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Editorial Introduction

Krishna Ravi Srinivas*

Welcome to the first issue of Volume 26 of the Asian Biotechnology Development Review. With this issue, ABDR completes 25 years in existence! We express our sincere gratitude to all the contributors and all members of the International Editorial Advisory Board. The response to the last issue, a Special Issue on 'Biotechnology for Bioeconomy' was excellent.

The current issue features three articles and a book review. Two of the articles featured in this issue pertain to the linkages between biotechnology, agriculture and sustainable development in India's context. Meanwhile, the third article contextualises biotechnology within the concept of power in geopolitics and international relations, while highlighting the rise of Brazil as a case in point.

Use of biotechnology in enhancing agricultural productivity is an area that ADBR has published several articles on. The advent of cutting-edge techniques in synthetic biology, along with improved access to technologies such as drones is ushering in a new era of hi-tech agriculture. In addition to enhancing productivity, the diffusion of such innovative applications can potentially render agriculture sustainable in environmental, economic and social terms. Two of the articles featured in this issue evaluate and elaborate upon this highly relevant theme. Neha Sehra, Rajbeer Singh and Anjan Chamuah explore whether drone-mounted spraying techniques can help in rendering agriculture more sustainable as well as in achieving sustainable development goals (SDG). These techniques are analysed through the lens of the responsible innovation framework. The authors illuminate the multiple ways through which the employment of these techniques can help India achieve SDGs.

The article by Anupama Vijayakumar presents biotechnology as a core dimension of the concept of national power in international relations. It presents biotechnology as a means to power in light of Brazil's rise to become a major pole of power in the international system in the post-Cold War era. The article examines the nuances within Brazil's domestic

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biotechnology policies. It explains how Brazil combines its strength in biotechnology with efficient diplomatic manoeuvring to defend its national interest and grow its clout over global affairs. It argues that biotechnology has served as a great equaliser of power in North-South relations. The article concludes that Brazil's strategies on biotechnology entail good practices that emerging economies in Asia and Africa can follow to improve their relative standing in the multipolar world.

The potential of Plant Growth Promoting rhizobacteria (PGPR), to bolster plant's resilience to environmental and climatic stresses, has been discussed in the article authored by Rashmi Jain, Abhishek Mathur, Devendra Singh and Ashish Rohilla. This analysis delineates the types of rhizobacteria, and critically examines the studies that have practically applied PGPR to achieve sustainable production. The authors shed light on PGPRs specific role in enhancing plant resilience and bringing about an abatement in the use of chemical fertilisers containing nitrogen and phosphorous. They conclude that the integration of PGPRs into mainstream farming systems will increase as agriculture moves towards more eco-friendly and efficient practices. However, this will also depend upon the government's enactment of supportive policies.

Amit Kumar's review of Cristiano Luis Lenzi's recent work titled *Transgenics in Dispute: Political Conflicts in the Commercial Liberation of GMOs in Brazil* adds significant value to this issue.

Your comments, responses and ideas are welcomed.

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Deployment of Drones for Sustainable Development in Indian Agriculture

Neha Sehra*, Rajbeer Singh*, Anjan Chamuah**

Abstract: Integrating drones in Indian agriculture presents a transformative potential, ushering in a new era of sustainable farming practices. In India, various incidents tell a story of how pesticides, seeds, and many more applications, once deemed a boon for agricultural progress, have gradually unfolded into a complex web of ecological and health challenges. Presently, the case of drones for spraying purposes in agriculture brings forth compiling advantages. These include enhanced precision in results, alleviation of the diverse adverse effects linked with manual spraying methods, operational feasibility in inclement weather conditions, utility in cultivating tall-standing crops and addressing the complexities of manual spraying for crops such as paddy and sugarcane. This paper explores the role of drones in promoting spraying applications in Indian agriculture. The study addresses two research questions: how can the utilisation of drones for spraying applications contribute to the sustainability of Indian agriculture, and how can drone-assisted spraying applications contribute to achieving the Sustainable Development Goals (SDGs) in Indian agriculture? To accomplish this, a responsible innovation approach is adopted as a theoretical framework to explore the dimensions of innovations in drone mounted spraying in Indian agriculture, juxtaposed by erratic weather conditions and knitted by diverse values and norms. The snowball sampling technique was employed to identify the interviewees and collect qualitative data. For this, in-depth interviews were conducted in person or by using Zoom. The findings suggest that efficiency, capability, effectiveness, gender equality, trust, and accuracy are certain values embedded in drone technology that assist in achieving the SDGs in Indian agriculture.

Keywords: Agriculture; Responsible Innovation; Drones; Sustainability; Spraying.

Introduction

The Ministry of Agriculture and Farmer's Welfare released the "Third advanced estimate of the production of major crops for the agriculture" year 2022-23, where they mentioned that agricultural production of food grains in India touched a record of 315.7 million tonnes in 2021-22, and it estimated at 330.53 million tonnes food grains production in 2022-23, the highest ever(MA&FW, 2023).This has been possible courtesy of the existing production system, post-harvest system, agriculture marketing, etc., and technology intervention. However, currently, the challenge is

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to match the population's growing demands by promoting more private-sector involvement in the form of partnerships. There has been a significant increase in the demand for vegetables, flowers, fruits, etc., due to increased export opportunities and the Indian diet shift towards healthy food. In an interview with the business line, Aditya Vazirani, CEO of Robinsons Global Logistics Solution mentioned that there has been an incredible change in the demand and supply trends before and after COVID19 lockdown. People adapt from farm to fork as a "new normal"(Gandhi, 2020). Due to this, many farmers today are interested in horticulture, floriculture, and other cash crops, which could give them better earnings. However, these require new impetus, better facilities, innovative technology, and more capital. It is known that the majority of farmers are resource-poor; more than 90 per cent of farmers have land holdings smaller than 4 hectares cultivating nearly 55 per cent of the arable land (IARI, 2009).

The vicious cycle of poverty in agriculture starts from low productivity. It follows through with the minimum marketable surpluses and returns, resulting in low income, minimum savings, and low re-investment, ultimately prompting less agriculture production. Other major factors which stop the agriculture sector from picking up pace are abiotic (drought, heat stress, cold stress, soil salinity) and biotic (including insect pests, fungi, bacteria, and nematodes) stress conditions which are also mainly influencing crop productivity in agriculture field (Chaudhary and Kumar, 2022). In India, several incidents tell stories of unintended consequences of using pesticides, herbicides, seed adulteration, Bt Brinjal controversy, etc. On the one side, it portrayed the image of vibrant crops swaying in a gentle breeze, but on the other side, an idyllic façade lies a tale of unintended consequences. A story of how pesticides, seeds, and many more applications can once be deemed a boon for agriculture progress has gradually unfolded into a complex web of ecological and health challenges.

Henceforth, judicious use of all kinds of technology and fertilisers is crucial to promote sustainability in agriculture practices. The advent of drones also known as UAV technology in Indian agriculture applications has revolutionised the sector by its smart practices in aerial spraying, monitoring, and crop-cutting experiments, while adhering to sustainability norms. The different values embedded during the design of the technology make it withstand adverse weather anomalies, user friendly in deployment and gathering information.

On 25 September 2015, the United Nations introduced 17 Sustainable Development Goals (SDGs), and their 169 targets are part of this agenda

(FAO, 2015). This paper covered those SDGs that targeted promoting sustainable technologies to increase agriculture production.

To achieve those SDGs and solve various challenges in Indian agriculture production, this paper's objective is to explore the role of drones in promoting spraying applications in Indian agriculture. To address this objective, this paper dealt with two research questions: how can the utilisation of drone for spraying applications contribute to the sustainability of Indian agriculture? How can drone assisted spraying applications contribute to achieving the SDGs in Indian agriculture?

The approach, Responsible Innovation (RI) (Singh and Kroesen, 2012; Stilgoe *et al*., 2013; Von Schomberg, 2013) claims to address the sustainability of emerging technology. Also, few studies on drone in Indian agriculture (Chamuah and Singh, 2023, 2022, 2021, 2020a, 2020b) ensure that RI has become a significant theoretical framework by its objectives to ensure ethical acceptability, societal desirability and sustainability.

To examine the research questions, this paper will proceed as follows: First, it describes the theoretical framework used for the study in section1.2. In section 1.3, describes the case study on Drone in Indian agriculture. Section 1.4 explains the methodology, representing the data to be collected and methods to be used. Section 1.5 illustrates the paper's results and discussion, which comprises the analysis part of the paper with a variety of information. In the section 1.6 conclusion briefly summarise the paper.

Responsible Innovation Framework

Responsible innovation (RI) originates in the early 2000s' national nanotechnology programme in the USA and similar dialogues on emerging technologies in mainland Europe and the UK (Lukovics *et al*., 2017; Owen and Goldberg, 2010; Rip and van Lente, 2013). However, there are some aspects like care, responsibility, cross-cultural conceptualisation, and types of sustainability (social, environmental, and economic) that are not well described in other innovation studies by Freeman (1988), Lundvall (1992), Nelson (1993), Edquist (1997), Breschi and Malerba(1997), Carlsson and Stankiewicz (1995), and later literature. In this context, responsible innovation emerged as an innovative approach that considers accountability, responsibility, sustainability (social, economic, environmental), and value inclusion in innovation (Chamuah and Singh, 2020b; Mishra and Singh, 2018; Setiawan *et al*., 2017; Setiawan and Singh, 2015; Singh and Kroesen, 2012; Von Schomberg, 2013).

The definition of RI occurs from different academic literature and documents. The definitions which are widely used and accepted in the revealed literature review are given by von Schomberg (2011), Stilgoe (2013), and Singh and Kroesen (2012). However, the definition given by von Schomberg (2011) and Stilgoe (2013) is based on the European framework.

In response to this discussion, Singh and Kroesen (2012) proposed an essential viewpoint about being careful towards certain social, economic, and environmental values by including participation as an essential dimension where more and more stakeholders give their opinions and take part in the process of societal acceptance of an innovation. He also explains the different dimensions of RI from a developing country's (here, India) perspective (Chamuah and Singh, 2022, 2020b; Mishra and Singh, 2018; Setiawan *et al*., 2019; Setiawan and Singh, 2015; Singh and Kroesen, 2012). Therefore, the RI approach given by Singh and Kroesen (2012) is adopted as the theoretical framework for the study.

Responsible innovation means to be caring or ensuring care for certain values for social, economic and environmental sustainability by engaging in anticipation, reflexivity, deliberation, responsiveness and participation for bringing up any change in any idea, product, process, method, way of doing business, technology, etc. in order to bring them into a specific market or use them in a society.

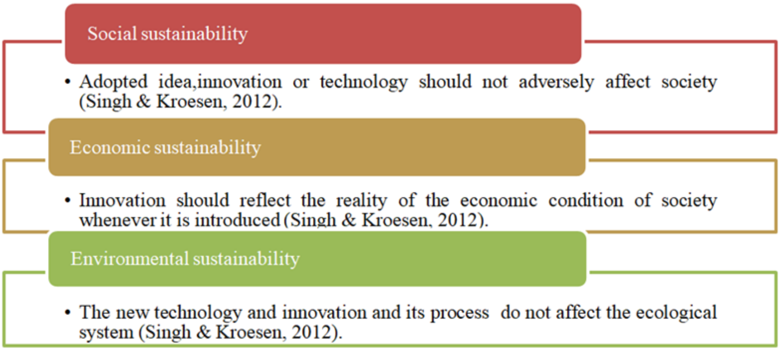
Sustainability is an essential aspect of innovations. Innovation can be said to be successful only if it can retain social, economic, and environmental sustainability (Burget *et al*., 2017), which are also the objectives of the adopted theoretical approach of the study. The objective of the next section is to show how sustainability and innovation are interlinked.

The Sustainability Perspective

The sustainability perspective is defined by Bruntland (1987) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition is widely accepted and adopted as a general term on a global level (Wever and Vogtländer, 2015). Another definition given by Brown defined sustainability as addressing environmental, social, and economic issues collectively to ensure a balanced and enduring future for humanity (Brown, 1981). Several studies claim that the Brundtland report was partly based on Brown's (1981) views (Frankelius *et al*., 2019).

The adopted RI framework defines three types of sustainability. Singh & Kroesen (2012) rightly explained that for adopting certain values, innovation should ensure social, economic, and environmental sustainability.

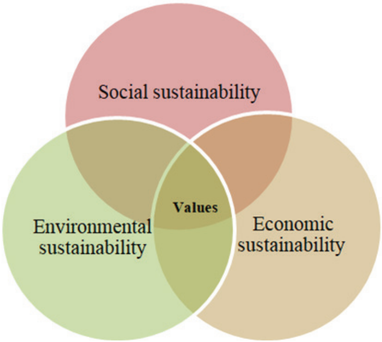
Figure 1: Three Types of Sustainability with Their Objectives



Source: Authors' compilation.

The above Figure 1 indicates types of sustainability. The further contribution to this concept is given by Chamuah and Singh in their paper, "Securing sustainability in Indian agriculture through civilian UAVs: a responsible innovation perspective," which has discussed the values that are responsible for creating sustainability in agriculture like capability, transparency, and trust, affordability and efficiency (Chamuah and Singh, 2020b). The same as another paper written by Kumari and Singh (2019, tit. E-Mobility through RRI to achieve social sustainability: a case study of women commuters in Delhi) focuses on the future e-mobility PTS in India, including the women-centric values to be socially sustainable (Kumari and Singh, 2019). She defined women's safety from the social sustainability perspective, discussing values like trust, psychological safety, feeling welcome, and gender equality. These values are used as a socially sustainable parameter.

