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Soybean response (Glycine max L.) under the use of biostimulants: A literature review

Corresponding author
João Henrique Barbosa da Silva
Federal University of Paraiba
henrique485560@gmail.com

Antônio Veimar da Silva
Federal University of Paraiba

Carla Michelle da Silva
Federal University of Viçosa

Philip Moab Duarte Amorim
Federal University of the Agreste of Pernambuco

Ellen Vitória Barbosa do Carmo
Federal University of Paraiba

Kelson da Silva Carvalho
Federal University of Paraiba

Arthur Henrique Peixe da Cunha Martins
Federal University of Paraiba

Karla Cristina de Barros Franca
Rural Federal University of Pernambuco

Bianca Alves Custódio
State University of Piauí

Erisson Marques da Silva
Federal University of Alagoas

Francisco Pereira dos Santos Filho
State University of Piauí

Ozael David Valério da Silva
Agricultural Defense Agency of the State of Piauí

Djair Alves da Mata
Universidade Federal da Paraíba

Abstract. Soybean (*Glycine max* L.) is a crop with prominence in Brazil and worldwide. The increase in soybean production and production capacity is associated with scientific and technological advances in the productive sector. One of these

advances is the use of biostimulants. In this sense, this work aimed to review current knowledge about the effects of biostimulants on soybeans, highlighting the direct or indirect response of the plant when using such substances. This review was carried out through a research with a qualitative approach, being considered a literature review of the narrative type, using other studies and research at the same theme, in high impact magazines from the last five years or more that were relevant to the study, with subsequent critical reading about the subject. Based on found results, it is clear the use of biostimulants in soybeans is a potential alternative input for increasing the growth and development of the crop, as they are able to provide increments in its productive variables. However, further research is needed in order to provide better information on agronomic interests.
Keywords: Nutrition, Soybean farming, *Glycine max*.

Contextualization and Analysis

Soybean (*Glycine max* L.), is the oilseed crop that has the largest expansion in the world, standing out in Brazilian agriculture for its high socioeconomic importance, leaving Brazil in the ranking of the largest producer in the world, facing a projection of 151.4 million tons (Conab, 2023). Among legumes, soy has been one of the most important, enabling food and nutritional security (Hailemariam et al., 2021).

In addition, it is an excellent source of mineral nutrients and secondary metabolites, which makes it essential for human health, and its cultivation is carried out in approximately 127.60 million hectares of land, with annual production that reaches 364.07 million tonnes globally (USDA, 2021). These results are linked by their food and feed values, such as cooking oils, proteins and fibers, as well as in the manufacture of lubricants, plastics, varnishes, soap and biodiesel (Gaonkar & Rosentrater, 2019).

However, it is known that there is a need to increase agricultural production, especially due to the continuous growth of the world population, with perspectives that point to a requirement for an increase of 1.3% per year in the production of this crop (Johnson et al., 2023). To meet this need, efforts have been used in soybean breeding, with good progress through the advancement of effective innovations, most of which are related to improving adaptability to different growing regions. However, one of the main challenges for increasing the productivity of this crop without increasing the production area is through technologies such as the use of biostimulants (Johnson et al., 2023).

Biostimulants are substances with the capacity to help improvement the nutritional efficiency of plants, helping to withstand problems of biotic and abiotic stress, such as diseases, temperatures, cultivation conditions and cultivation environments, and may increase production without taking into account the nutritional content (Nair et al., 2019). At this point, several studies have been carried out to investigate the influence of biostimulants on the production of legumes, such as soybeans, seeking to meet the growing world demand (Vasconcelos, 2019; Sauvu-Jonasse et al., 2020; Cavalcante et al., 2020; Katu et al., 2022).

Therefore, the aim of this study was to review current knowledge about the effects of biostimulants on soybean (*Glycine max* L.), highlighting the direct or indirect response of the plant when using such substances.

Type of study

This review was carried out through a research with a qualitative approach, being done through a descriptive analysis, with the indirect documentation technique, being characterized as a narrative literature review. Still, the work is such of indirect documentation, making use of documentary research, specifically for data collection and bibliographical research.

In this sense, it is a literature review of the narrative type which it refers to a research method where other studies and research are used at the same.

Technical procedures

Published works in high-impact journals (national and international) were used, by reference authors and knowledge in the study area, based on website data and through digital libraries: Scientific Electronic Library Online (SCIELO), Web of scienses and SCOPUS, during the last 5 years or more that are relevant to the related research, with subsequent critical reading of the subject.

For chosen papers, the following descriptors were used: "soy", "*Glycine max* (L.) Merrill", "biostimulants", "bioregulators", "vegetable stimulants", "oilseed", "legumes", among others. Because it is a narrative literature review, in which the choice of articles to compose the theoretical foundation of the work does not require the exhaustion of a data source, there was no defined flowchart referring to each stage of research selection, considering the used breadth.

