Seed Coating with Beneficial Microbes for Precision Farming

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Abstract

Seed coating is a technique used to cover seeds with adhesive agents in order to improve seed performance and create plants while reducing the cost of production. Seed coating has been broadly used in agriculture as an effective means of alleviating biotic and abiotic stress, thereby enhancing the crop yield, growth and health, to meet the needs of precision farming development. Plant growth promoting microorganisms (PGPM) are recognized as an important contributor to increasing agricultural productivity by direct application to the rhizosphere and tissues of plants or seed inoculation.During traditional inoculation processes, however, many factors such as inadequate microbial survival, impediment to the application of biocontrol inocula to seeds, and exposure to unsuitable temperature and light in subsequent seed storage force us to explore effective and reliable microbial application methods.Because of its ecological health and socio-economic dimensions, biological seed coating with PGPM has recently been suggested as an alternative to traditional seed treatment (such as fertilizer and protective products).In this paper, technology of microbial seed coating and its contribution to the sustainable precision farming are discussed.

Keywords: Fertilizer, Precision farming, Plant growth promoting microorganisms, Seed coating, Seed treatment

Introduction

Approximately 9.25 million people are currently suffering from hunger around the world and an additional. 2 billion people are expected to be added by 2.050[1]. Current agricultural practices, for example inputs of pesticides, fertilizer and animal waste, adversely influence the environment because they highly pollute the resources of soil,air and water and decrease the biodiversity of ecosystems. Therefore, there is a need to develop new agricultural strategies. Precision farming has been described as knowledge-based management strategies to optimize the production of crop biomass from both economic and ecological perspective[2].This aims to use new technologies to produce the right quantity of agrochemicals (e.g. fertilizers and pesticides) to promote crop production, safety and productivity in a good way. The application of PGPM [e.g. rhizobia, Plant growth promoting bacteria (PGPB) and arbuscular mycorrhizal fungi (AMF)] has been seen as a promising alternative to traditional farming techniques, as it can sustain the safety and efficiency of the agroecosystem[2], [3]. However, due to poor bio inoculant survival rates, the commercialization of the microbial inoculants as bio fertilizers and/or biocontrol agents can be affected. Exploring formulations that provide high densities of microbial inoculants with high rates of survival during storage is therefore a critical step in the development and establishment of beneficial inoculants[4].Considering the challenges with a growing world population and climate change, there is a growing interest in developing agricultural practices (e.g. precision farming) alone or in conjunction with other methods (e.g. seed treatment) that can minimize the use of agrochemicals while maintaining agricultural productivity, cost-effectiveness and food security at the same time[2], [4].A key success factor for the seed treatment market is the production of a full safety solution in a single product, which is eco-friendly, cost-effective and environmentally responsible, against various environmental stresses. In general, farmers prefer an easy-to-use seed treatment that may protect crops from biotic (e.g. phytopathogens) and abiotic stress (e.g. salinity and drought) [5]. Microbial seed coating has recently been considered an effective and reliable technique for the efficient distribution of inocula as it contributes significantly to the production of coated seeds in order to meet high standards of safety and efficacy[3], [6]. In addition, current agricultural equipment can more evenly plant homogeneous (size and shape) coated seeds along with better plant density control, thus achieving or approaching precision farming.

1. *Seed coating*

Seed coating is reliable technique for applying exogenous materials (for example, colorants, biopolymers, biocontrol agents and microbes) close to germinating seeds, that ultimately improves the seed quality (vigor and viability) and yield by improving seed placement and performance[7]. The coating deliver the seeds in a bigger, heavier, rounder, and more uniform shape that can be individually mounted with improved depth control and spacing. Seed coating is known as a biological tool for the establishment of stands as well as a seed quality stimulant[2], [7].The seed coating process itself can generally be broken down into three main types based on shape, size, weight, and use properties of the coated seeds.

1.1. *Film coating:*

Film coating is a technique of encapsulating the seeds using rotating drum machines with a thin layer of liquid slurry form made up of plasticizers, polymers, pigments and solvents. The thin layer of coating does not change the shape and size of seeds significantly, but it enhances seed handling characteristics while minimizing or eliminating dust-off product [8](e.g. biological, pesticides, and micronutrients).

1.2. *Pelleting:*

Pelleting is a method of coating seeds with the inert materials (such as talc, calcium peroxide, sand, bentonite and diatomaceous soil) to allow accurate metering and improve plantability by altering the size, shape and weight. It transforms thin seeds into bigger, spherically shaped seeds that can easily be picked out in the field[1]. It helps to make the planting of very small or irregularly formed seeds grow quickly and precisely for such seeds.

1.3. *Encrusting:*

Encrusting is a process by which seeds are covered with a small amount of adhesive and inert material to allow accurate mechanical seed metering. It creates a smoother surface, a more uniform shape, and increases seed weight and size that can be used in greenhouse or field, thereby exploiting the efficiency of seed planting. Mostly this approach is used on plants benefiting from seed singulation while not needing thinning after the emergence[7]. Encrusting requires more seed weight than film coating and slightly less weight than pelleting that is more cost-effective than pelleting.

