# Information Memorandum

Protoplast-Based Hatchery Services for the Scalable Cultivation of *Asparagopsis taxiformis*

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# 1. Executive Summary

Methane emissions from ruminant livestock present one of the most pressing climate challenges of our time. With a global warming potential more than 80 times that of carbon dioxide over a 20-year period, methane is responsible for approximately one-third of anthropogenic greenhouse gas emissions from agriculture. As global demand for animal protein rises - expected to increase by over 68% by 2050 - the livestock industry faces intensifying pressure to adopt methane mitigation strategies that are both scalable and economically viable.

*Asparagopsis taxiformis*, a red seaweed endemic to Australian coastal waters, has been shown to reduce enteric methane emissions in ruminant livestock by up to 98% in vitro and more than 80% in vivo. Its integration into livestock feed as a methane-reducing additive represents a transformative opportunity for emissions abatement. However, the seaweed's commercial viability is constrained by the absence of a robust, scalable propagation system capable of meeting growing market demand.

Traditional propagation methods - via spore release or tissue fragmentation - are seasonal, inconsistent, and labour-intensive. These methods are not equipped to support year-round, industrial-scale production. Addressing this propagation bottleneck is critical to realising the full climate mitigation and economic potential of *A. taxiformis*.

In response, our research team at the University of Western Australia and supported by the CRC for Developing Northern Australia has initiated a groundbreaking program to develop a novel protoplast-based propagation platform. This platform enables the release and cultivation of totipotent cells (plant cells with their cell walls removed that retain the full genetic potential to regenerate into an entire seaweed plant under the right conditions) capable of regenerating into whole plants under laboratory conditions. To date, we have achieved the successful enzymatic isolation of viable protoplasts from *A. taxiformis*, representing the first report of its kind globally.

While this achievement is a vital milestone, the technology is not yet complete. Two critical research challenges remain: first, to optimise and scale the production of λ-carrageenase - the key enzyme for cell wall digestion - and second, to develop reliable regeneration protocols to grow protoplasts into viable, aquaculture-ready plantlets.

This Information Memorandum outlines a targeted three-year research and development strategy to address these challenges. We are now seeking investment and strategic partners to help advance this technology to full commercial readiness, with a view to establishing the world’s first hatchery platform for protoplast-based *A. taxiformis* seedling production

# 2. The Challenge: Current Propagation Methods Are Inadequate

Despite increasing interest in *A. taxiformis* as a methane mitigation solution, its commercial deployment is severely limited by current propagation methods. These include:

Spore-based propagation, while natural, depends on the seasonal reproduction of gametophytes and environmental triggers that are difficult to simulate at commercial scale. Sporulation events are unpredictable, and the yields are low - typically ~ 5,000 spores per gram of mature frond tissue. Moreover, gametophyte reproduction is highly sensitive to environmental fluctuations, including temperature and light, resulting in inconsistent propagule availability. Furthermore, spore liberation can also be inconsistent with between 0 – 400 spores released per viable cystocarp (avg. ~ 50), frond fecundity can be highly variable under natural conditions and resource (time, labour, infrastructure) intensive under controlled conditions.

Fragmentation, the mechanical division of adult tissue into smaller pieces, offers a more immediate method of propagation. However, this approach leads to heterogenous stock due to the genetic variability within donor material. It also risks introducing pathogens and suffers from slow build up of stock to generate commercial quantities of propagation units (seedlings).

Both approaches are unable to reliably deliver the volume and quality required to support scalable seaweed farming. These limitations also impede the development of selective breeding and genetic improvement programs, which depend on clonal propagation of high-performing genotypes.

