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Popular Article

Impact of Soil Microbes in Sustainable Agriculture Development

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Overview

Aggregate of potential microorganisms in the soil emerged as vital components for sustainable agriculture production. Some of the beneficial microorganism plays crucial role in the plant growth promoting activities like fixation, mineralization, solubilization, and mobilization of nutrients. In addition, release of the plant growth–promoting substances such as auxin and gibberellin hormones, mediated by interactions between host plant roots and microbes in the rhizosphere. Some of the plant species have been identified for symbiotic association with microbes and actively involved in the supply of mineral nutrients with expense of minimal energy. Identification, isolation and standardization of such type of microorganism for the formulation of strategic biofertilizer play vital role in the ecofriendly and sustainable agriculture production. Furthermore, the probiotic microorganism like lactobacillus being used as dietary supplement in the functional food products. Therefore, the effective uses of microbiome accelerate the promotion of sustainable agriculture development along with environmental safety.

1. Introduction

The higher demands of the agricultural products and shortage of agricultural land require doubling crop yields using sustainable means in the coming future. Rapid increase in the global population to 8.9 billion people by 2050 needs higher demand of the agricultural products (Poveda, 2021). Traditional crop production system employing chemical fertilizer pesticides, fungicides, and herbicides, enable the protection of crop plants against pathogens and ensure better yield. Long-term uses of these agro-chemicals are harmful to the environment and causes pollution in the soil, atmosphere and water (Al-Ani, 2018). Therefore, sustainable crop production needs novel approaches of crop production in the era of global warming and climate change to ensure global food security to the increasing population. Incorporation of beneficial microbes in to crop production provides strength to the sustainable agricultural production (Koskey, et al., 2021). In context to impact of soil microbes in sustainable crop production, several studies have been conducted and reported the role of microbes in plant fitness as well as improvement of soil health and fertility (Lopes, et al., 2021).

2. Plant microbiome

Plant microbiomes are agriculturally important resources enhancing plant growth and improve plant nutrition uptake through solubilization of P, K, Zn, and nitrogen fixation. Several studies revealed that microbes might increase crop yields, remove contaminants, inhibit pathogens, and produce fixed nitrogen or novel substances (Trivedi, et al., 2021). Furthermore, plant microbiome indicated that microbe acts on plants directly or indirectly. Several microbes are directly involved in the hormonal regulation including gibberellic acid (GA), abscisic acid (ABA), cytokinin (CK), and auxin/indole-3-acetic acid (AUX)); and the production of enzymes such as 1-aminocyclopropane-1-carboxylic acid (ACC) deaminase as well as biological nitrogen fixation (Egamberdieva, et al., 2017). On other hand, some microbes are involved in the production of bacteriocins, lipopeptides, proteases, siderophores and other volatile compounds (Vannier, et al., 2019).

3. Why Microbes are useful in agricultural sustainability?

Naturally occurring microorganism including bacteria, archaea, fungi as well as insects, annelids and algae can be applied as inoculants to increase soil microbial diversity. Efficient microbial community to the soil ecosystem improves soil quality, soil health, growth, yield and quality of crops (Inbaraj, 2021). Microbes have potential to pay in sustainable agriculture production due to their ability in the promotion of plant growth substances and enhancement of the effects of biotic and abiotic threats (Munir, et al., 2022). Therefore, selected species of microorganisms including plant growth promoting rhizobacteria, N_2-fixing cyanobacteria, plant disease suppressive bacteria and fungi, soil toxicant degrading microbes, actinomycetes and other useful microbes provide strength to the development of ecofriendly system for sustainable agriculture production (Poria, et al., 2022).

4. Involvement of soil microbes in sustainable agriculture production

Soil microbes play a key role in determining the nutrient content of our food through the mineralization of degradable organic compounds to inorganic forms that are readily available to crops. The large diversity of microbiome in soil affects its microbial ecology, including its primary productivity and nutrient cycling. Sustainable agriculture production comprise the practices, such as intercropping, crop rotation, green manuring, conservation tillage, cover crops, and adopting biofertilizers (figure).

Figure: Diagrammatic presentation of the role of soil microbes in sustainable agriculture development.

4.1. Intercropping: Intercropping is one of the important agronomical practices to minimize land and water demand, and offers an inexpensive management strategy towards sustainable agriculture development in the era of climate change. In addition to sustainable agriculture development, intercropping play's vital role in the maintaining yield stability of the crops (Awaad and El-Naggar, 2018). The significant effects of the intercropping also facilitate suitable environments to the soil microorganism and biological nitrogen fixation. Therefore, intercropping practices positively leads in the improvements of biochemical and physiological characteristics of the plant rhizosphere. Intercropping practices can also encourage the proliferation of natural enemies;

reduce disease and insect injury to the crops (Nawaz, et al., 2016).

