

Independent reviews further show that the major active constituents of *A. macrocephala* include volatile oils, polysaccharides, and lactones, and that polysaccharides themselves are important pharmacodynamic substances rather than only reserve carbohydrates. Therefore, any fertilization practice that simultaneously favors lactone and polysaccharide accumulation is directly relevant to medicinal quality formation in this crop (Figure 2) (Liu et al., 2022; Li et al., 2022).

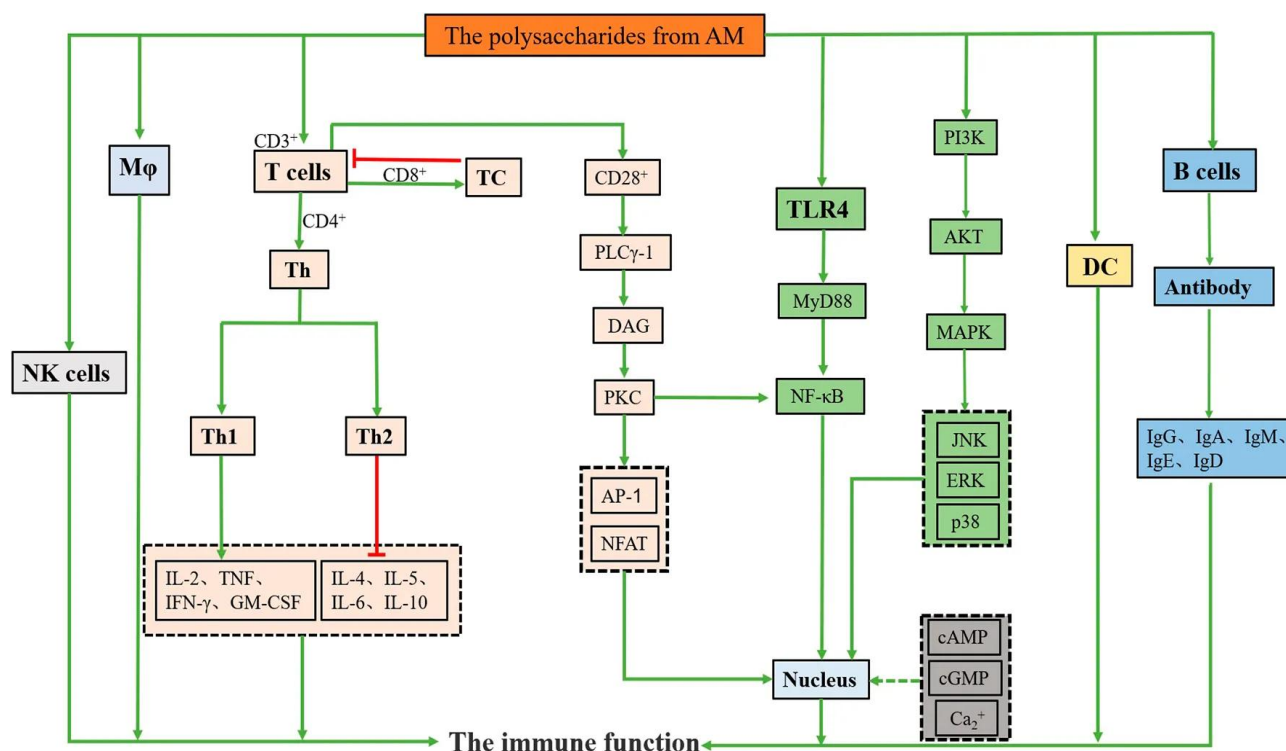


Figure 2 Immunomodulation activity mechanisms of polysaccharides from *A. macrocephala* (Adopted from Liu et al., 2022)

The likely mechanism is that organic substitution enhances secondary metabolism through rhizosphere signaling, carbon supply, and regulation of terpenoid biosynthesis pathways. In *A. macrocephala*, elicitation with exogenous plant polysaccharides significantly increased biomass, atractylenolides, and polysaccharides, and RT-qPCR showed that the induced terpenoid increase mainly depended on the mevalonate pathway (Zhou et al., 2021). Rhizosphere evidence also supports this interpretation: multiple bacterial and fungal genera in *A. macrocephala* soils were positively or negatively correlated with the accumulation of polysaccharides, atractylone, and lactones I-III, indicating that active-component formation is tightly linked to microbial community structure (Song et al., 2023). Similar organic-input responses have been reported in other medicinal plants: bio-organic fertilizer increased lignans, flavonoids, polysaccharides, and polyphenols in *Schisandra chinensis*, while integrated organic and inorganic fertilization improved rhizome bioactive content in *Kaempferia galanga* (Saitama et al., 2025; Xu et al., 2025). Together, these findings suggest that organic fertilizer substitution promotes quality formation in *A. macrocephala* by coordinating nutrient availability with secondary-metabolite biosynthesis and rhizosphere biological activation.

4.2 Effects on volatile components and quality evaluation of medicinal materials

The quality of *A. macrocephala* medicinal materials is strongly associated with its volatile components, especially atractylone and related sesquiterpenes, so the effect of organic substitution on volatile profiles is a central quality issue. Comparative metabolomic and GC/MS studies show that *A. macrocephala* is chemically characterized by volatile oils dominated by atractylone, while atractylolactones also serve as distinguishing constituents among *Atractylodes* species (Zhang et al., 2025). A GC/MS chemometric study of 59 batches identified 50 volatile components and proposed five characteristic markers for *Atractylodes* quality evaluation, including atractylone and atractylenolide I. More broadly, volatile oils are recognized as important active constituents and characteristic