Journal of Intellectual Property Rights
Vol 31, September 2026, pp. 815-825
DOI: 10.56042/jipr.v31i5.23383

Legislating in the Grey: Seaweeds, Definitional Uncertainty, and Plant Variety Protection in India

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Received: 6th September 2025; revised: 4th February 2026

India and several other countries are now investing towards aquaculture, and even experimenting with more cultivation based on marine aquaculture, specifically seaweeds. There are several usages in several different industries, such as food, skincare, pharmaceuticals, etc. This boom in seaweed cultivation poses a question as to whether new cultivated varieties of seaweed would have similar protection as terrestrial plants. The paper delves into the definitional uncertainty regarding aquatic plants under the Plant Variety Protection Act, specifically seaweed, as they are technically algae, not plants. The paper looks towards Eastern countries and how they have a broader definition of plant variety to accommodate more varieties of plants. The paper suggests more definitional clarity as well as certain administrative measures for ease of plant variety protection of seaweeds.

Keywords: Plant Variety Protection, Seaweeds, India, Legislative Approach

Nearly 2000 years ago, the Roman poet Virgil wrote, "*Nihil Vilior Alga*," meaning that nothing is more worthless than seaweed.[1] Ironically, in 2022, the Food and Agriculture Organisation published a report stating that the world had produced 37.8 million tonnes of algae for consumption.[2] The numbers are set to increase, as the United Nations has declared the 2021–2030 decade as the *Decade of Ocean Science for Sustainable Development*, under which sustainable nourishment from oceanic resources is an agenda item.[3] Countries such as China, Indonesia, and South Korea have become the largest producers of seaweed, making it a 16.5-billion-dollar (US) industry. This rising global emphasis on seaweed is not incidental; it is rooted in the recognition of its vast potential across multiple domains. Seaweed has long been acknowledged as a versatile bioproduct, with applications spanning agriculture, food processing, medicine, and industrial biotechnology. The scientific community, even decades ago, recognised seaweed as a sustainable, renewable marine biomass with high productivity and biochemical richness, making it an attractive resource for countries seeking both ecological and economic benefits.[4] It is being utilised in five major industries: food, drugs, chemicals, fertilisers, and gums. This, however, is not the end; even the skincare and makeup industries are now reliant on seaweed and seaweed derivatives, generating up to 190 million dollars (US) in revenue at the moment, and this is set to almost double in the next 5 years.[5]

Seaweed, traditionally a staple in certain cuisines, has transcended its humble origins to become a significant driver across sectors ranging from food and beverage to health and wellness, where its bioactive compounds are being explored for pharmaceutical and nutraceutical applications.[6] Furthermore, seaweed plays a crucial role in environmental solutions, particularly in bioremediation efforts. This multifaceted utility has led to a notable increase in research, development, and intellectual property (IP) filings globally, with a significant concentration in Asian countries such as China, South Korea, and Japan.[7]

The world's major producers and consumers of seaweed are currently China, Japan, and South Korea; these East Asian nations cumulatively account for nearly 90 per cent of global algae production. These countries also benefit from extensive and viable coastlines for seaweed farming: China possesses over 32,000 km of coastline, South Korea around 14,000 km, and Japan approximately 29,751 km, all of which offer favourable environmental conditions and existing infrastructure to support large-scale aquaculture. China has invested millions of yuan in producing higher-quality seaweed, subsidising farmers, and funding research on cultivation methods. Japan and South

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Korea have also invested in the algae production market. South Korea's seaweed industry is propelled by robust government support, which includes direct subsidies, infrastructure investment, and dedicated policies to expand aquaculture and maintain competitiveness.[8] The Ministry of Oceans and Fisheries plans to increase seaweed farming area by 1% in 2026, backed by supplementary budgets targeting both expansion and modernisation, such as upgrading drying equipment and advancing disease management to address challenges like rising sea temperatures and illegal farming. This comprehensive public support is coupled with a focus on research and technological innovation, including selective breeding for disease resistance and the integration of automation and artificial intelligence to optimise farming efficiency. Long-term initiatives, such as the Aquaculture Disaster Insurance program and efforts to transition to eco-friendly cultivation practices, reinforce industry resilience against environmental and market fluctuations. The results of these strategies are evident in South Korea's global leadership in seaweed production and exports. Annual output has surged (over 1.7 million tonnes), and exports of products like *gim* (dried seaweed) have consistently broken records, surpassing 1 trillion won in revenue for consecutive years.[9] Government-backed research and education ensure consistent quality, while increasing demand for seaweed-based foods and nutraceuticals at home and abroad drives market expansion and encourages sustainability.[10] The country's approach blends industrial policy with a commitment to ecological stewardship, positioning seaweed as both an economic powerhouse for coastal communities and a strategic resource for adaptation and mitigation in the face of climate change.[11]

