

### **5.3 Safety and standardized management**

While PGRs offer substantial benefits, improper use can result in phytotoxicity, fruit deformities, or residue accumulation. Phytotoxic effects are often dose-dependent and can manifest as leaf burn, fruit drop, or abnormal growth patterns (Desta and Amare, 2021; Jain et al., 2023). To mitigate these risks, it is essential to adhere to recommended safety intervals between application and harvest, ensuring that residue levels remain within safe limits for human consumption (Kumar et al., 2023). Regular monitoring and residue analysis are advised, especially when using synthetic PGRs or in export-oriented production systems.

The adoption of standardized operational procedures is crucial for the safe and effective use of PGRs in loquat cultivation. Guidelines should specify the appropriate PGR type, concentration, timing, application method (spraying or smearing), and safety precautions (Desta and Amare, 2021; Jain et al., 2023; Kumar et al., 2023). Field training for workers, use of personal protective equipment, and record-keeping of application details are recommended best practices. Additionally, periodic field trials and extension services can help update growers on the latest research findings and regulatory requirements, promoting responsible and sustainable PGR use in loquat orchards.

## **6 Current Issues and Research Challenges**

### **6.1 Dosage and safety concerns**

PGR effect on loquat was found to be extremely dose-dependent in experiments, and the plant response vs. dosage relationship is not always linear. Under- and over-doses generate sub-optimal or toxic effects, which make it difficult to determine safe and optimal dosages for growth stages and organs. This diversity underscores the need for proper dosage standards to avoid unwanted impacts on plant health and fruit quality (Surya et al., 2020; Desta and Amare, 2021; Surya et al., 2021).

### **6.2 Regional adaptability differences due to variety and climate factors**

Loquat varieties and PGR sensitivity vary significantly depending on genetic origin and environmental factors. Climatic conditions of the region, irrigation system, and stress severity (e.g., drought stress, frost stress) influence loquat plant response to PGR application. Regional differences in this context make it challenging to attempt overall application guidelines and highlight the need for ongoing location- and variety-dependent investigations (Gugliuzza et al., 2020; Wang et al., 2021).

### **6.3 Potential side effects on fruit development and quality**

While PGRs can induce growth and stress tolerance, there is potential for unforeseen side effects on fruit form, nutritional content, and overall quality. For example, some treatments could increase some of the growth qualities but negatively affect others, e.g., leaf or fruit form, or not have a significant impact on all the desired qualities. The ignoring of potential negative effects on postharvest quality and fruit development remains a significant concern (Surya et al., 2020).

### **6.4 Lack of molecular-level understanding of regulatory mechanisms**

In contrast, there is scant information on the molecular bases of the physiological and biochemical responses of PGRs in loquat (Tranbarger and Tadeo, 2025). Gene expression and signal transduction mechanisms have started to be explored in more recent investigations on PGR-induced stress responses, but overall knowledge at the molecular level is sporadic. This knowledge gap limits the possibility for optimization of PGR application and design of targeted interventions for improved fruit set and stress resistance (Sabagh et al., 2021; Wang et al., 2021).

## **7 Future Research Directions and Application Prospects**

### **7.1 Screening and development of efficient and low-toxicity new growth regulators**

Current research is laying a lot of emphasis on the synthesis of new PGRs with low toxicity and high activity. Synthetic researches are being attempted towards synthesizing new classes of PGRs such as phenylurea derivatives and phytohormone functional analogues with increased bioactivity and reduced toxicity. Encapsulation