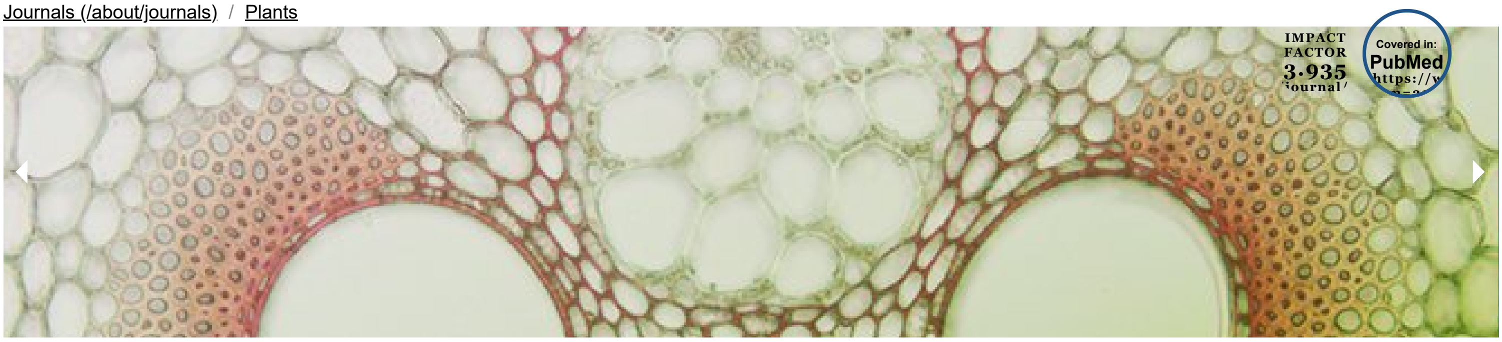


Journal Description

Plants

Plants is an international, scientific, **peer-reviewed (https://www.mdpi.com/editorial_process)**, open access journal published semimonthly online by MDPI. The **Australian Society of Plant Scientists (ASPS) (https://www.asps.org.au/)**, the **Spanish Phytopathological Society (SEF) (https://sef.es/en)**, the **Spanish Society of Plant Physiology (SEFV) (http://www.sefv.es/)**, the **Spanish Society of Horticultural Sciences (SECH) (http://www.sech.info/)** and the **Italian Society of Phytotherapy (S.I.Fit.) (http://www.sifit.org/)** are affiliated with *Plants* and their members receive a discount on the article processing charges.

- **Open Access (https://www.mdpi.com/openaccess)** — free for readers, with **article processing charges (APC) (https://www.mdpi.com/journal/plants/apc)** paid by authors or their institutions.
- **High Visibility:** indexed within **Scopus (https://www.scopus.com/sourceid/21100788294)**, **SCIE (Web of Science) (https://mjl.clarivate.com/search-results?issn=2223-7747&hide_exact_match_fl=true&utm_source=mjl&utm_medium=share-by-link&utm_campaign=search-results-share-this-journal)**, **PubMed (https://pubmed.ncbi.nlm.nih.gov/?term=%22plants+%28basel%29%22+%5Bjournal%5D&sort=pubdate)**, **PMC (https://preview.ncbi.nlm.nih.gov/pmc/journals/2909/)**, **PubAg (https://pubag.nal.usda.gov/?_=1643989552119&f%5Bjournal_name%5D%5B%5D=Plants&q=plants&search_field=journal_text&sort=date-desc)**, **AGRIS (https://agris.fao.org/agris-search/index.do)**, **CAPlus / SciFinder (https://sso.cas.org/as/authorization.oauth2?response_type=code&client_id=scifinder-n&redirect_uri=https%3A%2F%2Fscifinder-** [illegible] **ioianMiLCJzdWZmaXgiOiJUYWozcGUu)**, and many **other databases (https://www.mdpi.com/journal/plants/indexing)**.
res.com%2Fd_attachment%2Fplants%2Fplants-10-02237%2Farticle_deploy%2Fplants-10-02237-v2.pdf)
- **Journal Rank:** JCR - Q1 (*Plant Sciences*) / CiteScore - Q2 (*Plant Science*)
- **Rapid Publication:** manuscripts are peer-reviewed and a first decision provided to authors approximately 13.1 days after submission; acceptance to publication is undertaken in 3.4 days (median values for papers published in this journal in the second half of 2021).
- **Recognition of Reviewers:** reviewers who provide timely, thorough peer-review reports receive vouchers entitling them to a discount on the APC of their next publication in any MDPI journal, in appreciation of the work done.

Impact Factor: 3.935 (2020)

Imprint Information (/journal/plants/imprint) **Journal Flyer (/journal/plants/plants_flyer.pdf)** **Open Access (https://www.mdpi.com/about/openaccess)**
ISSN: 2223-7747

Latest Articles

Open Access Article **(/2223-7747/11/3/459/pdf)**

Trade-Off between Facilitation and Interference of Allelopathic Compounds in Vegetation Recovery: The Case of *Rosmarinus officinalis* in Degraded Gypsum Habitats (/2223-7747/11/3/459)

by **Helena García-Robles (https://sciprofiles.com/profile/2017954)**, **Eva María Cañadas (https://sciprofiles.com/profile/author/TW1KOG9oby9lWmkyRXhDQ0R5aEZ4dz09)**, **Juan Lorite (https://sciprofiles.com/profile/836329)** and **Emilia Fernández-Ondoño (https://sciprofiles.com/profile/293317)**

Plants **2022**, *11*(3), 459; **https://doi.org/10.3390/plants11030459 (https://doi.org/10.3390/plants11030459)** - 07 Feb 2022

Abstract *Rosmarinus officinalis* advantageously competes with other species in restored gypsum outcrops, and further research is needed to understand the causes. Specifically, we focus on the potential allelopathic effects derived from its terpenes on the emergence of gypsum species. To this end, we **[...] Read more.**

(This article belongs to the Special Issue **Plant–Plant Allelopathic Interactions (/journal/plants/special_issues/plant_plant_allelopathic_interactions)**)

Open Access Article **(/2223-7747/11/3/458/pdf)**

"I Climbed a Fig Tree, on an Apple Bashing Spree, Only Pears Fell Free": Economic, Symbolic and Intrinsic Values of Plants Occurring in Slovenian Folk Songs Collected by K. Štrekelj (1895–1912) (/2223-7747/11/3/458)

by Živa Fišer (https://sciprofiles.com/profile/2017987)

Plants **2022**, *11*(3), 458; https://doi.org/10.3390/plants11030458 (https://doi.org/10.3390/plants11030458) - 07 Feb 2022

Abstract In this study we examine the occurrence of plants and their symbolic, economic, and intrinsic values in Slovenian folk songs. We have analyzed songs published by the ethnologist Karel Štrekelj between 1895 and 1912. Of the 8686 songs studied, plants occur in 1246 [...] Read more.

(This article belongs to the Special Issue **Historical Ethnobotany: Interpreting the Old Records (/journal/plants/special_issues/historical_ethnobotany)**)

Open Access Article (/2223-7747/11/3/457/pdf)

Isolation of the Novel Strain *Bacillus amyloliquefaciens* F9 and Identification of Lipopeptide Extract Components Responsible for Activity against *Xanthomonas citri* subsp. *citri* (/2223-7747/11/3/457)

by Xin Wang (https://sciprofiles.com/profile/author/bHVDYjFhZXFhbDc0ZUlzSGRURXlmMnpLb2tsdEc2WW10TDMwQ2NXK05qbz0=), Liqiong Liang (https://sciprofiles.com/profile/author/emNKWWszbGtscFVrT2hnY3ZwVnM4eFJNclFkSDVxMHl0N0hnR0tCQVR0bz0=), Hang Shao (https://sciprofiles.com/profile/author/OGZNSDYycHduOU1OQ0ZSRm9FS2NoN1JWSU9ydkNLN1pnTlYrdGtMYTR0cz0=), Xiaoxin Ye (https://sciprofiles.com/profile/2052866), Xiaobei Yang (https://sciprofiles.com/profile/author/TGlxb1V0ckl3K0x4ajdJaXJnQnJXRnBsQ3FXTi9LekM0WkM0c0l1ODVoUT0=), Xiaoyun Chen (https://sciprofiles.com/profile/author/eUhoMi9mYTRnMjk0ZnZRRHl1eEFwVkxCdXlvQmtrd3NrMzdITzQrczdvYz0=), Yu Shi (https://sciprofiles.com/profile/author/ejZLU0dTV3BqL0VFR1FmZC91VmZPdXFPY1A0ZVk2dnUvT21XMlRzZjNrMD0=), Lianhui Zhang (https://sciprofiles.com/profile/1266058), Linghui Xu (https://sciprofiles.com/profile/1995783) and Junxia Wang (https://sciprofiles.com/profile/1018696)

Plants **2022**, *11*(3), 457; https://doi.org/10.3390/plants11030457 (https://doi.org/10.3390/plants11030457) - 07 Feb 2022

Abstract Citrus canker, caused by *Xanthomonas citri* subsp. *citri* (*Xcc*), is a quarantine disease that seriously affects citrus production worldwide. The use of microorganisms and their products for biological control has been proven to be effective in controlling *Xanthomonas* disease. In this [...] Read more.

(This article belongs to the Special Issue **Biological Control of Plant Diseases Caused by Pathogenic Microorganisms (/journal/plants/special_issues/pathogenic_microorganisms)**)

Open Access Article (/2223-7747/11/3/456/pdf)

Combining Hyperspectral Reflectance Indices and Multivariate Analysis to Estimate Different Units of Chlorophyll Content of Spring Wheat under Salinity Conditions (/2223-7747/11/3/456)

by Salah El-Hendawy (https://sciprofiles.com/profile/583116), Yaser Hassan Dewir (https://sciprofiles.com/profile/591049), Salah Elsayed (https://sciprofiles.com/profile/1131871), Urs Schmidhalter (https://sciprofiles.com/profile/205001), Khalid Al-Gaadi (https://sciprofiles.com/profile/author/WG1lTHowYlNDMVc4VTVaaDlMU29lZnBCNnNwWk9QZHhlK1FRTzMwNzJicz0=), ElKamil Tola (https://sciprofiles.com/profile/101661), Yahya Refay (https://sciprofiles.com/profile/author/TFQwaGJoZVBhZTg1RTJxejhic1dvTmJRUmhNb0pQbytXVWNCN2FsQnRoUT0=), Muhammad Usman Tahir (https://sciprofiles.com/profile/author/THRha2o0bThZOXVSMDJZVVRuZkFid1FkUUluckxuMW5Cc3pVOUVNblJXdz0=) and Wael M. Hassan (https://sciprofiles.com/profile/590800)

Plants **2022**, *11*(3), 456; https://doi.org/10.3390/plants11030456 (https://doi.org/10.3390/plants11030456) - 07 Feb 2022

Abstract Although plant chlorophyll (Chl) is one of the important elements in monitoring plant stress and reflects the photosynthetic capacity of plants, their measurement in the lab is generally time- and cost-inefficient and based on a small part of the leaf. This study examines [...] Read more.

(This article belongs to the Special Issue **Salinity Stress in Plants and Molecular Responses 2.0 (/journal/plants/special_issues/salinity_stress2)**)

Open Access Article (/2223-7747/11/3/455/pdf)

UPLC-PDA-MS/MS Profiling and Healing Activity of Polyphenol-Rich Fraction of *Alhagi maurorum* against Oral Ulcer in Rats (/2223-7747/11/3/455)

by Hala El-Zahar (https://sciprofiles.com/profile/1953890), Esther T. Menze (https://sciprofiles.com/profile/author/OXhsdERkNzRKeHBiTVloSzVPK2RPaUpzUFpjRnNDN1VLZ2o1d1JGa2Eybz0=), Heba Handoussa (https://sciprofiles.com/profile/773353), Ahmed K. Osman (https://sciprofiles.com/profile/2025946), Mohamed El-Shazly (https://sciprofiles.com/profile/883701), Nada M. Mostafa (https://sciprofiles.com/profile/931034) and Noha Swilam (https://sciprofiles.com/profile/402004)

Plants **2022**, *11*(3), 455; https://doi.org/10.3390/plants11030455 (https://doi.org/10.3390/plants11030455) - 07 Feb 2022

Abstract Camelthorn, *Alhagi maurorum* Boiss, family Fabaceae has long been used in African folk medicine owing to its richness in pharmacologically active metabolites. The crude extract (CEAM), ethyl acetate fraction (EFAM) and *n*-butanol (BFAM) fraction of *A. maurorum* aerial parts were investigated for [...] Read more.

(This article belongs to the Special Issue **Polyphenols in Plants (/journal/plants/special_issues/Polyphenols_Plants)**)

► Show Figures

(/plants/plants-11-00455/article_deploy/html/images/plants-11-00455-g001a-550.jpg) (/plants/plants-11-00455/article_deploy/html/images/plants-11-00455-g001b-550.jpg) (/plants/plants-11-00455/article_deploy/html/images/plants-11-00455-g002-550.jpg) (/plants/plants-11-00455/article_deploy/html/images/plants-11-00455-g003-550.jpg) (/plants/plants-11-00455/article_deploy/html/images/plants-11-00455-g004-550.jpg) (/plants/plants-11-00455/article_deploy/html/images/plants-11-00455-g005-550.jpg) (/plants/plants-11-00455/article_deploy/html/images/plants-11-00455-g006-550.jpg)

Open Access Communication (/2223-7747/11/3/454/pdf)

Functional Antagonism of WRI1 and TCP20 Modulates *GH3.3* Expression to Maintain Auxin Homeostasis in Roots (/2223-7747/11/3/454)

by Que Kong (https://sciprofiles.com/profile/author/MjI3Um9OTjd1RG9tQUtNQUpaM0hnUHh5SDZ1dDhqWVJXS2JoR1hPS2tKRT0=), Pui Man Low (https://sciprofiles.com/profile/author/UzJsR21QVGVKaG5rTFF4eWhuV0lwdThWUFBWSEdZb2NMd0NtUE9HRFh3bz0=), Audrey R. Q. Lim (https://sciprofiles.com/profile/author/L1pzMWlqbmJhMnQ0aWpJYzdHRUpqeStta3lrNDY5S0hKQXFrNG5kL01nQT0=), Yuzhou Yang (https://sciprofiles.com/profile/author/amFEQmZPN0tlNGpNYzVXVUdNZktiaUZFYk11aUxGcmNtdHkrOUV3OWc1Zz0=), Ling Yuan (https://sciprofiles.com/profile/803627) and Wei Ma (https://sciprofiles.com/profile/754971)

Plants **2022**, *11*(3), 454; https://doi.org/10.3390/plants11030454 (https://doi.org/10.3390/plants11030454) - 07 Feb 2022

Abstract Auxin is a well-studied phytohormone, vital for diverse plant developmental processes. The *GH3* genes are one of the major auxin responsive genes, whose expression changes lead to modulation of plant development and auxin homeostasis. However, the transcriptional regulation of these *GH3* genes remains [...] Read more.

(This article belongs to the Special Issue **10th Anniversary of *Plants*—Recent Advances and Perspectives (/journal/plants/special_issues/10th_anniversary_plants)**)

► Show Figures

(/plants/plants-11-00454/article_deploy/html/images/plants-11-00454-g001-550.jpg) (/plants/plants-11-00454/article_deploy/html/images/plants-11-00454-g002-550.jpg) (/plants/plants-11-00454/article_deploy/html/images/plants-11-00454-g003-550.jpg)

Open Access Editorial (/2223-7747/11/3/453/pdf)

Crop Adaptation to Elevated CO_2 and Temperature (/2223-7747/11/3/453)
MDPI (/)
by James Bunce (https://sciprofiles.com/profile/281281)
Plants **2022**, *11*(3), 453; https://doi.org/10.3390/plants11030453 (https://doi.org/10.3390/plants11030453) - 07 Feb 2022

Abstract There is no ambiguity about the fact that both atmospheric CO_2 levels and air temperatures are continuing to increase [...] **Full article (/2223-7747/11/3/453)**
(This article belongs to the Special Issue **Crop Adaptation to Elevated CO_2 and Temperature (/journal/plants/special_issues/Crop_Temperature)**)

Open Access Article (/2223-7747/11/3/452/pdf)

Antidiabetic Activity and In Silico Molecular Docking of Polyphenols from *Ammannia baccifera* L. subsp. Aegyptiaca (Willd.) Koehne Waste: Structure Elucidation of Undescribed Acylated Flavonol Diglucoside (/2223-7747/11/3/452)

by Noha Swilam (https://sciprofiles.com/profile/402004),
Mahmoud A. M. Nawwar (https://sciprofiles.com/profile/author/dGlxRmZYMGZKa0c0SEkxMW9iMGMwNlpOOUFZTE1lUXp4WnFUV2o3VmFDdz0=),
Rasha A. Radwan (https://sciprofiles.com/profile/author/ZllwVk52U09XMS9HdXNzZ3R4S1duTUJzd0FpRlhkWnFDS1d5RlIUNGFFQT0=) and
Eman S. Mostafa (https://sciprofiles.com/profile/1501188)
Plants **2022**, *11*(3), 452; https://doi.org/10.3390/plants11030452 (registering DOI) - 06 Feb 2022

Abstract Chemical investigation of the aerial parts of *Ammania aegyptiaca* ethanol extract (AEEE) showed high concentrations of polyphenol and flavonoid content, with notable antioxidant activity. Undescribed acylated diglucoside flavonol myricetin 3-*O*-β-$^4C_1$-(6″-*O*-galloyl glucopyranoside) 7-*O* **[...] Read more.**
(This article belongs to the Special Issue **Polyphenols in Plants (/journal/plants/special_issues/Polyphenols_Plants)**)

► **Show Figures**

(/plants/plants-11-00452/article_deploy/html/images/plants-11-00452-ag-550.jpg) (/plants/plants-11-00452/article_deploy/html/images/plants-11-00452-g001-550.jpg)
(/plants/plants-11-00452/article_deploy/html/images/plants-11-00452-g002-550.jpg) (/plants/plants-11-00452/article_deploy/html/images/plants-11-00452-g003-550.jpg)
(/plants/plants-11-00452/article_deploy/html/images/plants-11-00452-g004-550.jpg) (/plants/plants-11-00452/article_deploy/html/images/plants-11-00452-g005-550.jpg)
(/plants/plants-11-00452/article_deploy/html/images/plants-11-00452-g006-550.jpg) (/plants/plants-11-00452/article_deploy/html/images/plants-11-00452-g007-550.jpg)
(/plants/plants-11-00452/article_deploy/html/images/plants-11-00452-g008-550.jpg) (/plants/plants-11-00452/article_deploy/html/images/plants-11-00452-g009-550.jpg)

Open Access Feature Paper Article (/2223-7747/11/3/451/pdf)

Flax and Sorghum: Multi-Element Contents and Nutritional Values within 210 Varieties and Potential Selection for Future Climates to Sustain Food Security (/2223-7747/11/3/451)

by Gokhan Hacisalihoglu (https://sciprofiles.com/profile/1197664) and Paul R. Armstrong (https://sciprofiles.com/profile/2023801)
Plants **2022**, *11*(3), 451; https://doi.org/10.3390/plants11030451 (https://doi.org/10.3390/plants11030451) - 06 Feb 2022

Abstract The Dietary Guidelines for Americans recommends giving priority to nutrient-dense foods while decreasing energy-dense foods. Although both flax (*Linum usitatissimum*) and sorghum (*Sorghum bicolor*) are rich in various essential minerals, their ionomes have yet to be investigated. Furthermore, previous **[...] Read more.**
(This article belongs to the Special Issue **Unraveling the Mechanisms of Zn Efficiency in Crop Plants: From Lab to Field Applications (/journal/plants/special_issues/Zn_Efficiency)**)

Open Access Review (/2223-7747/11/3/450/pdf)

Sulfur in Seeds: An Overview (/2223-7747/11/3/450)

by Sananda Mondal (https://sciprofiles.com/profile/1979173),
Kalipada Pramanik (https://sciprofiles.com/profile/author/Y0txbjRNeSsrNGVoK2g5N3BNNjZWNXd2R3BJcTc1NWFPOVp3cWw0c1hkTTFYMlBDV3dETUhKekpocTN1akh1a
,
Debasish Panda (https://sciprofiles.com/profile/2001514), Debjani Dutta (https://sciprofiles.com/profile/2030188),
Snehashis Karmakar (https://sciprofiles.com/profile/2024436) and
Bandana Bose (https://sciprofiles.com/profile/author/V0djZFlGYys4UTg1SExzTnRhMG1od2tmQldZeXVKQUhDQ3lrZHBZVGJYbz0=)
Plants **2022**, *11*(3), 450; https://doi.org/10.3390/plants11030450 (https://doi.org/10.3390/plants11030450) - 06 Feb 2022