Table 1: Comparative Propagation Potential of *Asparagopsis taxiformis*

| **Propagation Method** | **Estimated Yield per kg Frond Biomass** | **Seasonality** | **Genetic Uniformity** | **Labour Intensity** | **Contamination Risk** | **Scalability** |
|---|---|---|---|---|---|---|
| **Spore-based** | ~5,000 spores* per gram of seaweed | High (seasonally triggered) | Low | High | Moderate | Limited (seasonal, variable) |
| **Fragmentation** | Highly variable | Low | Low | Moderate | High | Moderate |
| **Protoplast-based (in development)** | $10^6$ - $10^8$ protoplasts per gram of seaweed | None (lab-controlled) | High (clonal) | Low (can be automated) | Low (sterile process) | High (pending R&D completion) |

**based on 50 spores/cystocarp × 100 cystocarps/frond × 1,000 fronds/kg*

# 3. Our Solution: Protoplast-Based Propagation Technology

Protoplast-based propagation offers a transformative alternative to conventional seaweed propagation. This method involves the enzymatic removal of cell walls to produce protoplasts - naked plant cells that retain the ability to regenerate into complete individuals. The technology allows for the clonal propagation of selected strains, enabling consistent quality, trait selection, and exponential yield from minimal biomass.

Our team has successfully isolated viable protoplasts from the dermal tissue of wild *A. taxiformis* gametophytes using a customised enzymatic protocol. This marks the first time protoplasts have been extracted from this species and sets the stage for the development of a full protoplast-to-plantlet production system.

This innovative approach addresses the key limitations of existing propagation methods:

- It allows year-round propagation independent of environmental conditions.
- It significantly increases the yield potential per gram of biomass.
- It enables genetic uniformity and the creation of elite donor lines.
- It supports biosecure propagation suitable for commercial hatcheries.

