SPEAKER: Professor Günter Neumann, University of Hohenheim

Biostimulants: What factors influence their effectiveness?

The second webinar of the "Biostimulants in Focus" series addressed the question on factors influencing the efficacy of biostimulants. While biostimulants demonstrate impressive results under controlled conditions, reproducing these effects under field conditions is often challenging. Professor Günter Neumann, a renowned agricultural scientist at the University of Hohenheim, shed light on the complex factors that determine a biostimulant's efficacy and presented findings from extensive field studies and meta-analyses.

What are biostimulants?

Biostimulants, often referred to as bioeffectors or plant tonics, are microorganisms or natural bioactive substances that stimulate plant growth but do not have a direct fertilizing effect.

Their goal is to improve the nutrient utilization of crops, increase stress tolerance of plants, or enhance final product quality. In some cases, they can also have direct plant protection effects, but these fall under the category of plant protection products and are subject to different approval procedures.

Günter Neumann is a German agricultural scientist at the University of Hohenheim. He is a plant physiologist, a specialist in rhizosphere research, and was the scientific coordinator of the EU research project Biofector.

The challenge of a mulivariable environment: From greenhouse to field trials

The efficacy of biostimulants has been demonstrated in numerous studies under controlled conditions. However, the transferability of these effects to field conditions presents a complex challenge.

The EU project BioFector, which was conducted over five years in eleven European countries, examined over 38 biostimulant preparations in more than 150 greenhouse and field trials. The results demonstrate that yield or growth increases could be achieved in most but not in all cases under filed conditions.

Similar observations have been made in extensive field trial programs conducted by the Chambers of Agriculture in Germany in recent years using microbial and non-microbial biostimulants. Only a vertain proportion of the trials showed statistically significant effects that were positive and economically viable.

These findings underline the need for further research to better understand the factors influencing the variability of results under field conditions as basis to specifically adapt the use of biostimulants for constant results in future.

(https://cordis.europa.eu/project/id/312117)

Meta-analyses: A look at scientific data over the years

For Biostimulants, the accusation of being "snake oil" is unjustified, as there are manifold experimental results in which biostimulants show great positive effects. The often negatively mentioned variability of effects under field conditions is rather due to influencing environmental factors that are not yet sufficiently understood.

To better understand the effectiveness of biostimulants, larger trial series and meta-studies are needed. In the last five years, approximately 1,800 studies on biostimulants have been published, which served as a basis for such meta-studies. Four different meta-studies on biostimulants have already been published in the last three years. Also they show a generalpostitive tendency of yield increade of on average 10% - but with significant deviations in oth directions.

"The high variability of the effects under field conditions is rather due to influencing factors that are not yet sufficiently known."
Prof. Günter Neumann

Similar effects of different products: The role of stress responses

A meta-study of the BioFactor project showed that both non-microbial biostimulants (algal extracts, humic acids, plant extracts) and microbial products, or combinations thereof, showed a tendency for growth and yield-enhancing effects, and all products had similar effects on the measured parameters. A field study conducted as part of the project at over 150 different locations confirmed this result: The yield effects were relatively similar for different biostimulants (an average increase of 10%), despite the significantly different compositions of the tested products.

The explanation for these results lies in the mode of action of biostimulants. Higher plants react to stress factors with a cellular stress response, which often includes oxidative stress. Stress leads to the increased formation of free radicals, which cause cell damage. Although plants possess detoxification mechanisms for these radicals, these mechanisms can be impaired under stress.

Biostimulants, whether microbial or non-microbial, have a signaling effect similar to moderate stress. They specifically activate plant stress responses. Algal extracts and plant extracts, humic acids, and protein preparations - all contain signaling substances that stimulate the cellular stress response. The same activation of stress adaptations also occurs when plants are treated with microbial biostimulants.

Product-specific effects: nutrients and pathogen defense

In addition to these general stress responses, biostimulants also have product-specific effects. These include:

- *Direct promotion of nutrient uptake processes: The best-known example is the nodule bacterial symbiosis in legumes, which improves nitrogen fixation. Mycorrhizae stimulate phosphate uptake, and humic substances can stimulate nitrogen uptake processes.*
- *Suppression of pathogens: Some strains of bacteria produce antibiotics that can inhibit the growth of harmful microorganisms.*
- *Beneficial microorganisms in the root zone: They are proven to produce phytohormones that positively influence plant growth and development, flower and fruit set.*

Priming and induction are the two basic mechanisms of action of biostimulants, even though their specific molecular pathways and interactions are very complex in detail.

Biostimulants improve plant stress tolerance

Biostimulants help the plant exploiting its genetic potential for stress tolerance. They stimulate and strenghten stress adaptation similar to a training effect in sports — trained individuals perform better than untrained ones. However, biostimulants generally do not introduce additional traits into the plant, but rather strengthen existing traits. They can therefore be used for stress prevention, but their effectiveness depends on the underlying plant genomic information and envrionmental conditions.

"Biostimulants act like a training effect - they help to exploit the genetic potential of the plant to cope with stress by adaptation."
Prof. Günter Neumann

Direct promotion of nutrient availability and uptake processes: The best known example is the nodule bacterial symbiosis in legumes

Influence of climatic factors and soil properties

Meta-studies show that climatic factors and soil properties influence the effectiveness of biostimulants.