India, with a coastline of 7,517 km, has also begun to assert itself in the aquaculture sector. The Indian government has increasingly promoted seaweed cultivation to strengthen the fisheries sector, support coastal livelihoods, and advance the broader objectives of the blue economy. Initiatives such as the *Pradhan Mantri Matsya Sampada Yojana* (PMMSY) underscore this commitment by allocating significant funds for the development of seaweed cultivation across coastal states and research institutions. This policy invested ₹20,050 crore to boost the fisheries sector. Seaweed farming is a key focus under this scheme. The government has allocated a total budget of ₹640 crores for seaweed cultivation in India from 2020 to 2025 to boost the seaweed industry, promote sustainability, and increase production to 1.12 million tonnes over the next five years. The budget also focuses on building infrastructure for further production, including the establishment of a Multipurpose Seaweed Park in Tamil Nadu and the development of a Seaweed Brood Bank in Daman and Diu. So far, 46,095 rafts and 65,330 monocline tube nets have been approved for seaweed farming. The Kori Creek Pilot Project in Gujarat focuses on developing new seaweed varieties. The project at Kori and Padala Creeks, undertaken by ICAR-CMFRI (Central Marine Fisheries Research Institute), is set to commence harvesting in the financial year 2025-26, with a target of 25,000 tons per year.[12] Since the native variety of seaweed is not beneficial enough, the government of India has also decided to import varieties of seaweed. These numbers show that in the Asian world, seaweed production is at an all-time high and set to grow further.[13] Therefore, the need to produce better, more sustainable, and more cost-effective seaweed varieties that are stronger and more suitable for use is being considered worldwide. Countries are deploying significant financial resources to develop or import new seaweed varieties into their territorial waters.

Seaweed farming in some parts of the world is almost a thousand-year-old practice. In the Western World, Ireland is an example of a place where seaweed harvesting, and traditional use have deep historical roots. Historical studies show that while most practices were small-scale and localised along the coast, they provide early evidence of intentional human management of seaweed resources, a precursor to controlled cultivation. Guiry & Morrison have reported that both drift and attached seaweeds, primarily kelps and wracks, were gathered along the Irish coast for centuries, dating back to Neolithic times, to supplement impoverished soils and serve as food and animal feed.[14] In the 18th and 19th centuries, kelp was harvested and burnt in kelp kilns, a significant industry for producing kelp ash used as fertiliser, in glassmaking, soap manufacturing, and as a source of iodine.[15]Moreover, medieval records suggest that monastic communities harvested seaweed over 1,000 years ago as part of their diet and subsistence strategy, illustrating an early, organised relationship with marine biomass. In the broader context, widespread historical use of seaweed as fertiliser and livestock fodder across coastal Atlantic Europe, including Ireland, is well documented. This lays the groundwork for thinking about how seaweed

might be scaled up under modern farming regimes rather than merely wild collection. The transition from opportunistic coastal gathering to structured, rope-based cultivation, as has happened elsewhere, rests on this legacy and the recognition of seaweed's multipurpose utility in food, soil health, industry, and increasingly, biotech.

In this backdrop, on the one hand, we have an increased global aquaculture thrust, and, second, seaweed is not only found and harvested from the open ocean but also cultivated by farmers, including the development of new varieties. Historically, seaweed was harvested; now it is produced, and therefore constitutes intellectual property. The question of intellectual property over life forms presents unique challenges due to ethical considerations about ownership of life and its limits, and because it deviates from traditional forms of intellectual property, which, even though they focus on intangible property, still treat inanimate creations as property. As per WIPO Patentscope, there have been 16,880 patents filed for seaweed-related technology, seaweed derivatives, and extracts of seaweed. China leads the field with approximately 9,000 patent filings, followed by Japan and South Korea in second and third place, respectively. These patent filings are not just for seaweeds; they also cover machines for harvesting seaweed, seaweed-based fertilisers, drugs, and other derivative products.[16] In this year (2025) alone, there have been 121 filings about seaweed internationally. Indians have also demonstrated a growing interest in seaweed-based technologies as reflected in their intellectual property filings. As of the most recent data, 94 seaweed-related patent applications were published in India from 2001 to 2025, with the majority (65) focused on value addition. However, only 16 patents were granted over this period, spanning biotechnology, food, pharmaceuticals, and biopolymers. In comparison to patents, trademarks specifically for seaweed products in India exist but are fewer in number, with some filings for food, nutraceuticals, and agricultural derivatives under relevant trademark classes.[17] Copyright registrations for seaweed-related innovations are rare because Indian copyright law primarily applies to artistic, literary, or branding content, rather than biotechnological inventions or processes. This shows that a seaweed-based monopoly is not an absurd or concocted figment of imagination but a reality.

