A complementary view comes from pakchoi grown in pots with four fertilization treatments: control (no input), chemical fertilizer, organic fertilizer, and a Bacillus-containing bio-organic fertilizer (BF). After 30 days, BF treatment significantly increased plant height and biomass and raised soil available potassium and pH relative to unfertilized soil, while high-throughput sequencing revealed a marked restructuring of bacterial and fungal communities, including enrichment of beneficial genera such as Streptomyces and Mortierella (Wang et al., 2022). Network and functional predictions indicated that BF promoted bacterial dominance, enhanced mineral element metabolism, and increased saprotrophic fungi, supporting a mechanistic link between inoculant addition, microbial community assembly, and nutrient-related enzyme functions in the rhizosphere (Wang et al., 2022). Together, these results illustrate that case-study designs can combine agronomic measurements with molecular and biochemical indicators to quantify changes in soil biological activity.

7.3 Evaluation of application effectiveness and practical significance

Evaluation of application effectiveness in tomato systems centers on whether biofertilizers can maintain yield while reducing mineral fertilizer and simultaneously improve fruit quality. Under field and pot conditions, the combination of 75% conventional NPK with Trichoderma-enriched bio-organic fertilizer produced tomato yields equivalent to those achieved with 100% NPK alone, demonstrating that a quarter of the chemical fertilizer could be saved without yield penalty (Ye et al., 2020). Moreover, the BF treatment significantly increased total soluble sugars and vitamin C by up to 24% and 57%, respectively, while reducing nitrate accumulation by as much as 62% relative to CF, implying substantial gains in nutritional value and safety that go beyond mere yield maintenance. From an environmental and economic standpoint, such a regime reduces reliance on synthetic fertilizers, lowers potential nitrate leaching and residue risks, and can improve marketability due to enhanced quality traits.

Cucumber case studies in organic systems highlight the capacity of plant-based biofertilizers to raise productivity through optimized foliar dosing. In Aodai cucumber, foliar application of a plant-residue biofertilizer significantly increased the number of marketable fruits per plant, mean fruit mass, and both marketable and total yields, with a 3% solution identified as the most efficient concentration for yield enhancement under the tested conditions (Da Silva Tamwing et al., 2020). The authors attributed the effectiveness of foliar application to rapid leaf uptake of macro- and micronutrients and the stimulation of plant defense metabolism, which reduced the need for additional pest and disease control interventions during the cycle. Collectively, these tomato and cucumber case studies suggest that, when appropriately formulated and combined with moderate mineral or organic inputs, biofertilizers can be practically significant tools for improving soil biological activity, sustaining or increasing yields, and enhancing vegetable quality within sustainable production systems.

8 Conclusion and Outlook

Research over the past decades shows that biofertilizers are central to linking soil biological activity with crop productivity. Microbial inoculants such as plant growth-promoting rhizobacteria, arbuscular mycorrhizal fungi, and microbial consortia enhance nutrient availability, modulate phytohormones, and improve plant tolerance to abiotic and biotic stresses, thereby supporting higher yields with lower dependence on synthetic fertilizers. Global and national meta-analyses confirm that, under field conditions, biofertilizers significantly increase yields across many crops, including vegetables, while also improving soil enzymatic activities, organic matter, and the abundance of beneficial microbial groups that underpin long-term soil fertility.

In vegetable systems, biofertilizers and bio-organic formulations improve not only productivity but also nutritional quality and safety, largely through soil-mediated effects. Field synthesis for China shows that biofertilizer application increases vitamin C, protein, and carotenoids while reducing nitrate accumulation, and these quality gains coincide with higher soil urease and phosphatase activities and a shift toward beneficial microbiota. Case studies and reviews focused on vegetable crops similarly highlight that combining biofertilizers with organic amendments and/or reduced mineral fertilization enhances soil biota diversity and supports sustainable vegetable production, providing a viable pathway to reconcile yield goals with environmental protection.