AGRIALLIS
Science for Agriculture and Allied Sector: A Monthly Magazine
Volume 6, Issue 3
www.agriallis.com

Article Id
AL04323

SUPERCHARGING PRODUCE: THE POWER OF INDUCED RESISTANCE IN FIGHTING POSTHARVEST DISEASES

[1]S Naveen Nayaka*, [2]Kuleshwar Prasad Sahu, [3]Pankaj Kumar Sinha and [4]Chandramani Patel

Email
nayaknaveen597@gmail.com

[1]Division of Plant Pathology, ICAR-Indian Agricultural Research Institute, New Delhi- 110012, India

[2]Rani Lakshmi Bai Central Agriculture University, Jhansi, Uttar Pradesh- 284003, India

[3]ICAR-Indian Agricultural Research Institute, Jharkhand- 825405, India

[4]Jawaharlal Nehru University, New Delhi- -110067, India

Postharvest losses of fruits and vegetables are a significant global concern, ranging from 5-25% in developed nations to 20-50% in developing nations. Factors such as senescence, mechanical injury, and decay contribute to these losses. The withdrawal of synthetic fungicides has led to an increase in decay-causing fungi. Research on induced resistance has emerged as an alternative to synthetic fungicides, enhancing plant defenses against pathogens. Advances in molecular biology and genomics have improved our understanding of postharvest quality. This study explores how induced resistance is influenced by host maturity, ripening processes, and senescence, offering insights into enhancing crop quality and consumer health.

The estimated postharvest losses range from 5-25% in developed nations and 20-50% in developing nations, depending on factors such as the type of product, variety, and the methods involved in marketing and handling (Kader, 2002). Hence, the mitigation of food loss and food waste is a significant global concern in terms of society, economy, nutrition, and the environment. According to the FAO, around 14% of global food production is lost, excluding the levels of retail and consumption. At these levels, 17% of food is wasted (FAO, 2021). The withdrawal or restrictions on the use of broad-spectrum synthetic fungicides have led to an increase in the occurrence of decay-causing fungi that were previously considered less harmful to most crops. These fungi include pathogens in the genera *Rhizopus*, *Mucor*, *Alternaria*, *Aspergillus*, and *Penicillium* (Romanazzi and Moumni, 2022). As the demand for healthier and more accessible fresh fruits and vegetables increases, the capacity to prevent postharvest illnesses has become a crucial factor in extending the shelf life of crops. Research on induced resistance in stored produce has significantly increased in the past 25 years. This has resulted in the practical use of induced-resistance technologies as viable alternatives to synthetic fungicides for controlling postharvest infections. Activating a plant's natural defense mechanisms in fruits and vegetables involves using external physical, chemical, and biological methods to induce physiological changes. These alterations enhance the plant's ability to protect against fungal diseases causing rot, crucial for integrated disease management during storage. Advances in monitoring processes have improved understanding of postharvest quality affected by technologies used before and during storage, storage conditions, and packing protocols. Comprehensive tools are essential to understand how various elements affect a host's disease resistance, enhancing crop quality and consumer health (Romanazzi et al., 2016). This study articulates how these approaches have facilitated the understanding of the impact of host maturity, ripening processes, and senescence on the mechanism of induced resistance to postharvest disease.

Induced Resistance by Postharvest Treatments

Several treatments that have been shown to trigger resistance in plants after being infected by a pathogen have been administered to harvested fruits and vegetables (Romanazzi et al., 2016). These physical, natural, and synthetic substances cause physiological changes

