Organic fertilization provides an alternative approach to improving the vineyard soil environment. Organic fertilizers can supply nutrients while increasing soil organic matter, improving soil structure, porosity, water-holding capacity, and nutrient-buffering capacity, and enhancing microbial abundance and soil enzyme activity (James et al., 2023; Visconti et al., 2024; Wu et al., 2024). Hazarika et al. (2024) established 14 combined treatments involving organic fertilizers and microbial inoculants. Among them, the treatment consisting of pig manure + Azospirillum + PSB + KSB + Trichoderma + CPP + BD500 + BD501 resulted in the highest levels of soil organic carbon, total carbon, total N, available N/P/K, Mn, Zn, and CEC, together with the greatest populations of bacteria and actinomycetes and the highest concentrations of Mn, Zn, and chlorophyll in grape leaves. Mairata et al. (2024) further reported that organic mulches can improve nutrient-poor semiarid soils and enhance stress tolerance. However, the effects of organic amendments vary according to the type of organic material, initial soil fertility, grape cultivar, and environmental conditions. Kokkonen et al. (2025) found that some organic treatments had only limited effects on leaf nutrient concentrations, yield, and grape juice composition, while certain treatments even reduced yield, indicating that organic fertilization practices need to be optimized according to specific vineyard conditions.

This study investigates the effects of organic fertilization on vineyard soil health, nutrient uptake, and fruit quality, with particular emphasis on the responses of the integrated "soil–grapevine–fruit" continuum. Changes in soil organic matter, nutrient availability, physical properties, biological activity, and microbial functions will be evaluated, and their potential contributions to improved nutrient uptake efficiency, yield components, and fruit quality traits, including sugar content, acidity, phenolic compounds, and other biochemical characteristics, will be further examined. This study is expected to provide a scientific basis for reducing dependence on chemical fertilizers and achieving high-yield, high-quality, and sustainable grape production.

2 Types and Characteristics of Organic Fertilizers Used in Grapevines

2.1 Animal- and plant-derived organic fertilizers

Animal- and plant-derived fertilizers in vineyards commonly include manure-based inputs and composted crop residues. Vineyard studies have tested farmyard manure, pig manure, sheep manure, composted steer manure, and mixtures of pruning residues or straw with farm manure, showing that these materials can improve soil properties and, in many cases, vine performance (Wilson et al., 2021; Hazarika et al., 2024). Plant-derived and winery-derived materials are also increasingly important, especially pruning waste, legume cover crop residues, grape pomace compost, and grape pomace vermicompost, because they recycle vineyard by-products into nutrient sources and organic matter inputs (Kokkonen et al., 2025).

These materials differ markedly in nutrient composition and decomposition characteristics. For example, Kokkonen et al. (2025) reported substantial differences in the dry-basis concentrations of nitrogen (N), phosphorus (P), and potassium (K) between compost and vermicompost derived from grape pomace, with grape pomace compost containing higher nutrient concentrations than grape pomace vermicompost. More broadly, compost nutrient composition, organic carbon content, and biological activity vary with feedstock origin and processing, so materials with similar sources can still produce different nutrient release patterns and vine responses (Mitropoulou et al., 2025). Organic amendments usually decompose more slowly than mineral fertilizers, providing nutrients over a longer part of the growing season, but this gradual release can delay vine uptake in the first years after application (Lucchetta et al., 2023).

2.2 Bio-organic fertilizers and microbial amendments

Bio-organic fertilizers combine organic nutrient sources with living microbial inoculants. In grapevine systems, these inoculants include *Azospirillum*, phosphate-solubilizing bacteria, potash-solubilizing bacteria, *Trichoderma harzianum*, *Bacillus amyloliquefaciens*, arbuscular mycorrhizal fungi, and fungal consortia added to composts or other carriers (Hazarika et al., 2024; Liu et al., 2024). Their function extends beyond direct nutrient supply because beneficial microbes can increase nutrient availability, modulate phytohormones, improve root development, and suppress pathogenic organisms (Kumar et al., 2022; Liu et al., 2024).