Green Bioinoculants

Subjects: Agriculture, Dairy & Animal Science

Contributor: R. Z. Sayyed

Biofertilizers are emerging as a suitable alternative to counteract the adverse environmental impacts exerted by synthetic agrochemicals. Biofertilizers facilitate the overall growth and yield of crops in an eco-friendly manner.

Keywords: Biofertilizer ; Bioinoculant ; PGPR

1. Introduction

The advent of the Green Revolution in the latter part of the twentieth century triggered a worldwide boom in the agriculture sector. By introducing new high-yielding seed varieties and increasing the use of synthetic fertilizers, pesticides, and other agrochemicals, the Green Revolution contributed significantly to enhanced plant productivity and crop yields [1]. The global agricultural landscape has drastically changed since then. Rampant overuse of synthetic agrochemicals for enhancing crop productivity has deteriorated the biological and physicochemical health of the arable soil, leading to a declining trend in agricultural productivity across the globe over the past few decades [2][3][4]. In the present scenario, there is a shrinkage of land resources and the depletion of biological wealth. In order to fulfill the escalating demand for sustainable agriculture, the yield and productivity of agricultural crops need to be concurrently increased with the production of agriculture-related commodities. There is no single or straightforward solution to the above-mentioned intricate, ecological, socio-economic, and technical glitches existing in promoting sustainable agriculture [1].

Promoting sustainable agriculture with a gradual decrease in the use of synthetic agrochemicals and more prominent utilization of the bio-waste-derived substances [5][6] as well as the biological and genetic potential of crop plants and microorganisms is an effective strategy to combat the rapid environmental deterioration while ensuring high agricultural productivity and better soil health [7]. In addition to the genetic manipulation of the crop physiology and metabolism for yield enhancement, certain members of the soil microbial community, particularly those residing in the plant rhizosphere, might assist plants in preventing or partially overcoming the environmental stresses [8][9]. Search for eco-friendly alternatives to mitigate the harmful effects of toxic agrochemicals led to the discovery and subsequent use of biofertilizers and other microbial-based products, including organic extracts and vermicompost teas [10][11][12]. These microbial products are non-toxic, environment-friendly, and act as potential tools for plant growth promotion and disease control. Thus, the biological potential and fertility of soil could be increased, whereas the hazardous effects of agrochemicals could be decreased by employing microbial formulations to fertilize agricultural crops [13][14][15]. The use of efficient plant growth promoting rhizobacteria (PGPR) as biofertilizers and biological control agents is deliberated as a suitable substitute for minimizing the use of synthetic agrochemicals in crop production [16][17][18][19].

2. Biofertilizers

During the past two decades, the term biofertilizer or bioinoculant has been derived in various ways due to the commendable progress achieved in the studies of the association between microorganisms and plants. A biofertilizer is most commonly defined as “a substance which contains living microorganisms which, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant” [16]. Dineshkumar et al. [20] later proposed a modified definition of biofertilizers as “products (carrier or liquid based) containing living or dormant microbes (bacteria, actinomycetes, fungi, algae) alone or in combination, which help in fixing atmospheric nitrogen or solubilizers soil nutrients in addition to the secretion of growth promoting substances for enhancing crop growth and yield”.

The microorganisms present in the biofertilizers employ several mechanisms to provide benefits to the crop plants. They can either be efficient in nitrogen fixation, phosphate solubilization, and plant growth promotion or can possess a combination of all such traits [21][23][22][24]. Biofertilizers can fix atmospheric N_2 through the biological nitrogen fixation

(BNF) process, solubilize nutrients required by the plants, such as phosphate, zinc, and potassium, and also secrete plant growth promoting substances, including various hormones [25][26]. Further, when applied as seed or soil inoculants, biofertilizers can multiply, participate in nutrient cycling, and help in crop production for sustainable farming [27][28][29].

The microbial inoculants possess several advantages over their chemical counterparts [30][31][32]. They are eco-friendly, sound sources of renewable nutrients required for maintaining soil health and biology [13][23][29]. Furthermore, they exhibit antagonistic activity against several agricultural pathogens and combat abiotic stresses [8][33][34][35][36]. Various microbial taxa have been commercially used as efficient biofertilizers, based on their ability to obtain nutrients from the soil, fix atmospheric N_2, stimulate the solubilization of nutrients, and act as biocontrol agents [37].

