Plant Microbiome Engineering: A Sustainable Management Approach for Plant Growth and Disease Management in Temperate Fruits

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Abstract

The plant microbiome is an integral part of the host and increasingly recognised as playing fundamental roles in plant growth and health. Plant microbiome engineering, or phytomicrobiome engineering (PME), is potentially useful, but as-yet-unexplored new approach that could be used to improve plant productivity, health, and growth in a variety of environmental settings. The capacity of the plant microbiome in limited environmental conditions and the idea of enhancing microbial functions may promote plant development vis-a-visproduction and productivity.

Introduction

Temperate fruit trees are adapted to the temperate zone climate in mid-latitudes grown in a variety of climates across the globe to high latitudes. In temperate regions of the world, pome, stone, and nut fruits are major commercial fruit tree crops. These fruits belong to the Rosaceae family, which also includes species of pome (apple, quince, and pear) and stone fruits (apricot, peach, plum, almond, and cherry).Total 48% of the world's fruit production comes from temperate fruit trees. However, China, Turkey, USA, Brazil, Italy, South Africa, and Spain cultivate about 50% of the world's temperate fruit crop in various climatic zones. Almost 10% of the world's word fruit is produced in India. Temperate fruits have a strong export orientation and a significant potential for foreign exchange earnings. Himachal Pradesh, Jammu & Kashmir, Uttaranchal, and other eastern hilly states of India are the growing regions for temperate fruits such as apple, pear, peach, plum, apricot, almond, walnut, etc. Temperate fruit are susceptible to several biotic and abiotic stresses and among them diseases caused by various pathogens are of great economic importance. Scab, early leaf fall, powdery mildew, Alternaria leaf spots, collar and root rots, cankers, leaf curl, leaf spots and viruses are prevalent diseases in temperate fruits. Chemical pesticides are frequently sprayed on crops with the primary objective of eliminating or reducing disease invasion, infection, or severity in order to prevent crop losses caused by diseases. But it's becoming more and more obvious that using chemical pesticides over an extended period of time has a number of negative effects on both the environment and human health. Wide range of pesticides can be hazardous to people in both acute and chronic forms, and it is increasingly becoming clear that these chemicals also harm non-target organisms including pollinator species, pollute water and soil, and cause extensive harm to the larger ecosystem. Plant-associated microbiome plays crucial roles in enhancing the uptake of nutrients by plants and provides defence against both biotic and abiotic stresses. Furthermore, these various microbial communities that make up the plant microbiome carry out a variety of tasks, including nitrogen fixation, nutrient solubilization, defence against harmful plant pathogens, and the synthesis of phytohormones, such as indole acetic acid, auxin, gibberellin, abscisic acid, aminocyclopropane-1-carboxylate deaminase, and antibiotics. They also help plants develop induced resistance to pathogens and encourage the growth of other beneficial microorganisms.

