Overview of studies on plant-soil feedback

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Abstract

Studies of feedback between plants and soil are mainly concentrated in the process of vegetation restoration in physical properties change and the law, above ground vegetation type on the influence of amount of rhizosphere microorganisms and plants grow in the rhizosphere microbes change trend, in the process of a certain stage or research succession of plant rhizosphere microbial community changes, changes of soil biological community succession of vegetation is to enhance or inhibit and whether plants - soil biological feedback helps to the long-term development of the ecological system is still not clear. In order to make the plant-soil feedback theory applicable universally, it is necessary to study the plant-soil feedback relationship in different succession stages in the same ecosystem in the future. In addition, the relationship between the stoichiometric ratio of carbon, nitrogen and phosphorus corresponding to the plant-soil feedback mechanism in different ecosystems under different environmental conditions and nutrient cycling still needs to be further studied.

Keywords

Plant-soil feedback, Rhizosphere soil, soil ecosystem.

1. Introduction

The natural properties of soil mainly depend on its chemical, physical and biological properties, which have important influences on plant growth, production and reproduction, and are closely related to plant species, community structure and productivity [1-5].Plants affect soil properties through the input of chemical compounds and organic matter, mainly through providing habitats or resources for soil microorganisms and soil animals and influencing soil hydrological processes and surface temperature [6-7].The effects of plants on the biological and abiotic properties of soil in turn change the ability of the soil to supply plants. Studies have found that the interaction between plants and soil is the main factor driving plant diversity and ecosystem function [8-11].This change in soil properties caused by plants will in turn affect Plant growth and production, which is Plant soil feedback (PSF)[12-13,2], also known as Plant soil interaction [14-16,9,7].The academic term of plant-soil feedback was originally used to express the interaction between plants and soil organisms [14,12], which has been widely adopted by ecologists. Nowadays, plant-soil feedback has become an ecological concept, and a considerable part of literature review has focused on the role and role of positive or negative plant-soil feedback in the community structure and ecological function of the ecosystem, such as plant growth, species richness and succession, etc. [17-20,2, 9,12].

2. Research progress

As early as 1000 years ago, people have realized the importance of plant-soil feedback in agriculture and horticultural management. In agriculture, plant-soil feedback is generally manifested as soil nutrient depletion or accumulation of specific soil-borne pathogens. The reason for the decline in crop yields was not discovered until the 19th century. Soil diseases or fatigue can alleviate the diseases caused by continuous cropping by sterilizing soil, indicating that soil organisms play an important role in crop growth [21].In the mid-to-late 20th century, soil was no longer suitable for the growth of certain crops, especially when global economic development forced farmers to plant crops with higher yields and shorter crop rotation periods. Ecologists by way of farming and early plant and plant diseases and insect pests of observation have benefited a lot from the process of interaction between, the relationship between agriculture and ecology has become a complete cycle system, such as natural feedback between plants and soil in the system research results, have been used to develop and test crops sustainable production methods.

Ecologists have long known that wild plants can affect nutrient breakdown and mineralization, which in turn affects plant growth. For example, Muller's (1884) theory of humus thickness indicates that different plants will produce litter of different sizes, and the different nature of litter will have different effects on soil organisms and other soil properties, but this effect will eventually affect plant growth in the form of feedback [22].Different natures of litters can affect the plant community structure by changing the decomposition and nutrient mineralization rate, so as to colonize the plant species. For example, increased litter-decomposition would promote the settlement of Molinia caerulea, which in turn would cause Erica tetralix to die off, turning the heath wilderness into a meadow [23-24].

Studies have shown that some plants, compared with other plants growing in rhizosphere soil, will show the so-called "home field advantage" when growing in the soil of decomposition of their own litters [25]. Of course, there may be other reasons for this phenomenon [26].In California, for example, a low in the west of the trees in the forest, the study found that some plants such as pine, medicine Ling (Pinus muricata) rely on mycorrhizal fungi to reduce nitrogen cycle process, these plants can be a favorable to its ectotrophic mycorrhiza fungi to absorption of nitrogen in the organic matter, and these fungi is not conducive to the growth of other kinds of plant [27].Handley's [28] 's study on Calluna vulgaris (UK) and Wardle[29]' s study on the Swedish island shows that some plants can prevent the mineralization of nitrogen by producing a large amount of polyphenol litters, and the blocking of nitrogen mineralization is not conducive to the growth of plants in the early stage of succession [30].

