Improvements in vegetative growth are usually accompanied by enhanced leaf nutrient status and photosynthetic performance. Under arid conditions, combined organic and inorganic fertilization significantly increased transpiration rate, stomatal conductance, and net photosynthetic rate in grapevines (Chen et al., 2023). Partial replacement of synthetic nitrogen with organic nitrogen improved seedling photosynthetic performance and root growth, with intermediate substitution rates producing the greatest enhancement in photosynthesis, whereas excessively high substitution rates could exert inhibitory effects (Han et al., 2025). Piva et al. (2020) reported that organic and biodynamic management also increased leaf photosynthetic activity, Rubisco efficiency, PSII quantum yield, SPAD index, and shoot growth in young BRS Carmem grapevines during at least one growing season. However, these beneficial effects have certain limitations. In a Riesling vineyard trial, organic and biodynamic management reduced lateral leaf area, leaf area index (LAI) during ripening, pruning weight, and some physiological performance indicators compared with integrated management, although canopy size remained within an acceptable range for maintaining normal assimilation capacity (Döring et al., 2015).

5.2 Effects on reproductive development

Organic fertilization affects reproductive development mainly by altering vine nutritional balance before and after bloom. Evidence from Riesling indicates that reduced physiological performance after full bloom under organic and biodynamic management can limit berry size determination and reduce cluster weight when water competition from cover crops is not controlled (Döring et al., 2015). By contrast, integrated organic-mineral programs in warmer regions generally hastened maturation and improved fruiting, suggesting that better nutrient balance and canopy function support flowering, fruit set, and early berry growth (Alsalhy et al., 2021; El-Salhy et al., 2025). Organic substitution with reduced N plus organic fertilizer also improved photosynthetic efficiency and N utilization in Shine Muscat, factors closely associated with reproductive performance (Huang et al., 2026). Seasonal uptake studies further indicate that flowering is a critical period for N and B demand, while berry bulking is a key phase for P, Ca, and Mg acquisition, so the reproductive benefit of organic fertilization depends on whether nutrient mineralization matches these stages (Saleh et al., 2026).

Effects on cluster development and berry size are better documented and generally positive under well-balanced organic fertilization. In Flame Seedless, all combined fertilization treatments increased yield and improved cluster and berry traits relative to mineral fertilization alone. In Red Roomy, combined fertilization increased cluster and berry characteristics, and the triple-form treatment increased berry number by 21.49% and yield by 12.09% while also improving berry sugars and anthocyanin (El-Salhy et al., 2025). In a two-year Shine Muscat field study, vertical berry diameter and single-berry weight had significant positive effects on total yield, indicating that organic fertilizer substitution enhanced production partly by improving berry morphology (Huang et al., 2026). Short-term biostimulant evidence points in the same direction, with amino acid treatments increasing cluster length, cluster width, cluster weight, berry number per cluster, 100-berry volume, and yield per vine, although those results reflect one-season responses rather than accumulated soil effects (Saleh et al., 2026).

5.3 Effects on yield and production stability

Yield per vine and cluster productivity usually improve under moderate organic substitution or combined fertilization. In arid drip-irrigated vineyards, combined organic-inorganic fertilization increased yield by 6.68%-19.12%, with the 50:50 organic-to-inorganic ratio recommended under 720 mm irrigation (Chen et al., 2023). In Shine Muscat, reducing N by 20%-30% and adding organic fertilizer increased yield by 18.2% and 96.0% under the 0.8N + OF treatment across two seasons and delivered the highest economic return (Huang et al., 2026). Wu et al. (2024) found that two commercial organic fertilizers increased yield by 19.04% and 16.26%, whereas sheep manure and fermented corn stalk residue decreased yield, showing that material quality strongly affects productivity. Medium-term Mediterranean field data showed similar yields under organic and inorganic fertilization after 10 years, while compost in a restored hillslope vineyard produced a trend toward higher first-year yield with improved vegetative performance and nutrient uptake (García-Orenes et al., 2016; Lucchetta et al., 2023).