



## BIOPIRACY OF HEIRLOOM SEEDS: ECOLOGICAL RISKS AND THE BIOLOGICAL NECESSITY FOR CONSERVATION POLICIES

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**Abstract:** This study aims to examine the impacts of the recent increase in biopiracy and bio-smuggling activities on heirloom seeds and to evaluate the implications of these practices on ecological balance and food sovereignty. In particular, the illegal collection of plant genetic resources and their patenting followed by re-sale to their countries of origin have brought the concept of biopiracy to the forefront. Such practices pose significant threats to local agricultural systems, farmers' rights, and biological diversity. This research, which is based on an extensive review of the literature, emphasizes that the preservation of heirloom seeds is not only a cultural and agricultural necessity but also a critical component of sustaining ecological balance. The smuggling of heirloom seeds abroad and their subsequent genetic modification and commercial cultivation in different geographical regions not only undermines the biological heritage of the source countries but also disrupts ecological systems. When cultivated outside their native habitats, these plants may exhibit invasive species behavior or trigger ecological imbalances in new environments. Moreover, this process exacerbates the degradation of already fragile local ecosystems, especially in the context of climate change. This study highlights the urgent need for comprehensive national and international policies to protect heirloom seeds in biodiversity-rich countries such as Türkiye. Based on literature-derived data, the study presents a set of policy recommendations developed by the authors to combat biopiracy through legal, scientific, and social awareness frameworks. These recommendations offer strategic guidance for both nature conservation and sustainable agricultural policymaking.

**Keywords:** Biopiracy, Ecological balance, Heirloom seeds, Plant genetic resources, Sustainability

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### 1. Introduction

Biodiversity is an indispensable resource for the functioning of ecosystems, the maintenance of food security, and human well-being (FAO, 2019; IPBES, 2019). However, this richness is currently under severe threat due to habitat loss, climate change, intensive agricultural practices, and the impacts of globalization (CBD, 2020).

Among these threats, one of the most pressing issues in recent years has been 'biopiracy,' referring to the unauthorized or inequitable acquisition of genetic resources, particularly heirloom seeds (Louafi and Tobin, 2005; Robinson, 2010). Biopiracy not only undermines ecological balance but also violates the rights of traditional knowledge holders and local communities. Therefore, the protection of heirloom seeds has become a critical necessity for ensuring the sustainability of biodiversity and safeguarding biocultural heritage for future generations.

Biopiracy is defined as the illegal acquisition and commercialization of a country's biological resources,

particularly local plant genetic material. This phenomenon is not merely the theft of a species but also the usurpation of the rights of local communities that have preserved and developed these resources for centuries. In this context, biopiracy refers not only to the unlawful appropriation of biological materials but also to the exclusion of local communities' innovation and knowledge production processes through intellectual property regimes (Drahos and Frankel, 2012). The unlawful collection and export of heirloom seeds can lead to the irreversible loss of genetic heritage, while corporations often subject these resources to genetic modification and patenting, forcing the country of origin to repurchase its own resources at high costs. The consequences extend beyond economic losses, causing severe ecological disruptions; when seeds are removed from their natural habitats, they may either fail to adapt to new environments or, conversely, spread invasively, threatening native species and reducing biodiversity. Combined with the pressures of climate change, this process further weakens the resilience of already fragile



ecosystems (Gulyani and Singh, 2010; Güler, 2022; Güler 2025).

In countries rich in biodiversity, such as Türkiye, home to thousands of endemic plant species, biopiracy must be addressed not only as an environmental concern but also as a matter of national security. Addressing the impacts of biopiracy on heirloom seeds requires closing legal gaps, accelerating scientific inventory studies, and enhancing public awareness. Thus, the protection of heirloom seeds is not only about preserving cultural heritage but also about ensuring ecological stability, food sovereignty, and sustainable development for the future (Ribeiro and Ribeiro 2019; TAGEM 2021; Erat and Balık, 2022; Güler 2025).

