



EXPANDING THE ADOPTION OF INNOVATIVE BIOFERMENTATION TECHNOLOGIES IN KENYA.

DESK STUDY 3: UTILIZING BIOFERMENTATION FOR NATURAL FERTILIZERS PRODUCTION.

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Preface: Desk study on the economic feasibility of biofermentation in Kenya

The three desk studies, commissioned by Gatsby Africa, refer to industrial segments that at first sight might appear disjointed from one another, yet they are contiguous in their process technology utilization and can be examined from a holistic point of view.

The common thread that the studies all outline is the opportunity for the creation of sovereign production capability in Kenya with a potential economic contribution in substituting imports impacting the foreign trade deficit, conservatively assessed at 200M€ per annum for the three segments. The second common thread is the introduction of new applications of state-of-the-art biofermentation technology – a technology that is rapidly expanding and is expected to be one of the green technologies of the future, applicable to many different industrial areas.

All segments, be it acetic acid, protein substitutes for poultry, and animal feed or biofertilizers, originate from similar processing technologies for their generation, namely biofermentation.

The desk research streams were allocated to three different experts, the outcome might sound at first varied in its potential outcome, yet they come at different investment-readiness stages that could determine at first sight a priority option choice.

The potential expressed by each of the reports refers to the maturity stage of the respective industries and the deriving appetite for investment, but all segments appear to be ready for investment in local production and present cost savings fundamentals if locally engaged, in substitution of foreign dependency.

The most granular exercise was conducted on Acetic Acid, followed by Poultry feeds and Rhizobium.

Acetic Acid calls for ready-investor engagement in established state-of-the-art technology. Before being investor ready, however, further engagement with producers, off takers and investors is needed, as well as further detailed market analysis.

Producing locally the protein content of poultry feeds is dependent on the establishment in Kenya of the latest technological capacity and biological innovations in the field of biofermentation. The production and efficient use of local feedstock needs to be maximized to ensure viability in such a strategic segment of the local economy.

Economies of scale will play a relevant role, supply of feedstock being a second priority.

Rhizobium is native to Kenya, and ready for takeoff. Local capacity and expert knowledge are available, and many studies have previously been conducted. Given its environmental credentials and impact, it needs capital investment to support local and proven expertise. A shift towards bio fertilization of staple crops, in particular beans, is required through a broad collaboration between all stakeholders in the value chain in the Eastern Africa region.

Nairobi, December 2024

1.0 Executive Summary

- High-level summary of the entire study, including key findings, recommendations, and a roadmap for action.

The biofertilizer segment in Kenya has lived innovation in its own turf some 40 years ago through the research of Prof. Keya¹ and his alumni; the link that Academia and Industry created with MEA Fertilizers² in early 2000 taking up the challenge of marketing Rhizobium under the BioFix brand, specific to legumes. The initiative did not have lasting success because of the crushing competition of inorganic fertilizers: easier to use, pervasively present in the market, and supported by Agricultural policies.

Widespread utilization in Kenya suffered from the relatively scarce historical penetration of Soybean cultivation in the country, preferring other legume food crops to this labor intensive and less ROI-attractive cultivar³. The market remains underserved.

Yet biofertilizers are cheaper when one compares them with inorganic fertilizers which are at a 1:3 ratio and are superior in yields, and sustainability.

The paradigm shift to BioFix as a legume fertilizer was not adequately interpreted at all levels of the value chain: the product has marginal commercial presence in Kenya, less so in the neighboring Countries with a different cultivation mix, covering species not particularly labored in Kenya, such as Soybean and Groundnuts.

There is an important market for legumes, but also a much wider market in cereals that are pillar to the East African diets: maize, wheat, sugarcane and rice. If research focused on the development of microbial based inoculants(biofertilizers), there would be very strong arguments (price, performance, sustainability) for farmers to substitute chemical fertilizers with bioinoculators for large sways of agriculture cultivars in East Africa.

Some pre-requisites must be taken into account, as the bioinoculator application process differs from inorganic fertilizers and must be taught by vendors with support of Public Powers, understanding such bio inputs help mitigating a importation of synthetic fertilizers which is estimated at about 500M\$/annum “big picture” and would contribute towards adoption of sustainable farming practices and enhance creation of a sovereign industry that has its core key success factor in collaborative research programs compliant with the soils where products are being marketed.

¹ <https://knasciences.or.ke/78-prof-keya-o-shellemiah>

² <https://ipmo.uonbi.ac.ke/node/212>

³ <https://www.gatsbyafrica.org.uk/insight/leveraging-east-africas-soya-bean-opportunity/#:~:text=Soya%20bean%2C%20the%20world's%20most,development%20interventions%20and%20policy%20reforms.>

There is adequate knowledgeable human resource in Kenya that is ready to engage in broader market penetration, though they require support in scaling up, both from an industrial process and a marketing penetration, banking on the lessons learnt in the 2010's.

Initial estimates suggest that there is potential for the creation of a sustainable 35M€ industry replacing about 90M€ worth of chemical imports.

This figure does not account for carbon credits for sequestration of Nitrogen chemical fertilizer substitution.

There is no upcoming disruptive innovation in this domain, it is more about getting the fundamentals right with a strong view to sustainability and sovereign capacity creation.

2.0 Introduction

2.1 Background information on biofertilization.

Biofertilization has been adopted in several parts of the world as a valid and sustainable substitute for conventional inorganic chemical fertilizers.

Bioinoculation is a natural fertilization technique applied to roots, seeds and soil (a.k.a.: the rhizosphere⁴), creating a conducive environment for germination and plant growth leading to higher yields. Through biological lab research, bacterial strains are isolated that release nutrients in the environment they operate within.

