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Effects of Organic Fertilizer Substitution for Chemical Fertilizers on Yield and Quality Formation of *Atractylodes macrocephala*

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Abstract This review examines the effects of organic fertilizer substitution for chemical fertilizers on the growth environment, yield formation, quality accumulation, stress resistance, and ecological benefits of *Atractylodes macrocephala* Koidz. The results indicate that organic fertilizer substitution provides favorable conditions for the growth and development of *A. macrocephala* by increasing soil organic matter content, improving soil physicochemical properties, optimizing nutrient supply, and regulating rhizosphere microbial community structure. Meanwhile, organic fertilizer substitution promotes rhizome yield by enhancing root development, increasing photosynthetic assimilate accumulation, and regulating dry matter allocation. In terms of quality formation, organic fertilizer substitution facilitates the accumulation of key active constituents, including atractylenolides, polysaccharides, and volatile oils, and its underlying mechanisms are closely associated with nutrient regulation, activation of secondary metabolic pathways, and rhizosphere microbial-mediated regulation. Furthermore, organic fertilizer substitution improves the stress resistance of *A. macrocephala*, reduces agricultural non-point source pollution, promotes resource recycling, and supports the sustainable development of the medicinal plant industry. However, suitable substitution ratios vary among different ecological regions and cultivation conditions, and the molecular mechanisms underlying quality formation and precision fertilization systems require further investigation. Future studies should integrate multi-omics approaches, precise soil monitoring, and intelligent management technologies to establish a quality-oriented, green, and efficient cultivation system for *Atractylodes macrocephala*.

Keywords *Atractylodes macrocephala*; Organic fertilizer substitution; Yield formation; Medicinal quality; Green cultivation

1 Introduction

Atractylodes macrocephala Koidz., commonly known as Baizhu, is one of the most important traditional Chinese medicinal plants in East Asia and has been used for more than 2 000 years. Its rhizome is widely employed in clinical and health-related applications, and modern studies attribute its medicinal value to multiple bioactive constituents, especially sesquiterpenoids such as atractylenolides and atractylone, as well as polysaccharides and other secondary metabolites (Cui et al., 2025). Pharmacological studies indicate that *A. macrocephala* has anti-inflammatory, antioxidant, neuroprotective, immunomodulatory, gastrointestinal regulatory, and other bioactivities, which has sustained strong clinical and market demand for this species (Zhu et al., 2018). At the same time, the medicinal quality of *A. macrocephala* depends not only on rhizome yield, but also on the accumulation of key active compounds, because atractylenolides, atractylone, and related constituents are widely used as quality markers for evaluating its pharmacological potential and consistency. Recent work further shows that both biomass and active component content are significantly higher in authentic production areas than in emerging production regions, while rhizome growth and phytochemical composition can respond differently to environmental conditions, indicating that the industry increasingly requires cultivation practices that can coordinate both yield and quality rather than pursuing output alone (Zhou et al., 2025; Lee et al., 2025).

With the expansion of artificial cultivation and rising demand for high-quality medicinal materials, *A. macrocephala* production faces increasingly strict requirements for stable yield, superior medicinal quality, and ecological sustainability. Wild resources have become scarce because of increasing demand, habitat degradation, and slow growth, which has made standardized cultivation the main pathway for ensuring supply (Cui et al., 2025). However, studies on *A. macrocephala* indicate that achieving consistent quality in cultivation remains difficult,