Intellectual Property in Seaweed is a reality; therefore, it must be considered how to protect it. When it comes to life forms, there are two ways in which intellectual property in seaweed varieties can be protected: one is patent law, and the other is plant variety law. Patent laws were developed to address mechanical inventions and are therefore not suitable for life-forms, which, even though they appear similar, can exhibit wide variations. Further, plants / plant-like organisms cannot be precisely written description, and traditional plant breeding techniques did not qualify as inventive enough for patent protection.[18] Moreover, Patenting of life-forms in India comes under the broad exclusion of Section 3(j) of the Patent Act, which excludes ….

> *"Plants, and animals in whole or any part thereof other than microorganisms but including seeds, varieties, and species, and essentially biological processes …*"

This position on the exclusion of patents as a viable form of intellectual property protection will be further clarified in the next section on the basis of the nature of seaweeds. This paper focuses on how seaweeds can be protected within plant variety laws, the challenges that arise and the gaps in the law in India. The authors argue, first, that there is variation in whether seaweeds are considered plants under the legal taxonomy, and second, that this variation in definition poses legislative and other challenges for protecting seaweeds. The authors are keenly aware of the challenges regarding the sustainable use and protection of marine resources, but the environmental and sustainability challenges are beyond the scope of this paper at present.

The first part of the paper deals with why plant variety is the only suitable law for the protection of created seaweed varieties. This can only be discussed once the nature of the seaweed is known and any alternative intellectual property protection can be discarded. The next section deals with the nature to further this argument.

The Nature of Seaweed

The first issue to tackle when it comes to intellectual property protection of seaweed is to classify it in law. Seaweed is essentially a macroalgae, predominantly red, green and brown. Their classification is based on the distinct pigments present in their structures. Although they are photosynthetic organisms that can produce their own

food using light, they differ from terrestrial plants by lacking true roots, stems, and leaves. Instead, they often possess specialised structures, such as holdfasts for attachment to solid substrates or may float freely in marine environments.[19] While scientific classification distinguishes macroalgae from vascular plants, common dictionary definitions frequently do not recognise this gap, broadly classifying seaweed as a form of 'plant'. For example, Merriam-Webster defines seaweed as "any of various aquatic and chiefly marine brown, red, or green algae... a plant growing in the sea." Oxford Learners Dictionary also aligns with this perspective, defining seaweed as "a plant that grows in the ocean or on rocks at the edge of the ocean". This common linguistic usage provides a foundational basis for legal interpretations that may group algae within the broader category of "plants" for intellectual property purposes, beyond the scope of patents. Further, they are macroscopic, meaning they do not fall within the microscopic organisms that can be patented.

The three main groups of macroalgae, Phaeophytes (brown seaweeds), Rhodophytes (red seaweeds), and Chlorophytes (green seaweeds), exhibit diverse evolutionary histories and biochemical compositions. For instance, Rhodophytes constitute the largest group of marine macroalgae, encompassing over 6,200 known species. These different groups are adapted to varying light conditions: green seaweeds typically thrive in shallower waters, while red and brown seaweeds, with darker pigments, are adapted to deeper aquatic environments.[20] Aside from the wide variation among seaweeds as a whole, three common elements emerge: they are aquatic (freshwater/marine), macroscopic, and plants. This determination sets the tone for the type of intellectual property protection.

Key Challenges in the Intellectual Property Regime

There is only one sustainable approach to intellectual property protection for Seaweeds: the plant variety protection mechanism. Keeping in mind the definition of seaweed above, it therefore becomes imperative to discuss the key aspects of whether the current statutes, as they are, can include seaweed varieties. To get to that part, an overview of the plant variety protection system worldwide is necessary.

Plant Variety

The roots of plant variety protection trace back to Gregor Mendel, whose 19th-century experiments with pea plants laid the foundation for the field of plant genetics. Mendel's laws of inheritance showed that traits could be passed from parent plants to their offspring in predictable patterns, laying the foundation for the development of varieties.[21] Later, in the early 20th century, breeders like Luther Burbank's work were influential in demonstrating the potential of controlled hybridisation and selection and Stark Brothers, whose cultivation of varieties such as 'Delicious' applesemerged through selective breeding to meet commercial and consumer preferences.[22] These breeding efforts were motivated not just by scientific curiosity but by the desire to produce uniform, high-yield, disease-resistant, and appealing crops that could dominate agricultural markets.[23] This led to the growth of specific intellectual property laws for plants. In 1930, the United States introduced the Plant Patent Act, which allowed inventors to patent *asexually reproduced (cloned) plant varieties*, such as roses or fruit trees. With advances in agricultural breeding and the growing reliance on seed-propagated crops, the U.S. enacted the Plant Variety Protection Act (PVPA) in 1970 to protect *sexually reproduced* and *tuber-propagated* plants. PVPA certificates required that plant varieties meet the internationally accepted criteria of novelty, distinctness, uniformity, and stability (NDUS). Crucially, the PVPA included provisions for a breeder's exemption, allowing others to use protected varieties for further breeding, and a farmer's exemption, permitting seed-saving for personal use, balancing private innovation with public interest and traditional agricultural practices. They further brought in utility patents to cover plants not covered by either of the above. This tripartite system of plant patents, PVPA, and utility patents makes the U.S. one of the most comprehensive jurisdictions for plant-related intellectual property.