Abstract Sulfur is a growth-limiting and secondary macronutrient as well as an indispensable component for several cellular components of crop plants. Over the years various scientists have conducted several experiments on sulfur metabolism based on different aspects of plants. Sulfur metabolism in seeds has **[...] Read more.**
(This article belongs to the Special Issue **Plant Sulfur Network (/journal/plants/special_issues/Plant_Sulfur)**)

► **Show Figures**
View PDF (chrome-extension://dagcmkpagjlhakfdhnbomgmjdpkdklff/enhanced-reader.html?openApp&pdf=https%3A%2F%2Fmdpi-res.com%2Fd_attachment%2Fplants%2Fplants-10-02237%2Farticle_deploy%2Fplants-10-02237-v2.pdf)
(/plants/plants-11-00450/article_deploy/html/images/plants-11-00450-g001-550.jpg)

Open Access Article (/2223-7747/11/3/449/pdf)

Monoterpene Synthase Genes and Monoterpene Profiles in *Pinus nigra* subsp. *laricio* (/2223-7747/11/3/449)

by Enrica Alicandri (https://sciprofiles.com/profile/2049467), Stefano Covino (https://sciprofiles.com/profile/540878),
Bartolomeo Sebastiani (https://sciprofiles.com/profile/author/UmN2c1lvalRreDlqbkxoS0RzdDhyand2WjQ0eVJldlpMWkd2a1dQclRyVT0=),
Anna Rita Paolacci (https://sciprofiles.com/profile/author/eEFDTjNlNmhRU3FyQTRmNW9yM0xoMitLMnRYUEd4Z2x3YXZQbEdXYnByND0=),
Maurizio Badiani (https://sciprofiles.com/profile/1071317), Agostino Sorgonà (https://sciprofiles.com/profile/1094059) and
Mario Ciaffi (https://sciprofiles.com/profile/1213836)
Plants **2022**, *11*(3), 449; https://doi.org/10.3390/plants11030449 (https://doi.org/10.3390/plants11030449) - 06 Feb 2022

Abstract In the present study, we carried out a quantitative analysis of the monoterpenes composition in different tissues of the non-model conifer *Pinus nigra* J.F. Arnold subsp. *laricio* Palib. ex Maire (*P. laricio*, in short). All the *P. laricio* tissues examined showed **[...] Read more.**
(This article belongs to the Section **Plant Genetics, Genomics and Biotechnology (/journal/plants/sections/Plant_Genetics)**)

More Articles... (/search?q=&journal=plants&sort=pubdate&page_count=50)

plants (/journal/plants)

Submit to *Plants* (https://susy.mdpi.com/user/manuscripts/upload?form[journal_id]=137)

Review for *Plants* (https://susy.mdpi.com/volunteer/journals/review)

View PDF (chrome-extension://dagcmkpagjlhakfdhnbomgmjdpkdklff/enhanced-reader.html?openApp&pdf=https%3A%2F%2Fmdpi-res.com%2Fd_attachment%2Fplants%2Fplants-10-02237%2Farticle_deploy%2Fplants-10-02237-v2.pdf)

Highly Accessed Articles

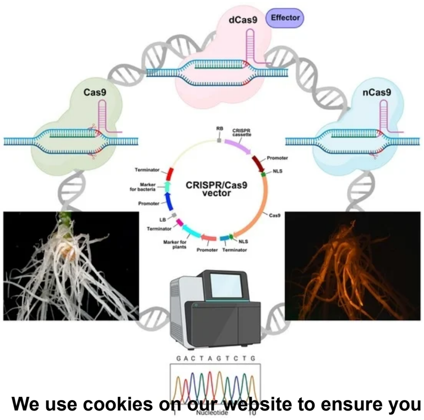
Review

Hairy CRISPR: Genome Editing in Plants Using Hairy Root Transformation (/2223-7747/11/1/51)

by **Alexey S. Kiryushkin (/search?authors=Alexey%20S.%20Kiryushkin&orcid=0000-0002-9916-4819)** et al.

Plants **2022**

Published: 24 December 2021

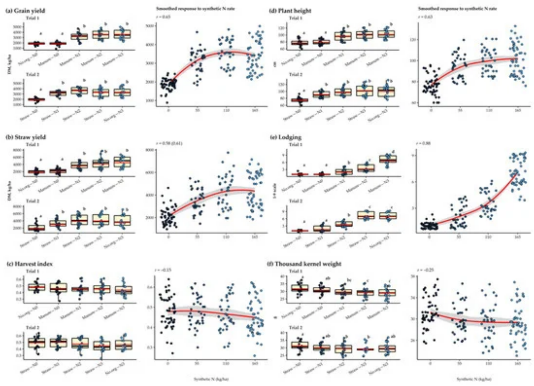


(/2223-7747/11/1/51)

Article

The Effect of Cultivation Practices on Agronomic Performance, Elemental Composition and Isotopic Signature of Spring Oat (*Avena sativa* L.) (/2223-7747/11/2/169)

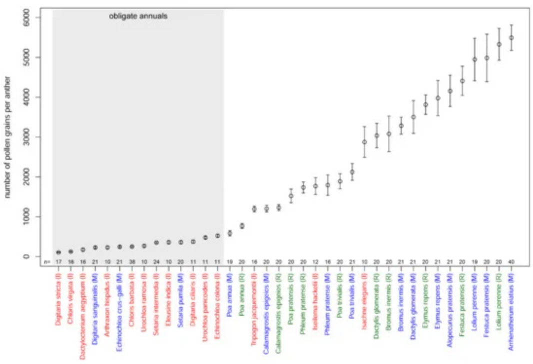
by **Aleš Kolmanič (/search?authors=Ale%C5%A1%20Kolmani%C4%8D&orcid=0000-0001-7060-2347)** et al.
(/)
Plants **2022**
Published: 9 January 2022



(/2223-7747/11/2/169)

Review
Deficiencies in the Risk Assessment of Genetically Engineered Bt Cowpea Approved for Cultivation in Nigeria: A Critical Review (/2223-7747/11/3/380)
by **Christoph Then (/search?authors=Christoph%20Then&orcid=)** et al.
Plants **2022**
Published: 29 January 2022

Article
Pollen Production of Selected Grass Species in Russia and India at the Levels of Anther, Flower and Inflorescence (/2223-7747/11/3/285)
by **Elena Severova (/search?authors=Elena%20Severova&orcid=0000-0002-0547-5625)** et al.
Plants **2022**
Published: 21 January 2022



(/2223-7747/11/3/285)

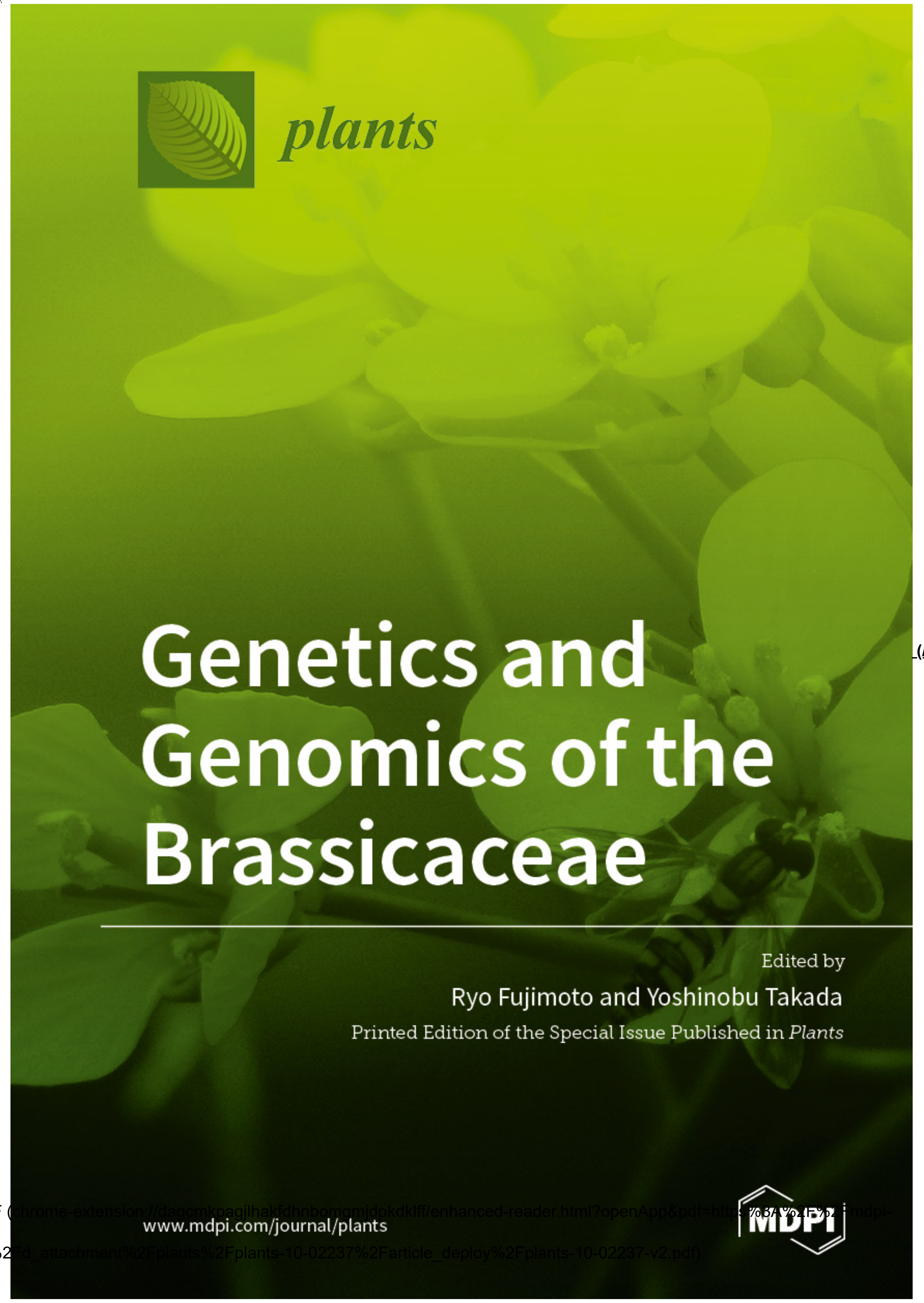
View More... (/search?q=&journal=plants&sort=article_viewedby&page_count=50)

Latest Books

Reprint Book
Genetics and Genomics of the Brassicaceae (/books/pdfview/book/4829)
Editors: Ryo Fujimoto, Yoshinobu Takada

View PDF (chrome-extension://dagcmkpagjlhakfdhnbomgmjdpkdklff/enhanced-reader.html?openApp&pdf=https%3A%2F%2Fmdpi-res.com%2Fd_attachment%2Fplants%2Fplants-10-02237%2Farticle_deploy%2Fplants-10-02237-v2.pdf)

MDPI (/)

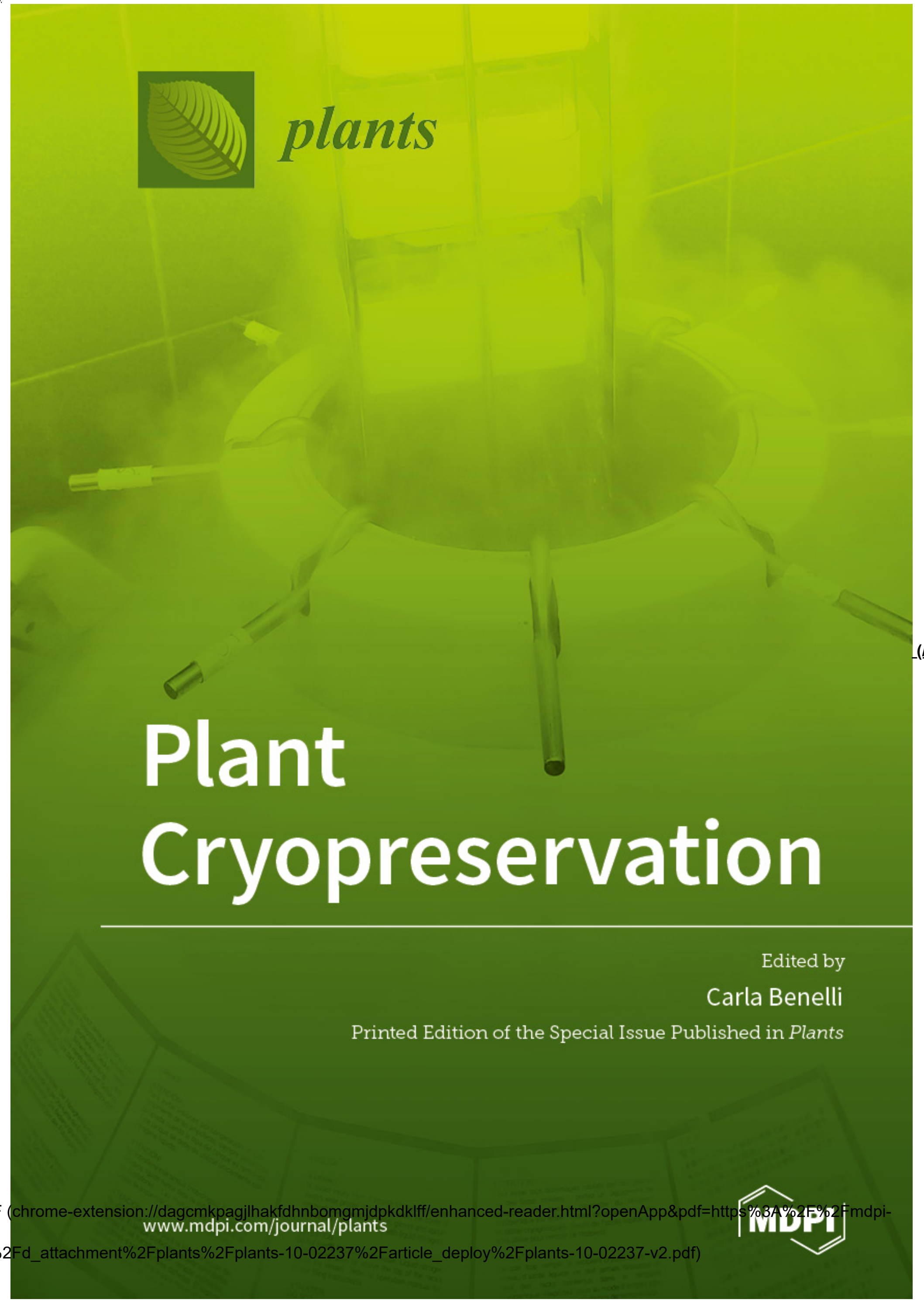


(/books/pdfview/book/4829)

View PDF (chrome-extension://dagcmkpagjlhakfdhnbomgmjdpkdklff/enhanced-reader.html?openApp&pdf=https%3A%2F%2Fmdpi-res.com%2Fd_attachment%2Fplants%2Fplants-10-02237%2Farticle_deploy%2Fplants-10-02237-v2.pdf)

Reprint Book
Plant Cryopreservation (/books/pdfview/book/4798)
Editor: Carla Benelli

MDPI (/)



(/books/pdfview/book/4798)

View PDF (chrome-extension://dagcmkpagjlhakfdhnbomgmjdpkdklff/enhanced-reader.html?openApp&pdf=https%3A%2F%2Fmdpi-res.com%2Fd_attachment%2Fplants%2Fplants-10-02237%2Farticle_deploy%2Fplants-10-02237-v2.pdf)

More Open Access Books... (/books/search?type_books=bookReprint&selectJournal=plants)

E-Mail Alert

Add your e-mail address to receive forthcoming issues of this journal:

Enter Your E-Mail Address...

Subscribe

News

22 November 2021
721 MDPI Editorial Board Members Receiving "2021 Highly Cited Researchers" Distinction (/journal/plants/announcements/3261)

16 November 2021
Topical Advisory Panel Established to Support Editorial Board (/journal/plants/announcements/3241)

25 October 2021
Open Access Week 2021 | It Matters How We Open Knowledge: Building Structural Equity, 25–31 October (/journal/plants/announcements/3198)

More News & Announcements... (/journal/plants/announcements)

Topics

Topic in *Plants*, *Microorganisms*
Mechanisms of Resistance to Plant Diseases (/topics/mechanisms_resistance_plant_diseases_volume)

Editors-in-Chief: Attila L. Ádám, Lorant Király
Deadline: 15 February 2022

Topic in *Diversity*, *Plants*, *BioChem*
Advances in Research with Bryophytes (/topics/bryophytes_research)
Deadline: 30 March 2022

Topic in *Agriculture*, *Agronomy*, *Plants*, *Horticulturae*
Physiological and Molecular Characterization of Crop Tolerance to Abiotic Stresses (/topics/Crop_Tolerance_Abiotic_Stresses)
Editors-in-Chief: Pirjo Mäkelä, Mercè Llugany, Peter A. Roussos, Mumtaz Cheema
Deadline: 1 May 2022

Topic in *Horticulturae*, *Agriculture*, *Agronomy*, *Crops*, *Plants*
Plant Nutrition Biofortification (/topics/Plant_Nutrition_Biofortification)
Deadline: 25 September 2022

More Topics (/topics?journal_id=137)

Conferences

Announce Your Conference (/events/add)

5–8 April 2022
Viruses 2022 - At the Leading Edge of Virology Research (/journal/plants/events/13959)

View PDF (chrome-extension://dagcmkpagjlhakfdhnbomgmjdpkdklff/enhanced-reader.html?openApp&pdf=https%3A%2F%2Fmdpi-res.com%2Fd_attachment%2Fplants%2Fplants-10-02237%2Farticle_deploy%2Fplants-10-02237-v2.pdf)

(/journal/plants/events/13959)

12–16 June 2022
8th International Symposium on Structure and Function of Roots (/journal/plants/events/12821)

[(/journal/plants/events/12821)](/journal/plants/events/12821)

16 February–16 April 2022

[XIV International Symposium on Plant Bioregulators in Fruit Production (/journal/plants/events/14091)](/journal/plants/events/14091)

[(/journal/plants/events/14091)](/journal/plants/events/14091)

More Conferences... (/journal/plants/events)

Special Issues

Edit a Special Issue (/journalproposal/sendproposalspecialissue/plants)

Special Issue in *Plants*
Mineral Nutrition and Plant Abiotic Stress Resistance (/journal/plants/special_issues/Mineral_Nutrition_Plant_Abiotic_Stress_Resistance)
Guest Editors: Barbara Hawrylak-Nowak, Renata Matraszek-Gawron, Sławomir Dresler
Deadline: 10 February 2022

Special Issue in *Plants*
Wild Halophytes: Tools for Understanding Salt Tolerance Mechanisms of Plants and for Adapting Agriculture to Climate Change (/journal/plants/special_issues/halophytes)
Guest Editors: Oscar Vicente, Marius-Nicusor Grigore
Deadline: 20 February 2022

Special Issue in *Plants*
Genetic Improvement of Cereal Crops for Resistance to Biotic and Abiotic Stresses (/journal/plants/special_issues/cereal_crops)
Guest Editors: Grazia Maria Borrelli, Daniela Marone
Deadline: 28 February 2022

Special Issue in *Plants*
Olive Breeding (/journal/plants/special_issues/olive_breeding)
Guest Editors: Luis Rallo, Fernando Pliego Alfaro, Pilar Rallo, Concepción Muñoz Díez, Carlos Trapero
Deadline: 15 March 2022

More Special Issues (/journal/plants/special_issues)

Topical Collections

Topical Collection in *Plants*
New Trends in Plant Science in Italy (/journal/plants/special_issues/Plant_Science_Italy)
View PDF (chrome-extension://dagcmkpagjlhakfdhnbomgmjdpkdklff/enhanced-reader.html?openApp&pdf=https%3A%2F%2Fmdpi-res.com%2Fd_attachment%2Fplants%2Fplants-10-02237%2Farticle_deploy%2Fplants-10-02237-v2.pdf)
Collection Editors: Claudio Moser, Massimo Galbiati

Topical Collection in *Plants*
New Trends in Plant Science in China (/journal/plants/special_issues/Plant_Science_China)
Collection Editors: Ming Chen, Dijun Chen

Topical Collection in *Plants*
Essential Oils of Plants (Chemical Composition, Variation and Properties) (/journal/plants/special_issues/Essential_Oils_Plants)
Collection Editors: Jésus Palá-Pául, Joe Brophy

Topical Collection in *Plants*
Feature Papers in Plant Ecology (/journal/plants/special_issues/plant_ecology_fp)
Collection Editors: Ismael Aranda, Fernando Henrique Reboredo, Roberta Masin

More Topical Collections (/journal/plants/topical_collections)

***Plants* (/journal/plants)**, EISSN 2223-7747, Published by MDPI **Disclaimer**

RSS (/rss/journal/plants) **Content Alert (/journal/plants/toc-alert)**

Further Information

Article Processing Charges (/apc)
Pay an Invoice (/about/payment)
Open Access Policy (/openaccess)
Contact MDPI (/about/contact)
Jobs at MDPI (https://careers.mdpi.com)

Guidelines

plants (/journal/plants)

IMPACT FACTOR 3.935

Covered in: PubMed

Affiliated Society:

AUSTRALIAN SOCIETY OF PLANT SCIENTISTS **(https://serve.mdpi.com/www/my_files/cliiik.php?oaparams=0bannerid=5209zoneid=4cb=7798ea**

About *Plants*

Aims

Plants (ISSN 2223-7747) is an international and multidisciplinary scientific open access journal that covers all key areas of plant science. It publishes review articles, regular research articles, communications, and short notes in the fields of structural, functional and experimental botany. In addition to fundamental disciplines such as morphology, systematics, physiology and ecology of plants, the journal welcomes all types of articles in the field of applied plant science.

