

Supplementary Materials

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2 **S1. Additional results**

3 The key components of the BMC applied to BBFs are summarized in Table 1, providing a
4 structured framework for analyzing their commercialization pathways. This table serves as a
5 foundation for the following discussion, outlining the critical aspects of value proposition, value
6 creation and delivery, and value capture.

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9 Table S1. Business Model Canvas for Bio-Based Fertilizers: Key components and insights

Key Partners	Key Activities	Value Proposition	Customer Relationships	Customer Segments
<p>Suppliers: Farmers, waste management companies, and recycling firms that provide essential feedstocks for BBF production.</p> <p>Collaborators: Researchers, agricultural extension services, policymakers, NGOs, and media organizations driving innovation,</p>	<p>Production: Nutrient recovery and fertilizer production.</p> <p>Logistics: Biomass collection, transport, storage, and quality control.</p> <p>R&D: Process optimization, scaling technologies, ensuring compatibility with existing infrastructure, and driving innovation in sustainable production.</p>	<p>Economic Value: Comparable or superior plant growth and yields using recovered nutrients; Product-Service Systems.</p> <p>Environmental Value: Reduce reliance on fossil-based resources, recycle biowaste, cut GHG emissions and nutrient leaching, enhance soil health, and promote sustainable nutrient</p>	<p>Co-Creation: Collaborate with farmers and researchers to improve products through shared expertise and feedback.</p> <p>Peer Influence: Leverage farmer networks to share knowledge and promote sustainable practices.</p> <p>Engagement: Build trust via education, and online communities.</p>	<p>Primary Users: Farmers and nurserymen seeking sustainable alternatives to conventional fertilizers.</p> <p>Target Segments: Environmentally conscious and premium customers willing to pay for certified, eco-friendly products that align with their values.</p> <p>Adoption Opportunities: Eco-labelling, certification and branding strategies to</p>

<p>knowledge dissemination, and regulatory support.</p> <p>Logistics Partners:</p> <p>Transport and distribution partners ensuring efficient supply chain operations and seamless delivery of raw materials and finished products.</p>	<p>Key Resources</p> <p>Tangible Resources:</p> <p>Biomass, biostimulants, biodegradable coatings.</p> <p>Intangible Resources:</p> <p>Research facilities, advanced technologies, and expertise.</p> <p>Human Resources:</p> <p>Skilled workforce and collaborative teams.</p>	<p>cycling.</p> <p>Social Value: Support local job creation, stimulate rural economies, foster community engagement, ensure fair competition, and improve health and safety through hygienized BBFs.</p>	<p>Channels</p> <p>Traditional: Print media, agricultural fairs, posters, and field demonstrations.</p> <p>Digital: Social media, webinars, agricultural apps, and video content.</p> <p>Support: Efficient logistics, proper product handling, and after-sales technical assistance.</p>	<p>build trust and market appeal. Address knowledge gaps and build confidence through education, technical support and demonstration trials to showcase BBFs effectiveness.</p>
<p>Cost Structure</p> <p>Major Costs: Biomass sourcing, logistics, quality control, regulatory compliance, and navigating lengthy approval processes.</p> <p>Key Investments: Technology development, advanced nutrient recovery methods, strategic marketing, and premium packaging to differentiate BBFs.</p> <p>Cost Optimization: Leverage economies of scale, high-quality</p>		<p>Revenue Streams</p> <p>Primary Revenue Streams: Fertilizer sales, soil testing, consulting, distribution, specialty products, and licensing.</p> <p>Pricing Strategies: Competitive pricing to drive market adoption and maximize share, or premium pricing to reflect quality, environmental benefits, and customization.</p> <p>Additional Revenue Streams: Value-added services (e.g., customer</p>		

concentrated biobased materials, and innovative recovery technologies to streamline production and reduce costs.

support and loyalty programs), subsidies, and EU funding to support R&D and commercialization efforts.

S2. Business model considerations for bio-based fertilizers

The BMC framework facilitates a structured analysis of value proposition, value creation and delivery, and value capture specific to BBFs. The value proposition of BBFs combines economic, environmental, and social benefits. BBFs support comparable or superior plant growth to conventional fertilizers while integrating services like nutrient management and logistics to enhance adoption. Environmentally, BBFs reduce reliance on fossil-based resources, recycle bio-waste, lower GHG emissions, and improve soil health, addressing ecological challenges in agriculture. Socially, BBFs foster local job creation, stimulate rural economies, and enhance health and safety through hygienization processes. However, challenges such as nutrient variability, timing of nutrient availability, and potential health risks require mitigation strategies to maximize their potential as sustainable fertilizer alternatives.

Market blocks, as critical components of value creation and delivery, play a pivotal role in driving the adoption of BBFs. Market adoption requires understanding behavioral drivers, including financial motivations, self-efficacy, attitudes toward climate change, and the key product attributes like nutrient content, organic matter, cost, and ease of application. Targeted marketing, certification, eco-labeling, and branding are essential for building trust, particularly among environmentally aware consumers. Effective channel management, combining traditional and digital media, training programs based on farmers' existing knowledge and practices, and tailored after-sales support are key to enhancing product awareness, market adoption and customer loyalty. Peer influence and online communities also play crucial roles in customer relationship management by promoting knowledge exchange, collaboration and co-creation. Key activities like nutrient recovery, ongoing R&D, and logistical management are critical for BBF production, while resources—including biowaste, biostimulants, coatings tailored for controlled nutrient release, flexible nutrient recovery technologies, skilled expertise, research facilities, funds, and innovative organizational culture—are essential for the model's success. Diverse and adaptable nutrient recovery methods must address the variability in

waste sources and product qualities, ensuring consistent performance across varied agricultural applications. Collaborations with stakeholders like farmers, policymakers, researchers, and NGOs support resource acquisition, technology development, and BBF commercialization. Partnerships between the fertilizer and biomass-supplying sectors are crucial for value chain coordination. Competitive pricing relative to mineral fertilizers supports market penetration, while premium pricing can be justified by emphasizing BBFs' environmental benefits. Additional revenue sources, including value-added services and subsidies, are important for long-term sustainability, helping make bio-based products financially viable. To remain competitive, companies must optimize production processes and logistics, use high quality concentrated biobased material and innovate cost-effective nutrient recovery methods.