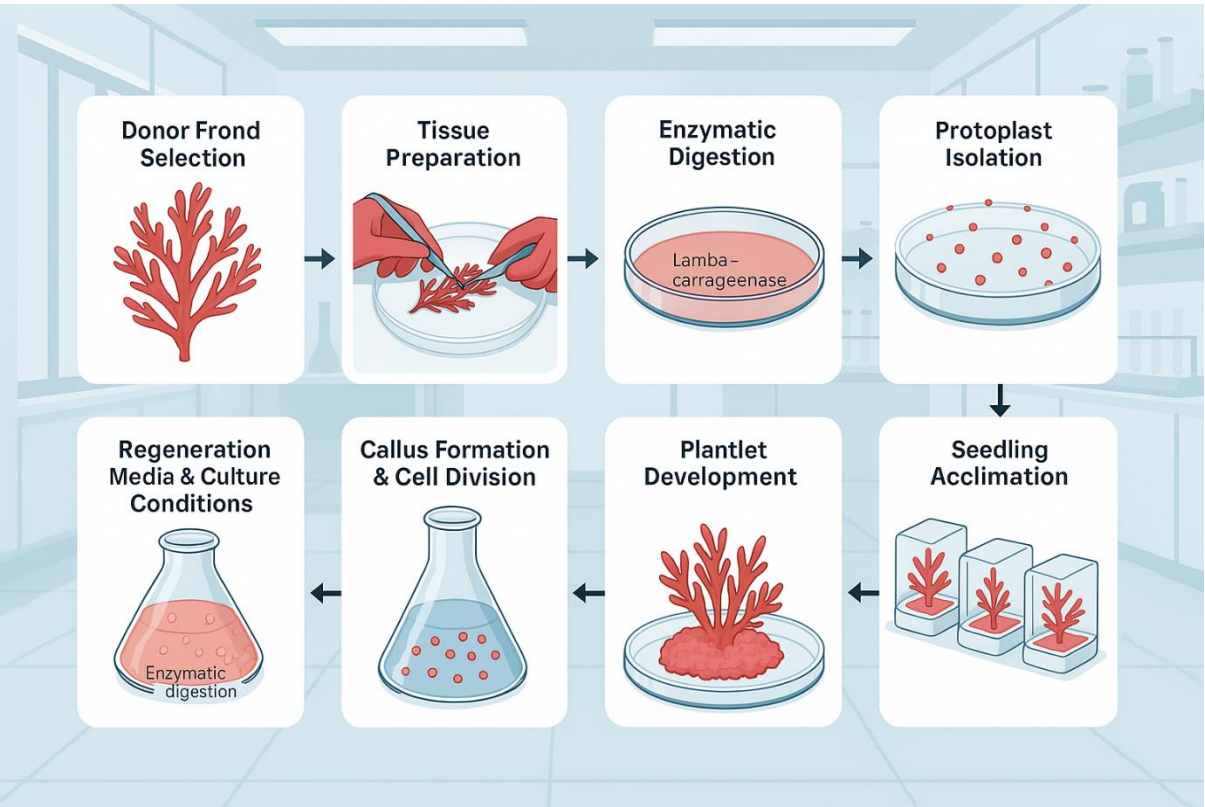



Figure 1: Flow diagram illustrating the full *seaweed-to-protoplast-to-seedling* production pathway for *Asparagopsis taxiformis*.

# 4. Scientific Foundation and Key Milestones Achieved

A detailed biochemical characterisation of the *A. taxiformis* cell wall structure formed the foundation of our work. We discovered that the cell wall comprises a high proportion of sulphated galactans - approximately 60% λ-carrageenan and 40% β-agaran -making it structurally more complex than most land plants or other macroalgae.

Table 1: Chemical analysis of *A. taxiformis* cell wall for identification of sugar monomers.

| Sugar monomer | Amount (ug) | Weight (%) |
|---|---|---|
| **Galactose (Gal)** | 1.1134 | 11.134% |
| **Glucose (Glu)** | 0.0626 | 0.323% |
| **Xylose (Xyl)** | 0.0336 | 0.178% |

