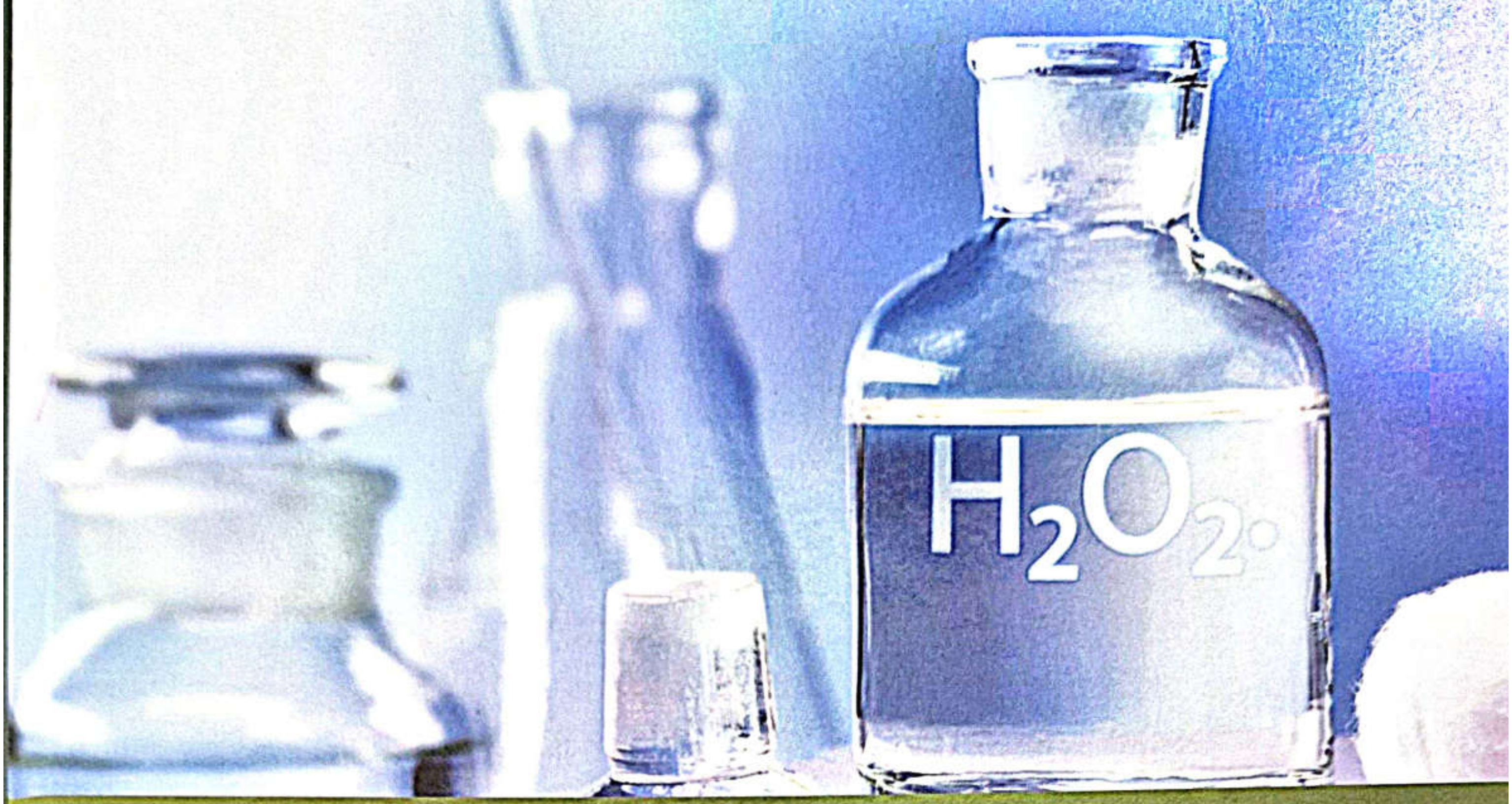

Hydrogen Peroxide

Signaling Mechanisms and Crosstalk in Plant Development and Stress Responses

Edited by Mohd Tanveer Alam Khan, Taiba Saeed, Aqeel Ahmad, Qazi Fariduddin, and Mohammad Yusuf

CRC Press
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CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an Informa business

Hydrogen Peroxide

Hydrogen peroxide (H_2O_2) is recognized as a crucial signaling molecule that mediates physiological and biochemical processes in plants, regulating various development and stress responses. *Hydrogen Peroxide: Signaling Mechanisms and Crosstalk in Plant Development and Stress Responses* presents a comprehensive overview of hydrogen peroxide's modes of action in plants, demonstrating the important role played in plant stress signaling and communication. It introduces key topics in H_2O_2 research such as plant signaling, molecular responses, and interaction with other hormones.

