Vol.2 Issue-6, FEB 2022 (e-ISSN: 2582-8223)

Soil Microbes-Plants-Insect Herbivores: A Tritrophic Interaction

Uttam Kumar[1], Patel Nidhibahen[2], Parmar Prashant[2], Ashok Choudhary[3], S. K. Jat[4]
[1]College of Tropical Agriculture, Hainan University, Haikou, China
[2]College of Plant Protection, Fujian Agriculture and Forestry University, China
[3]G.B.Pant University of Agriculture and Technology, Pantnagar
[4]Assistant Professor, AU, Kota

ARTICLE ID: 17

Introduction

Plants are acting as a link between the numerous kinds of herbivores and non-pathogenic root-associated microbes which are providing benefits to the plant against insect herbivores (Aljbory et al., 2018). We can also call them mediators of multitrophic interactions between microbes and insects. Moreover, plant vegetation also interlinks below ground and above ground community members, such as soil-borne microbes and above-ground insects (Pena et al., 2016). Soil properties and soil history also have a major impact on insect herbivores (Howard et al., 2018).Sometimes a normal soil amendment can have a major detrimental effect on insect herbivores and sometimes many seasonal soil amendments are required for better control on the negative effect of insects on plants (Thomson et al., 2010). Soil properties affect the soil microbiome and this can have direct and indirect effects on the insect herbivores either aboveground or belowground (Pineda et al., 2017).

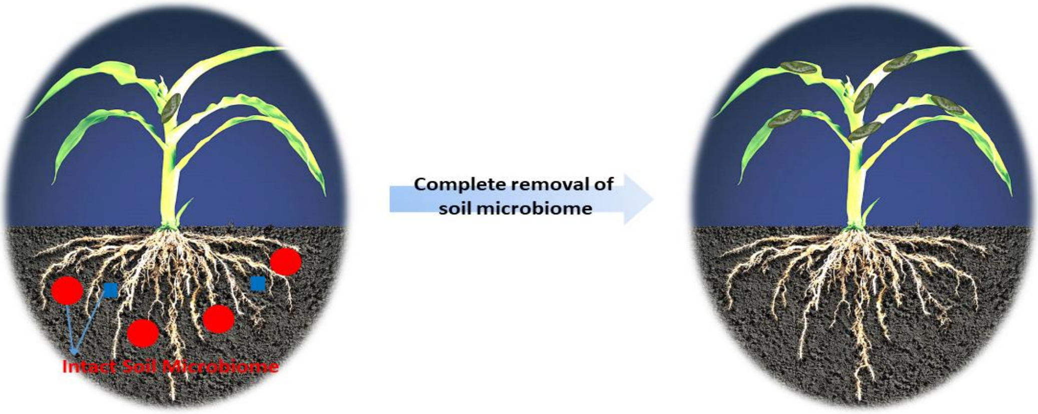

Figure 1: When the soil microbiome is removed completely from the soil the infestation of insect herbivores increases many folds as studied by Hubbard et al., 2019.

JUST AGRICULTURE
multidisciplinary e-Newsletter

Genetic and ecological modifications are being used together to achieve higher crop yields whilst minimizing negative impacts on the ecosystem. Keeping these things in mind, scientists are following various strategies like improving the plant resistance against herbivores and other kinds of abiotic stresses, conservational biological management, and improving the plant growth. Here the importance of such kind of microbes comes in front of the researchers as they are naturally available and don't have any negative impacts on the agro-ecosystem.In this article, we have covered the interaction between different microbes with plants, herbivores, and the tritrophic interaction between plants, microbes, and herbivores.