Bioinoculators offer the following advantages:

- **Improve seed germination and seedling vigor**
- **Enhance nutrient uptake**
- **Increase stress tolerance**
- **Boost yields**
- **Control of soilborne pathogens**

This is the domain where this study will concentrate upon.

Kenya has been at the innovation forefront in this domain since the early 1970s, when the now retired Prof. Keya from University of Nairobi, department of Land Resource Management and Agricultural Technologies, introduced the technology of exploiting beneficial soil microsymbionts called Rhizobium bacteria for inoculating legume seeds improve their nitrogen-fixation capability and raise crop yield.

The initiative was backed by FAO, UNESCO and UNEP, and included the creation of MIRCEN (Microbial Research Centers) across several African Countries backed by local Academia. Recently the [N2Africa](#), a Network funded through Bill Melinda Gates Foundation and coordinated by Wageningen University in Holland rekindled the interest on the Rhizobium work in a number of African countries with an aim of increasing adoption and accessibility of biofertilizers to the small scale farmers .

The aim was a better usage of the environment and open the path towards the creation of sovereign solutions to address structural dependencies on foreign trade and imports,

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https://www.google.com/search?q=definition+of+rhizosphere&gs_lcrp=EgZjaHJvbWUqDAGAEAAyRhj5ARiABDIMCAAQABhGGPkbGIAEMggIARAAGBYHjIICAIQABgWGB4yDQgDEAAyhgMYgAQYigUyBwgEEAAy7wUyBwgFEAAy7wUyCggGEAAygaAQYogTSAQg2NjE0ajBqN6gCALACAA&sourceid=chrome&ie=UTF-8&si=ACC90nzhFW-fOieS-I060ZQl1KsOjaMgqPDPEqdHVMDQmu1kzil4cmnlSJEPawDBHCvd7f7ZByxKG3yHCSsatfk9XBlmnj3r3qxMl6czomu4FKNJa6DL3l8%3D&ictx=1&ved=2ahUKEwj0geiRk5GKAxB1AIHHdqaGbwQ9YYDegQIGhAC

particularly in strategic domains such as food safety. The programme was active until the year 2000.

2.2 Bio-inoculation.

Bioinoculators are microbial preparations that are industrially replicated from so-called mother cultures.

At first, a starter culture is developed based on scientific evidence of its biological benefits to selected crops, then pure colonies of identified bacteria are isolated, and the strains are grown in incubation.

Such activities originate from laboratory research, identifying the cooperative combinations that are suitable for selected crops. There are no “one-fits-all” bacterial strain solution that works for all crops. Research is needed to adapt the strain to the crop of interest, called “formulation technology”, the basis for bioinoculators. A few of these bacterial-driven solutions have proven to be extremely beneficial to increase yields in specific cultures, **in particular Rhizobium for leguminous crops.**

Bioinoculants offer great potential for adoption to other than leguminous crops, if increased research on beneficial bacterial strains for other crops is conducted locally.

Bioinoculators cannot be applied randomly in the field like conventional fertilizer. Their application needs to comply with a minimal set of Standard Operating Procedures (SOP) and methodologies to have an optimal impact. For example, Rhizobium, the strain that has the greatest potential for impact in Kenya, cannot be applied on planted seeds, but needs to be applied **on** seeds **prior** to being planted.

Appendix 3 offers a pictorial view of the process.

Bioinoculators have multiple advantages:

- They do not deplete the soil.
- They are cooperative in nature, contributing to nitrogen fixation within the seed/plant they are associated with. Nitrogen fixation is one of the fundamental elements for plants’ healthy growth.
- They are sustainable: soils and cultures display positive natural reactions to inoculators.
- They are cheaper than conventional fertilizers and offer better yields.
- They are extremely dependent on soil’s pH, determining positive or moderate acceptance of the bioinoculator as nitrogen-fixing agent.

Appendix 1 lists the bacterial strains mostly used worldwide in bioinoculation.

The mother culture of Rhizobium, one of the most successful standardized bacterial strains, is available either in liquid form (through Yeast Extract Mannitol or YEM) or in solid form (through Agar, a jelly-like substance consisting of polysaccharides obtained from the cell walls of some species of red algae, primarily from "ogonori" and "tengusa").

2.3 The potential of Rhizobium as a bioinoculant in Kenya

2.3.1 A focus on legumes.

Kenya has no sizeable soybean or groundnuts cultivars.

Rhizobium as biofertilizer has principally been directed to legumes, a subsistence cultivar for small holder farmers in local agriculture and export crops for large scale farmers. The potential to use bioinoculator for other crops like maize, wheat, sugarcane and rice is conditional to the expansion of research to other bacterial strains that have similar beneficial effects on these crops as Rhizobium has on legumes. Developing new strains for new crops has the potential to disrupt the conventional chemical fertilizer market, offering better yields, while ensuring sustainable agricultural practices.

In contrast, the use of Rhizobium can be upscaled tomorrow, provided the necessary soil assessment is conducted first. Decades of chemical fertilizer utilization have resulted in soil's depletion and acidification, leading to necessary preliminary soil assessment for determining optimal uptake, even in the case of Rhizobium. Other elements such as proximity of the Rhizobium production units to farmer communities and marketing (awareness raising and training) are part of the success factors of such an upscaling.