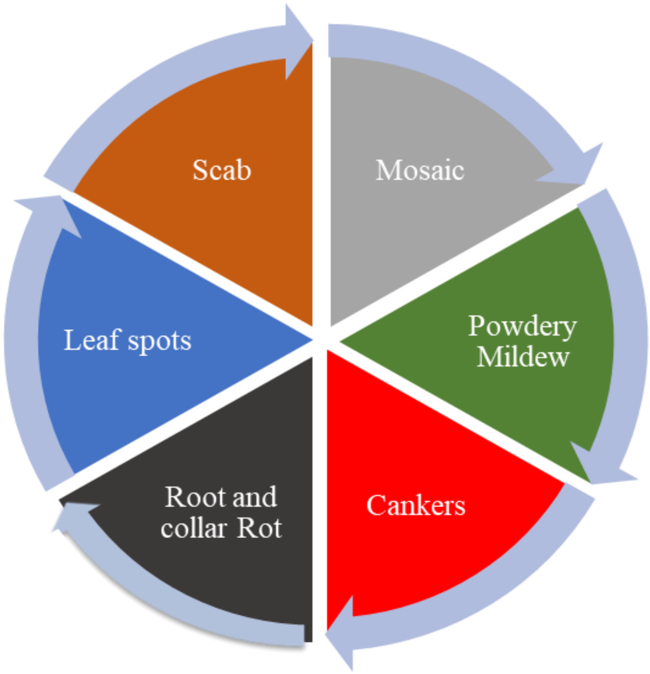

Figure 1. Different diseases of temperate fruits

Microbiome and Engineering

The "microbiome" as all of the microorganisms in a community, and specifically, as the microbial communities connected to a plant that are able to survive, grow, and interact with various plant tissues, including roots, shoots, leaves, flowers, and seeds. Plant microbiomes have the potential to be advantageous; offering plants an adaptive edge while simultaneously protecting them from possible pathogens and promoting growth, health, and productivity. Among the various groups of species, the bacterial microbiome has garnered increased attention due to its beneficial interactions and importance for sustainable agriculture. This can influence beneficial plant activities like growth limitations, phytopathogen activity, and the improvement of plant growth and health through influence of the bacterial microbiome and the creation of bioinoculants. This could potentially reduce the need for chemical fertilisers. Plant growth-promoting bacteria (PGPB) are rhizospheric or endophytic bacteria that stimulate plant growth. In certain instances, the microbiome plays a fundamental role in basic processes like plant development or the growth of vital organs like the root, which facilitates the plant's better uptake of water and nutrients. In order to improve diagnoses and treatments in plants that can eventually be applied to animals and humans, it may be more beneficial to manipulate the phytomicrobiome. Nonetheless, the phytomicrobiome is typically linked to a variety of microbes that are important components of agricultural output and serve a vital role. A major global proposition, sustainability in agriculture has been realised with the use of several microorganisms. The globe is moving towards economically viable and environmentally safe methods that could be applied to increase agricultural productivity. For Earth to survive, an appropriate farming system is therefore essential. To meet the need for food, crop production per area of agricultural land must be increased in this regard. Recommendations state that different approaches could lead to a comparable improvement in plant health. The microbiome of plants has a significant impact on both the host's growth and development and the availability of nutrients. As a result, plants "engineer" and recruit a local microbiome based on natural exudate, adapting this habitat to support their existence. Plant microbiomes offer significant health benefits in addition to protection, including enhanced plant growth and productivity and environmental adaption. The majority of microorganisms are located in biomes where they frequently modify plant physiology and help plants withstand harmful incursions. These microorganisms are grouped together inside the microbiome on the tissues and surface of the host plants. As a result, the bimodal connection permits nutrient uptake, supporting the host's development and resistance to environmental stressors. Microbial compositions can be changed to enhance host phenotypes and beneficial effects ecosystems through microbiome engineering. The three main associations—the rhizosphere (root-attached soil), endosphere (internal tissue), and phyllosphere (aboveground parts)—plants are linked to a diverse array of microbes, including bacteria, oomycetes, fungi, viruses, and archaea. These microbes carry out important functions that affect host health and fitness and are found in a specific region of the plant microbiome. The rhizosphere is the most intricate and varied microbial community niche among them. Through evolution, plants have developed intricate, mutually advantageous connections with the microbes in their environment. Most studies have concentrated on the fungal and bacterial communities within the plant microbiome, despite the fact that archaea, protists, viruses, and bacteria are all present. Therefore, core microorganisms have a high potential to organise microbiomes through methods that are beneficial to host plants, while hub microbiomes include more specialised microorganisms created solely based on their location inside a network structure with a specific function. The various ways of microbiome engineering are as under:

Enhancing mechanisms that promote plant growth

Protozoa, viruses, fungi, bacteria, and archaea are some of the various organism types that make up the microbiome. Due to its impact on plant physiology and development, this variety of microbial communities is essential to plant functioning. Plant microbiomes have the potential to be advantageous, shielding the plant from possible pathogens, enhancing plant fitness and growth, and fostering tolerance to abiotic stresses. Inevitably, transmitted by soil plant pathogens that colonise the roots of plants and successfully subvert plant innate defences by breaching the protective microbial protect of beneficial organisms and causing disease are also passed down to the rhizosphere microbiome.

Improving the phytoremediation process

An affordable, solar-powered, and ecologically benign method of soil remediation is called phytoremediation. This technology addresses the pre-existing contamination in the system biome by utilising plant abilities to intercept, take up, accumulate, and translocate contaminants. The efficiency of phytoremediation depends on plants contaminant concentration, soil pH, nutrients and oxidoreduction as well as those microorganisms that are associated with soil and plants, respectively.