2. *Seed coating Agents*

2.1. *Protectants*

Chemical pesticides (such as bactericides, insecticides, fungicides, herbicides and nematicides) are the key protectants agents used for coating. In general, when conditions are positive forphytopathogens to shape predation and infection, the application of protective substances may increase plant establishment, germination rate, growth and yield. However, certain protectants coating (e.g. insecticides and fungicides) that adversely affect the environment and may result in contamination of the agroecosystem[9].An insecticide containing clothianidin neonicotinoid and β-cyfluthrin non-systemic pyrethroid, coated with *B. napus* seeds have induced density decreases, colony growth and wild bee reproduction under field conditions. Such insecticidal application can therefore jeopardize wild bees in agricultural landscapes[2], [7]. Therefore, a promising option was proposed to improve the non-toxic and biodegradable properties of coatings by using microbes with biocontrol properties.

2.2. *Micronutrients*

Seed coating with polymer micronutrients (likepotassium (K), phosphorus (P), copper (Cu), zinc (Zn) and manganese (Mn)) or nutrient-rich plant substance (such as biochar) may provide plant host nutrients available during the growth of plant, thus achieving optimal crop production. The *T. aestivum* seed coating with a mixture of Mn, Cu, and Zn polymer has led to improved nutrient uptake and grain yield (e.g., N, P, and Cu)[8]. Despite its broad application, the critical micronutrient status in plants and soil must be assessed before making the fertilizer recommendations.

2.3. *Growth Stimulants*

The combination of growth stimulant attributes and their application that seed coating has remarkable potential to enhance the plant development, growth, and physiological functions. Growth stimulants may be used as a cheap, sustainable and green source for the cycle of seed coating. Nonetheless, the form of growth stimulant coatings may be varied to delay thehamper root growth, germination, biocontrol and fertilization functions, and attach the seeds to the surrounding soils[3], [5].Therefore, the application of PGPM with a range of plant growth promoting features such as the development of siderophores and phytohormones to seeds via coating to deliver PGPM, especially where response of plant depends on rhizosphere colonization may be an efficient and effective alternative to the growth stimulants[7].

2.4. *Microorganisms*

As bio fertilizers and/or biocontrol inocula, beneficial microbes (PGPB and AMF) have been widely used. Seed coating was considered a convenient and efficient tool for incorporating the beneficial microbes to soil and consequently to the rhizosphere or tissues of plants. However, there are still limiting factors in the marketing and implementation of bioinoculants, specifically because of poor microbial survival and ineffective plant host colonization[9]. Exploring formulations that provide high microbial inoculants cell density and survival rates during storage is therefore a crucial step towards the production of successful inoculants. In terms of the bacterial coating, bacterial cells may be directly trapped by ionic interactions in the polyelectrolyte complex with alternating charges resulting from an acidic (e.g. sulfonic and carboxylic) and the basic component (e.g. amino function) (like chitosan polymer) ionic interactions, as their membrane of cell is negatively charged or, alternatively, they can initially be stuck in inorganic porous carriers (such as calcium alginate hydrogels) that ensure a suitable shelf-life in the formulation and controlled release[10].

3. *Application of microbial seed coating in agriculture*

In the lab, greenhouse and field trials, PGPM inoculants were delivered/applied successfully to a variety of crop seeds using various types (e.g. pelleting, film coating and incrusting) and coating material (fillers and binders). Until now more research on the microbial seed coating was conducted with the vegetables (such as *Beta vulgaris, A. cepa, C. scolymus, D. carota, Lycopersicumesculentum, Lepidiumsativum and Solanum lycopersicum*), legumes (such as *M. sativa, G. max* and *V. unguiculata*), cereals (such as *T. aestivum, Sorghum bicolor*, and *Z.mays*) and oilseeds (such as *G. hirsutum, B. napus*, and *Sesamumindicum*)[5], [10].It is well known that under biotic and / or abiotic stress microbial seed covering is able to confer stress tolerances on host plants, which enhance crop health, enhancing growth efficiency in adverse conditions, both biotically (e.g. phytopathogens) and abiotically (e.g. salinity, drought, cooling, or heat)[2], [9]. The ability to provide crop productivities and stress tolerance benefits has recently received a significant emphasis on seed coating with functional PGPM strains.

3.1. *Seed plantability improvement*

The main process of microbial seed coating (for example, weight, size, shape) is the standardization of the seed morphological properties that can generally boost field sowability, crop growth and yield, market class factors, and harvest efficiency[11]. In the weight-enhancement, seed flux through the machinery and improve coating integrity can be added to the weight of reasonably large quantities of materials, as well as microbial inoculants (such as polymer adhesives, colored pigments, pesticides, or dyes. The delayed germination and development of coated seeds is usually the major obstacle to widespread use. Several studies showed that germination delays of different plant species for example *Capsicum annuum, D. carota, Z.mays* and *L. sativa* were observed and this was due to the negative effect on water imbibition and the available oxygen in seeds by the coating agents[2],

[11]. But the germination rates were not affected by the microbial coating. This can be attributed to improvements in viability and seed vigor in the microbial workings (e.g. plant hormones like auxin and gibberellin synthesis). For example, polymer adhesives like xanthan gums, gum arabic, methyl cellulosis, polyacrylamide and polyvinyl pyrrolidone have generally been used to improve the survival of seed inoculants by means of the formulations that maintain an optimal water activity for microbial survival[12]. Nevertheless, the ways in which these seed additives work have been ignored and understood inadequately.