As highlighted by Elliott (2011), biopiracy is a global issue rooted in historical exploitation and contemporary inequities, demanding international recognition and collective action involving governments, researchers, industry, farmers, and indigenous people. In the literature, heirloom seeds are generally referred to as "heirloom seeds" or "landrace varieties." Beviláqua et al. (2014) define them as follows: "Heirloom seeds are varieties produced by farmers, which may be of local origin or come from other regions/countries, but through long-term cultivation in a particular place, they undergo a process of specific adaptation to the environment." In Brazil and Portugal, they are described as "sementes crioulas," which are not only genetic material but also carriers of traditional knowledge, elements that enhance socio-bioagricultural diversity, resources that support the peasant way of life, and sources closely linked to agroecological and/or organic production.

In this context, the purpose of this study is to examine the impacts of the recent increase in biopiracy and bio-smuggling activities on heirloom seeds, to assess their consequences for ecological balance and food sovereignty, and to contribute to the development of solution-oriented policy recommendations based on legal, scientific, and social awareness frameworks. To achieve this purpose, the study employs a bibliometric analysis of the scientific literature on biopiracy, genetic resources, and heirloom seeds. This method enables the identification of research trends, thematic gaps, and dominant policy perspectives, thereby strengthening the analytical framework of the study and providing an evidence-based foundation for the proposed recommendations.

## **2. Materials and Methods**

### **2.1. Data Collection**

For the bibliometric analysis, only Web of Science data were used, as this database provides the most advanced and detailed coverage of peer-reviewed scientific literature. Bibliographic records were downloaded from the Web of Science Core Collection in BibTeX format, including full records and cited references, and used as the input dataset for the bibliometric analysis. The bibliometric analysis was conducted to systematically

identify research trends, thematic concentrations, and gaps in studies addressing biopiracy, genetic resources, and heirloom seeds, thereby supporting the overall objective of the study. This approach enables a structured evaluation of the scientific landscape and provides an empirical basis for interpreting the ecological and policy-related implications of biopiracy. In addition, publications obtained from Google Scholar, Scopus, and the YÖK Thesis Database were considered in the discussion section to contextualize the bibliometric findings and enrich the interpretation of the results.

### **2.2. Analysis**

A search was conducted using the keywords "*biopiracy*", "*bio-piracy*", "*bio piracy*", "*heirloom seed*", "*landrace varieties*", "*traditional seeds*", "*local seeds*", "*genetic resources*", and "*plant genetic resources*" (Figure 1). The retrieved bibliographic data were analyzed in R Studio using the bibliometrix package (Tırnık, 2020; Abdullah, 2022), which is widely employed for bibliometric and scientometric analyses to examine publication trends, citation structures, keyword co-occurrence, and collaboration networks. Previous studies have demonstrated that R-based bibliometric analysis tools are increasingly used in biology and science education research and are effective in revealing publication trends and research dynamics (Abdullah, 2022). In recent years, R Studio has been widely adopted not only in ecological and agricultural sciences but also in fields such as educational sciences and microbiology for bibliometric and mapping analyses (Fidiastuti, 2025). This analytical framework follows established bibliometric approaches applied in recent studies, where R-based bibliometric tools have been effectively used to map scientific production and research dynamics across disciplines.

In line with this methodological approach, R Studio has become one of the most widely used statistical analysis tools and is frequently preferred by researchers conducting bibliometric studies in the field of biology. Bibliometric analysis is a method that examines scientific literature through quantitative indicators to reveal research trends, collaboration patterns, and thematic developments. In this way, the data in this study were evaluated objectively, systematically, and in a visually interpretable manner (Kurtuluş and Bilen, 2021).

### **2.3. Indicators**

The dataset was examined in terms of publication year distribution, country contributions, author collaborations, citation frequencies, and thematic focus areas.

### **2.4. Visualization and Discussion**

Findings were visualized through graphs, trend lines, and network maps to ensure clarity in the poster presentation. The results were further discussed in light of case reports, legal practices, and the relevant literature.

