BIOSTIMULANTS AND THEIR ROLE IN THE DEVELOPMENT OF MAIZE CROPS

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Abstract

The increase in food demand stimulates activities aimed at improving the productivity and quality characteristics of the crops obtained. Maize (Zea mays L.) is one such plant, which, along with wheat and rice, is one of the three most important crops in the world due to its many uses. Modern agriculture tends to minimize the use of mineral fertilizers and chemical plant protection products, which are replaced by products with natural origin. This group includes the biostimulants that have, as one of the main tasks, stress mitigation. Climate change alters regular weather seasonality and maize is one of the main crops affected by irregular water regimes.
Biostimulants have attracted the attention of maize growers due to their effectiveness in promoting morphological, physiological and biochemical processes in crops. The biostimulants boosts the physiological activity of plants by stimulating the photosynthetic process. Recent results from the specialized literature show that the application of biostimulants enhances the physiological performance of maize under both optimal environmental conditions and abiotic stress caused by water deficit. In this context, the use of biostimulants can be a useful tool to mitigate the adverse effects of climate change on maize plants.

Key words**: **maize, biostimulants, abiotic stress, improvement

INTRODUCTION

Maize or corn (*Zea mays* L.) is an important cereal crop of the world. It is a source of nutrition as well as phytochemical compounds (Paunescu et al, 2016).
Maize, which was originally domesticated from a weed species in central Mexico, has become an important worldwide commercial crop after 7,000 years of development, with a wide range of uses in food, feed, industrial raw materials and bioenergy. In 2018, global annual maize production was approximately 1.148 billion tonnes. China contributed 257.3 million tons (22.4%), second only to the United States, which produced 366.6 million tons (31.9%), becoming the world's second largest maize producer (Ma et al., 2021).
However, feeding 18% of the world's population with less than 9% of arable land has become a major challenge for China's agricultural production but also for the entire world. The human population is projected to reach 9.6 billion by 2050, which will

consequently require at least a doubling of current agricultural production (Duan et al., 2021). In this context, reducing food waste brings many benefits to people and the planet (Bonciu et al., 2021 a).

The increase in food demand stimulates activities aimed at improving the productivity and quality characteristics of the crops obtained. Also, genetic modified crops have all the potential for ensuring food security (Roșculete et al., 2018). Maize (*Zea mays* L.) is one such plant, which, along with wheat and rice, is one of the three most important crops in the world due to its many uses.

The main producers of maize are the United States, Brazil and China, where corn production in the US is almost six times higher than in the European Union (Krzyzanowski, 2016).

Modern agriculture tends to minimize the use of mineral fertilizers and chemical plant protection products, which are replaced by products with natural origin. This group includes biostimulants that have, as one of the main tasks, stress mitigation (Kapela et al., 2020).

Maize, like other grains, requires careful work. A key factor is to learn and implement a new maize cultivation technology, taking into account the effects of fertilizers and their combinations on the crop structure. The fertilization influence is very important, because it determines the number of plants per surface unit, i.e. one of the factors that influence the structure of grain production (Milander, 2015).

The influence of nitrogen fertilization is particularly great in the early stages of development, when weather conditions can cause stress to maize. Properly selected fertilizers and their combinations at the beginning of plant growth positively influence yield and production (Balawejder et al., 2020).

The extreme variability of climatic conditions, which is a particularly important characteristic of Romania's climate, poses difficult problems not only to agricultural production, but also to cereals breeding programs (Păunescu, 2018). Under drought conditions, oxidative degradation products occur at the cellular level, leading to oxidative stress. Numerous experiments on the study of grains drought resistance showed cell-based induction of enzyme oxidative stress protection systems (Păunescu et al., 2021).

The definition of biostimulants is broad and not precise enough. There are two main characteristics that distinguish biostimulants from fertilizers and plant protection products. A biostimulant can be any substance or mixture of substances of natural origin that improves the condition of crops without causing unwanted side effects (du Jardin, 2015).

Natural products, called biostimulants, increase plant nutrient utilization efficiency, abiotic stress tolerance, and improve crop quality. Numerous scientific studies have shown that biostimulants have a positive effect on crop production and soil quality improvement (Rouphael et al., 2018).

Although this term has been known for a long time, in the specialized literature its definition was given only in 2007 as "preparation containing substances, other than fertilizers, which promote plant growth when applied in small quantities" (du Jardin, 2015). The separation of biostimulants from other products is based on two principles: on action (beneficial influence); by exclusion (they are not nutrients, pesticides and soil improvers) (du Jardin, 2015).

Biostimulants contain substances and/or microorganisms whose function, when applied to plants or introduced into the rhizosphere, independently of the nutrient content of the product, stimulates natural

processes due to the improvement of the efficiency of the use of nutrients (du Jardin, 2015).