The main aim of our journal is to encourage scientists and research groups to publish theoretical and experimental results of research in all fundamental and applied fields of plant science. The full experimental procedure must be provided so that the results can be reproduced. There is no limitation on the length of articles for this journal.

Scope

Journal covers the following interest areas and sub-areas in plant science:

- plant cytology and histology
- plant anatomy and morphology
- systematics, taxonomy and classification
- plant physiology and ecophysiology
- plant genetics, molecular biology and biochemistry
- ecology and biogeography of plants
- phytocenology
- evolutionary biology, plant phylogeny and paleobotany
- plant diversity and conservation biology
- experimental and applied plant science: new methods in experimental botany; biology of medicinal plants; ethnobotany; biological effects of active substances from plants; phytomedicine; new plant products, active substances and secondary metabolites; plant drug development; agricultural plants; plants derived food; horticultural plants; phytopathology; plant biotechnology; interactions between plants and other organisms; the importance of plants in the environment; the use of plants in biological control; crop protection and pesticides

MDPI Publication Ethics Statement

C O P E (http://publicationethics.org/members/publishers?name=MDPI) *Plants* is a member of the Committee on Publication Ethics (**COPE (http://publicationethics.org/)**). MDPI takes the responsibility to enforce a rigorous peer-review together with strict ethical policies and standards to ensure to add high quality scientific works to the field of scholarly publication. Unfortunately, cases of plagiarism, data falsification, inappropriate authorship credit, and the like, do arise. MDPI takes such publishing ethics issues very seriously and our editors are trained to proceed in such cases with a zero tolerance policy. To verify the originality of content submitted to our journals, we use iThenticate to check submissions against previous publications. MDPI works with **Publons (https://publons.com/)** to provide reviewers with credit for their work.

Book Reviews

Authors and publishers are encouraged to send review copies of their recent related books to the following address. Received books will be listed as *Books Received* within the journal's *News & Announcements* section.

MDPI
St. Alban-Anlage 66
CH-4052 Basel
Switzerland

E-mail: **(mailto:support@mdpi.com?subject=Book Reviews for MDPI Journals)**

Copyright / Open Access

Articles published in *Plants* will be Open-Access articles distributed under the terms and conditions of the Creative Commons Attribution License (CC BY). The copyright is retained by the author(s). MDPI will insert the following note at the end of the published text:

Reprints

Back to Top

Reprints may be ordered. Please contact (mailto:publisher@mdpi.com) for more information on how to order reprints.

Announcement and Advertisement

Announcements regarding academic activities such as conferences are published for free in the *News & Announcements* section of the journal. Advertisement can be either published or placed on the pertinent website. Contact e-mail address is (mailto:plants@mdpi.com).

Editorial Office

For further MDPI contacts, see here (/about/contact).

Article Menu

Open Access Article

Overexpression of the *Panax ginseng CYP703* Alters Cutin Composition of Reproductive Tissues in Arabidopsis

by
Jihyun Kim (https://sciprofiles.com/profile/author/bmFzdGd4THlkTDd6NngwOGxTUy8xd042NWlEcU9NdUZ6ZmdHZUxSejZWcz0=) [1,†] (mailto:please_login) (https://orcid.org/0000-0001-9994-4412),
Jeniffer Silva (https://sciprofiles.com/profile/1160821) [2,†] (mailto:please_login),
Chanwoo Park (https://sciprofiles.com/profile/author/MlJlNmhiM3hCSSs1RnFjV1V6Ukx5bE1ZWTV1VjF2cmpHR0ppMit2UzRCQT0=) [1] (mailto:please_login),
Younghun Kim (https://sciprofiles.com/profile/author/cXA3b0lOSUQ5WXN1YldkVlUzaVAzSlFOcHJ3T242cE9teWxFaHZZOEVwQT0=) [1] (mailto:please_login),
Nayeon Park (https://sciprofiles.com/profile/author/K0VOdDRWajA5QWdNQ2ZidGRGczRwQ0RkNlhyTVZJd2J1a0RwaEFCQUtXVT0=) [1] (mailto:please_login),
Johan Sukweenadhi (https://sciprofiles.com/profile/author/SHdOamR4VE1qdUtmQXNnTjVDbHRxbThlMVpUUEZHcUd2WHh0ZkZDaDAycz0=) [3] (mailto:please_login),
Junping Yu (https://sciprofiles.com/profile/author/bWdUcUgyVWFlaUNnVy8xa1hOVUpNMm90RmwzYkliN2FmcWFGbExndVRJWT0=) [4] (mailto:please_login),
Jianxin Shi (https://sciprofiles.com/profile/164724) [5] (mailto:please_login) (https://orcid.org/0000-0002-7717-0863),
Dabing Zhang (https://sciprofiles.com/profile/1054230) [5] (mailto:please_login),
Keun Ki Kim (https://sciprofiles.com/profile/author/Lzd2bzUyVGQveHBOQ3phcUVaS2hyWjh6SU90VXZqTnBKaXRnazZ4Qnk3RT0=) [1] (mailto:please_login),
Hong-Joo Son (https://sciprofiles.com/profile/1563499) [1] (mailto:please_login) (https://orcid.org/0000-0001-7186-1228),
Hyeon Cheal Park (https://sciprofiles.com/profile/author/QnpiRWF4SG5kK0RZTXFPYjhUcURqbVhvTDZyb1NqZ1NNeEhST0lML1BPcz0=) [1] (mailto:please_login),
Chang-Oh Hong (https://sciprofiles.com/profile/1561482) [1] (mailto:please_login),
Kwang Min Lee (https://sciprofiles.com/profile/1441278) [1] (mailto:please_login) (https://orcid.org/0000-0001-7691-5686) and
Yu-Jin Kim (https://sciprofiles.com/profile/1104682) [1,*] (mailto:please_login) (https://orcid.org/0000-0003-2562-615X)

[1] Department of Life Science and Environmental Biochemistry, Life and Industry Convergence Research Institute, Pusan National University, Miryang 50463, Korea
[2] Department of Research and Development, The Bridge Biofoundry, Ciudad de Saber, Clayton 0843-03081, Panama
[3] Department of Plant Biotechnology, Faculty of Biotechnology, Universitas Surabaya, Raya Kalirungkut, Kalirungkut, Surabaya 60294, East Java, Indonesia
[4] Key Laboratory of Biotechnology Shaanxi Province, College of Life Sciences, Chinese Education Ministry's Key Laboratory of Western Resources and Modern Biotechnology, Northwest University, Xi'an 710069, China
[5] Joint International Research Laboratory of Metabolic and Developmental Sciences, School of Life Sciences and Biotechnology, Shanghai Jiao Tong University, Shanghai 200240, China
* Author to whom correspondence should be addressed.
† These authors contributed equally to this work.

Academic Editor: Baohong Zhang

Plants **2022**, *11*(3), 383; https://doi.org/10.3390/plants11030383 (https://doi.org/10.3390/plants11030383)

Received: 24 December 2021 / Revised: 27 January 2022 / Accepted: 28 January 2022 / Published: 30 January 2022

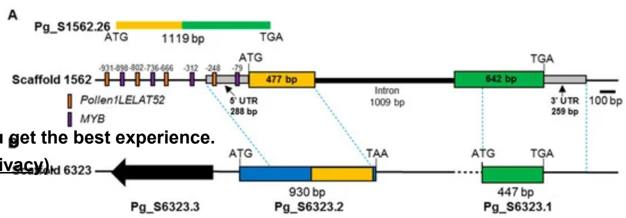
(This article belongs to the Special Issue The Role of Lipid-Hydrolyzing Proteins in Plant Growth (/journal/plants/special_issues/lipid_protein))

Abstract

Cytochrome P450 (CYP) catalyzes a wide variety of monooxygenation reactions in plant primary and secondary metabolisms. Land plants contain CYP703, belonging to the CYP71 clan, which catalyzes the biochemical pathway of fatty acid hydroxylation, especially in male reproductive tissues. Korean/Asian ginseng (*Panax ginseng* Meyer) has been regarded as one of important medicinal plant for a long time, however the molecular mechanism is less known on its development. In this study, we identified and characterized a *CYP703A* gene in *P. ginseng* (*PgCYP703A4*), regarding reproductive development. *PgCYP703A4* shared a high-sequence identity (81–83%) with predicted amino acid as CYP703 in *Dancus carota*, *Pistacia vera*, and *Camellia sinensis* as well as 76% of amino acid sequence identity with reported *CYP703* in *Arabidopsis thaliana* and 75% with *Oryza sativa*. Amino acid alignment and phylogenetic comparison of *P. ginseng* with higher plants and known *A. thaliana* members clearly distinguish the CYP703 members, each containing the AATDTS oxygen binding motif and PERH as a clade signature. The expression of *PgCYP704B1* was only detected in *P. ginseng* flower buds, particularly in meiotic cells and the tapetum layer of developing anther, indicating the conserved role on male reproduction with At- and Os- CYP703. To acquire the clue of function, we transformed the *PgCYP703A4* in *A. thaliana*. Independent overexpressing lines (*PgCYP703A4*ox) increased silique size and seed number, and altered the contents of fatty acids composition of cutin monomer in the siliques. Our results indicate that *PgCYP703A4* is involved in fatty acid hydroxylation which affects cutin production and fruit size. View Full-Text (/2223-7747/11/3/383/htm)

Keywords: cytochrome P450 (/search?q=cytochrome%20P450); reproductive tissues (/search?q=reproductive%20tissues); *PgCYP703A4* (/search?q=PgCYP703A4); fatty acid (/search?q=fatty%20acid); reproduction (/search?q=reproduction); *Panax ginseng* (/search?q=Panax%20ginseng)

▼ Show Figures



(/plants/plants-11-00383/article_deploy/html/images/plants-11-00383-g001.png) (/plants/plants-11-00383/article_deploy/html/images/plants-11-00383-g002.png)
(/plants/plants-11-00383/article_deploy/html/images/plants-11-00383-g003.png) (/plants/plants-11-00383/article_deploy/html/images/plants-11-00383-g004.png)
(/plants/plants-11-00383/article_deploy/html/images/plants-11-00383-g005.png)

Supplementary Material

Supplementary File 1:
ZIP-Document (/2223-7747/11/3/383/s1) (ZIP, 787 KiB)

Share and Cite

(mailto:?&subject=From%20MDPI%3A%20%22Overexpression%20of%20the%20Panax%20ginseng%20CYP703%20Alters%20Cutin%20Composition%20of%20Reproductive%20Tissues
sequence%20identity%20%2881%26ndash%3B83%25%29%20with%20predicted%20amino%20acid%20as%20CYP703%20in%20Dancus%20carota%2C%20Pistacia%20vera%2C
(https://twitter.com/intent/tweet?text=Overexpression+of+the+Panax+ginseng+CYP703+Alters+Cutin+Composition+of+Reproductive+Tissues+in+Arabidopsis&hashtags=mdpiplants&url=https%3A%2F%2Fw
(http://www.linkedin.com/shareArticle?mini=true&url=https%3A%2F%2Fwww.mdpi.com%2F1477478&title=Overexpression%20of%20the%20Panax%20ginseng%20CYP703%20Alters%20Cutin%20Composition%20of
(https://www.facebook.com/sharer.php?u=https://www.mdpi.com/1477478) (https://www.reddit.com/submit?url=https://www.mdpi.com/1477478)
(https://www.mendeley.com/import/?url=https://www.mdpi.com/1477478)

MDPI and ACS Style

Kim, J.; Silva, J.; Park, C.; Kim, Y.; Park, N.; Sukweenadhi, J.; Yu, J.; Shi, J.; Zhang, D.; Kim, K.K.; Son, H.-J.; Park, H.C.; Hong, C.-O.; Lee, K.M.; Kim, Y.-J. Overexpression of the *Panax ginseng CYP703* Alters Cutin Composition of Reproductive Tissues in Arabidopsis. *Plants* **2022**, *11*, 383. https://doi.org/10.3390/plants11030383

AMA Style

Kim J, Silva J, Park C, Kim Y, Park N, Sukweenadhi J, Yu J, Shi J, Zhang D, Kim KK, Son H-J, Park HC, Hong C-O, Lee KM, Kim Y-J. Overexpression of the *Panax ginseng CYP703* Alters Cutin Composition of Reproductive Tissues in Arabidopsis. *Plants*. 2022; 11(3):383. https://doi.org/10.3390/plants11030383

Chicago/Turabian Style

Kim, Jihyun, Jeniffer Silva, Chanwoo Park, Younghun Kim, Nayeon Park, Johan Sukweenadhi, Junping Yu, Jianxin Shi, Dabing Zhang, Keun K. Kim, Hong-Joo Son, Hyeon C. Park, Chang-Oh Hong, Kwang M. Lee, and Yu-Jin Kim. 2022. "Overexpression of the *Panax ginseng CYP703* Alters Cutin Composition of Reproductive Tissues in Arabidopsis" *Plants* 11, no. 3: 383. https://doi.org/10.3390/plants11030383

Find Other Styles

Type a publisher, journal or format name

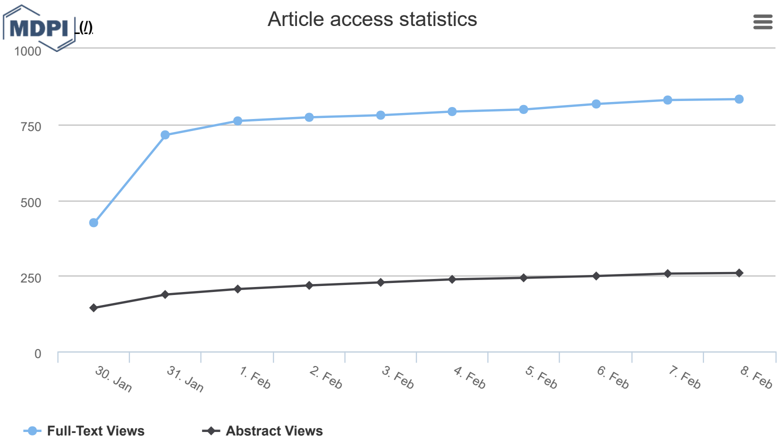
Note that from the first issue of 2016, MDPI journals use article numbers instead of page numbers. See further details **here (https://www.mdpi.com/about/announcements/784)**.

Article Metrics

Citations

Crossref	Google Scholar
0	title=Overexpression+of+the

Article Access Statistics



For more information on the journal statistics, click **here (/journal/plants/stats)**.

Multiple requests from the same IP address are counted as one view.

Author Biographies

Kwang Min Lee (https://sciprofiles.com/profile/1441278)

He is professor of Department of Life Science and Environmental Biochemistry, Life

Yu-Jin Kim (https://sciprofiles.com/profile/1104682)

https://www.researchgate.net/profile/Yu-Jin-Kim

Plants (/journal/plants), EISSN 2223-7747, Published by MDPI **Disclaimer**

plants (/journal/plants)

IMPACT FACTOR 3.935

Covered in: PubMed

Submit to *Plants* (https://susy.mdpi.com/user/manuscripts/upload?form[journal_id]=137)

Review for *Plants* (https://susy.mdpi.com/volunteer/journals/review)

Journal Menu

► Journal Menu

- *Plants* Home (/journal/plants)
- Aims & Scope (/journal/plants/about)
- Editorial Board (/journal/plants/editors)
- Reviewer Board (/journal/plants/submission_reviewers)
- Topical Advisory Panel (/journal/plants/topical_advisory_panel)
- Instructions for Authors (/journal/plants/instructions)
- Special Issues (/journal/plants/special_issues)
- Sections & Collections (/journal/plants/sections)
- Article Processing Charge (/journal/plants/apc)
- Indexing & Archiving (/journal/plants/indexing)
- Editor's Choice Articles (/journal/plants/editors_choice)
- Most Cited & Viewed (/journal/plants/most_cited)
- Journal Statistics (/journal/plants/stats)
- Journal History (/journal/plants/history)
- Journal Awards (/journal/plants/awards)
- Society Collaborations (/journal/plants/societies)
- Conferences (/journal/plants/events)
- Editorial Office (/journal/plants/editorial_office)

Journal Browser

► Journal Browser

volume

Affiliated Society:

SOCIEDAD ESPAÑOLA DE FITOPATOLOGÍA (https://serve.mdpi.com/www/my_files/cliiik.php?oaparams=0bannerid=6555zoneid=4cb=66f27c1f

Editorial Board

- Advisory Board
- Editorial Board
- Plant Physiology and Metabolism Section (/journal/plants/sectioneditors/Plant_Physiology_Metabolism)
- Phytochemistry Section (/journal/plants/sectioneditors/phytochemistry)
- Plant Protection and Biotic Interactions Section (/journal/plants/sectioneditors/plant_protection)
- Plant Molecular Biology Section (/journal/plants/sectioneditors/Plant_Molecular_Biology)
- Plant Development and Morphogenesis Section (/journal/plants/sectioneditors/plant_morphology)
- Plant Ecology Section (/journal/plants/sectioneditors/functional_plant_ecology)
- Plant Cell Biology Section (/journal/plants/sectioneditors/plant_cell_biol)

- Plant Systematics, Taxonomy, Nomenclature and Classification Section (/journal/plants/sectioneditors/Plant_Systematics_Taxonomy_Nomenclature_and_Classification)
- Plant Genetics, Genomics and Biotechnology Section (/journal/plants/sectioneditors/Plant_Genetics)
- Plant Modeling Section (/journal/plants/sectioneditors/plant_modeling)
- Plant Response to Abiotic Stress and Climate Change Section (/journal/plants/sectioneditors/plant_response_abiotic_stress)
- Plant Nutrition Section (/journal/plants/sectioneditors/Plant_Nutrition)
- Plant–Soil Interactions Section (/journal/plants/sectioneditors/plant-soil-interactions)
- Crop Physiology and Crop Production Section (/journal/plants/sectioneditors/Crop_Physiology_Crop_Production)
- Plant Structural Biology Section (/journal/plants/sectioneditors/Plant_Structural_Biology)
- Plant Systems and Synthetic Biology Section (/journal/plants/sectioneditors/Plant_Systems_Synthetic_Biology)
- Horticultural Science and Ornamental Plants Section (/journal/plants/sectioneditors/Horticultural_Science_Ornamental_Plants)
- Plant Genetic Resources Section (/journal/plants/sectioneditors/Plant_Genetic_Resources)

Editors (19)

Prof. Dr. Dilantha Fernando

Website (http://home.cc.umanitoba.ca/%7Efernando/) SciProfiles (https://sciprofiles.com/profile/3066)

Editor-in-Chief

Department of Plant Science, University of Manitoba, Winnipeg, MB R3T 2N2, Canada

Interests: canola and wheat pathology; epidemiology of plant pathogens; evolution/genetic variation of fungal pathogens; biological control of plant diseases; breeding for disease resistance microbial; ecology and microbial interactions

Special Issues, Collections and Topics in MDPI journals

Dr. Yong-Bi Fu *

Website (http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1181940775526&lang=eng)

SciProfiles (https://sciprofiles.com/profile/7708)

Section Editor-in-Chief

Plant Gene Resources of Canada, Saskatoon Research Centre, Agriculture and Agri-Food Canada, 107 Science Place, Saskatoon, SK S7N 0X2, Canada

Interests: crop genetic diversity and domestication; plant population and conservation genetics; molecular characterization and conservation of plant germplasm; in situ conservation and utilization of native plants; molecular markers and DNA sequence analysis

* Section: Plant Genetic Resources

Prof. Dr. Baohong Zhang *

Website (https://biology.ecu.edu/faculty/baohong-zhang/) SciProfiles (https://sciprofiles.com/profile/130933)

Section Editor-in-Chief

Department of Biology, East Carolina University, Greenville, NC 27858, USA

Interests: genome editing; small regulatory RNAs; molecular genetics; plant biotechnology; abiotic stress; gene expression and regulation

* Section: Plant Systems and Synthetic Biology

Special Issues, Collections and Topics in MDPI journals

Dr. Fermin Morales *

Website (https://www.idab.csic.es/agricultura-sostenible-y-ecotoxicologia/) SciProfiles (https://sciprofiles.com/profile/723188)