- **Climatic factors:** Both microbial and non-microbial biostimulants demonstrate the highest efficacy in dry and tropical climates. In temperate climates with higher humus content, higher microbial activity, higher soil fertility, and lesser influence of stress factors, the effects of biostimulants are often lower.
- **Soil properties:** As soil humus content increases, the effects of biostimulants slightly decrease. Soils with higher humus content often have natural biostimulant potential. Soil pH also plays a role, with efficacy tending to be higher at acidic and alkaline soil pH values than in the neutral range.

"In addition to climatic factors and soil properties, nutrient availability, degradation system, and crop type also influence the effectiveness of biostimulants."
Prof. Günter Neumann

Influence of nutrient avail-ability

Nutrient availability also influ-ences the effectiveness of bio-stimulants.

- **Fertilizers:** Biostimulants exhibit particularly pro-nounced effects when combined with certain organic fertilizers based on animal by-products that offer good nitrogen and phosphate availability. These fertilizers promote the establishment of beneficial microorganisms in the root zone and improve carbon availability for these microorganisms.
- **Phosphate:** The effectiveness of biostimulants, both microbial and non-microbial, is best with a moderate availability of soluble phosphate. As these products stimulate root growth, the spacial accessability for phospahte is increased. The putative phosphate-dissolving effect of microorganisms appears to play a rather minor role in plant nutrition.
- **Nitrogen:** A new generation of nitrogen-fixing bacteria, which can also colonize leaves, is currently being used for plant inoculation and is intended to reduce the need for nitrate fertilizer. However, extensive field trials show a lack of reproducibility of the promised effects. These bacteria are highly susceptible to stress during the colonization phase, and the studies so far failed in demonstrating that the postulated nitrogen fixation actually reaches the plant.

Influence of different cultivation systems and crop types

The effectiveness of biostimu-lants is also influenced by different cultivation systems and crop types.

- **Cultivation systems:** Biostimulants tend to be more effective in greenhouse trials than under field conditions. The early phase of microorganism establishment at the root is critical for success. Trials with tomatoes in organic outdoor cultivation in Hungary, in which the tomatoes were pre-grown in the greenhouse and micro-organisms were introduced before planting in the field, the treatment showed significant yield effects.
- **Crops:** Legumes, vegetables, and fruit crops tend to respond better to biostimulants than arable crops. The application of biostimulants is particularly difficult for root and tuber crops, such as potatoes.
- **Variety effects:**

Biostimulants can significantly improve stress tolerance in sensitive varieties, while hardly any effect is observed in tolerant breeds.

Legumes, vegetables, and fruit crops tend to respond better to biostimulants than arable crops.

Summary and outlook

Biostimulants have a narrow window of efficacy, especially under field conditions. With sufficient nutrient availability or little stress impact, the effects are often reduced. For microbial biostimulants especially, stress during the colonization phase is detrimental.

Biostimulant's efficacy is enhan-ced by dry/tropical climatic conditions, low humus content, suboptimal pH values, salt stress, a moderate supply of soluble phosphate as well as an organic fertilizing regime. Legumes, vegetable and fruit crops, and varieties with low stress tolerance tend to show better effects.

There is currently no clear evidence of a contribution to non-symbiotic nitrogen fixation by leaf-colonizing bacteria or to the microbial mobilization of poorly soluble phosphates. Interactions with naturally occurring soil microorganisms are a broad field of research that is just being intensively investigated.

The effectiveness of biostimulants is influenced by a variety of factors, and it is important to understand these factors to ensure reliable results.

Agriculture needs more confidence in the use of biostimulants and a better understanding of the complex interrelationships in the agri-cultural ecosystem.

Biostimulants target fundamental mechanisms that strengthen the immune system of plants and soil. It is important to consider the importance of the soil microbiome for a healty plant development.

The effects of biostimulants may differ in the future due to climate change and more frequent extreme weather events. Biostimulants can become an important tool in a farmers' toolboxe to respond to these adverse events. However, it is important to provide users with accurate information about the conditions under which positive effects can be expected.

"Agriculture needs more confidence in the use of biostimulants and a better understanding of the complex interrelationships within the agricultural ecosystem."
Prof. Günter Neumann

Biostimulants can become an important tool in a farmers' toolbox to prepare for and respond to extreme weather events.

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In our webinar series "Biostimulants in Focus," guests from agriculture and science explore how biostimulants promote plant growth, strengthen resistance to stress, and improve soil quality. Practical and understandable.

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Key messages from the webinar

- The effectiveness of biostimulants is variable under field conditions and is influenced by numerous factors.
- Biostimulants activate plant stress adaptations and can improve the utilization of its genetic potential for stress resistance.
- Climatic factors, soil properties, nutrient availability, cultivation systems, crop type and crop variety play an important role in the effectiveness of biostimulants.
- Meta-studies provide valuable insights into the conditions under which biostimulants are effective.
- There is a need for more research and information for users to ensure reliableresults with the use of biostimulants.