Bioformulation in Biological Control for Plant Diseases - A Review

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Abstract

Bioformulation for plant growth promotion continue to inspire research and development in many fields. Increase in soil fertility, plant growth promotion, and suppression of phytopathogens are the targets of the bioformulation industry that leads to the development of ecofriendly environment. The rhizosphere bacteria have immense application in sustainable agriculture as ecofriendly biofertilizer and biopesticides. Intensive commercial farming involves excessive use of chemical fertilizers and pesticides. It is feared that practice of using chemical fertilizers and pesticides continually would result in gradual aggravation of soil fertility. The aim of the review is to assess the biologically control of plant pathogens in with the effective development of bioinoculant industry.

Keywords: *carrier based bioformulation, growth promotion, biocontrol, biofertilizer, rhizosphere bacteria, plant pathogens.*

I. INTRODUCTION

The development and use of Trichoderma and Talaromyces -based bioformulations with talc and rice bran may be a potentially effective method in controlling Rhizoctonia solani induced sugar beet damping-off disease. May have practical application in the formulation of disease management strategies in an integrated pest management (IPM) program in which reduction of yield loss, reduction of chemical pesticide application and protection of the agricultural environment and biological resources are the main concerns (Kakvan et al, 2013).

Trichoderma species have shown highly promising results against Fusarium oxysporum f. sp. melonis under different experimental conditions. In the studies of Suárez-Estrella et al. (2007), Trichoderma harzianum 2413 reduced the incidence of melon wilt in a greenhouse experiment. In previous research, we showed that selected isolates of Trichoderma spp. were efficient to control soil-borne pathogens of melon in field conditions (Gava and Menezes, 2012). Trichoderma spp. are the most widely studied biological control agents (BCAs) for root and shoot pathogens, applied even in post-harvest (Woo et al., 2014). Trichoderma species are soil inhabitants, competitive saprophytes, and facultative mycoparasites that can colonize the soil and rhizosphere (Harman et al., 2004). Their mechanisms of action include the lysis of fungal hyphae with enzymes such as chitinase, proteases, and glucanases (Shahid et al., 2014), the induction of phytoalexin accumulation by the host (Yedidia et al., 2003), the production of antibiotics (El-Hasan et al., 2006; Reino et al., 2008) and modulation of plant hormones (Martínez-Medina et al., 2010).

Using bioformulations with entomopathogen fungi for biological control of insect pests we can point out the easiness of production of its infective units on a commercial scale, the simplicity of usage in field conditions, the low cost of its utilization, and mainly, the reduction on environmental impact (Lopes et al, 2013, Nussenbaum et al, 2013, Borisade and Magan, 2014, Blanford et al, 2011, Zahran et al, 2013). Interactions between entomopathogenic fungi with phytosanitary products, such as chemical insecticides (e.g. Decis OC), fungicides (e.g. Manzate 800) or herbicides (e.g. Granoxone) are important to evaluate new formulations, since it can be positive when an additive or synergistic action occurs with the entomopathogen and the product. The formulation is a need for compatibility testing, seeking more selective products and able to promote the conservation of the pathogen in the field for a longer period of time (Borges et al, 2011; Vidau et al, 2011).

In India, specific formulations of Pseudomonas spp. strains have been developed to combat various pathogens in rice, banana and pigeon pea (Rabindran & Vidhyasekaran 1996; Vidhyasekaran et al. 1997a, 1997b). With a view to standardize specific Pseudomonas spp. strains for the management of red rot disease of sugarcane, we have optimized talc formulations for sett treatment and soil application and efficacy of different strains against the disease development in the cane stalks.

Biological control using microbial antagonists has been shown to be a suitable and ecologically friendly candidate for the replacement of chemical pesticides. Different bacterial and fungal antagonists have proved to be potential biocontrol agents against many plant pathogenic fungi and bacteria (Dutta, 1981;

Papavizas, 1995; Matta and Garibadli, 1997; Menendez and Godeas, 1998; Adebanjo and Bankole, 2004; Eziashi et al., 006; Naraghi et al., 2006, 2007; Gentili et al., 2008; Jahanifar et al., 2008; Heydari and Pessarakli, 2010; Gerami et al., 2013).The use of chemical fungicides as seed treatment is the most common strategy for controlling this disease in the field which most of the time is not effective due to the long term application and appearance of resistant races of the pathogen (Weller, 1991; Heydari and Pessarakli, 2010). Several microorganisms have been reported as plant pathogen antagonists, but only a small number were applied on a commercial scale. Most of this is due to a lack of consistency of the results from field trials (Fravel, 2005).