Similarly, in Europe, economic interests drove the demand for exclusive rights to control the production and sale of their varieties, not only to recoup research investments but to secure a competitive edge in the global agricultural market. This led to the establishment of systems like the UPOV Convention (International Union for the Protection of New Varieties of Plants), which formalised the recognition of plant breeders' rights and defined the criteria of distinctness, uniformity, and stability (NDUS) for protected varieties. The convention does not discriminate between sexually and asexually reproducing plants, but rather bases protection on characteristics. Europe has centred itself around a *sui generis* system aligned with UPOV. The modern regime

of international intellectual property stems from the TRIPS Agreement. Article 27.3(b) of the TRIPS Agreement requires WTO members to provide plant variety protection either through patents or an "*effective sui generis system*," prompting widespread adoption of UPOV-type regimes. The European Union responded by establishing the Community Plant Variety Office (CPVO) in 1995, which grants Community Plant Variety Rights (CPVRs) enforceable across all EU member states. Like the PVPA, CPVRs rely on DUS testing and grant exclusive commercial rights for 25 years, extendable to 30 years for certain species, such as trees and vines. A hallmark of the European system is the strong breeder's exemption, allowing protected varieties to be freely used for the development of new ones. This ensures that plant breeding remains dynamic, innovative, and open to competition. However, Europe has had to grapple with tensions between plant variety rights and patent law, especially concerning biotechnological inventions.

Under the TRIPS regime, India has opted for a *sui generis* system of protection, as provided by the Protection of Plant Varieties and Farmers' Rights Act, 2001 and the rules and regulations therein, based on the Novelty, Distinctiveness, Uniformity, Stability criteria, in line with and in conformity with the UPOV.

The international scenario, therefore, demonstrates how plants, once a common resource, have become subject to exclusive rights regimes, driven by both the goal of improving agriculture and the economic incentive to protect innovation. This shift reflects increasing complexity. On one hand, intellectual property protection is crucial for encouraging investment in agricultural research, especially given the need for climate-resilient crops and global food security. On the other hand, critics argue that overprotection and monopolisation, especially via utility patents, can undermine public interest, restrict breeding freedom, and increase dependency on a few large firms. The challenge is to ensure that intellectual property serves not only commercial interests but also the broader goals of sustainability, inclusivity, and innovation in agriculture. This next phase is the one being discussed here regarding the viability of protecting seaweed varieties under plant variety protection laws.

Definitional Issues with Plant variety, variety and Cultivars

The paper in the previous sections focused on what seaweed is and then on the origin of the plant variety system; this section focuses on which varieties can be protected. A plant variety refers to a *specific, distinguishable group of plants within the same species* that share a set of consistent and heritable characteristics, such as shape, colour, resistance to pests, or yield capacity. These characteristics set them apart from other varieties and remain stable through successive generations, which is central to agricultural innovation, plant breeding, and, more recently, intellectual property law.[24] This section focuses on two key elements: the definition of "variety" in the international legal nomenclature, and the definition of "plant".

Plant Variety is protected by law, but variety is not a scientific term per se; botanical taxonomy is not in complete agreement on what lies below the species level, and it can be sub-species, forma, cultivars, varieties, etc.[25]In taxonomy, a "variety" (or *varietas*) is a formally ranked category below the species and subspecies levels, used sparingly and primarily in botanical nomenclature, not necessarily tied to commercial traits or agricultural performance. The word 'variety' used in *legal taxonomy* has no traceable historical origin, nor does any legal document establish a cohesive logic for what constitutes a variety or a correlation to scientific taxonomy, which can lead to multiple issues in legal interpretation. Common usage suggests 'variety' to be different from 'cultivars', and yet legal texts do not actually refer to this difference, even though logically 'variety' can be both cultivated and wild, while 'cultivars' are the actual focus of intellectual property laws, as they have human intervention.[26] Further, the definition in international law seems to be centred around "plant grouping within a single botanical taxon of the *lowest known rank*",[27] but nomenclature differences can exist; in different territories, a subspecies in one, can be a cultivar in another and a variety in the third, while science would recognise them all maybe same/maybe differently, in law they might be different, and can lead to different results of protection in different territories. However, this legal definition often does not align with how taxonomists and marine biologists classify organisms in scientific terms. In the case of seaweed, which belongs largely to marine algae, the mismatch becomes more pronounced. Seaweeds do not always conform to the reproductive patterns, phenotypic traits, or genetic stability expected under the PVP definition of a "variety". Many seaweed populations display high phenotypic plasticity, meaning they can alter their

form in response to environmental conditions, making it difficult to demonstrate the required uniformity and stability.[28] Moreover, asexual reproduction methods common in terrestrial crops may not be applicable or may work very differently in seaweeds, which often have complex life cycles involving alternation of generations or fragmentation-based propagation.