Figure 2: Commonality Between Three Types of Sustainability



Source: Singh *et al.*, 2021.

Figure 2, shows the relationship between the three types of sustainability, and the commonality between these three types of sustainability is a set of values (Singh *et al*., 2021). Values refer to what a person or a group of people consider necessary in life. Values are individual preferences from important collective choices (Mishra, 2022; Singh *et al*., 2021). The collective choices become universal and cultural-specific choices (Mishra and Singh, 2018; Setiawan *et al*., 2017; Singh *et al*., 2021; Singh and Kroesen, 2012).

Values change to occur with the interaction of users and stakeholders, along with societal development and technological interjection (Friedman *et al*., 2013). In our case, the advent of drone has made a change to agriculture and also to the universal values like privacy and the safety of the user of the technology. Thus, the value like safety may be understood as the absence of risk or as the reduction of risks in as far as reasonably considerable and desirable but both meanings refer to the same value, i.e., 'safety' (Van de Poel, 2021). The relevance of values for a technology depends on the evaluative dimensions such as safety, privacy, sustainability can potentially impact(Van de Poel, 2021).

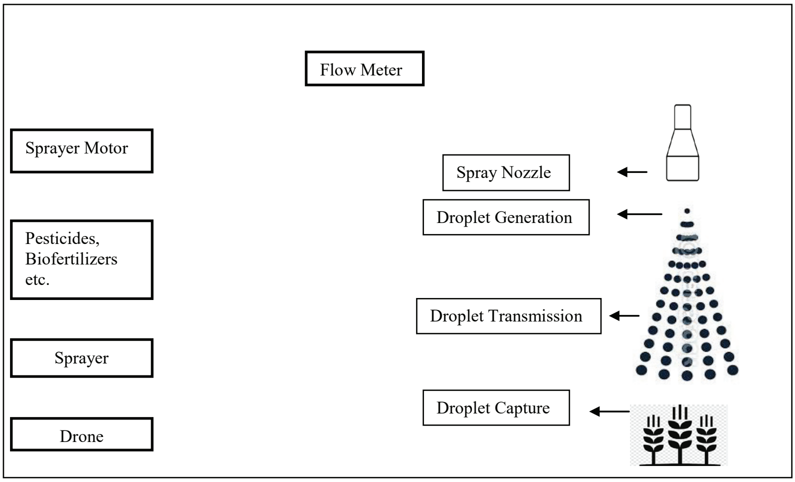
Application of Drones in Indian Agriculture

In India, the first-ever agriculture policy was announced in 2000 to achieve an output growth rate of 4 per cent per annum in the agriculture sector based on the efficient use of resources(MoA&FW, 2014). A cultivator (farmer) earns less than one-third of the income of a non-farm worker. This is a major cause of rural distress (Chand, 2019). Government focus is needed to promote farmers' welfare, reduce agrarian distress, and raise the income of farmers at a faster rate, thereby achieving the target of "Doubling Farmers' Income by 2022-23" (NITI Aayog, 2017). The government of India introduced drones in agriculture as one of the beneficial technologies to help achieve these targets. In simple words, drone is defined as pilotless aircraft (Chamuah and Singh, 2020b).They have a wide range of applications in agriculture which includes soil sampling, fertiliser application, pesticide spraying, animal population surveillance (Beriya, 2022), crop cutting experiments (CCE), crop damage assessment, and capturing a real-time image(Chamuah and Singh, 2022). This paper focused on spraying application because it has been widely used in various farms, and the Indian government also took some initiatives. It introduced separate crop-specific Standard Operating Procedures (SOPs), defining more precise and safe use of drone technology for pesticide application.

Spraying Application by Drone in Indian Agriculture

Drone can also spray fertiliser and pesticides on agricultural fields. Drone technology is introduced in spraying because there is a labour shortage and increased input cost of crop production. Also, it saves more time by covering large areas within a very short period. The main components of drone for spraying are a pressure nozzle, spraying controller, pesticide box, hall flow sensor, small diaphragm pump, and field map interpretation system(Rahman *et al*., 2021). In Figure 3, the drones are linked with the sprayer to apply pesticides or fertilisers, releasing them as droplets under pressure through a connected nozzle. The spray motor generates the ideal pressure to distribute the fluid effectively. The spraying controller employs a hall flow sensor to gauge the fluid flow, promoting the sprayer's nozzles into action. The drone utilised for spraying tasks can vary based on their speed, payload capacity, and the number of nozzles employed. Using drones for dispensing fertiliser and pesticides boasts superior efficiency compared to conventional methods. Drones curtail human exposure to harmful gases and reduce time and expenses with limited human power (Rahman *et al*., 2021). Figure 3 also shows the three primary transport processes which can be used to describe the distribution of a liquid from drones in agriculture (Woods, 2003). The first is droplet generation which creates a large number of droplets. Second is droplet transmission which describe as the movement of the droplets from the nozzle through the air to the targets and the third, droplet capture- when the droplets strike the targeted crops.

Figure 3: Distribution of a Liquid from Drone



Source: Authors' compilation.

Methodology

This study aims to analyse the case of drone's deployment in spraying applications of Indian agriculture. This paper uses a qualitative and exploratory-based approach because the deployment of drones is nascent in India, and the governance structure is evolving. With the help of literature survey questionnaires (LSQ) (Chamuah and Singh, 2020a), the gathered literature is systematically reviewed in formulating the research problem and questions of the study. The research objective was substantiated by conducting in-depth interviews with the stakeholders. Stakeholders were contacted through LinkedIn, and official emails and snowball techniques were used. Interviews were conducted face-to-face using an alternative medium like Zoom to collect qualitative data. The stakeholders were selected based on their active participation in deploying drones in Indian agriculture. Stakeholders included were MNCFC (Mahalanobis National Crop Forecast Centre), DGCA, RARI (Rajasthan Agricultural Research Institute), NECTAR (North East Centre for Technology Application and Reach), MoA&FW (Ministry of Agriculture and Farmer Welfare), Agriculture Universities, and certain companies like Iotech, Drone destination, Aeronica, and Pilots, etc. Some data were gathered through secondary literature sources like newspapers, journals, FICCI (Federation of Indian Chambers of Commerce and Industry) reports, NITI (National Institution for Transforming India) Aayog reports, SOPs (Standard Operating Procedures), conferences, and talks organised by the government are covered with the help of YouTube videos, LinkedIn, etc. The interviews were conducted depending on the availability of the respondents. Due to Covid19, getting approval for interviews from government offices and stakeholders was a humongous task, the officials hardly responded to emails, which took a longer time in completing the interviews. The author also participated in Bharat Drone Mahotsav, 2022. It was a great opportunity to meet all the stakeholders under one roof, attend various talk sessions and get valuable insights about drones in Indian agriculture.

Result and Discussion

In an era marked by the imperative of sustainable practices in every facet of human activity, the agricultural sector stands at the crossroads of transformation. As global populations burgeon and environmental concerns escalate, the incorporation of cutting-edge technologies becomes paramount. Drones, commonly known as UAVs (Unmanned Aerial Vehicles), have emerged as a pivotal tool in revolutionising farming practices and fostering agricultural sustainability.

Drones creating sustainability in Indian agriculture

In this section, the paper describes the values which are embedded while deploying drones in spraying to create sustainability in Indian agriculture. It also addresses the research question; how can the utilisation of drones for spraying application contribute to the sustainability of Indian agriculture?

Drones are embedded with multiple values, which have created sustainability in spraying applications. With the help of a responsible innovation framework, this study identified some values which can be responsible for creating sustainability in Indian agriculture in further points.

- **Efficiency:** It defines a ratio between the drones fulfilling its function and efforts to get a particular result (Chamuah and Singh, 2023, 2020b, 2020a). From the interview with Solanki (2023), as a pilot, she observed that drone-based spraying is more efficient than the manual sprayer. Solanki illustrated that the Indian government is actively advocating for the adoption of drones in spraying practices, driven by the conviction that drones can significantly curtail instances of human health issues such as cancer, hypersensitivity, asthma, etc. Within India, numerous instances have emerged wherein individuals with a background in agriculture have fallen victim to these debilitating ailments. The repercussions stemming from applying pesticides and other chemical agents in agriculture activities are gradual and prolonged, amplifying their inherent peril (Solanki, 2023).

  Additionally, Manual spraying exhibits various limitations, including excessive chemical application, scarcity of farm labor, lower spray uniformity, environmental degradation, and limited coverage. These conventional methods result in higher pesticide application costs and offer suboptimal pest and disease management outcomes. To address these drawbacks, the implementation of a drone-mounted sprayer has been initiated. The interview with Dr Wandkear (2022) illustrates that applying pesticides is less compared to manual spraying. To enhance operational efficiency, optimising the configuration of spraying applications by drones is crucial. This application should be tailored to dispense high-concentration and low-volume sprays. Typically, spray rates for drone setups range from 1 to 2 liters per hectare, significantly lower about 25 to 50 times than those of conventional spraying techniques. However, given the heightened concentration of the sprays, it is imperative for application to exercise caution. They must ensure the spray pattern avoids excessive overlap or gaps, preventing undesirable outcomes like inadequate pest prevention.
- **Capability:** Capability is the power and ability of drone technology to do something (Chamuah and Singh, 2020b). In an interview with Dr Wandkear (2022), he explained that drones could spray 1.15 and 1.08 hectares per hour for paddy crops, respectively. Spraying

the pesticide with a drone from 3.5 m height gives a higher droplet coverage rate and uniformity on the wheat canopy than ground spraying. Utilisation of drones for pesticide spraying can result in substantial benefits, including an 80 per cent reduction in operational time, a 90 per cent decrease in water consumption and 50 per cent reduction in pesticide usage. Dr Wandkear also mentioned that drones are capable of paddy and sugarcane crops. Paddy fields are often waterlogged, making it challenging for manual labour to navigate and carry out tasks like spraying. Drones can swiftly cover large areas without being affected by wet and muddy conditions, saving time and labour costs. Manually accessing paddy fields can result in soil compaction, which is detrimental to crop growth. However, drones fly above the fields, thus reducing soil compaction and preserving the soil structure. The interview with Solanki (2023) exemplifies that drones can be programmed to follow specific flight paths, adjusting altitude and spray release patterns according to the crop's characteristics and growth stage. Sugarcane plants can grow quite tall, making it difficult for manual sprayers to reach all parts of the plant. Drones can fly at adjustable altitudes, ensuring that sprays reach the top and bottom of the plants. Drones offer a practical solution to overcome the challenges posed by the humid conditions in paddy and sugarcane crop fields.

- **Effectiveness:** Defined as the degree to which drones fulfil their function while applying in agriculture. In an interview with Dr Jaat (2022), they mentioned the case in point that in 2020, the Rajasthan plant protection department used drones for locust-affect regions. Indeed, drones have proven to be highly effective in combating locust infestations. It can swiftly cover large areas and enable quick identification and tracking of locust swarms(Goswami, 2020). Drones with spraying systems can target locust swarms precisely, minimising chemical usage.
- **Gender equality:** It is achieved when males, females, and transgender enjoythe same rights and opportunities, and they all are equally valued and favoured (Mishra, 2022). Bharat Drone Mahatsov, held in New Delhi (2021), allows meeting and interviewing Mayasri. She is a 24-year Transwoman who has worked as a pilot and qualifying training instructor. Mayasri, along with fourteen other individuals from the LGBTQ+ community, successfully finished a course conducted at Chennai's Center for Aerospace Research, Anna University (Mayasri, 2022). They have been certified as pilots and trainers under the Remote

Pilot Training Organisation (RPTO) (Mayasri, 2022; Sidharth, 2022). Presently, Mayasri is employed as a pilot and working with Daksha Unmanned Systems and is an expert in flying a Multi-rotor used for mapping, surveillance, agro-spraying, seed dispersal, etc. In an interview with Solanki (2023), presently working with Syngenta Company; before that, she worked with the Haryana government. It illustrates that drone is a technology that is inherently gender-neutral. An individual's gender does not influence its functionality and capabilities. Anyone, regardless of their gender, can operate and engage with drone technology effectively.

- **Trust:** It is defined as a human expectation of natural phenomena and machine performance (Chamuah and Singh, 2020b; Mishra, 2022). During the interview with Dr Yadav (2023), a government employee closely associated with the Haryana government and actively involved in initiating multiple projects under ICAR (Indian Council for agriculture research), it was revealed that the Haryana government actively promoting drone technology for agriculture spraying. The government is not only providing complimentary training to approximately five hundred farmers to enable them to become proficient drone pilots in the agriculture domain, but it has also taken a pioneering step by establishing "DRISHYA" (the Drone Imaging and Information Service of Haryana Limited) a platform for surveying infrastructure projects, monitoring of agriculture and horticulture crops, and surveillance of sensitive areas for security purposes, etc. This initiative showcases the government's trust in drone technology for generating employment opportunities for youth (Solanki, 2023; Yadav, 2023).
- **Accuracy:** Refers to the degree of correctness or closeness to the actual or intended value that can be achieved. Drones have proven to provide accurate and precise agricultural spraying results. An interview with Solanki (2023) mentioned that drones are equipped with advanced GPS technology that ensures accurate navigation and positioning. This allows for targeted spraying and a precise flight path. Drones maintain a consistent flight altitude and speed, ensuring a consistent application rate across the field. According to Dr Wandkear, drones can utilise digital mapping software to plan and optimise spraying routes (Wandkear, 2022). This can help to efficient coverage and minimises the risk of missing areas. Using drones in spraying applications can eliminate errors, enhancing accuracy on the field (Solanki, 2023; Wandkear, 2022; Yadav, 2023).