The high doses of chemical fungicides can result in environmental pollution, deterioration of human health, and increase in resistance of the target fungi to fungicides. Biological control has been investigated for its potential to provide a more viable and sustainable means to control southern stem rot. Attempts to develop biological control of Sclerotium rolfsii have been reported in many crops such as peanut and soybean (Ambang et al., 2008; Ozgonen et al., 2010; Ika et al., 2011; Rakh et al., 2011).

Plant Growth Promontory Bioformulation

PGPR would be beneficial not only for plant growth but also for reduction of insect pest attack. One of the common means of application of bacterial inoculants to soil is in the form of bioformulations. Viability of inoculum in an appropriate formulation for a certain length of time is important for commercialization of the technology (Bashan, 1998). Previous reports are also available where Bacillus bioformulations could survive upto one year (El-Hassan and Gowen, 2006). Carrier based preparations of two PGPR such as Bacillus subtilis and Pseudomonas corrugata developed in formulations were also evaluated for their growth promotion, rhizosphere colonization and viability under storage (Trivedi et al, 2005).

Viswanathan and Samiyappan (2008) reported that the potential of suppressing Colletotrichum falcatum causing systemic infection in sugarcane stalks by Pseudomonas spp. strains under field conditions. These studies also proved that Pseudomonas spp. treatment has improved cane yield and sugar yield in the trials. Different sugar mills in the country have evinced keen interest in promoting this new technique for the management of C. falcatum in sugarcane.

Chakravarty and Kalita (2011) showed the suppression of bacterial wilt with concomitant improvement in yield and yield attributes of bio formulation treated crops compared to inoculated control reinforces Pseudomonas fluorescens as a biocontrol agent of bacterial wilt in brinjal as well as plant growth promoting rhizobacteria (Ramesh, Joshi and Ghanekar 2008). However, intensive screening of indigenous strains of P. fluorescens, development of improved carriers and large scale field trials under different climatic conditions are necessitated for evolving formulations with better disease control activity in the field.

Raj et al, Chuaboon and Prathuangwong (2003, 2007) reported to indicate a future possibility that plant growth promoting rhizobacteria bioformulations can be used to promote growth and health of economic crops.

A bioformulation using humic acid and a suitable microorganism namely, Pseudomonas fluorescens has been developed to replace chemical fertilizers. This liquid formulation in addition to facilitates long shelf life, zero contamination, no need of carriers, convenience of handling, storage and transportation has easy to use with irrigation. The mixed formulation of humic acid along with the microorganism namely Pseudomonas fluorescens can be used for the dual purpose viz., crop protection and enhanced production. The liquid bio-formulation was tested and compared for viability as well as its inhibitory characteristics against Fusarium oxysporum, a fungus which cause wilt of tomato. Field studies were conducted for two crop varieties- radish and tomato (Agrawal Pushpa et al, 2013).

Chakraborty et al (2013) have shown that all three isolates have potential as plant growth promoters to increase the growth of tea plants in experimental plot. Increase in growth was associated with phosphate solubilization, defense enzymes as well as increased accumulation of phenolics. Viabilities of the isolates in bioformulations of talc, saw dust and rice husk were also examined. In comparison to Serratia marcescens, bioformulations of Bacillus amyloliquefaciens and B. pumilus were more useful in field application due to the formation of endospores by bacilli.

Biological control in bioformulation

Biological control of plant pathogen is becoming an important component of plant disease management practices. This alternative control strategy can solve many persistent problems in agriculture including fungicide residues causing environmental pollution and human health hazard, and also inducing pathogen resistance (Commare et al., 2002; Cook,2002;

Bharathi et al., 2004; Chaluvaraju et al., 2004; Anitha and Rabeeth, 2009; Chen et al., 2009; Ardakani et al., 2010,2011; Haggag and Wafaa, 2012).The integrated management of cacao black pod disease, biological control was first initiated in Cameroon early in the 2000's and has led to the development of a formulation using mycoparasitic strains of Trichoderma asperellum as active ingredient. Field applications showed that the formulation improved the flowering activity of cacao trees as well as pod development, while reducing Phytophthora infection in flower cushions (Tondje et al., 2007; Deberdt et al., 2008).

