International Journal of Biological Innovations

Available online: http://ijbi.org.in | http://www.gesa.org.in/journals.php

DOI: https://doi.org/10.46505/IJBI.2019.1107

Review Article

E-ISSN: 2582-1032

Allelochemical Stress, ROS and Plant Defence System

Deepmala Singh

Department of Botany
Dr. Ambedkar Government Post Graduate College, Unchahar, Raebareli (U.P.), India
Corresponding author: deepmalab4u@gmail.com

Received: 23.01.2019 Reviewed: 31.01.2019 Accepted: 05.02.2019

Abstract: In nature plants grow close to each other, hence there must be a competition arises between them for nutrition and space. For their survival plants must have some strategy to defense and attack. Plants produce various secondary metabolites which may not be of nutritional values and have toxic effects. These metabolites when released out of plants and come in contact with another plant, exerts some effects (deleterious or beneficial) on recipient plant. These metabolites are known as allelochemicals or allelopathins. Allelochemicals also serve as defense agent against herbivores or competing plants due to their toxic nature. They maybe used as a toolfor attack. They exert biotic stress which is called as allelochemical stress or allelopathy. Present study investigates the adverse impact of allelopathy on recipient plant with special reference to production of ROS, oxidative stress and defense enzyme system.

Keywords: Allelochemicals, Allelopathy, Biotic stress, Catalase, Superoxide dismutase, Peroxidase, ROS.

Introduction

Production of secondary metabolites takes place in plants through several biochemical cycles. These chemical are of varied nature such as; organic acids, alcohols, aldehydes, phenols, flavonoids, tannins, terpenoids, amino acids, steroid and alkaloids etc. There is a common term allelochemical used for such secondary metabolites which escape out of plant body via. Volatilization, exudation, leaching, residues, and start affecting neighboring plants. The detrimental effects of allelochemicals on recipient plants are studied under allelopathy as biotic stress (Rice, 1984; Singh *et al*, 2009a). Autotoxity is also observed as a type of allelopathy where allelochemicals released form a plant inhibit growth of other plants of same species. Crop residue able to reduce seedling growth and seed germination of same crop plants of next season if staying in crop fields (Singh *et al*, 2008, 2010).However, in agro ecosystem allelochemicals are also reported to be beneficial, when present in very low concentration (Singh *et al*, 2015). Allelochemical stress and its effects are now detected and reported at molecular, structural, biochemical, physiological and ecological level (Bogatek and Gniazdowska, 2007).

ROS production and oxidative stress

ROS (reactive oxygen species) generation takes place during electron transferin various cellular organelles. Chloroplast, peroxisomes and mitochondria are the major sites of ROS production but it was reported that only 1% ROS escaped from its natural path during normal condition (Asada and Takahashi, 1987). These diverted ROS are the precursor of oxidative injury, under stress condition. It is well documented that allelochemicals inhibit plant growth by causing oxidative stress, by triggering the excessive production of ROS through different channel (Cruz-Ortega *et al*, 2007). The ROS include free radicals like superoxide radicals ($O_2^{\cdot}$-), hydroxyl radical (.OH), also some non-radical molecules such as hydrogen peroxidase (H_2O_2) and singlet oxygen ($^1O_2$). The toxic level of ROS can affect membrane permeability, protein disintegration, DNA damage, lipid peroxidation (Smirnoff, 1993) and ultimately programmed cell death (Neill *et al*, 2002; Ding *et al*, 2007).Oxidative stress is defined as the state where enzymatic actions are insufficient to balance the production of ROS within cell (Apel and Hirt, 2004).

Plant defense system

Due to allelopathic interactions secondary metabolites of one plant enters into other plant, these allelochemicals are able to interfere and alter the normal biochemical reactions within recipient plant, which causes accumulation of ROS in higher concentration and lead to oxidative burst. To cope up with this damage plant device some defense mechanism this includes enzymatic and non-enzymatic defense system.

Some low molecular weight compatible solutes are formed in response to oxidative injury, like carotenoids, proline, ascorbate, tocopherols, glutathione and phenolic compounds. They are commonly termed as osmolytes as their main function is to maintain cell volume, water potential and turgor pressure during stress condition. The phenomenon is known as osmotic adjustment. Osmolytes are potential scavengers of ROS along with antioxidative enzymes. Superoxide dismutase (SOD) is the first line of defense which detoxifies singlet oxygen and converts them into H_2O_2 (Sharma *et al*, 2012).This metalloenzyme exist in three specific forms. MnSOD with manganese in the active site found in mitochondria, copper zinc containing CuZnSOD present in cytoplasm andiron containing FeSOD in chloroplast. Peroxidases exist in two forms ascorbate peroxidase (APX) and glutathione peroxidase (GPX). The main function of peroxidases is to scavenge H_2O_2 present in vacuoles, cell wall and cytosol (Gomez et al, 2004). H_2O_2 located in peroxisomes is quenched by a tetrameric enzyme catalase (CAT). CAT converts H_2O_2 into water and oxygen (Bailly *et al*, 2004). Formation of antioxidative enzyme is triggered by the over accumulation of ROS within cell, so ROS also serve as a signal molecule for enhanced production of antioxidants.

Conclusion

Allelochemicals exerts biotic stress to neighboring plant by reaching inside them. Impacts of allelopathy can be easily noticed as retarded growth, necrosis of roots and shoot tips, dis-colouration of leaves, lack of root hair. However, at cellular level production of ROS and related oxidative stress in general has been proposed as one of the major mechanisms of action of allelochemicals. Allelochemicals not only promote ROS production in many tissues but also disturb the delicate balance between ROS and its scavengers, hence enhanced oxidative injury.