Drone's Contribution to Achieving SDGs in Indian Agriculture

In section 1.5.1, this paper has elaborated on the values embedded in drones and that they assist in achieving sustainability in Indian agriculture. As technology evolves, Drones have transcended their conventional roles to become transformative instruments of positive change. This intersection of innovation and sustainability showcases how drones drive progress across diverse domains while contributing to the global agenda of fostering equitable growth, environmental preservation, and social well-being. This exploration delves into the innovative ways drones are not just revolutionising farming techniques but also paving the way for a more sustainable and resilient future with the core principle of achieving SDGs. This section addresses the second research question: How can drone-assisted spraying applications contribute to achieving the Sustainable development goals (SDGs) in Indian agriculture?

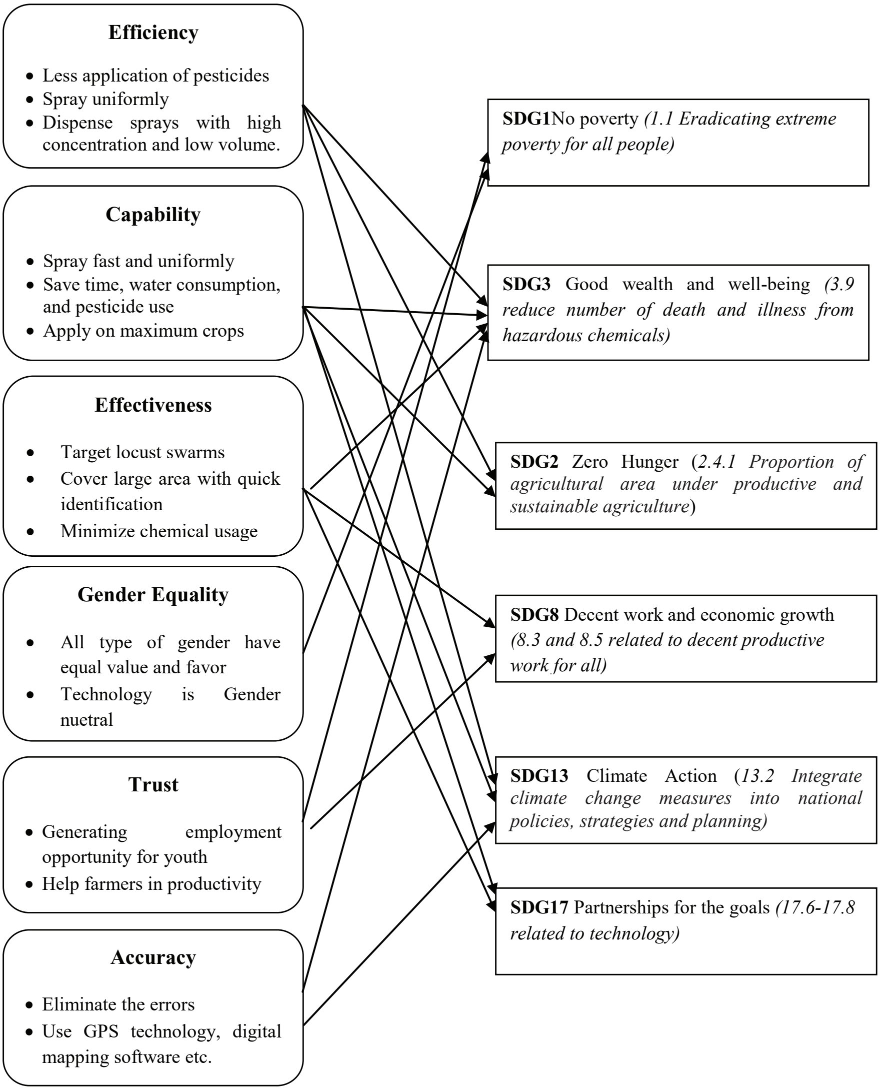
In Figure 4, shows the identified values that can create sustainability in Indian agriculture while deploying drones in spraying applications. It also shows how each value helped to achieve the SDGs in Indian agriculture.

SDG 2 strongly emphasises integrating sustainability into agriculture practices. Goal 2.4 explicitly outlines the objective of ensuring sustainable food production and implementing resilient agricultural activities by 2030. These efforts are aimed at increasing productivity and production in a manner that safeguards ecosystems. The values identified, such as efficiency, capabilities, trust, accuracy, and effectiveness, have played a pivotal role in ensuring the responsible use of drones in Indian agriculture, intending to attain SDG2.

In alignment with SDG 3, the focus is on ensuring universal health and well-being across all age groups. The values such as; efficiency, capability, effectiveness, and accuracy have been prominently demonstrated in using drones for agriculture spraying. Drone technology ensures public health and wellbeing by reducing the quantity of pesticides and insecticides employed while preserving the integrity of the soil structure. Meanwhile, SDG 8 underscores the pursuit of decent work and economic growth. Under objective 8.5, the aspiration is to attain complete and progressive employment opportunities, ensuring dignity and fairness for all, irrespective of gender, age, disability, or other factors. Equal remuneration for work of comparable value is also an integral part of this goal. Gender equality, effectiveness, and trust ensure drone technology can operate and engage any gender, generating employment opportunities for youth.

Turning to SDG 17 targets 17.6 through 17.8 underscore the critical role of technology in promoting sustainability. These targets stress using technology to drive positive environmental, social, and economic outcomes. This underscores the importance of collaboration and partnerships to harness technological advancements for the betterment of society and the planet.

Figure 4: Identified Values Fulfilling the SDGs in Agriculture



Source: Authors' compilation.

Conclusion

Drones have seen exponential growth in recent years. Within the sphere of Indian agriculture, these state-of–the-art technologies have been integrated to enhance crop productivity. Drones prove invaluable in scenarios where human intervention is unfeasible for the application of chemicals to crops due to inaccessibility or labour shortages. Also, drones expedite and simplify the spraying process, rendering it more efficient. Drones are embedded with multiple values, which have created sustainability in spraying applications. With the help of a responsible innovation framework, this paper identified some values which can be responsible for creating sustainability in Indian agriculture. Those embedded values are efficiency, capability, effectiveness, gender equality, trust, and accuracy in drone technology that assist in achieving the SDGs in Indian agriculture. Through a comprehensive analysis, it is evident that drone-assisted spraying applications offer a range of benefits that are vital for the agriculture sector's resilience, efficiency, and equitable growth.

The efficiency of drones in spraying applications, demonstrated through superior precision, reduced chemical usage, and increased coverage rates, addresses the issue of limited resources and labour shortages faced by many farmers. Moreover, the drone's capabilities extend to diverse terrain, from waterlogged paddy fields to tall-standing crops like sugarcane, ensuring that spraying applications are no longer hindered by physical barriers. The effectiveness of drone-assisted spraying, highlighted by their role in combating locust infestations and providing targeted pest and disease management, directly contributes to achieving SDG 2–Zero Hunger. These technologies promise to enhance crop yields while minimising the environmental impact of pesticide usage. Additionally, the incorporation of drones transcends gender norms, as exemplified by Mayasri, a transwoman, successfully navigating a career in drone piloting. This embodiment of gender equality aligns with SDG5–Gender Equality and underscores the inclusive nature of technology. Trust and accuracy are the foundations of successful drone applications. State governments like that of Haryana actively promoting drone technology, as well as initiatives like "DRISHYA," reflect the growing trust in drones as tools for generating employment opportunities and addressing agricultural challenges. The accuracy of drone spraying, facilitated by advanced GPS technology, precise flight paths, and targeted application, minimises chemical overlap and ensures a consistent application rate, thus supporting SDG 3-Good Health and Well-being.

The paper's exploration of drone's contributions to achieving SDGs demonstrates that drones serve as enablers of positive change across a multitude of domains. They not only enhance agricultural practices but also contribute to broader societal and environmental goals. The alignment between drone embedded values and the SDGs underscores the integral role technology plays in promoting sustainability, inclusivity, and equitable growth.

An inherent limitation of this paper lies in the ongoing evolution of drone technology and, consequently, the continuous evolution of stakeholders within the Agriculture sector. In the realm of Indian agriculture, the utilisation of drones in spraying applications began a few years ago, resulting in a relatively small number of stakeholders involved.

The integration of drones into Indian agriculture signifies a remarkable opportunity for transformative change. Drones driven by values of efficiency, capability, effectiveness, gender equality, trust, and accuracy, offer the potential to revolutionise farming practices and contribute significantly to the attainment of Sustainable Development Goals. Through collaboration, partnerships, and the responsible use of technology, drones can truly usher in a new era of sustainable farming practices, resilience, and positive impact, while advancing India's journey towards the SDGs.

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Biotechnology as a Means to Power: Rise of Brazil as a Case in Point

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Abstract: The global diffusion of biotechnology has played a pivotal role in restructuring the global order in the post-Cold War era. Institution of a strong domestic base in biotech has arguably allowed emerging economies in the Global South to negotiate with developed countries from a position of strength. This paper critically examines the rise of Brazil as a case in point to examine the role of biotechnology as a great equaliser of power in North-South relations. It identifies the institution of a strong domestic biotechnology base as a primary facilitator of Brazil's emergence as a globally influential player. The paper does so through delineating the various means through which Brazil has drawn from biotechnology to boost its international image and influence. Firstly, it analyses the nuances within Brazil's domestic biotechnology strategy while underlining their catalytic effect in driving fast-paced advances in the field. Brazil's policy successes with respect to genomics and biofuels are highlighted. The paper discusses Brazil's employment of biotechnology as an effective foreign policy tool in niche diplomacy ventures of health, agriculture, and biofuels to grow its clout in the Global South. Brazil's tactful ability to combine its biotechnology expertise with skilful diplomatic manoeuvring to pioneer novel normative paradigms that favour the Global South has been studied. The paper concludes that Brazil's biotechnology strategy presents a good model for emerging economies in Asia and Africa to emulate to improve their relative standing in the multipolar world.

Keywords: Biotechnology, Brazil, South-South Cooperation, Biofuels, Health Diplomacy, Agricultural Biotechnology.

Introduction

The criticality of biotechnology for national power, national security and economic prosperity is an established fact in the modern era. Biotechnology and its subfields including genomics, biomaterials and biomimetics feature in the critical technology lists published by major powers including the United States of America (USA), European Union (EU), Australia, Japan and India. An enhanced understanding of the criticality of biotechnology to national power calculations has arguably been more profound in the post-pandemic era. As Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) brought the global economy to a grinding halt, biotechnology offered requisite solutions. Amid health security moving right to the centre of traditional national security concerns, the field has received a "renewed

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focus" (Fischer *et al.*, 2020). Nation-states around the world in this context have been growing increasingly cognizant of the ability of biotechnology to enhance their power. The bioeconomy enabled by parallel advances in biotech, engineering and computing in today's world has evolved as a distinct component of economic power. A key component of critical global supply chains, biotech has further become indispensable to technology and policy responses crafted to address threats to health security and energy security (Naik, 2023). However, compared to the evolving discourse on digital technologies and its impact on global power dynamics, "biotechnology is not much talked about" (Suri, 2022, p. 444).

The global diffusion of biotechnology and employment in manufacturing in general have played a pivotal role in restructuring the global order in the post-Cold War era. However, the narratives on the evolution of a multipolar world have largely revolved around economics and the diffusion of Information and Communication Technologies (ICT). Along with ICTs, countries in the developing world saw advances in biotechnology as a medium to catch up with the industrialised nation-states of the West. The bulk of the R&D in biotechnology had been concentrated in the industrialised world during the last decades of the 20th Century. In the post-1980s period, various emerging economies have focused on crafting prudent policy measures geared toward creating a thriving domestic bioeconomy.

Capitalising on unique advantages such as human capital and indigenous knowledge, the governments of these countries sought to evolve solutions to local agricultural or public health concerns. This allowed the biotech industry in the developing world to "take up the WHO's charge of developing more effective treatments to address worldwide health concerns and food science issues" (Korenbilt, 2006, p. 56). In doing so, they reduced their dependence on costly imports of biotech products, while enhancing their reputation and bargaining power in global forums. The exact role that biotechnology played as a great equaliser of power in North-South relations warrants an in-depth examination in this context.

The simultaneous rise of Brazil as a global leader in biotech and a major pole of power in the multipolar world can be identified as a valid case in point to undertake this critical examination. Institution of a strong domestic biotechnology base can be identified as a primary facilitator of Brazil's emergence as a globally influential player. Brazil employs biotechnology as a foreign policy tool by sharing its know-how with countries in the developing world through technical assistance programmes. This, in turn, has allowed Brazil to grow its clout and cement the perception of the state as a champion of the Global South. Emerging economies in Asia and Africa can effectively draw best practices from the Brazilian template of South-South cooperation to initiate technology cooperation ventures.