References

1. Kesavan, C.; Swaminathan, M.S. Modern technologies for sustainable food and nutrition security. Curr. Sci. 2018, 115, 1876–1883, doi:10.18520/cs/v115/i10/1876-1883.
2. Pingali, L. Green revolution: Impacts, limits, and the path ahead. Proc. Natl. Acad. Sci. USA 2012, 109, 12302–12308, doi:10.1073/pnas.0912953109.
3. Yang, ; Fang, S. Practices, perceptions, and implications of fertilizer use in East-Central China. Ambio 2015, 44, 647–652, doi:10.1007/s13280-015-0639-7.
4. Bishnoi, Agriculture and the dark side of chemical fertilizers. Environ. Anal. Ecol. Stud. 2018, 3, EAES.000552.2018, doi:10.31031/EAES.2018.03.000552.
5. Fascella, ; Montoneri, E.; Ginepro, M.; Francavilla, M. Effect of urban biowaste derived soluble substances on growth, photosynthesis and ornamental value of Euphorbia × lomi. Sci. Hortic. 2015, 197, 90–98, doi:10.1016/j.scienta.2015.10.042.
6. Fascella, ; Montoneri, E.; Francavilla, M. Biowaste versus fossil sourced auxiliaries for plant cultivation: The Lantana case study. J. Clean. Prod. 2018, 185, 322–330, doi:10.1016/j.jclepro.2018.02.242.
7. Liu, ; Ma, K.; Ciais, P.; Polasky, S. Reducing human nitrogen use for food production. Sci. Rep. 2016, 6, 30104, doi:10.1038/srep30104.
8. Ilangumaran, ; Smith, D.L. Plant growth promoting rhizobacteria in amelioration of salinity stress: A systems biology perspective. Front. Plant Sci. 2017, 8, 1768, doi:10.3389/fpls.2017.01768.
9. De Souza, ; Ambrosini, A.; Passaglia, L.M.P. Plant growth-promoting bacteria as inoculants in agricultural soils. Genet. Mol. Biol. 2015, 38, 401–419, doi:10.1590/S1415-475738420150053.
10. Mishra, ; Wang, K.-H.; Sipes, B.S.; Tian, M. Suppression of root-knot nematode by vermicompost tea prepared from different curing ages of vermicompost. Plant Dis. 2017, 101, 734–737, doi:10.1094/PDIS-07-16-1068-RE.
11. Arancon, Q.; Owens, J.D.; Converse, C. The effects of vermicompost tea on the growth and yield of lettuce and tomato in a non-circulating hydroponics system. J. Plant Nutr. 2019, 42, 2447–2458, doi:10.1080/01904167.2019.1655049.
12. Akinnuoye-Adelabu, B.; Steenhuisen, S.; Bredenhand, E. Improving pea quality with vermicompost tea and aqueous biochar: Prospects for sustainable farming in Southern Africa. S. Afr. J. Bot. 2019, 123, 278–285, doi:10.1016/j.sajb.2019.03.009.
13. Raklami, ; Bechtaoui, N.; Tahiri, A.; Anli, M.; Meddich, A.; Oufdou, K. Use of rhizobacteria and mycorrhizae consortium in the open field as a strategy for improving crop nutrition, productivity and soil fertility. Front. Microbiol. 2019, 10, 1106, doi:10.3389/fmicb.2019.01106.
14. Jabborova, ; Wirth, S.; Kannepalli, A.; Narimanov, A.; Desouky, S.; Davranov, K.; Sayyed, R.Z.; El Enshasy, H.; Malek, R.A.; Syed, A.; et al. Co-Inoculation of rhizobacteria and biochar application improves growth and nutrients in soybean and enriches soil nutrients and enzymes. Agronomy 2020, 10, 1142, doi:10.3390/agronomy10081142.
15. Sharma, B.; Sayyed, R.Z.; Trivedi, M.H.; Gobi, T.A. Phosphate solubilizing microbes: Sustainable approach for managing phosphorus deficiency in agricultural soils. Springerplus 2013, 2, 587, doi:10.1186/2193-1801-2-587.
16. Vessey, K. Plant growth promoting rhizobacteria as biofertilizers. Plant Soil 2003, 255, 571–586, doi:10.1023/A:1026037216893.
17. Anli, ; Baslam, M.; Tahiri, A.; Raklami, A.; Symanczik, S.; Boutasknit, A.; Ait-El-Mokhtar, M.; Ben-Laouane, R.; Toubali, S.; Ait Rahou, Y.; et al. Biofertilizers as strategies to improve photosynthetic apparatus, growth, and drought stress tolerance in the date palm. Front. Plant Sci. 2020, 11, 516818, doi:10.3389/fpls.2020.516818.