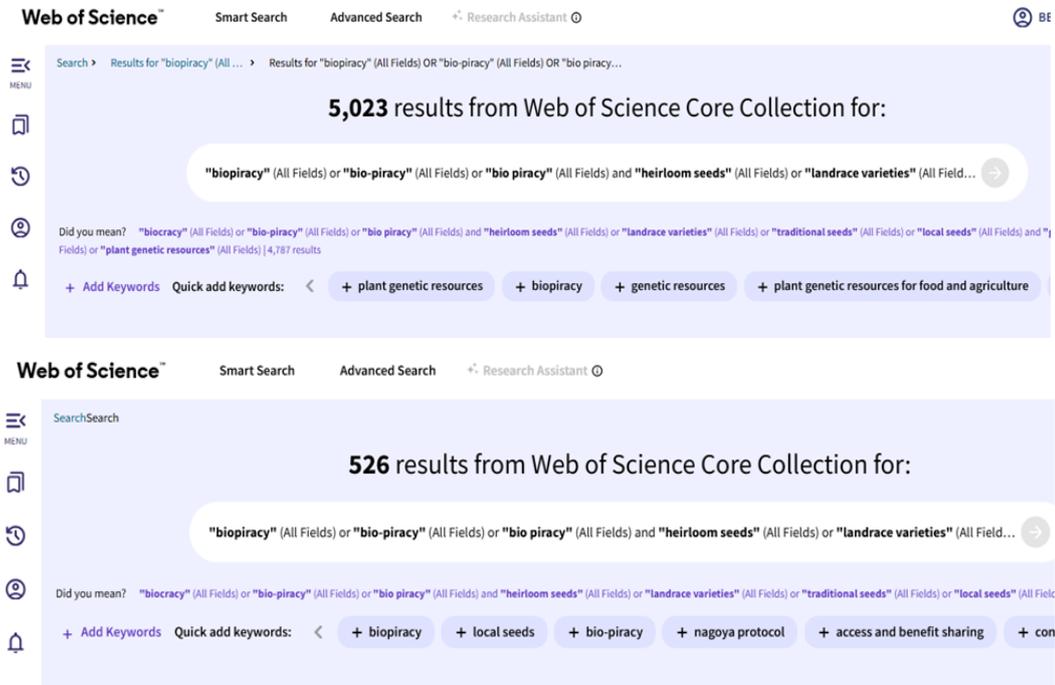


Figure 1. Web of Science search results.

### 3. Results and Discussion

Between 1980 and 2025, 5024 documents, 1196 sources, and 15,779 authors were identified. The annual average growth rate was 12.58 %, indicating increasing academic attention to the subject. Studies were predominantly multi-authored with an average of 4.84 authors per paper, while single-authored works were limited to 520. The rate of international co-authorship was 24.9 %. A total of 10,664 different keywords were used, reflecting the thematic diversity of the field. The average document age was 9.65 years, and the mean citation rate was 13.02 per paper. These results suggest that the topic of biopiracy and heirloom seeds is both current and of high impact potential. The findings further reveal that research on biopiracy and heirloom seeds has attracted increasing attention from scholars over the past four decades, with a rapid growth trend in recent years. The

prominence of collaborative studies underscores the interdisciplinary and international dimensions of the subject. Moreover, the wide variety of keywords indicates that the issue is addressed not only from ecological and agricultural perspectives but also from legal and socio-economic standpoints. (See Figures 2 and 3).

The analysis shows that Plant Genetic Resources–Characterization and Utilization and Genetic Resources and Crop Evolution are the leading journals in terms of both number of publications and citation impact. Sources such as Frontiers in Plant Science and Crop Science also play a significant role, indicating an interdisciplinary research structure. The cumulative trend reveals a rapid increase in contributions from these journals, especially after 2010, highlighting the growing scientific attention to biopiracy and plant genetic resources.

