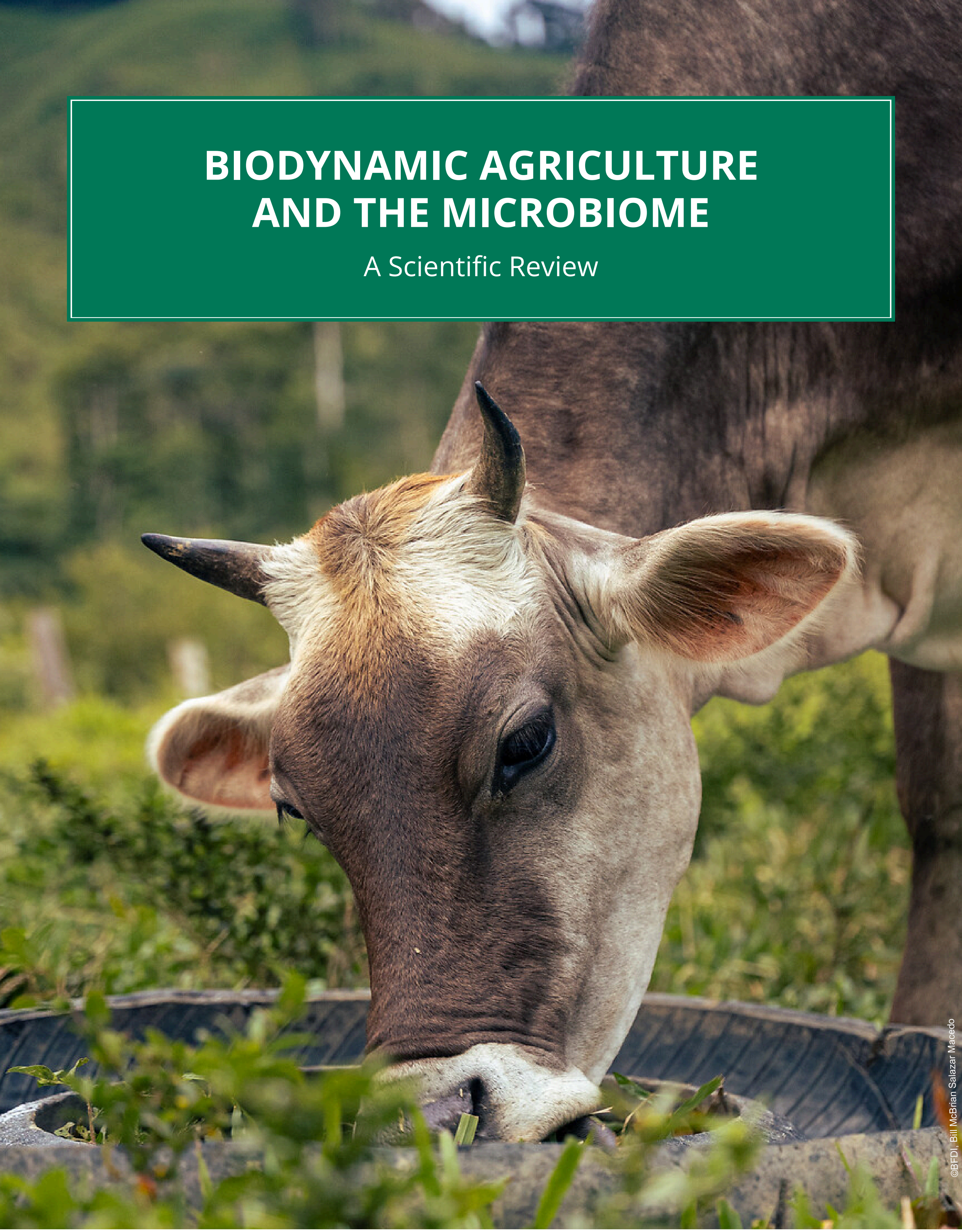
BIODYNAMIC AGRICULTURE AND THE MICROBIOME

A Scientific Review



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Goetheanum Agriculture

Biodynamie Recherche

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This booklet is a collective work from the Biodynamic Federation Demeter International, Biodynamie Recherche, Demeter Germany, the Forschungsring, and the Agriculture section in the Goetheanum.

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OVERVIEW

BIODYNAMICS AND THE MICROBIOME: SUMMARY

In recent years, scientists have shown how important invisible microorganisms are for healthy soils and plants. These tiny living beings—bacteria, fungi, and others—help plants absorb nutrients, protect them from diseases, and keep ecosystems functioning. This summary explains what current research says about how biodynamic farming influences these microbial communities.