Prowess in biotechnology has further allowed Brazil to challenge existing mechanisms of global governance to suit the interests of the developing world. Combining the same with diplomatic tactfulness, Brazil has pioneered novel paradigms that reflect the Global South's interests in areas including trade, health, and climate change. Brazil's employment of biotechnology herein presents a good model for emerging economies in Asia and Africa to emulate to improve their relative standing in the multipolar world.

In this context, this paper shall strive to explore the role of biotechnology in shaping global power dynamics. It shall do so through critically analysing Brazil's rise as a case in point. The paper shall proceed by studying the evolution of Brazil's domestic biotechnology sector and its role in equipping Brazil with a competitive edge in the global market. It then attempts to contextualise Brazil's approach to fostering biotechnology within its diplomacy with the developing world, particularly in the areas of agriculture, health, and biofuels. It finally elucidates how Brazil used its capabilities in biotechnology as a shield to protect its national interest, while boosting its bargaining power to attain the goal of evolving as a global agenda setter.

Brazil's Policy Successes in the Biotechnology Sector: A Critical Examination

The nuances within Brazil's domestic biotechnology strategy are relevant to understand from the point of view of assessing its role as a catalyst in driving fast-paced advances in the field. It further holds significance as the normative basis on which global perceptions of Brazil's power and influence rest upon. Moreover, domestic policy itself assumes precedence in Brazil's foreign policy as a central means of leverage. The country projects its "diffusible socio-economic model" as one that is the ideal path for the global south to follow. Through knowledge sharing and technical assistance learned from its own successes, Brazil reasserts its "role and commitment to global development and solidarity" (Menezes and Vieira, 2022, p. 116). Brazil's domestic biotechnology strategy has been widely studied as a viable model for developing countries to accelerate their growth (Albano and Padma, 2007). Brazil developed itself as a "genomic power" across a short time-period through innovative cost-effective strategies that combined ICT with biotech to institute virtual research centres (United Nations Commission on Trade and Development, 2004, p. 22). Until Brazil made a grand entry into the world of genome research in the early 1980s, genome sequencing had been perceived as a highly specialised field of research that had only been carried out by large organisations such as the Institute of Genomic Research (TIGR) in the United States of America (USA) and the Sanger Center situated in the United Kingdom (United Nations Conference on Trade and Development, 2004).

Brazil's national biotechnology programme, the Programa Nacional de Biotechnologia (PRONAB) was initiated in 1981. Since the early years of the programme, Brazil has been said to have made concerted efforts towards "integrating institutions and budgets relating to biotechnology applications in agriculture, energy and health" (Quezada, 2006, p. 194). The Organisation of Nucleotide Sequencing and Analysis (ONSA), its virtual research institute was perhaps the first of its kind in the field of biotechnology research and was established by stringing together a network of 34 laboratories associated with universities and institutes of higher learning (Bonalume, 1997). Through opting for a virtual R&D setup, Brazil sought to overcome financial hurdles associated with instituting capacity in an advanced field of technology. Brazil's unique strategy to forge ahead in the area of biotechnology drew worldwide attention in 1997 as the ONSA became the very first entity in the world to sequence a plant pathogen. *Xylella Fastidiosa*, the pathogen that Brazil successfully sequenced was estimated to cost at least $100 million dollars of loss for Sao Paolo's orange industry at the time (United Nations Conference on Trade and Development, 2004).

Use of biotechnology to address public health concerns is another area where Brazil holds an international reputation in. Analysing the development of Brazil's health and pharmaceutical policies at the domestic level evidences the institutionalisation of a rights-based approach. Brazil effectively steered the successes in its health sector while utilising the same to spur growth in its pharmaceutical industry. Brazil's strategy is centred on encouraging local production of generic drugs while negotiating price cuts with pharmaceutical firms that control patents over vital medicines. Its domestic strategy is complemented by a foreign policy which seeks to highlight and safeguard the capability of its domestic market to continue delivering products to fulfil its goals with respect to health equity (Flynn, 2013, p. 71). The introduction of the Biotechnology Development Policy (PDP) in 2007 has been said to reflect the Brazilian government's efforts to sharpen its edge in the global market. The policy charts out the way for Brazil "to capitalise on and conserve Brazil's immense natural resources and biodiversity, transforming them into bio-businesses and wealth" (Florêncio , *et al.*, 2020). The subsequent period has witnessed the Brazilian government make concerted efforts to institute through investments, a national industrial complex in areas including health (Santana, 2019, p. 74).

In addition to genomics research that pertains to agriculture and health, Brazil has a wealth of experience in managing an ethanol economy. The country has historically looked upon sugarcane-based biofuels as a solution to address challenges to its energy and economic security. Its maiden attempt at utilising sugarcane to produce biofuels has been dated back to the 1930s. The production boomed by World War II, as Brazil started to suffer the implications of global oil supply chain disruption during the time (Rossi *et al.*, 2021).

The experience of the 1973 oil embargo prompted a re-look at biofuels. The "Proálcool" (Pro-alcohol) programme introduced in 1975, went on to have a transformative effect on Brazil's energy economy as a whole and revolutionised its transport sector. The government's introduction of a prudent policy herein was actualised by the active involvement of Brazil's research institutions and scientific community. The work undertaken by the Brazilian Agricultural Research Corporation (Embrapa)[1] on sugarcane productivity contributed to substantially reducing biofuel prices. Meanwhile, Brazilian engineers have globally pioneered the R&D on flex engines[2] that accommodate fuel blending since the 1990s and thereby played an instrumental role in the greening of its transport sector (Corrêa do Lago, 2022).

The incremental policy approach to promoting biofuels helped Brazil significantly cut down its carbon dioxide equivalent emissions to the tune of 1.34 billion tonnes. It additionally helped decrease air pollution and improve air quality in major cities including Sao Paolo. These successes in combination have made Brazil the sole country in the world "to implant a large-scale alternative fuel to petroleum" (Vieira do Nascimento, 2014). Moreover, Brazilian biofuel firms are some of the most sought-after players to provide low-carbon alternatives to critical sectors of transportation. While aerospace company Embraer is in the process of implementing innovative ethanol blending technologies to produce sustainable aviation fuel, Raizen has signed an agreement with the Ferrari Formula 1 team to supply "second-generation, high-performance ethanol" (Samora and Slattery, 2021). All these factors have allowed Brazil to possess a moral authority with respect to the road the world must take in order to achieve decarbonisation at a massive level while emerging as a "green power" (Gardini, 2016, p. 15).

Biotechnology in Brazil's Diplomacy with the Global South

Brazil has demonstrated proficiency in transforming its domestic successes in biotechnology into strategies for international cooperation and influence. In doing so, it has arguably crafted its own sphere of influence in the Global South. Achievements that draw majorly from biotechnology have effectively served as a vehicle to create perceptions of its ability to tackle complex problems unique to the Global South. This in turn has allowed Brazil to present through its foreign policy and diplomacy, an attractive technology cooperation template for emerging powers (Pino, 2010). Compared to traditional models of North-South Cooperation, Brazil's technology cooperation as an aid mechanism purportedly allows for "more space and autonomy for recipient countries and seeks the institutional strengthening of allies as a condition for transfer of financial resources and know-how" (Gardini, 2016, p. 9).

The Brazilian model of South-South Cooperation (SSC) was reconfigured in the period following Lula da Silva's ascension to the presidency in 2003. Offsetting the asymmetries (in terms of power or capabilities) was identified as a fundamental objective of Brazil's foreign aid during this time. This reflected Brazil's awareness that its own security depended on having a prosperous neighbourhood. South America, Central America and the Caribbean were identified as priority areas in this regard. Meanwhile, Africa also evolved as an important priority in Brazil's moral bid to right the historical wrong of slavery. Through the transfer of technology and knowledge, Brazil has sought to pave the way for structural changes in their partners' socio-economic development, along with building strong institutions. Lula's "diplomacy of solidarity" in a way also strived to enhance Brazil's role and presence in political and economic spheres (Zilla, 2017).

Health diplomacy is perhaps one area where Brazil's expertise in biotechnology made a credible case for its ability to address global crisis in general and concerns of the Global South in particular. Brazil made its foray into health diplomacy in a major way in the early-2000s under the leadership of President Fernando Henrique Cardoso. As Brazil employed its genomic power to combat HIV/AIDS at home through capitalising on its biotech industry's ability to produce anti retrovirals (ARV), the Brazilian model of fighting AIDS gained international recognition. Brazil led the global fight against AIDS through distributing ARVs to the Lusophone countries in Africa, while supplementing the same with information campaigns on the prevention of Sexually Transmitted Diseases. The Oswaldo Cruz Foundation (Fiocruz) along with Brazil's Ministry of Health played a central role in conceptualising and implementing health diplomacy strategies. For instance, Fiocruz was pivotal in transferring necessary know-how and organisational knowledge that helped set up Africa's first public-owned ARV factory in Mozambique in 2013 (Gayard, 2019). Fiocruz has also been setting up and strengthening public health institutions in Argentina and El Salvador (Fiocruz, 2023). In addition to HIV/AIDS, Brazil's health diplomacy has sought to tackle public health crises relating to tuberculosis and malaria

(Almeida, Lima and des Campos, 2023).

The role of Brazil in facilitating agricultural development in Africa is said to have been increasingly "noticeable" in recent times (Cabral *et al.*, 2016). As a leader in biofuels and agriculture, Brazil serves "as a valuable source of expertise for developing countries with tropical climates" (Ferber, 2012, p. 80). The work done by Embrapa has been accorded a key role in Brazil's biotechnology cooperation with countries in the Global South. Embrapa as an institution itself is said to be widely admired in Africa, with African countries having expressed a desire "to create their own Embrapas, with support from development co-operation programmes" (Cabral, 2021, p. 806). It opened its first centre in Africa in Accra, Ghana, in 2006, which serves as an institute for training and research mobilisation for the continent.

In collaboration with partners including the World Bank and various state governments, Embrapa is actively involved in a number of projects in Africa ranging from rice cultivation in Senegal to training local scientists in agricultural biotechnology in Mozambique (Wilson Center, 2011). The C-4 project implemented during 2009-2013 was Brazil's first largescale project for technical cooperation (Di Stefano and Barbosa, 2017). Embrapa and the Brazilian Cooperation Agency (ABC) sought to transfer environment-friendly, high-yield and high-quality cotton (Cotton-4) to West African countries including Benin, Burkina Faso, Mali, and Chad. The agencies involved herein adopted a full-spectrum approach that focused on institution and capacity-building, along with the transfer of technology. For instance, in Mali, the initiative resulted in the setting up of an entomology lab and a cold storage facility for keeping genetic resources, in addition to sample processing facilities (Embrapa, 2023). In Mali, in particular, the initiative is said to have resulted in a soaring of cotton production. The second phase of the project which commenced in 2014 also included Togo and focused on capacity reinforcement to the end of enhancing their ability to evolve technological solutions. Brazil has employed its experiences from C-4 to forge biotechnology cooperation projects with Mozambique and Malawi and in Latin America involving Peru and Argentina (Embrapa, 2023).

Due to the environmental and climactic similarities between the Brazilian cerrado and the African savannah, Brazil has sought to present its expertise in sugarcane-based ethanol as an attractive means to address their energy needs. The idea here was for Brazil to replicate its own domestic policies, albeit to a lesser extent. It therefore sought to present itself in a leadership role, especially as environment had become an issue of high politics by the dawn of the 21st Century. President Lula undertook at least 29 visits to African countries during the 2003-2010 period, while generously offering Brazil's expertise on biofuels. Biofuels were featured in cooperation agreements inked with countries that he visited. By 2015, Lula's biofuel diplomacy would result in biofuel agreements being signed with at least fourteen countries located in the western and sub-Saharan regions (Afionis *et al.*, 2013).

Meanwhile, it signed a Memorandum of Understanding (MoU) with the United States of America (USA) in 2007. Under this initiative, the two countries attempted to implement bioenergy programmes first in Central America and the Caribbean and later in African nations including Senegal and Guinea-Bissau (Dalgaard, 2012). While its "ethanol diplomacy" arguably contributed to asserting its perception as a green power, Brazil's inability to translate its biotech expertise into tangible results on the ground has been noted. For instance, the prohibitive costs associated with ethanol processing plants, food security concerns and political instability in Africa have hindered Brazil's efforts to replicate its domestic successes through diplomacy. Moreover, its relative ineffectiveness has been "attributed to the international context" in which Brazil attempted to spearhead biofuels in the Global South (Dalgaard, 2012).

Brazil has attempted to pool its expertise in biofuels with that of India, another major player in the Global South which is leading the global charge for affordable energy transition mechanisms. During former Brazilian President Jair Bolsonaro's visit to New Delhi in 2020, India and Brazil signed 3 MoUs on bioenergy cooperation, which has been followed up by a meeting of the joint working group in 2021 (Corrêa do Lago, 2022; Ministry of Petroleum and Natural Gas, 2022). Along with the USA and India, Brazil is also a founding member of the Global Biofuel Alliance, which has been hailed as a key outcome of the 2023 G20 New Delhi Summit. The coalition is expected to play a key role in forging tangible diplomatic outcomes that Both Brazil and India can capitalise on at the global climate change negotiations (Kala, 2023). The groundwork for such bilateral cooperation to proceed fruitfully has already been laid within the larger framework of India-Brazil biotechnology cooperation, particularly in the area of health. Both the countries have worked together "in developing partnerships for setting the agenda in multilateral forums like the WHO and WTO as well as in the IBSA or BRICS forums" (Chaturvedi, 2011, P.2). BRICS and IBSA in particular have demonstrated successful templates for collaboration to address health issues that pertain to the Global South such as AIDS and malaria (Thorsteinsdóttir *et al.*, 2010; Chaturvedi & Thorsteinsdóttir, 2012). Brazil's biotechnology cooperation with the Global South in the areas of health, agriculture and energy has served to enhance its diplomatic clout in international affairs. The following section shall delve into how Brazil combines technological prowess with diplomatic tactfulness to set a global agenda and build novel norms in these areas.