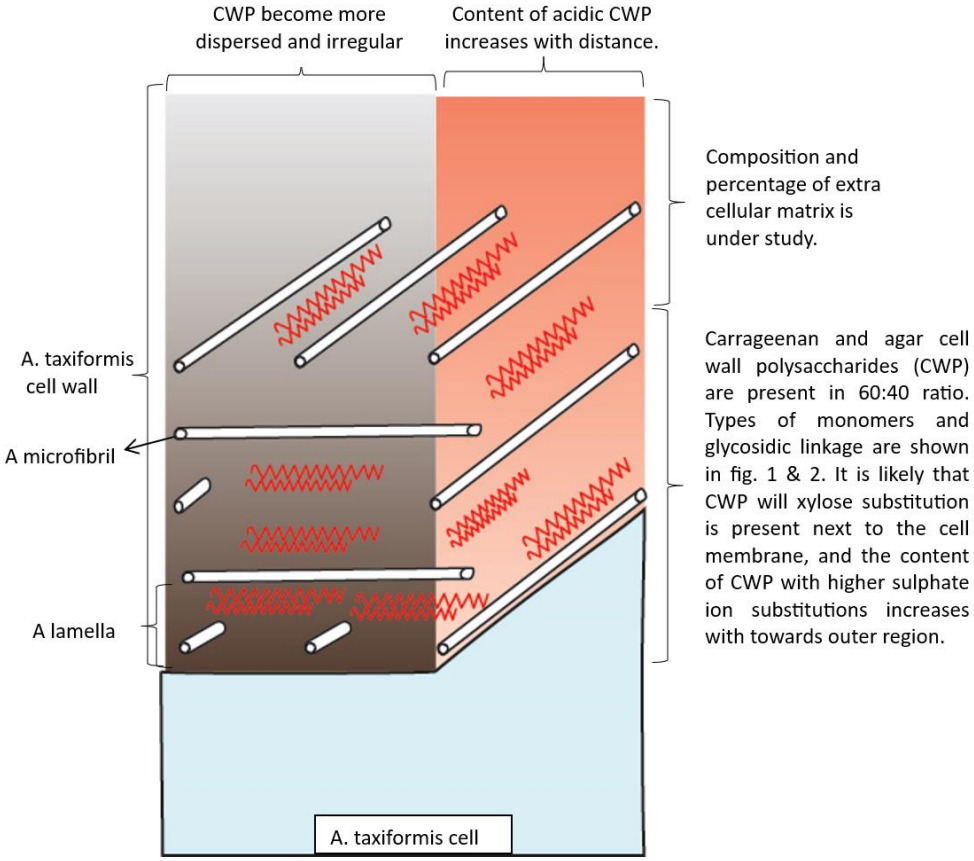



Figure 2: Hypothetical model of *A. taxiformis* cell wall polysaccharides

To digest this matrix and release viable protoplasts, we identified and optimised a cocktail of eight enzymes, including cellulase, papain, sulfatase, β-agarase, and λ-carrageenase. Initial experiments confirmed that standard commercial enzymes alone were insufficient. As a result, we engineered a recombinant λ-carrageenase production system using transgenic *E. coli*. Initial protein expression was achieved, but further development is needed to improve enzyme folding, activity, and yield.

With our custom enzyme mix, we successfully performed plasmolysis followed by enzymatic digestion to release protoplasts. These were confirmed via microscopy and staining protocols to be intact and viable.

# 5. Next Phase R&D Program: A Structured Approach to Commercialisation

The development of a commercially viable protoplast-based propagation system for *Asparagopsis taxiformis* requires a concerted, phased research effort over the next three years. Our R&D roadmap is structured around four core workstreams, each targeting a key limitation identified in the current state of the technology.

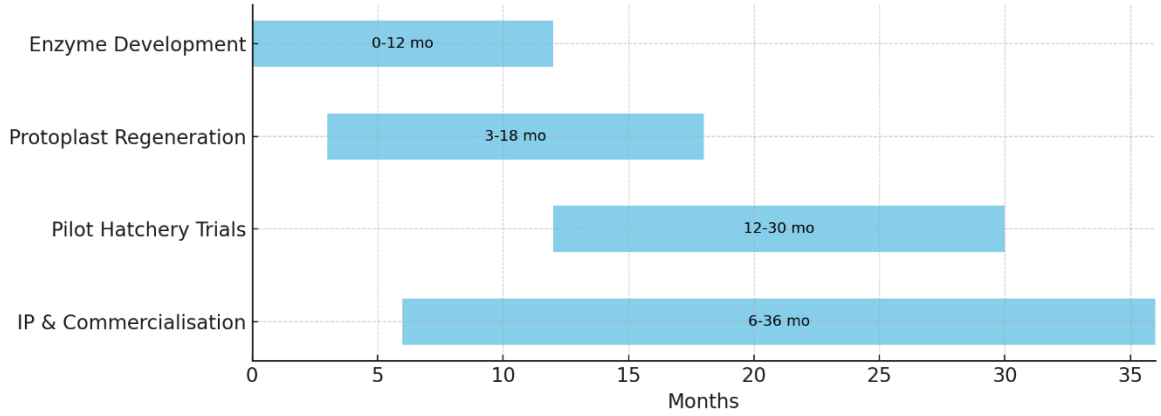



Figure 3: R&D roadmap for protoplast-based propagation of A. taxiformis.

The first stream focuses on the production and optimisation of the enzyme λ-carrageenase. This enzyme is critical for cell wall degradation and protoplast release, yet it is currently not available in sufficient quality or quantity from commercial suppliers. We have initiated in-house biosynthesis using genetically engineered *E. coli*, and the next step involves optimising protein expression, purification, and folding protocols to improve enzymatic activity and scalability. Achieving a cost-effective and consistent supply of λ-carrageenase is foundational to enabling industrial-level protoplast isolation.

The second workstream addresses the regeneration of protoplasts into viable plantlets. While protoplast isolation has been achieved, their transformation into fully formed juvenile plants remains a complex challenge. We will undertake systematic testing of culture media, light and temperature regimes, hormonal stimulants, and osmotic balance to optimise conditions for cell wall reformation, mitosis, and differentiation. The success of this stage will demonstrate the

viability of protoplasts as a propagation tool and enable seedling production independent of environmental constraints.