18. Dong, ; Li, Y.; Xu, J.; Yang, J.; Wei, G.; Shen, L.; Ding, W.; Chen, S. Biofertilizers regulate the soil microbial community and enhance Panax ginseng yields. Chin. Med. 2019, 14, 20, doi:10.1186/s13020-019-0241-1.
19. Atieno, ; Herrmann, L.; Nguyen, H.T.; Phan, H.T.; Nguyen, N.K.; Srean, P.; Than, M.M.; Zhiyong, R.; Tittabutr, P.; Shutsrirung, A.; et al. Assessment of biofertilizer use for sustainable agriculture in the Great Mekong Region. J. Environ. Manag. 2020, 275, 111300, doi: 10.1016/j.jenvman.2020.111300.
20. Dineshkumar, ; Kumaravel, R.; Gopalsamy, J.; Sikder, M.N.A.; Sampathkumar, P. Microalgae as bio-fertilizers for rice growth and seed yield productivity. Waste Biomass Valorization 2018, 9, 793–800, doi:10.1007/s12649-017-9873-5.
21. Mahanty, ; Bhattacharjee, S.; Goswami, M.; Bhattacharyya, P.; Das, B.; Ghosh, A.; Tribedi, P. Biofertilizers: A potential approach for sustainable agriculture development. Environ. Sci. Pollut. Res. 2017, 24, 3315–3335, doi:10.1007/s11356-016-8104-0.
22. Zandi, ; Basu, S.K. Role of plant growth-promoting rhizobacteria (PGPR) as biofertilizers in stabilizing agricultural ecosystems. In Organic Farming for Sustainable Agriculture; Nandwani, D., Ed.; Springer: Cham, Switzerland, 2016; pp. 71–87, doi:10.1007/978-3-319-26803-3_3.
23. Bhardwaj, ; Ansari, M.W.; Sahoo, R.K.; Tuteja, N. Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. Microb. Cell Fact. 2014, 13, 1–10.
24. Ritika, ; Utpal, D. Biofertilizer, a way towards organic agriculture: A review. Afr. J. Microbiol. Res. 2014, 8, 2332–2343, doi:10.5897/ajmr2013.6374.
25. Borkar, G. Microbes as Bio-Fertilizers and Their Production Technology, 1st ed.; WPI Publishing: New York, NY, USA, 2015.
26. Kumar, M.; Reddy, C.G.; Phogat, M.; Korav, S. Role of bio-fertilizers towards sustainable agricultural development: A review. J. Pharm. Phytochem. 2018, 7, 1915–1921.
27. Itelima, ; Bang, W.J.; Onyimba, I.A.; Sila, M.D.; Egbere, O.J. Bio-fertilizers as key player in enhancing soil fertility and crop productivity: A review. J. Microbiol. Biotechnol. Rep. 2018, 2, 22–28.
28. Singh, S.; Pandey, V.C.; Singh, D.P. Efficient soil microorganisms: A new dimension for sustainable agriculture and environmental development. Agric. Ecosyst. Environ. 2011, 140, 339–353.
29. Sun, ; Bai, Z.; Bao, L.; Xue, L.; Zhang, S.; Wei, Y.; Zhang, Z.; Zhuang, G.; Zhuang, X. Bacillus subtilis biofertilizer mitigating agricultural ammonia emission and shifting soil nitrogen cycling microbiomes. Environ. Int. 2020, 144, 105989, doi:10.1016/j.envint.2020.105989.
30. Backer, ; Rokem, J.S.; Ilangumaran, G.; Lamont, J.; Praslickova, D.; Ricci, E.; Subramanian, S.; Smith, D.L. Plant growth-promoting rhizobacteria: Context, mechanisms of action, and roadmap to commercialization of biostimulants for sustainable agriculture. Front. Plant Sci. 2018, 9, 1473, doi:10.3389/fpls.2018.01473.
31. Mahajan, ; Gupta, R.D. Bio-fertilizers: Their kinds and requirement in India. In Integrated Nutrient Management (INM) in a Sustainable Rice—Wheat Cropping System; Mahajan, A., Gupta, R.D., Eds.; Springer: Dordrecht, The Netherlands, 2009; pp. 75–100.
32. Meena, ; Swapnil, P.; Divyanshu, K.; Kumar, S.; Tripathi, Y.N.; Zehra, A.; Marwal, A.; Upadhyay, R.S. PGPR-mediated induction of systemic resistance and physiochemical alterations in plants against the pathogens: Current perspectives. J. Basic Microbiol. 2020, 60, 828–861, doi:10.1002/jobm.202000370.
33. Timmusk, ; Kim, S.-B.; Nevo, E.; Abd El Daim, I.; Ek, B.; Bergquist, J.; Behers, L. Sfp-type PPTase inactivation promotes bacterial biofilm formation and ability to enhance wheat drought tolerance. Front. Microbiol. 2015, 6, 387, doi:10.3389/fmicb.2015.00387.
34. Bharti, ; Pandey, S.S.; Barnawal, D.; Patel, V.K.; Kalra, A. Plant growth promoting rhizobacteria Dietzia natronolimnaea modulates the expression of stress responsive genes providing protection of wheat from salinity stress. Sci. Rep. 2016, 6, 34768, doi:10.1038/srep34768.
35. Sharma, ; Kulkarni, J.; Jha, B. Halotolerant rhizobacteria promote growth and enhance salinity tolerance in peanut. Front. Microbiol. 2016, 7, 1600, doi:10.3389/fmicb.2016.01600.
36. Timmusk, ; Abd El-Daim, I.A.; Copolovici, L.; Tanilas, T.; Kännaste, A.; Behers, L.; Nevo, E.; Seisenbaeva, G.; Stenström, E.; Niinemets, Ü. Drought-tolerance of wheat improved by rhizosphere bacteria from harsh environments: Enhanced biomass production and reduced emissions of stress volatiles. PLoS ONE 2014, 9, e96086, doi:10.1371/journal.pone.0096086.
37. Schütz, L.; Gattinger, A.; Meier, M.; Müller, A.; Boller, T.; Mäder, P.; Mathimaran, N. Improving crop yield and nutrient use efficiency via biofertilization—A global meta-analysis. Front. Plant Sci. 2018, 8, 2204, doi:10.3389/fpls.2017.02204.