Colegio de Postgraduados

The plant microbiome as a driver for business models in agriculture that reach unicorn status

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ABSTRACT

Objective: to analyze the business model of the agricultural company based on the plant microbiome that is the first to achieve the Unicorn designation.

Design/Methodology/Approach: this paper reports a single case study by applying the deviant case technique. This approach was chosen because Indigo Agriculture (Indigo Ag) is paramount as a company specialized in agricultural technology that has achieved the top position on the list of the 50 most disruptive companies in the world.

Results: this analysis of the business model reveals how the company has overcome the adversities of agricultural activity, transforming disadvantages into advantages. This was achieved through the convergence of technologies such as computational biology and machine learning. As well as building alliances with universities, seed production companies, microorganism breeding companies; with granting of guarantees for farmers through shared risk and technical support. It is also notable that they preserved the identity of those sustainably produced grains through direct links between farmers and buyers.

Limitations/Implications of the study: business confidentiality and lack of public financial data limited this study to a qualitative analysis based on secondary sources, such as industry reports and documented interviews with experts. This limitation restricts the financial evaluation of the profitability and economic efficiency of Indigo Ag's business model.

Findings/Conclusions: innovations developed by Indigo Ag are centered on plant microbiome. However, there are several additional elements that explain the high performance and rapid positioning of the company.

Keywords: regenerative agriculture, unicorn company, plant microbiome, business models.

Citation: Loaeza-Joachin, J., Muñoz-Rodríguez, M., Aguilar-Gallegos, N., & Islas-Moreno, A. (2025). The plant microbiome as a driver for business models in agriculture that reach unicorn status. *Agro Productividad*. https://doi.org/10.32854/1vbchd89

Academic Editor: Jorge Cadena Iñiguez
Associate Editor: Dra. Lucero del Mar Ruiz Posadas
Guest Editor: Juan Francisco Aguirre Medina

Received: January 7, 2025.
Accepted: November 16, 2025.
Published on-line: January XX, 2026.

Agro Productividad, 18(12). December. 2025. pp: 11-21.

INTRODUCTION

Agriculture faces the structural challenge of increasing food production without compromising environmental sustainability. For decades, the increase in agricultural yields has been based on the intensive use of chemically synthesized inputs, which has generated adverse effects on ecosystems and human health. Added to this is the pressure to reduce emissions from the food system, which is responsible for about a third of greenhouse gases (Crippa *et al.*, 2021).

In this context, biotechnology innovations are emerging that promise to transform the way food is produced, including the use of the plant microbiome. This is composited of bacteria, fungi, archaea and viruses that inhabit the rhizosphere, endosphere and phylosphere of plants, and whose joint action favors growth, health and resilience of agricultural crops (Olanrewaju *et al.*, 2024).

The agronomic potential of the microbiome has raised the interest of the industry, driving the formulation of biofertilizers, biopesticides, and biostimulants. This trend is reflected in the growth of the agricultural microbes market, which is identified as one of the most dynamic areas within biological inputs for agriculture (Batista & Singh, 2021).

However, despite its scientific relevance, little is known about the conditions that allow this type of innovation to scale into viable and sustainable business models. Understanding how a plant microbiome-based company managed to position itself in the market can offer key guidance for entrepreneurs, policymakers, and research institutions interested in accelerating the transition to regenerative agriculture.

This study aimed to analyze the business model of the agricultural company based on the plant microbiome that was the first to achieve the Unicorn designation.

MATERIALS AND METHODS

The study was conducted through a unique case study design, which comprises the in-depth analysis of a case whose own value lies in qualities that allow a greater understanding of the phenomenon under study (Heale & Twycross, 2018). This method has been used to analyze companies that achieve outstanding performance levels and that manage to complete highly challenging processes. The case analyzed is the U.S. company Indigo Agriculture, which was listed as the first unicorn company in agricultural technology (Chandaria *et al.*, 2021). According to Brown & Wiles (2020), a unicorn company is one that reaches a value of a billion dollars in less than 10 years without operations in the stock market.