Secondly, the term "plant" itself remains undefined in law. The original focus of UPOV was on commercially bred, seed-reproduced, and agriculturally significant terrestrial species, which were the mainstay of breeding activity and food systems in the mid-20th century.[29]Therefore, there was no requirement to precisely define a plant. However, modern agriculture challenges this; for example, mushrooms are scientifically classified as fungi and are also foraged, as are lichens and aquatic plants such as foxnuts.[30] None of these fit into the traditional category of plants, and therefore, a legal definition is required. The legal silence on what constitutes a "plant" creates conceptual and regulatory ambiguities, particularly as the scope of plant variety protection has expanded beyond traditional terrestrial crops to encompass a wider spectrum of life forms, including fungi and algae.[31]

The 1961 Act of UPOV, under Article 3, provided that plant variety protection would be granted only to those genera and species that were listed by each member state. This reflected the agricultural priorities of the time, where a fixed Annexe (Annexe I) categorised "obligatory" and "optional" species for protection. These mostly included staple crops such as wheat, rice, and maize, as well as key horticultural varieties like apples and roses. The rationale was firmly rooted in commercial agriculture, with an assumption that innovation and breeding were largely confined to these sectors.[32] This orientation made sense in a post-war context where national food security and commercial breeding industries focused almost exclusively on land-based crops and fruiting plants.

However, by the time the 1991 Act of UPOV was adopted, the structure of protection had shifted dramatically. The fixed list of genera/species was removed, and Article 3 of the 1991 Act instead required member states to progressively expand protection to all plant genera and species, with full coverage expected within ten years of joining. This expansion was driven by the increasing recognition of the value of diverse breeding work not only in major crops but also in vines, ornamentals, forages, and niche species. Still, despite the broadened scope, the Convention did not address the definitional question of what counts as a "plant" from a biological or taxonomic standpoint. This has opened the door for legal uncertainty, especially in cases involving organisms at the margins of plant taxonomy, such as algae or fungi.

The absence of a clear definition becomes more problematic when considering organisms like seaweed, which is typically grouped under algae, a polyphyletic group that is not part of the true plant kingdom under modern taxonomy. Some UPOV members, however, have taken independent steps. UPOV internal working documents and member guidance have acknowledged *that some national laws extend plant variety protection to "plants/fungi" or "plants/algae", depending on their own legislative interpretation.* For example, some jurisdictions include economically valuable organisms, such as mushrooms or seaweeds, within the scope of plant variety protection due to their agricultural or industrial relevance, even if they are not strictly considered plants.

In this context, a UPOV working group has issued a document suggesting that member states be allowed *to adopt their own terminology for coverage*, whether "plants", "plants and fungi", or "plants and algae", to ensure national alignment with breeding practices and regulatory goals. Importantly, the document emphasises that denomination systems (i.e., naming of varieties) should follow consistent, transparent rules regardless of the genus or species involved.[33] A list compiling different denominational practices across countries, such as reliance on the International Code of Nomenclature for algae, fungi, and plants (ICNAP) or distinct local practices, strengthens the case for a more inclusive, harmonised global understanding of plant variety protection. However, the formal status of this UPOV document remains unclear; it may still be in the discussion stages or not yet adopted, potentially due to opposition or differing views among member states regarding the expansion of definitions and classifications.

Further complicating the issue is that both UPOV and TRIPS (Article 27.3(b)) defer to member states in establishing *sui generis* systems for the protection of plant varieties. This means that while TRIPS mandates "effective" protection, it does not prescribe specific taxonomic limitations, giving members some

latitude to define "plant varieties" in ways that reflect their agricultural and ecological realities. As a result, the scope of protected organisms can vary significantly across jurisdictions. Some countries, especially those with robust aquaculture sectors, may wish to include seaweed under plant variety regimes for economic reasons, despite the biological tension this creates with traditional plant-based definitions.[34]Unless explicitly clarified by amendments to the Convention or binding interpretation, this flexibility may lead to the fragmentation of national approaches and to potential disputes over eligibility and enforcement. A comprehensive approach that accounts for scientific taxonomy, breeding practice, and economic use will be essential if plant variety protection is to remain relevant and equitable in a rapidly diversifying biological landscape.

