Biodiversity and patents: Overview of plants and fungi covered by patents

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Social Impact Statement
Patents can be used as a measure of innovation and to illustrate the commercial potential of plant and fungal biodiversity. The proportion of plant species named in patents represents only 6.2% of plant species, whereas the proportion of fungi is likely less than 0.4%. Fungi clearly justify further research. Innovation on a species usually drives more innovation on that species. We suggest that we should ensure that commercialization frameworks encourage studies on a greater diversity of plants and fungi. This could not only increase the range of biodiversity-based products and associated income but also incentivize their conservation and encourage more fundamental research.

Summary
In this review, patents are used as a measure of innovation, and data show that a low proportion of plant and fungal biodiversity is mentioned in patents. The proportion of plant species named in patents represents only 6.2% of plant species, whereas the proportion of fungi is most likely less than 0.4%. The number of species within a plant family mentioned in patents varies greatly. The following families having the greatest numbers: Asteraceae with 1,445 species (4.5% of species), Fabaceae with 1,299 species (5.8%), Poaceae with 1,008 species (8.5%), and Rosaceae with 718 species (12.7%). Case studies from Brazil, Ethiopia, and South Africa explore some of the controversies associated with patenting, especially when patents have not taken prior art into account. In contrast, a case study on plants and fungi used in traditional Chinese medicine illustrates their economic value and their potential to support new innovations. Innovative ways to use plant and fungal biodiversity has the potential to generate wealth, reduce poverty, improve human well-being and in theory incentivize biodiversity conservation. International and national policies and laws that aim to facilitate equitable benefit-sharing associated with access to and use of genetic diversity need to be reviewed to help facilitate innovation, as well as ensure that the rights of communities to use these resources are recognized and supported.
1 | INTRODUCTION

This review provides an overview of the diversity of species of plants and fungi subject to patents and some of the challenges associated with patenting these resources. As a species, Homo sapiens has evolved using available biodiversity and domesticated those species that were found to be highly beneficial for consumption and trade (Meyer, DuVal, & Jensen, 2012). Over time, we have concentrated on commercializing a narrow range of plants and fungi to support our day-to-day activities, especially those living in urban environments. The plants and fungi we use are fundamental to the quality of our lives (Keune et al., 2013), yet it is not always easy to identify, retrospectively, the steps made to optimize the economic benefits of some species over others.

One way to monitor the diversity of plants and fungi subject to commercial use is to monitor those that are subject to different forms of Intellectual Property Rights, such as patents, and also record which species have and are being traditionally used (see reviews by Grace et al. (2020), Howes et al. (2020), Prescott et al. (2018) and Ulian et al. (2020)). In this review, we use patents as one way to illustrate innovation in the use of plant and fungal resources. The commercialization of plant and fungal genetic resources via patents has the potential to generate wealth, reduce poverty, improve human well-being and in theory incentivize biodiversity conservation. Therefore, a case could be made to increase the diversity of plants and fungi being commercialized. To help realize this potential, international policy agreements have been established that govern access to and sharing of benefits from the utilization of genetic resources and associated traditional knowledge. However, these policies and their related national laws have so far largely failed to achieve the intended outcomes (Laird et al., 2020). Laws also differ among countries in the legal frameworks for patents (Jarvie, 2016).

For example, some laws allow whole plants/fungi and the products from those materials to be subject to patent restriction, which could include restrictions for their use as food or feed (Correa, Correa, & De Jonge, 2020). Therefore, in some cases patents may not be the appropriate commercial pathway.

Value chain analysis provides a route to evaluate the role of different groups in the commercialization process and shows that usually the provider of the raw material gains less than those involved in producing the final product (Hishe, Asfaw, & Giday, 2016; FDA, 2018; Havardi-Burger, Mempel, & Bitsch, 2020). How to increase the utilization of biodiversity in ways that provide income for all involved is a huge challenge, especially for those in low- and middle-Gross Domestic Product economies (Stannard & Moeller, 2013) at a time when we are witnessing a substantial increase in the loss in biodiversity (IPBES, 2019; Nic Lughadha et al., 2020). Patents are in themselves only one step in the commercialization process and will require investment and a market, but if supported by appropriate agreements could illustrate the economic importance of plant and fungal diversity.

2 | POLICIES ASSOCIATED WITH THE USE OF BIODIVERSITY

The Convention on Biological Diversity (CBD) aims to provide a fairer system associated with the exploitation of genetic resources. The CBD prescribes that agreements should be founded on mutually agreed terms, with equitable benefits to countries and local communities that provide resources and knowledge and help conserve biodiversity and support its sustainable use (https://www.cbd.int). A series of additional agreements and protocols have been developed, including the Nagoya Protocol (https://www.cbd.int/abs) and its Internationally Recognized Certificates of Compliance and the Aichi Biodiversity Targets (https://www.cbd.int/sp/targets/) (see review by Williams et al. (2020)).