Biotechnology as an Agenda-Setting Tool at Multilateral Negotiations

Brazil's employment of biotechnology as a shield to safeguard its national interest through setting a global agenda can be best understood through studying its negotiating strategy at key multilateral forums pertaining to trade and climate change. Any formal arrangement or treaty mechanism envisaged to address concerns within these issue-areas would be unsuccessful without Brazil's consensus. Rising states may attempt to gain select material capabilities to challenge the international order through utilising different strategies. In this respect, material sources of power are combined with efficient diplomatic manoeuvring to call for redesigning or setting new norms that suit their national interest.

The overall approach herein is geared toward giving them a greater say in decision-making by negotiating from a position of strength. This further helps such states to present themselves as "reformers" of the problematic international order (Vieira, 2012). Further, power in negotiations is said to flow from the possession of resources that are valuable to the negotiating partner in a particular situation (Mandell, Petraeus and Subrmanian, 2020). Biotechnology in Brazil's case constitutes a key resource that other negotiating parties place a value upon. Brazil's leadership in biofuels, equips it with an informal veto[3] in climate change negotiations. Meanwhile, Brazil's successes in the domestic biopharmaceutical and agribiotech industry render it a valuable player in trade and intellectual property negotiations.

Brazil's strategy at the negotiations of the Trade-Related Aspects of Intellectual Property Rights (TRIPS) negotiations was primarily motivated by the need to defend the country's ability to ensure access to life-saving drugs to its citizens. It had demonstrated the viability of its stance through demonstrating the success of its domestic policies in tackling AIDS and drawing from the same to back its health diplomacy. As it started to face the USA's wrath for its compulsory licensing regime in the early Global South 2000s, Brazil effectively employed the success of its domestic programme as a shield to defend itself from the US Trade Representative. To defend the country's national interest, Brazilian institutions including government bodies, industry lobbies and civil society organisations came together to synergise their efforts. Drawing from the success of its domestic AIDS programme, Brazil's foreign ministry and health ministry joined hands in health diplomacy, while coordinating efforts in areas including technology partnerships (Flynn, 2013). The two entities further initiated a wider scheme to actively engage civil society organisations, while simultaneously building a case for Brazil as a representative of the developing world's interests.

For instance, Brazilian negotiators successfully employed an argument grounded on the right to health to obtain price discounts and compulsory licenses for Merck's efavirenz in 2007. Drawing from its own constitutional jurisprudence, Brazilian diplomats actively sought to present access to life-saving drugs as a fundamental human right at forums such as the UN Commission on Human Rights and the WHO. It joined hands with its compatriots in the Global South including India, Mexico and Thailand to add to its negotiating heft. The Doha Declaration, 2001 effectively went on to reflect the interests of the developing world as the WTO members agreed "that the TRIPS Agreement does not and should not prevent members from taking measures to protect public health" (World Trade Organization, 2001). It sponsored a 2007 resolution at the UN Human Rights Council highlighting the "right of everyone to the enjoyment of the highest attainable standard of physical and mental health" (UN Human Rights Council, 2007). The resolution paved the way for a UN Special Rapporteur's Report which clearly agreed with Brazil's position that TRIPS was rendering life-saving drugs inaccessible while making it difficult for countries to ensure a right to health.

Similarly, Brazil's status as a green power makes it an indispensable player at negotiating forums on climate change and sustainable development. The notion of green power in this context entails elements of "sustainability, innovation and power" (Never, 2013, p. 3). Looking beyond attributes such as material resources and market dominance over clean technologies, green power pertains to the kind of influence a country can wield in steering the direction of energy transition and sustainable practices.

Brazil has been a key initiator of the international discourse on sustainable development as the best means to fight global warming since the 1990s. Brazil can continue to draw from its technical and policy expertise in biotechnology to show the world a path to emulate in agriculture as well as biodiversity and environmental protection. The Intergovernmental Panel on Climate Change (IPCC) has projected with high confidence the adverse effects climate change could have on food security. Extreme weather events and changes to precipitation patterns would affect crop yields while aggravating risks to a global food supply. Meanwhile, an increase in carbon dioxide in the environment has been projected to lower the nutritional quality of produce and render pastoral systems vulnerable (Intergovernmental Panel on Climate Change, 2019). "No other country in the world, not even the major agribusiness players, has the same conditions as Brazil to advance sustainable food production in the coming decades" (Da Conceição *et al.*, 2019, p. 391). Breakthroughs in biotechnology, particularly in "tropical agriculture, soil treatment and seeds" can potentially bolster Brazil's status as a "food superpower" (Omestad, 2008) with a structural veto in global climate change negotiations (Never, 2013, p. 15).

The richness of Brazil's biodiversity has been termed a source of power and political influence (Ellwanger, Nobre and Chies, 2023). Home to the Amazon rainforests, Brazil possesses critical know-how with respect to reforestation, a central means of climate change adaptation as envisaged in the UN Framework Convention on Climate Change (UNFCCC). Having played a prominent role in international negotiations concerning forest protection, Brazil alone is said to possess the ability to "make or break negotiations for an international REDD+ mechanism[4] to mitigate climate change" (Allan and Dauvergne, 2013, p. 1318). Brazil's negotiators were vehemently opposed to any mechanism that would allow developed countries to impose restrictions on deforestation in developing countries to meet their own emission reduction goals.

Brazil has alternatively vouched for a system that puts the onus on developed countries to fund REDD+ projects, while allowing developing countries to receive carbon credits for emissions reduction from reforestation. The country in subsequent years has gone on to evolve as a top recipient of REDD+ funds (Recio, 2022). Amid the return of Lula da Silva to power, Brazil's leadership in the world's fight against climate change can be further expected to grow. Lula is reported to have already set in motion the plans to build a "Coalition of Rainforest Nations" with countries including Indonesia and the Democratic Republic of Congo (DRC). Together, the countries have the largest amount of forest carbon credits, which equips them with an edge in bargaining. The coalition may negotiate fiercely to convince the developed nations of the world to accelerate their efforts to stop deforestation (Taylor, 2022). Knowledge of biotechnology as a tool of biodiversity management is likely to enhance Brazil's ability to solve major global crises in the future in the true way that a green power can be expected to.

Conclusion

Technological niches such as biotechnology may be employed by emerging economies in Asia and Africa to catch up with developed countries. The role of biotechnology in facilitating Brazil's emergence as a leader of the Global South stands as a strong testament to this fact. Forging ahead with R&D in biotechnology can be understood to have enhanced Brazil's self-confidence and global perception as a player capable of setting global agenda in issue-areas including health and climate change. Brazil has drawn from biotechnology to mainstream a narrative of its own model of socio-economic development as the ideal one for the global south to follow. It has then proceeded to combine its expertise in biotechnology in health, agriculture, and biofuels with an adaptive yet tactful diplomacy to grow its clout in the Global South. The success of its domestic policies in these areas and its diplomatic legacy of engagements in the developing world have allowed it to influence international norm-setting in a manner that reflects their unique concerns.

As evident from Brazil's example, biotechnology has played a pivotal role in reducing power asymmetry in North-South relations. Capabilities in biotechnology in this regard have allowed Brazil to negotiate from a position of strength with the developed nations of the world. Acquisition of formidable indigenous capabilities in biotechnology may further help developing countries spur growth across multiple sectors, improve the quality of life and thereby boost economic development. Indigenous capabilities in biotechnology may further be employed as a bargaining tool to ward off undesirable policy overtures, that threaten to stunt emerging economies' growth potential. Brazil's approach to domestic capacity-building and bioeconomy management is unique, cost-effective and is worthy of imitation by emerging economies in Asia and Africa. The country's employment of biotechnology as a foreign policy tool herein embodies a number of best practices that can guide successful South-South and North-South cooperation. It thereby presents a good model for emerging economies in Asia and Africa to improve their relative standing in the multipolar world.

Endnotes

[1] Embrapa itself was founded in 1973 with the stated objective to provide Brazil with "food security and a leading position in the international market for food, fibre and energy" (Embrapa 2023).

[2] "Flex fuel engines are cars built to run with pure gasoline, pure ethanol (hydrated ethanol) or with any mix proportion of ethanol or gasoline, as they have sensors that can detect the proportion and adjust ignition electronically" (Goldemberg 2013, 548).

[3] Informal veto pertains to an actor's ability to walk away from the negotiation table, thereby imposing considerable costs on other negotiators. By walking away or employing informal veto, the actor in question has the power to render any resultant negotiated arrangement meaningless (Narlikar and Narlikar 2014).

[4] REDD+ is a framework created by the UNFCCC Conference of the Parties (COP) to guide activities in the forest sector (UNFCCC 2023). While REDD stands for "reducing

emissions from deforestation and forest degradation", the plus signifies "the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries" (UNESCAP n.d.).

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Fostering Sustainable Plant Growth with Rhizozpheric Allies: A Review

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Abstract: Plant growth promoting rhizobacteria are classified as microorganisms residing in the rhizosphere, possessing diverse capabilities linked to plant development and well-being. PGPRs through various direct and indirect mechanisms, exert their influence on plant development. The advantages offered by these bacteria encompass heightened accessibility to nutrients, synthesis of phytohormones, facilitation of shoot and root growth, defense against numerous plant pathogens, and diminished disease susceptibility. Furthermore, PGPR contributes to plant resilience against environmental stresses like salinity and drought, alongside the synthesis of enzymes that mitigate the damaging effects of heavy metals. In the realm of sustainable agriculture, PGPR has emerged as a pivotal strategy, showcasing the potential to curtail the reliance on synthetic fertilisers and pesticides. This is achieved by fostering plant vigour and health, as well as augmenting soil quality. While a multitude of investigations regarding PGPR can be found in the literature, this review places emphasis on studies that have practically applied PGPR to sustainable production. These applications enable a reduction in the consumption of fertilisers like phosphorus and nitrogen, as well as fungicides, while concurrently enhancing nutrient absorption. With the overarching aim of advancing sustainable agricultural practices, diverse aspects are covered in this review, including various government schemes and initiatives, innovative fertilisation methods, the role of seed microbiomes in rhizosphere colonisation, the diversity of rhizospheric microorganisms, nitrogen fixation as a means to minimise chemical fertiliser use, phosphorus solubilisation and mineralisation, and the synthesis of siderophores and phytohormones to decrease reliance on fungicides and pesticides.

Keywords: PGPR, biofertiliser, bioinoculant, rhizosphere, sustainable agriculture, sustainable environment, soil fertility

Introduction

PGPR encompass autonomous bacteria playing directly in fostering plant development and root formation within plant communities [Hayat *et al*, 2010]. Their functions extend to nitrogen fixation, phosphate conversion from insoluble to soluble forms, and various phytohormone secretion, the

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conversion of insoluble phosphates into soluble forms, and the secretion of various plant hormones. The ecological significance of PGPR has captivated scientific attention over recent years. Presently, PGPR finds extensive application in agriculture, particularly in the domains of biofertilisation and the cycling of minerals within ecosystems (Shah *et al*, 2021). Existing literature reveals that merely 2 per cent–5 per cent of rhizosphere bacteria are classified as PGPR, establishing them as a pivotal instrument in the realm of sustainable agriculture (Antoun and Prevost, 2005). Through diverse investigations, it has been elucidated that PGPR adheres to the soil surface through ion exchange processes. Given that numerous plants struggle to access organic elemental sources, these PGPRs assume the role of supplying plants with inorganic elemental forms, thus sustaining soil fertility—a vital facet of ecologically responsible agriculture (Goswami, 2016). Among the array of genera represented within PGPR bacteria are *Arthrobacter, Burkholderia, Bacillus, Derxia, Beijerinckia, Acinetobacter, Ochrobactrum, Paenobacillus, Enterobacter, Pseudomonas,Lactobacillus, Azospirillum, Pantoae, Alcaligenes, Acetobacter, Serratia, Rhodococcus, Zoogloea, Azoarcus, Azotobacter, Gluconacetobacter, Herbaspirillum, Stenotrophomonas*, and *Klebsiella* (Vega-Celedón *et al*, 2021).

Over the past few years, the trajectory of PGPR research has highlighted the significance of microbial consortia in activities related to plant growth promotion (PGP). Governments worldwide implement various schemes and policies based on agroecological practices, technology adoption support, financial assistance through subsidies, soil health programs etc. to support and promote sustainable agriculture. These initiatives aim to address challenges such as environmental degradation, resource depletion, and economic instability in the agricultural sector. Numerous accounts demonstrate a diverse array of microorganisms within their challenging ecosystems, engaging in interactions with other microorganisms both within and between species. Enhanced information and a deeper understanding of bacterial attributes, contributing the plant growth promotion could inspire and catalyse the innovation of inventive approaches to harness PGPR's potential in dynamic and unpredictable environmental and climatic conditions. (Ole´nska *et al*, 2020).