Case selection is a crucial stage of research based on unique case studies. To this end, the deviant cases technique was used, which consists of identifying the case whose behavior in one or more variables of interest is significantly different from the usual behavior within a group (Bennett, 2022). Since there is no registry that integrates information on companies based on plant microbiome, we began by making a list of companies that are more frequently mentioned in scientific articles. Articles search was done in Scopus considering publications between 2011 and 2021 that contained the keywords: company OR business OR industry AND "plant microbiome" OR "microbial inoculant".

A total of 60 papers including articles and scientific reviews were collected. After the detailed review, five companies referred to in these articles were identified. To increase the number of companies, the snowball method was used, that is, citations were identified within the paragraphs in which those companies were mentioned. The citations corresponded to news and other scientific articles that mentioned some other companies based on plant microbiome. In the end, a total of 20 companies was identified (Table 1).

The companies most frequently mentioned in the documents were Indigo Agriculture, with four mentions in Batista & Singh (2021); Fox (2015); Singh, (2017) and Waltz (2017); and the company New Leaf Symbiotics. This shows us that the scientific community has identified certain plant microbiome companies stating them as new players in the agriculture inputs industry.

Table 1. List of agriculture companies based on plant microbiome.

Name	Year Founded	Country	Website
Aphea Bio	2017	Belgium	https://aphea.bio/
Joyn Bio LLC	2017	USA	https://joynbio.com/
Boots Biome Inc.	2016	USA	https://boostbiomes.com/
Biome Makers Inc.	2015	USA	https://biomemakers.com/
Bioconsortia	2014	USA	https://bioconsortia.com/
Indigo Ag	2014	USA	https://www.indigoag.com/
BioAg	2013	Denmark	https://biosolutions.novozymes.com/en/bioag
Zymergen	2013	USA	https://www.zymergen.com/
Agbiome	2012	USA	https://www.agbiome.com/
Adaptive Symbiotic technologies	2011	USA	https://www.adsymtech.com/
Pivot Bio Inc.	2011	USA	https://www.pivotbio.com/
Symborg	2010	Spain	https://symborg.com/es/
Plant Response	2008	USA	https://plantresponse.com/
BioWish Technologies international Inc.	2007	USA	https://biowishtechnologies.com/
Concentric Ag	2007	Canada	https://www.concentricag.com/
Marrone Bio innovations- Syngenta	2006	USA	https://marronebio.com/
Intrinsyx Bio	2005	USA	https://intrinsyxbio.com/
NewLeaf Symbiotics Inc.	1999	USA	https://www.newleafsym.com
Certis Biologicals	1996	USA	https://www.certisbio.com/
Rizobacter	1983	Argentina	https://www.rizobacter.com/es

In this study, Indigo Agriculture (Indigo Ag) was selected as the deviant case because it is paramount among the identified companies as it is the only one, for now, to achieve the unicorn company designation. This recognition was granted in 2019 by Consumer News and Business Channel (CNBC), a leading global company in business news. The Disruptor 50 list measures disruption based on qualitative and quantitative information related to scalability, user growth, use of innovative technologies, and the size of the industry that is disruptive.

As a result of the recognition that Indigo Ag has achieved, a significant amount of information about the company has emerged. For this reason, Indigo Ag is also a convenient case study, as it offers opportunities for access to information in sufficient quantity and quality, which is crucial to successfully conduct research based on case studies.

Data collection and analysis

The research was conducted using the principle of constant comparison, which means that the data were collected and analyzed simultaneously. The information on the case of the company Indigo Ag was collected through the compilation and review of documentary sources. The information is concentrated in the period 2016-2022 and the sources include

the information published by the company itself on its website (https://www.indigoag.com/), as well as scientific articles, international reports, documented interviews, statistics, news and two case studies prepared by Harvard Business School.

On the other hand, the business model analysis was performed based on the Business Model Canvas (BMC) by Osterwalder & Pigneur (2010). BMC integrates nine modules from which the business logic of a company can be understood; 1) Customer segments, 2) Value propositions, 3) Channels, 4) Customer relationships, 5) Revenue streams, 6) Key resources, 7) Key activities, 8) Key partnerships, and 9) Cost structure (Figure 1). It should be noted that, due to business confidentiality and the absence of accessible public financial data, it was not possible to provide in this study specific details on the modules of revenue streams and cost structure of the business model of Indigo Ag.