Section Editor-in-Chief

Instituto de Agrobiotecnología (IdAB), CSIC-Gobierno de Navarra, Avda. de Pamplona 123, 31192 Mutilva, Navarra, Spain

Interests: agronomy; elevated CO_2; elevated temperature; grapevine biology; photosynthesis; plant adaptation to climate change; plant nutrition; plant physiology; plant stress physiology; water stress

Prof. Dr. Luigi Sanita' di Toppi *

Website (https://www.researchgate.net/profile/Luigi_Sanita_Di_Toppi) **SciProfiles (https://sciprofiles.com/profile/674174)**

Section Editor-in-Chief

Department of Biology, University of Pisa, via Luca Ghini 13, 56126 Pisa, Italy

Interests: heavy metals; metal homeostasis; phytochelatins; phytochelatin synthase; glutathione; plant evolution; lichens

* Section: Plant Response to Abiotic Stress and Climate Change

Special Issues, Collections and Topics in MDPI journals

Prof. Dr. Adriano Sofo *

Website (http://oldwww.unibas.it/utenti/sofo/home-eng.htm) **SciProfiles (https://sciprofiles.com/profile/43381)**

Section Editor-in-Chief

Department of European and Mediterranean Cultures: Architecture, Environment and Cultural Heritage (DiCEM), University of Basilicata, Via Lanera 20, 75100 Matera, Italy

Interests: agricultural and environmental chemistry; environmental botany; soil ecology

* Section: Plant–Soil Interactions

Special Issues, Collections and Topics in MDPI journals

Dr. Chris Helliwell

Website (https://people.csiro.au/H/C/Chris-Helliwell)

Associate Editor

CSIRO Agriculture and Food, Canberra, ACT 2601, Australia

Interests: plant development; flowering; epigenetics; brassica crops; RNAi; gene editing

Prof. Dr. Masayuki Fujita

SciProfiles (https://sciprofiles.com/profile/81323)

Associate Editor

Laboratory of Plant Stress Responses, Department of Plant Science, Faculty of Agriculture, Kagawa University, Miki-cho, Kita-gun, Kagawa 761-0795, Japan

Interests: plant stress physiology; plant biochemistry; abiotic stress

Special Issues, Collections and Topics in MDPI journals

Prof. Dr. Milan S. Stankovic

Website (https://www.pmf.kg.ac.rs/?id=284) **SciProfiles (https://sciprofiles.com/profile/7566)**

Associate Editor

Department of Biology and Ecology, Faculty of Science, University of Kragujevac, Str. Radoja Domanovića No. 12, 34000 Kragujevac, Serbia

Interests: plant biology and ecology

Special Issues, Collections and Topics in MDPI journals

Prof. Dr. Petronia Carillo *

Website (https://www.distabif.unicampania.it/dipartimento/docenti?MATRICOLA=057969)

SciProfiles (https://sciprofiles.com/profile/482582)

Section Associate Editor

Department of Environmental Biological and Pharmaceutical Sciences and Technologies University of Campania "Luigi Vanvitelli" Via Vivaldi 43, 81100 Caserta, Italy

Interests: role of compatible osmolytes in stress responses; plant metabolic profiling; regulation of carbon and nitrogen metabolism; effects of biostimulants on plant metabolism

* Section: Plant Physiology and Metabolism
MDPI (/)
Special Issues, Collections and Topics in MDPI journals

Prof. Dr. Veronica De Micco *
Website (https://www.docenti.unina.it/#!/professor/5645524f4e4943414445204d4943434f444d43564e4337375036344334 39354d/avvisi)
SciProfiles (https://sciprofiles.com/profile/829271)
Section Associate Editor
Department of Agricultural Sciences, University of Naples Federico II, 80055 Portici, NA, Italy
Interests: functional anatomical traits; linking structure and eco-physiology; plant hydraulics; wood formation; dendroecology; quantitative wood anatomy; stable isotopes; drought; ionizing radiation; altered gravity; crop biology in CEA; Mediterranean ecosystems; plant adaptive strategies in extra-terrestrial environments
* Section: Plant Response to Abiotic Stress and Climate Change
Special Issues, Collections and Topics in MDPI journals

Prof. Dr. Filippo Maggi *
Website (https://www.researchgate.net/profile/Filippo_Maggi) **SciProfiles (https://sciprofiles.com/profile/190370)**
Section Associate Editor
School of Pharmacy, University of Camerino, Camerino, Italy
Interests: medicinal and aromatic plants; essential oils; green extraction; phytochemistry; bioactivity
* Section: Phytochemistry
Special Issues, Collections and Topics in MDPI journals

Dr. Sotiris Tjamos *
Website (http://efp.aua.gr/en/userpages_en/61) **SciProfiles (https://sciprofiles.com/profile/570198)**
Section Associate Editor
Phytopathology Department, Agricultural University of Athens, 11855 Athens, Greece
Interests: biological control; epigenetics; microbial volatile organic conmpounds; plant–microbe interactions; soil-borne diseases; induced systemic resistance
* Section: Plant Protection and Biotic Interactions
Special Issues, Collections and Topics in MDPI journals

Dr. Christian Meyer *
Website (http://annuaire.inra.fr/afficherActivite.action?code=5133&type=AC) **SciProfiles (https://sciprofiles.com/profile/1272496)**
Section Associate Editor
Institut Jean-Pierre Bourgin, French National Institute for Agriculture, Food, and Environment (INRAE), Paris, France
Interests: role of the TOR kinase signalling pathway in plants; nitrate signalling
* Section: Crop Physiology and Crop Production

Advisory Board (2)

Prof. Dr. Shuangxia Jin
Website (https://www.researchgate.net/profile/Shuangxia_Jin) **SciProfiles (https://sciprofiles.com/profile/304371)**
College of Plant Science and Technology, Huazhong Agricultural University, Wuhan 430070, China
Interests: plant biotechnology (genome editing, transgenic methods, chloroplast transformations); plant genome; genomics; Omics; big data and so[illegible]

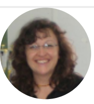
MDPI (/)

Prof. Dr. Gennaro Agrimi
[Website (https://www.uniba.it/docenti/agrimi-gennaro/en/docente)] [SciProfiles (https://sciprofiles.com/profile/233265)]
Department of Biosciences, Biotechnology and Biopharmaceutics, University of Bari, Bari, Italy
Interests: mitochondria; mitochondrial transporters; metabolism; TCA cycle-connected metabolism; organic acid metabolism; metabolic engineering

Dr. Mukhtar Ahmed
[Website1 (https://www.slu.se/en/ew-cv/mukhtar-ahmed/)] [Website2 (http://www.uaar.edu.pk/fcfs/faculty_details.php?fac_id=94&dept_id=1)] [SciProfiles (https://sciprofiles.com/profile/642768)]
1. Swedish University of Agricultural Sciences, Uppsala, Sweden
2. PMAS Arid Agriculture University, Rawalpindi, Punjab , Pakistan
Interests: agronomy; agroecosystems modeling; cropping systems; farm modeling; crop physiology; nutrients cycling; climate change; impact assessments; adaptation and mitigation
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***Sustainability*: Climate Resilient Sustainable Agricultural Production Systems (/journal/sustainability/special_issues/sust_agricult_prod_syst)**
Special Issue in ***Plants*: Agroecosystem Modeling (/journal/plants/special_issues/Agroecosystem_Modeling)**
Special Issue in ***Plants*: Plant Responses to Biotic and Abiotic Stresses: Crosstalk between Biochemistry and Ecophysiology (/journal/plants/special_issues/plant_Crosstalk)**
Special Issue in ***Sustainability*: Sustainable Agriculture Through Technological Intervention (/journal/sustainability/special_issues/sustainable_agri_tech_intervention)**

Prof. Dr. Mi-Jeong Ahn
[Website (https://www.marketscreener.com/business-leaders/Mi-Jung-Ahn-0FWVF7-E/biography/)]
[SciProfiles (https://sciprofiles.com/profile/483340)]
Gyeongsang National University, Jinju, South Korea
Interests: Standardization of herbal medicines (Inner-morphological study and chemical profiles); Natural products chemistry; Metabolomics

Dr. Anna Aksmann
[Website (https://www.researchgate.net/profile/Anna_Aksmann)] [SciProfiles (https://sciprofiles.com/profile/1028296)]
Department of Plant Physiology and Biotechnology, Faculty of Biology, University of Gdansk, Wita Stwosza str. 59, PL-80-308 Gdansk, Poland
Interests: abiotic stress; anthropogenic pollutants (herbicides, pharmaceuticals); green algae response to stress factors; Chlamydomonas reinhardtii; plant physiology and biochemistry
Special Issues, Collections and Topics in MDPI journals
Topical Collection in ***Plants*: Plant, Algae and Lichen Response to Abiotic Stress: from Molecules to Ecosystems (/journal/plants/special_issues/plant_algae_lichen_abiotic)**



Dr. Josefa M. Alamillo
[Website (http://www.uco.es/organiza/departamentos/botanica/es/personal/fisiologia-vegetal/personal-docente-e-investigador/54-personal/fisiologia-vegetal/personal-docente-e-investigador/135-josefa-munoz-alamillo)]
[SciProfiles (https://sciprofiles.com/profile/685530)]
Departamento de Botánica, Ecología y Fisiología Vegetal, Grupo de Fisiología Molecular y Biotecnología de Plantas, Campus de Excelencia Internacional Agroalimentario, CEIA3, Universidad de Córdoba, 1407 Córdoba, Spain
Interests: abiotic stress; drought tolerance; legumes; nitrogen fixation; purine nucleotides metabolism; ureides
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***Plants*: Drought Tolerance in Common Bean (/journal/plants/special_issues/Drought_Tolerance_Common_Bean)**

MDPI (/)

Prof. Dr. Emidio Albertini
[Website (https://www.unipg.it/personale/emidio.albertini/)] [SciProfiles (https://sciprofiles.com/profile/666196)]
Department of Agricultural, Food and Environmental Sciences, University of Perugia, 06121 Perugia, Italy
Interests: plant reproduction; epigenetics; apomixis; stresses; tomato; grape
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***Plants*: DNA Methylation in Plants (/journal/plants/special_issues/DNA_methylation_plants)**
Special Issue in ***International Journal of Molecular Sciences*: Molecular Analysis of Crop Diversity (/journal/ijms/special_issues/omic_analysis_crop)**

Prof. Dr. Robin G. Allaby
Website (https://warwick.ac.uk/fac/sci/lifesci/people/rallaby/)
School of Life Sciences, University of Warwick, Coventry CV4 7AL, UK
Interests: domestication; archaeogenomics; crop origins; crop evolution

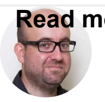
Prof. Dr. Artur Alves
Website (http://www.cesam.ua.pt/aalves) SciProfiles (https://sciprofiles.com/profile/525736)
CESAM-Centre for Environmental and Marine Studies, Department of Biology, University of Aveiro, 3810-193 Aveiro, Portugal
Interests: plant pathology; fungi; secondary metabolites; plant-microbe interactions
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***Microorganisms*: Fungal–Plant Interactions under Climate Change (/journal/microorganisms/special_issues/fungal_plant_climate)**

Prof. Dr. Mariana Amato
SciProfiles (https://sciprofiles.com/profile/1068781)
School oh Agriculture Forestry Food and, Environmental Sciences, Università della Basilicata, Viale dell'Ateneo Lucano 10, 85100 Potenza, Italy
Interests: plant roots; soil physics; soil-plant interactions; agronomy; geophysical methods for plant root research

Prof. Dr. Stephen O. Amoo
Website (https://www.arc.agric.za/arc-vopi/Pages/Crop%20Science/Medicinal-Plants.aspx)
SciProfiles (https://sciprofiles.com/profile/381390)
Agricultural Research Council–Vegetables, Industrial and Medicinal Plants, Private Bag X293, Pretoria 0001, South Africa
Interests: plant growth regulators; phytohormones; indigenous plant use; micropropagation; secondary metabolite production; biological activities; medicinal plants; plant tissue culture; ethnopharmacology; antimicrobial activity; ethnobotany; plant biotechnology; biostimulants; plant production
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***Plants*: Propagation and Cultivation of Medicinal Plants (/journal/plants/special_issues/propagation_medicinal_plants)**

Prof. Dr. Asunción Amorós
Website (https://universite.umh.es/profesores/fichaprofesor.asp?NP=3846) SciProfiles (https://sciprofiles.com/profile/896934)
Department of Applied Biology, Escuela Politécnica Superior de Orihuela (Miguel Hernández University of Elche), Ctra. Beniel Km 3.2, 03312 Orihuela, Spain
Interests: ethylene; brassinosteroid; phenols; antioxidant activity; jujube; capper

MDPI (/)



Dr. Iker Aranjuelo
Website (http://idab.es/grupo-de-investigacion-de-agricultura-sostenible-y-cambio-climatico/)
SciProfiles (https://sciprofiles.com/profile/657179)
Agrobiotechnology Institute (IdAB-CSIC)-Gobierno de Navarra, Campus de Arrosadia, E-31192-Mutilva Baja, Spain
Interests: climate change; cereals; N2 fixers; resource use efficiency; photosynthesis; stable isotopes; sustainable agriculture; yield and quality traits
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***Plants*: Photosynthetic Metabolism under Stressful Growth Conditions (/journal/plants/special_issues/Photosynthetic_Metabolism)**
Special Issue in ***Plants*: Cereal Physiology and Breeding (/journal/plants/special_issues/Cereal_Physiology_Breeding)**
Special Issue in ***Plants*: Crop Cultivation and Low Carbon Agriculture (/journal/plants/special_issues/Carbon_Agriculture)**

Dr. Vicent Arbona
Website (http://www.ecofisiologia.uji.es) SciProfiles (https://sciprofiles.com/profile/436617)
Departament de Ciències Agràries i del Medi Natural, Universitat Jaume I, Castelló de la Plana, Spain
Interests: abiotic stress; Arabidopsis; biochemistry; citrus; drought; flooding; metabolomics; plant physiology; tomato
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***International Journal of Molecular Sciences*: Plant Metabolism in Crops: A Systems Biology Perspective (/journal/ijms/special_issues/plants_metabolism)**

Prof. Dr. Carmen Arena
Website (http://www.dipartimentodibiologia.unina.it/personale/carmen-arena/) SciProfiles (https://sciprofiles.com/profile/969068)
University of Naples Federico II, Department of Biology, Naples, Italy
Interests: plant ecology; photosynthetic regulation mechanisms; antioxidant defences; plant-soil interactions; plants and abiotic stress; pollutants and photosynthesis
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***Plants*: Effects of Abiotic Stress on Plants 2020–2021 (/journal/plants/special_issues/Effects_Abiotic_Stress)**
Special Issue in ***Agriculture*: Cropping Systems: Implications on Climate and Environment (/journal/agriculture/special_issues/cropping_systems)**
Special Issue in ***Plants*: Oxidative Stress, PolyADP(ribosyl)ation and Antioxidant Defenses in Plants (/journal/plants/special_issues/Antioxidant_Defenses)**

Prof. Dr. Fernando Ponz Ascaso
Website (http://www.cbgp.upm.es/index.php/es/?option=com_content&view=article&id=18&x=1422)
Centro de Biotecnología y Genómica de Plantas (UPM-INIA), Campus Montegancedo, Autopista M40, km 38. Pozuelo de Alarcón, 28223 Madrid, Spain
Interests: plant-virus interactions; virus nanobiotechnology; plant molecular farming

Prof. Dr. Hagop Atamian
Website (https://www.chapman.edu/our-faculty/hagop-atamian) SciProfiles (https://sciprofiles.com/profile/480278)
Schmid College of Science and Technology, Chapman University, Orange, CA 92866, USA
Interests: understanding the molecular mechanisms of plant interactions with the environment; biotic interactions (insects, bacteria, fungi, nematodes); various biotic stresses (drought, cold, heat); high throughput sequencing; plant genotype and environment interactions

Prof. Dr. Jean-Christophe Avice
Website (https://www6.rennes.inra.fr/umreva) SciProfiles (https://sciprofiles.com/profile/138854)

UMR INRA-UCBN 950 Ecophysiologie Végétale, Agronomie & Nutritions N.C.S., UFR des Sciences, FED 4277 Normandie Végétal, Université de Caen Normandie, F-14032 Caen, France

Interests: nutrient use efficiency; plant nutrition; nitrogen and sulfur fertilization; plant responses to abiotic stress; plant senescence; seed quality; remobilization of nutrients; proteolytic mechanisms

Special Issues, Collections and Topics in MDPI journals

Special Issue in ***Plants*: Advances in Plant Sulfur Research (/journal/plants/special_issues/Sulfur_Metabolism)**

Dr. Germán Avila Sakar

Website (https://ion.uwinnipeg.ca/~gavila/) **SciProfiles (https://sciprofiles.com/profile/660770)**

Department of Biology, University of Winnipeg, 599 Portage Ave., Winnipeg, MB R3B 2G3, Canada

Interests: plant–animal interactions; herbivory; tolerance; resistance; resource allocation; sexual systems of plants; dioecy; monoecy; pollination; evolution of plant responses to herbivores; evolution of plant mating systems

Special Issues, Collections and Topics in MDPI journals

Special Issue in ***Plants*: Interaction Between Abiotic and Biotic Stresses in Plants (/journal/plants/special_issues/plant-salt-stress)**

Special Issue in ***Plants*: Interactions Between Abiotic and Biotic Stresses in Plants (/journal/plants/special_issues/stress_plants)**

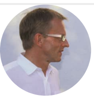
Special Issue in ***Plants*: Plant Evolutionary Ecology (/journal/plants/special_issues/Plant_Evolutionary_Ecology)**

Dr. Aziz Aziz

Website (https://www.univ-reims.fr/minisite_173/our-research-groups/immunity-and-beneficial-microorganisms/immunity-and-beneficial-microorganisms,22730,37873.html) **SciProfiles (https://sciprofiles.com/profile/250915)**

Lab RIBP 4707, University of Reims Champagne-Ardenne, SFR Condorcet FR-CNRS 3417, 51100 Reims, France

Interests: Plant-microbe interactions; beneficial microorganisms; Plant Immunity; signaling, metabolism; Induced resistance; plant defense; interactions between biotic and abiotic stresses



Dr. Christian Bachem

Website (https://www.wur.nl/en/Persons/Christiandr.-CWB-Christian-Bachem.htm) **SciProfiles (https://sciprofiles.com/profile/42113)**

Plant Breeding, Wageningen University and Research, Wageningen, The Netherlands

Interests: molecular signaling; plant organ development; sexual and vegetative reproduction; molecular environment-genotype interactions; abiotic stress; potato and Solanaceae biology

Prof. Dr. Tony Bacic

Website (https://scholars.latrobe.edu.au/display/tbacic) **SciProfiles (https://sciprofiles.com/profile/1293625)**

1. Department of Animal, Plant and Soil Sciences, School of Life Sciences, La Trobe University, Bundoora VIC 3068, Australia

2. Department of Forestry, School of Forestry and Biotechnology, Zhejiang A & F University, Lin'an District, Hangzhou 311300, China

Interests: structure, function & biosynthesis of complex carbohydrates; cell walls; cell surfaces; mechano-sensing; plant cell and molecular biology; plant physiology; plant biochemistry; proteomics; metabolomics; glycomics

Prof. Dr. Martin Backor

Website (http://martinbackor.science.upjs.sk/) **SciProfiles (https://sciprofiles.com/profile/1028295)**

Department of Botany, Institute of Biology and Ecology, P. J. Safarik University in Kosice, Manesova 23, 041 67 Kosice, Slovakia

Interests: lichens; algae; mosses; abiotic stress; heavy metals; secondary metabolism of lichens; polar ecology of lower plants

Special Issues, Collections and Topics in MDPI journals

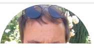
Topical Collection in ***Plants*: Plant, Algae and Lichen Response to Abiotic Stress: from Molecules to Ecosystems (/journal/plants/special_issues/plant_algae_lichen_abiotic)**

Special Issue in ***Plants*: Secondary Metabolites from Lichens and Biological Activity (/journal/plants/special_issues/secondary_metabolites_lichens_biological_activity)**

MDPI (/)

Dr. Aneta Helena Baczewska-Dąbrowska
[Website (https://www.researchgate.net/profile/Aneta_Baczewska-Dabrowska)]
Center for Conservation of Biological Diversity, Polish Academy of Sciences Botanical Garden, 02-973 Warsaw, 2 St. Prawdziwka, Poland
Interests: biotic and abiotic stress; trees; biomonitoring; environmental pollution
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***Plants*: Plants in Built-Up Areas (/journal/plants/special_issues/Plants_Built_Up)**