Ethnobotanical reviews such as those undertaken by Pushpangadan, George, Ijini, and Chithra (2018) in India can provide insight into the traditional uses of biodiversity and also enable that information to be available to others, including patents agents. This information supports patent processing in India. In 2002, the Indian government established an Access & Benefit Sharing (ABS) and Patent process (http://nbiandia.org/content/333/25/1/applicationstatus.html; http://nbiandia.org/content/683/61/1/approvals.html). The Indian Biodiversity Act requires prior approval from the National Biodiversity Authority to obtain biological resources for any form of commercial utilization and patent approval. This authority has received over 3,500 applications and has signed more than 1,000 ABS agreements, resulting in 2,428 applications for inventions of which 729 have been granted. The Indian approach is not to prevent patenting of bio-based inventions, but rather to facilitate it with the condition that benefits generated by the patent holder shall be shared in accordance with requirements under national ABS legislation. The benefits shared, in turn, are intended to be used for the conservation of the biological resources and the socioeconomic development of local communities. Despite these processes being in place and increased R&D spending since 2005 by the pharmaceutical industries in India (Banerji & Suri, 2019), there are very few examples of innovation-based products on plants from their diverse flora getting to the international market.

The International Treaty on Plant Genetic Resources for Food and Agriculture has a Standard Multilateral Transfer Agreement in place to enable benefits to be shared for crop species listed in its Annex (http://www.fao.org/plant-treaty/en). Currently, this benefit-sharing is funded by contributions from member states, although
contributions have been limited to date. It will take time to see if this fund delivers an increase in the diversity of plants being utilized for foods as well as increasing benefits to local farmers, especially as only 64 crops are represented in the Annex. As noted by Wynberg (2015), it is very difficult to trace and confirm the contributions of different players to the creation of new crops outside the patent/plant variety systems.

3 | RULES COVERING PATENTS ON GENETIC RESOURCES

Over the years, there have been changes in what can and cannot be covered by a patent. However, basic principles determine the potential for an idea or product to be patented: it must be new, involve an inventive step (not be obvious to someone with good knowledge and experience of the subject) and be capable of industrial application.

Some of the most significant changes in what can and cannot be included in patents have occurred with the implementation of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) under the World Trade Organisation (WTO) (Gates, 2014; Polo, 2019). However, interpretation of these guidelines varies among countries. Recent updates required on patent disclosure can be found on the WIPO site (https://www.wipo.int/export/sites/www/tk/en/documents/pdf/genetic_resou rces_disclosure.pdf).

4 | EXAMPLES OF PATENTS THAT DID NOT TAKE ALWAYS INTO ACCOUNT PRIOR ART

Gebru (2018) provides examples of controversies that have arisen because those filing patents did not provide full information about the background of their innovation, especially traditional knowledge about the uses of the named genetic resources, this can lead to accusations of “biopiracy.” The term was coined to illustrate the practice of commercially exploiting biological resources and/or traditional knowledge, especially through the patent system, without sharing the financial and/or non-monetary benefits with the source community, country, or knowledge holder (Amusan, 2014; Dutfield, 2007; Hamilton, 2006). Despite the development of national ABS laws and benefit-sharing agreements, there are still examples of patent filing and associated commercialization of by-products of genetic resources that have not taken into account; the providers of these resources or traditional knowledge holders, and the participation of people that have traditionally used the resource (Amusan, 2014; Dutfield, 2017; Dutfield & Suthersanen, 2019).

Four case studies (Cases 1–4) are presented to illustrate some of the ramifications that can occur when those filing patents have not taken into account the traditional uses of plants. The first case study involves patents associated with the commercialization of a grass known as teff (Eragrostis tef (Zucc.) Trotter) in Ethiopia, in which patent claims refer to uses of teff that were already known to communities. Case 2 (palm murumuru (Astrocaryum murumuru Mart.) and Case 3 (andiroba (Carapa guianensis Aubl.) relate to patents on the use of plants from Brazil without recognition of existing traditional uses. Case 4 from South Africa explains how biopiracy charges linked to patents have led to different outcomes for provider communities and traditional knowledge holders. These examples reveal the importance of considering biological distributions and cultural connections, given that most species and communities cross political boundaries. Other examples highlighted by Heinrich and Hesketh (2019) illustrate the importance of collaborations in developing patents, especially those from the country of origin of the genetic resource that is the subject of the patent.

These examples highlight the complexity of commercializing biodiversity via patents. Clarity on novelty within a patent needs to be robustly challenged and agreements dealing with equitable benefit-sharing associated with the commercialization of the patent also need to be in place. If funders and companies are going to invest in biodiversity-based patents then risks associated with inappropriate claims need to be mitigated. This can be addressed if inventors and those involved in filing the patent have involved stakeholders that represent the source of the genetic resource and those that have knowledge about traditional uses of the resource.