In Kenya, biofertilizers benefits are widely recognized within the scientific community and the agronomic sector but are marred by the competition of inorganic fertilizers through "pump and dump" practices, not properly regulated/legislated. While inorganic fertilizers are a chemical solution to soil fertility, excess or wrong usage has caused soil depletion over time, requiring additional volumes to reach the same results. Dispersion of chemical fertilizers residual elements is not beneficial to soils' health and subterranean water reserves. Regulation to promote the systematic adoption of alternatives to chemical fertilizers has been minimal in the Eastern African regions as inorganic fertilizers represent major commercial interests dominating the market. The conventional fertilizer importer business community did not concede space to more sustainable inputs for agriculture.

A conducive policy framework should promote usage of biofertilizers within African agriculture. In Kenya, sources indicate that the Kenyan Ministry of Agriculture, Livestock and Fisheries (MOALF) has had a draft Biofertilizer and Soil Conditioners Bill in development since at least 2006⁵. It is unclear if the draft has progressed. Currently, the

⁵ <https://cgspace.cgiar.org/server/api/core/bitstreams/3cd42328-336f-48b9-a9c4-963dacf0c298/content>

importation, manufacture, and sale of fertilizers and animal foodstuffs in Kenya are regulated under the Fertilizers and Animal Foodstuffs Act (Cap 345) under the State Department of Livestock⁶.

Kenya consumes about 820,000 metric T of inorganic fertilizer (source: Fertilizer Africa) resulting in a foreign debt of about 500M\$ in 2023.

In the EAC region the volume of inorganic fertilizers amounts to more than 3 M metric tons, a conservative figure.

The potential market is one of progressive substitution, driven by economic and sustainability reasons.

2.3.2 Total Addressable Market (TAM)

TAM for biofertilizers is based on a set of hypotheses defined by the author and is offered for understanding the potential of Rhizobium for legumes in Kenya.

Based on the World Bank study dating 2016⁷ and confirmed by Ministry of Agriculture, Livestock, and Fisheries, the total arable land in Kenya is assessed to be at 5,4M hectares, grossly distributed as 75% with Small Scale Farmers (SSF) and 25% Large Scale Farming (LSF).

The starting assumption is based on the percentage of land labored for legumes, 15% for SSF (self-subsistence/intercropping) and 20% for LSF (local and export markets).

	Est.d SSF Million	Ratio LSF/SSF on total	Total acreage Million Ha	Legumes %	M Ha	M Ac
SSF	7	0.75	4.05	0.15	0.61	1.50
LSF		0.25	1.35	0.2	0.27	0.67
Total			5.4		0.88	2.17

Leguminous crops allow for several harvesting cycles per year, with an average of 3 harvests in a calendar year for SSF and 2 for LSF. Each cycle requires inoculants in a proportion between 0,5 to 1L/Kg/Acre depending on the legume.

Rhizobium is marketed both in solid and liquid formats.

⁶ <https://cgspace.cgjar.org/server/api/core/bitstreams/3cd42328-336f-48b9-a9c4-963dacf0c298/content>

⁷ Kenya Economic Update: Anchoring High Growth
<https://www.worldbank.org/en/country/kenya/publication/kenya-economic-update-anchoring-high-growth-can-manufacturing-contribute-more>

The equivalence between fluid and solid volumes in inoculant products is not totally rigorous, we took the most reasonable assumption, 1:1.

We assume a higher rate of utilization of inorganic chemical fertilizer with LSF compared to SSF, based on purchasing power.

	Chem Fert Required Kg/Ac/Cycle	Cycles	Chem Fert Total Tons/Annum
SSF	25	3	112,539.38
LSF	50	2	66,690.00
Total			179,229.38

The conversion factor to traditional inorganic fertilizer equates to about 2x25Kg bags/Acre (1 per seeding or 2 per season) for 0.5L/Kg/Ac of inoculant for SSF and 1 L/Kg/Ac for LSF, based on purchasing power.

	BioFert Required Kg/Ac/Cycle	Cycles	BioFert Total Tons/Annum
SSF	0.5	3	2,251
LSF	1	2	1,334
Total			3,585

In summary, about 180,000mT of conventional chemical fertilizer can be replaced by 3,585 T of Rhizobium inoculant in solid or liquid form.

Chemical fertilizer is assumed at a cost of 3,500KES/50Kg bag, liquid Rhizobium retails for 1,300KES/Liter (10US\$/L).

In monetary terms, about 90M€ of conventional fertilizer could be substituted with about 34M€ worth of bioinoculant.

	Chemical	Units	Bioinoculant	Units
Total volume/annum	179,229	Tons	3,585	Tons
Cost per unit (KES)	3,500	50Kg Bag	1300	1Kg
Total Value (KES)	12,546,056,250	KES	4,659,963,750	KES
Total Value €	92,933,750	Euro	34,518,250	Euro

Soybean has the greatest potential for its positive response to Rhizobium inoculation, but in Kenyan agriculture such crop is a white elephant. In neighboring countries, the development of strains derived from Rhizobium has generated benefits in soybean and groundnuts (Zambia, Tanzania, Malawi), with Rhizobium acting as an efficient alternative to conventional fertilizers both in terms of volumes and yields.

Similar gains could be made for other cereal and grasses such as sugarcane, rice and maize, opening bioinoculants to staple food commodities through targeted research and industrial off take.

3.0 Production Capability

- Assessment of the current production landscape in Kenya, including the availability and suitability of resources for large-scale biofermentation.