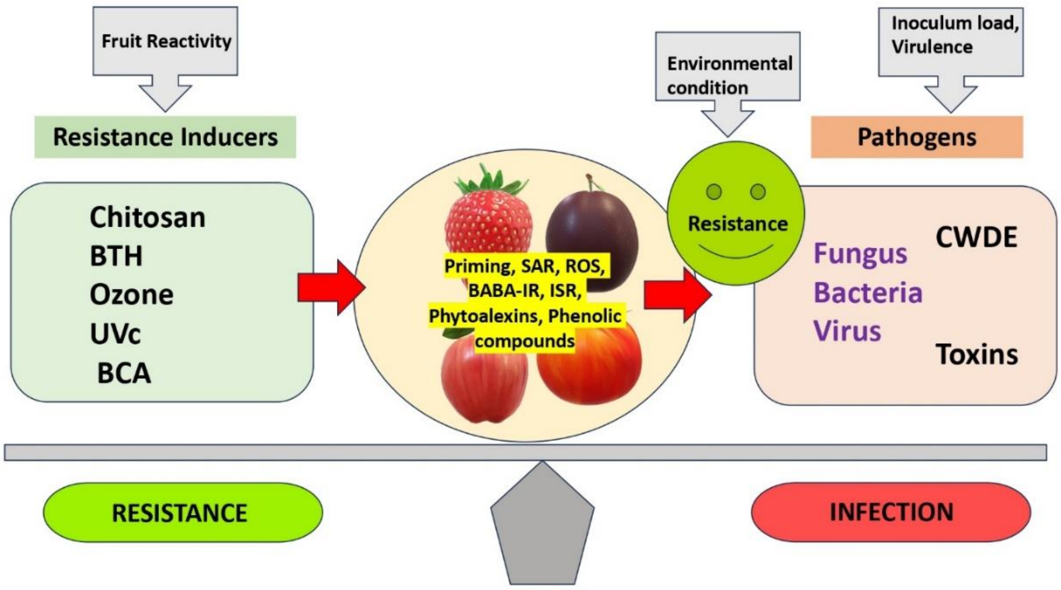

Fig.1 Dynamic balance between host resistance and pathogen infection in fruits and vegetables

that are closely connected to the defense mechanisms in the host tissues. The fruit's resistance or susceptibility to the infection is influenced by these responses, which are depending on the level of interaction with the pathogen. The key groups that they can be categorized into are: (a) the accumulation of PR proteins and hormone-dependent signaling; (b) the decrease in membrane lipid metabolism and improvement in ROS scavenging ability through the activation of antioxidant machinery, including enzymes such as catalase (CAT), POD, ascorbate peroxidase (APX), and superoxide dismutase (SOD); and (c) the synthesis of antimicrobial enzymatic activity of fruit-phenolic compounds, lignin, and enzymes such as CHT, glucanases (GLU), and phenylalanine ammonia-lyase (PAL) (Fig. 1). Host defensive responses that restrict pathogen colonization also impact other vital physiological processes, such as delaying ripening and senescence, which in turn impacts the taste and pace of softening of fruits (Lougheed et al., 1978). There are several factors which induces resistance responses in fruit and vegetables after postharvest treatments like.

I. Chemicals (biopolymer)

Chitosan, a biopolymer derived from crab shells, is a prominent substance that stimulates resistance. It possesses three distinct properties: antibacterial, evoking, and film-forming activities (Romanazzi et al., 2022). In host-pathogen interactions, the enzymes of the pathogens damage the host cell wall, which serves as an eliciting activity. This activity is termed endogenous elicitors that signal to plants that they are being infected by a pathogen. As a result, plants activate their defense mechanisms (Romanazzi et al., 2017). The biopolymer has the ability to directly stimulate the production of plant defense enzymes and the synthesis of secondary metabolites, including polyphenolic compounds, lignin, flavonoids, and phytoalexins, in several plant species (Malerba and Cerana, 2016). Additionally, it can enhance the antioxidant capacity of plants (Landi et al., 2021). Chitosan not only acts as a priming agent, but also forms a protective layer on the surface of the treated fruit. This layer helps maintain the freshness of the fruit by minimizing gas exchange, slowing down respiration and the ripening process, and reducing the fruit's physiological metabolism (Romanazzi et al., 2009). Chitosan exhibited antibacterial activity against a range of decay-causing fungi, resulting in reduced decay development and increased shelf life of various crops. This was achieved through the induction of defensive mechanisms and enhancement of antioxidant activities.