The company, as a private entity, do not disclose detailed financial information, which is common in the biotechnology sector and in companies with innovative business models. Given this context, the analysis of revenue streams and costs focused on secondary sources such as industry reports, previous case studies, and documented expert interviews, which provide an overview of their business strategies, albeit without precise financial figures. This qualitative approach limits the scope of the evaluation of the profitability and economic efficiency of the company, and is recognized as an inherent limitation of this research. The constant comparison principle was developed by classifying the information within the nine modules of the BMC framework, using adaptive analysis as the available data were revised.

RESULTS AND DISCUSSION

The BMC framework helps understanding how a company creates, delivers and captures value. The nine building modules of the business model of Indigo Ag are described below.

Customer segments

The market segment was identified primarily as farmers who purchase microbial products from Indigo Ag to inoculate their seeds. The first customers were farmers growing cotton in West Texas, who had the problem of water stress due to lack of water in the production area. Similarly, wheat farmers also relied on Indigo Ag's microbial products to counteract water stress issues (Sutherland *et al.*, 2019). Other customers were corn farmers in central Kansas, where in 2017 they received only 50% of the average rainfall; according to internal reports, sowing Indigo Ag's products increased their yields. Finally, farmers growing rice, soybeans, sunflower and cover crops are also customers.

Another type of customers are those agribusinesses that buy farmers' crops through the Marketplace. In 2017, partnership was announced with the client Grain Craft, the largest milling company in the U.S. that sells its premium flour in bulk and in bags for the bakery industry, pizzas and tortilla retail shops. For that customer, Indigo Ag hired wheat farmers who can produce huge harvests under a more sustainable production system.

In 2018, Indigo Ag announced a partnership with the Better Cotton Initiative (BCI), a global organization that has the world's largest cotton sustainability program. Within the framework of this partnership, Indigo Ag supports cotton farmers that ensure their

production is done under BCI criteria. On the other hand, in 2019, Indigo Ag announced a partnership with Anheuser-Busch, the leading brewer in the U.S. The partnership involved Indigo Ag farmers delivering 44 905 metric tons (Megagrams, Mg) of sustainably produced rice, through reducing water and nitrogen use.

A third group of customers are buyers of carbon credits, which have raised international interest. In February 2021, companies such as Maple Leaf Foods, Epiphany Craft Malt, The North Face, Cool Effect, Barclays, JPMorgan Chase, Dogfish Head Craft Brewery, New Belgium Brewing, Givewith, IBM, Shopify, and Boston Consulting Group committed to acquiring carbon credits to promote sustainability. Carbon credits are paid to farmers who comply with regenerative practices in relation to the amount of carbon sequestered in the soil. Indigo Ag recently made public such monitoring, reporting and verification process (Brummitt *et al.*, 2024).

Value propositions

Indigo Ag was founded in 2014 in Boston, Massachusetts, USA. This company generates value propositions based on "a better way to feed the planet" in alliance with farmers and buyers through the development of biological innovations such as the plant microbiome. As well as the use of data science and advisory services that improve profitability for farmers, environmental sustainability and consumer health (Iansiti *et al.*, 2019). In business models it is important to generate value for all stakeholders such as farmers, consumers, as well as for the environment and society (Baldassarre *et al.*, 2017).

According to the information reviewed on the company's website, Indigo Ag offers products and services under a sustainable and innovative approach. It currently offers products for crops such as cotton, wheat, corn, rice, soybeans, sunflower and cover crops. These microbial products meet objectives such as improving efficiency in nutrient absorption, providing resistance to drought and tolerance to high temperatures.

The information on the website reveals that the services offered by Indigo Ag are based on the advisory services by Indigo Agronomists for the adoption of regenerative agriculture practices, who through data captured in the field and satellite images formulate recommendations to improve agricultural productivity, as well as grain quality. The GeoInnovation team is in charge of data analysis through Atlas Indigo, a platform that integrates data from remote sensing, ground equipment, historical and meteorological data to study the dynamic variables that affect crop productivity.