Unconventional Fertilisers in Agriculture

The agricultural sector faces an ongoing challenge of enhancing both the quantity and quality of its output, along with refining the processes related to its quality, processing, and preservation. To augment crop yield, the cultivation of plants necessitates the efficient utilisation of mineral fertilisers. It is widely acknowledged that the precise application of mineral fertilisers of the soil plays a crucial role in elevating soil quality, bolstering its fertility, and promoting crop productivity (Uzakbaevna, 2022). Numerous agricultural methods might require adaptation to optimise the yield and quality of food production. As a result, ongoing adjustments to agronomic strategies are imperative. Over the past few years, numerous researchers have employed biofertilisers as a means to mitigate the environmental impact stemming from mineral fertilisers and to curtail associated expenses (Badr *et al*., 2022). Employing waste materials to create liquid fertilisers within the context of sustainable agriculture presents an encouraging approach with the potential to enhance food production. Pajura *et al*. (2023) authored an intriguing analysis that explores the fertiliser industry's predicament in generating adequate plant growth nutrients through more ecologically sound means and energy-efficient methods. As a resolution to this challenge, the concept of generating liquid fertilisers from waste substances possessing fertiliser attributes is put out as a solution, aiming to curtail the depletion of resources from nature and integrate principles of sustainable resource management. The study accentuates the existing laws within the European Union and Poland, which advocate for closed-loop economics, and underscores the necessity to derive fertilisers enriched with nutritional elements for plants from biodegradable materials or reclaimed resources. Furthermore, the analysis determines the types of waste resources harnessed as a matrix for fertiliser production, along with their pivotal chemical characteristics contributing to the progress in the growth of a plant. The investigation also underscores the significance of this avenue of research and highlights the importance of seeking out other waste categories suitable for repurposing within the framework of a closed-loop economics. The effects of a unique composite fertiliser made of both organic and inorganic components on the development of fragrant rice's growth, yield, and synthesis of aromatic compounds were investigated by Luo *et al*. (2021). Organic matter, superphosphate, urea, zinc sulfate, lanthanum chloride and potassium chloride were all included in the fertiliser mix. The new organic-inorganic compound fertiliser, conventional fertiliser, and no fertiliser application were all investigated in this four-year experiment. The findings indicated that, in comparison to the alternative treatments, the novel fertiliser significantly increased variables like the concentration of 2-acetyl-1-pyrroline, effective panicle count, seed-setting rate, grain yield, net photosynthetic rate, aboveground biomass, chlorophyll level in fragrant rice. This highlights the potential of novel fertilisers to produce high-quality grain composition and high productivity in fragrant rice. The advantages of utilising plant growth-promoting microorganisms (PGPMs) in hydroponics and vertical farming systems were covered by Dhawi *et al*. (2023). The utilisation of PGPMs can be maximised in these systems due to the controlled environment. The authors suggest pre-treating seeds or seedlings with a microbial suspension for aquaponic and aeroponic systems as well as a synchronised PGPM treatment using a biostimulant extract applied to the hydroponic medium. By 2027, it is expected that the global market for vertical farming will have grown to more than USD 10.02 billion as a result of the sustainable use of space, decreased water usage, absence of pesticides, and integration of accessible techniques for regulation of environment and harvest.

Government Schemes and Initiatives in Sustainable Agriculture: Transforming Agricultural Systems to Organic

Government schemes and initiatives play a pivotal role in the paradigm shift towards sustainable agriculture, specifically the transformation of conventional farming systems into organic practices. These programmes aim to promote environmentally friendly approaches, reduce dependency on synthetic inputs, and enhance the overall sustainability of agriculture. By providing support, incentives, and education, these initiatives encourage farmers to adopt organic farming methods, which contribute to improved soil health, biodiversity conservation, and reduced environmental impact. Through strategic policies and financial backing, governments actively contribute to fostering a more sustainable and resilient agricultural sector.

Following are some of the major initiatives taken by the Government and its overall impact:

1.1 Paramparagat Krishi Vikas Yojana (PKVY)[1,2]

Objectives:

1. Promote organic farming among rural youth/ farmers/ consumers/ traders
2. Disseminate the latest technologies in organic farming
3. Utilise the services of experts from the public agricultural research system in India
4. Organise a minimum of one cluster demonstration in a village

Role of PGPR in facilitating Paramparagat agriculture practices in India

In India, the integration of Plant Growth-Promoting Rhizobacteria (PGPR) into conventional agriculture practices is gaining attention due to its potential to enhance crop productivity and reduce reliance on chemical inputs. Here are some key points regarding PGPR and conventional agriculture practices in India:

1. Reducing Dependency on Chemicals: Conventional agriculture in India has traditionally relied heavily on synthetic fertilisers and pesticides. The use of PGPR offers a sustainable alternative by promoting plant growth and nutrient uptake, potentially reducing the need for chemical inputs.
2. Enhancing Nutrient Availability: PGPR strains, through processes like nitrogen fixation and phosphorus solubilisation, contribute to improving nutrient availability in the soil. This can be particularly beneficial in nutrient-deficient soils commonly found in various regions of India.
3. Disease Management: PGPR has demonstrated the ability to suppress soilborne pathogens and enhance plant resistance to diseases. Integrating PGPR into conventional practices can contribute to effective disease management strategies, reducing the reliance on chemical fungicides.
4. Improving Soil Health: Conventional agriculture practices often lead to soil degradation and loss of biodiversity. PGPR can contribute to soil health by promoting nutrient cycling, enhancing soil structure, and supporting a more balanced microbial community in the rhizosphere.
5. Crop-Specific Applications: Different crops have unique requirements, and PGPR formulations can be tailored to specific crops. Integrating crop-specific PGPR into conventional practices allows for a targeted approach to improving the health and productivity of individual crops.
6. Research and Adoption Challenges: While there is growing interest in the integration of PGPR, challenges remain in terms of research, awareness, and adoption by farmers. Continued research, extension services, and awareness campaigns are essential to facilitate the widespread adoption of PGPR in conventional agriculture.

The integration of PGPR into conventional agriculture practices in India holds promise for improving soil health, enhancing nutrient management, and mitigating the environmental impact of conventional farming. Continued research, awareness, and policy support are crucial for the successful adoption of PGPR in mainstream agriculture.

1.2 National Mission for Sustainable Agriculture (NMSA)[3]

Objectives:

The National Mission for Sustainable Agriculture (NMSA) has been formulated for enhancing agricultural productivity especially in rainfed areas focusing on integrated farming, water use efficiency, soil health management and synergising resource conservation.

Role PGPR in advancing sustainable farming practices

Plant Growth-Promoting Rhizobacteria (PGPR) play a pivotal role in advancing sustainable agriculture through various mechanisms that enhance plant growth, nutrient uptake, and stress resilience. Here are some key aspects of their contribution:

1 Biofertilisation: PGPR act as natural biofertilisers, reducing the reliance on synthetic chemical fertilisers. Their ability to fix atmospheric nitrogen and enhance nutrient availability contributes to sustainable and eco-friendly farming practices.
2 Disease Suppression: Many PGPR strains exhibit antagonistic properties against soilborne pathogens, providing a natural defense mechanism for plants. This biocontrol function helps reduce the need for chemical pesticides.
3 Stress Tolerance: PGPR enhance plant resilience to abiotic stresses such as drought, salinity, and heavy metal toxicity. Their presence in the rhizosphere triggers stress-responsive pathways in plants, promoting survival under adverse conditions.
4 Improved Soil Structure: PGPR contribute to soil health by producing substances that enhance soil structure, water retention, and nutrient absorption. This leads to better overall soil quality and reduced environmental impact.
5 Reduced Environmental Impact: The use of PGPR aligns with sustainable agriculture practices by reducing the environmental footprint associated with chemical inputs. This contributes to the conservation of soil and water resources.
6 Boosted Crop Yields: The synergistic interactions between PGPR and plants often lead to increased crop yields. This is a key factor in ensuring food security and meeting the demands of a growing global population.

PGPR play a multifaceted role in sustainable agriculture by promoting efficient resource utilisation, reducing environmental impact, and enhancing the overall resilience and productivity of crops. Their integration into farming practices represents a promising avenue for achieving long-term agricultural sustainability.

1.3 Soil health card scheme[4]

Objectives:

SHM aims at promoting Integrated Nutrient Management (INM) through judicious use of chemical fertilisers including secondary and micro-nutrients in conjunction with organic manures and bio-fertilisers for improving soil health and its productivity; strengthening of soil and fertiliser testing facilities to provide soil test-based recommendations to farmers for improving soil fertility; ensuring quality control requirements of fertilisers, bio-fertilisers and organic fertilisers.

Role of PGPR in Soil Health Management

The role of Plant Growth-Promoting Rhizobacteria (PGPR) in soil health management is crucial for maintaining sustainable and productive agricultural systems. Here are key aspects of their contribution to soil health:

1. Nutrient Cycling and Availability: PGPR contribute to nutrient cycling in the soil by solubilising minerals, fixing atmospheric nitrogen, and making nutrients more available to plants. This enhances the overall nutrient content and fertility of the soil.
2. Biofertilisation: PGPR act as natural biofertilisers, reducing the need for synthetic chemical fertilisers. Their ability to fix atmospheric nitrogen and release nutrients from organic matter contributes to improved soil fertility.
3. Disease Suppression: Many PGPR strains have antagonistic effects against soilborne pathogens. By producing antimicrobial compounds and inducing systemic resistance in plants, PGPR help suppress the proliferation of harmful pathogens, promoting a healthier soil environment.
4. Enhanced Soil Structure: PGPR contribute to soil aggregation and structure by producing substances like exopolysaccharides. This enhances water infiltration, aeration, and root penetration, leading to improved overall soil physical properties.
5. Bioremediation: Some PGPR strains possess the ability to degrade pollutants and contaminants in the soil. This includes the degradation of organic pollutants and the immobilisation or sequestration of heavy metals, contributing to soil remediation efforts.
6. Promotion of Plant Growth: PGPR stimulate root growth and development, leading to increased root surface area and nutrient absorption. This results in healthier and more vigorous plants, contributing to improved overall soil-plant interactions.

PGPR play a multifaceted role in soil health management by promoting nutrient cycling, disease suppression, soil structure improvement, and overall sustainability. Their integration into agricultural practices can contribute to the long-term health and productivity of soils.

Microbiota of Seed: Enabling Colonising of the Rhizosphere

A diverse array of endophytic microorganisms harbour by seeds, with bacteria being particularly prominent, and these are selected by the plant owing to their multifarious benefits (Verma *et al*, 2019; Kuz´niar *et al*., 2020; Santoyo *et al*., 2021). In the beginning, these microorganisms establish their presence in the rhizosphere; later, they take up residence within the plant's tissues as endophytes and eventually make their way into the seeds (Samreen *et al*., 2021). In numerous references, endophytes assume a pivotal role in seed germination, preservation, and growth, and their presence is frequently observed in soil environments. According to the findings, from the rhizosphere, these bacteria are selected by plants due to the advantages they confer, ensuring their presence upon seed planting (Kumar *et al*., 2020). Seed endophyte colonisation is influenced by distinct chemical compositions, just like every other plant organ. Additionally, the plant's defense system prevents excessive population density within the plant organ, thereby mitigating the risk of infection resulting from quorum sensing (Li *et al*., 2029; Kandel *et al*., 2017). Vertical transmission of endophytic seeds occurs when they move to the plant's stem from the root. In contrast to remote rhizobacteria, bacterial endophytes closely engage with the developing embryo during the seed's germination. By initiating the production of hormones like auxin and cytokinin, participating in nitrogen fixation and aiding in the phosphorus and potassium solubilisation, seed endophytes can contribute to the growth and development of seedlings. Seeds containing endophytes additionally confer advantages to plants, including enhanced resilience against both living (biotic) and non-living (abiotic) challenges and improved overall adaptability (Truyens *et al*., 2015; Basu *et al*., 2021). From maize seeds, 23 microbial endophytes (bacteria) were isolated by Pal *et al*. (2022) and 74 per cent exhibited a variety of capabilities, for instance, the capacity to make phosphate soluble forms and fixing nitrogen is shown by all the isolates. The ability to produce auxin was observed in 70 per cent of them. During the study, numerous isolates resist the growth of phytopathogen like *Rhizoctonia solani* and *Fusarium* sp. demonstrating biological control ability. From rice cultivar seeds, *Bacillus* species, *Citrobacter* species, *Flavobacterium* species, and *Pantoa* species, among others, have been isolated for the first time by Jana *et al*. (2023). Among these, the highest production of gibberellin, indole acetic acid (IAA) and hydrogen cyanide (HCN) has been shown by *Citrobacter*. *Pantoa* simultaneously displayed the highest efficiency for producing ammonia and soluble forms of potassium and phosphate. These results suggest that endophytes of separated seeds hold the potential to promote expansion and overall growth and support host plants in combating various plant pathogens, like bacteria and fungus, to enable production that is sustainable.