II. Physical therapy (Heat treatment)

Physical therapy also demonstrated a substantial increase in fruit resistance. Peach, strawberry, and mango fruit that were exposed to heat stress exhibited the activation of transcription factors that increase fruit resistance (Luria et al., 2014) and postpone fruit maturity. Exposing strawberries to heat treatment directly stimulated the plant's defense mechanisms, leading to the buildup of PAL, CHT, CAT, APX, and SOD. This resulted in a decrease in the size of gray mold lesions by 60%. Strawberry fruit that were subjected to a hypobaric atmosphere exhibited induced resistance to *Botrytis cinerea* and *Rhizopus stolonifer*. This resistance was associated with enhanced activity of the enzymes CHT, PAL, and POD, as well as better fruit storability (Hashmi et al., 2013). Short-term hypobaric treatments can prevent the aging process of table grapes, strawberries, and sweet cherries. This treatment resulted in a decrease in gray mold lesions in table grapes that were inoculated, as compared to an inoculated control that was kept at ambient pressure Furthermore, physical therapies have been associated with the activation of systemic acquired resistance (SAR), in addition to their direct physiological effects such as reducing ethylene production in tissues treated at low atmospheric pressure (hypobaric conditions) (Conrath et al., 2015). Hence, the results suggest that the defense mechanisms triggered by living organisms and/or non-living factors to prevent pathogen growth might have significant physiological impacts on the host, leading to enhanced fruit preservation. The challenge lies in explaining the phenomenon of resistance induction, which can effectively inhibit the growth of fungi and last for a significant duration (Luna et al., 2012). Furthermore, there is evidence suggesting that this resistance may even be inherited by future generations.

III. Synthetic Chemicals (SA, BABA)

Previous studies have demonstrated that applying SA and BABA treatments before harvesting can decrease the occurrence of *Penicillium digitatum* and *B. cinerea* diseases in orange and tomato fruits, respectively. These treatments delay the start of colony formation by 3-5 days and thereafter suppress colony growth by 50% (Wilkinson et al., 2018). Regarding BABA, the prolonged induced-resistance response was shown to be associated with a delay in fruit maturation (specifically, the ripening of red fruit per plant). This delay was also linked to the differential accumulation of certain metabolites, which were tentatively identified as lipids, alkaloids, terpenoids, and the plant hormone ABA (Wilkinson et al., 2018). Chemical inducers have the ability to initiate defense responses in fruits at a specific location. Additionally, they can stimulate the synthesis of immunological signals that can move throughout the plant, such as SA, methyl salicylate (MeSA), azelaic acid, glycerol 3-phosphate, and abietane-diterpenoid-dehydroabietinal (Chaturvedi et al., 2008).

IV. Genetic modification

Epigenetic mechanisms have been found to be responsible for the enduring nature of induced resistance in fruit. These systems have the ability to precisely regulate the expression of defense responses over extended periods of time, even across generations. The process of fruit development and ripening is affected by alterations in chromatin modifications and DNA methylation patterns (Joyce and Johnson, 1999). Given that fruits mostly consist of maternal tissues and that certain preharvest treatments can initiate enduring induced resistance, numerous research groups have endeavored to establish a connection between this induction and epigenetic alteration. Indeed, it is conceivable that intergenerational epigenetic pathways may contribute to the preparatory stages of fruit generated from authentic seed (Jaskiewicz et al., 2011). According to a recent experiment, potato seeds obtained from primed potato plants have demonstrated elevated levels of induced wound healing and resistance to dry rot in the next crop. To summarize, various categories of chemicals, including naturally occurring metabolites, inorganic compounds, and synthetic chemicals, as well as a variety of physical therapies, such as, can serve as examples of abiotic agents that generate resistance.

Conclusion

Inducing resistance in fruit and vegetable tissues is a method to provide increased protection against decay that occurs after harvesting, both during storage and while on the shelf. The application of various non-living and living factors stimulates the physiological responses of the host, leading to the accumulation of defense compounds that restrict the growth of fungi. This process also delays the aging of fruits, allowing them to maintain their youthful state for extended periods. Additionally, it enhances the plant's capacity to protect itself against harmful pathogens. Induced resistance can provide a defense strategy against plant pathogens that are challenging to control with single resistance genes. It can activate specific mechanisms that trigger defense responses and modify mechanisms that are commonly found in various fruit crops. Additionally, it can activate mechanisms in fruits that are considered safe and potentially enhance fruit quality by increasing beneficial compounds such as phenols with antioxidant activity. Furthermore, induced resistance can be effective during both the growth and development of plants and fruits, offering opportunities for disease control before and after harvest.