Rhizobium, like other bioinoculant strains, was developed in the laboratory and then scaled to industrial requirement. University of Nairobi and MIRCEN engaged in a partnership in the 1990s with [MEA Fertilizers](#), a Kenyan company operating in chemical fertilizers who created a biofertilizers division. The division operated for about 10 years but then the Company opted back to inorganic product sales only. The reasons for such shift were the funding required to trigger awareness and create markets for the product, coupled to the stricter process compliance bioinoculation requires from inception (good manufacturing practices or GMP), including cold-room conservation and application methodology.

Strains were sourced from Academia (MIRCEN/UoN), isolated through autoclaves and developed with biofermentors in MEA facilities in Nakuru, where the processing equipment was located.

Interviews conducted for this report pointed to a lack of Governmental support, as awareness was left only to the Company marketing the product with little or no support from the Public Sector or for that matter the development of a conducive legislative framework.

As mentioned before, bioinoculant mode of application differs from conventional fertilizers and compels stricter protocols for optimal results: seeds are plunged into the biovector whether solid or liquid, and after a set period, seeds must be planted. Equally, shelf life of biofertilizers must be ensured through cold-chain storage calling for regulations defining expiry dates. Not respecting such protocol impacts the beneficial effects of the process.

Today, the scientific competence to produce rhizobium still exists in Kenya: University of Nairobi labs are capable to generate the required mother culture for an interested entrepreneur to take over and develop the market.

In alternative, mother culture can be imported (Australia, Belgium, Brazil, Germany, US, India) for it to be multiplied locally.

For biofertilization of other crops, open-source collaborative research is required through engagement with specialized agricultural biotechnology centers aimed at the staple crops mentioned previously such as maize, wheat and sugarcane. These research cycles would take between 1 months and 4 years for selection and testing of new strains or adapting existing ones to the local environment conditions. The testing cycle depends on the lifespan of the crop: for example, 18 months are required for validating the efficacy of bioinoculation on adult sugarcane.

- High-level overview of the biofermentation production capabilities in other East African countries (Rwanda, Uganda, Tanzania) derived from conversations with researchers.

In the Eastern and Southern Africa Regions, there have been initiatives to develop/improve strains other than Rhizobium for specific crops. For example, in Zambia [Mt. Makulu](#) research institute focused on soybean. In Uganda, Makerere University and in Zimbabwe [Marondera](#) university also focused on soybean and cowpea. Tanzania and Malawi-MoA started working on bacterial strains for groundnuts and soybean, but with unproven results.

Currently, three countries have the necessary knowledge for the commercial production of Rhizobium: Nigeria, South Africa and Kenya. Kenya services the East African regional market needs, particularly the Soybean markets (TZ, Ug, Mal, Zam), in a more limited way, the legumes market (subsistence and export) within its own boundaries.

Today applicable know-how converges on leguminous cultivars, while progress on staple crops has not yet reached the stage of commercial application (maize, wheat, sugarcane and rice) for African soils.

One of the key success factors of research in the domain of bacterial strains lies in a “Glocal” approach, where global research results are applied locally through controlled field testing.

Such research is no longer necessary for Rhizobium as the strains have been identified for the region, with proven effects, free from Intellectual Property rights.

To reintroduce the commercialization of rhizobium as a cheaper, and sustainable fertilizer or legumes, a PPP model framework could prove beneficial to parties involved (off taker, public powers and end users). As a result, **farmers would enjoy cheaper fertilizing compounds, and the Country would mitigate imports, save foreign currency and create a national industry of sustainable substitution.**

- Evaluation of Kenya's infrastructure and conditions for large-scale biofermentation, outlining key requirements and potential stakeholders.

There are organizations in Kenya that have either obsolete assets for medium scale production of bioinoculants or have small scale production lines (Lab⁺ type).

Former academics hold subject matter expertise in both laboratory and industrial process management. Private parties in Kenya have expressed an interest in considering the product for industrial scale-up and off take, more so if diversification of strains impacts commodities through scientific innovation.

In Kenya, the following actors have been identified based on processing capability and entrepreneurial ambition, for Rhizobium only:

Organisation	Status	Size	Current Skillset	Plusses/ minuses
MEA Fertilizers	Obsolescent infrastructure	Medium	Absent	Abandoned the market
Kumea	From MEA's ashes	Small	Medium	Took over MEA assets
UON	Labs to be restarted	Lab size	Present	Research contributor
Private Former Scientists	Operational Labs	Lab size+	Present	Lack of industrial assets

Two Rhizobium products are produced in Kenya, Biofix sold in solid compound, and Liquifix, sold in liquid format. Refer to Appendix 2 for the products marketed in Kenya and beyond.

From interviews conducted, the present production capacity is about 30,000L for the liquid version and about 20T for the solid, this latter figure might require further verification.

Based on the TAM analysis conducted prior, the market has considerable potential for development, both industrially and commercially.

4.0 Demand Trends (Local, Regional)

- Analysis of the local demand for the chosen biofermentation product(s) in Kenya, focusing on market needs and potential growth areas.

Biofertilizers (in particular Rhizobium), represent a strongly sustainable alternative in soil and crop management, particularly in countries dependent on inorganic fertilizers imports, like East Africa and across the Continent. Crops have higher yield, soils are healthier, reducing the importation of inorganic chemical fertilizers. If supported by the necessary research programs, there is ample space by including other crops in this transition to the sustainable use of

biofertilizers in Kenya. Presently, market efforts are primarily directed to industrial farming practices in Eastern Africa for Soybean and Groundnuts production, grown in several countries neighboring Kenya.

This provides an opportunity for Kenya to develop an export market for Rhizobium, restarting the industrial production of the product, currently not at scale and more driven by opportunity than by systemic market approach/presence.