Prof. Dr. Kwang-Hyun Baek
Website (https://www.researchgate.net/profile/Kwang-Hyun_Baek) SciProfiles (https://sciprofiles.com/profile/102108)
Department of Biotechnology, Yeungnam University, Gyeongsan, Gyeongbuk 38451, Korea
Interests: antimicrobial agents; synergistic effects; nanoparticles; essential oils; secondary metabolites; plant extracts; bacteria; fungi; viruses; multidrug-resistant; microorganisms
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***Molecules*: Advances of Metal and Metal Oxide Nanocomposites: Synthesis, Characterization and Biomedical Applications (/journal/molecules/special_issues/metal_nanocomposites_biomedical)**
Special Issue in ***Plants*: Impact of Metal and Metal Oxide Nanomaterials on Plant Research: Recent Advances and Challenges (/journal/plants/special_issues/metal_nanos)**



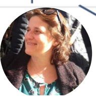
Dr. Christophe Bailly
Website (https://www.researchgate.net/profile/Christophe_Bailly) SciProfiles (https://sciprofiles.com/profile/1044055)
Sorbonne Université, Institut de Biologie Paris-Seine (IBPS), UMR7622 "Biologie du Développement", Paris, France
Interests: seed; dormancy; germination; longevity; reactive oxygen species; transcriptome; RNA metabolism; abiotic stress
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***International Journal of Molecular Sciences*: Physiological and Environmental Regulation of Seed Germination: From Signaling Events to Molecular Responses (/journal/ijms/special_issues/sdn)**

Dr. Andrzej Bajguz
Website (https://biologia.uwb.edu.pl/pracownicy/andrzej-bajguz-1/)
Department of Biology and Plant Ecology, Faculty of Biology, University of Bialystok, 15-245 Bialystok, Poland
Interests: adaptation to heavy metal stress; brassinosteroids; phytoecdysteroids; phytohormones
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***International Journal of Molecular Sciences*: Hormones and Animal-Derived Compounds of Plants (/journal/ijms/special_issues/hormones_plant)**
Special Issue in ***International Journal of Molecular Sciences*: Metal Stress in Plants (/journal/ijms/special_issues/Metal_Stress_Plants)**

Dr. Bénédicte Bakan
Website (https://www6.angers-nantes.inra.fr/bia/Page-d-accueil/Annuaire/B/BAKAN-Benedicte)
SciProfiles (https://sciprofiles.com/profile/334156)
INRA, Biopolymers Interactions Assemblies Research unit, La Géraudière, CEDEX 3, 44316 Nantes, France
Interests: fruit cuticles; polysaccharides; polyester; cutin; cutin synthase; gdsl-lipase

Dr. Salma Balazadeh
Website1 (https://www.mpimp-golm.mpg.de/balazadeh) Website2 (https://www.universiteitleiden.nl/en/staffmembers/salma-balazadeh#tab-1) SciProfiles (https://sciprofiles.com/profile/125040)
Institute of Molecular Plant Physiology, University of Potsdam and Max-Planck, Potsdam-Golm, Germany
Interests: transcription factors (TFs), gene regulatory networks (GRNs), leaf growth, senescence, abiotic stress, priming and memory
Special Issues, Collections and Topics in MDPI journals

Special Issue in ***Plants*: Plant Senescence (/journal/plants/special_issues/senescence)**



Prof. Dr. Raffaella Maria Balestrini

Website (http://www.ipsp.cnr.it/researchers/balestrini-raffaella-maria/?lang=en) **SciProfiles (https://sciprofiles.com/profile/453875)**

Institute for Sustainable Plant Protection National Research Council of Italy, IPSP-CNR, Turin, Italy

Interests: cell wall; genomics and fungal genomics of symbiotic fungi; mycorrhizal fungi; plant-microbe interactions; abiotic stresses

Special Issues, Collections and Topics in MDPI journals

Special Issue in ***Agriculture*: Plant-Microbe Interactions (/journal/agriculture/special_issues/Plant-Microbe_Interactions)**

Special Issue in ***International Journal of Molecular Sciences*: Cell-Specificity in Plants (/journal/ijms/special_issues/plant_cell_specificity)**

Special Issue in ***Agronomy*: Contribution of Arbuscular Mycorrhizal Symbiosis to Crop Growth (/journal/agronomy/special_issues/arbuscular_mycorrhizal_symbiosis_crop)**

Special Issue in ***Journal of Fungi*: Cell Wall Stress Response (/journal/jof/special_issues/cell_wall_stress_response)**

Special Issue in ***Journal of Fungi*: Mycorrhizal Fungi and Plants (/journal/jof/special_issues/Mycorrhizal_Plants)**

Special Issue in ***Plants*: Biostimulants as Growth Promoting and Stress Protecting Compounds (/journal/plants/special_issues/Protecting_Compounds)**

Special Issue in ***Resources*: Value-Added Compounds from Compost, Digestate and Agro-Industrial Waste (/journal/resources/special_issues/Value-Added_Compounds)**

Special Issue in ***International Journal of Molecular Sciences*: Biochemical and Molecular Regulations of Priming: How Plants Enhance Their Defence against Environmental Pressures (/journal/ijms/special_issues/Plants_Defence)**

Prof. Dr. Hanna Bandurska

SciProfiles (https://sciprofiles.com/profile/1099912)

Department of Plant Physiology, Poznan University of Life Sciences, Wołyńska 35, PL 60-637 Poznań, Poland

Interests: plant physiology; plant stress physiology; responses and resistance to abiotic stresses; (water deficit, salinity, UV-B, tropospheric ozone); cross resistance

Special Issues, Collections and Topics in MDPI journals

Special Issue in ***Plants*: Plant under Drought 2020-2021 (/journal/plants/special_issues/Plant_under_Drought_2021)**

Dr. Martin Banwell

Institute for Advanced and Applied Chemical Synthesis, Jinan University, Zhuhai 519070, China

Interests: natural products; alkaloid; bioactivity

Dr. Rita Baraldi

Website (http://www.bo.ibimet.cnr.it/staff/baraldi-rita) **SciProfiles (https://sciprofiles.com/profile/370260)**

Italian National Research Council, Institute of Biometeorology, 40129 Bologna, Italy

Interests: plant physiology and ecophysiology in relation to global change; Auxin and abscisic acid biosynthesis and metabolism; metabolism and physiology of biogenic volatile organic compound; phytoremediation; urban forest

Special Issues, Collections and Topics in MDPI journals

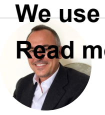
Special Issue in ***Forests*: Urban Forestry and Green Infrastructures (/journal/forests/special_issues/Urban_Forestry_Infrastructure)**

Dr. Roberto Barbato

SciProfiles (https://sciprofiles.com/profile/1976280)

Department of Science and Technological Innovation, University of Eastern Piedmont, I-15121 Alessandria, Italy

Interests: photosynthesis; abiotic stress; photoprotection; halophyte; salt stress



Prof. Dr. Gianni Barcaccia
(/)
[Website (https://www.dafnae.unipd.it/en/barcaccia)] [Website2 (http://www.giannibarcaccia.com/)]
[SciProfiles (https://sciprofiles.com/profile/84013)]
Department of Agronomy Food Natural Resources Animals Environment, Campus of Agripolis, University of Padova, 35020 Legnaro, Italy
Interests: plant breeding; applied genomics; population genetics; plant reproductive systems; molecular markers; food traceability
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***Plants*: Genomics for Plant Breeding (/journal/plants/special_issues/geno_breeding)**
Special Issue in ***Plants*: Genomics for Plant Breeding 2020–2021 (/journal/plants/special_issues/Genomics_Plant_Breeding_2020)**
Topics: **Plant Breeding, Genetics and Genomics (/topics/plant_breeding)**

Prof. Dr. Juan Barceló
[Website (http://gent.uab.cat/barcelo/)]
Department of Animal and Plant Biology and Ecology, Faculty of BioSciences, Universitat Autónoma de Barcelona, 08193-Bellaterra (Barcelona), Spain
Interests: plant stress physiology; salinity; metal toxicity

Prof. Dr. Davide Barreca
[Website (https://www.unime.it/it/persona/davide-barreca/curriculum)]
Department of Chemical, Biological, Pharmaceutical and Environmental Sciences, University of Messina, 98168 Messina, Italy
Interests: plant biochemistry; isolation and identification of polyphenols; evaluation of biological potentials of polyphenols on isolate cells in culture; identification of molecular mechanisms of antioxidants action
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***Plants*: Mechanisms of Plant Antioxidants Action (/journal/plants/special_issues/Plant_Antioxidants_Action)**
Special Issue in ***Plants*: Flavonoids: Secondary Metabolites with Multifunctional Biological Properties (/journal/plants/special_issues/flavonoids_metabolites)**
Special Issue in ***Plants*: Mechanisms of Plant Antioxidants' Action Volume II (/journal/plants/special_issues/antioxidants_2)**
Special Issue in ***International Journal of Molecular Sciences*: Bioactive Phenolics and Polyphenols 2021 (/journal/ijms/special_issues/bioactive_phenolics3)**
Special Issue in ***International Journal of Molecular Sciences*: Flavonoids and Their Impact on Human Health (/journal/ijms/special_issues/flavon)**

Dr. Igor Bartish
[Website (https://www.ibot.cas.cz/oddeleni-populacni-ekologie/?projects-category=extant-habitat-types-as-harbors-of-evolutionary-heritage&lang=en)] [SciProfiles (https://sciprofiles.com/profile/778953)]
Institute of Botany of the Academy of Sciences of the Czech Republic, CZ-25243 Pruhonice, Czech Republic
Interests: biogeography; population genetics; phylogeography; evolutionary ecology; phylogenetics; molecular systematics; paleoecology
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***Plants*: Phylogeography of the East Eurasian Flora (/journal/plants/special_issues/ecology_evolution_plant_diversity)**

Prof. Dr. Adriana Basile
[Website (http://www.dipartimentodibiologia.unina.it/personale/adriana-basile/)] [SciProfiles (https://sciprofiles.com/profile/48137]
Department of Biology, University of Naples "Federico II", 80126 Naples, Italy
Interests: plant cell; bryophyte; environmental pollution; response to stress; ultrastructure; molecular biology; biomarkers; bioactivities
Special Issues, Collections and Topics in MDPI journals
Special Issue in ***Molecules*: Essential Oils as Antimicrobial and Anti-infectious Agents (/journal/molecules/special_issues/essential_oils_antimicrobial)**
Special Issue in ***International Journal of Molecular Sciences*: Molecular Research on Bryophytes (/journal/ijms/special_issues/Bryophytes)**
Special Issue in ***Applied Sciences*: Application of Plant Natural Compounds (/journal/applsci/special_issues/plant_natural_compounds_application)**

Interests: functional genetics and genomics; plant development and molecular physiology; biological nitrogen fixation in legumes; hormonal interactions in tomato development; biochemistry of membrane transporters and transcription factors

Dr. Emilio Benitez

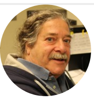
Website (http://www.eez.csic.es)

Estación Experimental del Zaidín (EEZ), Consejo Superior de Investigaciones Científicas (CSIC), Profesor Albareda, 1, 18008 Granada, Spain

Interests: landscape ecology; management intensity; soil microbiome; biological control

Special Issues, Collections and Topics in MDPI journals

Special Issue in ***Plants*: Multiple Ecosystem Services and Biodiversity in Agricultural Landscapes (/journal/plants/special_issues/Multiple_Ecosystem_Services)**



Prof. Dr. Gerald A. Berkowitz

Website (http://cag.uconn.edu/plsc/plsc/People/Faculty/Berkowitz.php) SciProfiles (https://sciprofiles.com/profile/92906)

Agricultural Biotechnology Laboratory, University of Connecticut, Storrs, CT 06269-4163, USA

Interests: plant cell signal transduction; ion channels; calcium signaling; plant immune responses to pathogens; brassinosteroid signaling

Special Issues, Collections and Topics in MDPI journals

Special Issue in ***Plants*: Calcium Signaling in Plants (/journal/plants/special_issues/calcium-signaling)**

Dr. Ángel Mérida Berlanga

Website (https://www.ibvf.us-csic.es/en/%C3%A1ngel)

Institute of Plant Biochemistry and Photosynthesis (IBVF) Consejo Superior de Investigaciones Científicas (CSIC)-Universidad de Sevilla (US), 41092 Sevilla, Spain

Interests: starch metabolism; starch granule initiation; carbon metabolism in plants; photosynthesis

Special Issues, Collections and Topics in MDPI journals

Special Issue in ***Plants*: Starch Metabolism in Plants (/journal/plants/special_issues/starch_meta)**

Dr. Alexandre Berr

Website (http://www.ibmp.cnrs.fr/) SciProfiles (https://sciprofiles.com/profile/970119)

Institut de Biologie Moléculaire des Plantes (IBMP), 12, rue du General Zimmer, CEDEX 02, 67084 Strasbourg, France

Interests: chromatin organisation and regulation

Special Issues, Collections and Topics in MDPI journals

Special Issue in ***Plants*: Chromatin Dynamics for Developmental Transitions in Plants (/journal/plants/special_issues/Chromatin_Dynamics_Plants)**

Prof. Dr. Assunta Bertaccini

Website (https://www.unibo.it/sitoweb/assunta.bertaccini/en)

Department of Agricultural and Food Sciences, Alma Mater Studiorum - University of Bologna, 40127 Bologna, BO, Italy

Interests: phytoplasmas; phytopathogenic bacteria; Candidatus Liberibacter; PCR/RFLP; sequencing; plant-pathogen interaction

Dr. Benoît Bertrand

Website (http://umr-ipme.ird.fr/annuaire/benoit-bertrand)

CIRAD, IRD, Interactions Plants - Micro-Organisms - Environment (IPME), Montpellier University, 911 Avenue Agropolis, BP 64501, 34394 Montpellier, France

Interests: plant response to abiotic stress and climate change

Special Issues, Collections and Topics in MDPI journals

Special Issue in ***Beverages*: Coffee Beverage (/journal/beverages/special_issues/coffee)**

***Plants* (/journal/plants)**, EISSN 2223-7747, Published by MDPI **Disclaimer**

Plants

COUNTRY

Switzerland

Universities and research institutions in Switzerland

SUBJECT AREA AND CATEGORY

Agricultural and Biological Sciences
- Ecology, Evolution, Behavior and Systematics
- Plant Science

Environmental Science
- Ecology

PUBLISHER

MDPI Multidisciplinary Digital Publishing Institute

H-INDEX

32

PUBLICATION TYPE

Journals

ISSN

22237747

COVERAGE

2012-2020

INFORMATION

Homepage

How to publish in this journal

plants@mdpi.com

SCOPE

Plants (ISSN 2223-7747), is an international and multidisciplinary scientific open access journal that covers all key areas of plant science. It publishes review articles, regular research articles, communications, and short notes in the fields of structural, functional and experimental botany. In addition to fundamental disciplines such as morphology, systematics, physiology and ecology of plants, the journal welcomes all types of articles in the field of applied plant science. The main aim of our journal is to encourage scientists and research groups to publish theoretical and experimental results of research in all fundamental and applied fields of plant science. The full experimental procedure must be provided so that the results can be reproduced. There is no limitation on the length of articles for this journal. Journal covers the following interest areas and sub-areas in plant science: -plant cytology and histology -plant anatomy and morphology -systematics, taxonomy and classification -plant physiology and ecophysiology -plant genetics, molecular biology and biochemistry -ecology and biogeography of plants -phytocenology -evolutionary biology, plant phylogeny and paleobotany -plant diversity and conservation biology -experimental and applied plant science: new methods in experimental botany; biology of medicinal plants; ethnobotany; biological effects of active substances from plants; phytomedicine; new plant products, active substances and secondary metabolites; plant drug development; agricultural plants; plants derived food; horticultural plants; phytopathology; plant biotechnology; interactions between plants and other organisms; the importance of plants in the environment; the use of plants in biological control; crop protection and pesticides

Join the conversation about this journal

Quartiles

FIND SIMILAR JOURNALS

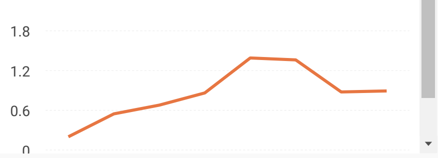
options

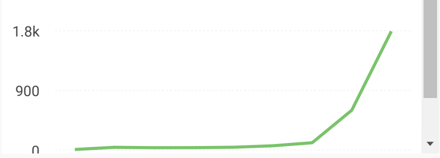
1	2	3	4	5
Frontiers in Plant Science	Planta	Plant Physiology and Biochemistry	BMC Plant Biology	Theoretical and Experimental Plant Physiology
CHE	DEU	FRA	GBR	USA
94% similarity	91% similarity	88% similarity	85% similarity	85% similarity

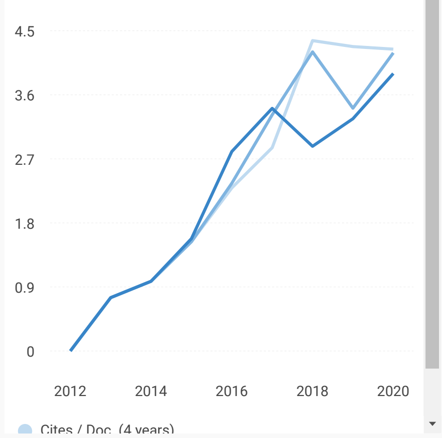
SJR

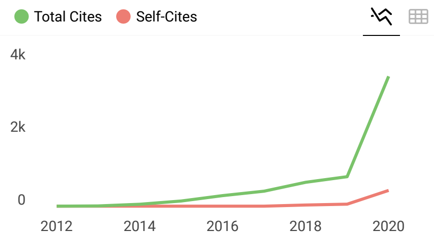
Total Documents

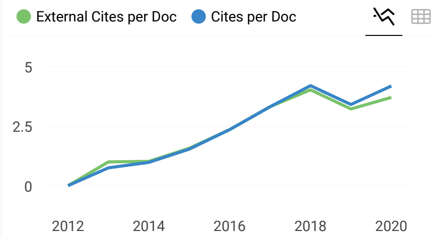
Citations per document

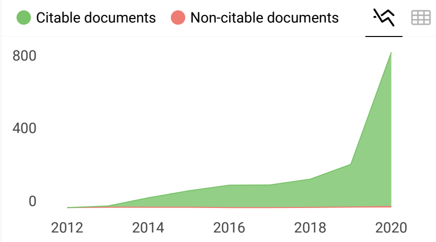


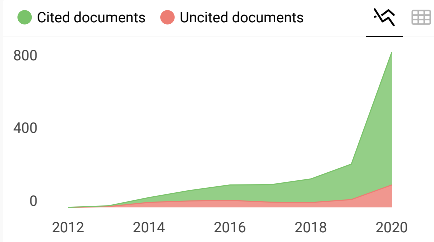












← Show this widget in your own website

Just copy the code below and paste within your html code:

<a href="https://www.scimag

Metrics based on Scopus® data as of April 2021

A

Ana Maria Castaño 3 months ago

Dear colleagues,

I would like to know if it is possible to propose an article referring to plant transformation in this journal.

Thank you very much.

Best regards, Ana.

reply

Melanie Ortiz 3 months ago

SCImago Team

Dear Ana Maria,
Thank you for contacting us.
We are sorry to tell you that SCImago Journal & Country Rank is not a journal. SJR is a portal with scientometric indicators of journals indexed in Elsevier/Scopus.
Unfortunately, we cannot help you with your request, we suggest you visit the journal's homepage (See scope and submission/author guidelines) or contact the journal's editorial staff , so they could inform you more deeply.
Best Regards, SCImago Team

C

Carmen Castillo 12 months ago

Dear colleages,

I was wondering if you can tell me when the ranking of 2020 will be published? and if the date is same for every year? I wonder if there are rankings by months.

