PittMoss® as a Delivery Mechanism for Biofertilizers and Inoculants

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Introduction

Advancements in agriculture are rapidly moving toward increased integration of microbiological developments that provide more sustainable plant nutrition, disease control, and growth enhancements. These microbiological enhancements are referred to as *biofertilizers*. One possible definition of biofertilizers is as follows:

> "*Vessey (2003) defined a biofertilizer as "a substance which contains living microorganisms which, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant". The microorganisms they contain are also called plant growth promoting rhizobacteria (PGPR) and result in benefits to the plant hosts after inoculation"* (European Union, 2020).

A vast array of bacterial, fungal, and algal associations are being advanced for integration into production systems which incorporate more sustainable methods for providing improved crop nutrition, biological disease control, and biological growth stimulation. Many companies are offering microbial inoculant formulations that have proven to provide an array of beneficial properties. One such formulation is called *Nitrix. Nitrix* is produced by Blacksmith Bioscience from Spring, Texas (Active Inoculum: *Paenibacillus polymyxa strain P28-2R*). In a small, comparative trial on a PittMoss growing blend, *Nitrix* was inoculated into the substrate and beet seeds were planted. The photograph in **Figure 1** presents the comparative results after approximately 6 weeks of growth. The plants on the right were inoculated, while the ones on the left were left untreated.

Figure 1. Comparison of beet growth when grown in a PittMoss® blend inoculated with Nitrix (right) and the PittMoss® blend alone (left).

A recent comprehensive review of the use of biofertilizers in commercial agriculture has been developed as part of a multinational, cooperative effort sponsored by the European Union. This effort was dubbed the *Bio-FIT Biofertilizer Project* (European Union, 2020). Key in their discussions are characteristics needed for effective and dependable delivery systems for incorporation into soils and seed inoculation. These properties are essential to maintain the viability of living organisms in storage as well as promote easy application. The *Bio-FIT* review presents a summary of those characteristics with a focus on seed and soil inoculation:

> *"A good carrier should have the following qualities:*
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> - *Highly absorptive (water-holding capacity) and easy to process;*
> - *Non-toxic to microorganisms;*
> - *Easy to sterilize effectively;*
> - *Available in adequate amounts and low-cost;*
> - *Provide good adhesion to seeds;*
> - *Has good buffering capacity;*
> - *High organic matter content and water-holding capacity of more than 50%.*
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> *Other essential criteria for carrier selection relating to the survival of the inoculant bacteria should be considered.*
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> - *Survival of the inoculant bacteria on seeds. Seeds are not always sown immediately after seed coating with the inoculant bacteria. The bacteria have to survive on seed surface against drying condition until placed into soil.*
> - *Survival of the inoculant bacteria during the storage period.*
> - *Survival of the inoculant bacteria in soil. After being introduced into the soil, the inoculant bacteria have to compete with native soil microorganisms for the nutrient and habitable niche and have to survive against grazing protozoa. Such carrier materials that offer the available nutrient and/or habitable micro-pores to the inoculant bacteria will be desirable. In this sense, materials with micro-porous structure, such as soil aggregate and charcoal, will be good carriers for soil inoculants."*

Peat has remained as a standard for applications as a dried, fine-textured material for seed coating but has been considered less desirable for soil applications and handling. The *Bio-FIT* review presents these comments about peat:

> *"The significant disadvantage of peat originates from the variability in its quality and composition, which are source-dependent. Peat is an undefined and complex material and different sources will vary in their ability to support cell growth and survival. Toxic compounds might also be released during sterilization, negatively influencing the growth and survival rate of desired microorganisms. This may bring about challenges to guarantee reliable quality and results in the field, as well as to identify the optimal storage conditions, or usage instructions. Regardless of these restrictions, peat remains the standard by which every other material is judged."*

PittMoss® is one of the best materials to replace peat because it meets the desired properties for biological carriers. Additionally, PittMoss® presents an opportunity to formulate delivery materials and systems that not only match the desired functions of carriers, but it can also serve as a substrate for improved survival and growth by providing structure, energy (in the form of labile carbon), and moisture. The inherent properties of the engineered PittMoss® substrates make adaptation to varied microbiological needs and applications a natural extension to current applications.

