

Biopesticides for Seed Treatment: Still a small market but accelerated Growth

The global crop protection seed treatment market is valued at USD\$4 billion today. While biocontrol represents only 5% to 10% of this total, it is growing at more than double the rate of the chemical based seed treatment market. With many companies, both global crop protection and traditional biopesticide manufacturers, investing heavily in discovery and development of microbial solutions, the future for biocontrol in seed treatment looks promising. Market consolidation in the crop protection and seed industry has led to only four companies representing over 80% of global revenues for seed treatment. With several global crop protection megamergers in process, this situation may be exacerbated even further. The end result is smaller companies must select partners carefully to gain market access for their biocontrol seed treatment solutions. They will need to bring a convincing story of the benefits their technology can offer and work closely with their partner on field development and testing of the products. Mark Trimmer, Managing Partner at DunhamTrimmer and Editor 2BMonthly has the story.

S EED TREATMENT specifically refers to the application of chemical products and/or biological organisms to the seed prior to sowing in order to suppress, control or repel pathogens, insects and other pests that attack seeds, seedlings or plants. Seed treatment offers a highly precise mode of applying products in the field, and provides a high level of protection against insects and disease while reducing potential exposure of humans and the environment to crop protection products. With 90 percent of the world's food coming from crops grown from seed, protection of seed from insect and disease pathogens is of critical importance to growers. The introduction of genetically modified seed dramatically increased the cost of seed, and as a result, growers expect a near perfect crop stand under most growing conditions. Seed treatments play a vital role in protecting the significant grower investment in high quality seed and helping to ensure the crop gets off to a good start.

A MODERN MARKET WITH CENTURIES OLD ROOTS!

Seed treatments have been used for nearly 350 years, beginning in 1670 when a ship carrying wheat grain sank off the coast of England near the city of Bristol. When the farmers close to the coast collected and planted the seeds soaked in seawater, they found that the crop that resulted was free from "smut" whereas

other farmers who planted with unsoaked grain experienced heavy smut infestation. As a result of this serendipitous discovery, early investigation of potential seed treatments included a range of chemicals and concoctions, including sea water, urine, lye, and a wide range of other creative solutions. The discovery of the value of organic mercury for seed treatment in 1912 accelerated the development of the first commercial seed treatment formulation called Panogen (mercury fungicide) developed in Sweden in 1938. Shortly thereafter, chemical compounds based on copper and mercury were developed and commercialized in Europe, USA, and elsewhere. In the 1950's, the broad spectrum contact fungicide Captan was introduced and rapidly became a standard seed treatment for maize (field corn). Most of the early seed treatments controlled surface pathogens, but were not absorbed by the germinating seedling and did not move systemically in the developing

plant. By the 1960's and 1970's, systemic fungicides such as carboxin and thiram were introduced, just as many of the early mercury based products were being removed from the market due to concerns about their toxicity to humans and the environment. Modern seed treatments are highly selective and are effective at low doses, often combining both contact and systemic activity. Products like the fungicide fludioxonil and neonicotinoid insecticides revolutionized the seed treatment market in the 1990's due to their low use rates and high level of performance. Improved water based formulations have also greatly improved the uniformity of seed coverage and boosted performance. However, the neonicotinoid insecticides have recently come under scrutiny for a potential link to honeybee colony collapse. Most recently, biological based seed treatments have become a big research focus at nearly all companies. They offer opportunity

Table 1: Key Microbial Biocontrol Agents Currently Used as Seed Treatments

Agrobacterium radiobacter	Nursery & fruit trees
Bacillus amyloliquefaciens	Many crops
Bacillus firmus	Maize, cotton, sorghum, soybean, sugarbeet, others
Bacillus subtilis	Many crops
Pseudomonas sp. Proradix	Potato
Burkholderia spp.	Cereals, maize, cotton, soybean, many vegetables
Pseudomonas trivialis	Lettuce, other salad plants
Pasteuria nishizawae	Soybean, sugarbeet
Pythium oligandrum	Broad range fruit, vegetable, ornamentals
Streptomyces griseoviridis	Ornamentals, vegetables, and tree seedlings
Streptomyces lydicus	Many crops
Trichoderma sp.	Many crops

to integrate with traditional chemical treatments to enhance or extend control, while helping to mitigate the development of pest resistance to chemical solutions. The global seed treatment market was valued at approximately USD\$6 billion in 2016 with a consolidated annual growth rate (CAGR) of over 10%. This includes all seed treatments – chemical crop protection, colorants, biopesticides, biostimulants, and other plant growth regulating and promoting substances. The crop protection seed treatment is valued at USD\$4 billion. Insecticides dominate and account for over 50% of total revenue followed by fungicides at 35%. Maize was the largest crop followed by soybean, wheat, canola and cotton. North America is the leading geography with over 40% of total global market. Syngenta and Bayer dominate from a company standpoint with over 60% of total market. The top four companies represent over 80% of revenue for seed treatments.