5 | EXISTING PATENTS ON PLANTS AND FUNGI

Oldham, Hall, and Forero (2013) reviewed 11 million patent documents from the USA, the European Patent Convention and the International Patent Cooperation Treaty published from 1976 to 2010. From the 11 million documents, they identified 95,303 Latin species names. When “cleaned and harmonized” using the Global Biodiversity Information Facility (GBIF), Species 2000, the Catalogue of Life and the World Patent Statistical Database (see Oldham et al., 2013 for more details), the number was reduced to 76,274 Latin species names of which 26,111 relate to plants and 7,918 to fungi.

The majority of plant patents relate to different aspects of breeding with a focus on the main staple food plants like Zea mays L. (maize), Oryza sativa L. (rice), Brassica napus L. (oilseed rape), Triticum aestivum L. (wheat), Hordeum vulgare L. (barley), Helianthus annuus L. (sunflower), Solanum tuberosum L. (potato), Brassica oleracea L. (ancestor of cabbage, cauliflower, broccoli, and Brussel sprouts), Sorghum bicolor (L.) Moench (sorghum), and Pisum sativum L. (pea) (Oldham et al., 2013). In addition, 39,900 patents were published for 527 of the 893 underutilized plant species listed by The Crops for the Future (http://www.underutilized-species.org/species/about_species.asp). However, most of these patents relate to non-food uses of these plants. Vincent et al. (2013) identified 3,546 species that are classified as relatives of crop plants and thus could contain economically important traits. There is clearly
greater potential to realizing the commercialization of these underutilized plants, with some innovations justifying patents. Jarvis (2016) found little evidence that legislative changes due to TRIPS had encouraged an increased diversity of species to be commercialized. Correa et al. (2020) in their overview of patents on food plants showed that 40% of countries in the Global South excludes the patentability of plants in their patent regimes. In contrast, most have followed the European approach that excludes plant varieties from patenting, but allows patenting of nucleic sequences that could enable the production and commercialization of by-products from the plant/fungi as sources of food. In taking these patents forward, it is important that the commercialization process takes into account the knowledge that local communities have about the specific plants and that patents do not restrict the use of plants as food in their source countries. Equally important is the need to ensure greater disclosure about the origin of both the genetic resource and associated knowledge in patent applications.

A review of patent activity in the UK undertaken by Oldham, Barnes, and Hall (2015) for the United Kingdom Intellectual Property Office (UKIPO) and the Department for Environment, Food and Rural Affairs (DEFRA) showed that of the patents filed between 1976 and 2010, reference was made to 3,922 species of plants and 1,692 species of fungi. Patents were granted in 91 countries. The USA, Australia, Japan, and China were the dominant markets for these patents. An analysis of where the species in these patents naturally occur identified 193 countries. However, it is difficult from reviewing just the patents the economic benefits, if any, realized by the different countries named in the patents.

In Oldham et al.’s (2015) UK review, the most frequently cited species was Beta vulgaris L. (581 mentions of this species in the Title. Abstract or Claims section of a patent (TAC), reflecting the use of this species in many biotechnology patents. Aloe vera (L.) Burm.f. had a high number of patents (247 TAC) with claims related to uses in cosmetics, medicine, and food. For fungi, the most cited were Candida albicans (C.P. Robin) Berkhout (330 TAC) and Aspergillus brasiliensis Varga, Frisvad et Samson (263 TAC). This reflects the fact that C. albicans is a target fungus for anti-microbial testing and A. brasiliensis is frequently used in biotechnology systems as a source of enzymes for a wide range of industrial uses, including high-fructose syrups and wine clarification (Ong, Abd-Aziz, Noraini, Karim, & Hassan, 2004). This example illustrates a key problem with fungal searches based on the Latin names as without reading the full patent it is difficult to identify whether the named fungus is the source or the target for the invention. If one removes the names of potential target organisms from the number of patents, then the number of species studied for new uses decreases to a few thousand (Oldham et al., 2015). There are fewer in-depth studies on the patents held on fungi than plants. However, there are clear examples that show increased interest in fungi (Hyde et al., 2019). For example, Cerimi, Akkaya, Pohl, Schmidt, and Neubauer (2019) identified 47 patents (from 2009–2018) covering the use of 27 species of fungi with relevance to packaging, textile, leather, and automotive industries. Most patents relate to activities in the USA and China. The complexity and diversity of fungal chemistry, as well as their ability to survive in different environments justifies further research.

Efferth et al. (2016) undertook a PubMed search of biomedical manuscripts between 1960 and 2014 of life science journals at the US National Institute of Health that mentioned patents. Their search showed that since 2011, there were over 1,500 publications per year that mentioned patents, illustrating the importance of looking at the patentability of research into the production of medicines. They did not provide examples of the biodiversity being studied but, in their review they highlight the need for having scientists from both low-income (often biodiversity-rich) and high-income countries (often lower biodiversity) involved in the research—supporting greater ownership and knowledge about the patent process. A critical element is that the source country should collaborate, as an equal partner, in the supply and potential production of the leads that result from their biodiversity. This is, of course, easier to achieve with leads that still require the original genetic resources; it is not so easy to achieve when a synthetic compound is involved that is derived from a natural ingredient.

