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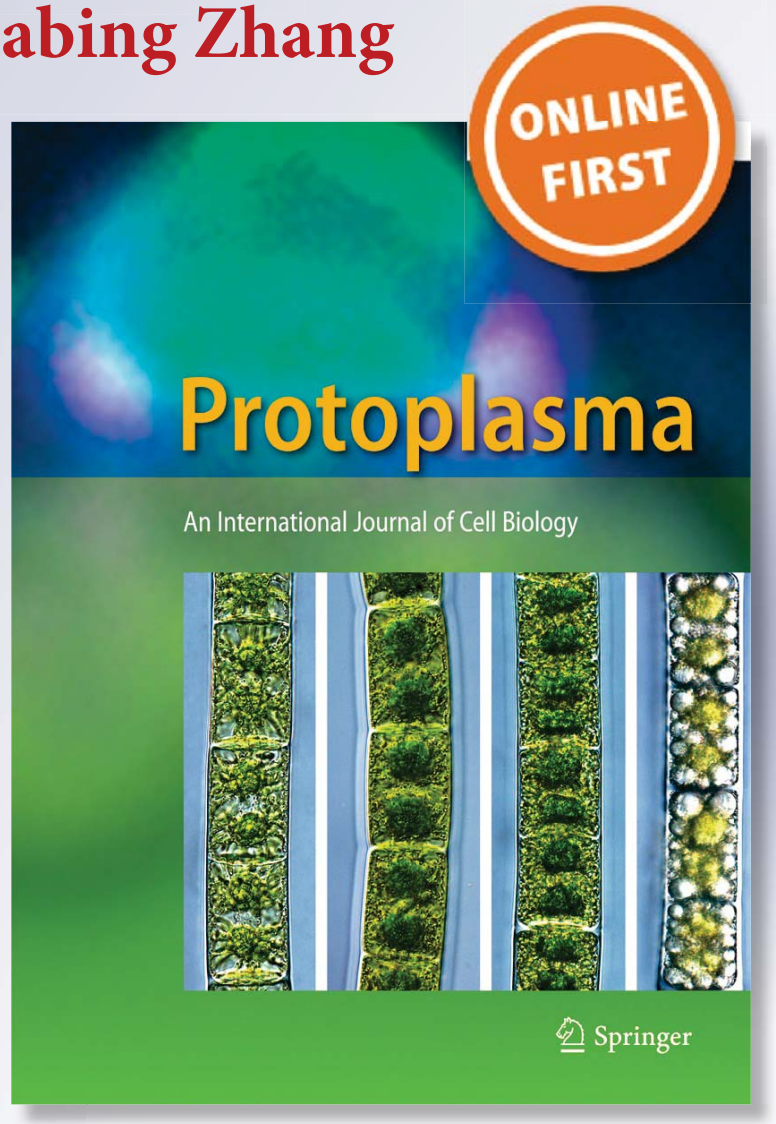

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ORIGINAL ARTICLE

Cytological characterization of anther development in *Panax ginseng* Meyer

Yu-Jin Kim[1,2] · **Moon-Gi Jang**[1] · **Lu Zhu**[2] · **Jeniffer Silva**[1] · **Xiaolei Zhu**[2] · **Johan Sukweenadhi**[1] · **Woo-Saeng Kwon**[1] · **Deok-Chun Yang**[1] · **Dabing Zhang**[2,3,4]

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Abstract Ginseng (*Panax ginseng*), a valued medicinal herb, is a slow-growing plant that flowers after 3 years of growth with the formation of a solitary terminal umbel inflorescence. However, little is known about cytological events during ginseng reproduction, such as the development of the male organ, the stamen. To better understand the mechanism controlling ginseng male reproductive development, here, we investigated the inflorescence and flower structure of ginseng. Moreover, we performed cytological analysis of anther morphogenesis and showed the common and specialized cytological events including the formation of four concentric cell layers surrounding male reproductive cells followed by subsequent cell differentiation and degeneration of tapetal cells, as well as the formation of mature pollen grains via meiosis and mitosis during ginseng anther development. Particularly, our transverse section and microscopic observations showed that the ginseng tapetal layer exhibits obvious nonsynchronous cell division evidenced by the observation of one or two tapetal layers frequently observed in one anther lobe, suggesting the unique control of cell division. To facilitate the future study on ginseng male reproduction, we grouped the anther development into 10 developmental stages according to the characterized cytological events.

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Yu-Jin Kim, Moon-Gi Jang and Lu Zhu contributed equally to this work.

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Keywords Pollen · Microspore · Cell division · Ginseng · Reproductive development · Stages of anther development

Introduction

In higher plants, male reproductive development is a complex biological process that includes stamen identity specification from the floral meristem, anther morphogenesis, and the formation of pollen grains via meiosis and mitosis within the flower (Wilson and Zhang 2009). Microsporogenesis and male gametogenesis within the anther are critical for alteration between diploid sporophyte and haploid gametophyte in flowering plants. Mature pollen grains (called microgametophytes) release sperm cells to the female reproductive structures for double fertilization, leading to the formation of seeds and/or fruits, which are essential for species survivals and agricultural production. To ensure successful male reproduction, the development of the somatic tissue, anther wall layers, and reproductive cells is tightly

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