MATERIALS AND METHODS

Due to increasing population there is more food demand, and from this point of view, maize can satisfy the food requirements as well as provide human nutrition along with number of health benefits.

The aim of this review was to provide some information regarding biostimulants and their role in the development of maize.

The used methods included searching of databases like Web of Science, Scopus, Google Scholar and ScienceDirect.

RESULTS AND DISCUSSIONS

Cereal crops deserve greater consideration as part of a healthy and nutritious diet to humans and animals (Bonciu et al., 2021b; Ișlicaru, et al., 2021; Paunescu et al., 2023). Cereals are cultivated in huge amounts, and are used as a staple food in most of the developing countries (Constantinescu et al., 2020; Roșculete et al., 2021).

Maize is a fast growing plant. Its need for essential nutrients is high, and the lack of these in any plant can slow its growth and reduce productivity. In maize crop, nutrient deficiencies at key growth stages can affect plant productivity (Bender et al., 2013).

Plant biostimulants are substances that can improve crop productivity and quality, increase soil nutrient availability, improve plant nutrient use efficiency, and promote soil organic matter decomposition and humification (Bonciu et al., 2020; Caradonia et al., 2019; Olaru et al., 2020). Recently, biostimulants are widely used in production because they can improve the productivity and quality of production, and can meet the economic and sustainability requirements of production.

The increasing use of humic substances as plant growth promoters has attracted attention due to their effects on nutrient use efficiency, crop quality and protection against abiotic stress (Olivares et al., 2017). Abiotic stress is one of the most important factors limiting food security and plant productivity. The increasing number of extreme events in many regions highlights the importance of crop protection for an economy based on agricultural production (Salehi Lisar et al., 2020).

Biostimulants have attracted the interest of maize growers due to their effectiveness in promoting morphological, physiological and biochemical processes in crops (Del Buono et al., 2021).

Biostimulants can improve the ability of plants to use and absorb nutrients, improve their growth and positively affect the quality of the final product. They can increase plant resistance to different types of abiotic stress, the ability to cope with adverse conditions and maintain productivity (Panfili et al., 2019). There is the probability that the use of biological preparations will allow more efficient use of nitrogen fertilizers to obtain optimal yields of maize. In addition, the use of biostimulants can also significantly reduce the cost of fertilizers, which reduces the environmental impact of agricultural technologies (Puglia et al., 2021).

The major challenge for agriculture in the coming decades will be the sustainable production of food crops to meet ever-increasing global demand (Bonciu, 2023; De Souza and Bonciu, 2022; Emmanuel and Babalola, 2020; Păunescu, 2023; Rădoi et al., 2022). Current agricultural systems rely heavily on the continuous application of mineral inputs, including mineral fertilizers, mainly nitrogen (N), phosphorus (P) and potassium (K), which contribute to increased yields but also lead

to decreased of terrestrial biological fertility (Igiehon and Babalola, 2018). As a result, in recent years there has been an emphasis on reducing input-intensive farming systems and on intensifying research to develop sustainable and ecological alternatives for food production.

According to the data, the biostimulants market in Europe is growing. In 2018, the market had a value of 753 million dollars and in 2020 it had reached 1.2 billion dollars. Estimates show that by 2025, the market of biostimulators will almost double, i.e. a total value of 2.1 billion dollars". According to the information published by MADR, there are 116 approved products in the biostimulants category on the Romanian market. Of these, only 18 products contain two active components (agrimedia.ro).

Biostimulants are used in agriculture in the form of formulations with different substances or products, such as microorganisms, microelements, enzymes, plant growth regulators. Consequently, biostimulants can increase the availability of nutritional factors, water retention, raise antioxidant activity, increase chlorophyll content, etc. The interaction between different components can differently influence the physiological state of the plant depending on the species and the stage of development; therefore it is necessary to research the biological activity of the biostimulants depending on the species and even the genotype. In this way, thanks to a deeper understanding of the specifics of the interaction of different components on the activity spectrum of biostimulants, the formulations of commercial products and their application regimens can be optimized (Jelev, 2016).

The effects of biostimulants can be multiple. They differ depending on the type of biostimulant used and the variety of the plant. However, it should be noted that most of them have a beneficial effect on crops (Tarantino et al., 2018).

Comparing the specifics of the physiological activity of biostimulants with those of other groups of products of biologically active substances, the arguments in favour of separating them into a separate group of preparations become clear. Considering this, first of all, Jelev and Dascaliuc (2016) analysed the specific and interference areas of the action of biostimulants with those of phytohormones, growth regulators and plant nutrition factors. Secondly, they characterized the sources of biostimulants, the methods of obtaining and using them.

A. Phytohormones

Phytohormones are synthesized naturally, participate in the regulation of growth, development and resistance of plants to abiotic and biotic stress factors. They influence the development of various physiological processes, including the formation of leaves and roots, cell expansion, apical dominance, fruit development and ripening. The following groups of phytohormones are known: auxins, gibberellins, cytokinins, abscisic acid and ethylene.