3.2. *Seed quality improvement*

The quality of seed (e.g. vigor, germination and humidity) is important for sustainable production of crops and the security of food. Sowing with PGPB and beneficial AMF as main active ingredients of organic seed coating agents (SCA) has been regarded as an important quality management feedback for improving the seed quality[12]. Sowing changes through these microbes will solve germination limitations through stands, an early beginning of metabolic enzyme activities and mobilization of resources.

3.3. *Growth and nutrition promotion*

Seed coating with the beneficial microbes is applied to enhance germination, plant growth, seed setting, nutritional value and harvest quality and yield. The microbial supply through coating can enhance the microbial cells survival and protect the functional microbes from a range of environmental stresses, such as salinity, drought, cooling or heating, pollutants and nutrient deficiency or excess, as compared to traditional inoculation techniques[7], [8]. As stated above, the carriers that are used to cover microbial seeds provide an appropriate amount of PGPM. This PGPM extension coating will ensure adequate shelf-life and a microenvironment. Microbes impart biotic and abiotic stress tolerance and increase plant growth, [8]productivity, development and nutrient value mainly include systemic resistance induction, mobilization and absorption of nutrients, hormonal homeostase, biocontrol, lipid peroxidation regulation, and biofilm formation.

3.4. *Biotic stress protection*

Seed coating is often used to deliver biocontrol inoculants to protect plant development and growth against different soil-borne or seed-borne phytopathogens, since it introduces bioinoculants into the rhizosphere where, phytopathogens are generally active and cause damping off seedlings and seed rots. While experimentally and commercially a wide range of bacterial and fungal biocontrol agents are used in farming, they are less commonly used as technology for seed coating[2], [10]. In most experiments, the direct immersion of the seeds into the aqueous suspensions of AMF or bacterial cells was used for the use of biocontrol inoculants. In addition, PGPB has also tried several different methods of coating seed with PGPB, like *Bacillus sp., Pseudomonas sp., Serratiaentomophila* and *Yersinia sp*. due to its potential for soil-borne physicians to control soil[11], [12]. It has been proven that long term, wide-ranging, biological control of phytopathogens could be provided by microbial active formulations and substances.

3.5. *Abiotic stress alleviation*

The key environmental factors that restrict worldwide development of crops are abiotic stresses (such as salinities, droughts, extreme temperatures, nutrients of deficiency). Under current climate change scenarios, drought has become the main concern for the agricultural production in the arid and semi-arid regions[2], [7], [13]. It is well known that the drought is capable of producing a variety of physiological reactions, including stomatal closure, alteration in gene expression level, and cell homeostasis disturbance. Plant benefits microbes adapted to adverse conditions of drought will assist their host plant in dealing with stress and enhancing plant growth through different means,[13] including antioxidants protection, phytohormone synthesis, exopolysaccharide (EPS) production. *Bacillus sp.* Coated Seed which enhanced the growth, yield and uptake of nutrient by *V. unguiculata***,** to improve the arid agriculture sustainability may provide a promising approach

CONCLUSION AND FUTURE ASPECTS

The seed layer is promising technology to advance precision farming, as it improves precise and secure applications and meets increasing automation requirements. The feasibility of seed coating with PGPB and AMF as a biotechnological approach to improving crop yield and quality is underscored in experimental evidence, although the mechanisms by which plants steer beneficial micro-biomass to increase resilience and growth to environmental stresses are not clear. The practical benefits of coating seeds with PGPM have been investigated in recent research. Furthermore, as an alternative to fungicides, the seed coating may be commercially applied as it offers better and equal biocontrol against various root rot diseases. To order that this technology can be properly prospected and potential, it is necessary to look for the cheaper media and make use of new plants that are still not being tested to seed coating. To date, seed coating inoculants are mainly for annual crops (for instance, legumes, cereals, and certain vegetables). Seed coating development in other farming products (e.g. fruits, vegetables, even crops of soil) may be a potential market for commercial inoculants, specifically for organic farming systems.

More studies are required with a view to better understanding different environmental stresses and the features of the plant-microbe-soil multifunctional interactions to enhance the microbial seed coating's effectiveness in the field. Hence, there is a need to understand behavior of the introduced microorganism through the seed coating at root level and their role in real field under the various environmental conditions. The future challenges that include microbial inoculum consortia selection that mayimprove the abiotic stress (e.g. salinity, drought, extreme temperatures and contaminants) in crops and enhance the quality of food, new carriers development based on the nanoparticles, optimization of the application devices and the time for polyannual crops, need researchers input from different disciplines in agriculture to enlarge the competent implementation of the PGPM**.**

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