Case 5 provides an overview of the number of patents associated with some of the most economically important plants and fungi used in traditional Chinese medicine. These patents mostly cover new uses, new chemistry, or ways to standardize quality extracts and illustrate that patents need not negatively impact the traditional uses of plants.

For this review, we undertook a patent search using Espacenet (https://www.epo.org/index.html) to look at the number of applications for fungal and plant patents submitted in the last 10 years (2010 to 2019). We concentrated on fungal patents that were for food (4,573), medicine (2,519), environmental use (2,122), cosmetic products (2,066), and enzymes (1,242). Many food patents covered processing and were very similar, especially those from China and Russia and referred to the use of unnamed fungi, including yeasts. There were very few patents filed from biodiversity-rich countries in South America and Africa other than Brazil and South Africa, respectively. Overall, most patent applications came from China, South Korea, and the USA. A high proportion of the patents from China classified under the title “environment” related to the use of fungi in fertilizers and organic ways to improve crop yield. Some interesting patents based on innovation from academic research cover the use of the white-rot fungus Phanerochaete sordida (P.Karst.) J.Erikss. & Ryvarden to degrade neonicotinoid insecticides (Mori et al., 2017; Wang, Hirai, & Kawagishi, 2012; Wang et al., 2019) and another white-rot fungus, Flammulina velutipes (Curtis) Singer, that contains enzymes that can break down plant lignin to yield ethanol, thus producing biofuel from plant biomass (Maehara et al., 2013). Another patent relates to the isolation of alkaloids from the marine fungus in the genus Scopulariopsis Bainier for the treatment of Herpes Simplex Virus 1 (US2018028523A1).

The Espacenet search for plants used in food identified 10,617 patents, medicine (7,595), environmental use (3,311), cosmetics (2,941), and enzymes (1,301). A similar picture emerges for the plants as for the fungi: China, the USA, South Korea, and Japan...
dominated the countries filing patents. Patents covered the use of plants to produce vaccines such as lettuce for the expression of Hepatitis B vaccines (CN110229847A). A high number covered the brewing of different health drinks, such as watermelon fruit wine (CN107057965A) and litchi fruit wine (CN107057969A). Other patents included the use of wood tar in combination with a complex mixture of plants to produce insect repellents (CN105685102A). Examples of cosmetic patents include the use of Sonchus oleraceus L (KR101917711B1), and Rhamnus yoshinoi Makino (KR101883310B1) for use in cosmetics for anti-aging properties, Chamaecyparis obtusa (Siebold & Zucc.) Endl. for the control of odours (KR101914900B1) and a mixture of “murumuru butter, Acai berry extract and Inca Inchi oil” to increase hair shine (EP3395410A1).

6 | OVERVIEW OF PLANT BIODIVERSITY BEING PATENTED, AND THOSE SPECIES ALREADY KNOWN TO HAVE USES

The most complete overview of species of plants covered by patents is that reported by Oldham et al. (2013). We used this list to provide an overview of the distribution of patents among different plant families.
We first compared the list of plants collated by Oldham et al. (2013) with the accepted names and synonyms within Kew’s World Checklist of Vascular Plants (WCVP, 2020) and International Plant Names Index (IPNI, 2020). The number of species collated by Oldham et al. (2013) was 26,111 names and this was reduced to 21,395, since some were ambiguous and the list also included the same species several times under alternative scientific synonyms (Data S1). The challenges and consequences of this ambiguity and inconsistency in plant nomenclature for regulation, trade, and conservation was explored by Allkin et al. (2017). When this list of 21,395 species is compared to the list of 40,258 useful plant species compiled by Diazgranados et al. (2020), there is an overlap of just 12,908 species (32.1%). In contrast, 27,049 species (67.2%) from the plant-use database are not mentioned in the patent list. This suggests that many opportunities exist for innovation from plants reported to have uses, let alone over 300,000 species not recorded as having uses. However, when selecting species for study care should be taken to avoid endangered species covered by CITES (The Convention on International Trade in Endangered Species of Wild Fauna and Flora; https://www.cites.org) or locally threatened species, unless patents cover ways to support their sustainability.

Of those species already in commercial use there are opportunities for patents to cover new uses, as well as ways to increase yield or for their propagation. This is illustrated by Case 5 which provides an overview of economically important plants and fungi used in traditional Chinese medicine. Although primarily used medicinally these resources are now subject to patents as functional foods and cosmetics. When Oldham et al.’s (2013) list is compared with Kew’s Medicinal Plant Names Service database (MPNS, 2020) which catalogs 27,745 taxa (26,079 species and 1666 infraspecies), there is an overlap of only 8,829 species (23.3%). 18,916 (49.9%) species, recorded in MPNS to have a medicinal use, do not appear in Oldham’s list. This again indicates ample opportunities for innovation.