4.2. Crop rotation: Crop rotation is another pattern of the sustainable agricultural system development to provide numerous benefits like building healthy soils, control of insects, pests and disease as well as nutrient cycling and decomposition of organic residue (Glaze-Corcoran, et al., 2020). Crop rotation has also important influence on the soil microbial properties **which** lead **to** the reduction in the loss of soil fertility. The appropriate choice of the crop rotation leads nutrient cycling by minimizing the short and long-term loss of the soil fertility (Devi and Kumar, 2020). In context to crop rotation, legume crops can mobilize soil and fertilizer P through the exudation of organic acid anions, such as citrate and malate and other compounds from their roots (Veneklaas, et al., 2003). Other crop rotation practices like replacement of dry season rice by maize in rice–rice rotation caused a reduction in soil C and N due to a 33–41% increase in the estimated amount of mineralized C and N during the dry season (Kelley, et al., 2003).

4.3. Conservation tillage: Conservation tillage practices include reduced or no tillage practices. Conservation tillage practices have been widely employed in the sustainable agricultural production systems. Conservation tillage can alter the spatial distribution of soil microbial populations and soil organic matter in the soil profile. Conservation tillage practices significantly leads **to** higher concentration of carbon and nitrogen along with water contents on the soil surface increased enzymatic activity levels with interference of microbial activities (Schmidt, et al., 2018). The meta-analyses data quantified the effect of conservation tillage in maximizing the soil microbial population and diversity. Additionally, the soil microbial diversity increase the soil enzymatic activity level helpful in the improvement of the physical property of the soil (Somenahally, et al., 2018).

4.4. Green manuring: Green manuring is one of the strategic practices of the incorporation of undecomposed green plants into soil to maintain the nutrient supply to the succeeding crop cultivars. Green manuring increases the organic soil matter, soil nutrients holding capacity and provide suitable platform for the survival of microorganism. In several studies, it has found that green manure crops increase microbial growth and their dynamics in soil by releasing nutrients and energy materials as root exudates and eventually enhance soil fertility and soil health((Kaul, et al., 2018). In addition to improve soil fertility, microbes synthesized polysaccharide gum that binds with soil particles to form soil aggregates and these soil aggregates maintained soil structure. It has been observed that microbial population, growth, and diversity are significantly influenced

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by GM and soil admixture. Some microbes have been identified to involve in the extracellular enzymatic activity transformations of nutrients from unavailable to available forms (Ghosh, et al., 2007).

4.5. Agroforestry: A multiple land use system in which crop is raised with perennial trees imparting in the minimizing the effect of climate change. Agroforestry is one of the sustainable land management option with great promise towards mitigating the rising atmospheric carbon dioxide level employing carbon sequestration. Furthermore, agroforestry may enhance the soil fertility and enhancement of physical properties, such as soil structure, porosity, and moisture retention through the extensive root system and canopy (Kumar, et al., 2015).

4.6. Biofertilizers: Biofertilizers are alternative source of chemical fertilizers supplied to the plants with help of microbes. Biofertilizers application in the soil may preserve agroecosystem is one of the significant goal of sustainable agriculture development. Application of biofertilizers in crop production **is** helpful in the improvement of soil health by improving water holding capacity, carbon storage, root growth, availability and cycling of essential nutrients (Salas-Marina, et al., 2011).

5. Conclusion and future prospects

Sustainable agriculture development employing microbial systems determined by diversity of microbes present in the soil rhizosphere. In context to sustainable agriculture development, microbes can contribute to soil health, crop productivity and health agroecosystem. A soil microbe accelerates nutrient cycling through organic matter decomposition and ecosystem functioning against deterioration of soil and water. The maintenance and improvement of soil health through microbial systems also improve our agricultural productivity and human health. In addition, soil microbial diversity and population may also accelerate biofortification approach in coming future. The production of biofortified staple crops mainly depends on the content of available soil nutrients for plants and then human health and nutrition. Promising results have been obtained using the biofortification of different nutrients or vitamins for many crops under different climatic conditions. In future, dense population of beneficial microbes in the soil provides strength to the sustainable agriculture production as well as improvement in the mineral nutrient contents in cultivated plants.

