compost- and manure-based treatments can increase soil total N, available P, and water-soluble carbohydrates and, in some systems, also increase available N and K. In a disturbed hillslope vineyard, Lucchetta et al. (2023) found that compost improved mineral nutrient availability, but a significant increase in leaf N content became evident only after three consecutive years of application. This was associated with the relatively slow decomposition of organic matter and the initial microbial immobilization of newly mineralized N. Such slow-release characteristics can prolong nutrient supply and improve nutrient retention, although short-term responses may be limited and can vary among grape cultivars.

Organic fertilization generally has positive effects on soil pH, cation exchange capacity, and nutrient retention, although responses are not entirely consistent across studies. In a degraded vineyard, compost application increased soil pH and the concentrations of exchangeable K, Ca, Mn, and available P, while reducing P fixation (Wilson et al., 2021). In a grapevine study, Wu et al. (2024) showed that organic fertilizer buffered changes in soil pH and reduced soil alkalinity compared with chemical fertilizer. Broader soil-health studies further indicate that organic inputs can buffer soil acidification and enhance nutrient retention by increasing cation exchange capacity (CEC) and soil surface reactivity (Xing et al., 2025). Porous materials such as zeolite can further reduce nutrient leaching losses in vineyard soils (Doni et al., 2021).

3.3 Effects on soil biological activity

Organic fertilization increases microbial biomass and reshapes microbial community structure in vineyard soils. After a decade of organic management, vineyard soils had higher microbial biomass and altered microbial composition relative to inorganic fertilization, including increased fungal and Gram-positive bacterial abundance (García-Orenes et al., 2016). In disturbed hillslope vineyards, compost increased microbial growth from the second year onward and shifted communities toward copiotrophic and phosphorus-solubilizing bacteria while reducing pathogenic fungal strains (Lucchetta et al., 2023).

Organic fertilization also enhances enzyme activities involved in nutrient cycling. Vineyard experiments documented higher dehydrogenase, protease, urease, β-glucosidase, and phosphomonoesterase activity under organic systems than under inorganic fertilization (García-Orenes et al., 2016). Compost-treated vineyards showed stronger enzyme activity, especially for enzymes involved in the phosphorus cycle, and fungal-inoculated pruning-waste compost further increased soil enzyme activity (Lucchetta et al., 2023; Lucchetta et al., 2025). Additional grape studies found increases in catalase, dehydrogenase, urease, phosphatase, and other enzyme activities after organic fertilizer application (Tangolar et al., 2020; Wu et al., 2024). Broader long-term fertilization evidence suggests that organic inputs favor a more diverse and stable microbial community and slower, more regulated nutrient transformations than chemical fertilization alone.

4 Effects of Organic Fertilization on Nutrient Uptake in Grapevines

4.1 Regulation of macronutrient uptake

Organic fertilization often increases nitrogen availability and uptake, but the response depends strongly on amendment type and the balance between organic and mineral N sources. Bio-organic fertilizer increased soil available N and improved seedling growth in grapevine, while sewage sludge compost increased nitrate availability and vine N status, and integrated N management with 60%-80% mineral N plus 20%-40% organic and biofertilizer improved growth, yield, and berry quality better than mineral N alone (Muhammed et al., 2023). Organic amendments can also increase leaf P content and soil available P, as shown for grape pomace compost and vermicompost, poultry manure-based fertilization, and combined organic-biofertilizer treatments (Kokkonen et al., 2025). However, vineyard evidence is mixed because compost or vermicompost did not always increase leaf N, and long-term field studies in low-organic-matter soils found that organic fertilizers and AMF were not sufficient substitutes for mineral N supply.

Potassium uptake also responds positively to many organic fertilization programs, but the effect is shaped by initial soil fertility and by interactions with other nutrients. Municipal organic waste compost increased vine K status in Sangiovese, commercial organic fertilizers raised soil total and available K in greenhouse grapes, and grape pomace