TREATMENTS MOSTLY BASED UPON MICROBIALS.....

Biological seed treatments are predominantly based upon microbials with botanicals playing a much smaller part. The seed inoculants paved the way for these products. "Rhizobia based inoculant products have been used for nearly 100 years in legumes with growers recognizing their value year after year," says John Wilke, International Business Manager of Loveland Products (formerly managed seed treatment business for Loveland). "These products have really paved the way for microbial biocontrol seed treatments. This makes legume crops a

natural starting point for microbial biopesticides with seed treatments acting as an "entry point" for biopesticides to gain a larger foothold in row crops." Mike Hofer, Director, Seed Solutions Global Marketing at BASF agrees, noting that "seed applied, rhizobia inoculants that help the plant form effective nitrogen fixing nodules are already well established for legume crops in many countries."

Microbial biopesticides are often applied in conjunction with chemical seed treatments, with the chemical providing early season control and microbial providing extended control as it colonizes the developing roots. Although a small part of the market today, biologicals are one of the fastest growing seed treatment sectors due to their safety, pest resistance advantages, and easier registration path. A range of microbial organisms, including both bacteria and fungi, have been used successfully as seed treatments.

DunhamTrimmer estimates the global biocontrol seed treatment market revenue at approximately USD\$200 in 2017 and forecast it to grow to over USD\$550 by 2025. North America is the largest region in terms of value with 47% of the global market, followed by Europe with 24%. The USA is by far the largest individual country, followed by Brazil and France.

The global CAGR of the biocontrol seed treatment market is projected to exceed 20%, more than double the growth rate of the traditional chemical based crop protection seed treatment market. This will drive increased market share for biocontrol seed treatment from approximately 5% in 2017 to nearly 10% in 2025. The

Interview with BASF Mike Hofer, Director, Seed Solutions, Global Marketing



Because biologicals are derived from living organisms or natural extracts (including bacteria and fungi as well as beneficial insects) the properties of each biological can be very different with unique challenges and opportunities.

For example, some biological products are extremely stable while others require some special handling, such as temperature-controlled environments for storage and transport. On-seed survival is an important aspect of the development and commercialization of biological seed treatments. BASF offers a market leading 225 days on-seed survival with our Nodulator® Pro 225 giving seed companies more flexibility between application and the grower planting window. Compatibility with other products is another important aspect for biological seed treatments.

It is important to make sure biologicals are not mixed with products that might impede or eliminate their effectiveness.

As with any of our products, we continuously work to improve formulations, which includes ways to extend the shelf life and performance of our seed-applied biological products in order to extract their full potential. BASF has a new state-of-the-art R&D Center for Biologicals and Seed Solutions in Limburgerhof, Germany that has laboratories for product application tests including on-seed survival, shelf-life and compatibility.

Over the next five years, we see increasing use of biologicals to complement chemistry-based products, and indeed in some row crops they are already important. One example: seed-applied, rhizobia inoculants that help the plant form effective nitrogen fixing nodules, are already well-established for legume crops in many countries. Chemistry will always be more relied upon due to the typically wider spectrum of control and efficacy under most environmental conditions, but biologicals are already a contributor in row crops creating more integrated programs for growers with evolving needs. BASF has a strong biologicals pipeline for row crops including Integral® Pro, a seed-applied biofungicide for oilseed rape, in the final stages of regulatory approval in France and Germany. We also recently submitted applications with the U.S. EPA to register the seed-applied biofungicides Velondis™ Flex, Velondis™ Extra and Velondis™ Plus for use on soybeans, wheat and corn.

Interview with Ecosense Labs Ketan Mehta, Founder & CEO



Maintaining seed quality is of primary importance in development of a biocontrol seed treatment. Evaluation of various criteria that influence efficacy including adhesion characteristics, appearance, uniformity of loading, influence on planter efficiency and others are all key aspects of the development process. With all of the multiple coatings and

treatments being applied to GM seeds today, the final size of the seed needs to be monitored to ensure it doesn't exceed planter tolerances. And, of course, stability and viability of microbial treatments must demonstrate acceptable performance during handling, transport, and storage prior to sowing. The interaction of other treatments and coatings on microbial viability must be assessed to ensure they don't compromise viability of the microbial treatment. Biocontrol producing companies need to develop a close working relationship with seed companies to ensure all of these factors are assessed. The benefit of biocontrol seed treatments, particularly in row crops, is the ability to adapt and provide longer term benefits to the crop compared to traditional chemical treatments

majority of this growth is driven by increased adoption of microbial based seed treatment product use in row crops.