Rhizosphere Allies: Bio-Boosting Plant Resilience

The soil region near the roots that experience nutritional influence from root activity is termed the rhizosphere Basu *et al*., 2021; Bowen *et al*., 1999. During photosynthesis, plants allocate 10 to 40 per cent of their photosynthetic products into the rhizosphere through a process known as rhizodeposition. This enriches and fertilises the rhizospheric soil with organic energy-rich compounds like carbohydrates, amino acids and other nutrients (Vetterlein *et al*., 2020; Hassan *et al*., 2019). Altering the soil microbiota around the roots through rhizospheric fertilisation holds a notable influence. Through physiological mechanisms in plants that control interactions between plants and microorganisms and through the release of their exudates, plants can modify rhizospheric bacteria (Nuccio *et al*., 2020). The formation of the root microbiome and the selection of microorganisms within the root system take place over the course of two periods. A certain group of microorganisms from bulk soil and non-rhizosphere soil work together to colonise the rhizosphere during the first phase. A subset of the microorganisms from the rhizosphere subsequently invade the phyllosphere and endosphere during the second phase (Compant *et al*., 2021). A number of variables influence the composition of the microbiome and the holobionts of plants. The combination of a plant's genetic material and the genetic material of its associated microbiome forms holobiont. Interestingly, even though plants are cultivated under distinct conditions, they harbour the same sets of microorganisms. The core microbiome refers to the collection of microbes that survives in various plants. This core microbiome is shaped by factors that are universally present in various plants. Conversely, plant-specific factors lead to connections with microorganisms that are not components of the main microbiome. The process of roots to remove border cells and rhizodeposition provide nutrients and energy molecules for rhizospheric bacteria. In this context, an amplified root volume leads to a heightened rhizodeposition and removal of these cells. As a result, enhancing the nutrition and energy availability to the rhizospheric microbial community. Conversely, greater shoot development in the plant augments its efficiency of photosynthesis and produces more energy cells (del Carmen Orozco-Mosqueda *et al*., 2022). These microorganisms are referred to as phytostimulants, as they synthesise phytohormones that offer substantial advantages to themselves while also promoting the growth of both shoots and roots (Brunel *et al*., 2020). Phytohormones play a pivotal role in bolstering microorganism survival by counteracting the plant's defense mechanisms against them (del Carmen Orozco-Mosqueda *et al*., 2022; Brunel *et al*., 2020).

By initiating other avenues like inducing systemic resistance (ISR) and systemic acquired resistance (SAR) mechanisms within plants, PGPR can contribute to enhance plant growth. The plants employ these defense systems to safeguard themselves from pathogenic bacteria, viruses, and fungus (Rabari *et al*., 2022). Non-pathogenic bacteria cause ISR, which begins in the root and spreads to the shoot (Salwan *et al*., 2023). Ethylene and jasmonic acid signaling in the plant are necessary for this defense reaction. On the other hand, necrotic pathogenic bacteria with signaling molecules hold significance for both plant growth and defense (Khan *et al*., 2019).

Nurturing Plant Growth: Microorganisms' Expertise in Action

Commodity commercialisation has expanded along with population growth, while agricultural fields have shrunk as a result of soil erosion. The demand to maintain productivity has been particularly intense in the food manufacturing industry (Ole´nska *et al*, 2020). Consequently, there has been a reliance on chemical fertilisers and pesticides. However, these compounds may cause environmental issues and human health concerns, if they are used excessively. The present agricultural landscape requires alternatives to lower production costs, environmental effects, and reliance on inputs without lowering yield. In this way, promising microbial agents, might be employed as a beneficial substitute since they exhibit a number of traits associated to plant growth (Basu *et al*., 2021; Khatoon *et al*., 2020; Ahluwalia *et al*., 2020). The microbes with its host plant may communicate in a beneficial, detrimental, or neutral way. The use of plant-beneficial microorganisms as biological pesticides and biological fertilisers, could significantly boost and improve crop yield and safety. To lessen reliance on chemical fertilisers and pesticides, the task at hand is to encourage farmers worldwide to use biofertilisers and biological control agents (Ole´nska *et al*, 2020; Egamberdieva *et al*., 2019). Numerous crop plants might communicate with microbial organisms, particularly those that support plant growth, enhancing their capacity for growth and development while bolstering resistance against pathogens. A number of microorganism-produced metabolites have garnered attention for their commercial use due to their beneficial properties in fostering plant growth, large-scale production, biocontrol effectiveness, and enabling effective formulation (Ole´nska *et al*, 2020; del Carmen Orozco *et al*., 2022). To safeguard plants from both living and non-living stressors, biological complexes like biological pesticides and biological fertilisers are proven to be helpful. These compounds achieve this by producing siderophores and growth hormones. Thus, enhancing nutrient absorption, boosting output and generating inimical substances including hydrogen cyanides, volatile chemicals, antibiotics and hydrolytic enzymes. (Vetterlein *et al*., 2020).

Nitrogen Fixation: Diminish Reliance on Chemical Fertilisers

Numerous mechanisms involved in crop production require nitrogen (N) (Bhavya and Geetha, 2021). The yield of grains is heavily reliant on adequate N supply, and with the escalating demand for food, the nitrogen requirement increasing significantly (Riaz *et al*., 2021). The Application of nitrogen fertiliser on crops like rice, maize, potatoes, and wheat, has boosted their yield. However, inefficient nitrogen utilisation is the result of processes such as denitrification, N leaching, and ammonia volatilisation. According to the data, rice farming accounts for between 21 and 25 per cent of all nitrogen fertiliser use worldwide. In the field of plant physiology, nitrogen is considered the most crucial nutrient, and this importance is ascribed to it (Wickramasinghe *et al*., 2021). In maize cultivation, nitrogen serves as a pivotal nutrient needed in significant quantities. It has a critical function in synthesising nucleic acids, adenosine triphosphate (ATP), chlorophyll, and amino acids. Hence, maize's potential yield directly correlates with augmenting nitrogen fertiliser application (Hussain *et al*., 2022). A pathway to lessen the need for chemical N fertilisers is through biological nitrogen fixation (BNF). Remarkably, BNF contributes to over 60 per cent of the Earth's fixed nitrogen. Given this, optimising BNF within agriculture is gaining prominence for attaining the surging dietary needs of the rising world's populace. A comprehensive knowledge of diverse nitrogen-fixing bacteria and their mechanisms is required to accomplish this (Jia *et al*., 2021). According to research, *Kosakonia radicincitans*, a nitrogen-fixing bacteria from *Pennisetum giganteum* was recognised and utilised by Jia *et al*. (2021). These scientists found that adding microorganisms to chemical fertiliser reduced its effectiveness by 25 per cent. In plants, the increased metrics for accessible phosphorus, alkali hydrolyzed nitrogen, vitamin C, soluble sugar, soluble form of protein content, chlorophyll content, weight and height are due to this synergistic approach. According to a research (Song *et al*., 2021), replacing synthetic N fertilisers with cyanobacteria *Anabaena azotica* in a field experiment for two years, alleviates urea utilisation during rice cultivation. The findings unveiled that the amount of rice produced was not significantly affected when 50 per cent urea was substituted for the cyanobacteria. Moreover, the findings also showed that *A. azotica* substituting limited urea, significantly reduced nitrate leaching, ammonium-N losses, whereas traditional fertilisation caused the greatest N loss. Furthermore, using *A. azotica* in place of 50 per cent of urea during the later stages of the rice season retains more soil nitrogen in comparison to traditional fertilisers. This is due to *A. azotica's* capacity to capture, immobilise, and postpone nitrogen discharge, offering substantial advantages to the soil's nitrogen cycling dynamics, and ultimately reducing noteworthy nitrogen leaching. The Diazotroph microorganisms like *A. azotica* have been studied to assess its effects on maize yield. Significantly, Tapia-Garcia (2020) emphasised the identification of *Burkholderia*, the predominant nitrogen-fixing endophyte linked to maize, as a noteworthy advancement. The prospects of these isolates are high as revealed when they extensively settled in tissues of maize, thereby resulting in a substantial boost in yield. According to a study carried out to explore the interactions between maize and endophytes, assessing their impact on maize yield in both controlled laboratory settings and field conditions Sheoran (Sheoran *et al*., 2021). The significant upsurge in yield is noticed in coupling *Klebsiella pneumoniae* with *Herbaspirillum seropedicae* endophytes. Meanwhile, experiments involving native maize varieties with strains of *Azospirillum brasilense* and *Azotobacter chroococcum* under tropical conditions resulted in an increase in maize productivity by 1–1.5-fold Pandey *et al*. (1998).

Crucial Elements: Phosphorus Solubilization, Mineralization, and Siderophore Production

A critical macronutrient for growth and metabolism of plant is phosphorus (P). Nevertheless, upon introduction into soil, P rapidly becomes immobilised due to interactions with positive metal ions of aluminium, iron, and cadmium or adherence to the surface of the mineral, limiting the Phosphorus accessibility for plant absorption (Khan *et al*., 2009). In both the mechanisms whether physiological or biochemical, plants require phosphates for processes like resistance against diseases, legumes nitrogen fixation, ripening of crop, seed and floral development, growth of stem and root, and photosynthesis. The most significant variable limiting the productivity of agriculture is phosphorus (Wan *et al*., 2020; Nath *et al*., 2017). According to a study (Wang *et al*., 2020), bacterial genera, namely *Stenotrophomonas*, *Cupriavidus*, *Acinetobacter*, *Pseudomonas*, *Massilia*, *Bacillus*, *Ochrobactrum* and *Arthrobacter* were examined for their phosphorus solubilising potential. The outcomes highlighted Acinetobacter's impressive proficiency in phosphorus solubilisation, positioning it as a viable contender for upgrading soil fertility and overall quality (Wan *et al*, 2020). According to Liu *et al*.'s research (Liu *et al*., 2020), for the bioavailability of soluble phosphates in the plants, phosphorus-solubilising bacteria dissolve complex inorganic phosphorus by releasing small molecular organic acids. These acids then change the soil characteristics and subtly affect the rhizospheric microbial population. The ability of microorganisms like *Pseudomonas pseudoalcaligenes*, *Enterobacter cloacae*, and *Bacillus thuringiensis* to make available the inorganic (calcium phosphate) or organic (phytin) forms of phosphorus is through solubilisation process (Pantigoso *et al*., 2023).

The research revealed that threonine functions in enhancing bacterial solubilisation and the absorption of diverse nutrients by plants. The authors also proposed a viable strategy to release stored phosphorus in agriculture fields by using specialised chemicals released by these bacteria. Kour *et al*. (2019)examined how well different groups of PGPR, such as *Proteus, Klebsiella Acinetobacter*, *Staphylococcus*, *Pseudomonas, Enterobacter* and *Bacillus* were able to convert sizable amount of phosphorus from soil samples from the lesser Himalayas ecosystem into simpler soluble forms. As a result, these bacteria might be employed to lower the phosphorus fertilisers quantity. Iron (Fe) is another crucial nutrient for plants. Usually, it manifests as Fe3+ and Fe2+.Iron in soil can exist in a variety of forms, including oxyhydroxides and insoluble hydroxides in aerobic settings, which prevent plants from absorbing it. However, the low-molecular-weight iron chelators with a strong attraction for multiplex iron known as siderophores, are released by PGPR. Numerous genera of PGPR like *Rhizobium*, *Serratia*, *Bacillus*, *Azotobacter*, *Pseudomonas* and *Enterobacter* produce compounds of siderophores. These siderophores extracellularly and intracellularly are hydrophilic and under a scarcity of iron dissolve complex iron present in mineral elements or organic compounds and have the ability to create strong structural compounds with radioactive particles and metallic contaminants. These strains of PGPR that produce siderophores alleviate the adverse impacts of hazardous metal in polluted soils and are advantageous in bolstering plant growth (Da Silva *et al*., 2023). Several methods, including chelating and releasing iron, direct absorption of siderophore-iron complexes, and ligand exchange, are used by plants to assimilate iron from siderophores. In addition to securing iron, siderophores also reduce plant stress brought on by metallic toxins. The low molecular weight molecules called siderophores with a strong affinity for Fe3+ are produced by pseudomonads (Din *et al*., 2019). Phytopathogens like *Pythium*, *Fusarium* and *Aspergillus* species are strongly inhibited by biocontrol like pseudomonads effectively (Gandhi *et al*., 2012). It has been demonstrated that the siderophore pyroverdine, produced by pseudomonads, reduces potato wilt brought on by *Fusarium oxysporum* (Rajesh *et al*., 2012). The phytopathogens, *Fusarium graminearum*, *Macrophomina phaseolina* and *Fusarium moniliforme* were likewise suppressed by peanuts and maize (Rejsek *et al*., 2012). Therefore, a deficiency in iron may prevent development and growth. The ferric oxidation state of iron (Fe3+) is largely unavailable in soil and will form hydroxides with incredibly low saturation variables resulting in no availability to rhizospheric microbial community and plants (Silva *et al*., 2021). The significantly more soluble form, the ferrous (Fe2+) state, is available to plants, but it precipitates quickly in the environment after oxidising into Fe3+ (McLaren *et al*., 2020). Numerous microorganisms have absorption mechanisms for iron (Fe3+) using low-molecular-mass organic compounds (iron chelators) and siderophores for surviving during scarcity of iron. Under such situations, siderophores serve as solubilising agents for iron by reducing it to Fe2+ from Fe3+ on bacterial membranes. Thus, making it available to both themselves and plants (Richardson *et al*., 2011). The potential for abiotic degradation of siderophores in the environment, which might take place through hydrolysis and/or oxidation pathways, is another crucial factor to take into account, according to Ferreira (Ferreira *et al*., 2019). When siderophores with hydroxamate moieties are hydrolyzed, hydroxylamine groups can occur, which oxidises Fe2+ to Fe3+. Trihydroxamate siderophore, a hydrolyzed version of coprogen, was discovered in lab research and is efficient transporter of iron in plants like maize and cucumber. These facts lead to an approach for utilising presumptive siderophore with the inclusion of suicidal subunits may facilitate decrease, dissoluteness, and delivery of iron to microorganisms. Sunlight exposure has also changed the siderophore dissolution and mineral dissolution processes. Both the type of siderophore and the presence of bound Fe may have varied impacts. In a study on the effects of four organophosphate pesticides on soil microorganisms that produce siderophores or plant growth-promoting rhizobacteria (PGPR), Kumar (2019) examined the effects of acephate, monocrotophos, glyphosate and phorate. Five soil bacteria that produce siderophores were examined both separately and in combination with the pesticides: Salmonella typhimurium, Bacillus brevis, Azotobacter vinelandii, Pseudomonas fluorescens and Rhizobium leguminosarum. The outcome of siderophore generation test revealed the effect which is dependent on dose, with pesticide combinations having greater effects than the individual pesticides. The four pesticides had negative impacts on siderophore production in a general order of glyphosate, monocrotophos, and phorate, which was in line with the pesticides' toxic levels. The study showed that the PGPR strain Pseudomonas fluorescens was least affected by pesticides (13-66 per cent), whereas Salmonella typhimurium was least affected (20-75 per cent). Azotobacter vinelandii (22-81 per cent), Rhizobium leguminosarum (21-72 per cent), Bacillus brevis (19-80 per cent), Salmonella typhimurium (20-75 per cent) and Pseudomonas fluorescens (13-66 per cent) were all negatively impacted by pesticides. Additionally, the PGPR strains were not significantly adversely affected by the combined addition of glycine and monocrotophos.