Of the 452 plant families, 368 have at least one species linked to a patent. The number of species from each family which are cited in one or more patents varies greatly (Figure 1). For example, families with the most species mentioned in patents are the Asteraceae with 1,445 species (4.5% of species), Fabaceae with 1,299 species (5.8%), Poaceae with 1,008 species (8.5%), and Rosaceae with 718 species (12.7%). Thus, within these diversity-rich families only a small proportion of species are cited in patents. Whether these families or less well-studied families would lead to more innovation is a hypothesis worth testing.

Kew’s nomenclatural and medicinal catalogs are not as comprehensive for fungi, preventing a similar analysis of fungal patents. A review of the uses of fungi in the State of the Worlds Fungi Report 2018 provides an overview of the diversity of fungi being used in food, medicine, and industry (Willis, 2018).

7 | CONCLUDING REMARKS

There are two clear outcomes from this review. First, only a narrow range of plants and fungi are currently subject to patents. For plants, if we use the data from the Oldham et al. (2013) report, this is 6.2% (21,395/347,298 = the revised number of plant species mentioned by Oldham et al./number of vascular plant species reported in WCVP (2020) and for fungi this is between 5.4% and about 0.4% (7918/148,000 = the number of fungi species mentioned by Oldham et al./ the number of named species of fungi (Species fungorum, 2020); or 7918/2.2 m = the number of fungi species mentioned by Oldham 2.2 m an estimate of the number of fungal species (Hawksworth & Lücking, 2017). Second, if countries are to increase the economic wealth derived from their biodiversity, it is important that they increase the research undertaken on these resources. This in turn will improve the opportunities for the discovery of attributes directly or indirectly associated with species that could be patented. However, it is critical to emphasize that patents are not the only route to successful commercialization; many species in trade today do not have associated patents, and factors such as value-adding, market access, and knowledge networks are often much more important attributes than patents (Wynberg, Silverston, & Lombard, 2009). It is also clear that there needs to be more support to enable current ABS policies to work. Patent agencies and those filing patents need to be more aware of the traditional uses of the genetic resource associated with the patents and the origin of these genetic resources. This also requires a legal obligation for those filing patents to disclose this information, alongside proof of appropriate benefit-sharing agreements. This disclosure requirement has been increasing adopted by countries, but agreement on an international approach remains stalled.

Currently, it is very difficult to map the economic benefits from the exploitation of a species of plant or fungi as a result of a patent. Value chain analysis would suggest that those involved in the supply of the raw material gain less that those involved in the production of the final product. However, communities in biodiverse-rich source countries could clearly benefit from commercialization of their genetic resources. If public and private research bodies are to invest in biodiversity research and the commercialization of products based on genetic resources, then those investing in the commercialization of any resulting patents need confidence that risks associated with ABS issues have been minimized. Source countries, in turn, need to be assured that this knowledge will be used to benefit both people and conservation in a fair and equitable manner.

7.1 | CASE STUDY 1. THE PATENTING OF TEFF

Ethiopia’s indigenous crop teff (Eragrostis tef (Zucc.) Trotter) was first domesticated in Ethiopia between 4,000 B.C.E. and 1,000 B.C.E. Teff is an Ethiopian ancient grain used to make injera, a spongy fermented flatbread that is a food staple of Ethiopian culture. A Dutch company Health and Performance Food International (HPFI) filed a patent application on the processing of teff flour and related products in the Netherlands in 2003 and via the European Patent Office (EPO) in 2004. They then signed an ABS agreement in 2005 with the Ethiopian Institute of Biodiversity Conservation, together
with the Ethiopian Agricultural Research Organisation (Andersen & Winge, 2012; Dalle, 2010). The teff patent was granted by EPO in 2007. According to Andersen and Winge (2012), "It was a pilot case of the implementation of the CBD in terms of ABS, and expectations were high. However, implementation of the agreement failed as HPFI was declared bankrupt in 2009." As part of the ABS agreement, HPFI was given access to teff varieties, with the right to use these varieties to produce a wide range of specified food and beverage products not traditional in Ethiopia. In return, the company was to share monetary and non-monetary benefits with Ethiopia. By the time HPFI was declared bankrupt, Ethiopia had received only EUR 4,000. However, prior to the bankruptcy, the HPFI directors had transferred IP to new companies. These companies continued to produce and sell teff flour and teff products, expanding their activities to other countries. The new companies are not party to the original agreement, and thus not bound by the obligations of HPFI toward Ethiopia, although they did operate under the same directors.