.....BUT FACING CHALLENGES

One of biggest challenges is maintaining the viability of the microbial so that it can multiply after the seed is sown and protect the developing root. Unlike other seed treatment technologies, microbes are living organisms that must survive under harsh conditions until the seed is sown. Formulation technology and seed handling are critical to achieving success. "On seed survival is an important aspect of the development and commercialization of biological seed treatments," says Mike Hofer.

Successful formulation goes beyond just maintaining viability. "The microbial biopesticide must not compromise seed safety and seed quality which are of primary

importance," says Ketan Mehta, CEO of Ecosense Labs. "Microbial biopesticides are only one part of what is often a complex mix involving multiple coatings and treatments on the seed. We have to be aware of the adhesion characteristics of all treatments and ensure the final physical size of the seed does not adversely compromise planter performance." Avoiding antagonism between all of the products used in seed coatings is a key concern. "Compatibility with other products is an important aspect for biological seed treatments. It's important to make sure biologicals are not mixed with products that might impede or eliminate their effectiveness," says Mike Hofer. Another challenge is keeping use rate at an acceptable level for seed treatments. "Getting the rate low enough to coat the seed at an economical rate in comparison to chemicals is a big challenge.

Microbials can be bulky, often containing spent fermentation solids in the formulation," said Pam Marrone, CEO & Founder of Marrone Bio Innovations.

MERGERS AND ACQUISITIONS IN SEEDS AND PLANT PROTECTION SHAPING THE MARKETPLACE

The biocontrol seed treatment

market is in a very early growth stage today, but there are clear signs that rapid expansion is on the horizon for the near future. Biopesticide companies have been providing seed treatments based on traditional solutions such as *Trichoderma* spp. or *Bacillus subtilis* for some time. BASF signaled their strong inter-

Interview with Marrone Bio Innovations Pam Marrone, CEO & Founder



"Marrone Bio has a partnership with Albaugh who has stacked our Burkholderia (killed) bioinsecticide/nematicide bacteria with their chemicals and a biochemical biostimulant on the seed. They launched under the brand BIO ST in 2017 after conducting more than 65 trials in 2016 showing the increased yield with the stacked treatment compared to other seed treatments on the market. In addition, Marrone Bio and Groundwork BioAg, Ltd (Groundwork) have announced successful seed treatment field trials of the world's first all-biological comprehensive crop protection seed treatment. The treatments tested in corn and soybeans contained a mycorrhizal inoculant from Groundwork, as well as a bioinsecticide, a bionematicide, and a biofungicide from Marrone Bio. In corn, the two bio-stacked treatments reduced corn rootworm populations and

corn lodging, at least as well or better than the commercial chemical standard. Reduced corn rootworm damage generally correlated with increased yields. BioStacked Seed Treatment (BSST) 1 provided an average increase of 10.9 bushels (+5.8%), and BSST Treatment 2 an average increase of 12.5 bushels (+7.2%). Respectively, these improvements were 3 and 7.4 bushels higher than the commercial standard, which included chemical insecticide, nematicide and fungicides. For trials targeting corn nematodes, most BSST treatments and the commercial chemical standard reduced nematode populations. Yields for BSST Treatments 1 and 2 averaged 16 and 22 bushels (7.3% and 10.4%) higher than untreated seeds, respectively. BSST Treatment 2 increased yields by 4.5 bushels over the standard chemical seed treatment (insecticide, nematicide, fungicides). In soybeans, Marrone Bio nematicides combined with Groundwork's mycorrhizal inoculant reduced soybean cyst nematodes as effectively as did the commercial standard treatment. Yields of BSST-treated soybeans averaged 8 bushels per acre (+15%) higher than those of untreated soybeans. Field trials, including semi-commercial trials continue in 2017 with an eye towards 2018 market entry".

est in the seed treatment sector when they acquired Becker Underwood for more than USD\$1 billion in late 2012. This investment added biological seed treatment expertise as well as capabilities with colorants and polymer based seed coatings. Subsequently, BASF continued to invest in biocontrol and seed solutions with a new R&D center at their Limburgerhof, Germany site. BASF views research on biological solutions represented as an opportunity to complement their traditional chemical crop protection, particularly when used in combination as seed treatments. The new facility brought added capabilities to test on seed survival, shelf life, and compatibility of biological agents used in seed treatments.