To combat with the oxidative burst several osmolytes are produced in response together with multiple defense enzymes. SOD, CAT, APX and GPX scavenges different forms of ROS. It is reported that activity of these enzymes increased during stress condition (Table 1). ROS is also responsible for activation of these defense enzymes. It acts as signal molecule which triggers activation of defense and repair enzymes. Defense enzymes help the plant in mitigating the adverse effect of allelochemical stress.

Table.1: Allelopathic effect of donar plant on antioxidant enzymes of recipient plant in lowconcentration.

Donar plant	**Recipient plant**	**Antioxidant enzymes (unit/g fresh wt)**	**Reference**
Nicotiana	*Zea mays*	Increased	Singh *et al*, 2009b
Helianthus annus	*Lycopersicon esculentum*	Increased	Macias *et al*, 2002
Zea mays	*Zea mays*	No significant difference	Singh *et al*, 2010
Callicarpa acuminate	*Zea mays*	Decreased	Cruz-Ortega *et al*, 2002
Helianthus annus	*Brassica campestris*	Increased	Oracz *et al*, 2007

REFERENCES

1. **Apel K. and Hirt H.** (2004). Reactive oxygen species: Metabolism, oxidative stress and signal transduction. *Annual Review of Plant Biology*. 55: 373-399.
2. **Asada K. and Takahashi M.** (1987). Production and scavenging of active oxygen in photosynthesis. Photoinhibition: topics of photosynthesis, 9th edition.: 227-287p.
3. **Bailly C., Leymerie J., Lehner A., Rousseau S, Come D. and Corbeneau F.** (2004). Catalase activity and expression in developing sunflower seeds as related to drying. *Journal of Experimental Botany*. 55 (396): 475-483.
4. **Bogatek R. and Gniazdowska A.** (2007). ROS and phytohormones in plant-plant allelopathic interaction. *Plant signaling and behavior*. 2(4): 317-318.
5. **Cruz-Ortega R., Ayala-Cordero G. and Anaya A. L.** (2002). Allelochemical stress produced by the aqueous leachates of *Calicarpa acuminate*: Effects on roots of bean, maize and tomato. *Physiologia Plantarum*. 116 (1):20–27.
6. **Cruz-Ortega R., Lara-Nunez A. and Anaya A. L.** (2007). Allelochemical stress can trigger oxidative damage in receptor plants, mode of action of phytotoxicity. *Plant signaling and behavior*. 2(4): 269-270.
7. **Ding J., Sun Y., Xiao C. L., Shi K., Zhou Y. H. and Yu J.Q.** (2007). Physiological basis of different allelopathic reactions of cucumber and fig leaf gourd plants to cinnamic acid. *Journal of Experimental Botany*. 58(13): 3765-3773.

8. **Gomez J. M., Jimenez A., Olmos E. and Seveilla F.** (2004). Location and effects of long term NaCl stresson superoxide dismutase and ascorbate peroxidase isoenzymes of pea (*Pisum sativum* cv. Puget) chloroplast. *Journal of Experimental Botany*. 55 (394): 119-130.

9. **Macias F. A., Verela R. M., Torres A., Galindo J.L.G. and Molinillo J.M.G.** (2002). Allelochemicals from sunflower: chemistry, bioactivity and application. In: Inderjit and A.U. Mallik (eds.). Chemical Ecology of Plants: Allelopathy in Aquatic and Terrestrial Ecosystems. *Birkhauser Verlag, Basel*. 73–87p.

10. **Neill S. J., Desikan R. and Hancock J.T.** (2002). Hydrogen peroxide signaling. *Current Opinion Plant Biology*. 5(5): 388-395.

11. **Oracz K., Bailly C., Gniazdowska A., Co ˆme D., Corbineau F. and Bogatek R.** (2007). Induction of oxidative stress by sunflower phytotoxins in germinating mustard seeds. *J. Chem. Ecol.* 33 (2):251–264.

12. **Rice E. L.** (1984). Allelopathy, 2nd edition, Academic Press, New York. 422p.

13. **Sampietro D. A. and Vattuone M. A.** (2006). Sugarcane straw and its phytochemicals as growth regulators of weed and crop plants. *Plant Growth Regul*. 48 (1):21–27.

14. **Sharma P., Jha A. B., Dubey R. S. and Pessarakli M.** (2012). Reactive oxygen species, oxidative damage, and antioxidative defense mechanism in plants under stressful conditions. *Journal of Botany*. 26p. DOI: 10.1155/2012/217037.

15. **Smirnoff N.** (1993). The role of active oxygen in the response of plants to water deficit and desiccation. *New Phytologist*.125 (1): 27-58.

16. **Singh N.B., Singh A. and Singh D.** (2008). Autotoxic effects of Lycopersicon esculentum. *Allelopathy Journal*. 22(2): 429-442.

17. **Singh A., Singh D. and Singh N.B.** (2009a). Allelochemical stress produced by aqueous leachate of *Nicotiana plumbaginifolia* Viv. *Plant Growth Regul*. 58 (2):163–171.

18. **Singh N.B., Singh D. and Singh A.** (2009b). Modification of physiological responses of water stressed *Zea mays* seedlings by leachate of *Nicotiana plumbaginifolia*. *General and Applied Plant Physiology*. 35 (1–2): 51–63.

19. **Singh N. B., Singh A. and Singh D.** (2010). Autotoxicity of maize and its mitigation by plant growth promoting rhizobacterium, *Paenibacillus polymyxa*. *Allelopathy Journal*. 25 (1): 195-204.

20. **Singh N. B., Singh D. and Singh A.** (2015). Biological seed priming mitigates the effects of water stress in sunflower seedlings. *Physiol. Mol. Biol. Plants*. 21(2): 207-214.