The patent also covers the milling of flour from these grains to a fine powder and then mixing with water to make a dough. These activities are common in Ethiopia and therefore lack novelty. The teff patent excludes all other parties, including Ethiopia, in utilizing teff for most forms of relevant production and marketing in the countries where the patent is granted. This marginalized Ethiopia from utilizing its own teff genetic resources. The teff patent created a monopoly that made it impossible for Ethiopia to enter into ABS agreements on teff with other companies in countries where the patent is valid, even after termination of the teff agreement. After delays, the Ethiopian Attorney General's Office announced in May 2018 that it was filing a case against those involved in the teff patent at the International Court of Arbitration in Paris. However, before the case was launched, the patent owners sued another Dutch company, Bakels, that had been marketing its own teff baked goods for patent infringement. The Dutch patent office declared that HPFI's patents were invalid in the Netherlands because they "lack inventiveness." This decision was upheld by the District Court in the Hague. However, the patents are still valid in Belgium, Germany, Austria, Italy, and the UK. Thus, although the patent dispute was between two Dutch companies, the ruling gives the Attorney General's Office of Ethiopia a good opportunity to claim and register the patent right on the use patenting of teff to the concerned international body.

This example illustrates a breakdown in the spirit of the original CBD that stakeholders in a country from which a genetic resource comes should have been involved in the initial patents and it also highlights a lack of rigor by the patent agents to have spotted prior art associated with the use of teff when the patent was filed.

8 | CASE STUDY 2. DEVELOPMENT OF A SOAP FROM MURUMURA

Since the 1990s, the Ashaninka Indians, of the Amonia River Kampa in the State of Acre (northern region of Brazil) have been involved in sustainable development projects. Through the partnership of the Ashaninka Apiwtxa Association with the Indigenous Research Centre (CPI), the Ashaninka Indians surveyed the native plant species for potential products based on their traditional knowledge. In 1996, a researcher hired by Ashaninka Apiwtxa and CPI, started a company Tawaya without indigenous participation and developed a soap from murumuru (Astrocaryum murumuru Mart.), a palm tree common in the Amazon region and used traditionally by the Ashaninka as a moisturizer and medicine (Pimenta & Moura, 2010).

In 2004, the company obtained the registration of murumuru soap in the Brazilian Health Regulatory Agency and began marketing the soap in early 2005. The soap marketing process was carried out without consulting the Ashaninka and without their participation (Pimenta & Moura, 2010).

In 2006, the Federal Public Ministry in Acre proceeded with a civil public lawsuit to investigate the improper use of the traditional knowledge by Tawaya (Pimenta & Moura, 2010). In 2019, the Genetic Heritage Management Council, based on the current 2015 Brazilian ABS legislation, Law nº 13,123, ruled in favor of the Ashaninka people. They ruled that the Tawaya company made improper use of traditional knowledge of the indigenous people in the manufacture of murumuru soap and for not sharing the benefits with the indigenous community. The company will have to pay a R $ 5 million fine.

9 | CASE STUDY 3. PATENTS FILED ON ANDIROBA

Patents filed on two species of plants known collectively as andiroba (Carapa guianensis Aubl.) from Central America and the Northern parts of South America and Carapa procera DC from West Tropical Africa to the Central African Republic and also occurring in the Northern parts of South America (http://www.plantsoftthe-worldonline.org/) serve to illustrate the importance of making sure a patent is not based on prior art. Between 1990 and 2011, 114 patents were filed on andiroba, of which only nine were granted (Amaral & Fierro, 2013). Most were rejected as they were based on traditional knowledge and there was no innovation in the patent. Looking at what was covered by these patents and who was filing them provides an insight into the international interest in these species. Most applications covered the composition of an extract or oil from the seeds of andiroba, often combined with other materials for a range of uses, including medicinal and dental as well as toiletry, pest repellent and biocide products—uses to which there are prior art claims. The highest number of patents were filed in Brazil (19) followed by France (9). Where, a patent is filed often indicates where the first primary interest/market is. In Brazil, most patents were filed by individuals rather than companies and it is not clear from the patents what involvement, if any, local communities had in the background work associated with the patent. It is of interest that within Brazil the greater number of applications were concentrated in the regions of major research centers in the Southeast, whereas few were from the Northern regions. Amaral and Fierro (2013) suggest that this highlights a need to help facilitate research in the Northern regions of Brazil, that have the greatest biodiversity, in ways that help them in the commercialization of their resources.
The first, and perhaps best known, case was that of the succulent *Hoodia gordonii* (Masson) Sweet ex Decne., long used traditionally as a mood enhancer, were patented in 2000 by researchers after they obtained medicinal knowledge and assistance from Nama-speaking traditional healers. The prior informed consent of knowledge holders was not obtained prior to patent registration. Later on, however, the patent holder HGH pharmaceuticals acknowledged the San as being the "primary knowledge holders" of the traditional knowledge, and entered into a benefit-sharing agreement to pay royalties to the San and to the villages from where the knowledge was obtained (Chennells, 2013).

