functional product research, and the comprehensive utilization of medicinal plant resources. Its industrial value and market attention have therefore continued to increase.

From the perspective of industrial development, *F. thunbergii* has medicinal, economic, and regional specialty agricultural value, making it an important crop for promoting local Chinese medicinal material industries and increasing farmers' income. With growing market demand and ecological constraints on wild resources, the supply of *F. thunbergii* has gradually shifted from wild collection to artificial cultivation. Stable, high-yield, and high-quality cultivation has therefore become a key issue in current industrial development (Sui et al., 2021; Du et al., 2024; Liu et al., 2025a). Major production areas such as Zhejiang have developed a relatively mature cultivation foundation as well as processing and distribution systems. However, in production practice, *F. thunbergii* still faces problems such as yield fluctuation, uneven quality, and unstable contents of active components. Since the underground bulb is the medicinal part of *F. thunbergii*, yield formation is influenced not only by cultivar, seed bulb quality, and cultivation management, but also closely related to light, temperature, water, soil, and regional ecological conditions. Existing studies have shown that cultivation environments and agronomic measures, including fertilizer type and application rate, potassium nutrition, organic fertilizer and biochar amendment, shading intensity, soil disinfestation, and biological control, can significantly affect bulb biomass, peimine/peiminine contents, and levels of other steroidal alkaloids in *F. thunbergii* (Cheng et al., 2023; Huang et al., 2024a). Therefore, different cultivation environments may affect final yield and medicinal quality by changing plant growth rhythm, photosynthetic efficiency, dry matter accumulation, rhizosphere microecology, and bulb enlargement.

At present, *F. thunbergii* production has gradually shifted from traditional experience-based cultivation to standardized, large-scale, and high-quality cultivation. Simply pursuing bulb yield can no longer meet the requirements of the medicinal material market and quality evaluation systems. Studies have shown that yield-oriented intensive cultivation may be associated with a decline in the levels of medicinal components in bulbs, while the accumulation of peimine-type steroidal alkaloids varies with species, organs, developmental stages, and environmental conditions (Sui et al., 2021; Huang et al., 2024a). For example, appropriate potassium and organic fertilizer application can simultaneously increase bulb yield and peimine content, whereas shading or certain stress-mimicking measures may increase alkaloid concentrations but are often accompanied by reduced biomass (Liu et al., 2025a). This indicates that high yield does not necessarily equate to high quality. If cultivation environment regulation is inappropriate, plant growth may be restricted, disease incidence may increase, bulb marketability may decline, or peimine accumulation may be insufficient. Therefore, in *F. thunbergii* production, greater attention should be paid to the coordination between "yield formation" and "quality formation." On the one hand, optimizing light-temperature-water-fertilizer management, improving soil structure, regulating the field microclimate, and reducing continuous cropping obstacles can enhance plant growth stability and bulb yield. On the other hand, the promoting effects of suitable environmental conditions on peimine synthesis, transport, and accumulation should also be emphasized to provide a basis for improving the medicinal quality of *F. thunbergii*.

This study will explore the effects of cultivation environment on the yield of *Fritillaria thunbergii* and peimine accumulation. Focusing on the growth and developmental characteristics, yield formation process, and peimine accumulation patterns of *F. thunbergii*, this study will systematically analyze the regulatory effects of light, temperature, water, soil, regional ecological conditions, and cultivation patterns on its growth and quality formation. Existing studies have explored individual factors such as potassium application rate, organic fertilizer type, shading treatment, soil disinfestation, and biological control; however, comprehensive evaluations that simultaneously link specific cultivation environments with bulb yield and peimine accumulation remain relatively limited. In addition, transcriptomic and metabolomic studies have shown that the effects of cultivation environment on the growth and quality of *F. thunbergii* may be mediated by regulating hormone signaling, rhizosphere microecology, and the expression of key genes involved in steroidal alkaloid biosynthesis. Therefore, this study will further analyze the possible mechanisms by which environmental factors regulate photosynthesis, dry matter accumulation, and secondary metabolism. It aims to clarify the intrinsic relationships between