Features

- Discusses experiments interrelated to H_2O_2 signaling pathway in plants under various environmental conditions.
- Addresses important concerns in H_2O_2 research from a wide range of organisms, including plants and prokaryotes such as bacteria and archaea.
- Collects, summarizes, and presents developments in plant signaling and communication.
- Aids scientists and breeders in developing strategies to enhance plant growth and stress tolerance.

Environmental stress is destructively disturbing plant growth and efficiency, resulting in concerns to improve food crop yield, and H_2O_2 has immense field implications as it is vital in regulating plant growth and stress responses. *Hydrogen Peroxide: Signaling Mechanisms and Crosstalk in Plant Development and Stress Responses* is an invaluable resource for researchers and scientists to use as a guide to conduct studies on environmental conditions of the plant hydrogen peroxide signaling systems.

Designed cover image: Shutterstock

First edition published 2025
by CRC Press
2385 NW Executive Center Drive, Suite 320, Boca Raton FL 33431

and by CRC Press
4 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

CRC Press is an imprint of Taylor & Francis Group, LLC

Library of Congress Cataloging-in-Publication Data
Names: Khan, Tanveer Alam, editor. | Saeed, Taiba, editor. | Ahmad, Aqeel, editor. |
Fariduddin, Qazi, editor. | Yusuf, Mohammad (Lecturer in biology) editor.
Title: Hydrogen peroxide : signalling mechanisms and crosstalk in plant
development and stress responses / edited by Tanveer Alam Khan, Taiba
Saeed, Aqeel Ahmad, Qazi Fariduddin, and Mohammad Yusuf.
Description: First edition. | Boca Raton, FL : CRC Press, 2025. |
Includes bibliographical references and index. |
Identifiers: LCCN 2024043153 (print) | LCCN 2024043154 (ebook) |
ISBN 9781032610443 (hardback) | ISBN 9781032647678 (paperback) |
ISBN 9781032647692 (epub)
Subjects: LCSH: Plant cellular signal transduction. | Hydrogen peroxide. |
Plants—Effect of stress on. | Plant defenses.
Classification: LCC QK754 .H94 2025 (print) | LCC QK754 (ebook) |
DDC 571.7/42—dc23/eng/20250111
LC record available at https://lccn.loc.gov/2024043153
LC ebook record available at https://lccn.loc.gov/2024043154

ISBN: 9781032610443 (hbk)
ISBN: 9781032647678 (pbk)
ISBN: 9781032647692 (ebk)

DOI: 10.1201/9781032647692

Typeset in Times
by codeMantra

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Nilofer and Abdul Mazeed

INTRODUCTION

Horticulture is a subfield of agriculture which deals with garden crops usually fruits, vegetables, and ornamental plants. The word horticulture is derived from two Latin words *hortus*, which means "garden or orchard" and *cultura*, which means "to cultivate". Although it alludes to heavy commercial production, in everyday usage it applies to all sorts of garden maintenance. Though all forms of production inherently have tight ties to one another, horticulture is positioned between field agriculture and residential gardening in terms of scale. The two types of plants grown in horticulture are plants for food (pomology and olericulture) and plants for adornment (floriculture and landscape horticulture). Fruit and nut crops are the focus of pomology; edible herbaceous plants, moreover such as carrots (edible root), asparagus (edible stem), lettuce (edible leaf), cauliflower (edible flower buds), tomatoes (edible fruit), and peas (edible seed), are the subject of olericulture. Culturing flowers and decorative plants, such as cut flowers, potted plants, and greenery, is known as floriculture. Plants for the landscape, such as grass turf, and particular interest in nursery crops including shrubs, trees, and vines are included in the wide area of landscape horticulture. Numerous elements, including topography, climate, and other geographical variances, affect both the crop's success and the horticulturist's area of expertise. Climatic changes such as altering soil and irrigation water, increasing the buildup of salts in agricultural soil, and decreasing the quantity and quality of irrigation water in agricultural areas globally, particularly in arid regions will have a detrimental effect on plant production; this will result in soil salinization and poor irrigation water quality (Corwin, 2021). One of the main abiotic stresses affecting horticultural crops, particularly vegetables, is the salinity of the soil and water. Light, temperature, water, humidity, and nutrition are additional environmental factors that impact plant growth. It's critical to comprehend how these elements impact horticulture crops' growth and development.

Oxidative stress causes stressed plants to produce excess hydrogen peroxide, a non-radical reactive oxygen species (ROS) that builds up. Although hydrogen peroxide (H_2O_2) is known to be toxic and to cause oxidative damage to plant tissues, some recent research has demonstrated that, when applied at low concentrations, H_2O_2 can improve plant growth and mitigate the negative effects of stress on plants by increasing the activity of antioxidant enzymes, the stability of plant membranes, and the metabolism of lipids, fatty acids, and carbohydrates (Sun et al., 2016; Gohari et al., 2020). H_2O_2 also alters physiological processes, which boost a plant's resistance to abiotic stress. Applying H_2O_2 is an easy, practical, economical, and effective strategy to support plants in their defense against abiotic stress. It improves plant growth and yield, relative water content, membrane stability index, and photosynthetic efficiency (Hajivar and Zare-Bavani, 2019).

