi, and Lipentsev 2024).

6. Conclusions

Small-scale breeders' access and equity are restricted by the current patent system, which stifles innovation by exacerbating economic inequality. It is imperative to move towards an inclusive patent system that strikes a balance between access and IPRs. Incorporating open-access licensing of patents, blockchain transparency for filed and granted patents, and AI-driven automation can hasten sustainable agriculture while guaranteeing fair resource distribution. Patent ecosystems must embrace decentralized, moral frameworks that safeguard inventors' financial interests while encouraging cooperation in Industry 6.0 and 7.0 advancements. A redesigned system that incorporates benefit sharing arrangements, open access, and cooperative licensing would stimulate innovation, improve accessibility, and offer more options for agricultural businesses.

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