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References

1. Al-Ani, L.K.T. (2018). Trichoderma: Beneficial role in sustainable agriculture by plant disease management. In Plant Microbiome: Stress Response; Egamberdieva, D., Ahmad, P., Eds.; Springer: Singapore, Volume 5, pp. 105–126
2. Awaad, H. and El-Naggar, N. (2018). Potential role of intercropping in maintaining and cilitating environmental sustainability. Sustainability of agricultural environment in egypt: part I - soil-water-food nexus. Hdb Env Chem. 76:81–100. DOI: 10.1007/698_2017_163
3. Devi, P. and Kumar, P. (2020). Enhancement effect of biofertilizers on germination percentage and plant height in maize grown under chromium toxic soil. J Pharmacognosy Phytochem. 9:702–7. doi.10.3389/fsoil.2022.821589
4. Egamberdieva, D., Wirth, S.J., Alqarawi, A.A., Abd_Allah, E.F., Hashem, A. (2017). Phytohormones and Beneficial Microbes: Essential Components for Plants to Balance Stress and Fitness. Front. Microbiol. 8, 2104.
5. Ghosh, P.K., Bandyopadhyay, K.K., Wanjari, R.H., Manna, M.C., Misra, A.K., Mohanty, M. (2007). Legume effect for enhancing productivity and nutrient use-efficiency in major cropping systems– an Indian perspective: a review. J Sustain Agr. 30:59–86. https://doi.org/10.1300/J064v30n01_07
6. Glaze-Corcoran, S., Hashemi, M., Sadeghpour, A., Jahanzad, E., Afshar, R.K., Liu, X. (2020). Understanding intercropping to improve agricultural resiliency and environmental sustainability. Adv Agron.162:199–256. https://*doi: 10.1016/bs.agron.2020.02.004*
7. Inbaraj, M.P. (2021). Plant-Microbe Interactions in Alleviating Abiotic Stress—A Mini Review. Front. Agron. 3, 667903.
8. Kaul, A., Kaur, R., Choudhary, A.K., Sepat, S., Dass, A. (2018). Importance of green manuring in sustainable agriculture. Popular Kheti. 3:2361–6.
9. Kelley, K.W., Long, J.H., Todd, T.C. (2003). Long-term crop rotations affect soybean yield, seed weight, and soil chemical properties. Field Crops Res. 83:41–50. *doi: 10.1016/S0378-4290(03)00055-8*
10. Koskey, G., Mburu, S.W., Awino, R., Njeru, E.M., Maingi, J.M. (2021). Potential Use of Beneficial Microorganisms for Soil Amelioration, Phytopathogen Biocontrol, and Sustainable Crop Production in Smallholder Agroecosystems. Front. Sustain. Food Syst. 5, 130.

11. Kumar, A., Sharma, S., Mishra, S., Dames, J.F. (2015). *Arbuscular mycorrhizal* inoculation improves growth and antioxidative response of *Jatropha curcas* (L.) under Na2SO4 salt stress. Plant Biosyst. 149:260– 9. https://doi.org/10.1080/11263504.2013.845268

12. Lopes, M.J.D.S., Dias-Filho, M.B., Gurgel, E.S.C. (2021). Successful Plant Growth-Promoting Microbes: Inoculation Methods and Abiotic Factors. Front. Sustain. Food Syst. 5, 606454.

13. Munir, N., Hanif, M., Abideen, Z., Sohail, M., El-Keblawy, A., Radicetti, E., Mancinelli, R., Haider, G. (2022). Mechanisms and Strategies of Plant Microbiome Interactions to Mitigate Abiotic Stresses. Agronomy, 12, 2069.

14. Nawaz, M., Mabubu, J.I., Hua, H. (2016). Current status and advancement of biopesticides: microbial and botanical pesticides. J Entomolo Zoo Stud. 4:241246

15. Poria, V., D ˛ebiec-Andrzejewska, K., Fiodor, A., Lyzohub, M., Ajijah, N., Singh, S., Pranaw, K. (2022). Plant Growth-Promoting Bacteria (PGPB) integrated phytotechnology: A sustainable approach for remediation of marginal lands. Front. Plant Sci. 13, 999866.

16. Poveda, J. (2021). Insect frass in the development of sustainable agriculture. A review. Agron Sustain Dev. 41:1–10. *doi: 10.1007/s13593-020-00656-x*

17. Salas-Marina, M.A., Silva-Flores, M.A., Uresti-Rivera, E.E., Castro-Longoria, E., Herrera-Estrella, A., Casas-Flores, S. (2011). Colonization of Arabidopsis roots by *Trichoderma atroviride* promotes growth and enhances systemic disease resistance through jasmonic acid/ethylene and salicylic acid pathways. Eur J Plant Pathol. 131:15–26. *doi: 10.1007/s10658-011-9782-6*

18. Schmidt, R., Gravuer, K., Bossange, A.V., Mitchell, J., Scow, K. (2018). Long-term use of cover crops and no-till shift soil microbial community life strategies in agricultural soil. PLoS ONE. 13:e0192953doi: 10.1371/journal.pone.0192953

19. Somenahally, A., DuPont, J.I., Brady, J., McLawrence, J., Northup, B., Gowda, P. (2018). Microbial communities in soil profile are more responsive to legacy effects of wheat-cover crop rotations than tillage systems. Soil Biol Biochem. 123:126–35. https://doi.org/10.1016/j.soilbio.2018.04.025

20. Trivedi, P., Mattupalli, C., Eversole, K., Leach, J.E. (2011). Enabling sustainable agriculture through understanding and enhancement of microbiomes. Transley Review. New Phytol. 230:2129–47. https://doi.org/10.1111/nph.17319

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21. Vannier, N., Agler, M., Hacquard, S. (2019). Microbiota-mediated disease resistance in plants. PLoS Pathog. 15, e1007740.

22. Veneklaas, E.J., Stevens, J., Cawthray, G.R., Turner, S., Grigg, A.M., Lambers, H. (2003). Chickpea and white lupine rhizosphere carboxylates vary with soil properties and enhance phosphorus uptake. Plant Soil. 248:187– 97. https://doi.org/10.1023/A:1022367312851