The acquisition of Pasteuria Bioscience by Syngenta and the launch of their Pasteuria nishizawae technology as a soybean seed treatment under the Clariva® brand name for soybean cyst nematode control was a real ground breaker for biocontrol seed treatments. This was the first use of a microbial seed treatment on a major row crop by a global crop protection company. It also demonstrated that a microbial treatment could provide performance equal to traditional chemicals, with the added advantage of greatly improved user and environmental safety. The Clariva label was subsequently expanded to include control of sugarbeet cyst nematode and Syngenta has just obtained approval in Brazil as well (see Syngenta box).

Seed Treatment DROC



Interview with Monsanto
Thomas Schaefer, Global Seed Applied Solutions
Portfolio Strategy Lead



Most of biological seed treatments we focus on are living organisms – so maintaining the microbes’ viability is key to achieving the farmers’ goal, which is efficacy. We’re always looking at ways to extend the shelf life of microbial seed treatments, and we had a breakthrough in recent years. Scientists at Monsanto and Novozymes, our partner in The BioAg Alliance, discovered a way to increase the shelf life of Penicillium bilaiae. That fungus is the active ingredient in our Acceleron B-300 SAT product we introduced to farmers this year (2017.) What it means for farmers is that their corn seed can come pretreated with

Acceleron B-300 SAT, which is a huge convenience advantage for them.

The BioAg Alliance is primarily focused on corn and soybeans, and we are adding wheat to our pipeline this year as well. Soybean growers would benefit from a nematicide like the one we have in our development pipeline, and what we’re learning in those field trials could potentially apply to our corn and wheat research as well. Today, the biggest markets are in the U.S., Canada, Brazil and Argentina. We expect Europe, the Middle East, Africa and Asia to emerge as larger markets in the coming years. We expect our Soybean BioNematicide project to be first out of the gate. It’s expected to provide an additional tool for growers to control nematodes, those microscopic parasitic worms that damage plants. It’s still early in our research and development stage, but we’re expecting it to continue to show activity against different nematodes, including soybean cyst nematode. The Alliance will continue field tests to confirm efficacy in combination with a range of other chemical and biological seed treatments.

The strategic alliance of Monsanto and Novozymes to form the BioAg Alliance in 2013 has led to the investment of sub-

stantial resources into the discovery and development of novel microbial solutions. Initial success came with biostimulant seed treatment products, with Acceleron B-300 SAT derived from a naturally occurring soil fungus launching in 2017 as a seed inoculant for maize (field corn). Monsanto added this inoculant to all new maize hybrids, amounting to 10% to 20% of its total maize sales. The BioAg Alliance has also had success in the biocontrol realm. Tom Schaefer, Global Seed

Applied Solutions Portfolio Lead for Monsanto commented on a novel microbial based soybean bionematicide in their pipeline. “It’s still early in our research and development stage, but we’re expecting it to continue to show activity against different nematodes, including soybean cyst nematode. The Alliance will continue field tests to confirm efficacy in combination with a range of other chemical and biological seed treatments.” One of the major benefits in seed treatment is integration of biological and traditional chemical solutions. “The value of integrated pest management programs is a major potential benefit of these innovations. In my career at Monsanto I’ve worked across crops and technologies and there’s a common thread in battling insects, weeds and diseases – an integrated, systems approach is a must. A biological product – a soybean nematicide as an example – is recommended to be part of a systems approach, and certainly not a silver bullet to battling pests,” said Schaefer. (see Monsanto box) The traditional biopesticide companies are also working hard to develop seed treatment solutions. Marrone Bio has inked several partnerships, including those with Albaugh and Koch Agronomic Services, to commercialize their microbial assets as seed treatments (see box for details). Included among these offerings are one which is a completely biological based solution – called a BioStacked Seed Treatment by Marrone which combines a bioinsecticide, bionematicide, and a biofungicide from Marrone with a mycorrhizal inoculant from Groundwork BioAg. Pam Marrone commented, “Seed treatment is an entry point for biocontrols in row crops. Clearly, stacking microbes with chemicals on treated seed has been a winning strategy for Bayer, Monsanto, and Syngenta.”