The third workstream aims to integrate the protoplast propagation system into a pilot-scale hatchery. We plan to establish a controlled cultivation environment to trial early-stage plantlets generated via protoplast regeneration. These trials will assess critical performance metrics such as survival, growth rate, resilience, and ease of handling. Findings from this phase will inform hatchery operating procedures and provide key data for scaling up commercial production.

Finally, our fourth workstream focuses on intellectual property and commercialisation strategy. We will seek protection for innovations in enzyme synthesis, protoplast handling, and regeneration protocols. Concurrently, we will explore partnerships with livestock feed producers, aquaculture firms, and biotechnology investors to design a service-oriented model for delivering seedlings to market.

## 6. Strategic Significance and Industry Relevance

The deployment of a scalable seedling supply chain is the linchpin for unlocking the commercial potential of *Asparagopsis taxiformis*. Our protoplast-based propagation system directly responds to industry demands for consistent, high-quality, and clonally propagated biomass that can be cultivated year-round. By enabling this upstream capability, our work supports downstream stakeholders across the emerging *Asparagopsis* value chain.

For livestock feed producers, a stable supply of high-performing seaweed biomass ensures the reliability and efficacy of methane-reducing feed products. For livestock producers, the integration of these products into feeding regimes presents an opportunity to reduce emissions, generate carbon credits, and improve ESG credentials. Furthermore, carbon market developers stand to benefit from validated abatement pathways supported by seaweed-based interventions.

Beyond the livestock industry, protoplast-based cultivation opens avenues for selective breeding, trait enhancement, and the development of novel applications in pharmaceuticals, functional foods, and cosmetics. The ability to clone elite donor lines positions this technology as a platform for future value creation in marine biotechnology.

The opportunity is timely. Governments and businesses are aligning rapidly around net zero commitments. Australia, in particular, has a comparative advantage in seaweed R&D, coastal production zones, and regulatory momentum. Our platform has the potential to elevate Australia's leadership in the blue economy and position *A. taxiformis* as a flagship climate solution.

# 7. Investment Requirements and Return Potential

To bring this innovation to commercial readiness, we are seeking a staged investment of AUD $1.5 to $2.0 million over a 36-month period. This funding will support the delivery of four core workstreams: (1) enzyme development and scale-up, (2) protoplast regeneration protocols, (3) pilot hatchery operations, and (4) IP protection and commercial engagement. It will also fund critical infrastructure, personnel, consumables, and stakeholder coordination.

The targeted outcomes from this investment include:

- The production of a scalable, cost-effective supply of λ-carrageenase to enable commercial protoplast isolation.
- A validated and repeatable protocol for regenerating protoplasts into aquaculture-ready plantlets under controlled hatchery conditions.
- A functioning pilot hatchery producing early-stage seedlings for grow-out trials.
- Secured intellectual property across enzyme synthesis, regeneration techniques, and propagation processes.
- A commercial roadmap linking seedling delivery to early adopters, feed manufacturers, aquaculture operations, and carbon credit providers.

The **return potential** of this investment is substantial and includes both financial and strategic dimensions. Seedling supply is a foundational component of the emerging *Asparagopsis* value chain. With the ability to clonally propagate elite lines, our system will underpin biomass production across onshore (and offshore) farming systems. The core commercial benefits include:

- **Licensing revenue** from propagation IP and enzymatic formulations.
- **Sales of proprietary seedlings** to seaweed farms and aquaculture operators.
- **Equity or revenue sharing in spin-off companies** established for hatchery service provision.
- **Exclusive access to elite cultivars**, enabling preferred supply arrangements with high-volume growers or methane-reduction product developers.

A scalable, protoplast-based hatchery platform will allow seedling production at volumes previously unattainable through conventional methods. Pricing will depend on several factors including genetic quality, production costs, and buyer volume.