EFFECT OF BIODYNAMICS ON THE SOIL MICROBIOME

Studies carried out over several decades show that biodynamic soils are generally more alive than conventional ones. They contain more kinds of microorganisms and show higher biological activity. Long-term experiments, such as the well-known DOK trial, reveal that biodynamic fields tend to be more fertile and more resilient. Large reviews of scientific data also place biodynamics among the farming systems that best support soil life. In vineyards and other crops, biodynamic soils often show richer communities of beneficial fungi and bacteria that help plants grow and cope with stress.

EFFECTS OF BIODYNAMIC PREPARATIONS ON THE MICROBIOME

Biodynamic preparations (like horn manure or fermented plant extracts) naturally contain many useful microorganisms. Research shows that these preparations may act like “microbial boosters,” adding helpful bacteria and fungi to the soil. Some recent studies even confirm that when these preparations are applied, soils end up with more microorganisms that support plant growth and health. Their composition depends on how they are made and matured, which helps explain why their effects can vary.

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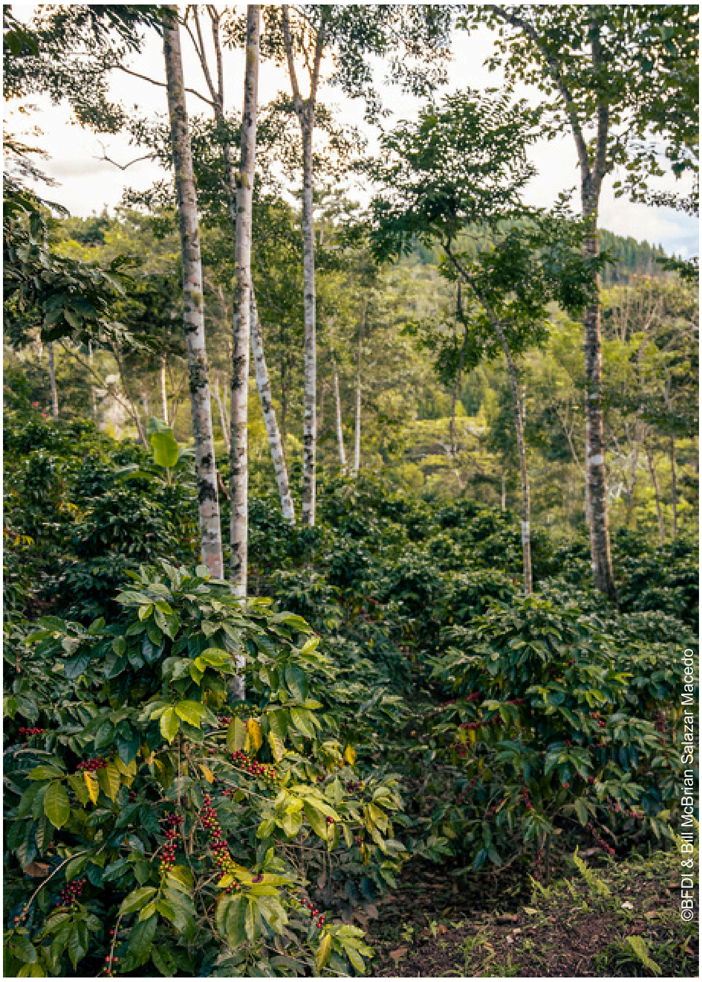
INFLUENCE OF BIODYNAMICS ON THE PLANT MICROBIOME

Biodynamic practices do not just influence soil life: they also shape the microorganisms living on and inside plants. In vineyards, grapes and bark of vines grown under biodynamic management often host a greater variety of microbes. Some of these microbes even make it into the grape juice during winemaking, create a natural link from soil to wine. Similar effects are seen in other fruits: for example, biodynamic apples tend to contain more beneficial bacteria and fewer harmful ones. This suggests that farming methods can influence the microbial quality of the food we eat.

PERSPECTIVES AND CONCLUSIONS

Overall, current research indicates that biodynamic farming supports diverse and beneficial microbial communities in both soil and plants. Biodynamic preparations appear to contribute useful microorganisms, and their effects can be seen all the way from soil health to the characteristics of harvested products. Future studies will explore how these microbial changes affect taste, nutritional value, and shelf life. For now, biodynamics stands out as a farming approach that encourages living, healthy ecosystems.



