Microbial Fertilizer[1]

Microbial fertilizers use bacteria to facilitate crops' absorption of nutrients, improving yields and reducing the need for synthetic fertilizers. Further testing and adaptation of microbial fertilizers to new agroecological contexts is needed to transition these technologies to scale in low- and middle-income countries.

1. Context

Nitrogen fertilizer is key to increasing yields in some regions, but synthetic fertilizer is a major source of emissions and environmental degradation. Globally, the production and use of synthetic fertilizer generate between 1 and 5 percent of global carbon dioxide emissions. Fertilizer use varies significantly across regions. The fertilizer application rate in sub-Saharan Africa is one-seventh of that in East and South Asia. Fertilizer underuse in Africa limits productivity, while heavy use of synthetic fertilizers in Asia leads to adverse environmental effects, in addition to high fiscal costs from subsidies.

2. Microbial Fertilizers

Microbial fertilizers use bacteria to facilitate the absorption of nutrients necessary for plant and soil health. Different types of microbial fertilizers are tailored to specific crops and nutrients. Some formulations use a single bacterium, such as Rhizobium or Azospirillum, while others combine two or more bacteria. Most microbial fertilizers target biological nitrogen fixation, though new formulations also facilitate phosphorus and potassium absorption.

3. Potential impact and cost-effectiveness

Microbial fertilizers could reduce emissions from synthetic fertilizers, generating billions in social benefits. Microbial fertilizers could reduce emissions from fertilizer production by 98 percent, relative to synthetic fertilizers. Using USD 190 as the social cost of carbon, each ton of

[1] This is a draft document that will be updated periodically until the publication of the Innovation Commission final report

synthetic fertilizer replaced by nitrogen fixation would be worth between USD 1,820 and USD 2,530.[2]

Rhizobium is an effective fertilizer for legumes and is widely adopted in some regions. In the 1990s, the Brazilian Agricultural Research Corporation (Embrapa) developed a microbial fertilizer using Rhizobium to enhance biological nitrogen fixation in soybeans. To date, around 100 million acres of soybean in Brazil use Rhizobium, which can increase yields by 10 to 30 percent in chickpeas, common beans, cowpeas, fava beans, peanuts, and soybeans, (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15). However, soil conditions influence its effectiveness. For example, Rhizobium may have limited or no effects in acutely degraded soils. Rhizobium provides proof of concept that microbial fertilizers can reach scale in middle-income countries.

New technologies have the potential to reduce the need for synthetic fertilizer in other staple crops. In the United States, PivotBio reprograms microbes to reduce or replace the need for fertilizer.[3]. Their main product, Proven40, combines 40 microbes to enhance biological nitrogen fixation in maize. Proven40 is being used on about 10 million acres of corn in the United States. At an earlier stage of development and not yet on the market, Kula Bio is working on a technique that allows the bacterium Xanthobacter autotrophicus to facilitate nitrogen fixation in any crop. This technique uses bioreactors to increase the microbial density of X. autotrophicus, which would allow bacteria to survive for longer periods in the soil–which can be a challenge with microbial fertilizers.

4. Potential pathways for scale

Greater funding could support the testing and adaptation of microbial fertilizers for low- and middle-income countries. Microbial fertilizers have been developed and adopted at scale in the United States and Brazil, and are being adopted commercially in other upper-middle and high-income countries. However, given significant upfront costs and potentially lower expected returns, the private sector is likely to underinvest in adapting microbial fertilizers for use in many low- and middle-income contexts. As a first step, donors could support the testing and adaptation of microbial fertilizers that have a proven record. If testing yields successful results and microbial fertilizer is adopted by a substantial number of farmers in some countries, testing could be expanded to other countries and complemented with sequenced investments to transition the technology to scale.

[2] Calculations based on EPA 2022, Yüzbaşıoğlu et al. 2021, and Zhang et al. 2013.
[3] The microbes are gene-edited but do not contain foreign DNA.

5. Potential path forward

Funding for microbial fertilizers should be sequenced and tracked based on the initial success of local trials. As an initial step, donors could support the testing and adaptation of microbial fertilizers in low- and lower-middle-income countries. Initial tests for microbial fertilizers targeting maize in Kenya offer promising early results. PivotBio has completed a set of research station trials in Kenya in collaboration with the Kenya Agricultural Livestock Research Organization (KALRO). These trials have shown that microbes work as well as synthetic fertilizers under local conditions, and PivotBio expects the technology to be marketable in Kenya in 2024 or 2025.

Testing microbial fertilizers in low- and middle-income countries would cost USD 250,000 to USD 3.5 million per country. The testing process used for PivotBio in Kenya could potentially be replicated in Angola, Ethiopia, Ghana, Kenya, Malawi, Mali, Nigeria, South Africa, Tanzania, and Zambia, which collectively produce almost 80 percent of maize in the region**.** Donors could consider partially or fully supporting:

- **Research station trials, at a cost of USD 250,000 to USD 500,000 each, to test the technology under local conditions;**
- **Farm trials, at a cost of USD 2 million each.** If research trials are successful, they could be followed by farm trials covering a substantial geographical area. Farm trials would ensure representative biological data on plants and microbes, and would enable measuring the stability and persistence of microbial fertilizers in the soil across space and over time;
- **Incorporating local strains of bacteria from each country to optimize microbial fertilizers for the local context, at a cost of USD 1 million per type of fertilizer per country.** Even if research station trials and farmer trials demonstrate that the technology works well, incorporating local strains of bacteria from the country could further enhance its performance. PivotBio has already developed a second generation of its technology for Kenya following this tailoring process.

Public sector support for farmers to purchase microbial fertilizers, once they have been successfully tested and adapted, could reduce the use of synthetic fertilizer, reducing emissions and environmental degradation. Subsidizing microbial fertilizers could reduce the use of synthetic fertilizers, which have negative environmental externalities. Currently, many governments subsidize synthetic fertilizers creating further incentives for farmers to over-apply synthetic fertilizers without substantial yield gains. This imposes significant environmental and fiscal costs. While rolling back subsidies can be politically challenging, replacing subsidies for synthetic fertilizers with locally appropriate microbial varieties could be a more palatable measure while reducing environmental and fiscal costs. Subsidies would have to follow the successful testing and adapting of the technology.

Finally, establishing a fund to solicit proposals to develop, test, and adapt innovations for climate change, food security, and agriculture could support the development of cost-effective innovations to encourage the adoption of microbial fertilizers among smallholder farmers in low- and middle-income countries.