BIO-CONTROL AGENTS IN MANAGEMENT OF POST-HARVEST DISEASES

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Abstract: Plant diseases are among the main constraints affecting the production and productivity of crops both in terms of quality and quantity. Use of chemicals continues to be the major tactic to mitigate the menace of crop diseases. However, because of the environmental concerns, health conscious attitude of human beings and other hazards associated with the use of chemicals, use of bio agents to suppress the disease-causing activity of plant pathogens is gaining importance. Of various biological approaches, the use of antagonistic microorganisms is becoming popular throughout the world. Several postharvest diseases can now be controlled by microbial antagonists. Although the mechanism(s) by which microbial antagonists suppress the postharvest diseases is still unknown, competition for nutrients and space is most widely accepted mechanism of their action. In addition, production of antibiotics, direct parasitism, and possibly induced resistance in the harvested commodity are other modes of their actions by which they suppress the activity of postharvest pathogens in fruits and vegetables. Microbial antagonists are applied either before or after harvest, but postharvest applications are more effective than preharvest applications. Efficacy of microbial antagonist(s) can be enhanced if they are used with salt additives, nutrients and natural plant products and physical treatments.

Keywords: Antibiosis, Bio-Control, Parasitism, Post-Harvest.

1.Introduction: Post-harvest diseases need to be controlled to maintain the quality and abundance of fruits and vegetables produced by growers around the world. Post-harvest decay of fruits and vegetables accounts for significant level of post-harvest losses. It is estimated that about 20-25 percent of the harvested fruits and vegetables are decayed by pathogens even in developed countries (Singh and Sharma,2007). In developing countries, the percent loss is quite high ranging up to 50 percent (Eceket and Ogawa,1985). And these losses were managed by fungicides and it has contributed significant increases in the quality and quantity of the produce over the past years. The excessive use of agrochemicals leads to the environmental pollution and health issues, fear-mongering by some opponents of pesticide, has led to considerable change in people's attitude towards the use of agrochemicals. The purposeful utilization of living organisms whether introduced or indigenous, other than the disease resistant host plants, to suppress the activities or populations of one or more plant pathogens is referred to as biocontrol. Among different biological approaches, use of the microbial antagonists like yeasts, fungi, and bacteria is quite promising and gaining popularity (Korsten, 2006).

2.Criteria for an ideal antagonist: A potential microbial antagonist should have certain desirable characteristics to make it an ideal bioagent (Barkai-Golan, 2001): The antagonist should be: [1] genetically stable; [2] effective at low concentrations; [3] not fastidious in its nutritional requirements; [4] capable of surviving under adverse environmental conditions; [5] effective against a wide range of the pathogens and different harvested commodities; [6] resistant to pesticides; [7] a non-producer of metabolites harmful to human; [8] non-pathogenic to the host; [9] preparable in a form that can be effectively stored and dispensed; and [10] compatible with other chemical and physical treatments. In addition, a microbial antagonist should have an adaptive advantage over specific pathogen (Wilson and Wisniewski, 1989).

3.Mode of Action: Biological control using antagonists has proved to be one of the most promising alternatives, either alone or part of an integrated pest management policy to reduce pesticide use (Wilson and Wisniewski, 1993). However, it is important to understand the mode of action of the microbial antagonists because, it will help in developing some additional means and procedures for better results from the known antagonists, and it will also help in selecting more effective and desirable antagonists or strains of antagonists (Wilson and Wisniewski, 1989).

3.1. Competition for nutrients and space: Competition for nutrition and space between the microbial antagonists and the pathogen is considered as the major mode of action by which microbial antagonists suppress pathogens causing decay in harvested fruits and vegetables (Droby *et al*., 1989). Competition for nutrients was demonstrated for *Pichia guilliermondii* against *Penicillium digitatum* co-cultivated on synthetic media (Droby *et al*., 1989): the addition of exogenous nutrients resulted in a reduced efficacy because the antagonists offered better results when nutrients were scarce. Rapid colonization of fruit wound by the antagonist is critical for decay control and manipulations leading to improved colonization enhance biocontrol (Mercier and Wilson, 1994). Thus, microbial antagonists should have the ability to grow more rapidly than the pathogen. Competition for rare but essential micronutrients, such as iron, has also shown to be important in biological disease control. Plants actively respond to a variety of environmental stimulating factors, including gravity, light, temperature, physical stress, water and nutrient availability and chemicals produced by soil and plant associated microorganisms (Audenaert *et al*., 2002). These stimuli will either induce or condition the host plant defenses through biochemical changes that enhance resistance against subsequent infection by a variety of pathogens.