**TOPICS**

### 10 | CASE STUDY 4. SOUTH AFRICA EXAMPLES OF PATENTS

South Africa is the third most biodiverse country in the world, with some 22,000 plant species (https://www.sa-venues.com/plant-life/) and 1,160 fungal species (Kinge, Goldman, Jacobs, Ndiritu, & Gryzenhout, 2020) identified. It has also been at the global forefront of regulating access and benefit sharing (Crouch, Douwes, Wolfson, Smith, & Edwards, 2008; Wynberg, 2018). Over the past 20 years a suite of benefit-sharing agreements has been negotiated, many triggered by the lodging of patents—and associated disregard of traditional knowledge.

The first, and perhaps best known, case was that of the succulent *Hoodia gordonii* (Masson) Sweet ex Decne., long used to stave off hunger and thirst by the indigenous San, the oldest—and most marginalized—human inhabitants of Africa (Deacon & Deacon, 1999). The active ingredients of the plant were patented in 1998 by the South African-based Council for Scientific and Industrial Research (CSIR) for the purpose of developing anti-obesity products (Wynberg & Chennells, 2009). This was done without the consent or knowledge of indigenous San. The CSIR was subsequently forced to negotiate with the South African San Council, which in turn led to a benefit-sharing agreement in 2003. Because *Hoodia* occurs across the region, the agreement took into account the need to benefit indigenous San in Namibia, Botswana, and Angola.

Properties of the succulent *Mesembryanthemum tortuosum* L. (=*Sceletium tortuosum* (L.) N.E. Br.), used traditionally as a mood enhancer, were patented in 2000 by researchers after they obtained medicinal knowledge and assistance from Nama-speaking traditional healers. The prior informed consent of knowledge holders was not obtained prior to patent registration. Later on, however, the patent holder HGH pharmaceuticals acknowledged the San as being the "primary knowledge holders" of the traditional knowledge, and entered into a benefit-sharing agreement to pay royalties to the San and to the villages from where the knowledge was obtained (Chennells, 2013).

### TABLE 1  Top species exported from China in 2017 that are used in Traditional Chinese medicines (TCM)a

| Name of TCM | Botanical names | Exported quantity (Tonne) | Export values (million USD) | Prices USD/kg | No of patent publicationsb |
|-------------|----------------|--------------------------|-----------------------------|--------------|---------------------------|
| 1 人参       | Panax ginseng C.A.Mey. | 2,177.7 | 112.9 | 51.84 | 757 |
| 2 枸杞子     | Lycium barbarum L. | 12,670.9 | 101.7 | 8.03  | 137 |
| 3 肉桂,肉桂花 | *Cinnamomum cassia* (L.) J.Presl | 50,410.5 | 94.7 | 1.88  | (134) |
| 4 红枣        | Ziziphus jujube Mill. | 9,886.1 | 33.4 | 3.37  | 7 |
| 5 茯苓        | *Wolfiporia extensa* (Peck) Ginnrs (syn. Poria cocos) | 6,436.5 | 29.2 | 4.53  | 179 |
| 6 冬虫夏草    | *Ophiocordyceps sinensis* (Berk.) G.H.Sung, J.M.Sung, H.Hywel-Jones & Spatafora | 1.0 | 27.8 | 27,599.70 | 123 |
| 7 半夏     | Pinellia ternata (Thunb.) Makino | 3,016.4 | 27.4 | 9.09  | 43 |
| 8 当归     | Angelica sinensis (Oliv.) Diels | 2,724.0 | 25.4 | 9.32  | 230 |
| 9 党参     | Codonopsis pilosula subsp. tangshen (Oliv.) D.Y.Hong | 3,452.5 | 23.9 | 6.94  | 83 |
| 10 西洋参    | *Panax quinquefolius* L. | 665.5 | 22.9 | 34.37 | 274 |
| 11 菊花     | Scutellaria baicalensis (Ramat.) Georgi | 4,362.3 | 21.2 | 4.86  | 62 |
| 12 黄芪     | *Astragalus propinquus* Schischkin (syn. *Astragalus membranaceus* Fisch.) | 3,376.7 | 20.6 | 6.10  | 388 |
| 13 甘草     | *Rehmannia glutinosa* (Gaertn.) DC. | 6,829.9 | 19.6 | 2.88  | 168 |
| 14 黄连     | *Scutellaria baicalensis* Georgi | 3,272.8 | 13.1 | 4.02  | 353 |
| 15 黄芩     | *Codonopsis pilosula* subsp. tangshen (Oliv.) D.Y.Hong | 3,452.5 | 23.9 | 6.94  | 83 |
| 16 山药     | *Paeonia lactiflora* Pall. | 4,675.3 | 14.8 | 3.15  | 166 |
| 17 白术     | *Atractylodes macrocephala* Koidz. | 3,908.4 | 16.9 | 4.33  | 71 |
| 18 白芍     | *Glycyrrhiza uralensis* Fisch. ex DC. | 2,549.2 | 15.9 | 6.25  | 295 |
| 19 半夏     | *Astragalus membranaceus* Fisch.) | 6,103.6 | 17.7 | 3.85  | 7 |
| 20 当归     | *Astragalus membranaceus* Fisch. | 6,829.9 | 19.6 | 2.88  | 168 |

