

Organic manures and mulches also influence tree nutrition and water relations. Fertigating slurry-composting-biofiltration liquid manure increased shoot growth, leaf N and K, soil exchangeable K, fruit weight, and yield compared with mineral fertilization, though leaf Ca and Mg declined and K accumulation risk required periodic soil testing (Park et al., 2013). Long-term compost or manure mulching in orchards more broadly reduces bulk density, loosens soil, increases nutrient elements and organic content, and improves crop yield and quality (Wang and Wang, 2016; Goldan et al., 2023). In mature peach orchards, municipal mulch with or without poultry litter buffered soil water relative to bare soil, reduced soil Cu, increased soil P and, in some cases, increased fruit size and tree growth, while enabling reductions in synthetic fertilizer inputs (Lawrence and Melgar, 2024).

6.2 Canopy management and crop load regulation

Canopy training and pruning determine light distribution, labor efficiency, and the balance between vegetative growth and fruiting. Traditional vase systems often show uneven light distribution and high pruning labor, whereas planar or multi-axis systems (central leader, Catalan vase, Quad-V, Tri-V) in intensive orchards improve light uniformity, fruit size, and soluble solids, while reducing total labor by up to 39% and production costs by about 15% (Iglesias and Echeverría, 2022; Oran et al., 2024). Within a given system, shorter pruning (heading bearing branches to 20-40 cm) reduced fruit number and yield per tree but increased average fruit weight and diameter, illustrating the trade-off between total yield and size (Saraginovski and Kiprijanovski, 2021).

Crop load regulation through fruit thinning is critical for balancing yield and quality and for efficient water use. In 'Xiahui 5', thinning twice at 20 and 40 days after full bloom increased individual fruit weight (to ~186 g), yield (~981 kg/ha), external and internal quality, and leaf water-use and CO₂-use efficiency, while saving labor compared with blossom thinning plus fruit thinning (Zhang et al., 2024). In 'Royal Gem', combinations of fruit thinning and summer pruning lowered total yield but significantly increased average fruit weight, firmness, and diameter, again showing that reducing sink number enhances fruit size and market value (Lesičar et al., 2017). Experiments with flat peaches confirm that higher crop loads increase total yield but reduce fruit weight and circumference and lower soluble solids content, whereas lower loads favor fruit quality and antioxidant compounds (Mazzoni et al., 2022).

6.3 Monitoring and diagnostic techniques

Leaf and soil diagnostics underpin rational fertilization that supports high yield without excess inputs. In peach orchards amended with compost, leaf sampling at standardized times after full bloom is used to quantify total N, P, K, Ca, Mg, and B, enabling evaluation of tree nutritional status under different compost rates and supporting adjustment of applications (Melo et al., 2016). Organic-amended orchards also highlight the need for periodic soil testing to detect nutrient accumulation (e.g., K under slurry manure fertigations) and guide safe long-term management (Park et al., 2013; Lawrence and Melgar, 2024). More broadly, intelligent orchard nutrient diagnosis is moving toward rapid, often spectral, detection of tree and soil nutrients combined with models to generate cultivar- and stage-specific nutrient standards for precision fertilization (Yuan et al., 2024).

For irrigation, soil-moisture sensing and automated scheduling tools link water status to tree demand. Traditional soil-based readings (TDR, capacitive sensors) and UAV imagery allow efficient monitoring of soil moisture, evapotranspiration, and canopy status in tree crops, supporting precise irrigation decisions (Tirado-Corbalá et al., 2021). Capacitance probes, already used in best-management programs, can measure volumetric water and ion content; they are especially sensitive to changes in K concentration and thus could feed decision-support systems for both irrigation and nutrient management (Strooboscher et al., 2024).

In drip-irrigated orchards, automated scheduling that combines FAO water-balance models with feedback from capacitance soil-moisture sensors has been shown (in apples) to match lysimeter-measured evapotranspiration in vigorous sectors while automatically reducing irrigation in less vigorous sectors, illustrating how sensor-driven systems can adapt water supply to spatial variability within orchards (Domínguez-Niño et al., 2020).