1. Tritrophic interaction between microbes-plants and herbivores

Microbes, plants, and insects are part of the same ecosystem, and in an ecosystem, these three elements can have either direct interaction or indirect interaction. Few interactions are mediated by the plants, and changes are made by insects in the plants, which affect the microbes in the soil. When a plant gets attacked by an insect, it can respond in many different ways. For instance, plants can change the quantity and quality of root exudates, and plants can also modify the soil properties, and this can lead to changes in the plant-microbe interaction. When some changes occur in the distant organs and tissues of the plant due to the attack of insects on plant tissues, it can have an effect on soil microbes and the organisms below ground (Kong et al., 2019), and these changes might not affect the soil microbes in equal proportion. This has been shown by one of the studies done by Landgraf et al. (2012) on *Medicagotruncatula*. In *Medicagotruncatula*, when the leaf was mechanically wounded many times more than at local level, Jasmonic acid (JA) was increased, but there was a difference in the colonization of mycorrhiza and rhizobacteria (Rivero et al., 2019). It was observed that the colony of mycorrhiza was showing an increasing trend while rhizobacteria remained unaffected.

In addition, acetoin and 2, 3-butanediol are the two volatile organic compounds (VOCs) that are released by bacillus species and were the first to be known for the initiation of induced systemic resistance (ISR), and this initiation is dependent on the ethylene (ET) pathway rather than the salicylic acid (SA) and JA pathways in Arabidopsis plant (Kong et al., 2018, Li et al., 2019). When some insects infest the plant, some of the VOCs are also produced by the plant, and these are termed "herbivore-induced plant volatiles" (HIPVs). The schematic illustration is shown in figure 3. These volatiles can affect the plant directly or indirectly. Directly, they can either poison the herbivore or repel it. Indirectly, they can help attract the natural enemies of the herbivores (Walters et al., 2017, Lackner et al., 2019).

After the initial study by Ryu et al. (2004), many more studies related to these chemicals have been done. In one of the studies, the expression of terpene genes was initiated by the leaf-chewing herbivores via the JA signalling pathway. This can have a role in insect-plant interaction (Erb et al., 2019). In one of the similar kinds of studies, scientists have shown that when *P. fluorescens*WCS417r (currently called *Pseudomonas simiae*WCS417r) colonizes the roots of Arabidopsis, it leads to the increment of plant volatiles which are dependent on JA signalling pathway genes when the caterpillar feeds on the plant (Disi et al.,2019).

In one of the other studies, when rhizobacterium was added, the expression of some of the genes like TPS03 and TPS04 was decreased due to the suppression of the aromatic compounds like terpene (*E*)-α-bergamotene when a caterpillar attacked the plant. Due to this suppression, an increasing number of parasitoids are attracted towards the caterpillar and it leads to an indirect defence against insect herbivores (Block et al., 2019). These kinds of studies provide evidence that these chemicals can be of great use in controlling insect herbivores in an eco-friendly and better way. We can apply much more innovative ideas and research in this field.

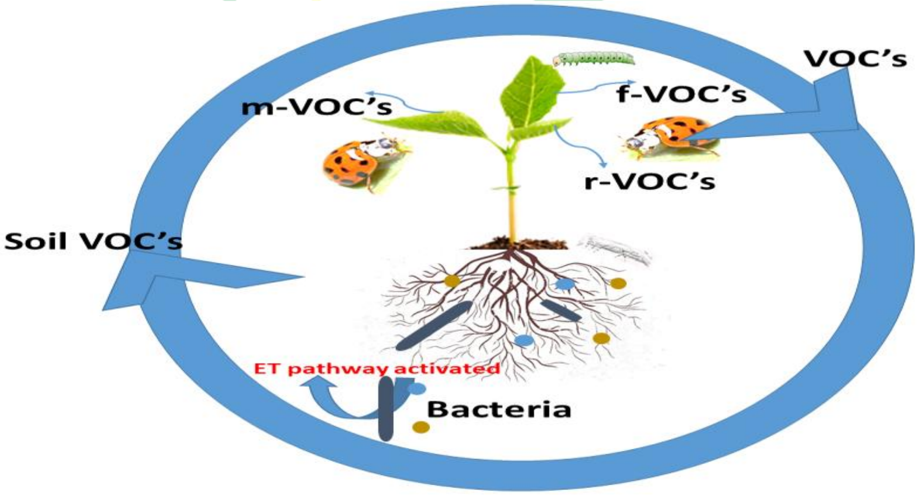

Figure 2: Soil microbes like Bacillus species initiate the ISR with the help of volatile organic compounds (VOC's) like acetoin and 2,3-butanediol, and this is dependent on the initiation of