This terminological divergence raises a broader question about whether PVP systems, designed around terrestrial, seed-based agriculture, are suitable for marine bioresources, such as seaweed. For instance, should a newly cultivated strain of *Kappaphycus alvarezii* (a commercially valuable red seaweed) that differs in growth rate or carrageenan content be eligible for plant variety protection, even if it cannot meet the DUS criteria strictly due to ecological variability? These scientific and legal mismatches risk either excluding valuable aquatic innovations from IP protection or forcing them into inappropriate frameworks that do not reflect their biological realities. Thus, aligning the terminology and criteria of plant variety law with scientific taxonomy, especially for non-traditional species such as seaweed, is essential to ensure fair, effective, and scientifically grounded regulation.

The original intent behind the establishment of Plant Variety Protection (PVP) under frameworks like the UPOV Convention (1961) was firmly rooted in the context of terrestrial agriculture. The concept of a plant variety was developed primarily to protect the intellectual and commercial interests of breeders of food crops, fruit-bearing plants, and ornamentals. These were typically land-based, seed- or tuber-propagated species that could be bred for traits like disease resistance, higher yield, uniformity, and market appeal. Even as the UPOV system evolved, including through the 1991 Act, the expansion of eligible species was primarily designed to encompass a wider range of commercial terrestrial crops, such as vines, forages, shrubs, and root vegetables. There was no explicit contemplation or inclusion of aquatic plants, fungi, or non-traditional organisms, such as seaweed, in these early protection schemes. The focus was overwhelmingly on plants relevant to global food security and commercial agriculture namely, cereals, vegetables, and floriculture species.

The broader inclusion of other life forms was not an intentional design feature, but rather a consequence of more open definitions and the discretion given to member states. It was only the national implementations of UPOV or sui generis systems under TRIPS Article 27.3(b) that later began to explore extending protection to non-traditional or marginal taxa, such as algae or fungi.

Empirical data on the grant of PVP to aquatic plants, fungi, or algae is limited, underscoring how exceptional these cases are. However, there are a few scattered instances. China developed a seaweed variety, *Zhongbao No.* 1, and registered it under its Plant Variety Law. Not only a single variety, rather China has registered more varieties of seaweed itself. Till 2025, approximately fifteen seaweed varieties have been registered with the Chinese Ministry of Fisheries and Aquaculture. The East Asian nations of Korea and Japan are not far behind; they have also registered seaweed varieties in their respective countries. Korea has approximately 19 registered varieties of Seaweed, of which 13 are *Pyropia*, 5 are *Undaria*, and 1 is *Saccharina*. Japan also has about 15 registered seaweed varieties.[35]

Tale of Three Approaches: Overcoming the Definitional Issue

Internationally, three approaches are employed: legislative changes or administrative modifications to include fungi, multicellular algae, and aquatic plants within the scope of plant variety laws. The third approach is a combination of legislative and administrative measures to protect seaweeds as intellectual property.

In the *legislative approach*, the law is expanded, for example, in Japan, which, under its Plant Variety Protection and Seed Act (initial law from 1998, with amendments as recent as 2022), defines "agricultural, forestry, and aquatic plants", including *multicellular algae*, within its protected category under Article 2. This broad definition indicates explicit legislative recognition that seaweed falls within the PVP scope, although actual seaweed registrations are still rare in global statistics. The 2022 amendments introduced stronger enforcement powers, provisions to prevent export or unauthorised cultivation of registered

varieties, and clearer infringement presumptions based on variety descriptions.

The second approach, *the administrative approach*, adopted by China and others, is to update their lists of varieties eligible for protection. In 2022 alone, China accounted for the majority of new PVP applications worldwide (27,260 globally). Though sources specific to seaweed protection in China remain limited, the sheer scale and momentum suggest that China's flexible domestic legislation may also allow coverage of aquatic macroalgae. Given that TRIPS and UPOV obligations permit national *sui generis* definitions, China likely has statutory space to include seaweed if desired, especially given its coastal seaweed industry and R&D investment.

The South Korean approach is *the mixed approach*. South Korea adopted its Plant Variety Protection Act in 2012 (entered into force in 2013), aligning fully with UPOV 1991 principles. Article 3 declares that "all plant varieties" are eligible for protection, without restriction by genus or species. Significantly, Korea extended its scheme in 2012 to include seaweed, and by 2019 had registered 19 seaweed cultivars: 13 *Pyropia*, 5 *Undaria*, and 1 *Saccharina* under its PVP system. Varietal protection is administered jointly by the Aquatic Plant Variety Centre of NIFS and other bodies, demonstrating an integrated freshwater/marine PVP approach. Moreover, South Korea offers dual protection: breeders can register under PVP (with DUS testing and breeders' exemptions) or via utility patents, which can even cover plants, their parts, breeding methods, and genetic modifications without exclusions typical of European regimes. This multi-tier approach highlights South Korea's flexible and expansive IP support for innovation, including in seaweed.