In addition to the export opportunity, Kenyan Large-Scale Farmers specialized in legumes export are the obvious commercial target whereas Small Scale Farmers cultivating legumes for subsistence complete the addressable market defined in section 2.

For doing so, the benefits of bioinoculant solutions need to be coupled with a robust education pillar that transfers the process knowledge to the local farmer.

Rhizobium is not a novelty per se, in the past it suffered supply chain gaps with minimal awareness creation to support its introduction into the local market.

- Initial identification and description of the interest areas of entrepreneurs, innovators, and investors in biofermentation in the region.

At least two entrepreneurs contacted confirmed their engagement in Rhizobium, those currently producing Biofix and Liquifix.

None presently has capacity at scale or up to date processing technology: their mode of operation builds on networks created when Rhizobium was first commercially introduced in Kenya. We could define their activity as driven by repetitive business.

Market penetration remains tied to product availability (production and inventory) but more importantly to marketing strategy, working capital and supportive policies.

Interviewees stated that should strains diversification into commodities reach industrial adoption, there would be ample local offtake, in sugarcane and maize.

Strains specific to such cultivars exist (Brazil, Mexico, Philippines), yet adaptation to local soils requires investment in locally structured protocols so that indigenous strains can be optimized.

In practice, research has to develop/identify the bacteria that are most suited to the local soil conditions and crop species in a controlled test environment, combining lab and field activities.

- Identification of potential offtake partners and their general requirements.

The potential industrial off taker profiles encountered are entrepreneurs already engaged in agriculture, whether with their own commercially exploited land, contract farmers or inputs resellers. The appetite is driven by the increased yields, serving export markets and national markets alike.

Small-scale farmers require more marketing and on-field activities, with a focus on the improvement of the local economy.

In Kenya alone, large scale farming organisation like [VegPro](#), [East African Growers](#), [Frigoken](#), [Forest foods](#) and [Agventure](#) would be the natural local targets for bioinoculants.

Extension to East Africa necessitates more in-depth analysis and in-country investigation for it to become exploitable intelligence, yet it is no mystery that sleeping giants like Tanzania with abundant and underexploited arable land would become the next target.

5.0 Market Dynamics & Structure

- Competitive landscape mapping, including leading players (locally and possibly regionally) and customer segments.

This is an underserved local market that was approached in the past, but current local players are challenged by larger multinationals (BASF, Syngenta, Bayer) who randomly propose their solution without the same commercial drive applied for their core products such as pesticides or conventional specific fertilizers.

Biofertilization has not been fully embraced by locally present multinationals, as it also calls for marketing efforts beyond their span of control and core business.

We highlighted in previous sections the suggestion to consider PPPs and a shared drive towards vulgarization of practices and broader research diversification towards staple crops or cash crops beyond the subsistence pattern.

The Kenyan producers interviewed, whether partially established or “garage outfits” stated that there is a greater addressable market **out of country than in Kenya**. Their assessment is that once awareness raising is supported by local authorities or leading NGOs/International organizations, the sector can thrive if combined with progressive research/innovation.

Lack of extensive Soybean cultivar in Kenya is the objective reason for such export-driven position: such a crop has less returns for farmers as it requires process transformation cycles from farm to fork, contrary to other legumes.

- Identification of potential competitors and analysis of Kenya's competitive advantages in the biofermentation sector.

Kenya has experimented the biofertilizer option in the past and has been challenged in its evolution by the more commercially available presence of inorganic fertilizer importers (about 6) with blending capabilities, importing (not producing) about 800,000T of inorganic fertilizer yearly.

Soil acidification is the indirect result of widespread application of inadequate chemical fertilizers and should be a strong signal for public and private stakeholders to engage a conversion roadmap towards softer and friendlier techniques for the environment.

Conventional fertilizers have been in use for decades, their mode of application is basic and accessible, supported by the drive of accelerating food self-sufficiency.

The sizeable conventional fertilizer industry should not be a barrier to bioinnovation and the transition to more sustainable fertilization practices.

Biofertilizer know-how exists in Kenya, eventually in the past the transition from research to commercialization has not adequately been managed, with entrepreneurs in the domain serving more business in export markets than in country.

6.0 Potential Economic Contribution

- Qualitative assessment of the potential for job creation and economic uplift in various areas of the value chain.

The use of biofertilizers and more specifically bioinoculators can lead to the economic uplift of communities: more food on the table of small-scale farmers with lower cost of inputs.

The bioinoculant cost per Acre of seeds planted comes at about 10€ versus 25€ and upwards for inorganic fertilizer. This represents a solid saving on the cost of inputs per harvest cycle, that can be 3 to 4, depending on the variety planted.

Picking on the previous TAM indicative assessment:

- 180,000T inorganic fertilizer: 90M€ (50Kg@25€)
- 3,600T Rhizobium : 34M€ (1L@10€)

This offers an idea of the market value for Rhizobium bioinoculators in Kenya, with clear cost advantage for its users, but also creation of sovereign capacity with positive impact on foreign debt, sustainability advantages, and improved food self-sufficiency.

For the industrial process, a skilled workforce in biotechnologies both at lab and industrial level for operating the bioreactors value chain will be in demand.

It might not be appropriate to sketch a number without granular datasets, but considering the gap between current assessed production and full market requirement, the gap is about 70-fold.

On indirect job creation, only field training can deliver value to the local farmers communities. Typically, one field operator trains between 100 and 200 farmers, depending on distance and extension: this area of engagement is fundamental for ensuring knowledge

transfer the rhizobium application methodology and awareness about the positive economic impact of using Rhizobium as the fertilizer of choice.