the ET pathway. There are VOCs which are induced by the herbivore infestation and are termed "herbivore induced plant volatiles" (HIPVs). The emission of these VOC's attracts the natural enemies.

2. Host immunity modulations through soil microbes

Every microorganism has two ways to save itself from the immune system of the host: either to hide or to modulate the immune system of the host through some chemicals or some molecules. Every microorganism in the body of the host is recognized as an alien by the immune system of the host, whether the microorganism is beneficial or detrimental to the host body (Thakur et al., 2019). For the establishment of a relationship between the host and the microbe, the modulation of the immune system is a necessary step. Compounds like flagellin and chitin are normally identified by pattern recognition receptors (PRRs) in the host immune system, and these patterns are normally known as microbe associated molecular patterns (MAMPs) and pathogen associated molecular patterns (PAMPs). Basically, identification of these patterns is the initiating step in plant defense (Shehzadi et al., 2019). For the initiation of ISR, beneficial soil microbes must have a colony near the root system of the plant. MAMPs and PAMPs together are known as MAMP-triggered immunity (MTI) (Van der et al., 2019). And avoidance of MTI can lead the microbes to successful and effective colonization of the host's root (Bulgari et al., 2019).

Soil microbes which are beneficial to the plants have co-evolved with the plant and have developed strategies which can overcome the host immune system, especially the MTI for the colony formation in the roots and the mutual benefits of plants and microbes both. When soil microbes play the role of mediator in ISR, it mostly depends on the priming. Priming is a good way to suppress the immune system in the roots because it saves a lot of energy (Ling et al., 2019). When ISR-insensitive insects attack the leaves of the plants, then priming becomes irrelevant because priming takes place only when the insect initiates the ISR. In one of the studies done by Song et al., when mycorrhizacolonises the roots of tomato plants, it leads to the over expression of genes like protease inhibitor (PI-1) and allene oxide cyclase (AOC), which are involved in the defence of the plant. This is called priming based defence in tomato plants (Du et al., 2019). A similar kind of study was done by Ahn et al. in arabidopsis priming and its effects were shown by the *Pseudomonas putida* LSW17S gene, which was based on NPR1, ET, and the JA pathway (Jain et al., 2019).

JUST AGRICULTURE multidisciplinary e-Newsletter

References

Aljbory, Z. and Chen, M.S., 2018. Indirect plant defense against insect herbivores: a review. *Insect science*, *25*(1), pp.2-23

Block, A.K., Vaughan, M.M., Schmelz, E.A. and Christensen, S.A., 2019. Biosynthesis and function of terpenoid defense compounds in maize (Zea mays). *Planta*, *249*(1), pp.21-30.

Bulgari, D., Montagna, M., Gobbi, E. and Faoro, F., 2019. Green Technology: Bacteria-Based Approach Could Lead to Unsuspected Microbe–Plant–Animal Interactions. *Microorganisms*, *7*(2), p.44.

De la Peña, E., Baeten, L., Steel, H., Viaene, N., De Sutter, N., De Schrijver, A. and Verheyen, K., 2016. Beyond plant–soil feedbacks: mechanisms driving plant community shifts due to land-use legacies in post-agricultural forests. *Functional Ecology*, *30*(7), pp.1073-1085.

Disi, J., Simmons, J. and Zebelo, S., 2019. Plant Growth-Promoting Rhizobacteria-Induced Defense Against Insect Herbivores. In *Field Crops: Sustainable Management by PGPR* (pp. 385-410). Springer, Cham.

