Available online at SciVarse ScienceDirect

Chinese Herbal Medicines (CHM)

ISSN 1674-6384

Journal homepage: www.tiprpress.com E-mail: chm@tiprpress.com

Review

Production of Active Compounds in Medicinal Plants: From Plant Tissue Culture to Biosynthesis

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ARTICLE INFO

Article history

Received: November 30, 2016

Revised: January 23, 2017

Accepted: February 9, 2017

Available online: March 13, 2017

DOI: 10.1016/S1674-6384(17)60085-6

ABSTRACT

Over past decades plant tissue culture has emerged as an alternative of whole plant cultivation in the production of valuable secondary metabolites. Adventitious roots culture of *Panax ginseng* and *Echinacea purpure* has reached the scale of 1 − 10 kL. Some molecular biological techniques, such as transgenic technology and genetic stability are increasingly used in the studies on plant tissue cultures. The studies on elicitors have deepened into the induction mechanism, including signal molecules, functional genes, and so on. More and more biological elicitors, such as *A. niger* and yeast are used to increase the active compounds in plant tissue cultures. We also discussed the application of synthetic biology in the studies on biosynthesis of artemisinin, paclitaxel, and tanshinon. The studies on active ingredients biosynthesis of medicinal plants provide unprecedented possibilities to achieve mass production of active ingredients. Plant tissue cultures can not only produce active ingredients but also as experimental materials for biosynthesis. In order to improve the contents of active compounds in medicinal plants, following aspects could be carried out gene interference or gene silencing, gene overexpression, combination with chemical synthesis, application of elicitors, and site-directed mutagenesis of the key enzymes.

Key words

biosynthesis; functional gene; medicinal plant tissue culture; secondary metabolites

1. Introduction

In recent decades, plant cell, tissue, and organ cultures have emerged as an alternative over whole plant cultivation for the production of secondary metabolites which are used as pharmaceuticals, flavours, fragrances, colouring agents, food additives, and agrochemicals (Paek et al, 2014). Plant tissue cultures can not only produce active ingredients but also as

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Fund: Major Increase and Decrease of the Central Level (2060302)

experimental materials for studies on synthetic biology. More recently, active ingredients biosynthesis of medicinal plants are being achieved through genetic and metabolic engineering approaches. Table 1 lists the production of active compounds through plant tissue culture or synthetic biology method. In this review, we summarized production of active compounds in medicinal plants by using plant tissue cultures and synthetic biology. We also discussed the relationship between plant tissue cultures and synthetic biology.

2. Production of active compounds through plant tissue culture

At present, cells, adventitious roots, hairy roots, shoots, and embryos have been successfully cultivated for the large scale production of secondary metabolites. Recent advances in plant cell, tissue, and organ culture research mainly focus on optimization of culture conditions, composition comparison, elicitors, transgenic technology, and genetic stability.

Table 1 Production of secondary metabolites in medicinal plants through bioengineering

Components	Secondary metabolites	Plants	Sources	References
terpenoids	taxuyunnanine c, taxol	*Taxus chinensis* (Pilger) Rehd.	cell, biosynthesis	Gao et al, 2010; Zhou et al, 2015; Zhang et al, 2010
	saponin	*Panax quinquefolius* L.; *A. Senticosus*; *P. ginseng*; *Bupleurum falcatum*	cell, hairy root, biosynthsis	Hao et al, 2010; Zhao et al, 2011; Tao et al, 2011; Balusamy et al, 2013; Moses et al, 2014
	glycyrrhizic acid	*Glycyrrhiza uralensis* Fisch.	hairy root	Zhang et al, 2011; Yang et al, 2014
	triterpenoid	*Codonopsis lanceolatae* (Sieb. et Zucc.) Trauv.	hairy root	Kim et al, 2011
	valerenic acid	*Valeriana officinalis* Linn.	hairy root	Torkamani et al, 2014
	saikosaponin	*Bupleurum chinense* DC.	adventitious root	Sun et al, 2013
	triptolide	*Tripterygii wilfordii* Hook.F.	adventitious root	Zhu et al, 2014a
	tanshinones	*Salvia miltiorrhiza* Bunge (Lamiaceae)	cell, hairy root, biosynthesis	Zhao et al, 2010; Guo et al, 2013
	artemisinin	*Artemisia annua* Linn	biosynthesis	Paddon et al, 2013
flavonoids	favonoids	*Ginkgo biloba* Linn; *Saussurea involucrate* Kar. et Kir. ex Maxim.	cell; hairy root	Hao et al, 2010; Hu, Han, and Zhou, 2011. Zhang et al, 2013; Qiao et al, 2011
	licochalcone a, total flavonoid	*G. uralensis*	hairy root	Zhang et al, 2011
alkaloids	alkaloid	*Fritillaria cirrhosa* D. Don.	cell	Wang et al, 2011
	total alkaloid, catharanthine, vindoline	*Catharanthus roseus* (L.) G. Don	cell, biosynthesis	Shukla et al, 2010; Moerkercke et al, 2015
	campothecin	*Campototheca acuminate* Decaisne	cell	Qi et al, 2010a; 2010b
	atractylodin	*Atractylodes lancea* (Thunb.) DC.	cell	Zhao et al, 2010
	ephedrine	*Ephedrae sinica* Staph	cell	Gandi et al, 2012
	tropane alkaloids	*Anisodus acutangulus* C. Y.	hairy root	Cao et al, 2014
	scopolamine, hyoscyamine	*Datura stramonium* Linn	hairy root	Sun et al, 2013
	vincamine	*C. roseus*	hairy root	Verma et al, 2014
	wilforine	*T. wilfordii*	adventitious root	Zhu, et al, 2014
	tricyclic aromatic quinines	*Aloe vera* (Linn.) N.L.	adventitious root	Lee et al, 2013
penylpropanoids	coumarins	*Angelica archangelica* L.	cell	Tomas et al, 2012
phenolic acids	phenolic acids, chlorogenic acid	*Eryngium planum* L.	cell	Kikowska et al, 2012
	rosmarinic acid	*S. miltorrhiza*	hairy root	Sheng and Chen, 2013;
	caffeic acid	*E. purpure*	adventitious root	Cui, 2013
quinones	acetylshikonin	*Arnebia euchroma* (Royle) Johnst; *Radix Arnebiae* Seu. Lithospermi	cell, hairy root	Baranek et al, 2012; Li et al, 2010; He et al, 2010
	anthroquinones	*Morinda officinalis* How.	hairy root	Zheng et al, 2014
	aloe emodin	*A. vera* Burman var. *chinensis* (Haw) Berg	adventitious root	Lee et al, 2013
	chrysophanol	*A. vera* *B. chinensis*	adventitious root	Lee et al, 2013
steroids	phytoecdysteroids	*Achyranthes bidentata* Blume	cell	Wang et al, 2013
	guggulsterone	*Commiphora wightii* (Arn.) Bhand.	cell	Suthar and Ramawat, 2010