Whether plant - soil feedback affects plant community structure depends on the effect of feedback mechanism on symbiotic plants. Soil - borne pathogens have long been considered less specific than aboveground pathogens, but more specific than mycorrhizal fungi. However, studies continue to show that the biological composition of soil is quite specific [31,18].When combing various components of plant-soil feedback, it is necessary to take into account the strong difference in the way of resource exchange between arbuscular mycorrhizal fungi and individual plants [32]. Sometimes, they may play the role of pathogens [33] and may play a negative feedback role on plant growth [34].

For some plants, when the accumulation of rhizophagous insects [35-36], nematodes [37] and bioindividuals that feed on plant debris [38-39] reaches a certain level, their feedback to plants will affect the performance of this or other plants and thus affect the vegetation structure [40].Although a large number of studies have been conducted on soil-borne pathogens and rhizoophagous animals in agricultural systems, similar studies are rare in natural ecosystems. On the other hand, plant-soil feedback through humus has been extensively studied in natural ecosystems [41].

The specificity of the exudate of toxic chemical compounds in plant roots is another mechanism for plant-soil feedback [42].Direct studies of the effects of these chemical compounds, though numerous, are obscure because it is difficult to distinguish between other factors such as toxic compounds produced by soil microorganisms during decomposition [43].Nevertheless, some studies have found that plants can directly produce phytochemical compounds without soil biological interference [44-45].At present, the research value of phytogram in natural ecosystem is more than that in agricultural system [46], and the idea that phytogram compounds produced by foreign plants will be beneficial to the invasion of foreign plants [47] is becoming a new hotspot for scientists to study the plant-soil feedback interaction in natural system. The change in the intensity and direction of the interaction studied by the plant-soil feedback model [12] indicates that the plant community structure is in a process of dynamic change: it can evolve from the coexistence of different plant species to the final dominance or invasion of a single plant species by foreign plants. The specificity of plant-soil feedback may lead to a decrease in the succession and negative feedback of mixed plant communities, which also explains why the biomass of a single plant is lower than that of mixed plant communities.

3. Conclusion

Of the existing research mainly concentrated in the process of vegetation restoration in physical properties change and the law, above ground vegetation type on the influence of amount of rhizosphere microorganisms and plant rhizosphere microorganisms in the process of growth trends, a certain stage or research succession of plant rhizosphere microbial community changes, changes of soil biological community succession of vegetation is to enhance or inhibit and whether plants - soil biological feedback helps to the long-term development of the ecological system is still not clear [48].In order to make the plant-soil feedback theory applicable universally, it is necessary to study the plant-soil feedback relationship in different succession stages in the same ecosystem in the future [7].In addition, the relationship between the stoichiometric ratio of carbon, nitrogen and phosphorus corresponding to the plant-soil feedback mechanism in different ecosystems under different environmental conditions and nutrient cycling still needs to be further studied [49].

References

[1] GRAYSTON S. J., WANG S., CAMPBELL C. D. AND EDWARDS A. C. (1998) Selective influence of plant species on microbial diversity in the rhizosphere. *Soil Biology and Biochemistry*, 30, 369-378.

[2] EHRENFELD J. G., RAVIT B. AND ELGERSMA K. (2005) Feedback in the plant-soil system. *Annu. Rev. Environ. Resour.*, 30, 75-115.

[3] HARTMANN A., SCHMID M., VAN TUINEN D. AND BERG G. (2009) Plant-driven selection of microbes. *Plant and soil*, 321, 235-257.

[4] BEVER J. D., DICKIE I. A., FACELLI E., FACELLI J. M., KLIRONOMOS J., MOORA M., RILLIG M. C., STOCK W. D., TIBBETT M. AND ZOBEL M. (2010) Rooting theories of plant community ecology in microbial interactions. *Trends in Ecology & Evolution*, 25, 468-478.

[5] HARRISON K. A. AND BARDGETT R. D. (2010) Influence of plant species and soil conditions on plant–soil feedback in mixed grassland communities. *Journal of Ecology*, 98, 384-395.

[6] VAN DAM N. M. (2009) Belowground herbivory and plant defenses. *Annu. Rev. Ecol. Evol. Syst.*, 40, 373-391.

[7] BARDGETT R. D. AND WARDLE D. A. (2010) *Aboveground-belowground linkages: Biotic interactions, ecosystem processes, and global change*: Oxford University Press Oxford.

[8] WARDLE D., BONNER K. AND BARKER G. (2002) Linkages between plant litter decomposition, litter quality, and vegetation responses to herbivores. *Functional Ecology*, 16, 585-595.

