availability and vegetative growth in Sangiovese, but excessive mineralization reduced yield and berry quality, while overuse of compost plus mineral fertilizer raised exchangeable nutrients without improving vine response in subtropical vineyards (Baldi et al., 2022; Kokkonen et al., 2025).

7.2 Coordination of organic fertilization with vineyard management

Organic fertilization is more effective when coordinated with irrigation and soil-moisture management. In extremely arid vineyards, imbalanced water–fertilizer systems limited yield and quality, whereas combined organic–inorganic fertilization under optimized drip irrigation improved soil nutrients, vine growth, yield, and berry quality (Chen et al., 2023). In semi-arid nutrient-poor vineyards, spent mushroom compost mulch increased soil water content, leaf N, vegetative growth, and yield, while straw mulch improved soil water content, reduced soil temperature, and improved plant water status and gas exchange (Mairata et al., 2024). Broader dryland evidence supports this mechanism: organic mulching reduces evaporation, conserves water in the root zone, limits erosion, and increases soil organic matter and water-holding capacity (Demo and Bogale, 2024).

Integration with cover cropping, mulching, and soil conservation is also central to vineyard nutrient management. Cover crops can increase organic matter, reduce erosion, improve biodiversity, and supply nutrients, but permanent cover crops can also compete with vines for water and nutrients. Mairata et al. (2024) pointed out that organic mulches provide a useful alternative because they control weeds and erosion while reducing compaction and increasing porosity, aggregate stability, and nutritional content in the shallow soil layer. Conservation tillage and plant-waste incorporation are likewise associated with better long-term soil health and yield resilience, whereas continuous cultivation can reduce organic matter and soil permeability over time (Kaya et al., 2024a). These combined practices align with broader soil-conservation principles in sustainable agriculture, where cover cropping, conservation tillage, and organic amendments preserve fertility, water, and biodiversity (Hasan et al., 2023).

7.3 Optimization of organic fertilization strategies

Optimization depends first on matching fertilizer type and application rate to vineyard requirements. The chemical composition, maturity, and mineralization rate of organic materials determine whether they support balanced vegetative and reproductive growth or push vines toward excess vigor (Baldi et al., 2022; Hasan et al., 2023). Material choice matters strongly: in nutrient-poor soils, spent mushroom compost performed better than straw or pruning-debris mulch for short-term vine development because of its richer nutrient composition and lower C/N ratio (Mairata et al., 2024). Rate also matters: grapevine seedlings responded best to 25% organic substitution with spent mushroom substrate, while higher substitution rates failed to further improve soil N, photosynthesis, or root architecture (Han et al., 2025). Reviews of vineyard fertilization similarly conclude that fertilizer systems should combine manure, mineral fertilizer, and supplemental nutrition over time, and that high mineral doses can reduce yield (Monastyrskiy et al., 2022).

Optimization also requires site- and cultivar-specific nutrient management. Vineyard fertilizer programs should be nutrient-specific and based on soil testing, plant analysis, pruning returns, and management factors that shape nutrient-use efficiency. Long-term field data collected by Lisek and Popińska (2025) in Poland showed that organic fertilizers, AMF, and biostimulants were not adequate substitutes for mineral fertilization in low-organic-matter soils, especially for N supply, and that mineral fertilization should be continuously readjusted rather than applied routinely. Subtropical vineyards also showed cultivar-dependent responses: grape pomace compost and vermicompost increased soil P and K availability, but leaf nutrient status, yield, and quality changed little in Chardonnay and sometimes declined in Isabella, especially under already adequate soil fertility or high-rainfall conditions (Kokkonen et al., 2025).

These findings support a shift from fixed fertilizer recipes toward adaptive nutrient management (Figure 3). Organic fertilizer type and substitution rate should be determined according to soil nutrient status, amendment mineralization characteristics, cultivar demand, irrigation conditions, and plant nutritional diagnosis, followed by continuous monitoring and adjustment during vineyard production.