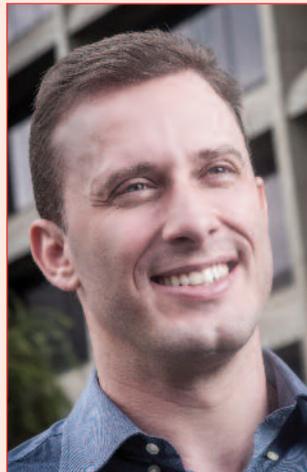
In addition, R&D efforts into the plant microbiome by a range of recently formed companies including AgBiome, Bioconsortia, Indigo Ag, and others suggests more novel microbial treatments are on the horizon. While some of these companies are focused on biostimulant solutions, most also include biocontrol as a target of the discovery and development efforts.

And nearly all major crop protection companies include biological product R&D as part of their pipeline. Bayer, BASF, Monsanto BioAg, and Syngenta who just inked an agreement with Valagro covering seed treatment with biostimulants each have significant biological R&D efforts and evaluate seed treatment potential as part of their development programs.

MARKET ACCESS: A KEY TO SUCCESS

There are two seed treatment segments from a marketing viewpoint. The largest and most important is the pre-treated seed (pre-packaging) segment, while the post-treated (post packaging) seed treatment segment is much smaller depending on the crop. Pre-treated seed market commonly involves treatment with a range of actives, often combining chemicals and biologicals for pest control, as well as biostimulants, plant growth promoters, and fertilizers. Pretreated seed is packaged and sold as a unit to the channel and ultimately the end user. Maize is the largest crop segment and is almost exclusively pretreated. The majority of vegetable seeds are also pre-treated. The post treatment segment includes seed that is treated within the channel right before the grower takes delivery. Cotton and soybeans are examples of the largest crops within the post-treated seed segment. Given that formulation stability and shelf life are often challenging for biological

Interview with Syngenta Andre Negreiros, Global Seed Care Manager - Nematicides Matthias Brandl, Head, Biologicals R&D



"Biocontrols, whether used as over-the-top sprays or as seed treatments, offer unique opportunities for new Crop Protection products that will complement conventional crop protection tools (synthetic chemistry) with new modes-of-action and excellent integrated crop program possibilities. There is certainly good market growth of those products at the moment. However, significant market growth will only happen, if new biocontrols demonstrate reliable, consistent biological activities comparable with synthetic chemistries. They need to be compatible with existing



products but also fit seamlessly into conventional application regimes not requiring special farm machinery or additional passes/efforts. Clariva® has been proven an excellent new technology in modern soybean cyst nematode management. Its performance is already satisfying thousands of farmers in the US and Canada, and it complements our chemical portfolio and host resistance to soybean cyst nematode very well. We see good further growth in existing markets (North America), but also in new markets (eg. Brazil) where we have just achieved registration"

cal products, especially the microbials, the post treatment segment in these crops may represent a potential opportunity for biologicals to gain early access while formulations are improved to address stability on the seed. Global crop protection companies have substantial assets, both personnel and money, dedicated to market access, ensuring they can rapidly introduce new technology into key markets. They also frequently have access to chemical seed treatments which can be combined with microbials to create novel offers. This means they can bring a portfolio of seed treat-

ments across a range of crops to market in parallel over multiple geographies. Additionally, leading global crop protection companies such as Bayer, Syngenta, Dupont and Monsanto all have important seed business as well. This means these companies are also using their recent biological investments (Syngenta-Pasteuria; Monsanto-BioAg) to build their own seed treatment package of biological and chemicals for use on their own seed varieties. Smaller biocontrol companies often find market access to be a critical hurdle they must overcome to succeed. These companies are

often limited to only one or two technologies and lack ready access to chemical seed treatments needed to create combined microbial and chemical offers. Their resource limitations often mean they are forced to introduce products to new geographies sequentially rather than in parallel. This market access limitation can create opportunity, as seen recently when biocontrol companies have collaborated to combine their efforts in developing a complete bio package for a particular crop.

Market access limitations are also highly dependent upon the crop. Maize, the largest single crop for seed treatment, is dominated by Monsanto and DuPont-Pioneer in the USA and Americas. Other crops like soybeans, wheat, cotton and annual vegetable crops may offer more options where market access is not dominated by one or two companies or where a high percentage of seed is post-treated.

Market consolidation in the crop protection and seed industry has led to only four companies representing over 80% of global revenues for seed treatment. With several global crop protection megamergers in process, this situation may be exacerbated even further.

The end result is smaller companies must select partners carefully to gain market access for their biocontrol seed treatment solutions. They will need to bring a convincing story of the benefits their technology can offer and work closely with their partner on field development and testing of the products. Those companies with unique solutions with a strong foundation in solid science that can build good working relationships with partners will find opportunities to overcome these market access hurdles. ■