With this technology, Indigo Ag has been able to characterize local soil conditions, draw field boundaries, and understand differences in crop yields across regions. In addition, with this data analysis, Indigo Ag is able to provide a real-time market view, helping farmers to adjust their harvest times. This business model shows that integrating services with the product is often attractive to farmers. It is relevant because training in regenerative practices can have positive effects on efficient carbon sequestration (Burns, 2021). For this goal, the support of agronomists is important for farmers supported by carbon credits.

The service offered by Indigo Atlas benefits farmers, traders, investors, buyers, grain traders, government agencies, and other industry participants.

Channels

In the case of inputs, Indigo Ag uses the established channel of the seed producers, who agree to impregnate their seeds with microbial consortia and then market those to farmers through their distribution network, seeking to maintain a direct relationship with the producer (Iansiti *et al.*, 2018).

In the case of grains produced by Indigo farmers, the most important channel is the Marketplace, which allows companies to contact farmers directly to market grains and fibers (Anshari *et al.*, 2019).

With this platform, Indigo Ag has managed to make innovation that prevents farmers from depending on larger collection companies and intermediaries, thus Indigo Agriculture manages to reach agribusinesses directly. Another key channel for Indigo Ag is their website, where Indigo Transport is located, a platform with which the logistical details are defined, for the collection and delivery of the crops.

Customer Relationships

Due to rising input costs, low sales prices of crops, and negative climate impacts, farmers face the greatest risk within agrifood chains. Therefore, Indigo Ag developed a model to reduce risk through microbial products and data analysis. Their model consists of sharing risks and rewards. In the first launch of its product Indigo Cotton® Indigo Ag did not charge upfront for microbial treatments. Instead, the payment was agreed as a fixed amount per acre after harvest, provided that increases in production were in fact achieved (Iansiti *et al.*, 2018). To improve production, Indigo Ag offers technical support through Indigo Agronomists, who work with farmers throughout the season using data to make better decisions about implementing regenerative and agronomic practices.

An important aspect that benefits the relationship with farmers is that Indigo Ag conducts commercial trials, where environmental conditions are realistic and not controlled as in small trials. Benefit is supported on the greater confidence that farmers have in the results obtained from trials under actual conditions.

On the other hand, through the Marketplace platform, Indigo Ag manages to de-commoditize sustainably produced grains by preserving their identity throughout the marketing chain. Through that platform, farmers have access to a large number of buyers, who can select the best grain supplier according to their needs. In this way, the best customers are obtained for each production. Another advantage for farmers is that access to the Marketplace is free and includes follow-up with grain marketers. Finally, by using the platform, farmers have protection of their transactions through insurance.

Revenue streams

As it was discussed in Customer Relationships, Indigo Ag started by sharing risks and profits with farmers, *i.e.*, the company did not charge upfront for microbial treatments, but tied income to the results obtained by farmers. For example, in the case of cotton, a charge of USD10 per acre (24.71 USD per hectare) was proposed, as long as an increase was achieved in yield, higher than 30 pounds (13.60 kg) of fiber (14.2% of added value)

(Kephart *et al.*, 2018). Although the pay-for-performance structure has been a part of Indigo Ag's strategy, the company has also adopted other business models.

Subscription model: Indigo Ag has created a subscription-based model where farmers periodically pay for the use of services and products. That model is linked to crop yield, is also called pay-for-results. This means that farmers pay based on the productive benefits they obtain, such as increased yield or improved soil health.

Sales of biological products: a key aspect of Indigo Ag's revenue is the sale of its microbial products such as biofertilizers, biopesticides and biostimulants for corn, cotton, wheat and soybeans. These products are sold through a network of distributors in various states in the United States.

Data-driven services, analytics and consulting: another segment of Indigo Ag's revenue comes from the digital services it offers to farmers and agribusiness. These services include soil microbiome analysis, yield projections, and data-driven recommendations. Data are collected in the field through sensors and stored in Indigo Ag platforms that allow them to obtain other sources of income.

Key resources

Through exploring the company's website, it was identified that one of Indigo Ag's base technologies is the computational biology platform, through which DNA sequencing is performed to identify microbes and classify the effects on plants. In addition, the company developed a satellite imagery and artificial intelligence platform, Indigo Atlas Insights©, with which automatic learning is implemented on satellite, meteorological and historical data that are recorded through remote sensors, and ground and meteorological equipment. Atlas Insights© enables the development of models that assess crop health, productivity, and other factors at different scales, field, county, state, and nationwide.

