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## Seed Treatment: Demand for Sustainable Agriculture – A Review

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Seed treatment, a one-time application of pesticides directly onto crop seeds, is increasingly recognized as a pivotal component in sustainable agriculture. It addresses a critical phase in crop cultivation, safeguarding young plants from pests and diseases and ensuring a successful crop establishment. Furthermore, by enhancing the protection of seeds and enabling them to thrive irrespective of field conditions, seed treatment stands as a formidable strategy akin to human vaccines in its capacity to fortify plant health from the outset. This not only underscores the demand for sustainable agriculture but highlights the efficiency and necessity of seed treatments in meeting global food security needs while maintaining ecological balance.

Our discussion ventures into the intricate dynamics of seed treatment, examining its vital role in boosting crop performance and its contribution to eco-friendly agricultural practices. We analyze how treated seeds are instrumental in mitigating the use of additional spray applications, thereby shielding biodiversity and soil health. Furthermore, we explore the burgeoning demand for treated seed in the global market and assess the innovations that promise to enhance this age-old practice. This foundational exploration sets the stage for a deeper understanding of seed treatment as a key player in the pursuit of sustainable agriculture.

### What is Seed Treatment?

Seed treatment encompasses a variety of methods aimed at enhancing the protection and growth of seeds and seedlings. Understanding the intricacies of seed treatment is crucial for achieving healthy and vigorous crops. Here, we break down the core aspects of seed treatment to provide a clear understanding.

### Definition and Purpose

- Seed treatment involves the application of biological, physical, or chemical agents to seeds. This process is designed to protect seeds and plants from pests and diseases, thereby improving the establishment of healthy crops.
- It's important to distinguish seed treatment from seed coating. While seed treatment focuses on protecting and improving crop establishment, seed coating involves applying exogenous materials to the seed, which may include protectants or biostimulants.

### Types of Treatments and Their Targets

- **Fungus Control:** Seeds may be treated to control fungus, which can spread disease, reduce yield, and lower crop quality.
- **Insecticide Treatment:** Some seeds are treated with insecticides to protect seedlings from insects that feed on them.
- **Safety Measures:** Treated seeds are often dyed to indicate the presence of pesticides and require proper handling and disposal to prevent exposure and environmental harm.

## Benefits and Methods

- **Protection and Growth:** Seed treatment controls seed-borne or soil-borne pathogenic organisms and storage insects, thereby improving germination, seedling protection, and crop yield.
- **Application Methods:** Various methods such as seed dressing, seed coating, and seed pelleting are used to apply treatments, ensuring targeted and efficient protection.
- **Environmental Considerations:** By reducing the area in contact with crop protection products, seed treatment minimizes environmental impact, decreases the effect on non-target organisms, and reduces product movement in the environment.

## Types of Seed Treatment

Understanding the various types of seed treatment is essential for selecting the right approach for your seeds. Here's a breakdown of the main types and methods:

### Main Types of Seed Treatment

- **Pre-sowing Treatments:** These are applied before sowing to protect seeds from pathogens and pests right from the moment they are planted. This category includes:
  - **Fungicide Seed Treatment:** Targets fungal diseases like smuts and rots, with specific types such as disinfection, disinfestation, and protection based on the purpose and the presence of pathogens.
  - **Seed Treatment Insecticides:** Designed to protect seeds from insect infestations, with specific chemicals effective against particular pests. Sometimes, mixtures are used to target multiple insect species.
  - **Biological Seed Treatments:** Involves applying beneficial microorganisms to seeds to improve root growth, nutrient uptake, and plant vigor. These treatments are beneficial for crops like corn, soybean, cotton, peanut, and wheat.

### Methods of Application

- **Hardening:** By soaking seeds in specific solutions, this method enhances their resilience to cold and drought conditions.
- **Fortification:** This process enriches seeds with nutrients to increase seedling vigor and improve tolerance to unfavorable soil environments.
- **Pelleting:** Increases the shape, size, and weight of seeds by coating them with inert substances, enhancing their handling and sowing characteristics.
- **Infusion and Osmotic Priming:** Involve treating seeds with organic solvents or osmotic agents like polyethylene glycol (PEG) to improve germination rates and seedling vigor.

### Specialized Treatments for Storage

- **Pre-storage and Mid-storage Treatments:** Aim to protect seeds from insect and pathogen attack during storage. These include the use of halogens, antioxidants, fungicides, and bactericides to shield seeds from oxidative damage and pathogen attacks. Additionally, seeds might be soaked in water or chemical solutions to raise moisture content temporarily before drying back to safe limits for dry storage.

## The Rising Demand for Seed Treatment

The global seed treatment market is witnessing a remarkable growth trajectory, underscored by compelling statistics that project a vibrant future for this sector. Here are key insights that encapsulate this burgeoning demand:

- **Market Growth Over the Years:**
  - In 2022, the market was valued at approximately USD 6.1 billion.
  - By 2027, it is expected to reach USD 9.2 billion, growing at a CAGR of 8.3%.
  - Looking further ahead, projections indicate a surge to USD 15.5 billion by 2033, with a steady growth rate (CAGR) of 8.4% from 2024 to 2033.

- The most ambitious forecast suggests the market could expand to USD 26.01 billion by 2029, driven by an impressive CAGR of 12.62%.