India

The Emergence of the Legal Issue

India has devised *sui generis* legislation for the protection of plant varieties, as mandated by the TRIPs agreement, and for protecting the rights of small farmers. In India, the legal definition of a "*plant variety*" under Section 2 (za) of the Protection of Plant Varieties and Farmers' Rights Act, 2001 closely aligns with the UPOV Convention's terminology. It describes "*a variety as a plant grouping within a single botanical taxon, identifiable by its characteristics, and ensuring uniformity and stability*",[36] mirroring UPOV's NDUS criteria. However, the statute nowhere defines 'plant' or 'variety', which brings the definitional issue to India. There was no discussion on this point during the discussion of the plant variety protection bill (the present Act); the internationally accepted definition of a plant variety was adopted without modifications for Indian species or for scientific engagement. The other portions of the act seem to be focused on the terrestrial, seed-based agriculture as well, for example, section 3(5)(b), identification of members of the PPVFR authority, has a diverse range of members, but none from the fisheries, aquaculture, or marine departments. The thrust of the Act lies in its spirit to protect farmers' varieties. However, Section 2(k) of the definition of a farmer relies on persons who cultivate land themselves or through others, while it recognises farmers of wild/traditional varieties. Cultivated seaweed farmers would not fall into either of these categories. Arguably, the Indian landscape does not traditionally have much marine agriculture, nor does its food culture naturally incorporate non-fish sea elements. However, growing business incentives have led to new rules and businesses, and therefore, India must adapt its laws.

Further, the Indian government's 2024 notification on guidelines for the import of live seaweeds defines seaweed expressly *as macroalgae*, distinct from terrestrial cropsand plants.[37] The notification reveals a clear legislative intent to promote macroalgal production and investment into new seaweed varieties, with goals such as increasing seaweed production but also proving that the government considers algae not to be plants, thereby strengthening the argument, and by framing seaweed as macroalgae, the government signals intent to foster germplasm diversity, breeding research, and commercialisation areas where intellectual property clarity would be critical. If so, then definitional clarity makes the first step.

An inconsistency remains: under India's Allocation of Business Rules (1961) and maritime legislation, seaweed is legally classified as "fish" for administrative purposes, reportedly to place governance under the Department of Fisheries rather than agriculture. This dual identity as both macroalgae and fish creates regulatory ambiguity. It may affect which administrative authority handles seaweed variety protection and whether the PPVFR Act or fisheries laws govern claims and rights. This raises a fundamental issue: when a seaweed variety protected in Korea, Japan, or elsewhere is imported to

India for agricultural or cultivation purposes, it would be classified as fish, which would create issues in customs, excise, and taxation laws, as well as market sales. It would affect its safety classification, as standards would differ for fish and macroalgae, further complicating the situation for producers/cultivators and disincentivising them.

In effect, while Section 2(za) of the PPVFR Act could formally encompass seaweed, the unique biological characteristics of macroalgae, coupled with administrative overlaps and taxonomic ambiguities, underscore the need for clear amendments or guidelines. This would align legal protection with scientific realities and facilitate coherent investment, breeding, and commercialisation strategies for seaweed in India. The nature of seaweeds, such as *Kappaphycus* and *Gracilaria*, and other macroalgal species differs markedly from that of typical agronomic crops.[39]

India is significantly scaling up investment in macroalgae cultivation, aiming to boost seaweed production and encourage the development of new varieties through agricultural and IP policy measures. In this context, examples from Korea and Japan demonstrate that nations at the forefront of seaweed breeding have adapted their plant variety statutes to explicitly include seaweed, establish administrative mechanisms (such as aquatic plant variety offices), and support the registration of marine cultivars.

Given these precedents, India would benefit from a clearer legal articulation of how seaweeds fit within its PVP scheme *e.g.*, defining macroalgae explicitly as eligible, establishing standards or guidelines for NDUS testing in aquatic species, and assigning responsibility within administrative agencies. Without such clarity, India risks replicating the ambiguities and implementation gaps seen in Indonesia or aligning strictly with terrestrial-focused models that fail to reflect the biological realities of seaweed.[38] Drawing on experiences across East Asia, India's next legislative or regulatory steps should explicitly calibrate the PVP system to the country's distinctive aquatic biology, ensuring that its policy and investment ambitions for macroalgae innovation can be effectively supported.