B. Plant growth regulators and secondary metabolites.

Plant growth regulators (RPR) are chemical products, natural or synthetic, which, when applied to seeds or plants, modify the characteristics of growth, development, resistance to stress factors and finally influence plant productivity parameters.

C. The group of secondary metabolites (MS) represents a large number of natural compounds that are not directly involved in primary metabolism, but contribute to the survival of plants in natural conditions. Among them we can mention inhibitors, which suppress plant growth and retardants, which restrain plant growth by braking cell divisions and the elongation of

stem cells, thus regulating the height of plants without influencing their morphology.

D. Plant nutrition factors.

Plant growth and development processes are also influenced by nutritional factors. They participate in the regulation of the activity of enzymes involved in metabolic processes, their presence being absolutely necessary for the life cycle of plants.

From the above mentions, it follows that biostimulants it is working through mechanisms that differ from those characteristic of mineral fertilizers (their action being independent of the presence of mineral elements in the products). They differ from crop protection products because they only stimulate plant vigor and have no direct action on pests. In this way, biostimulants are complementary to the factors of nutrition and protection of crops, by definition being clearly distinguished from phytohormones, fertilizers and protective substances.

Biofertilizers, represented by bacterial or fungal inoculators, have similar properties, which are applied to plants to increase the availability of nutrients and contribute to their use by plants, regardless of the nutrient content of the inoculant. Some biofertilizers also act as biocontrol preparations, protecting plants from pests through competition, antibiosis, parasitism and the induction of systemic plant resistance.

Due to these common properties, these groups of organisms have been proposed to be included in the category of biostimulants (du Jardin, 2015).

Biostimulants it is working through mechanisms that differ from those characteristic of mineral fertilizers (their action is independent of the presence of mineral elements in the preparations) and crop protection products. They protect the plants indirectly, without directly affecting the pests; the beneficial effect is reflected on the vigor of the plants, which complementarily improves the nutrition and protection of crops.

The plants resulting from the treated seeds show the induction of a physiological state that ensures increased vigor and tolerance to stress.

Being complex products, biostimulants show diverse and often unexpected effects on plants. This is due to the simultaneous influence of biostimulants on pre-existing and induced factors, especially on the balance between the content of abscisic acid and other phytohormones. Bacterial and mycorrhizal biostimulants are known to have the potential to improve agronomic and physiological traits of crops, especially under stress conditions (Rouphael and Colla, 2020). The studies conducted indicated that the use of the tested biostimulants did not affect the biodiversity of soil bacteria in the rhizosphere. This may be attributed to the fact that the microbial treatments accounted for a small fraction of the microbial diversity in the rhizo-microbiome (Nuzzo et al., 2020).

However, it must also be considered that microbiome changes are the consequence of centuries of coevolution and that plants actively seek microbial interactions. Thus, it is not surprising that numerous results revealed moderate differences in the root microbiome among different treatments. Regarding the insignificant impact of fertilization with 30% less N on the soil rhizomicrobiome, the results are consistent with Maris et al. (2021).

Based on the source and composition, biostimulants were classified into three groups: preparations containing humic substances (1), amino acids (2) and substances extracted from seaweed (3).

In general, maize production is mainly affected by environmental factors, including

solar radiation, humidity, temperature and nutrients. Hussain et al (2019) showed that drought stress results in field crop yield losses of up to 30-90%.

Through the BIOSTIM project (PN-III-P2-2.1.-PTE-2016-0073) financed by UEFISCDI, in 2016-2018, it was possible to achieve a superior valorization of post-harvest plant residues, by building a biodegradation platform, in which chopped residues biodegrade naturally, by adding lignocellulolytic microorganisms and water. Depending on the temperature, biodegradation can take place in 7 to 14 days, after which extracts (infusion and maceration) of medicinal and aromatic plants such as *Tagetes patula* (watercress), *Ocimum basilicum* (green and red basil), *Artemisia dracunculus* are added (tarragon), *Mentha piperita* (mint), *Thymus vulgaris* (thyme), *Lavandula angustifolia* (lavender), *Capsicum annuum* (hot pepper). By squeezing the fermented compost, the main product is obtained (the liquid biostimulator - BIOSTIM) and a secondary product, represented by a solid organic substrate (generically called BRAISOL) (Trifan et al., 2018).

In maize grown on agricultural land fertilized with 84 kg N/ha, 80 kg P2O5/ha, the highest increase in production was obtained at the dose of 2 l BIOSTIM/ha in three treatments (concentration 0.66%), in which ensured an increase of 4991 kg/ha (56.4%), returning 831.8 kg per liter of product (Trifan et al., 2018).