### Impact on Crop Performance

The transformative impact of seed treatment on crop performance is evident across various metrics, from germination to yield. Let's delve into the specifics:

- **Germination and Early Growth:**
- **Seed Germination:** Biological seed treatments are shown to improve seed germination by an average of  $7\pm 6\%$ , setting the stage for a successful crop cycle right from the start.
- **Seedling Emergence:** A significant enhancement in seedling emergence by  $91\pm 5\%$  is observed with biological seed treatments, ensuring that a higher proportion of seeds translate into viable plants.
- **Plant Biomass:** The application of biological seed treatments contributes to a  $53\pm 5\%$  increase in plant biomass, demonstrating enhanced growth and vigor in the treated crops.
- **Disease Control and Yield:**
- **Disease Control:** These treatments provide a substantial  $55\pm 1\%$  control over diseases, safeguarding the crops during crucial early development stages.
- **Crop Yield:** Perhaps most importantly, biological seed treatments culminate in a  $21\pm 2\%$  increase in crop yield, underscoring their role in boosting agricultural productivity.
- **Environmental and Economic Benefits:**
- **Reduced Environmental Impact:** By decreasing the number of spray applications of agrichemical products and lessening exposures to non-target species including humans and pollinators, seed treatment plays a pivotal role in reducing the environmental footprint of crop production.
- **Enhanced Sustainability:** Treated seeds offer a highly efficient and sustainable way to boost food security, helping crops thrive and reach their full yield potential without the excessive use of chemicals or pesticides.
- **Economic Advantages:** Seed treatments enable more sustainable farming practices that not only produce higher, more stable crop yields but also ensure the stable supply of nutritious, high-quality, and affordable food.

### Sustainable Agricultural Practices

In the realm of sustainable agriculture, seed treatment emerges as a crucial practice, significantly reducing the environmental impact and bolstering the efficiency of agricultural inputs. Here, we delve into the sustainable practices and innovations that underscore the importance of seed treatment in modern agriculture:

- **Environmental Impact Reduction:**
- Seed treatment minimizes the need for spray applications, reducing exposure to non-target species, including humans and pollinators, by over 90%.
- Soil surface exposure to chemicals is greatly diminished, offering a more targeted approach that preserves biodiversity.
- Stewardship practices ensure that the handling of treated seeds minimizes risk to non-target organisms, emphasizing the responsible management of agricultural inputs.
- **Advancements in Biological and Nanotechnology:**
- Biological seed treatments harness living organisms to bolster plant growth and resilience, contributing to a sustainable solution for feeding the global population without adverse effects on human health or the environment.
- These treatments not only help seeds reach their full genetic potential but also support sustainable farming practices like no-till and reduced-till, which are integral to soil health and carbon sequestration.

## Challenges and Limitations

While seed treatment has emerged as a cornerstone in sustainable agriculture, it's essential to recognize the challenges and limitations that accompany its implementation. These hurdles not only impact the effectiveness of treatments but also pose questions regarding their economic viability and application methodologies.

- **Effectiveness and Economic Concerns:**

- Not a universal remedy: Seed treatments don't offer a one-size-fits-all solution, and their effectiveness can vary based on the specific problem being targeted.
- Cost vs. Benefit: There's a risk that the costs of treatment could outweigh the profits gained, especially if the treatment is ineffective or targeted at the wrong problem.
- Application errors: Improper application can result in seeds that are more deficient than the original, negating the benefits of treatment.

- **Challenges in Biological Seed Treatment Adoption:**

- Awareness: A significant barrier is the lack of awareness among farmers about the benefits and proper use of seed treatments, limiting their potential in disease management.
- Shelf Life and Quality: Biological seed treatments face issues with shelf life and quality, making their adoption less appealing.
- Standardization: The absence of standardized application methods poses a challenge, complicating the process for farmers.
- Time for Effects: The longer time required to see visible effects from biological treatments can deter farmers looking for immediate results.
- Knowledge Gaps: There are considerable knowledge and awareness gaps among farmers regarding the use of biological seed treatments.

- **Environmental and Diagnostic Challenges:**

- Cold Weather: Extreme persistent cold can challenge the effectiveness of seed treatments, limiting their utility in certain climates.
- Pest Management: Managing soil-dwelling pests such as wireworms and insect larvae remains difficult, as early diagnosis is challenging.
- Continuous Use: Despite these challenges, the commercial use of chemical seed treatments for a wide range of crops is expected to continue, highlighting the need for sustainable and effective solutions.

## Conclusion

Through an extensive exploration of seed treatment's role and implications within sustainable agriculture, we've unearthed the multifaceted benefits and challenges this practice presents. The significance of seed treatment extends beyond merely enhancing crop performance; it embodies a crucial strategy in meeting the exigent demands of food security while adhering to principles of environmental sustainability. The discussion illuminated the dynamic relationship between advancements in seed treatment technology—spanning biological, chemical, and nanotechnological methods—and their contributions toward optimizing agricultural productivity and ecological stewardship.

As we progress, the ongoing dialogue between innovation and sustainability within the realm of seed treatment invites continuous research and adaptation. The challenges outlined, including the economic viability, application methodologies, and environmental considerations, underscore the necessity for a balanced approach. By integrating technological innovations with traditional wisdom, and addressing regulatory and market demands, the future of seed treatment promises not only enhanced agricultural outcomes but also a robust foundation for the sustainable nourishment of the global population.

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