A formulated product must be economical to produce, easy to apply in the crop production system, efficacies with an adequate number of viable cells when used, and a shelf-stable formulated product retraining biocontrol activity comparable to fresh cells of the agent. Delivery systems employing biocontrol agent include dust or powder, alginate pellet, and starch or extruded granule that the effective strains are necessary to be grown in various organic and inert carries, such as diatomaceous earth, manure or animal dung (Raj et al., 2003; Schisler et al., 2004; Sharathchandra et al., 2004; Amran, 2006; Pushpalatha et al., 2007; Preecha and Prathuangwong, 2009; Omer, 2010; Senthilraja et al., 2010; Siripornvisal and Trilux, 2011). The yeast Meyerozyma caribbica L6A2 is an efficient biocontrol for the phytopathogenic Colletotrichum gloeosporioides, presenting different antagonistic mechanisms of action such as competition for space and nutrients, production of hydrolytic enzymes, parasitism and biofilm formation through quorum sensing. According to the action mechanisms observed, it is assessed that the presence of yeast cells is necessary in the formula to carrying out biological control. This information needs to be taken account for further studies, especially in formulation and large scale production. (Bautista-Rosales et al. 2013).

This investigation is aimed at providing a better biocontrol action against fungal pathogens as well as insects affecting maize crop. Nanosilica treated maize possesses rough leaf surface and good physical strength than that treated with bulk silica due to higher silica accumulation. A combination of *Pseudomonas fluorescence* and silica nanoparticles in soil enhances phenolic activity and hence reduces the stress by the suppression of responsive enzymes in maize. This elevated level of phenols is found to induce silica accumulation in leaf epidermis, thereby conferring a protective physical barrier as well as induced disease resistance. Thus, one can formulate an effective biofertilizer/biocomposite for sustainable crop cultivation by using nanosilica (Suriyaprabha Rangaraj et al, 2014).

Damam et al. (2015) suggested that simultaneous screening of rhizobacteria for growth and yield promotion under pot and field experiment is a good tool to select effective PGPR strains (Pantoea agglomerans (Cf 7), Pseudomonas putida (Te 1), Bacillus subtilis (Cf 60) and Pseudomonas sp. (Av 30) for biofertilizer development biotechnology and potential biocontrol agent against pathogen (Macrophomina phaseolina) individually and also in combinations. (Damam et al. 2015).

The biological control of pathogens, although subject to numerous ecological limitations, is expected to become an important part of the control measures employed against Ralstonia solanacearum. In the present study, the application of Trichoderma parareesei + Trichoderma parareesei + Pseudomonas fluorescens + Bacillus subtilis + Azotobacter chroococcum based bio-formulations promises as an effective biocontrol option along with better plant growth, yield and soil health management of Tomato plant (Bharat et al. 2016).

Research Areas for Development of Bioformulation

Biocontrol approaches may help to develop bioformulations an eco-friendly control strategy for managing plant disease (Heydari and Misaghi, 1998, 2003; Bharathi et al., 2004; Heydari and Gharedaghli, 2007 ;).

The development of stable formulations of antagonistic bacteria and other biocontrol agents is of great importance to many countries, especially those where subsistence agriculture is prominent, soil-borne diseases are the main problem, and fungicides are unaffordable. Formulation and establishment of biocontrol agents are very important for their effectiveness. The formulations we have developed and tested can be used for controlling Plant diseases and possibly other plant-pathogen combinations. They have the potential to replace chemical fungicides and to be utilized as an important component of integrated pest management (IPM), which is a promising approach to a sustainable agriculture (Ardakani et al, 2010).

A bioformulation can improve product stability and also protect bacteria against different environmental conditions and provide initial food source. Application of PGPR either to increase crop health or to manage plant diseases depends on the development of commercial formulations with suitable carriers that support the survival of bacteria for a considerable length of time., it is imperative to evaluate the survival of the immobilized bacteria in different carriers and also their ability to retain attributes for plant growth promotion (Aeron et al., 2011).