References

Chaturvedi, R., Krothapalli, K., Makandar, R., Nandi, A., Sparks, A.A., Roth, M.R., Welti, R. and Shah, J., (2008) Plastid ω3-fatty acid desaturase-dependent accumulation of a systemic acquired resistance inducing activity in petiole exudates of Arabidopsis thaliana is independent of jasmonic acid. *The Plant Journal*, *54*(1), pp.106-117.

Conrath, U., Beckers, G.J., Langenbach, C.J. and Jaskiewicz, M.R., (2015) Priming for enhanced defense. *Annual review of phytopathology*, *53*, pp.97-119.

Fruit, F.A.O., (2021) Vegetables–your dietary essentials. *The International Year of Fruits and Vegetables*, p.36.

Hashmi, M.S., East, A.R., Palmer, J.S. and Heyes, J.A., (2013) April. Strawberries inoculated after hypobaric treatment exhibit reduced fungal decay suggesting induced resistance. In *II International Symposium on Discovery and Development of Innovative Strategies for Postharvest Disease Management 1053* (pp. 163-168).

Jaskiewicz, M., Conrath, U. and Peterhänsel, C., (2011) Chromatin modification acts as a memory for systemic acquired resistance in the plant stress response. *EMBO reports*, *12*(1), pp.50-55.

Joyce, D.C. and Johnson, G.I., (1999) Prospects for exploitation of natural disease resistance in harvested horticultural crops. *Postharvest News and Information*, *10*(3), pp.8-45.

Kader, A.A., (2002) *Postharvest technology of horticultural crops* (Vol. 3311). University of California Agriculture and Natural Resources.

Landi, L., Peralta-Ruiz, Y., Chaves-López, C. and Romanazzi, G., (2021) Chitosan coating enriched with Ruta graveolens L. essential oil reduces postharvest anthracnose of papaya (Carica papaya L.) and modulates defense-related gene expression. *Frontiers in Plant Science*, *12*, p.765806.

Lougheed, E.C., Murr, D.P. and Berard, L., (1978) Low Pressure Storage for Horticultural Crops1. *HortScience*, *13*(1), pp.21-27.

Luna, E., Bruce, T.J., Roberts, M.R., Flors, V. and Ton, J., (2012) Next-generation systemic acquired resistance. *Plant physiology*, *158*(2), pp.844-853.

Luria, N., Sela, N., Yaari, M., Feygenberg, O., Kobiler, I., Lers, A. and Prusky, D., (2014) De-novo assembly of mango fruit peel transcriptome reveals mechanisms of mango response to hot water treatment. *BMC genomics*, *15*, pp.1-15.

Malerba, M. and Cerana, R., (2016) Chitosan effects on plant systems. *International journal of molecular sciences*, *17*(7), p.996.

Romanazzi, G. and Moumni, M., (2022) Chitosan and other edible coatings to extend shelf life, manage postharvest decay, and reduce loss and waste of fresh fruits and vegetables. *Current Opinion in Biotechnology*, *78*, p.102834.

Romanazzi, G., Feliziani, E., Baños, S.B. and Sivakumar, D., (2017) Shelf life extension of fresh fruit and vegetables by chitosan treatment. *Critical reviews in food science and nutrition*, *57*(3), pp.579-601.

Romanazzi, G., Gabler, F.M., Margosan, D., Mackey, B.E. and Smilanick, J.L., (2009) Effect of chitosan dissolved in different acids on its ability to control postharvest gray mold of table grape. *Phytopathology*, *99*(9), pp.1028-1036.

Romanazzi, G., Orçonneau, Y., Moumni, M., Davillerd, Y. and Marchand, P.A., (2022) Basic substances, a sustainable tool to complement and eventually replace synthetic pesticides in the management of pre and postharvest diseases: reviewed instructions for users. *Molecules*, *27*(11), p.3484.

Romanazzi, G., Sanzani, S.M., Bi, Y., Tian, S., Martínez, P.G. and Alkan, N., (2016) Induced resistance to control postharvest decay of fruit and vegetables. *Postharvest Biology and Technology*, *122*, pp.82-94.

Wilkinson, S.W., Pastor, V., Paplauskas, S., Pétriacq, P. and Luna, E., (2018) Long-lasting β-aminobutyric acid-induced resistance protects tomato fruit against Botrytis cinerea. *Plant Pathology*, *67*(1), pp.30-41.