In regard to human resources, Indigo Ag had 25 employees with doctoral degrees and 17 with master's degrees in 2016, with whom it created a multidisciplinary team highly specialized in the different areas of the company such as business, agriculture, academic researchers and science (Iansiti *et al.*, 2018).

Key activities

With the visits and review of the information on the company's website, it was recognized that the development of Indigo Ag's microbial products requires certain key activities (Figure 1). The first is the identification of outstanding plants in adverse environments. It is hypothesized that those plants have a microbiome that allows them to withstand high temperatures, saline soils and present greater resistance to pests and diseases. Once such a plant is identified by field scientists, it is extracted from the soil to be taken to the laboratory where a sequencing of its endophytic microorganisms is performed. Another way Indigo Ag obtains endophytic microorganisms is through the payment of licenses to universities that have already performed the sequencing. Among those universities, the University of Texas and the University of Arizona are included in the US; also, the University of Saskatchewan in Canada; and Flinders University, in Australia.

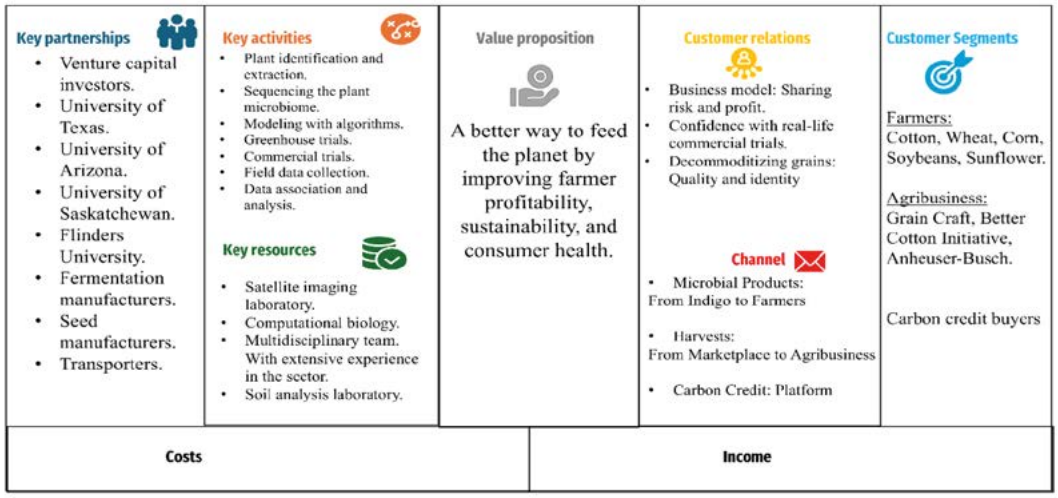

Figure 1. The Indigo Agriculture business model; based on the Business Model Canvas (BMC) by Osterwalder & Pigneur (2010).

After obtaining the endophytic microbes, with the support of computational biology and machine learning, modeling is done with algorithms that predict in which environments microorganisms can express their potential to improve productivity. Subsequently, microorganisms are reproduced through high-precision fermentation to establish trials with greenhouse seedlings, then on soils under cover, and finally on a commercial scale.

Key partnerships

A key part of Indigo Ag's success are the venture capitalists, thanks to whom funding for the research and development of microbial products was achieved. Major investors include Insignia-Flagship, Alaska Permanent Fund, Biallier Gifford, Activant Capital, Investment Corporation of Dubai, FedEx and Pacific Western Bank. Thus, between February 2016 and August 2020 Indigo Ag managed to raise a total of 1.2 billion dollars from series B to F, which represents one of the largest private equity financings in the agricultural technology sector (Manning, 2016) and a growing valuation of the company by investors.

Also relevant for Indigo Ag is the partnership made with universities to access strains already studied and expand the diversity of microorganisms. In addition, alliances with universities allow tests and trials to be implemented, which even are consolidated in partner research that favors the continuous improvement of Indigo Ag's microbial products.