Shelf Life Increased for Bioformulation

Research on nitrogen fixation and phosphate solubilization by plant growth promoting rhizobacteria(PGPR) is progress on but little research can be done on potassium solubilization which is third major essential macronutrient for plant growth. This will not only increase the field of the inoculants but also create confidence among the farmers for their use. A part from that future research in optimizing growth condition and increased shelf life of PGPR products, not phytotoxic to crop plants, tolerate adverse environmental condition, higher yield and cost effective PGPR products for use of agricultural farmer will be also helpful (Gupta et al. 2015).

The talc based bioformulation of Pseudomonas fluorescens RRb-11 isolate showed maximum shelf life and survivability in rhizosphere to reduce disease intensity of bacterial blight of rice and thereby increase yield when applied as seed treatment, seedling root dip and soil drenching in combination (Jambhulkar and Sharma, 2014).

The most common solutions to this problem of survival time have been air-dried and lyophilized preparations (Kosanke et al. 1992). The lowered water content in the final product is responsible for long-term survival during storage. The bacteria in the formulation remain inactive, resistant to environmental stresses, insensitive to contamination, and are more compatible with fertilizer application (Bashan 1998). The dehydration phase is perhaps the most critical of the entire formulation process especially for nonspore-forming bacteria (Shah-Smith and Burns 1997).

Bacterial survival is affected by several variables: the culture medium used for bacterial cultivation, the physiological state of the bacteria when harvested from the medium, the use of protective materials, the type of drying technology used, and the rate of dehydration (Paul et al. 1993).

One of the major challenges for the inoculant industry is to develop an improved formulation that provides high shelf-life, high number of viable cells, protection against soil environment, convenience to use, and cost effective (Smith 1992). More studies on the practical aspects of mass-production and formulation need to be undertaken to make new bioformulations that are stable, effective, safer, and more cost-effective. There is an urgent need to develop a definite correlation between agriculturists, microbiologists, biotechnologists, industrialists, and farmers (Fig. 1).