Low-concentration H_2O_2 application increases accumulation of inorganic and organic solutes, fresh herb production, and essential oil *ocimum* spp. while Na^+ and Cl^- content decreases under salt stress (Silva et al., 2019); in tomato improved growth traits and increased fruit count was observed by Hajivar and Zare-Bavani (2019); under salt stress, growth and development of wheat root increased (Li et al., 2011); improved plant resistance to salt stress by decreased accumulation of H_2O and MDA and increased antioxidant enzyme activity (Li et al., 2011;Liu et al., 2022); and H_2O_2 spray improved the growth and production of soursop plants while reducing the detrimental effects of salt stress.

Additionally, it improved the water and mineral condition of stressed maize plants (Guzel and Terzi, 2013). However, the concentration, application technique, plant type, and developmental stage all affect the effectiveness of the application of H_2O_2 (Capitulino et al., 2023), while both seed priming and foliar spraying with H_2O_2 mitigate the negative effects of drought stress, foliar treatment is the most effective method that significantly increased yield and yield components of rice stressed plants (Jira-anunkul and Pattanagul, 2021). As documented in wheat, high concentrations of H_2O_2 hindered plant development, produced substantial oxidative damage, and eventually resulted in plant cell death and low concentrations of H_2O_2 strengthened the antioxidative defense system and raised crop yields (Asghar et al., 2021).

INDUSTRIAL HISTORY OF HYDROGEN PEROXIDE

Louis Jacques Thenard made the initial discovery of H_2O_2 in 1818 when he observed the interaction between barium peroxide and nitric acid (McDonnell, 2014). Up to the development of three methods-electrolytic, anthraquinone, and isopropyl-alcohol oxidation in the middle of the 20th century, variations of this reaction were use and nowadays, the bulk of industrial manufacturing uses the anthraquinone auto-oxidation process, which was initially created by DuPont Chemical (Wernimont et al., 1998). As the formula indicates, H_2O_2 is composed of two hydrogen and two oxygen atoms, with one oxygen atom bonded to both hydrogen and the additional oxygen atom as a valence tetrad. At industrial quantities above 10%, it exists as a pale blue liquid; however, when diluted to the 3% concentration often seen in pharmacies, it loses all color. H_2O_2 is a moderately unstable substance that may break down spontaneously or with the help of a catalyst under a range of environmental circumstances. The spectrum of catalysts includes naturally occurring enzymes like catalase (Bosmans et al., 2016; Van Haute et al., 2015), inorganic metals like manganese or iron oxides (McDonnell, 2014), and UV radiation from the sun (Sichel et al., 2009). This reaction can be regulated in a way that is particular to the application by using catalysts, whether used alone or in conjunction with catalysts. H_2O_2 is used in a wide range of global sectors, including pulp and paper, detergent production, wastewater purification, and fertigation systems.

Water treatment processes and industrial applications have long employed hydrogen peroxide (H_2O_2) as a potent oxidant. When H_2O_2 is catalyzed in water, it can generate a variety of free radicals and other reactive species. These organisms possess the capacity to alter or decompose organic substances (Petri et al., 2003). It is a chemical that is safe for the environment and is largely produced in plant cells during respiration, photosynthesis, and photorespiration. A small quantity is also produced during photosynthesis (Slesak et al., 2007). Concern over hydrogen peroxide's impact on fruit quality and plant growth and development is growing on a global scale. During photosynthesis, photorespiration, and respiration processes, plant cells are the primary source of hydrogen peroxide production. Being the most stable of the so-called ROS, it is essential for physiological processes as a signaling molecule. Increases in intra- and intercellular H_2O_2 levels when applied at the ideal concentration positively influenced fruit growth, development, and quality.

Carbon dioxide (CO_2) and water (H_2O) are used by plants during photosynthesis to make carbohydrate ($C_6H_{12}O_6$) and release oxygen (O_2). The carbohydrate is then turned into energy during respiration and utilized to construct new tissues. While respiration may happen at any time, in both light and dark conditions, photosynthesis requires light. The presence of O_2 in the earth's atmosphere is believed originates from photosynthesis activity (Slesak et al., 2007). A molecule with two unpaired electrons, each in a distinct π^* anti-bonding, is oxygen in its ground state. O_2's orbital and divalent reduction is a difficult procedure that calls for the creation of univalent intermediates. When a lone electron is compiled, O_2 is reduced to the superoxide anion radical, which demands energy input.

H_2O_2 is a molecule that has no net charge and is a member of the non-radical ROS (Halliwell, 2006). Hydrogen peroxide is much preferred to be a long-range signaling element than superoxide for this reason as well as the fact that H_2O_2 has a longer half-life than the radical superoxide