Find the digital version and more biodynamic facts here:
www.sektion-landwirtschaft.org/en/research/basics

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EFFECT OF BIODYNAMICS ON THE SOIL MICROBIOME

Over the past two decades, scientific research has been rediscovering a central actor in soil functioning and plant health: the microbiome. This community of microorganisms—bacteria, fungi, yeasts, viruses, protozoa—lives in and around plants: in the rhizosphere around the roots, in the phyllosphere covering leaves and stems, and even in the endosphere inside plant tissues. These invisible communities perform essential functions: they facilitate nutrient uptake, strengthen plants' natural defenses, degrade organic matter, and participate in key ecological cycles.

The question is whether certain farming practices, and in particular biodynamic agriculture, specifically influence the composition and functions of these microbial communities. This popularized synthesis presents the current state of knowledge, drawing on scientific references published in international journals.

Biodynamic agriculture shares with organic farming the rejection of synthetic pesticides and fertilizers. But it adds the use of specific preparations intended to stimulate soil and plant vitality. Several long-term studies have shown that biodynamic and organic systems support higher microbial biodiversity and greater soil fertility compared to conventional systems.

The DOK trial in Switzerland, initiated more than forty years ago, remains a benchmark. Mäder et al. (2002) showed that organic plots and especially biodynamic plots have higher soil biological activity and greater organic matter stability than conventionally managed plots. More recently, Krause et al. (2022) confirmed that the organic systems, and especially the biodynamic system, feature more living and resilient soils with microbial communities distinct from those observed in conventional farming. These results confirm that overall system management—including crop rotations, organic inputs, and tillage practices—has a lasting impact on microbial structure.

[5] Krause, H.-M., van der Heijden, M.G.A., & Schmid, B. (2022). *Long-term farming systems affect soil ecological quality.* Agronomy for Sustainable Development, 42, 84.

[6] Mäder, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P., & Niggli, U. (2002). *Soil fertility and biodiversity in organic farming.* Science, 296(5573), 1694–1697.

EFFECT OF BIODYNAMICS ON THE SOIL MICROBIOME

A major meta-analysis by Christel et al. (2021), compiling nearly one hundred studies, concluded that 70% of soil biological indicators improve in organic and biodynamic agriculture compared to conventional farming, and that biodynamics improves about 43% of indicators compared to organics. This ranking places biodynamics first, followed by organic farming, conservation farming, and finally conventional management. This shows that biodynamic agriculture generally promotes soil ecological quality, even though the specific effect of the preparations remains difficult to isolate.

Mycorrhizal fungi play a central role in nutrient uptake and plant health. Several agroecological studies have shown that their diversity tends to be higher in low-input systems, which often include organic and biodynamic practices. Although these studies do not specifically isolate biodynamics, they suggest that systems based on organic inputs and reduced tillage favor beneficial symbioses. In vineyards, a global survey of soil microbiomes by Gobbi et al. (2022) showed that farming practices strongly influence microbial composition. While this study did not focus exclusively on biodynamics, it confirmed that organic and biodynamic systems foster higher diversity and different structuring of the microbiome.

In Spain and the USA, Ortiz-Álvarez et al. (2021) found more stable microbial networks in soils under stress conditions in the order of biodynamic > organic > conventional. Zappelini et al. (2025) found higher microbial biomass, greater bacterial diversity and more complex microbial interaction networks in biodynamic farming compared to organic farming.

[1] Christel, A., Maron, P.-A., & Ranjard, L. (2021). *Impact of farming systems on soil ecological quality: a meta-analysis.* Environmental Chemistry Letters, 19, 4603–4625.

[2] Gobbi, A., Acedo, A., Imam, N. et al. (2022) *A global microbiome survey of vineyard soils highlights the microbial dimension of viticultural terroirs.* Commun Biol 5, 241.

[10] Ortiz-Álvarez, R., Fierer, N., de los Ríos, A., & Fernández-González, C. (2021). *Network properties of local fungal communities reveal the anthropogenic disturbance consequences of farming practices in vineyard soils.* mSystems, 6(3).

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EFFECTS OF BIODYNAMIC PREPARATIONS ON THE MICROBIOME

Biodynamic preparations, numbered 500 to 507, include for example horn manure or fermented plant extracts. They contain a wide diversity of microorganisms. Olimi et al. (2022) showed that they are rich in bacteria and fungi associated with plant growth promotion and soil health improvement. They can therefore be considered as natural microbial inoculants.