Thank you very much. Best regards, Carmen reply

Melanie Ortiz 11 months ago SCImago Team

Dear Carmen,
Thank you for contacting us. Our data come from Scopus, they annually send us an update of the data. This update is sent to us around April / May every year and SCImago updates its scientometric indicators once a year. The SJR for 2019 was released on 11 June 2020. Therefore, the indicators for 2020 will be available in June 2021.
Best Regards, SCImago Team

D

Dr. Rashmi Sharma 2 years ago

I Dr Rashmi Sharma Prof. want to become member Editorial Board.
Dr. Rashmi Sharma

reply

Leave a comment

Name

Email
(will not be published)

Saya bukan robot
reCAPTCHA
Privasi - Persyaratan

Submit

The users of Scimago Journal & Country Rank have the possibility to dialogue through comments linked to a specific journal. The purpose is to have a forum in which general doubts about the processes of publication in the journal, experiences and other issues derived from the publication of papers are resolved. For topics on particular articles, maintain the dialogue through the usual channels with your editor.

plants

MDPI

Article

Overexpression of the *Panax ginseng CYP703* Alters Cutin Composition of Reproductive Tissues in Arabidopsis

Jihyun Kim [1,†], Jeniffer Silva [2,†], Chanwoo Park [1], Younghun Kim [1], Nayeon Park [1], Johan Sukweenadhi [3], Junping Yu [4], Jianxin Shi [5], Dabing Zhang [5], Keun Ki Kim [1], Hong-Joo Son [1], Hyeon Cheal Park [1], Chang-Oh Hong [1], Kwang Min Lee [1] and Yu-Jin Kim [1,*]

1 Department of Life Science and Environmental Biochemistry, Life and Industry Convergence Research Institute, Pusan National University, Miryang 50463, Korea; jihyun0_0@pusan.ac.kr (J.K.); musgdmu8869@naver.com (C.P.); edward69543@naver.com (Y.K.); xosk126@naver.com (N.P.); kkkim@pusan.ac.kr (K.K.K.); shjoo@pusan.ac.kr (H.-J.S.); hcpark@pusan.ac.kr (H.C.P.); soilchem@pusan.ac.kr (C.-O.H.); leekm@pusan.ac.kr (K.M.L.)
2 Department of Research and Development, The Bridge Biofoundry, Ciudad de Saber, Clayton 0843-03081, Panama; jeniffersilva.yat@gmail.com
3 Department of Plant Biotechnology, Faculty of Biotechnology, Universitas Surabaya, Raya Kalirungkut, Kalirungkut, Surabaya 60294, East Java, Indonesia; sukweenadhi@gmail.com
4 Key Laboratory of Biotechnology Shaanxi Province, College of Life Sciences, Chinese Education Ministry's Key Laboratory of Western Resources and Modern Biotechnology, Northwest University, Xi'an 710069, China; yujunping521@sina.com
5 Joint International Research Laboratory of Metabolic and Developmental Sciences, School of Life Sciences and Biotechnology, Shanghai Jiao Tong University, Shanghai 200240, China; jianxin.shi@sjtu.edu.cn (J.S.); zhangdb@sjtu.edu.cn (D.Z.)
* Correspondence: yjkim2020@pusan.ac.kr; Tel.: +82-055-350-5546
† These authors contributed equally to this work.

Citation: Kim, J.; Silva, J.; Park, C.; Kim, Y.; Park, N.; Sukweenadhi, J.; Yu, J.; Shi, J.; Zhang, D.; Kim, K.K.; et al. Overexpression of the *Panax ginseng CYP703* Alters Cutin Composition of Reproductive Tissues in Arabidopsis. *Plants* **2022**, *11*, 383. https://doi.org/10.3390/plants11030383

Academic Editor: Baohong Zhang

Received: 24 December 2021
Accepted: 28 January 2022
Published: 30 January 2022

Abstract: Cytochrome P450 (CYP) catalyzes a wide variety of monooxygenation reactions in plant primary and secondary metabolisms. Land plants contain CYP703, belonging to the CYP71 clan, which catalyzes the biochemical pathway of fatty acid hydroxylation, especially in male reproductive tissues. Korean/Asian ginseng (*Panax ginseng* Meyer) has been regarded as one of important medicinal plant for a long time, however the molecular mechanism is less known on its development. In this study, we identified and characterized a *CYP703A* gene in *P. ginseng* (*PgCYP703A4*), regarding reproductive development. *PgCYP703A4* shared a high-sequence identity (81–83%) with predicted amino acid as CYP703 in *Dancus carota*, *Pistacia vera*, and *Camellia sinensis* as well as 76% of amino acid sequence identity with reported *CYP703* in *Arabidopsis thaliana* and 75% with *Oryza sativa*. Amino acid alignment and phylogenetic comparison of *P. ginseng* with higher plants and known *A. thaliana* members clearly distinguish the CYP703 members, each containing the AATDTS oxygen binding motif and PERH as a clade signature. The expression of *PgCYP704B1* was only detected in *P. ginseng* flower buds, particularly in meiotic cells and the tapetum layer of developing anther, indicating the conserved role on male reproduction with At- and Os- CYP703. To acquire the clue of function, we transformed the *PgCYP703A4* in *A. thaliana*. Independent overexpressing lines (*PgCYP703A4*ox) increased silique size and seed number, and altered the contents of fatty acids composition of cutin monomer in the siliques. Our results indicate that *PgCYP703A4* is involved in fatty acid hydroxylation which affects cutin production and fruit size.

Keywords: cytochrome P450; reproductive tissues; *PgCYP703A4*; fatty acid; reproduction; *Panax ginseng*

1. Introduction

The cytochrome P450 (CYP) superfamily of enzymes, which catalyze diverse substrates through oxygenation and hydroxylation reactions, are found in all organisms [1]. Plant CYPs are involved in a variety of biochemical pathways that produce primary and secondary metabolites, which constitute one of the largest families of enzymes in higher plants [2]. The diversification of land plant CYP families emerges during flowering plant evolution and specializes plant species with unique reactions [3]. The identification of CYP genes aids in understanding the evolution of various groups of enzymes and their conserved and diversified functions.

The *CYP703* gene family was found across the land plant taxa, suggesting that it encodes an essential function [4]. Land plants developed specialized cell layer to adapt to the environment, including cutin synthesis. As cutin cover in most plant organ of land plant, male reproductive organ of flowering plants is covered with a hydrophobic polymer barrier derived from fatty acids. The production of functional gametophytes leads to a successful proliferation in flowering plants [5]. Male reproduction is a complex and highly coordinated biological process that includes the development of the male reproductive organ: the stamen that contains the microspores and pollen. The study of male reproduction is important not only for increasing crop yield but for producing improved crops, such as superhybrid plants, through the use of male sterile lines [6].

The CYP703 family is involved in the in-chain hydroxylation of mid-chain fatty acids, which is essential for the biopolymers of pollen exine, the outer wall of a pollen grain [7,8], and cutin, one of the most abundant lipid polymers and an important adaptive trait of plants to their terrestrial environment [9]. *A. thaliana* CYP703A2 (AtCYP703A2) catalyzes the conversion of medium-chain saturated fatty acids to the corresponding monohydroxylated fatty acids, with a preferential hydroxylation of lauric acid at the C-7 position [8]. In comparison, *Oryza sativa* CYP703A3 (OsCYP703A3) can only catalyze in-chain hydroxylation of lauric acid (C12), preferentially at position 7 [7]. The *A. thaliana* mutant, *cyp703a2*, exhibits impaired pollen development and a partial male sterile phenotype due to the lack of an exine [8]. *O. sativa* CYP703A3 resulted in a complete male sterility with an abnormal anther epidermis, as well as defective pollen exine, indicating that the diversified function of CYP703A during evolution [7]. Both participated in a conserved pathway of in-chain hydroxylation of lauric acid that is required for male reproductive development. Some male-specific gene sequences that determine sex, where CYP703 was found, have been identified in the *Phoenix* tree which belongs to dioecious species. [10]. Further studies in other plants will help elucidate the diversified CYP703 function of fatty acid hydroxylation in plant reproductive development.

Panax ginseng is a perennial herb that has been cultivated for its highly valued root for medicinal purposes [11]. *P. ginseng* typically starts its reproduction at the third year of growth [12,13]. Attempts to increase the yield of *P. ginseng* and ginsenosides have been conducted by developing *P. ginseng* hybrids, and although they display heterosis, F1 hybrid plants exhibited male sterility that derived from pollen defects at the young microspore stage [13]. We previously studied and described the morphogenesis of the anther and carpel at a cytological level to understand and specify the reproductive developmental phases of *P. ginseng* [12,14] and identified the gene expression of *PgCYP703* in the anther tapetum layer [12]. Despite the importance of *P. ginseng* reproductive development, studies on functional gene analysis and molecular regulation remain scarce. In the studies presented here, we isolated and cloned the *CYP703A* gene from *P. ginseng*, *PgCYP703A*, which is highly expressed in flower buds during anther development. Surprisingly, in *A. thaliana*, overexpression of *PgCYP704B1* resulted in the enhanced in silique length, in terms of fruit size, which is potentially caused by the alteration of saturated fatty acids and hydroxy fatty acids in siliques.

2. Material and Methods

2.1. Plant Materials and Growth Conditions

The ginseng (*P. ginseng* Mayer) plant organs (root body, stem, leaf, flower bud, and fruit) were obtained from hydroponically cultured ginseng. Columbia ecotype (CS60000) of *A. thaliana* was used for gene overexpression. Sterilized seeds were sown on half-strength Murashige and Skoog medium (Duchefa Biochemie) containing 1% sucrose, 0.8% (*w*/*v*) agar, and pH 5.7. Three-day-old cold-treated seeds were germinated under long-day photoperiods of 16-h light/8-h dark at 23 °C. The transformants were screened on hygromycin (50-µg/mL)-selective medium plates. Ten-day-old seedlings were then transplanted to soil and cultivated for five weeks under the same light/dark conditions [15].

2.2. Identification of PgCYP703A4 Gene and Sequence Analysis

To obtain a coding sequence (CDS) of the *PgCYP703A4* gene, homologous sequences of *CYP703* was obtained based on *A. thaliana* sequence by homology-based PCR from *P. ginseng* flower cDNA. A complete genomic DNA sequence was obtained and analyzed from the database of the *P. ginseng* genome (http://ginsengdb.snu.ac.kr, accessed on 20 January 2022), and the putative ORF sequence was verified by sequencing after subcloning.

The predicted amino acid sequence of *PgCYP703A4* was used to search for homologous proteins via National Center for Biotechnology Information-Basic Local Alignment Search Tool (NCBI-BLASTX, http://www.ncbi.nlm.nih.gov/BLAST/, accessed on 18 January 2022). Sequence alignment was conducted using Clustal X V1.83, and a neighbor-joining tree was constructed using the MEGA4 software V.4.0.1, with the reliability of each node established by the bootstrap method. The subcellular localization for the N-terminus was predicted by PSORTdb (http://www.psort.org/psortb/, accessed on 18 January 2022) [16], and the hydropathy value was calculated using the previously described method [17]. The 1000-bp sequence upstream of the ATG-coding site in the genomic DNA sequence of *PgCYP703* were used as promoters to predict Cis-acting elements by New PLACE (http://www.dna.affrc.go.jp/PLACE/?action=newplace, accessed on 20 December 2021) [18].

2.3. Vector Construction and A. thaliana Transformation

The full-length *CYP703* gene was amplified from *P. ginseng* flower cDNA and cloned into the *Sal*I and *Spe*I sites of the pCAMBIA1390 vector containing the Cauliflower Mosaic Virus 35S promoter and yellow fluorescent protein. After nucleotide sequence verification, *A. thaliana* transformation was conducted using *Agrobacterium tumefaciens* C58C1 (pMP90) [19]. The insertion of transgenes into the transformants was confirmed via polymerase chain reaction (PCR). Heterozygous plants with a 3:1 segregation ratio on antibiotic plates which indicate the single gene insertion, were selected for additional analyses. Among the several T2 independent lines, two lines were selected for further statistical and metabolite analyses.

2.4. Gene Expression Analysis

Total RNA extraction from frozen samples was performed using the RNeasy Mini Kit (Qiagen, Valencia, CA, USA.), where 1-µg of the total RNA was used as a reverse transcription template. For qRT-PCR, 100-ng cDNA in a 10-µL reaction volume and SYBR® Green Sensimix Plus Master Mix (Quantace, Watford, England) were used. Specific primers for *PgCYP703A4* (F-5′-CTACGGGTGCAATGATGTTG-3′ and R-5′- TGCATGGAAAACGACTCA AG-3′) and a constitutively expressed *P. ginseng actin* gene (forward, 5′-AGAGATTCCGCTGT CCAGAA-3′ and reverse, 5′-ATCAGCGATACCAGGGAACA-3′) or *A. thaliana actin* gene (forward, 5′-GTGTGTCTTGTCTTATCTGGTTCG-3′ and reverse 5′-AATAGCTGCATTGT CACCCGATACT-3′) were used as an internal reference. qRT-PCR was conducted using a CFX Connect Real-Time PCR Detection System (BIO-RAD, Hercules, CA, USA) with the following program: 30 s at 95 °C, followed by 40 cycles of 95 °C for 3 s and 60 °C for 20 s. The threshold cycle (Ct) reflects the number of cycles where the fluorescence intensity at the original exponential stage of PCR amplification was significantly greater than the background fluorescence. To determine the relative fold differences in template abundance for each sample, the Ct value for *PgCYP703A4* was normalized to the Ct value for β-actin and calculated relative to a calibrator using the formula $2^{-\Delta\Delta Ct}$. Each qRT-PCR was technically repeated at least three times. Spatial expression of PgCYP703 transcript in ginseng anther was analyzed by In situ hybridization, as reported previously [12].

2.5. Histological Analysis

Semi-thin sectioning was performed using anthers of mature flowers from 4-week-old plants. After fixing in FAA, the samples were dehydrated with an ethanol gradient (70%, 80%, 90%, and 100%) allowing 30 min for each step. Samples were then embedded in KULZER Technovit 7100 cold polymerizing resin by pre-infiltration, infiltration, and embedding at 45 °C, according to the previously described methods [20]. Samples were sectioned to a thickness of 4 μm in an Ultratome III ultramicrotome (LBK) and stained with 0.25% toluidine blue O (Chroma Gesellshaft Shaud). Bright-field photographs of the anther and silique sections were obtained using a Nikon ECLIPSE 80i microscope.

Scanning electron microscopy (SEM) was employed to analyze mature anthers that were fixed in FAA and dehydrated using 20–100% ethanol (10% increments) allowing 3 min for each step. The samples were then dried at the critical point temperature (Leica EM CPD300). A 5-nm-thick Aurum coating was paced on the samples with a Leica EM SCD050 ion sputter. The Aurum-coated samples were observed using a Hitachi S3400N SEM.

2.6. Analysis of Silique Fatty Acids

Cutin from the siliques of 5-week-old plants were examined as previously described [15,21]. Dried siliques (10–20 mg) were extracted in 2 mL of chloroform and spiked with 10 μg of tetracosane (Fluka) as the internal standard. Solvent was evaporated under a light stream of nitrogen, and the compounds containing free hydroxyl and carboxyl groups were transformed to trimethysilyl ethers and esters using 20-μL bis-(N, N-trimethysilyl)-trifluoroacetamine (Sigma-Aldrich, St. Louis, MO, USA) in 20-μL pyridine for 40 min at 70 °C. The monomers were identified from their electron ionization–mass spectrometry spectra (70 eV, m/z 50 to 700) after GC separation (column 30 mm × 0.32 mm × 0.1 μm film thickness [DB-1; J&W Scientific]). Gas chromatography–mass spectrometry (GC-MS) (Agilent gas chromatograph coupled with an Agilent 5973N quadrupole mass selective detector) and gas chromatography–flame ionization detection (GC-FID) (Agilent 6890 gas chromatograph) analyses were conducted. The means of three independent replicates were statistically analyzed and compared with control (* $p < 0.05$) using Student's *t*-test.

3. Results

3.1. Identification of CYP703 Gene in P. ginseng

CYP families often have many paralogs, but the CYP703 family was reported to be a single-gene-member family [8]. Analysis of the *P. ginseng* genome scaffold and CDS revealed that *P. ginseng* contains two scaffold sequences with high similarity to CYP703. Among the two scaffolds, scaffold 1562 contained a full-length CDS of CYP703 (Pg_S1562.26), which contained a two-exons and one-intron structure (Figure 1), similar to the *A. thaliana* gene structure. On the contrary, two CDS sequences, S6323.1 and S6323.2, present in scaffold 6323 were partial sequences of CYP703. Therefore, we concluded that the *P. ginseng* genome encodes just one PgCYP703 member, whereas the others are nonfunctional genes. The recent genome duplications of the *P. ginseng* genome [22] might explain the presence of two genes that can duplicated, in which one of the gene has retained the original sequence and function, whereas the other became a pseudogene. Similarly, CYP703A was noted as a single functional sequence in the poplar genome (*Populus trichocarpa*) [8].

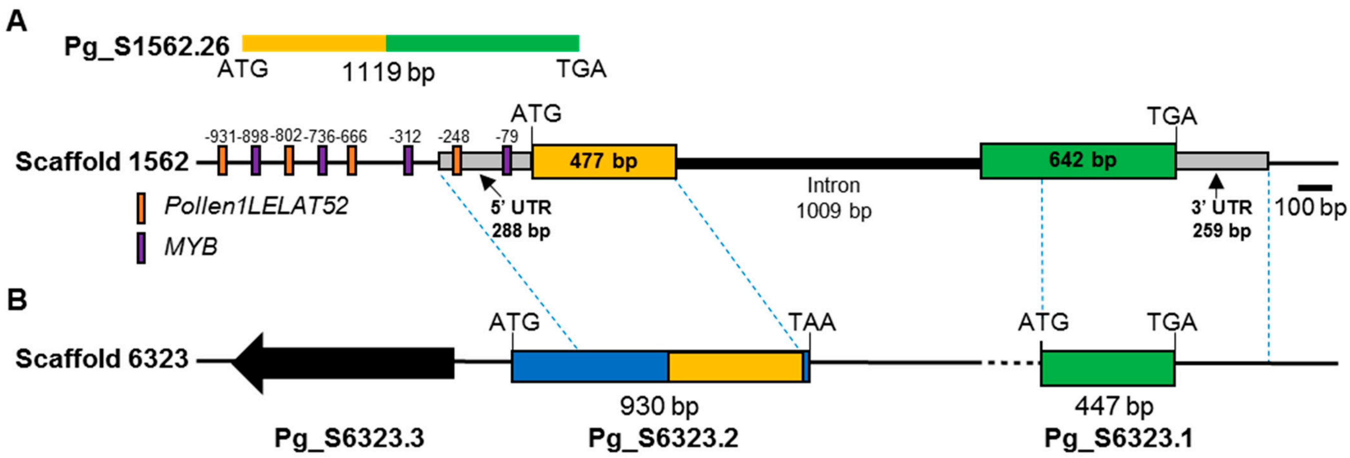


Figure 1. Analysis of gene and promoter structure of PgCYP703A4 and its pseudogene. Genomic sequence of scaffolds containing PgCYP703A4 and similar sequences were identified from the P. *ginseng* genome database (http://ginsengdb.snu.ac.kr/ accessed on 20 January 2022). (**A**) PgCYP703A4 gene was confimed as Pg_S1562.26 CDS, which encoded on Scaffold 1562. The coding regions (orange and green boxes) are interrupted by 1009 base pair (bp) intron. The upstream 1000-bp region from the translation start site has four POLLEN1LELAT52 binding-predicted sites and four MYBCORE binding-predicted sites. (**B**) A similar sequence structure was identified from Pg_scaffold6323 encoding two CDSs, assumed to be pseudogenes. The transcript was separated into two partial CDS sequences (Pg_S6323.2 and Pg_S6323.1). Dashed line indicates closed sequences between two scaffolds.

A putative ORF sequence, which had a length of 1119 bp and encoded 372 amino acids (Figure 1), was verified by sequencing, and an NCBI-BLAST search displayed the conserved superfamily CYP. There are three functionally reported genes: two CYP703A members registered in the Plant P450 Database (http://erda.dk/public/vgrid/PlantP450/, accessed on 10 December 2021) (CYP703A1 from a *Petunia hybrida* [23] and AtCYP703A2 [8]) and *O. sativa* CYP703A3 [7]. We named the CYP703 gene identified in *P. ginseng* as *PgCYP703A4*.

3.2. Sequence Alignment and Phylogenetic Analysis

CYP703 enzymes belong to the CYP71 clan, which includes the diverse families of P450 in plants [4,7]. To obtain information about the potential functions and evolutionary roles of *PgCYP703A4*, the full-length protein was used as a query to search for homologs in NCBI databases and the The *A. thaliana* Information Resource using NCBI-BLASTX. Highly similar homologs of PgCYP703A4 were detected in various dicot plant species whose genome sequences were available, although functional studies were limited. To see similarity of amino acids in various plant species, we selected the 10 closest sequences, and representative CYP71 members from *A. thaliana* were used to create a phylogenetic tree (Figure 2). Based on our phylogenetic comparison, *PgCYP703A4* was placed in subfamily CYP703, separate from the other subfamilies of the CYP71 clan; CYP98, CYP73, CYP78, CYP84, CYP82, CYP81, CYP76, CYP61, CYP83, CYP705, and CYP701. CYP78 members hydoxylate short-chain fatty acids [24], CYP73 family members hydroxylate cinnamic acid [25], and CYP84 members are involved in lignin and flavonoid synthesis [26], thus indicating CYP71 clan subfamilies are not specific, rather showed various functions on metabolites.