PittMoss® Properties & Observations

The array of biofertilizer types is vast, and new strains of bacteria, fungi, and algae are rapidly becoming more available. Applications include a myriad of inoculants for use in agricultural, silvicultural, and recreational nutrition and pest control management systems. Delivery systems include liquids, suspensions, powders, granules, composts, and assorted structural substrates. Propagated spores, living active cells, and propagules are delivered to desired locations to foster beneficial associations with plants. It is often important to supply carbon within the delivery system. PittMoss® could not only supply that necessary carbon but could also offer properties to enhance the survival, growth, and effectiveness of many microbes. By examining the physical, chemical, and biological properties of PittMoss® lignocellulosic substrates, we can better determine useful applications of this material for use in biofertilization advancements. An examination of those properties is presented in the following sections of this paper.

PHYSICAL PROPERTIES

Lignocellulosic plant fibers are the basis of PittMoss®. Fibers from paper and cardboard are currently used, but conceivably, PittMoss could be made from agricultural crops and processing waste. These carbon-based, lignocellulosic fibers are milled to be very fine, thus creating a product with immense surface area that provides extensive residence sites for microbes. The fine fibers are agglomerated into particles to provide structures with inherent micropores which absorb water and hold microbes. Additionally, the particles are structured with sufficient macropores between the particles. These macropores provide good gas exchange, allowing for healthy air penetration throughout the substrate. The formed particles are resistant to compaction and maintain their porosity despite handling and application. They can be prepared, stored, and handled – moist or dry – and, by measuring and controlling exact moisture levels, inoculum survival may be assured within the material. With increased and alternant processing, drying, and sizing, the inoculated granular particles could be structured as desired for specific uses and application using existing granular fertilizer application equipment, depending on their final desired use.

CHEMICAL PROPERTIES

The fibers that comprise PittMoss® granules can be made with varying ratios of lignin, cellulose, hemicellulose, starch, and sugars to meet the demands of specific microbial inocula. This may be done by incorporating various plant fibers and additives. This would provide carbon at various levels of microbial availability, allowing multiple microbial strains to exist within the substrate. Combinations of fibers from paper, cardboard, agricultural production, and processing waste are all possible. The unamended pH of most plant fibers ranges from 6.0 to 7.5 and can be adjusted up or down to match the range most suitable for various microbial strains. That is an advantage over peat, which requires liming and incubation before use to achieve optimal pH levels. Mineral additives are also easily incorporated during formulation. Additionally, lignocellulosic fibers are naturally free of toxic materials and heavy metals, limiting conditions toxic to microbes. Altogether, these properties make PittMoss® a good candidate for a microbial carrier.

BIOLOGICAL PROPERTIES

Clearly, PittMoss® fosters microbial activity. By simply blending inocula with this carbon-rich substrate, an immediate burst in respiration and composting activity occurs. In some simple observations of degraded soils amended with PittMoss® (which were obtained from some depleted California fields), carbon dioxide emissions increased almost immediately and continued for a long period, indicating much increased microbial activity. Composts blended with PittMoss® begin generating heat immediately after blending and can reach temperatures above 150°F within 36 hours. Fungal mycelium and sporulating bodies may be observed as little as 14 days after incorporation into blends. Following incorporation of PittMoss® into their own substrates, growers have commented on exceptional root development and essentially no disease development, suggesting a disease suppression effect from the microbiology that is active in the PittMoss® products. In a set of trials comparing the growth of poinsettias across several blends, a grower compared PittMoss® to their fully sphagnum peat-based blends on a separate workbench in their greenhouse, slightly isolated from their main crop. A severe case of root rot (pythium) developed in the main crop population. The grower applied fungicide to the main crop, but they did not treat the bench with the trail crops. Surprisingly, nearly all the crops in the sphagnum-based house blend suffered greatly, while those containing 1/3 PittMoss® all thrived. The exact mechanism of disease suppression was not determined, and may be due to signaling plant defenses, microbe to microbe parasitism, microbe production of toxins, competition for space within the rhizosphere, or competition for nutrients. Regardless, the observation of disease suppression was informative. Photographs of this trail are shown in **Figure 2**.

Figure 2. A comparison between poinsettia growth in blends with PittMoss® (top) and without (bottom) following infection by root rot (pythium) bacteria.

Summary

The observations noted in this paper lead us to conclude that PittMoss® has the necessary physical, chemical, and biological properties to make it an optimal carrier for biological inocula. The use of PittMoss® in this way could improve applications of inocula to soil in agriculture and forestry systems. Inoculated PittMoss® particles would then carry carbon, and possibly other critical associated micronutrients, which ensure microbial growth and survival until the microbes develop plant root associations. The applications are vast, and the market for such products is large. PittMoss® is therefore perfectly positioned to become a leader in sustainable biofertilizer delivery systems in multiple industries.

References

European Union. 2020. The Bio-FIT Project. Bio-fertilizers VET Training. https://bio-fit.eu/ (accessed 15 September 2023).