A recent review by Vaish et al. (2024) examined biodynamic preparations and the diversity of the microbial communities they harbor. This analysis shows that the different preparations (500 to 507) display rich and variable microbial compositions, dominated by bacterial and fungal groups associated with organic matter decomposition, nutrient mineralization, and plant defense stimulation. It also highlights that elaboration and maturation of biodynamic preparations strongly influence the structure of the microbial communities present, which may partly explain the differences in effectiveness observed in farming practices.

Among recent work, the study by Milke et al. (2024) tested the hypothesis that the biodynamic preparations horn manure and horn silica inoculate the soil with plant growth-promoting microorganisms (PGPM). These are bacteria and fungi that produce plant hormones or substances in the soil that help plants cope with growth stress. Biodynamic preparations contained high proportions of PGPM. When the preparations were sprayed, the soils in most cases had significantly higher proportions of PGPM.

GRAPES, PHYLLOSHPERE, AND VINE BARK

Several studies have directly examined the influence of farming systems, including biodynamics, on the microbes living on grape surfaces and aerial plant parts. A reference study showed that the grape microbiome varies with climate, soil, and farming practices. Part of this “microbial signature” remains detectable during fermentation (Mezzasalma et al., 2017). Vine bark, meanwhile, is a more stable and diverse microbial reservoir than grapes themselves. It is sensitive to both local conditions and human practices (Vitulo et al., 2019). This suggests that low-input practices such as biodynamics can help maintain a genuine “bank” of naturally occurring, useful microorganisms on the plant.

A targeted study compared grapes from biodynamic and traditional managed plots, tracking the evolution of the microbial flora (or microbiome) of the berries at the end of ripening and during fermentation. The authors reported differences in the composition and dynamics of microbial communities (Guzzon et al., 2016), suggesting that biodynamic management can influence the microbial profile of grapes and must.

In the same vein, Kecskeméti et al. (2016) examined epiphytic microbial communities on grape clusters grown under conventional, organic, and biodynamic systems. The study mainly highlights that grape microbiomes are sensitive to farming practices, and that biodynamics, like organics, plays a role in shaping these invisible communities.

[3] Guzzon, R., Gugole, S., Zanzotti, R., Malacarne, M., Larcher, R., von Wallbrunn, C., & Mescalchin, E. (2016). *Evaluation of the oenological suitability of grapes grown using biodynamic agriculture: the case of a bad vintage.* Journal of Applied Microbiology, 120(2), 355–365.

[4] Kecskeméti, E., Berkelmann-Löhnertz, B., & Reineke, A. (2016). Are epiphytic microbial communities in the carposphere of ripening grape clusters (Vitis vinifera L.) different between conventional, organic, and biodynamic grapes? PLOS ONE, 11(8).

[7] Mezzasalma, V., Sandionigi, A., Bruni, I., Bruno, A., Lovicu, G., Casiraghi, M., & Labra, M. (2017). *Grape microbiome as a reliable and persistent signature of field origin and environmental conditions in Cannonau wine production.* PLOS ONE, 12(9).

[8] Milke, F., Rodas-Gaitan, H., Meissner, G., Masson, V., Oltmanns, M., Möller, M., Wohlfahrt, Y., Kulig, B., Acedo, A., Athmann, M., & Fritz, J. (2024). *Enrichment of putative plant growth promoting microorganisms in biodynamic compared with organic agriculture soils.* ISME Communications, 4(1).

[9] Olimi, E., Baum, C., & Wurst, S. (2022). *Deciphering the microbial composition of biodynamic manures and extracts.* Frontiers in Soil Science, 2.

[11] Vaish, S., Singh, R., & Singh, A.K. (2024). *Meta-analysis of biodynamic preparations and their microbial communities.* Journal of Applied Research on Medicinal and Aromatic Plants, 35.

[12] Vitulo, N., Lemos Junior, W.J.F., Calgaro, M., Confalone, M., Felis, G.E., Zapparoli, G., ... & Nardi, T. (2019). Bark and grape microbiome of Vitis vinifera: influence of geography and agronomic practices. Frontiers in Microbiology, 10, 1220.