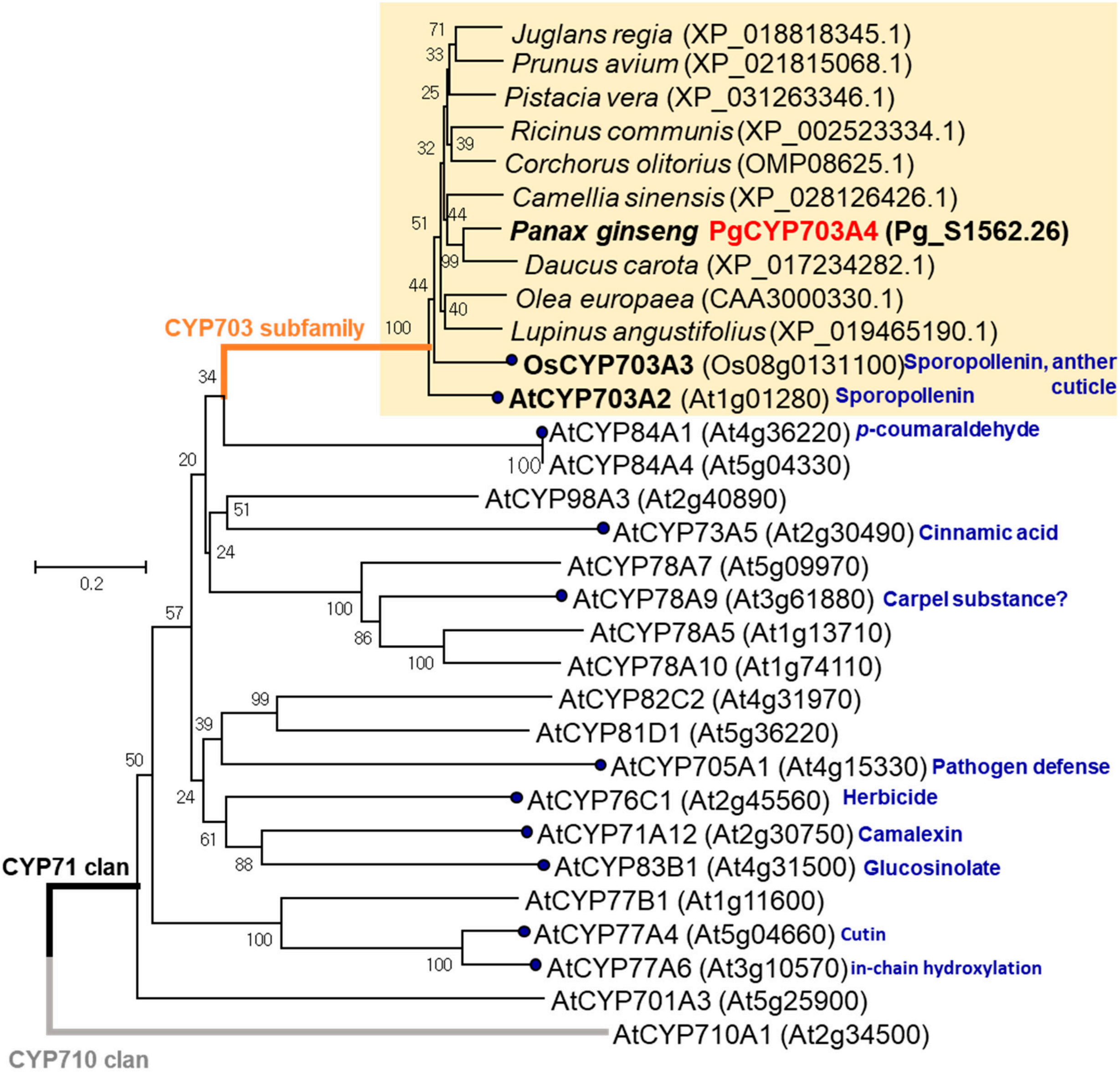


Figure 2. Phylogenetic analysis of PgCYP703. Neighbor-joining method analysis was conducted using the full-length amino acid sequences of PgCYP703A4 and closely related CYP703 subfamily members (Figure S1), in addition to the A. thaliana members of the CYP71 clan and outgroup of the CYP710 clan. The scale bar shows 0.2 amino acid substitutions per site. The reported CYP703A genes are distinguished by bold font with black dots. CYP703 subfamilies of the CYP71 clan are indicated by the yellow box. The functionally reported genes are indicated by circles and brief role in the right side. In figure, 'At' means *Arabidopsis thaliana*'s protein and 'Os' means *Oryza sativa*'s protein, and other plants are presented with full scientific name. NCBI accession numbers for other species and annotation numbers for *P. ginseng*, *A. thalina* and *O. sativa* species are indicated inside bracket.

Multiple sequence alignment (Figure S1) revealed that the CYP703 proteins and PgCYP703A4 contain the conserved domains of the axial ligand for heme, the I-helix involved in oxygen binding, the Arg of the "PERF" consensus, and the E-R-R of the K-helix consensus (KETLR). Of these domains, only the cysteine of the heme-binding domain and the E-R-R triad are conserved in all plant cytochrome P450 sequences [27,28]. CYP703 members have a Phe–His substitution in the P(E)R(F) domain of CYP, known as a clade signature of the CYP703 family [28]. In addition, CYP703 members have an A-A-T-D-T-S motif (Figure S1) in the A/G-G-X-E/D-T-T/S domain, which is involved in oxygen binding and activation [28]. Of the subfamilies in the CYP71 clan, substitution of A for the second G is unique to the CYP703 subfamily.

Plant P450s are usually bound to membranes, anchoring to the cytoplasmic surface of the endoplasmic reticulum (ER) through a short hydrophobic segment of their N-terminus [29] The predicted transit peptide of PgCYP703A4 (indicated arrow in Figure S1) was shown to be positioned at its N-terminus with a cytoplasmic location [16] targeting ER with 69% certainty, predicted by PSORT (Prediction of Protein Localization Sites, version 6.4) Prediction program. Fatty acids are hydroxylated in the ER of plant cells through members of the CYP family [8,30,31]. The PgCYP703 hydrophobicity profile and those of its closest homologs indicated that both the N- and C-terminal regions, as well as the CYP703 motifs, are highly conserved (Figure S2).

3.3. Gene Expression Analysis of PgCYP703A4

To verify the conserved function of *PgCYP703A4* in the male reproductive organ, as has been described for *A. thaliana* [8] and *O. sativa* [7], we conducted *PgCYP704B1* expression analysis via qRT-PCR using *P. ginseng* tissues, such as the see, root, stem, leaf, flower buds, and fruit at different age. *PgCYP703A4* was specifically expressed in flower buds (Figure 3A).

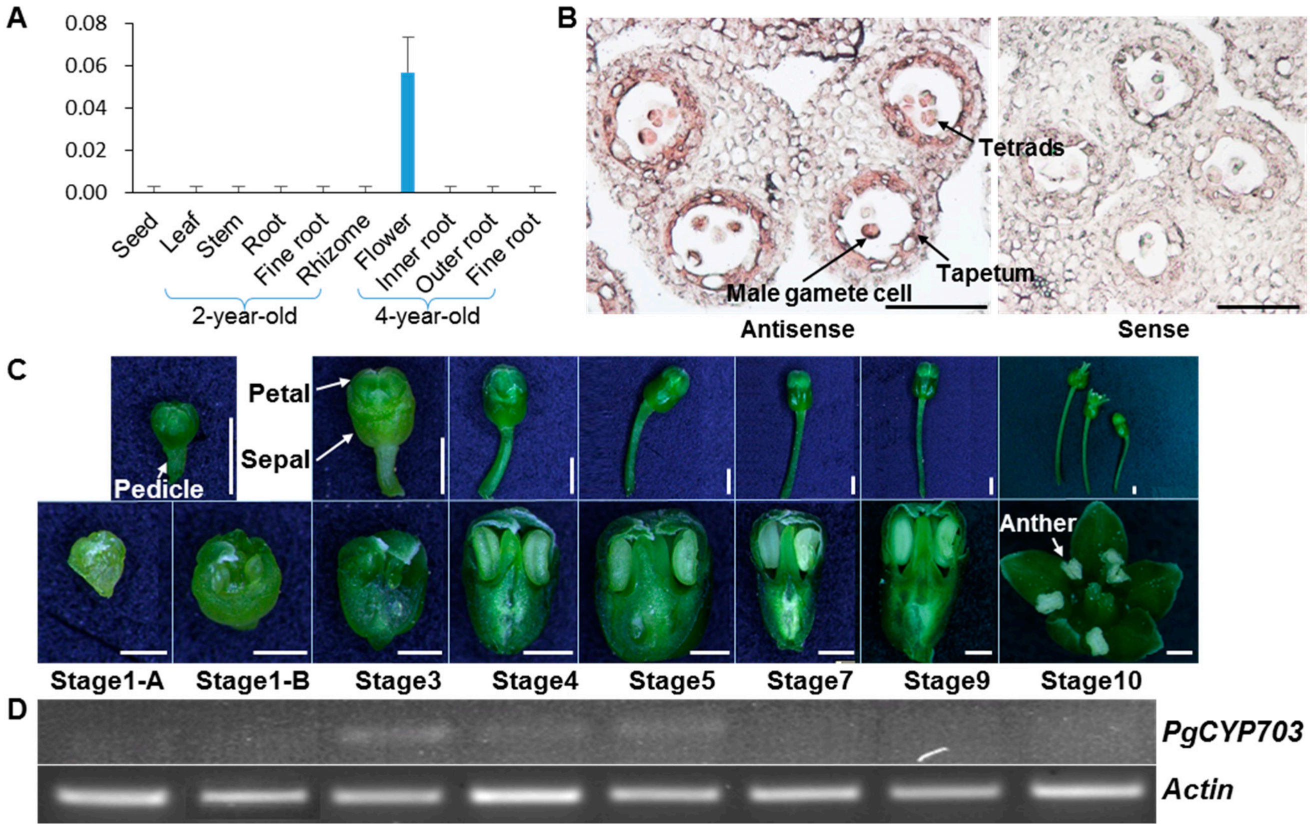


Figure 3. Tissue expression analysis of *PgCYP703A4* in *P. ginseng*. (**A**) Quantitative expression analysis of *PgCYP703A4* in various tissues at different age of *P. ginseng* plant. The expression levels were analyzed via realtime PCR, and *PgActin* served as the control. Values indicate mean of three technical replicates ± SE. (**B**) In situ hybridization analysis of *PgCYP703A4* in *P. ginseng* anther at stage 4 showing its expression (dark pink) in tapetal cells and microspores. Right image shows the anther with hybridized *PgCYP703A4* sense probe, as control. Scale bars indicate 500 µm. (**C**) Flower tissues of the *P. ginseng* at anther developmental stages [14] were used for RT-PCR. The scale bars of uppder photo indicate 1 mm, and lower photo indicate 500 µm. (**D**) RT-PCR gel images of PgCYP703A4 at seven stages of *P. ginseng* flowers show that *PgCYP703A4* are expressed only during Stage 3 to 5. *PgActin* served as a control.

In situ hybridization experiments revealed that *PgCYP703A4* was expressed in the tapetal cell layer and tetrad cells (meiocytes after the second meiosis) in the anther (Figure 3B). The tapetum, the innermost layer of anther wall, plays a crucial role in pollen development by nursing and releasing the microspore [32]. During the developmental stage of anther, the *PgCYP703A4* expression was observed in meiosis to form young microspores (Figure 3C,D) [13].

To illuminate the regulation of gene expression, the 1000-bp upstream region from the coding sequence of PgCYP703A4 was analyzed for cis-elements (Figure 1). The promoters contained various elements. Among them, we noted POLLEN1LELAT52 and MYBCORE, known as regulatory factors that are related to pollen and early pollen development, respectively [33,34]. These results indicated that MYBCORE and POLLEN1LELAT52 might bind to the promoters of *PgCYP703*, which leads to their specific expression during anther development.

3.4. Phenotype Analysis of PgCYP3A4 Overexpressing A. thaliana

Due to difficulties in obtaining transgenic regenerated *P. ginseng* plants, we generated *PgCYP703A4* overexpressing transgenic Arabidopsis (*PgCYP703A4ox*) to examine its functional role in planta (Figure 4A–D). The stable incorporation of the *PgCYP703A4* gene and its heteroexpression was confirmed via RT-PCR (Figure 4B). *PgCYP703A4ox* produced slightly taller plants compared with the wild type, but not significant (Figure 4A). Notably, the siliques increased in size by 20% compared with the wild type and *PgCYP703A4ox* siliuqes contain higher number of seeds than wile type significantly (Figure 4C,D).

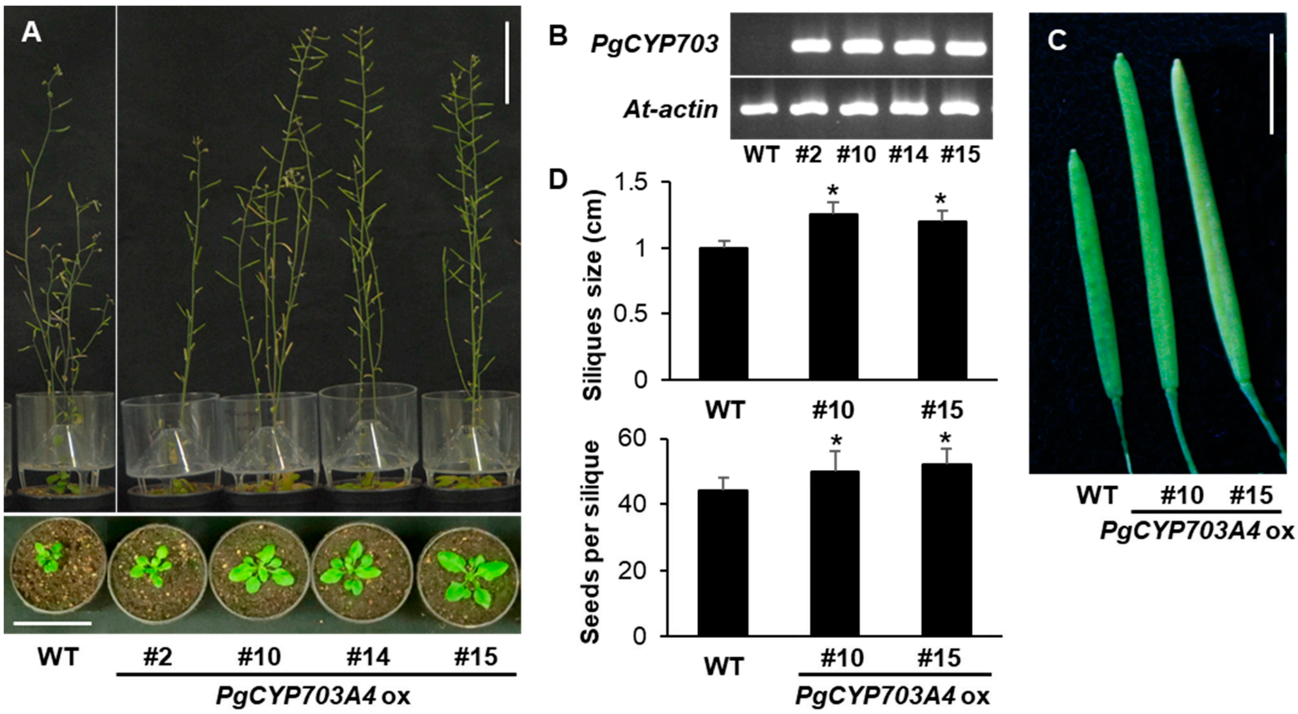


Figure 4. Phenotype analysis of PgCYP703A4 overexpressing A. thaliana. (**A**) Growth phenotype of four different PgCYP703A4 overexpression lines and wild type at 2 week- and 7 week- old. Scale bar indicates 5 cm. (**B**) Detection of PgCYP703A4 transcription in transgenic A. thaliana's rosette leaves. At actin served as the control. (**C**,**D**) Silique size of PgCYP703A4 overexpression lines. Scale bar indicates 5 mm. Values indicate mean of 20 biological replicates ± SD. * $p < 0.05$.

A. thaliana CYP703A3 mutant was reported to show impaired pollen walls lacking a normal exine layer, which leads to partial male sterility [8]. To determine how *PgCYP703A4* affects pollen wall formation, we observed the anthers and pollen phenotype by semi-thin cross-section and SEM (Figure S3). The anther, pollen, and pistil of *PgCYP703A4ox* appeared similar to the wild type, whereas *CYP703A3* exhibited aborted pollen without outer elegant wall formation (Figure S3). Therefore, pollen viability and reproductive organ function was not altered by *PgCYP703A4* gene overexpression.

3.5. Fatty Acid Composition of PgCYP703A4-Overexpressing A. thaliana

The cuticle, a hydrophobic layer that coats the surface of the aerial organs, such as leaves, stems, flowers, and fruits, is a biopolymer that is composed of two classes of lipophilic constituents, namely, cutin and waxes [35,36]. Since the silique phenotype of *PgCYP703A4ox* is elongated and the exocarp is made of cutin, we further conducted GC-MS and GC-FID.

The overall sum of cutin monomers were not significantly different between wild type and *PgCYP703ox* lines. We found that two independent lines alter the composition of fatty acids, with some variation, which might explain complex fatty acids metabolism for the cutin polymer. For example, compared with the wild type, the *PgCYP703A4ox* #10 significantly increased saturated fatty acids of C18:0, C18:1, C26:1 and C28:0, (Figure 5A), dicarboxylic fatty acids of C18:0, C22:0, C24:0, and C26:0 (Figure 5C) and terminal-hydroxy fatty acids of C18:3, C22:0, and C24:0 (Figure 5D), and C28:0 alcohol type (Figure 5E). *PgCYP703A4ox* #15 increased C24:0, C25:0, and C26:0 saturated fatty acids (Figure 5A), and 2-hydroxyl fatty acids, such as C16:0, C23:0, C24:0, C25:0, C26:0 (Figure 5B). The dicarboxylic fatty acids of C22:0 and C24:0 were significantly increased in the *PgCYP703A4ox* lines (Figure 5C). The levels of the terminal-hydroxy fatty acid C22:0 was found to increase up to two times in *PgCYP703A4ox* in comparison with the wild type (Figure 5D). These data indicate that the *PgCYP703A4* overexpression in *A. thaliana* affects the fatty acid composition of cutin monomers in siliques.

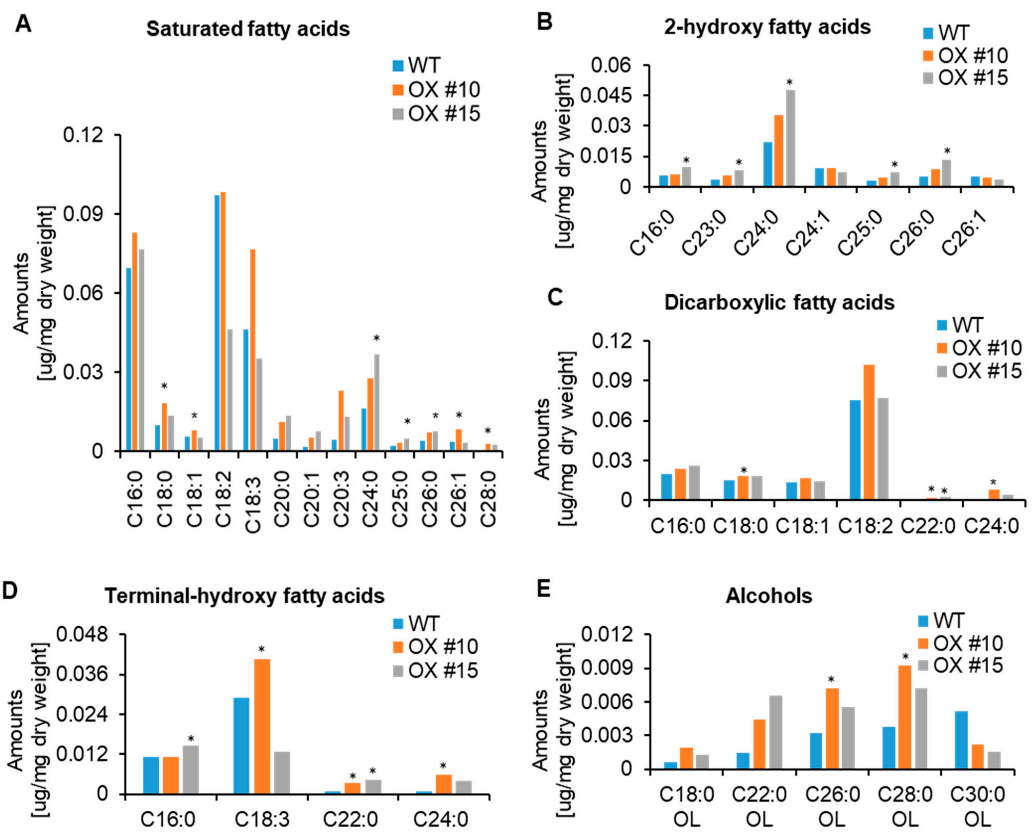


Figure 5. Chemical analysis of silique cutin monomers in wild type and PgCYP703ox lines via GC-MS and GC-FID. (**A**) Saturated fatty acids per milligram of dry weight (µg/mg). (**B**) 2-hydroxy fatty acids per milligram of dry weight (ug/mg). (**C**) Dicarboxylic fatty acids per milligram of dry weight (ug/mg). (**D**) Terminal-hydroxy fatty acids per milligram of dry weight (ug/mg). (**E**) Alcohols per milligram of dry weight (ug/mg). Values indicate mean of five biological replicates ± SD. * $p < 0.05$.