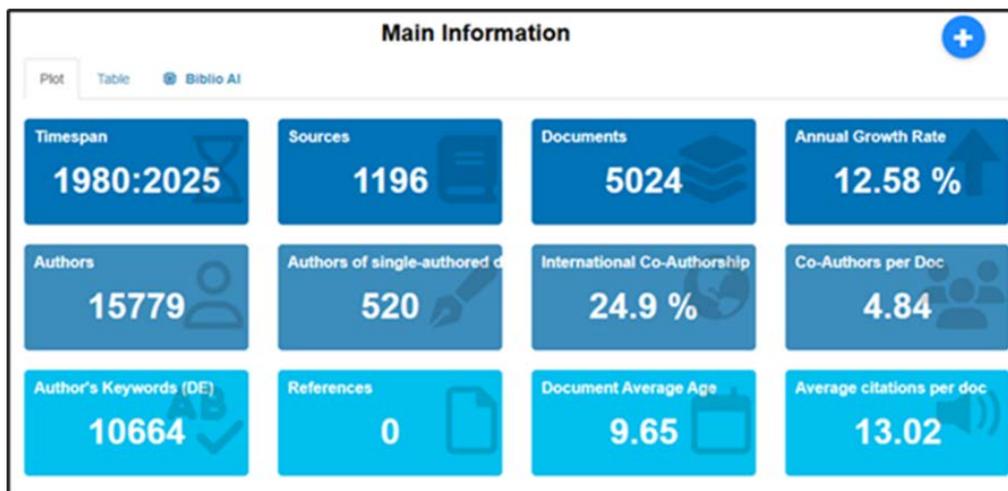


Figure 2. Main bibliometric indicators from Web of Science (1980–2025).

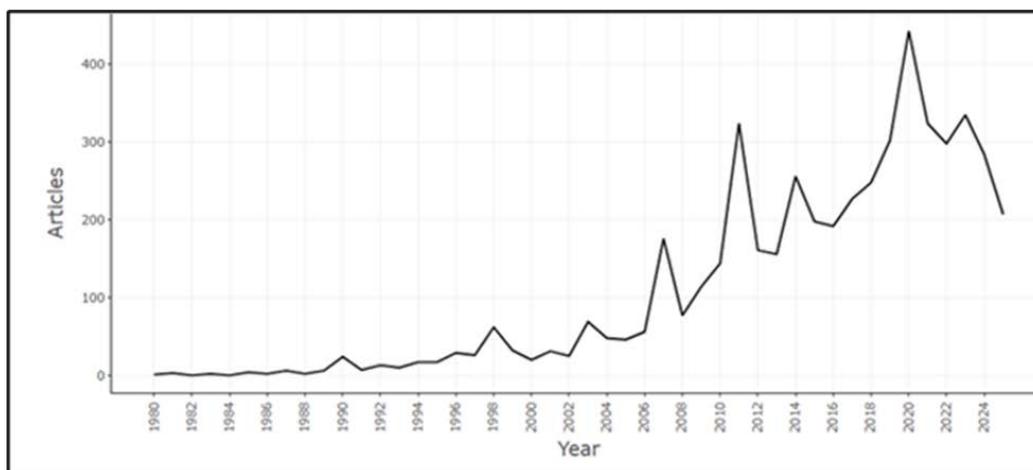


Figure 3. Annual number of publications on biopiracy and heirloom seeds in Web of Science (1980–2025).