3.2. Antibiosis: Production of antibiotics is the second important mechanism by which microbial antagonists suppress the pathogens of harvested fruits and vegetables. Many microbes secrete one or compounds possessing antibiotic activity. It has been shown that some antibiotics produced by microorganisms are particularly effective against plant pathogens and the diseases they cause. Bacterial antagonists like *Bacillus subtilis* and *Pseudomonas cepacia* Burkh are known to kill pathogens by producing antibiotic iturin (Gueldner *et al*., 1988). The antagonism so produced by *Bacillus subtilis* was effective in controlling fungal rot in citrus (Singh and Deverall, 1984). Although, antibiosis might be an effective tool for controlling postharvest diseases in a few fruits and vegetables, at present, emphasis is being given for the development of non-antibiotic producing microbial antagonists for the control of postharvest diseases of fruits and vegetables (El-Ghaouth *et al*., 2004). The use of antibiotics in food products is a major concern today, due to the development of human as well as plant pathogens resistant to these compounds.

3.3. Parasitism: Direct parasitism is yet another mode of action by which the antagonists interact with the pathogens. According to Wisniewski *et al*. (1991), a strong adhesion in vitro of *Pichia guilliermondii* antagonist to *Botrytis cinerea* mycelium is due to a lectin link. Similarly, El-Ghaouth *et al*., 1998 observed that *Candida saitona* attached strongly to the hyphae of *Botrytis cinerea* and caused swellings.

Lytic enzymes are also produced by the microbial antagonists to control the pathogenic microorganisms. These enzymes act by degrading the cell wall of the phytopathogenic fungi. Strong attachment of microbial antagonist with enhanced activity of cell wall degradation enzymes may be responsible for enhancing the efficacy of microbial agents in controlling the postharvest diseases of fruits and vegetables (Wisniewski *et al*., 1991).

3.4. Induced Resistance: Induced resistance is defined as the state of enhanced defensive capacity developed by plants when appropriately stimulated. Many antagonistic yeasts are effective when applied before pathogen inoculation. This observation suggested that application of yeast cell induce resistance in the fruit skin. Microbial antagonists induce disease resistance in the harvested commodities by the production of antifungal compounds, as in avocado (*Persea americana* Mill) fruit (Prusky *et al*., 1994) and accumulation of phytoalexins like scoparone and scopoletin in citrus fruit (Rodov *et al*., 1994). These antifungal compounds are produced by the microbial antagonists, thereby, providing biocontrol on the harvested commodities.

4.Application methods of microbial antagonist: After a potential microbial antagonist is selected, and its application method is to be found out. Usually, there are two method of application: pre-harvest application and post-harvest application.

4.1. Pre-harvest application: In several cases, pathogen infect fruits and vegetables in the field and their latent infection become major factor for decay during transportation or storage of fruits and vegetables. Therefore, pre-harvest application of microbial antagonistic culture is often effective to control post-harvest decay of fruits and vegetables(Irtwange,2006). The many purpose of preharvest application is to colonize the antagonist on the surface of fruits so that wounds inflicted during harvesting can be colonized by the antagonist before colonization of the pathogen. Although it is difficult to control post-harvest disease of strawberry even with pre-harvest application of fungicides, some success has been achieved with field application of various microbial antagonist like *Gliocladium roseum* Bainer, *Trichoderma harzianum* (Sutton *et al*,1997; Kovach *et al*,2000). Preharvest application of *Aureobasidium pullulans* reduced storage rots in strawberry significantly grapes, cherries and apples (Lima *et al*,1997; Schena *et al*,2003; Leibinger *et al*,1997).