Promoting bio control and antagonistic behaviours

Worldwide plant diseases are the primary source of significant financial losses for farmers. According to FAO estimates, pests and diseases account for about 25% of crop loss. There have been reports of regional variations: in more developed nations, diseases are thought to reduce crop yields by 10% annually on average, but in less developed regions, yield loss from diseases frequently surpasses 20%. Chemical pesticides are frequently sprayed on crops with the primary objective of eliminating or reducing the disease invasion, infection, or severity in order to prevent crop losses caused by diseases. But it's becoming more and more obvious that using chemical pesticides over an extended period of time has a number of negative effects on both the environment and human health. In this regard, there are many biological control traits that are present in an array of microbes, including colonisation and competition for food space, antibiosis, hyperparasitism and the generation of degradative enzymes. Furthermore, these plant-associated microorganisms form a mutual association that influences the host plant-associated microbiome and supports a vast array of bacterial taxa, many of which enhance plant growth and tolerance to biotic and abiotic stresses, inhibit plant diseases, break down xenobiotic compounds, and increase yields. By using artificial microbial consortia, it is possible to manipulate this enormous diversity of microorganisms, opening up new synergistic possibilities for improving disease management.

Exploiting Host-Mediated Microbiota Engineering for Protection of Plants against Diseases

Using cyclic differentiation and propagation, the host phenotype is used in host-mediated microbiota engineering (HMME), a biological technique that indirectly selects microbiota. By fostering microbial communities for positive effects on plant development and health, HMME is a promising strategy to enhance host performance. By observing phenotypic alterations in host plants following multiple generations of growth in the same location, this technique allows the selection of a specific microbiome. Therefore, the microbiome functions that affect host fitness are selected and manipulated through changes in host phenotypes.

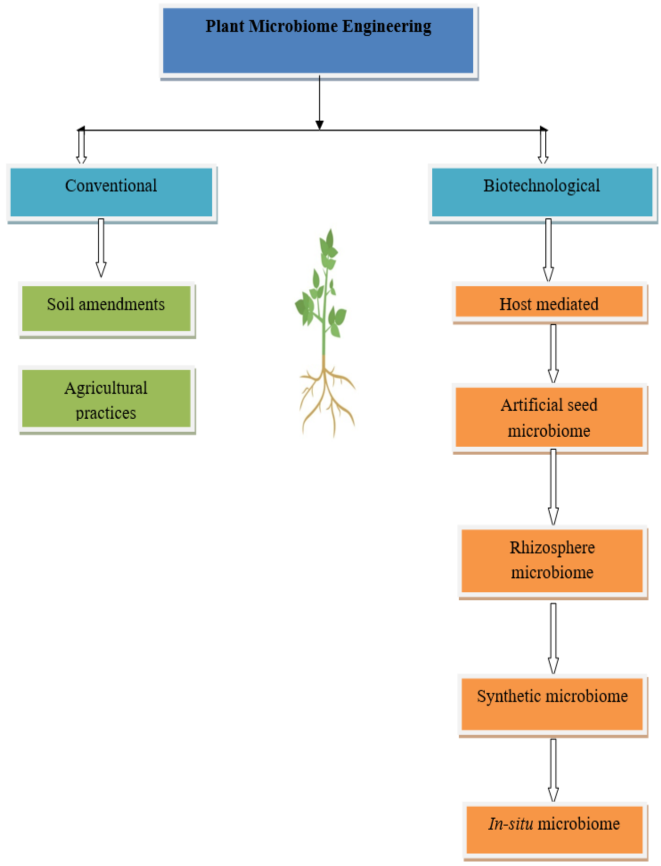

Figure 2. Engineering plant microbiome through conventional and biotechnological methods.

Limitations

The intricacy and dynamic character of plant-microbe interactions present a number of difficulties for plant microbiome engineering. A thorough knowledge of the roles and interactions of microbes is hampered by the complex and diverse structure of the plant the microbiome, which is impacted by environmental influences. There are many challenges in developing delivery systems to introduce and maintain the persistence of synthetic microorganisms in the plant rhizosphere. The field is further complicated by unintended ecological implications, possible disturbances to native ecosystems, and concerns about the long-term effects of modified plant microbiome on the plant and its surroundings. Plant microbiome engineering is made more complex by ethical issues relating to environmental sustainability and ecosystem integrity. These issues highlight the necessity of responsible methods and thorough analysis in order to fully realise the intriguing possibilities of this technology.

Conclusion

Over the past few decades, advances in our comprehension of the plant microbiome and rhizobiomes have made it possible to create integrated strategies that improve plant fitness. The host-mediated selection to engineer the plant microbiome can improve plant health. The co-evolution process that takes place in advantageous to suppressive soils (multigenerational generation) can be used as a model for this process. By employing this model, plants are able to choose their own "individualised" microbiome to mitigate the adverse impacts of a particular soil borne pathogen. The creation of the upcoming generation of bio inoculants is probably going to result from the use of this natural technology that controls the plant microbiome to regulate host health.

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