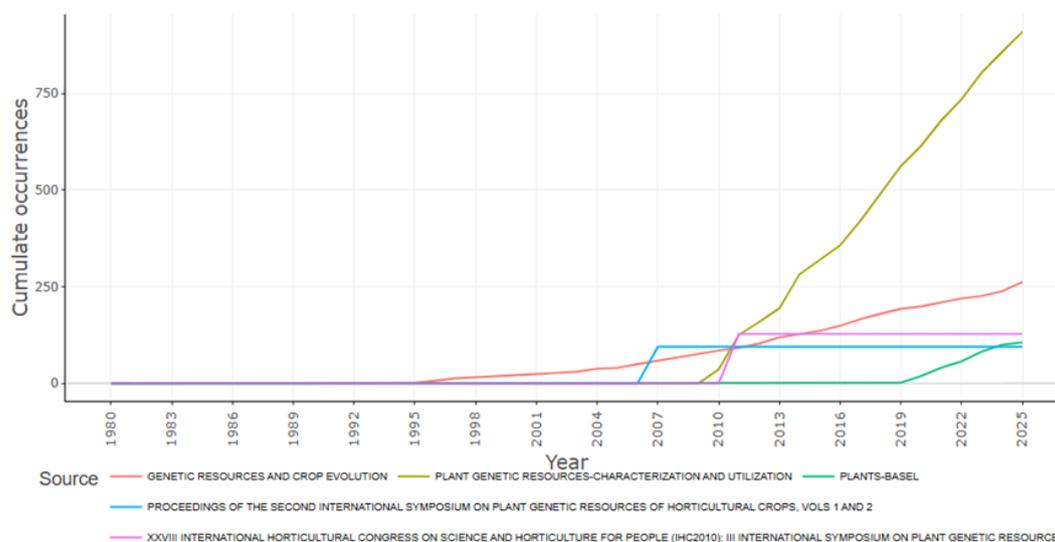


Figure 4. Cumulative occurrences of publications by source in Web of Science (1980–2025).

The most prolific authors are Singh M (50), Kumar A (45), and Maxted N (41). The top three institutions contributing to the field are the Indian Council of Agricultural Research (ICAR), the United States Department of Agriculture (USDA), and the ICAR–National Bureau of Plant Genetic Resources, reflecting their central role in global research production. At the country level, the highest number of publications comes from India, the USA, and Italy, with the world map further illustrating these nations’ leadership in biopiracy and plant genetic resources research. While these indicators reflect research productivity and geographical distribution, they do not directly represent the level of international collaboration, which would require a dedicated co-authorship or network analysis.

Keyword analysis shows that the most frequently used terms are genetic diversity (653), diversity (641), plant genetic resources (549), germplasm (380), and conservation (364). This indicates that research mainly focuses on genetic diversity, biodiversity conservation, and the sustainable management of plant genetic resources. The keyword “biopiracy” appeared 97 times (1%), suggesting that while it is not a dominant theme, it

has nonetheless gained increasing visibility in the literature. (See Figure 6-7).

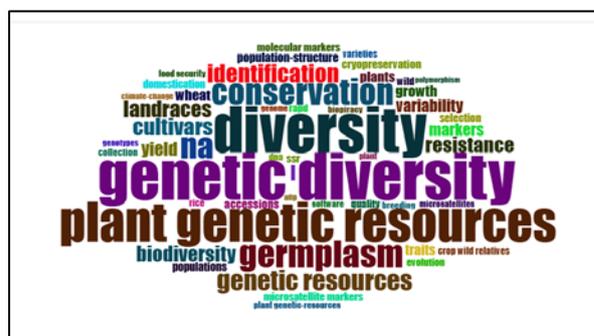


Figure 6. Word cloud of the most frequently used keywords in publications on biopiracy and plant genetic resources (1980–2025).

The bibliometric analysis revealed that publications on biopiracy and heirloom seeds have shown a rapid growth trend over the past 40 years, particularly after 2010, with an annual growth rate of 12.58%. The findings also indicate that studies are predominantly multi-authored



closely follow global trends and harmonize national regulations with policy recommendations outlined in international reports such as those of FAO, CBD, and IPBES.

In conclusion, the protection of heirloom seeds is not only about preserving a legacy inherited from the past but also about ensuring ecological stability, safeguarding future agricultural production capacity, and strengthening the global fight against biodiversity loss. This study contributes to increasing academic awareness of biopiracy research and provides a guiding framework for future interdisciplinary studies.

#### Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	B.M.Y.	H.K.
C	50	50
D	50	50
S	50	50
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50
FA	50	50

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

#### Conflict of Interest

The authors declare that there is no conflict of interest.

#### Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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