Similarly, alliances are made with companies for the large-scale reproduction of microorganisms whose potential has been validated. Finally, the partnership that Indigo Ag has with seed producing companies allows for a more direct relationship for microbial treatments to be applied to seeds that will be sown by Indigo Ag's partner farmers.

Cost structure

As mentioned above, a major component of Indigo Ag's business model is technological innovation that involves high costs in research and development (R+D). The development of biological products such as biostimulants, biofertilizers and biopesticides requires

significant investment, in laboratories, field trials and validation. According to MacDonald *et al.* (2023), companies responsible for agriculture biotechnology are used to allocate close to 10% of their annual revenue to R+D in their first years of operation.

Once their products reach the commercial scale, those costs related to production and scalability play the most important role. Since infrastructure is required to reproduce and process microorganism at a large-scale, this is the most crucial stage in bio-inputs elaboration (Lorenzoni *et al.*, 2024). As indicated by Kumawat *et al.* (2021), optimizing the supply chain and production capacity contributes to lowering the costs of agriculture microbial products. This is how Indigo Ag has achieved economies of scale, which has allowed the company to reduce manufacturing costs as it increases production.

There are also costs in logistics, which are related to products distribution. For Indigo Ag these costs are significant, because biological products have a limited life, therefore special care is necessary in storage and transport.

The business model of a *unicorn* company, based on plant microbiome, at the service of agriculture

In general, farmers are described in the literature as actors with a low level of education, reduced entrepreneurial skills and a highly reluctant attitude to innovate and take risks (Pindado & Sánchez, 2017). In turn, agricultural units are characterized by their small scale and high geographical dispersion. Likewise, agricultural production depends on biological processes that are characterized by being uncertain and requiring long execution times (Arafat *et al.*, 2020); defining situations that makes experimentation difficult. Such adverse characteristics, added to climate and economic challenges faced by farmers, mean that agriculture is usually considered an unattractive activity for the development of high technologically-disrupting businesses.

However, Indigo Ag's business model (Figure 1) provides insight into how a plant microbiome-based company can overcome the adversities inherent in agriculture and position itself as a disruptive company that has achieved unicorn designation. First, the use of technologies such as computational biology and machine learning for modeling, as well as the partnership with universities to expand the spectrum of microorganisms and with companies for mass production via precision fermentation, allows reducing the times and costs of experimentation and product development.

As a second point, Indigo Ag shares the risk with the farmer, offers proven products on a commercial scale and provides technical support through its agronomists. In this way, the company reduces the risk aversion of innovating on the part of farmers. Finally, for Indigo Ag's business model, the geographical dispersion of farmers does not represent a disadvantage. On the contrary, the diversity of environments allows the company to feed their data management platforms, as well as training their modeling algorithms.

In February 2017, the California-based VentureBeat published a note asking why there were no unicorn companies in agriculture. The portal found the explanation in the adversities usually documented in published papers on agricultural units; and about

stakeholders managing and operating those units. Seven months later, in September 2017, Indigo Ag was announced on local news portal as the new unicorn company in Boston (The Boston's Globe, 2017).

This study allows us to understand how a company manages to overcome the adversities inherent to agricultural activity and even manages to convert disadvantages into advantages. Indigo Ag achieved this through the convergence of technologies that accelerate R+D exponentially; through the construction of alliances, the granting of guarantees for farmers, and the preservation of the identity of sustainably produced grains.

CONCLUSIONS

The case study of the company Indigo Ag shows that the strategic integration of microbial biotechnology, digital traceability and risk management schemes can generate scalable business models even in traditionally adverse sectors such as agriculture. Their approach on the plant microbiome, complemented by institutional alliances and access to big capitals, has allowed the company to overcome structural barriers, thus positioning as a unicorn company.

The development of microbiome-based companies requires more than scientific innovation. This requires business ecosystems capable of directly linking producers with differentiated markets, accelerating technology adoption processes and attracting investment aimed at economic, social and environmental impacts. There are still gaps in knowledge about the potential of the plant microbiome to transform agrifood systems, so it is recommended to advance research that evaluates new business models and their contribution to the transition to regenerative agriculture.

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