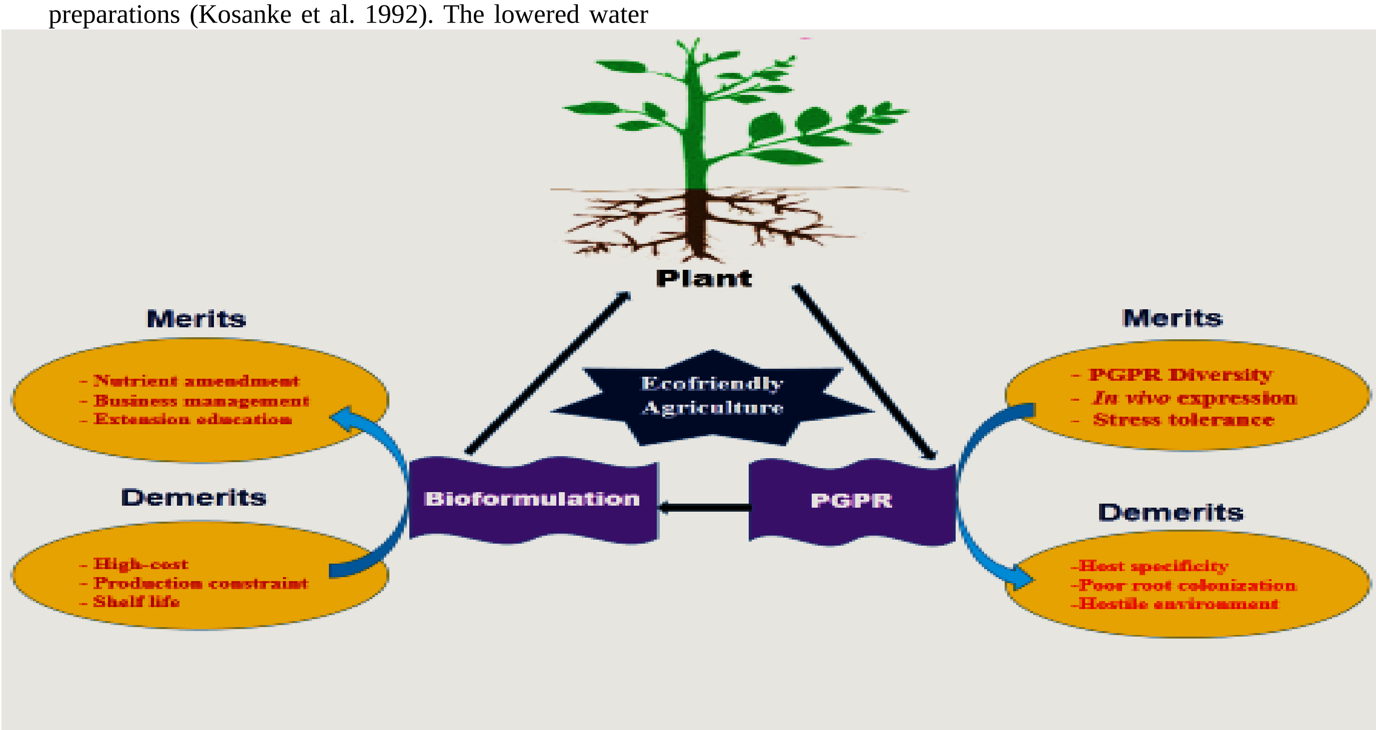

Fig. 1 Research and Development Strategies for Bioformulation Technology

Bioformulation Strategy

The results of the present study in the development of some new bioformulations are promising and may have practical application in the biological promotion of the growth of garlic in the field conditions. Obtaining positive results in the field conditions may replace or reduce the application of harmful chemical fertilizers and lead the garlic growers to increase the yield and production of this important crop and protect the agricultural environment and biological resources (Razak et al. 2015).

Peat and soil rich in organic matter are generally used in the preparation of legume inoculants and constitute a suitable carrier for the purpose. Peat and lignite, though good carriers, are not easily available and are expensive. The low cost and easily availability of carrier material are the major requirements for bioformulations in developing countries (Saha et al. 2001).

The carbon sources and minerals have been shown to have an important role in antifungal metabolite production by Pseudomonas biocontrol agents, suggesting that nutrient amendments to formulations may also be a useful strategy for improving biocontrol efficacy (Duffy and De´fago 1999). Soil amendment with chitin showed increase of the chitinolytic microbial populations and significantly reduced the incidence of fungal diseases in celery (Bell et al. 1998). Chitin supplementation supports the survival of Bacillus cereus and Bacillus circulans in the groundnut phylloplane and resulted in better control of early and late leaf spot disease (Kishore et al. 2005).

Remarkably low percentage of endospore formers was observed that survived after drying (Validov et al. 2007). This has been termed anhydrobiotic engineering (Fages 1992), in reference to anhydrobiotic organisms which naturally exhibit extreme desiccation tolerance (Validov et al. 2009). Similar observations of Garci ´ a de Castro et al. (2000) demonstrate the potential of this novel biotechnology for stabilizing nonsporulating organisms.

Reasons for Doing the Study

The use of biopesticides include increased environmental awareness, the pollution potential and health hazards from many conventional pesticides, as well as increasing global demand for organically grown food. Biopesticides can be used in rotation with conventional pesticides when used in Integrated Pest Management (IPM) programs. Such programs can offer high crop yields while dramatically reducing the use of conventional pesticides.

Conclusion

The survey of both conventional and organic growers indicates an interest in using biological products (Rzewnicki 2000), suggesting that the market potential of bioformulations will increase in coming years. Internationally, organic sales grew by 8% in 2010 and sales are now valued at €44.5 billion. Strong growth has continued in all the major European markets, and the US, and the outlook for this year is positive. The organic market in China has quadrupled in the past five years, while Organics Brazil reports an annual growth rate of 40% in the Brazilian market. Market analysts predict that organic sales in Asia will grow by 20% a year over the next three years. Thirty-seven million hectares of land worldwide are now farmed organically. (Ref: www.soilassociationscotland.org).

The global pesticide market was valued at approximately $40 billion in 2008. This figure increased to nearly $43 billion in 2009 and is expected to grow at a compound annual growth rate (CAGR) of 3.6% to reach $51 billion in 2014. BCC Research projects that the global biopesticide and synthetic pesticide market will grow from $54.8 billion in 2013 to nearly $61.8 billion by 2014 and to $83.7 billion by 2019 at a five-year compound annual growth rate (CAGR) of 6.3%, from 2014 through 2019. Biopesticides represent only 2. 89% (as on 2005) of the overall pesticide market in India and is expected to increase drastically in coming years. (Ref: http://www.prnewswire.com/news-releases/global-markets-for-biopesticides-279175451).

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