Further, with India importing seaweed strains for propagation, questions arise around novelty, prior use, and ownership. Imported varieties may not be considered novel or developed domestically, complicating breeder rights. There's also a risk of breaching international access and benefit-sharing obligations, especially under the Nagoya Protocol, if foreign varieties are cultivated without proper agreements.[39] A related concern is ecological impact. Introducing new seaweed strains, especially exotic ones like *Kappaphycus alvarezii*, has already shown detrimental effects on coral reefs in regions such as the Gulf of Mannar. Unchecked propagation may lead to invasive spread, harming local biodiversity. Seaweed farming in India is mostly community-based, which must be taken into account if seaweed protection is treated as a plant variety, and the conservation of genetic resources must also be considered.

In light of India's push for large-scale seaweed cultivation, the current legal framework needs clearer guidelines on NDUS evaluation, breeder rights for imported varieties, and environmental safeguards to ensure both innovation and sustainability.

Legal Framework and Challenges in India

Identification remains the primary challenge in protecting seaweed varieties, and India's notification allowing the import of new varieties creates an environment in which new varieties can be created through hybridisation and crossing. Therefore, statutory recognition is the foremost, but that is not the only challenge; the criteria used must be clarified or granted a degree of flexibility, as the biological nature of seaweeds such as *Kappaphycus* and *Gracilaria*, and other commercially valuable macroalgal species, present biological complexities that differ fundamentally from those of terrestrial crops, raising significant challenges for implementing the standard Novelty, Distinctiveness, Uniformity, Stability criteria in practice. Seaweeds are different from terrestrial crops. They have a life cycle involving morphologically and genetically distinct sporophyte and gametophyte phases. This biphasic life cycle complicates the identification of stable, heritable traits, as phenotypic characteristics may vary significantly between life stages. Unlike seed-propagated crops with well-defined generational stability, many commercially cultivated seaweeds rely on clonal or vegetative propagation to maintain desirable traits, complicating uniformity evaluations under conventional criteria, in which stability is a key requirement. Furthermore, environmental conditions, such as water temperature, salinity, nutrient availability, and light exposure, can alter both morphology and biochemical composition. This

plasticity means that a genetically uniform variety can display wide phenotypic variation across locations and seasons, weakening the predictability and reproducibility of descriptors essential to conventional plant variety testing. Consequently, strict uniformity requirements can unfairly exclude promising seaweed varieties with potentially valuable traits.[40]

Then comes the challenge of acceptable protocol in law, as there are standardised protocols for food crops, for which internationally recognised morphological and molecular descriptors exist (e.g., the UPOV protocol for rice or wheat). In contrast, seaweed varietal identification lacks standardised NDUS testing protocols recognised nationally or internationally. This gap undermines breeders' ability to confidently submit varieties for registration or defend derived rights in legal disputes. The law requires the submission of a variety of seeds for autonomous testing before registration (Section 19). There is, however, no protocol for organisms such as seaweeds. Therefore, several legislative issues and administrative overlaps need to be addressed, as they could lead to fragmented policy implementation, delays in registration, complications in the ascription and enforcement of rights, and further confusion among stakeholders.

Conclusion

The authors suggest recognising the potential of seaweeds as distinct intellectual property, with their definitive identification following the Japanese model within the definition of plant variety and supplementary guidelines for alternative assessment models. The authors also suggest that administrative notifications and guidelines be streamlined to facilitate the approval of seaweed varieties and effective enforcement. This cannot be done without interdisciplinary scientific consultation, involving marine biologists, agricultural scientists, and legal experts, to account for environmental factors, differences in morphology, and the lifecycle, among other considerations. Coordination among different governmental agencies, such as agriculture, fisheries, customs, etc., could prove pivotal for harnessing the economic benefits of seaweeds by regularising research, funding, import/export, recognition, and consolidation for breeders, as well as the distribution of benefits. It will promote legal conformity, enable India to utilise its coastline effectively, and meet both local and global demand for seaweed-based products. At the same time, it will encourage breeders to develop novel, high-yielding varieties with increased stress tolerance, supporting sustainable farming, carbon sequestration, and coastal ecosystem restoration through seaweed cultivation. It all begins with a minor change in the definition, with significant and far-reaching implications for the entire marine aquaculture system. India's recent policymaking has shown positive momentum in fostering the sector. Still, crafting seaweed-tailored DUS evaluation frameworks, clarifying ministerial responsibilities, and issuing dedicated guidelines or statutory amendments will be crucial to transform legal coverage into practical protection.

It is in India's larger interests to address specific concerns arising from seaweeds, and a clearer approach to seaweed could also open doors to address issues arising from specific groups, such as fungi (mushrooms), and even freshwater aquaculture, India being the largest exporter of fox-nuts, which come from an aquatic plant. The authors suggest that the legislative lacunae in the Plant Variety Act be addressed to adopt a more inclusive approach to the ever-expanding realm of intellectual property.

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