Harnessing Phytohormone: To Mitigate Fungicides and Pesticides Dependency

Phytohormones like gibberellin, cytokinin and indole-3-acetic acid (IAA) are produced by PGPB to maintain plant hormonal balance. IAA, in particular, directly regulates the plant's endogenous auxin reservoir. The total amount of IAA accessible to the plant and the plant's sensitivity to the hormone determine the overall impact of bacterially generated IAA on root development, which may have a beneficial or adverse effect. At low quantities, bacterial auxin may promote growth. When endogenous auxin levels are adequate, adding auxin released by PGPR may stifle or limit plant development. The efficiency of nutrient uptake is increased by the encouragement of lateral and adventitious root development by bacterial IAA. Furthermore, it encourages root exudation. As more bacterial growth results from increasing root exudation, this cycle continues. Although it is evident that IAA synthesis does not directly limit root elongation, this does not fully account for a plant's capacity to stimulate growth (Sukul *et al*., 2021). According to Khan *et al*.'s research (Khan *et al*., 2020), overusing fungicides in agriculture may culminate in a considerable buildup of active compounds in the soil, which can have a detrimental effect on crop productivity and health. A study was carried out to know the reaction of fungicides on Raphanus sativus (white radish) and observe interactions of radish plants with fungicide-tolerant PGPR. Plant growth promoting rhizobacteria was isolated from the rhizospheric region of mustard and cabbage. Based on their morphological, biochemical, and fragmented 16S rRNA gene sequences, the strains of fungicide-tolerant Plant growth promoting rhizobacteria had similarities with species of Pseudomonas. Exposure of PGPR to fungicides like hexaconazole and carbendazim revealed their tolerance towards high concentrations of fungicides. Microscopical analyses revealed that fungicides induced surface morphological deformation along with modifications in the permeability of membranes, but that bacterial isolates still produced plant growth stimulants when exposed to them. The effects of fungicides on R. sativus's germination, growth, and physiological development, were considerably reduced when plants were exposed to strains of PGPR. The application of carbendazim caused a loss of total dry biomass, a total plant length decrease by 54 per cent, a total chlorophyll reduction, a decrease in content of protein, and a reduction in the production of carotenoids by 29 per cent. It is observed that strains isolated from White radish plants developed in soil exposed to carbendazim, a 1O per cent increase in whole plant dry weight, overall plant length, and total chlorophyll content was noticed. The isolate also reduced malondialdehyde, proline, ascorbate glutathione, peroxidase, reductase (4 per cent) and catalase, improving plant performance. Combining the two isolates can efficiently improve radish plant development while using less fungicide inputs and remediate fungicide-contaminated soil. Gao et.al (2022)investigated, Pseudomonas spp. with its 3 strains originating from the iron-sufficient rhizosphere of apple rootstocks were examined. These strains were found to release compounds similar to indole acetic acid and siderophores. A noticeable enhancement in plant biomass, root growth, and Fe content was observed when Pseudomonas strains were applied to Fe-inefficient rootstocks in alkaline soil conditions. The bacteria exhibited the ability to produce pyoverdine, a siderophore that forms complexes with Fe3+ and enhances Fe bioavailability for plants. This pyoverdine (an extract of bacterial supernatant culture), was employed in hydroponic experiments involving a Fe-deficient solution. These tests led to a considerable decrease in the amount of Fe-deficiency-induced chlorosis and an improvement in Fe absorption.

Nutrient Efficiency Paradigms: Diminishing Reliance on Synthetic Fertilisers

More than half of the application of traditional N fertilisers to agricultural setup escapes into the environment, resulting in contamination of both water bodies and the atmosphere. To maintain robust crop yields while safeguarding the ecosystem, it becomes imperative to adopt agricultural practices that ensure the judicious application of fertilisers. Incorporating biofertilisers, which have established advantages for enhancing plant nourishment and soil vitality, represents a strategy to attain this goal. Due to their advantages in terms of both the economy and the environment, biofertilisers comprising PGPR are gaining popularity. Biofertilisers are included in the class of biostimulants (stimulants for plant growth), anticipating its I2 per cent expansion annually (Mosttafiz *et al*., 2012). Embracing sustainable agricultural approaches that entail the gradually alleviating synthetic agrochemical usage, heightened integration of materials derived from biowaste, and the exploitation of the biological and genetic capabilities of both crops and microorganisms presents a feasible approach to address the swift deterioration of environment, uphold robust agricultural output, and enhance soil well-being (Basu *et al*., 2021). The quest to find less harmful alternatives to the potentially harmful agrochemicals led to the discovery and subsequent use of biofertilisers and other microbial products such as organic extracts and vermicompost beverages. These microbial substances are environment friendly and do not cause any harm to plants, which could result in improved health and growth of plant. According to the findings of Bashir *et al*.'s (2015) study, the application of 100 kg of phosphorus to one hectare of wheat has a considerable effect on the amount of wheat that is produced. It will raise the harvest index, as well as the biological productivity, number of tillers, plant height and efficiency with regard to P. Grain production has witnessed a substantial upsurge. Ongoing research and validation efforts are imperative to formulate novel products. These products need to undergo assessment across diverse environmental contexts, encompassing factors like crop variety, climatic conditions, soil composition, and farming techniques. This comprehensive evaluation aims to establish a spectrum of potentially valuable microbial solutions. This approach would lead to a deeper understanding of their viability and feasibility in terms of sustainable production.

Future Prospects and Conclusion

The future prospects of Plant Growth-Promoting Rhizobacteria (PGPR) appear promising, supported by various government policies aimed at sustainable agriculture. PGPR, with its potential to enhance plant growth, improve nutrient uptake, and mitigate environmental stresses, aligns with the objectives of sustainable farming practices. Government policies that incentivise and promote the use of biofertilisers, including PGPR, contribute to reducing reliance on chemical inputs and minimising environmental impact.

As agriculture evolves towards more eco-friendly and efficient approaches, the integration of PGPR into mainstream farming systems is likely to increase. The symbiotic relationship between PGPR and plants aligns with broader agricultural goals, such as enhancing soil health, reducing chemical inputs, and ensuring long-term sustainability.

In conclusion, the future of PGPR is intertwined with the trajectory of sustainable agriculture, and supportive government policies play a crucial role in fostering the adoption and integration of PGPR for resilient and environmentally conscious farming practices.

Endnotes

[1] https://darpg.gov.in/sites/default/files/Paramparagat%20Krishi%20Vikas%20Yojana.pdf

[2] https://www.manage.gov.in/publications/reports/pkvy.pdf

[3] https://nmsa.dac.gov.in/

[4] https://soilhealth.dac.gov.in/

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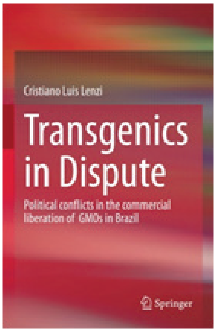
Book Review

Transgenics in Dispute: Political Conflicts in the Commercial Liberation of GMOs in Brazil



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Across countries and regions, the commercial releases of GMOs and GM seeds have been marred with controversies and conflicts, both in the scientific and non-scientific realms. Such controversies and conflicts have slowed the process of introduction of new biotechnologies and at times even led to moratoriums. The moratorium on the commercial release of GM Brinjal in India can be a case in point. Scholars have written on this capturing that whole saga (ISAAA, 2010; Chaturvedi and Srinivas, 2013).

This present book by Lenzi has attempted to elaborate on the political conflicts that ensued around the commercial liberation of the GMOs in Brazil. Apart from the Introduction and Conclusion chapters, there are five chapters in this book. In the second chapter titled "Environmental Policy Process: From Linear to Discursive Model", the author discusses the environmental policy process and the language of environmental policy. In doing so, he provides a detailed elaboration of the concepts such as discourse, frames and storylines. He also dwells on the methodological considerations related to the environmental policy process.

In the third chapter titled "Brave New World of Biotechnology", author explains the radical nature of biotechnology, and the associated risks. He also discusses in detail the ethical dimension of GM food and the distributive issues involved in the agricultural innovation. He identifies four sets of ethical dispute that encompasses aspects related to food safety, environmental risks, social consequences and trust. He went on to elaborate the importance of public perception in the formulation of public policies for GM food. The author further elaborates on the two distinct regulatory architectures that are prevailing in two regions namely the US and the Europe; and explains how these two regions have created a ‘regulatory polarization’ in the world in terms of regulating GMOs. In addition, the author also discusses the issue of ‘politicization of science’ and the labeling conflict that has emerged as one of the most controversial issues fueling the public debate about GM foods. Moving on, the author provides an anecdotal analysis of the commercial release of the Roundup Ready (RR) Soybean in Brazil in the late 1990s and the ensuing controversies, which are explained in detail in the subsequent chapters.

In the fourth chapter titled “A Territory Free of Transgenics: The Conflict over the Release of RR Soybean in Southern Brazil”, author argues that more than the issues involving risks and environmental safety of RR Soybeans, the conflict that occurred in RR Soybean was largely associated with the distributive issues involving land reforms, more so in Southern Brazil. The author also explains the emergence of the environmental justice (EJ) movement in Brazil in the context of the commercial release of GM seeds.

In the fifth chapter titled “Science in Dispute: Sound Science and the Conflict over Risk Analysis”, the author discusses the issues of the environmental risks posed by the commercial release of RR Soybean and issues of scientific uncertainty that permeated the decision-making process. Author explains the discursive conflict through the perspective of two distinct political alliances namely the liberation alliance and the precautionary political alliance.

Author examines the conflicts surrounding the labeling of RR Soybean in the sixth chapter titled “Labeling as Precaution: Substantial Equivalence and the Conflict over Labeling”. He analysed the whole issue through two distinct discourses precautionary labeling and conventional labeling.

In the penultimate chapter titled “Regulation Made in the United States: Regulatory Polarization and the Brazilian Case”, the author tries to answer the questions hovering around the question of whether the Brazilian regulatory model toe the line of American model or the European model. Author argues that since the release of RR Soybean, Brazil has not, unlike Europe, undergone any significant reformulation of its regulatory guidelines, except of the incorporation of a labeling system for GM foods, implying that the Brazilian model can be said to be closer to the American model.

In nutshell, this book analyses the conflict that ensued with the commercial release of Roundup Ready (RR) soybean in the late 1990s using a narrative analysis of political conflict. To analyse these controversies, the book focuses on three axes of narrative analyses viz. the conflict over distributive issues associated with the commercial release of RR soy; the conflict over scientific uncertainty associated with the environmental risks of GMOs; and the conflict over labeling policies. It examines this conflict featuring pro and anti-GMOS political alliances that got involved into heated debate over the introduction of genetically modified organisms (GMOs) in Brazilian agriculture.

This book can be of interest to both social and environmental scientists and researchers concerned with the risks associated with the new and emerging technologies that mediate our relationship with the environment and with the public perception. Since this book is a translation (using AI) of the original Portuguese edition "Transgênicos em disputa: Os conflitos políticos na liberação comercial dos OGMs no Brasil" by the author, the readers might find the text bit incoherent and unclear at times. Nevertheless, this book captures the controversy surrounding the release of RR Soybean in Brazil quite elaborately and provides some deep insights into the contestations that are part of such policy making processes.

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In this issue, there are three articles and one book review. The first article discusses the transformative potential of drones in promoting sustainable development in the agricultural sector. The second article, on the other hand, explores biotechnology as a means to power with reference to Brazil. The third and final article is about fostering sustainable plant growth with Rhizobacteria. The book review of a volume titled *Transgenics in Dispute: Political Conflicts in the Commercial Liberation of GMOs in Brazil* adds value to this issue.

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