- Quantitative estimates based on current manufacturing practices in Kenya if available.

The existing industry is artisanal, with ageing industrial components (autoclaves, fermenters/bioreactors) in need of capital injection.

There are willing entrepreneurs with process and market knowledge seeking partnerships, in particular former employees/partners of the MEA initiative.

Appendix 5 offers an unverified estimate of the required investment stated by a local actor.

From interviews conducted, we can conservatively assess an output of about 30,000L/annum of liquid Rhizobium and with less certainty, about 20T of solid Rhizobium. This output is distributed in Kenya and more importantly for export to East Africa.

- Outline the potential pathway for local production to contribute to the Kenyan economy.

The substitution of conventional inorganic fertilizer over time with biological resources should be a durable objective. Elements of the roadmap are listed in chapter 8 below.

The current fertilizer usage in Kenya and beyond is overly skewed towards inorganic chemical compounds, calling for several angles of reflection, foreign debt reduction, creation of sovereign wealth, sustainability but equally public power's support through legislation. These axes should push investment, advocacy and regulation towards more sustainable choices.

A conducive regulatory environment would help defining a new level-playing field, for example proportionately shifting the subsidy model currently operating from chemical fertilizers towards biofertilizers and their market re-launch.

The fertilizer subsidy program reinstated in 2022 by the Government developed a database of about 5,4M farmers eligible for the subsidy. This programme mapped the farming community in Kenya only four years ago. It went into some level of detail in recording the crops that required the subsidy.

The data in possession of the National Cereals and Produce Board offers quite a sizeable database for engaging the potential market and the development of pervasive a commercialization strategy.

Public authorities should also support the local industry by supporting knowledge sharing and creating the conducive environment for the development of locally applicable bio inoculator solutions and their dissemination.

7.0 Social and Environmental Impact

- Exploration of the potential social benefits of scaling up biofermentation.

Social impact relates to increased welfare for the bottom of the pyramid in agriculture given the lower cost of input and the higher yield, improving food security but equally more quality product for export markets, lowering foreign dependence.

From the environmental standpoint, the advantages of sustainable agricultural practices lead to soil restoration, less soil and water pollution and improved general well-being of the population.

A succinct review of other biofertilizing methods can be found in Appendix 4

8.0 Implementation Recommendations and Roadmap

- Action-oriented recommendations of priority actions and actors to drive the adoption of biofermentation applications and offtake.

The initial recommendation would focus on creating a conducive environment for the biofermentation business to thrive in Kenya and beyond.

Legumes are an exported commodity but also a subsistence resource as explained in this report. Identification of “champion” LSF willing to engage the change process is key as well as demonstrating the positive cost impact. SSF require more “product marketing” coupled with support from public authorities or international organizations. Efforts should be directed either to pilot farms or selected user groups with homogeneous soil condition and appropriate weather patterns.

Research should focus on N-S partnerships aimed at expanding the range of crops benefiting from bioinoculation/biofertilization, leveraging the current local knowledge. This can be achieved through funding calls either at EU level or through foundations/donor countries

- Roadmap outlining the steps needed to achieve the recommendations.
 - Availability of mother culture.
 - Quality assurance of strains/adaptation to local soils.
 - Update production facilities for scale-up (autoclaves, biofermentors, packaging units, cold-chain)
 - Supply chain synchronized with crop cycles (2-3 waves per annum).
 - Marketing strategy, territorially pervasive.
 - Sales network
 - SOP (Standard Operating Procedures) applied
 - Industry and farmers associations engagement

- Investor engagement
- Conducive legislative framework supporting sustainable agricultural practices, focus on bioinoculators/biofertilizers.
- International NGOs support through dissemination programs.
- Focused research partnerships along N-S cooperation for new streams/crops

9.0 Conclusion

- Concise summary of the study's findings and their implications for the development of biofermentation in Kenya.

Bioinoculators are a family of biofertilizers taking advantage of the cooperative action of some lab-isolated bacterial strains that have the primary benefit of dramatically improving nitrogen-fixation at the seed's root level and in the rhizosphere more in general. Rhizobium is the strain with established reputation in Kenya and neighboring Countries.

Although experiencing innovation in its own turf, Kenya is an underserved market that has not enjoyed massive adoption of such bioinoculants in its legume sector, for the following reasons:

- Lack of extensive cultures ideally suited for enjoying its benefits (Soybean and Groundnuts).
- Absence of pervasive communication on Rhizobium's unique value propositions for legumes.
- Limping knowledge transfer of the new process for its effective application by the farming community.
- Product's availability and accessibility to both Small-Scale and Large-Scale Farmers.

A few Kenyan entrepreneurs revived the product, with at least two indigenous products (one in liquid and one is solid form) commercially active, selling either to local farmers or to larger users in neighboring countries.

While price and yields should be no-brainers USP for the choice of Rhizobium vs conventional fertilizers for a slew of sustainability reasons, innovation in the domain would dramatically improve adoption, if non-leguminous crops could reap the same benefits legumes do through Rhizobium-like bacterial strains.

There is some minimally established capacity on Rhizobium in need of re-igniting both at processes level and at marketing level.

Support from local institutions could dramatically help the substitution of conventional fertilizer with the biological one, helping to reduce the foreign debt incurred by the imported chemical compounds while engaging the sustainability path.

The potential of swinging in time a yearly foreign debt of about 90M€ to a local industry of 34M€ should resonate to legislators, investors and entrepreneurs alike.