[9] BEVER J. D. (2003) Soil community feedback and the coexistence of competitors: Conceptual frameworks and empirical tests. *New Phytologist*, 157, 465-473.

[10] DE DEYN G. B., RAAIJMAKERS C. E., ZOOMER H. R., BERG M. P., DE RUITER P. C., VERHOEF H. A., BEZEMER T. M. AND VAN DER PUTTEN W. H. (2003) Soil invertebrate fauna enhances grassland succession and diversity. *Nature*, 422, 711-713.

[11] REINHART K. O., PACKER A., VAN DER PUTTEN W. H. AND CLAY K. (2003) Plant–soil biota interactions and spatial distribution of black cherry in its native and invasive ranges. *Ecology Letters*, 6, 1046-1050.

[12] BEVER J. D., WESTOVER K. M. AND ANTONOVICS J. (1997) Incorporating the soil community into plant population dynamics: The utility of the feedback approach. *Journal of Ecology*, 561-573.

[13] KULMATISKI A. AND KARDOL P. (2008) Getting plant—soil feedbacks out of the greenhouse: Experimental and conceptual approaches Progress in botany, pp. 449-472: Springer.

[14] BEVER J. D. (1994) Feeback between plants and their soil communities in an old field community. *Ecology*, 75, 1965-1977.

[15] BARDGETT R. D., SMITH R. S., SHIEL R. S., PEACOCK S., SIMKIN J. M., QUIRK H. AND HOBBS P. J. (2006) Parasitic plants indirectly regulate below-ground properties in grassland ecosystems. *Nature*, 439, 969-972.

[16] BEVER J. D., PLATT T. G. AND MORTON E. R. (2012) Microbial population and community dynamics on plant roots and their feedbacks on plant communities. *Annual review of microbiology*, 66, 265.

[17] REYNOLDS H. L., PACKER A., BEVER J. D. AND CLAY K. (2003) Grassroots ecology: Plant-microbe-soil interactions as drivers of plant community structure and dynamics. *Ecology*, 84, 2281-2291.

[18] VAN DER PUTTEN W. H. (2003) Plant defense belowground and spatiotemporal processes in natural vegetation. *Ecology*, 84, 2269-2280.

[19] REINHART K. O. AND CALLAWAY R. M. (2006) Soil biota and invasive plants. *New Phytologist*, 170, 445-457.

[20] REINHART K. O. (2012) The organization of plant communities: Negative plant–soil feedbacks and semiarid grasslands. *Ecology*, 93, 2377-85.

[21] HOESTRA H. (1968) Replant diseases of apple in the netherlands.

[22] MULLER P. (1884) Studier over skovjord, som bidrag til skovdyrkningens theori ii. *Om muld og mor i egeskove og paa heder. Tidsskrift for Skovbrug*, 7, 1-232.

[23] VAN DER PUTTEN W., VAN DIJK C. AND PETERS B. (1993) Plant-specific soil-borne diseases contribute to succession in foredune vegetation.

[24] BERENDSE F., SCHMITZ M. AND DE VISSER W. (1994) Experimental manipulation of succession in heathland ecosystems. *Oecologia*, 100, 38-44.

[25] AYRES E., STELTZER H., SIMMONS B. L., SIMPSON R. T., STEINWEG J. M., WALLENSTEIN M. D., MELLOR N., PARTON W. J., MOORE J. C. AND WALL D. H. (2009) Home-field advantage accelerates leaf litter decomposition in forests. *Soil Biology and Biochemistry*, 41, 606-610

[26] FRESCHET G. T., AERTS R. AND CORNELISSEN J. H. (2012) Multiple mechanisms for trait effects on litter decomposition: Moving beyond home - field advantage with a new hypothesis. *Journal of Ecology*, 100, 619-630.

[27] NORTHUP R. R., YU Z., DAHLGREN R. A. AND VOGT K. A. (1995) Polyphenol control of nitrogen release from pine litter. *Nature*, 377, 227-229.

[28] HANDLEY W. (1954) *Mull and mor formation in relation to forest soils*: HM Stationery Office.

[29] WARDLE D. A., JONSSON M., BANSAL S., BARDGETT R. D., GUNDALE M. J. AND METCALFE D. B. (2012) Linking vegetation change, carbon sequestration and biodiversity: Insights from island ecosystems in a long - term natural experiment. *Journal of Ecology*, 100, 16-30.