NATUR GRUP INTEGRAL in direct partnership with the Caracal Research Station has carried out a study to see the effectiveness of Daymsa products in maize cultivation. Both the control group and the group with Daymsa treatments had the same basic treatments, the only difference being the application of Daymsa products:

• Seed treatment - Raiza Mix - 2 liters / ton of seeds, it was used to treat the seed, being an excellent biostimulator for rooting;

• Foliar treatment T1 – herbicide together with 0.35 kg/ha of Naturamin WSP (antistress biostimulator with 80% free amino acids) and 1 ml/liter of the Sprayfix bioadjuvant to increase the effectiveness of the herbicide, applied in the 4-6 leaf phase;

• Foliar treatment T2 – 4 liters / ha Naturamin Zn (antistress biostimulator with 14% Free Amino Acids and 5% Zinc) and 1 ml/liter of the Sprayfix bioadjuvant (naturgrup.ro/porumb).

The cost of treatments with Daymsa products was 287 lei per hectare. These treatments resulted in an increase in maize production of 1214 kg (6439 kg production in the control group and 7653 kg production in the Daymsa group). Capitalizing on the increase in production and quality would mean somewhere around 971 lei per hectare – a good supplement for any farmer.

Corteva Agriscience has launched in Europe Utrisha™ N, the biostimulant with role in improving nutrition, as part of the portfolio of biological products, thus contributing to the fulfillment of the more sustainable demand for plant protection products.

Utrisha™ N is an alternative source of nitrogen that can provide vegetative plants with additional nitrogen to facilitate their growth. This innovative technology delivers value through the efficiency of integrated nutrition management under natural field conditions, adapting to plant growth needs and sustainably contributing to maximizing yield potential. This product will be available for a wide range of crops including field crops, vegetables, orchards, vines and will be launched across Europe except Turkey, the Netherlands and the Nordic countries.

The launch of Utrisha™ N represents an important step for Corteva in expanding its global biologics portfolio dedicated to the development of biostimulants, biocontrol and pheromone-based products with proven and predictable performance.

Utrisha™ N is based on the endophytic bacterium *Methylobacterium symbioticum*, which works in symbiosis with the plant to ensure the assimilation of the necessary nitrogen from the atmosphere.

Experiments with Utrisha were conducted in Missouri by Steinkamp et al. (2023). They were arranged in randomized blocks with six replications. There was no significant interaction between years and treatments for late June leaf chlorophyll and yield. Leaf chlorophyll increased with increasing nitrogen dose. All biological N management treatments had leaf chlorophyll content values similar to urea at 100 lbs n AC-1. The number of plants at harvest was 32,150 to 34,640 plants.

According to Steinkamp et al. (2023), the inclusion of a nitrification inhibitor such as nitrapyrin can increase maize yields and reduce gaseous N loss when used on poorly drained soils that are subject to dentification loss mechanisms.

A summary of symbiotic products in N-fixation in the northern USA was recently synthesized by Franzen et al (2023). In maize trials conducted in North Dakota, Minnesota, Illinois, Indiana, Missouri and Michigan, Envita significantly increased yield in 1 of 12 trials compared to the same rate of nitrogen applied alone. In North Dakota, Missouri, Michigan, Kentucky, and Ohio, Utrisha had no effect on maize grain yield compared to nitrogen application in eleven different trials.

ProveN or ProveN 40 applied in furrow or as a seed treatment significantly increased yield in 1 of 26 corn trials in Minnesota, Illinois, Missouri, Kansas, Michigan and Nebraska compared to the same N rate.

CONCLUSIONS

Plant biostimulants have the potential to play key roles in mediating the effects of climate change and improving sustainability by reducing non-agricultural chemical inputs and helping to improve plant stability under stress conditions.

They are a class of substances distinct from fertilizers and are divided into humic substances, protein hydrolysates, chitosan, and seaweed extracts, based on the responses they elicit in plants rather than their composition.

Depending on the source and composition, biostimulants were classified into three groups: preparations containing humic substances, amino acids and substances extracted from seaweed.

Biostimulants it is working through mechanisms that differ from those characteristic of mineral fertilizers and crop protection products. Being complex products, biostimulants show diverse and often unexpected effects on plants. This is due to the simultaneous influence of biostimulants on pre-existing and induced factors, especially on the balance between the content of abscisic acid and other phytohormones.

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Natur Grup Integral in direct partnership with the Caracal Research Station has carried out a study in order to identify the effectiveness of Daymsa products in maize, e.g. Raiza Mix, an excellent biostimulator for rooting, Naturamin WSP and Naturamin Zn (antistress biostimulants).

The application of biostimulants enhances the physiological performance of maize under both optimal environmental conditions and abiotic stress caused by water deficit. However, although these substances have been widely studied and used in agricultural production, there are few studies in which the effects of different biostimulants on maize grain quality and stress resistance have been evaluated.

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