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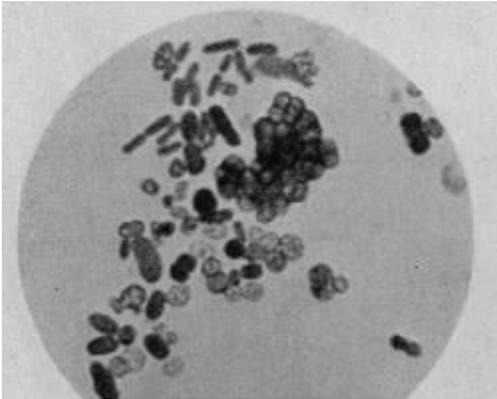
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Appendixes

- Any supporting data, tables, or figures that are not included in the main body of the report.

Appendix 1: Bacteria strains mostly utilized in agriculture

- **Azotobacter:**



<https://en.wikipedia.org/wiki/Azotobacter>

- Target Crops: Wheat, Rice, Maize, Cotton, Sugarcane, Vegetables, Fruits, and many others
- Yield Gains: Reported yield increases vary depending on soil conditions and crop type. However, studies have shown improvements ranging from 5% to 20%. Azotobacter enhances nitrogen fixation, improving plant growth and overall productivity.

Used in Kenya? It was promoted by UNDP and AGRA and through local academic research, but with scant results in the field.

- **Rhizobium:**



<https://milnepublishing.geneseo.edu/botany/chapter/rhizobium/>

- Target Crops: Leguminous plants (e.g., beans, peas, lentils, soybeans, alfalfa)

- Yield Gains: Yield gains are significant, often ranging from 20% to 50%, as Rhizobium forms a symbiotic relationship with legumes, facilitating nitrogen fixation and reducing the need for chemical fertilizers.

Used in Kenya? UON and Mircen developed the protocol, it got endowed through partnership with MEA with mixed successes. It is retailed in solid and liquid format in Kenya but more popular in Eastern Africa.

- **Pseudomonas fluorescens:**

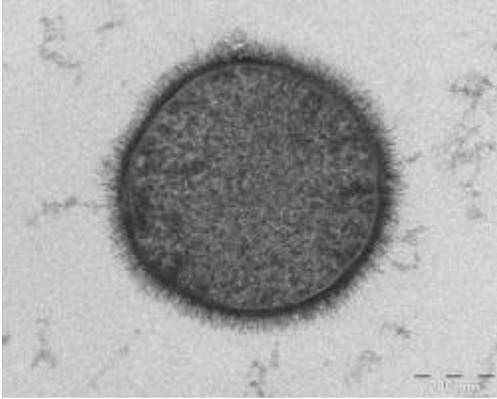


https://en.wikipedia.org/wiki/Pseudomonas_fluorescens

- Target Crops: A wide variety of crops including cereals, oilseeds, vegetables, fruits, and ornamentals
- Yield Gains: Reported yield increases can range from 5% to 30%, as Pseudomonas fluorescens produces plant growth-promoting substances and protects against soilborne pathogens.

Used in Kenya? This is not properly a fertilizer, rather a biopesticide that is antagonized in Kenya by the majors proposing chemical pesticides. It has been discontinued by leading international suppliers (Merck).

- **Bacillus subtilis:**



https://en.wikipedia.org/wiki/Bacillus_subtilis

- Target Crops: Cereals, vegetables, fruits.
- Yield Gains: Yield gains can range from 5% to 20%, as *Bacillus subtilis* helps solubilize nutrients, promotes root growth, and protects against plant diseases.

Used in Kenya? Again, not seen as fertilizer, rather a biopesticide that is antagonized in Kenya by the majors proposing chemical pesticides. The product in trade is called Mazao Regain and it is distributed by [Real IPM](#) in Thika.

- **Azospirillum:**



[https://waytogrow.net/blogs/plant-nutrition/5-](https://waytogrow.net/blogs/plant-nutrition/5-applications-for-azospirillum)

[applications-for-azospirillum](https://waytogrow.net/blogs/plant-nutrition/5-applications-for-azospirillum)

- Target Crops: Cereals (especially maize and wheat), sugarcane, and forage grasses
- Yield Gains: Reported yield increases can range from 5% to 25%, as *Azospirillum* promotes root development, enhances nutrient uptake, and improves stress tolerance in plants.

Used in Kenya? More used as top dressing, [Dudutech](#) in Naivasha promotes such product within its range, though it is not properly a fertilizer company, rather specialized in nematodes for integrated pest management.

Appendix 2: Products marketed in Kenya



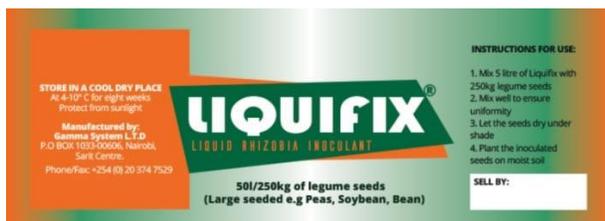
Legumefix, produced by Legume Technologies (UK) and distributed in Kenya and East Africa by Lachlan inter alia.

Rizoliq developed in Argentina for beans and soybeans, distributed in Kenya and East Africa by Syngenta.

HiStick, distributed by BASF, targeting soybean.



