

applied—mitigate these effects by reconfiguring hormonal networks: ABA, salicylic acid, ethylene and jasmonates primarily activate defense and osmotic adjustment, while auxin, GA and cytokinins maintain growth, with extensive crosstalk between stress and growth pathways (Sabagh et al., 2022; Baral et al., 2025).

GA-inhibiting triazoles such as paclobutrazol alter gibberellin, ABA and cytokinin levels, reducing excessive vegetative growth, enhancing carbohydrate accumulation, improving water status and strengthening tolerance to abiotic stress while supporting fruit number and quality (Desta and Amare, 2021; Sabagh et al., 2021). Under low sugar availability or environmental stress, sugar signaling promotes ABA and ethylene accumulation and disrupts auxin transport, driving fruit abscission; once sugar status improves, rising cytokinin and GA levels restore cell division and expansion and stabilize fruit set (Waadt et al., 2022; Zhao et al., 2025). Thus, PGR-mediated adjustment of hormonal networks links stress physiology directly to yield stability and fruit uniformity.

6 Application Strategies of PGRs in Eggplant Production

6.1 Application methods and timing

Plant growth regulators can substantially improve eggplant yield, stress tolerance, and fruit quality, but their benefits depend strongly on application method, timing, and dose. Foliar spraying is the most common method in eggplant, enabling rapid absorption and relatively precise timing around key stages such as vegetative growth, flowering, and early fruit set (Figure 2). Foliar application of α -tocopherol, ZnO nanoparticles, salicylic acid, potassium nitrate, thiourea, and biostimulants (garlic extract, vermicompost tea, yeast extract) enhanced growth, water status, antioxidant activity, and yield under both optimal and drought conditions (Semida et al., 2021; Akram et al., 2023). Foliar PGRs are usually applied with surfactants to improve cuticular penetration and uniform coverage (Akram et al., 2023; Dick and VanderWeide, 2025).

Root-zone or substrate applications are preferred for some systemic regulators such as paclobutrazol, which is more effective when applied to the growth medium than as a spray because of longer contact and uptake time (Desta and Amare, 2021). Seed priming with PGRs (e.g., α -tocopherol, guvermectin) can enhance early vigor and later yield response, representing a complementary strategy to foliar use (Liu et al., 2022; Akram et al., 2023).

Optimal timing is crop- and regulator-specific. In fruit crops, foliar PGRs applied at full bloom or shortly after flowering markedly influence fruit set, size, and quality (Aryal and Alf  rez, 2025; Baldissera et al., 2025). In eggplant, applications at vegetative and pre- or post-transplant stages, as well as around flowering and early fruit set, were most effective for stimulating canopy growth, maintaining water status, and improving yield and fruit traits under water stress (Ali et al., 2019; Wakchaure et al., 2020). Repeated applications may increase responses but excessive frequency can cause growth inhibition or oxidative damage.

6.2 Dosage optimization and combination use

PGRs exhibit clear dose–response relationships: low to moderate concentrations often stimulate growth and yield, whereas high doses can induce phytotoxicity or yield decline (Ali et al., 2019; Semida et al., 2021; Akram et al., 2023). In eggplant, moderate foliar levels of α -tocopherol or ZnO nanoparticles maximized growth and fruit yield under drought, while higher doses or over-frequent botanical sprays increased lipid peroxidation and reduced growth (Akram et al., 2023). Similar patterns are reported for auxins, gibberellins, and cytokinins in cucurbits and tree fruits, where recommended ppm ranges are critical to avoid negative effects on fruit quality or return bloom (Sabir et al., 2021; Baldissera et al., 2025).

Combination treatments can produce synergistic effects by targeting complementary hormonal pathways. In cucumber, combined auxin and gibberellin improved vegetative growth and fruit yield more than either alone (Gosai et al., 2020). In apple, combinations of cytokinin (BA) and auxin (NAA) increased yield and the proportion of large fruits beyond single applications (Baldissera et al., 2025). In eggplant under deficit irrigation, mixtures of salicylic acid, potassium nitrate, thiourea, or commercial biostimulants improved canopy traits, water productivity, and fruit quality compared with untreated controls, with some regulators more effective under