Protoplasma
DOI 10.1007/s00709-017-1081-4

ORIGINAL ARTICLE

Cytological analysis of ginseng carpel development

Jeniffer Silva[1] · Yu-Jin Kim[1,2] · Dexin Xiao[2] · Johan Sukweenadhi[1] · Tingting Hu[2] · Woo-Saeng Kwon[1] · Jianping Hu[2,3] · Deok-Chun Yang[1] · Dabing Zhang[2]

Received: 17 August 2016 / Accepted: 25 January 2017

Abstract *Panax ginseng* Meyer, commonly known as ginseng, is considered one of the most important herbs with pharmaceutical values due to the presence of ginsenosides and is cultivated for its highly valued root for medicinal purposes. Recently, it has been recognized that ginseng fruit contains high contents of triterpene such as ginsenoside Re as pharmaceutical compounds. However, it is unclear how carpel, the female reproductive tissue of flowers, is formed during the three-year-old growth before fruit is formed in ginseng plants. Here, we report *P. ginseng* carpel development at the cytological level, starting from the initial stage of ovule development to seed development. The carpel of *P. ginseng* is composed of two free stigmas, two free styles, and one epigynous bilocular ovary containing one ovule in each locule. Based on our cytological study, we propose that the female reproductive development in *P. ginseng* can be classified into seven stages: early phase of ovule development, megasporogenesis, megagametogenesis, pre-fertilization, fertilization, post-fertilization, and seed development. We also describe the correlation of the female and male gametophyte development and compare morphological differences in carpel development between ginseng and other higher plants. One unique feature for ginseng seed development is that it takes 40 days for the embryo to develop to the early torpedo stage and that the embryo is small relative to the seed size, which could be a feature of taxonomic importance. This study will provide an integral tool for the study of the reproductive development and breeding of *P. ginseng*.

Keywords *Panax ginseng* · Ontogeny · Ovule · Ultrastructure · Stages of carpel development

Handling Editor: Liwen Jiang

✉ Yu-Jin Kim
yujinkim@khu.ac.kr

✉ Deok-Chun Yang
dcyang@khu.ac.kr

✉ Dabing Zhang
zhangdb@sjtu.edu.cn

[1] Department of Oriental Medicine Biotechnology and Graduate School of Biotechnology, College of Life Science, Kyung Hee University, Yongin 446-701, South Korea

[2] Joint International Research Laboratory of Metabolic and Developmental Sciences, Shanghai Jiao Tong University–University of Adelaide Joint Centre for Agriculture and Health, School of Life Sciences and Biotechnology, Shanghai Jiao Tong University, Shanghai 20040, China

[3] Department of Energy Plant Research Laboratory, Michigan State University, East Lansing, MI 48824, USA

Introduction

Sexual reproduction is a major process in the life cycle of flowering plants, as it is essential for seed production to generate a new population of offspring (Robert et al. 2015; Zhang et al. 2015). This process depends on highly specialized reproductive organs, stamen (male) and carpel (female), which are protected by flower buds until anthesis. Both reproductive organs have tightly coordinated mechanisms that are indispensable for effective fertilization and production of viable seeds (Vivian-Smith et al. 2001; Robert et al. 2015). Through the fusion of haploid gametes, fertilization initiates the development of a new diploid organism (Dresselhaus et al. 2016). Following fertilization, the ovule develops into a seed while the surrounding carpel differentiates into a fruit to complete a successful reproduction (Coombe 1976; Vivian-Smith et al. 2001). The major seed components, embryo and endosperm, are formed after the fusion of two sperm cells with two dimorphic female gametes, the egg and the central cell, respectively (Dresselhaus et al. 2016). Successful

Published online: 02 February 2017