Du, M., Zhao, J., Tzeng, D.T., Liu, Y., Deng, L., Yang, T., Zhai, Q., Wu, F., Huang, Z., Zhou, M. and Wang, Q., 2017. MYC2 orchestrates a hierarchical transcriptional cascade that regulates jasmonate-mediated plant immunity in tomato. *The Plant Cell*, *29*(8), pp.1883-1906.

Erb, M. and Reymond, P., 2019.Molecular interactions between plants and insect herbivores. *Annual review of plant biology*, *70*, pp.527-557.

Howard, M.M., Kalske, A. and Kessler, A., 2018. Eco-evolutionary processes affecting plant–herbivore interactions during early community succession. *Oecologia*, *187*(2), pp.547-559.

Hubbard, C.J., Li, B., McMinn, R., Brock, M.T., Maignien, L., Ewers, B.E., Kliebenstein, D. and Weinig, C., 2019. The effect of rhizosphere microbes outweighs host plant genetics in reducing insect herbivory. *Molecular ecology*, *28*(7), pp.1801-1811.

Jain, S., Varma, A., Tuteja, N. and Choudhary, D.K., 2016.Bacteria-mediated elicitation of induced resistance in plants upon fungal phytopathogen. In *Plant-Microbe Interaction: An Approach to Sustainable Agriculture* (pp. 249-269). Springer, Singapore.

Kong, C.H., Xuan, T.D., Khanh, T.D., Tran, H.D. and Trung, N.T., 2019. Allelochemicals and signaling chemicals in plants. *Molecules*, *24*(15), p.2737.

Kong, H.G., Shin, T.S., Kim, T.H. and Ryu, C.M., 2018. Stereoisomers of the bacterial volatile compound 2, 3-Butanediol differently elicit systemic defense responses of pepper against multiple viruses in the field. *Frontiers in plant science*, *9*, p.90.

Lackner, S., Lackus, N.D., Paetz, C., Köllner, T.G. and Unsicker, S.B., 2019.Aboveground phytochemical responses to belowground herbivory in poplar trees and the consequence for leaf herbivore preference. *Plant, cell &environment*.

Li, F., Tang, M., Tang, X., Sun, W., Gong, J. and Yi, Y., 2019. Bacillus subtilis–Arabidopsis thaliana: a model interaction system for studying the role of volatile organic compounds in the interchange between plants and bacteria. *Botany*, *97*(12), pp.661-669.

Ling, R., 2019. Construction of a fusion protein for anchoring the inflammatory receptor NLRP3 to the cell membrane

Pineda, A., Kaplan, I. and Bezemer, T.M., 2017. Steering soil microbiomes to suppress aboveground insect pests. *Trends in plant science*, *22*(9), pp.770-778.

Rivero Bravo, J., 2019. Metabolic reprogramming in arbuscularmycorrhiza symbiosis for enhanced resistance and tolerance against stresses.

Shehzadi, A., Muhammad, H., Abbas, K., Ahmed, Z. and Saleem, S., 2018. Effect plant disease resistance genes: recent applications and future perspectives. *J Innov Bio-Res*, *1*, pp.86-103.

Thakur, M.P., van der Putten, W.H., Cobben, M.M., van Kleunen, M. and Geisen, S., 2019.Microbial invasions in terrestrial ecosystems. *Nature Reviews Microbiology*, *17*(10), pp.621-631.

Thomson, L.J., Macfadyen, S. and Hoffmann, A.A., 2010.Predicting the effects of climate change on natural enemies of agricultural pests. *Biological control*, *52*(3), pp.296-306.

Van der Burgh, A.M. and Joosten, M.H., 2019. Plant immunity: thinking outside and inside the box. *Trends in plant science*.

Walters, D., 2017. *Fortress Plant: How to survive when everything wants to eat you*. Oxford University Press.