To guide investor expectations, the following pricing tiers reflect potential average pricing for commercial sale, based on a standard unit of 1,000,000 seedlings:

| Seedling Tier | Price per 1,000,000 Seedlings (AUD) | Effective Unit Price (AUD) | Projected Revenue (10M Seedlings) |
|---|---|---|---|
| Base Line | $20,000 | $0.02 | $2.0 million |
| Enhanced Stock | $30,000 | $0.03 | $3.0 million |
| Elite Genetics | $40,000 | $0.04 | $4.0 million |

These estimates assume that each grower would purchase multiple 1,000,000-seedling batches per annum, particularly during hatchery expansion phases or seasonal crop cycles. Even under a modest adoption scenario - where 10 large-scale growers each purchase 5–10 million seedlings annually - the projected revenue could exceed AUD $2–4 million per annum.

This estimate excludes additional revenue streams such as licensing fees for propagation IP, sales of trait-enhanced lines, and consulting or support services. As adoption grows and international markets open, this pricing model can scale further, particularly for elite lines with measurable benefits to methane reduction, yield, or environmental resilience.

# 8. Team Capability and Infrastructure

The project is led by Dr John Statton, a marine scientist with over five years of hands-on experience cultivating seaweed, particularly within research-driven aquaculture systems. Dr Statton established and developed the Seaweed Aquaculture Research and Hatchery (SARaH) Lab at the University of Western Australia. Under his leadership, SARaH has grown into a dedicated research facility supporting seaweed growers and biotech companies. He brings a proven ability to integrate applied research with commercialisation strategies, particularly in scalable hatchery design, seedling propagation, and industry engagement.

The research team includes Dr Moon Sajid, a molecular biologist with expertise in microbial biosynthesis and enzyme engineering. Dr Sajid is responsible for the development and optimisation of λ-carrageenase production and the enzymatic extraction of protoplasts from *Asparagopsis taxiformis*. His work has already demonstrated success in transgenic expression of enzymes critical to the protoplast isolation process and is pivotal to achieving scale and cost-efficiency in this platform.

Supporting the next phase of the project is Matthew Ansell, a specialist in seaweed aquaculture and marine plant physiology. Matthew is leading the effort to identify optimal conditions for protoplast regeneration and plantlet development. His focus includes the refinement of media compositions, environmental parameters, and acclimatisation protocols to enable the reliable cultivation of seedlings suitable for commercial deployment.

Together, this team brings a unique blend of expertise in marine ecology, enzymatic biotechnology, and applied aquaculture. This multidisciplinary structure ensures the project is approached from both a scientific and operational lens. We maintain close collaborations with industry and regulatory bodies, ensuring our work remains aligned with market requirements and national standards.

The SARaH Lab is co-located within the Indian Ocean Marine Research Centre (IOMRC) at Watermans Bay. This facility provides:

- Sterile laboratory space for cell culture and protoplast experiments;
- Temperature-controlled aquaculture tanks for hatchery and grow-out trials;
- Molecular laboratories equipped for enzyme synthesis and analysis;
- High-resolution microscopy and imaging facilities;

- Access to vessel support, field sites, and regulatory advice through UWA's marine partnerships.

These capabilities make the University of Western Australia, the SARaH Lab, and its multidisciplinary team uniquely positioned to lead this pioneering effort in protoplast propagation and unlock the next chapter in scalable seaweed cultivation.

# 9. Conclusion and Next Steps

The development of a protoplast-based propagation platform for *Asparagopsis taxiformis* represents a frontier opportunity in the blue economy. This innovation addresses a key bottleneck in the global effort to deploy seaweed-based methane mitigation at scale. Through the strategic investment outlined in this Information Memorandum, we propose to complete the remaining scientific and operational milestones that will enable the commercial rollout of this platform.

The timing is ideal: *A. taxiformis* is already recognised as a climate-positive solution, yet supply constraints remain a limiting factor. Our solution not only addresses this but creates new foundations for genetic improvement, trait development, and diversified marine biotechnologies.

We invite forward-looking investors, research partners, and industry collaborators to engage with us. Your support can help unlock the full potential of seaweed as a tool for planetary health and sustainable development.

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