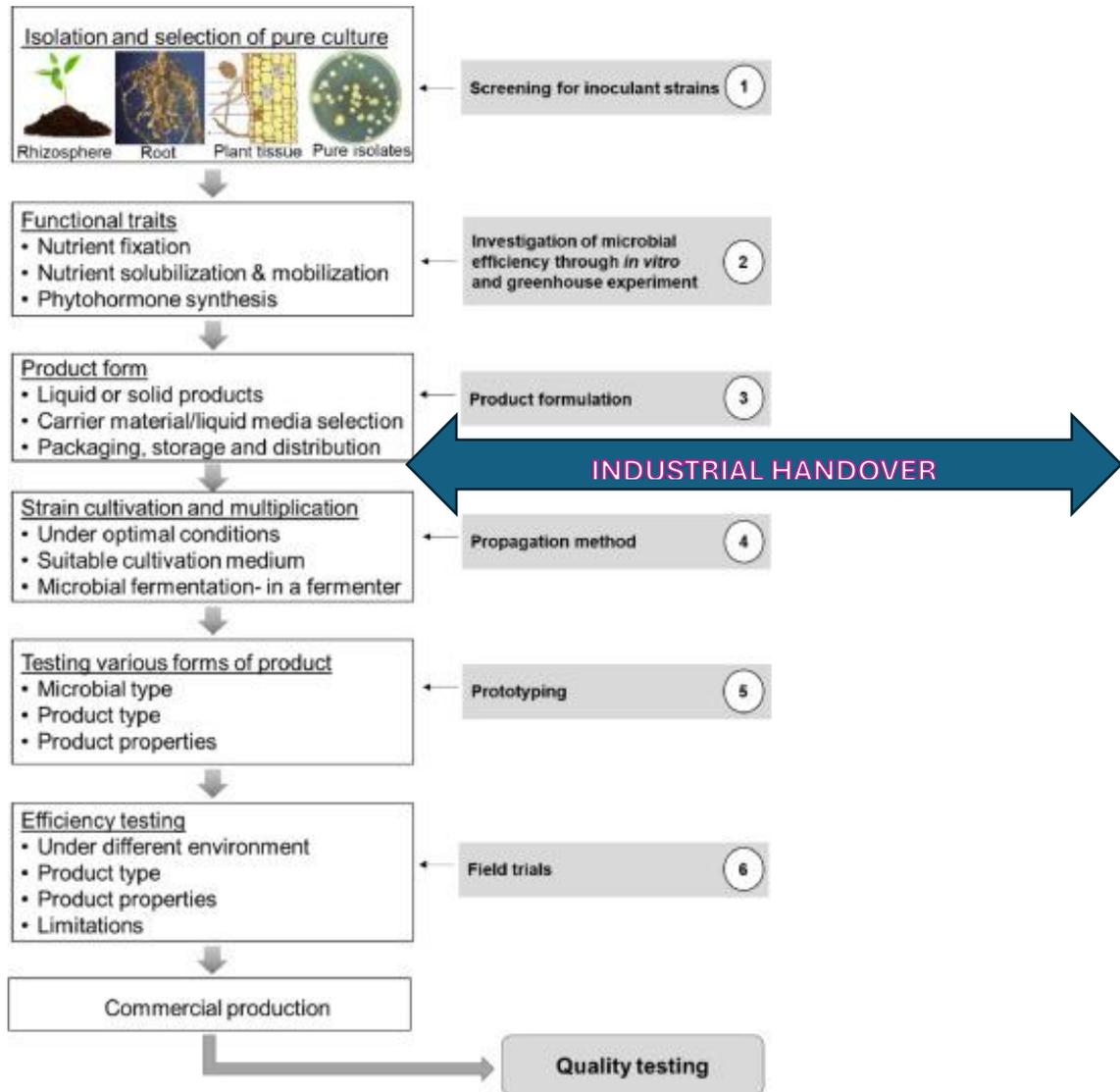
Biofix, the first solid biofertilizer developed and marketed in Kenya for beans and legumes.



Liquifix the liquid version of Rhizobium, developed by local scientists and marketers.

Appendix 3: The process⁸

The scientific/industrial process followed is as depicted in this flow chart:



At stage 4 the industrial offtake process starts, while from stages 1 to 3 it is a pure lab process. Rhizobium for example has passed those stages and commercial production can be triggered just with investment in industrial processes.

⁸ Scientific African 11 (2021) e00694

Appendix 4: other biofertilizing techniques.

If expanding to organically generated fertilizers/composts such as biomass or animal/vegetal waste recycling, challenges might arise from the collection and aggregation of waste materials required that could have environmental effects in terms of exhalations requiring monitoring particularly in case of conventional techniques applied.

It could be the case of processing of animal products like blood meal, feather meal, and some manure-based fertilizers involving industrial processing of animal byproducts: this may involve drying, grinding, and sterilization to create concentrated organic fertilizers.

Liquid organic fertilizers like fish emulsion and seaweed extract involve processing these materials into liquid fertilizers typically involving extraction, concentration, and sometimes dilution to create a usable liquid fertilizer.

Simpler composting methods are:

In-vessel composting, using large, enclosed containers to control temperature, moisture, and aeration for faster composting.

Windrow composting, piling organic materials in long rows with periodic turning to manage aeration and decomposition.

Vermicomposting, employing worms to break down organic matter, resulting in nutrient-rich castings.

Appendix 5: Unverified Estimates of required investments for a 200,000L site (Interview)

- Industrial Fermenter (700 LTR)
- Hammer Mill 10 HP (POSHOMILL)
- Industrial Autoclave
- Mixer (250 I)
- Curing Racks
- Laboratory chemicals and materials (Petri dishes, conical flasks, detergents)
- Cold room (medium size)
- Quality Assurance services
- Automatic FFS Packaging Machine
- Branded Packaging materials
- Computer (desktop workstation)
- Vehicle(s)

The total estimated costs for these \$500,000