4. Discussion

Plants have evolved a variety of enzymes for the in-chain α-, β-, and ω-hydroxylation of fatty acids. Hydroxylated fatty acids are the biosynthetic intermediates of plant biopolymers, such as cutin and suberin, which make up the barriers from land plant stress situations. Thus, fatty acid metabolic enzymes are critical for plants; however, the role of CYP members in controlling the development of *P. ginseng* has not been well studied. In this study, we characterized *PgCYP703A4* and its role in the fatty acid metabolism. The *PgCYP703A4* expression only detected at the flowering stage during microspore formation in the tapetum and gamete cells, which are active in sporopollenin synthesis. The overexpression of *PgCYP703A4* in *A. thaliana* increased silique size and seed production without affecting gamete cell, similar to *PgCYP704B1* [15].

CYPs constitute the largest family of enzymes in plant metabolism and represent plant evolution in terms of plant metabolism in development and adaptation, such as signaling, defense, and polymerization of complex chemical substances [37]. Among the 11 land plant clans, the CYP71 clan represents more than half of all CYPs in higher plants; consequently, a wide diversity of functions makes them more difficult to predict their preferred substrates than other clans [37]. In addition to CYP703, CYP77 family members, AtCYP77A4 and AtCYP77A6, can in-chain-hydroxylate fatty acids to form precursors of cutin [9,38,39]. Looking at their phylogenetic relationship, CYP703 diversified prior to the emergence of CYP77s as spore protectors. CYP703 is an ancient gene family that is required for land plants, whereas CYP77 is required in only angiosperms [37]. However, both CYP703A and CYP77A function as in-chain hydroxylases, compared with most other enzymes that are end-chain (ω) hydroxylase [30].

In addition, a part of the CYP71 clan, the CYP78 subfamily genes exhibited fatty acid hydroxylation reactions, particularly for short chains [24]. Different from a single member of CYP703 (Figure 2), the CYP78 family contains several members in *A. thaliana* (Figure 2), indicating late gene duplication for the species. CYP78A family members regulate reproductive organ development but are more related to female organs. *A. thaliana* gene *CYP78A9* was reported to be involved in the control of carpel shape [40]. The overexpression of *CYP78A9* results in large, seedless fruit, although the metabolites have not been discovered [40]. *O. sativa* gene *OsCYP78A13* promotes seed growth by regulating the embryo and endosperm size, as well as spikelet hull development [41]. *PaCYP78A9* regulates fruit size in *Prunus avium*, showing increases in silique and seed size in *A. thaliana* by hetero-overexpression [42]. In addition to the above studies of the CYP71 clan other functions include glucosinolate production [43], p-coumaraldehyde hydroxylation [44], and pathogen defense function [45], as indicated in Figure 2. It is clear that the CYP71 clan has a large diversity of functions, but only CYP703 and CYP78 families of this clan, have the conserved PERF consensus, and both subfamiles are involved in plant reproductive development. Further studies are required to identify its positive relationship with biological function.

In *P. ginseng*, reproductive development and functional studies are scarce. We previously identified a functional ortholog of *AtCYP704B1*, termed *PgCYP704B1* [15]. The CYP704B family, which belongs to the CYP86 clan, is involved in the ω-hydroxylation of long-chain fatty acids. Altered exine in the pollen wall was detected in mutant of *A. thaliana cyp704B1* [46], *Brassica napus CYP704B1* [47], and *O. sativa CYP704B2* [36]. However, *O. sativa CYP704B2* also had an undeveloped anther cuticle and sterile male phenotype [36]. It is similar to CYP703A, although it is in a separate clan. Similarly, CYP701A and CYP88A, which belong to the CYP71 and CYP85 clans, respectively, act sequentially in the same pathway as ent-kaurene oxidase and kaurenolic acid oxidase, respectively [48]. With the early evolution of CYPs, CYP703 and CYP704 could be involved in cutin biopolymer synthesis, particularly for pollen wall polymers, for in-chain and ω-hydroxylation, respectively. This study was limited by the difficulty of obtaining flowers from transgenic *P. ginseng*. However, further studies on *P. ginseng* development is required to develop hybrid and male sterile system for breeding.

Taken together, *PgCYP703A4*, a member of CYP703A in the CYP71 clan, and *PgCYP704B1* [22], in the CYP86 clan, are similarly expressed in the *P. ginseng* tapetum and meiotic cells, and overexpression in *A. thaliana* affects fatty acid metabolism in siliques. Previous studies on *A. thaliana* and *O. sativa* examined knockout mutants displaying partial or full male sterility [7,9,36,46] and therefore did not further investigate the phenotype regarding fruit development. This requires further investigation to determine the role of hydroxylated fatty acids in sporopollenin synthesis and the development of the silique cuticle.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/plants11030383/s1, Figure S1: Multiple alignment of PgCYP703 with homologous proteins from other plant species. Figure S2: Superimposed hydrophobicity profile predictions for PgCYP703A4 and selected homologs from the 703A4 family. Figure S3: Cytological analysis of an *Arabidopsis* mutant and the *PgCYP703A4* overexpression line.

Author Contributions: Y.-J.K. and D.Z. conceived and design the project and experiments. J.S. (Jeniffer Silva) and J.K. conducted the experiments and data arrangements. C.P., Y.K., N.P. and J.S. (Johan Sukweenadhi) contributed for bioinformatic analysis and plant growth. C.-O.H. and K.K.K. provide critical comments for metabolite analysis. J.Y. contributed for cytological analysis and J.S. (Jianxin Shi) performed the wax and cutin analysis. H.-J.S., H.C.P. and K.M.L. contributed for manuscript revision. Y.-J.K. and J.K. co-write the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by a 2-Year Research Grant of Pusan National University.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Nelson, D.R. Cytochrome P450 and the individuality of species. *Arch. Biochem. Biophys.* **1999**, *369*, 1–10. [CrossRef] [PubMed]
2. Chapple, C. Molecular-genetic analysis of plant cytochrome P450-dependent monooxygenases. *Annu Rev. Plant Biol.* **1998**, *49*, 311–343. [CrossRef] [PubMed]
3. Mizutani, M.; Ohta, D. Diversification of P450 genes during land plant evolution. *Annu Rev. Pland Biol.* **2010**, *61*, 291–315. [CrossRef] [PubMed]
4. Nelson, D.R.; Schuler, M.A.; Paquette, S.M.; Reichhart, W.R.; Bak, S. Comparative genomics of rice and Arabidopsis. Analysis of 727 cytochrome P450 genes and pseudogenes from a monocot and a dicot. *Plant Physiol.* **2004**, *135*, 756–772. [CrossRef] [PubMed]
5. Torutaeva, E.; Oh, S.A.; Park, S.K. Identification of new mutant alleles of *Augmin* subunits broadens spectrum of *Augmin* function during sexual reproduction in Arabidopsis. *J. Plant Biol.* **2020**, *63*, 485–494. [CrossRef]
6. Cui, X.; Wang, Q.; Yin, W.; Xu, H.; Wilson, Z.A.; Wei, C.; Pan, S.; Zhang, D. PMRD: A curated database for genes and mutants involved in plant male reproduction. *BMC Plant Biol.* **2012**, *12*, 215. [CrossRef]
7. Yang, X.; Wu, D.; Shi, J.; He, Y.; Pinot, F.; Grausem, B.; Yin, C.; Zhu, L.; Chen, M.; Luo, Z.; et al. Rice CYP703A3, a cytochrome P450 hydroxylase, is essential for development of anther cuticle and pollen exine. *J. Integr. Plant Biol.* **2014**, *56*, 979–994. [CrossRef]
8. Morant, M.; Jørgensen, K.; Schaller, H.; Pinot, F.; Møller, B.L.; Reichhart, D.W.; Bak, S. CYP703 is an ancient cytochrome P450 in land plants catalyzing in-chain hydroxylation of lauric acid to provide building blocks for sporopollenin synthesis in pollen. *Plant Cell* **2007**, *19*, 1473–1487. [CrossRef]
9. Li-Beisson, Y.; Pollard, M.; Sauveplane, V.; Pinot, F.; Ohlrogge, J.; Beisson, F. Nanoridges that characterize the surface morphology of flowers require the synthesis of cutin polyester. *Proc. Natl. Acad. Sci. USA* **2009**, *51*, 22008–22013. [CrossRef]
10. Torres, M.F.; Mathew, L.S.; Ahmed, I.; Al-Azwani, L.K.; Krueger, R.; Nuñez, D.R.; Mohamoud, Y.A.; Clark, A.G.; Suhre, K.; Malek, J.A. Genus-wide sequencing supports a two-locus model for sex-determination in *Phoenix*. *Nat. Commun.* **2018**, *9*, 3969. [CrossRef]
11. Kim, Y.J.; Zhang, D.; Yang, D.C. Biosynthesis and biotechnological production of ginsenosides. *Biotechnol. Adv.* **2015**, *33*, 717–735. [CrossRef] [PubMed]
12. Kim, Y.J.; Jang, M.G.; Zhu, L.; Silva, J.; Zhu, X.; Sukweenadhi, J.; Kwon, W.S.; Yang, D.C.; Zhang, D. Cytological characterization of anther development in *Panax ginseng* Meyer. *Protoplasma* **2015**, *253*, 1111–1124. [CrossRef] [PubMed]
13. Kim, Y.J.; Silva, J.; Zhang, D.; Shi, J.; Joo, S.C.; Jang, M.G.; Kwon, W.S.; Yang, D.C. Development of interspecies hybrids to increase *ginseng* biomass and ginsenoside yield. *Plant Cell Rep.* **2016**, *36*, 779–790. [CrossRef] [PubMed]
14. Silva, J.; Kim, Y.J.; Xiao, D.; Sukweenadhi, J.; Hu, T.; Kwon, W.S.; Hu, J.; Yang, D.C.; Zhang, D. Cytological analysis of *ginseng* carpel development. *Protoplasma* **2017**, *254*, 1909–1922. [CrossRef] [PubMed]

15. Silva, J.; Sukweenadhi, J.; Myagmarjav, D.; Mohanan, P.; Yu, J.; Shi, J.; Jung, K.H.; Zhang, D.; Yang, D.C.; Kim, Y.J. Overexpression of a novel cytochrome P450 monooxygenase gene, *CYP704B1*, from *Panax ginseng* increase biomass of reproductive tissues in transgenic Arabidopsis. *Mol. Biol. Rep.* **2020**, *47*, 4507–4518. [CrossRef] [PubMed]
16. Yu, N.Y.; Wagner, J.R.; Laird, M.R.; Melli, G.; Rey, S.; Lo, R.; Dao, P.; Sahinalp, S.C.; Ester, M.; Foster, L.J.; et al. PSORTb 3.0: Improved protein subcellular localization prediction with refned localization subcategories and predictive capabilities for all prokaryotes. *Bioinformatics* **2010**, *26*, 1608–1615. [CrossRef]
17. Kyte, J.; Doolittle, R.F. A simple method for displaying the hydropathic character of a protein. *J. Mol. Biol.* **1982**, *157*, 105–132. [CrossRef]
18. Prestridge, D.S. SIGNAL SCAN: A computer program that scans DNA sequences for eukaryotic transcriptional elements. *Bioinformatics* **1991**, *7*, 203–206. [CrossRef]
19. Betchtold, N.; Pelletier, G. In planta *Agrobacterium*-mediated transformation of adult *Arabidopsis thaliana* plants by vacuum infiltration. *Methods Mol. Biol.* **1998**, *82*, 256–266.
20. Zhang, Y.; Liang, W.; Shi, J.; Xu, J.; Zhang, D. *MYB56* encoding a *R2R3 MYB* transcription factor regulates seed size in *Arabidopsis thaliana*. *J. Integr. Plant Biol.* **2013**, *55*, 1166–1178. [CrossRef]
21. Jung, K.H.; Han, M.J.; Lee, D.Y.; Lee, Y.S.; Schreiber, L.; Franke, R.; Faust, A.; Yephremov, A.; Saedler, H.; Kim, Y.W.; et al. Wax-deficient anther1 is involved in cuticle and wax production in rice anther walls and is required for pollen development. *Plant Cell* **2006**, *18*, 3015–3032. [CrossRef]
22. Riederer, M.; Müller, C. *Biology of the Plant Cuticle*; Blackwell: Oxford, UK, 2006.
23. Imaishi, H.; Matsumoto, Y.; Ishitobi, U.; Ohkawa, H. Encoding of a cytochrome P450-dependent lauric acid monooxygenase by CYP703A1 specifically expressed in the floral buds of *Petunia hybrida*. *Biosci. Biotechnol. Biochem.* **1999**, *63*, 2082–2090. [CrossRef] [PubMed]
24. Kai, K.; Hashidzume, H.; Yoshimura, K.; Suzuki, H.; Sakurai, N.; Shibata, D.; Ohta, D. Metabolomics for the characterization of cytochromes P450-dependent fatty acid hydroxylation reactions in Arabidopsis. *Plant Biotechnol.* **2009**, *26*, 175–182. [CrossRef]
25. Pan, Y.; Michael, T.P.; Hudson, M.E.; Kay, S.A.; Chory, J.; Schuler, M.A. Cytochrome P450 monooxygenases as reporters for circadian-regulated pathways. *Plant Physiol.* **2009**, *150*, 858–878. [CrossRef] [PubMed]
26. Humphreys, J.M.; Hemm, M.R.; Chapple, C. New routes for lignin biosynthesis defined by biochemical characterization of recombinant ferulate 5-hydroxylase, a multifunctional cytochrome P450-dependent monooxygenase. *Proc. Natl. Acad. Sci. USA* **1999**, *96*, 10045–10050. [CrossRef] [PubMed]
27. Hasemann, C.A.; Kurumbail, R.G.; Boddupalli, S.S.; Peterson, J.A.; Deisenhofer, J. Structure and function of cytochromes P450: A comparative analysis of three crystal structures. *Structure* **1995**, *2*, 41–62. [CrossRef]
28. Reichhart, D.W.; Bak, S.; Paquette, S. Cytochromes P450. *Arab. Book* **2002**, *1*, e0028. [CrossRef] [PubMed]
29. Williams, P.A.; Cosme, J.; Sridhar, V.; Johnson, E.F.; McRee, D.E. Mammalian microsomal Cytochrome P450 monooxygenase: Structure adaptation for membrane binding and functional diversity. *Mol. Cell* **2000**, *5*, 121–131. [CrossRef]
30. Cabello-Hurtado, F.; Batard, Y.; Salaün, J.P.; Durst, F.; Pinot, F.; Reichhart, D.W. Cloning, expression in yeast, and functional characterization of CYP81B1, a plant cytochrome P450 that catalyzes in-chain hydroxylation of fatty acids. *J. Biol. Chem.* **1998**, *273*, 7260–7267. [CrossRef]
31. Kandel, S.; Sauveplane, V.; Olry, A.; Diss, L.; Benveniste, I.; Pinot, F. Cytochrome P450-dependent fatty acid hydroxylases in plants. *Phytochem. Rev.* **2006**, *5*, 359–372. [CrossRef]
32. Moon, S.; Hong, W.J.; Kim, Y.J.; Chandran, A.K.N.; Gho, Y.S.; Yoo, Y.H.; Nguyen, V.N.T.; An, G.; Park, S.K.; Jung, K.H. Comparative transcriptome analysis reveals gene regulatory mechanism of UDT1 on anther development. *J. Plant Biol.* **2020**, *63*, 289–296. [CrossRef]
33. Li, J.; Yuan, J.; Li, M. Characterization of putative cis-regulatory elements in genes preferentially expressed in Arabidopsis male meiocytes. *BioMed Res. Int.* **2014**, *708364*, 10.
34. Nguyen, T.D.; Moon, S.; Nguyen, V.N.T.; Gho, Y.; Chandran, A.K.N.; Soh, M.S.; Song, J.T.; An, G.; Oh, S.A.; Park, S.K.; et al. Genome-wide identification and analysis of rice genes preferentially expressed in pollen at an early developmental stage. *Plant Mol. Biol.* **2016**, *92*, 71–88. [CrossRef] [PubMed]
35. Kim, N.H.; Jayakodi, M.; Lee, S.C.; Choi, B.S.; Jang, W.; Lee, J.; Kim, H.H.; Waminal, N.E.; Lakshmanan, M.; Nguyen, B.V.; et al. Genome and evolution of the shade-requiring medicinal herb *Panax ginseng*. *Plant Biotechnol. J.* **2018**, *16*, 1904–1917. [CrossRef] [PubMed]
36. Li, H.; Pinot, F.; Sauveplane, V.; Reichhart, D.W.; Diehl, P.; Schreiber, L.; Franke, R.; Zhang, P.; Chen, L.; Gao, Y.; et al. Cytochrome P450 family member CYP704B2 catalyzes the ω -hydroxylation of fatty acids and is required for anther cutin biosynthesis and pollen exine formation in rice. *Plant Cell* **2010**, *22*, 173–190. [CrossRef]
37. Nelson, D.; Reichhart, D.W. A P450-centric view of plant evolution. *Plant J.* **2011**, *66*, 194–211. [CrossRef]
38. Sauveplane, V.; Kandel, S.; Kastner, P.E.; Ehlting, J.; Compagnon, V.; Werck- Reichhart, D.; Pinot, F. Arabidopsis thaliana CYP77A4 is the first cytochrome P450 able to catalyze the epoxidation of free fatty acids in plants. *FEBS J.* **2009**, *276*, 719–735. [CrossRef]
39. Pinot, F.; Beisson, F. Cytochrome P450 metabolizing fatty acids in plants: Characterization and physiological roles. *FEBS J.* **2011**, *278*, 195–205. [CrossRef]
40. Ito, T.; Meyerowitz, E.M. Overexpression of a gene encoding a cytochrome P450, CYP78A9, induces large and seedless fruit in Arabidopsis. *Plant Cell* **2000**, *9*, 1541–1550. [CrossRef]

41. Xu, F.; Fang, J.; Ou, S.; Gao, S.; Zhang, F.; Du, L.; Xiao, Y.; Wang, H.; Sun, X.; Chu, J.; et al. Variations in CYP78A13 coding region influence grain size and yield in rice. *Plant Cell* **2015**, *38*, 800–811. [CrossRef]
42. Qi, X.; Liu, C.; Song, L.; Li, Y.; Li, M. PaCYP78A9, a Cytochrome P450, regulates fruit size in Sweet Cherry (*Prunus avium L.*). *Front. Plant Sci.* **2017**, *8*, 2076. [CrossRef] [PubMed]
43. Naur, P.; Petersen, B.L.; Mikkelsen, M.D.; Bak, S.; Rasmussen, H.; Olsen, C.E.; Halkier, B.A. CYP83A1 and CYP83B1, Two nonredundant cytochrome P450 enzymes metabolizing oximes in the biosynthesis of glucosinolates in Arabidopsis. *Plant Physiol.* **2003**, *133*, 63–72. [CrossRef] [PubMed]
44. Weng, J.K.; Li, X.; Stout, J.; Chapple, C. Independent origins of syringyl lignin in vascular plants. *Proc. Natl. Acad. Sci. USA* **2008**, *105*, 7887–7892. [CrossRef] [PubMed]
45. Sohrabi, R.; Huh, J.H.; Badieyan, S.; Rakotondraibe, L.H.; Kliebenstein, D.J.; Sobrado, P.; Tholl, D. In planta variation of volatile biosynthesis: An alternative biosynthetic route to the formation of the pathogen-induced volatile homoterpene DMNT via triterpene degradation in Arabidopsis roots. *Plant Cell* **2015**, *27*, 874–890. [CrossRef]
46. Dobritsa, A.A.; Shrestha, J.; Morant, M.; Pinot, F.; Matsuno, M.; Swanson, R.; Moller, B.L.; Preuss, D. CYP704B1 is a long-chain fatty acid omega-hydroxylase essential for sporopollenin synthesis in pollen of Arabidopsis. *Plant Physiol.* **2009**, *151*, 574–589. [CrossRef] [PubMed]
47. Yi, B.; Zeng, F.; Lei, S.; Chen, Y.; Yao, X.; Zhu, Y.; Wen, J.; Shen, J.; Ma, C.; Tu, J.; et al. Two duplicate CYP704B1-homologous genes BnMs1 and BnMs2 are required for pollen exine formation and tapetal development in Brassica napus. *Plant J.* **2010**, *63*, 925–938. [CrossRef]
48. Helliwell, C.A.; Chandler, P.M.; Poole, A.; Dennis, E.S.; Peacock, W.J. The CYP88A cytochrome P450, ent-kaurenoic acid oxidase, catalyzes three steps of the gibberellin biosynthesis pathway. *Proc. Natl. Acad. Sci. USA* **2001**, *98*, 2065–2070. [CrossRef]