The soybean crop (Glycine max L.)

Soy is a species of Chinese origin, belonging to the Fabaceae family and is present throughout Brazil, being cultivated worldwide (Almeida Júnior et al., 2020). This crop has been used in agriculture for forage purposes and as large protein and oilseed for thousands of years, being known for its importance through domestication and reproduction improvements (Anderson et al., 2019; Pereira et al., 2021).

Furthermore, it is a species with a high source of polysaccharides, soluble fibers, phytosterols, lecithins, saponins and phytochemicals, especially isoflavones, which, individually or together, help to promote human health, reducing the occurrence of diseases such as hyperglycemia, hypertension, dyslipidemia, obesity, inflammation, cancer and others (Modgil et al., 2021). The survey of the 2022/2023 harvest for soybeans in grains shows values equivalent to 154.81 million tons, with exports of 95.07 million tons (Conab, 2023). As for soybean meal, for the same harvest, the prospects point to 39.75 million tons, with exports of 20.66 million tons. As for soybean oil, in the same harvest, Conab presents an export estimate close to 2.6 million tons. In Table 1, the balance of supply and demand for soybeans in thousand tons can be verified.

Table 1. Soy supply and demand balance - thousand of tons. **Source:** Adapted from Conab (2023).

Product	Harvest	Initial storage	Production	Import	Supply	Consumption	Export	Final storage
	2021/22	8.851,3	125.549,8	419,2	134.820,3	52.956,6	78.730,1	3.133,5
Soy in grains	2022/23	3.133,5	154.810,7	500,0	158,444,2	56,224,6	95.072,2	7.147,4
	2021/22	1.772,8	37.830,8	3,2	39.606,8	17.900,0	20.352,9	1.353,9
Bran	2022/23	1.353,9	39.743,0	5,0	41.101,9	18.100,0	20.661,6	2.340,3
	2021/22	492,0	9.996,7	24,4	10.513,1	7.409,0	2.596,8	507,3
Óil	2022/23	507,3	10.578,4	50,0	11.135,7	8.211,0	2.600,0	324,7

Furthermore, the soybean harvest has already reached 93.7% of the cultivated area, with concentration in the North, Northeast and South regions, with good production rates through edaphoclimatic conditions that helps a better development of crops (Conab, 2023).

G. max L. plants are herbaceous of the class Rosideae, order Fabales, family Fabaceae, subfamily Papilionoideae, tribe Phaseoleae, genus *Glycine* L., species max (Embrapa, 2021). Among the soybean varieties, the main ones have a healthy stem with few branches and roots with a main axis and many secondary ones, with leaves in trifoliate formats, autogamous fertilization flowers, typical of the subfamily Papileonoideae, with white, purple or intermediate colour.

Soybean species develop slightly arched pods, and when they mature these tend to evolve from green to pale yellow, light brown, brown or gray, and may have from one to five smooth, elliptical or globose seeds, with pale yellow integument and the presence of black, brown or straw-yellow hilum (Embrapa, 2021). Still, they present type of growth in an indeterminate, determinate or semi-determinate way.

Studies point out that the ideal size of soybeans is between 60 and 110 cm, which in commercial crops tends to facilitate mechanical harvesting, preventing the plants from falling over. In addition, it is known that the environmental production directly influences plant flowering, and consequently its cycle.

The soybean crop has vegetative and reproductive stages, as shown in Figure 1 and Table 2, respectively.

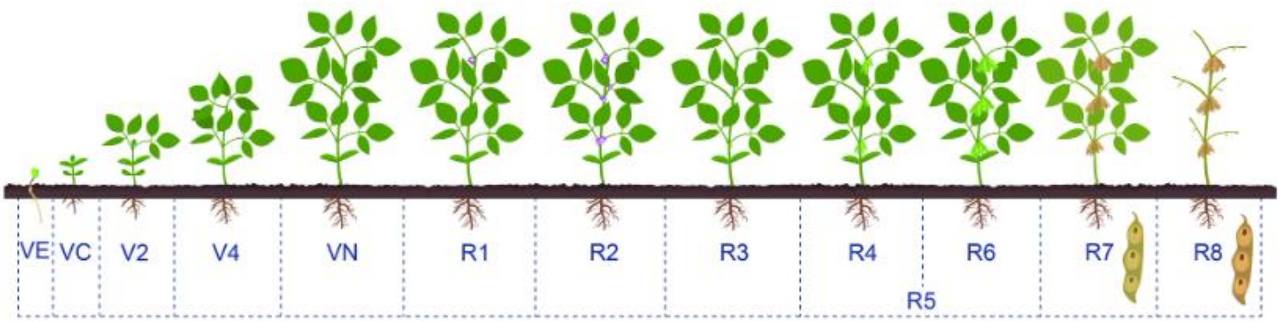

Figure 1. Phenological scale of the soy crop. **Source**: Fehr and Caviness (1977).