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EFFECTS OF BIODYNAMIC PREPARATIONS ON THE MICROBIOME

ENDOSPHERE AND PERSISTENCE INTO WINEMAKING

Beyond the berry surface, some bacteria and yeasts associated with biodynamic grapes persist into the fermentation stage (Mezzasalma et al., 2017). The authors showed that while part of the initial microbiome is replaced or diminished during fermentation, a significant fraction persists and interacts with fermentative yeasts. This partial transfer of the "harvest microbiome" into the must suggests the existence of an ecological continuum from soil to plant to cellar, where farming practices influence not only taxonomic composition but also key metabolic functions of fermentation, such as aroma production, sugar evolution, and microbial stability of the wine.

OTHER FRUIT CROPS: THE CASE OF APPLES

The influence of farming systems on plant microbiomes has also been studied in other fruit crops. In apples, Wassermann et al. (2019) showed that farming practices strongly shape the bacterial composition of fruit tissues. Apples from biodynamic practices showed higher diversity and different community balances compared to coventional ones, with more potentially beneficial bacteria and fewer pathogens. The distribution of bacteria also varied by fruit part—peel, flesh, or seeds. These results suggest that farming systems influence not only the microbiome of soils and plants, but also that of the fruits we eat, with potential implications for nutrition, health, and post-harvest conservation.

[7] Mezzasalma, V., Sandionigi, A., Bruni, I., Bruno, A., Lovicu, G., Casiraghi, M., & Labra, M. (2017). *Grape microbiome as a reliable and persistent signature of field origin and environmental conditions in Cannonau wine production.* PLOS ONE, 12(9).

[13] Wassermann, B., Müller, H., & Berg, G. (2019). *An Apple a Day: Which Bacteria Do We Eat With Organic and Conventional Apples?* Frontiers in Microbiology, 10, 1629.

PERSPECTIVES AND CONCLUSIONS

Overall, results converge toward a general finding: biodynamics influences soil microbiome composition, often by promoting greater diversity and beneficial organisms. Biodynamic preparations themselves bring microorganisms and can act as natural inoculants. The study by Milke et al. (2024) shows innovatively that biodynamic management enriches soils with plant growth-promoting microorganisms, with measurable functional effects. In vineyards, biodynamics is associated with richer microbial biodiversity, with effects extending into winemaking. In fruit, the apple case illustrates how biodynamic farming positively influences the microbial composition of the food itself.

Biodynamic preparations complement common organic farming practices such as composting, crop rotation and reduced tillage. Future research must examine not only the composition of the microbiome, but also its functions using metagenomics and metabolomics, and better understand how microbiomes contribute to product quality, whether in terms of flavour, shelf life or nutritional value. Research shows that biodynamic agriculture is associated with soil and plant microbiomes that can promote health and productivity. Biodynamic preparations work within a broader system of agroecological practices. This area of research is growing rapidly, and more light is likely to be shed on its mechanisms in the coming years.

[8] Milke, F., Rodas-Gaitan, H., Meissner, G., Masson, V., Oltmanns, M., Möller, M., Wohlfahrt, Y., Kulig, B., Acedo, A., Athmann, M., & Fritz, J. (2024). *Enrichment of putative plant growth promoting microorganisms in biodynamic compared with organic agriculture soils.* ISME Communications, 4(1).

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PARTNERS

The Biodynamic Federation Demeter International is the only agricultural association that has built up a network of individual certification bodies for biodynamic farmers worldwide. Today, they are a global community of farmers, winemakers, gardeners, beekeepers, researchers, advisors, trainers, certifiers, processors and traders to name a few. Find more information at: www.demeter.net

The aim of the Biodynamie Recherche association is to promote respect for and protection of the environment through biodynamic agriculture. It carries out scientific monitoring of work and publications in biodynamic agriculture at international level. It produces summaries, translations and articles which are made available to the Frenchspeaking public on its website and in specialist journals. Find more information at: www.biodynamie-recherche.org

Demeter is a private certification body for biodynamically produced food, cosmetics and textiles - complementary to the official organic regulations. Their specifications have been developed over the decades to become one of the most demanding. Find more information at: www.demeter.de

The Forschungring was founded in 1946 as the successor to the Versuchsrings of Anthroposophical Farmers. In the early years it was the umbrella organisation of the biodynamic movement. Today it is the central research institute for biodynamic and general ecological questions at the centre of a worldwide and growing biodynamic movement. Find more information at: www.forschungsring.de

Through its contacts with people active in the biodynamic movement around the world, the agriculture section encounters many questions, ideas and challenges. Together with their partners, they work on these themes in various international projects and events. In this way, they create spaces in which questions and challenges can be transformed into sources of inspiration for those active in biodynamic agriculture and the food sector. Find more information at: www.sektion-landwirtschaft.org

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