[30] HÄTTENSCHWILER S. AND VITOUSEK P. M. (2000) The role of polyphenols in terrestrial ecosystem nutrient cycling. *Trends in Ecology & Evolution*, 15, 238-243.

[31] KLIRONOMOS J. N. (2002) Feedback with soil biota contributes to plant rarity and invasiveness in communities. *Nature*, 417, 67-70.

[32] KIERS E. T., DUHAMEL M., BEESETTY Y., MENSAH J. A., FRANKEN O., VERBRUGGEN E., FELLBAUM C. R., KOWALCHUK G. A., HART M. M. AND BAGO A. (2011) Reciprocal rewards stabilize cooperation in the mycorrhizal symbiosis. *Science*, 333, 880-882.

[33] JOHNSON N. C., J - H. G. AND SMITH F. A. (1997) Functioning of mycorrhizal associations along the mutualism–parasitism continuum*. *New Phytologist*, 135, 575-585.

[34] CASTELLI J. P. AND CASPER B. B. (2003) Intraspecific am fungal variation contributes to plant-fungal feedback in a serpentine grassland. *Ecology*, 84, 323-336.

[35] BROWN V. K. AND GANGE A. C. (1990) Insect herbivory below ground. *Advances in ecological research*, 1-58.

[36] SCHÄDLER M., JUNG G., BRANDL R. AND AUGE H. (2004) Secondary succession is influenced by belowground insect herbivory on a productive site. *Oecologia*, 138, 242-252.

[37] VAN DER PUTTEN W. AND VAN DER STOEL C. (1998) Plant parasitic nematodes and spatio-temporal variation in natural vegetation. *Applied Soil Ecology*, 10, 253-262.

[38] INGHAM R. E., TROFYMOW J., INGHAM E. R. AND COLEMAN D. C. (1985) Interactions of bacteria, fungi, and their nematode grazers: Effects on nutrient cycling and plant growth. *Ecological monographs*, 55, 119-140.

[39] HÄTTENSCHWILER S., TIUNOV A. V. AND SCHEU S. (2005) Biodiversity and litter decomposition in terrestrial ecosystems. *Annual Review of Ecology, Evolution, and Systematics*, 191-218.

[40] EISENHAUER N., MILCU A., ALLAN E., NITSCHKE N., SCHERBER C., TEMPERTON V., WEIGELT A., WEISSER W. W. AND SCHEU S. (2011) Impact of above - and below - ground invertebrates on temporal and spatial stability of grassland of different diversity. *Journal of Ecology*, 99, 572-582.

[41] WARDLE D. A. (2002) *Communities and ecosystems: Linking the aboveground and belowground components*: Princeton University Press.

[42] LAU J. A., PULIAFICO K. P., KOPSHEVER J. A., STELTZER H., JARVIS E. P., SCHWARZLÄNDER M., STRAUSS S. Y. AND HUFBAUER R. A. (2008) Inference of allelopathy is complicated by effects

[43] INDERJIT, WARDLE D. A., KARBAN R. AND CALLAWAY R. M. (2011) The ecosystem and evolutionary contexts of allelopathy. *Trends in Ecology & Evolution*, 26, 655-662

[44] BAIS H. P., VEPACHEDU R., GILROY S., CALLAWAY R. M. AND VIVANCO J. M. (2003) Allelopathy and exotic plant invasion: From molecules and genes to species interactions. *Science*, 301, 1377-1380.

[45] VIVANCO J. M., BAIS H. P., STERMITZ F. R., THELEN G. C. AND CALLAWAY R. M. (2004) Biogeographical variation in community response to root allelochemistry: Novel weapons and

[46] BONANOMI G., GIANNINO F. AND MAZZOLENI S. (2005) Negative plant–soil feedback and species coexistence. *Oikos*, 111, 311-321.

[47] CALLAWAY R. M., THELEN G. C., RODRIGUEZ A. AND HOLBEN W. E. (2004) Soil biota and exotic

[48] WARDLE D. A., BARDGETT R. D., KLIRONOMOS J. N., SETÄLÄ H., VAN DER PUTTEN W. H. AND WALL D. H. (2004) Ecological linkages between aboveground and belowground biota. *Science*, 304, 1629-1633.

[49] ZECHMEISTER-BOLTENSTERN S., KEIBLINGER K. M., MOOSHAMMER M., PEÑUELAS J., RICHTER A., SARDANS J. AND WANEK W. (2015) The application of ecological tachometry to plant–microbialssoilrganic matter transformations. *Ecological monographs*, 85, 133-155.