4.2. Post-Harvest Application: Post-harvest application of microbial antagonistic is a better, practical and useful methods for controlling post-harvest diseases of fruits and vegetables. In this method, microbial cultures are applied either as post-harvest sprays or as dip in antagonistic solution (Irtwange,2006). Post-harvest application of *Trichoderma harzianum*, *Trichoderma viride, Gliocladium roseum* and *Paecilomyces variotii* bainier resulted in better control of botrytis rot in strawberries and Alternaria rot in lemon. A significant reduction in storage decay was achieved by bringing several yeast species in direct contact with wounds in the peel of the harvested fruits. For instance, direct contact of microbial antagonist and infected fruit peel has been quite useful for the suppression of the pathogen *Penicillium digitatum*, *Penicillium italicum* (Chalutz and Wilson,1990); *Botrytis cinerea* in apples (Gullino *et al*,1992).

However, all the pathogens do not react in similar fashion to a given antagonist.

5. Enhancing the bio efficacy of microbial antagonist: Salt additives also improve the bio efficacy of some microbial antagonists in controlling postharvest decay on fruits and vegetable (El-Ghaouth *et al*., 2004). Among different salt additives, calcium chloride, calcium propionate, sodium carbonate, sodium bicarbonate, potassium metabisulphite, ethanol and ammonium molybdate etc., have been found very successful when used with microbial antagonists for controlling postharvest diseases of fruits and vegetables more efficiently (Janisiewicz *et al*., 2008). However, the effectiveness of microbial antagonists depends upon the concentration of the antagonist, concentration of salt additive(s), their mutual compatibility and duration and time at which they are applied. Usually, the cultures should be applied well before the initiation of infection process (Barkai-Golan, 2001). The efficacy of the microbial antagonists can also be enhanced considerably by the addition of some nutritious compounds or natural plant products. For example, additions of nitrogenous compounds like L-aspargine and L-proline, and 2-deoxy-D-glucose, a sugar analog helped in enhancing the bio efficacy of microbial antagonists in controlling the postharvest decay rots in some fruits and vegetables. When applied in fruit wounds, the combination of *Candida saitona* and 2-deoxy-D-glucose (0.2%) controlled fruit decay on apples, oranges and lemons caused *by Botrytis cinerea, Penicillium expansum*, and *Penicillium digitatum* (El-Ghaouth *et al*., 2000). Some other useful recommendations have emerged out of the research conducted by the scientists for improving the bio efficacy of microbial antagonists. For example, a bioactive coating consisting of *Cryptococcus saitona* + glycochitosan has been developed to control fruit decay in apple (El-Ghaouth *et al*., 2000). The bio efficacy of microbial antagonists like *Debaryomyces hansenii, Cryptococcus laurentii, Rhodotorula glutinis, Trichoderma harzianum* etc., can be enhanced for effective control of postharvest rots on different fruits and vegetables by using additives like silicon, methyl jasmonate, salicylic acid, gibberellic acid or dipping fruit in beeswax or lac based formulations. Integration of microbial antagonists with physical methods such as curing or heat treatments could enhance the bio efficacy of microbial antagonists. For example, Singh and Mandal (2006) and Mandal *et al*. (2007) reported that hot water treated peaches inoculated with *Debaryomyces hansenii* could be stored for longer time than those inoculated alone with *Debaryomyces hansenii*, primarily by reducing the decay loss caused by Rhizopus rot. In apple, integration of yeasts microbial antagonists with hot water dipping or bruising has been applied to check postharvest rots caused by *Penicillium expansum* and *Botrytis cinerea* (Conway *et al*., 2007).

6. Future Prospects: In the present crop production scenario, the biocontrol is of utmost importance, but its potential is yet to be exploited fully mainly because the research in this area is still confined to the laboratory and very little attention has been paid to produce the commercial formulations of bio agents. Moreover, whatever has been commercially produced has not been used efficiently by the farmers owing to the lack of information regarding its use. So, it is need to popularize the concept of biocontrol agent by the extension agencies and universities.

Most of the biocontrol agents perform well in the laboratory but it fails to give its fullest potential in the field. This is because of the physiological and ecological constrains that limit the efficacy of the biocontrol agent. To overcome such problems in the field, genetic engineering can be effectively used. Such as mutation or protoplasm using PEG thereby increase the efficacy.

7. Conclusion: With people turning more health conscious, Biological control seem to the best alternative to disease suppression. Bio agents bring the disease suppression with no environmental hazards. Research has proved that the bio agents trigger the growth of plants. Bio agents themselves being nonpathogenic to plants need to be formulated in a way that favors the activity and survival of microbe it contains. Moreover, the novel concept of bio control needs a space outside the laboratory to see its fruits in present production systems.

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