### Notes:

a Data obtained from Department of Market Order and Ministry of Commerce of the People's Republic of China (2018).
b The number of patent publications that the species appear in from 1976 to 2010 data from Oldham et al. (2013).
c *C. cassia* is the species used in TCM. However, sometimes publications do not differentiate between *C. cassia* and *C. verum* J.Presl. In the Oldham et al. (2013) list the only species of *Cinnamomum* mentioned is *C. verum*. It is possible that some of the 134 patent publications cited in Oldham et al. (2013) refer to *C. cassia*. That is why the number is in brackets.
In the case of Pelargonium sidoides DC., a plant that occurs across the eastern part of South Africa and in Lesotho, pharmaceutical company Schwabe lodged several patents related to the plant’s use for treating upper respiratory infections. This led to accusations of “biopiracy” (ACB, 2008) and a patent challenge was brought by NGOs and Schwabe competitors objecting to the patent on the conventional grounds of lack of novelty, lack of inventive step, and insufficiency. Although the biopiracy arguments were rejected by the EPO, the patent was later revoked for lack of an inventive step.

Finally, the endemic rooibos plant (Aspalathus linearis (Burm.f.) R.Dahlgren) reveals how sometimes the patent and innovation landscape may be overlooked in the wider quest for justice. Since 2010, indigenous San and Khoi organizations have demanded that the 100-year-old rooibos industry recognize the role that their traditional knowledge played in its development (Wynberg, 2017). This led to the conclusion of a benefit-sharing agreement in 2019. However, little attention has been given by the government to the surge of interest in the plant’s biochemical and health properties. Much of this research is linked to more than 140 foreign patents. While many might be commercially dormant, they raise questions about how material was accessed and compliance with South Africa’s Biodiversity Act.

## 11 | CASE STUDY 5. VALUE AND PATENTS ON KEY PLANTS AND FUNGI USED IN TRADITIONAL CHINESE MEDICINE

Plants and fungi used in traditional Chinese medicines (TCM) are of economic importance to China. Table 1 provides a list of the top 19 species of plants and fungi used in TCM that are exported internationally, the volumes exported and the value. Added to this Table is the number of patents associated with each species as reported by Oldham et al. (2013). In contrast, to the patents discussed in Case studies 1–4, this case study is provided to illustrate that plants and fungi with a well-documented history of use can still generate a high number of patents. These patents do not restrict those using the plants and fungi traditionally. Prior art of the plants and fungi is also well documented in Chinese Pharmacopoeia and Materia Medica available to patent agencies when checking for innovation.

These patents illustrate the commercial interest in these resources. For example, patents for Panax ginseng C.A. Mey. include new methods to process the material (EP1467627B1) that can impact efficacy, whereas Rajabian, Rameshrad, and Hosseinzadeh (2019) provides a review of the patents that cover the use of P. ginseng for the treatment of different neurodegenerative diseases. Within China, they are encouraging the use of their resources and are looking at ways to cultivate the resources so that increased use does not result in over-harvesting of wild-harvested material as demand increased. This is especially true for high value material such as the fungus Ophiocordyceps sinensis (Berk.) G.H.Sung, J.M.Sung, Hywel-Jones & Spatafora. Hopping, Chignell, and Lambin (2018) reviewed the data on the availability of O. sinensis and showed that supply is negatively impacted by both over harvesting but also by climate change. Patents US8008060B2 and CN102550300A cover different methods of growing the fungus in artificial conditions that result in material with a similar chemical composition to wild harvested material. Other patents relate to non-medical uses, for example, Nestlé S.A. and L’Oréal S.A. are sharing a cosmetic patent using Lycium barbarum L. fruit extract as an agent to restore skin tone and firmness (ES2523853T3). A Korean patent with Codonopsis pilosula (Oliv.) D.Y.Hong as the active ingredient claims to control insects (KR2019005701A).

## ACKNOWLEDGEMENTS

The authors and trustees of the Royal Botanic Gardens, Kew and the Kew Foundation thank the Sfumato Foundation for generously funding the State of the World’s Plants and Fungi project. Thanks, are also given to the anonymous reviewers who helped guide the revision of the manuscript.

## AUTHORS’ CONTRIBUTIONS

M.S.J.S. planned the research, carried out the literature review and with contributions from R.F., L.W., R.W., M.daS., R.A., and S.D. wrote the text. E.B. analyzed data about plant names, F.F. the plant phylogeny analysis, B.G.Z., J.S.L., and Y.D.Q. contributed to Case study 5.

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