Table 2. Soy vegetative and reproductive stages. **Source:** Adapted from Fehr and Caviness (1977).

Vegetative stages	Reproductive stages
VE- Emergency	R1- Flourishing start
VC- Cotyledons	R2- Full flourisihing
V_1- First knot	R3- Pods starting formation
V_2- Second knot	R4- Full pods formation
V_3- Third knot	R5- Seeds starting filling
-	R6- Full seeds filling
-	R7- Maturation starting
V(n) - Tenth knot	R8- Full maturation

However, some biotic and abiotic factors influence soybean productivity, such as light, water, temperature, nutrients, diseases, pests and stress. To circumvent such problems, the dissemination of technologies becomes crucial, as is the case with the use of biostimulants, with research that already points to the effectiveness of these products for plants, making them a focus of agronomic interest (Nardi et al., 2016; Stadnik et al., 2017). Thus, in the following section, we will discuss the importance of biostimulants in soybean cultivation, with current research that shows the relevance of this form of technology to increase soybean production fields in Brazil and worldwide.

Use of biostimulants in soybean culture and plant response

Biostimulants are highly used technologies in agriculture, especially due to their potential for mitigating abiotic stresses in crops of agricultural interest, such as soybeans, also serving to overcome biotic problems such as pests and diseases, which makes their use becomes growing globally, reaching increases of 11% per year, and is therefore a good technological alternative to verticalize soybean production in Brazil and worldwide (Bhupenchandra et al., 2022).

Biostimulants, also known by several authors as synthetic or natural substances, originated from mixtures of two or more bioregulators, or these with other substances such as vitamins, amino acids and nutrients, and can be used in cultures via foliar fertilization or even in seed treatment (Santos et al., 2013).

The synthetic biostimulants most used today are those with a hormonal compound, which have cytokinin, auxin and gibberellin in their composition, which act in the cells plant growth and help stimulate the absorption of water and nutrients by the plant (Gonçalves et al., 2018).

Firstly, the physiological effects found by the action of auxin in soybean plants occur in cell elongation, apical dominance, phototropism and geotropism, introduction of roots and pod growth and seed formation, playing a fundamental role in plant growth and development (Sena et al., 2019).

Secondly, cytokinins have important functions such as delaying the senescence of plants, in addition to inhibiting the formation of free radicals, and consequently inhibiting the degradation of membrane phospholipids, in addition to participating in the regulation of other plant processes such as cell proliferation and morphogenesis of the aerial part and the root system (Taiz et al., 2017).

As for gibberellin, it is a hormone able to promote the physiological development of the plant, with the capacity to help in different phases of the plants, such as growth, synthesized in the cauline and root apex, being crucial in the physiological changes of flowering, sexual expression, germination, abscission and dormancy breaking, also acting on growth stem and seed development inside the pods (Taiz et al., 2017).

Thus, the application of biostimulants can be used in different ways, such as foliar, soil or fertirrigation, being a form of nutrient supplementation. In soy, important results have already been obtained with the use of biostimulants, such as those reported by Cavalcante et al. (2020), when evaluating the physiological characteristics and productivity of soybean grains subjected to the application of different biostimulants based on macronutrients, micronutrients, amino acids, plant extracts and natural complexes, in the management of water deficit, in which they observed a larger response of the plants to stress after using the products, as well as a physiological and productivity increase, emphasizing the efficiency of their use for the crop.

Thus, Santos et al. (2017) investigated the use of biostimulants, isolated and combined, in the agronomic performance of *Glycine max* (L.) plants, used in applications in three ways (via seed, via foliar and combined), obtaining positive results in the leaves dry mass variables, height plant, root dry mass and increase in plant root system.

In a study carried out by Santini et al. (2015), evaluating soybean crop productivity and economic viability due to the application of three biostimulants (Aminospeed Raiz, Stimulate® and Ultraseed®), via seed treatment, observed increasement in grain productivity, with larger gains in economic viability when compared to the control.

Silva and Sponchiado (2022), evaluating a biostimulant with biological assets from the seaweed extract Ascophyllum nodosum, as an alternative to increase the productivity of soybeans, observed increasement in the number of grains per plant, increasing the productivity of soybeans. On the other hand, Silva et al. (2023), observing the effects of the biostimulant Agri Gold® (*Ascophyllumnodosum*) on soybean growth and development, observed significant positive results only for height plants variables and production per bag, concluding that further studies are needed to corroborate or refute the found results by the authors.

Repke et al. (2022) when studying the use of biostimulants based on the extract of the seaweed *Ascophyllum nodosum* (L.) to increase soybean tolerance to high temperatures, found that foliar application improved the biometric and production characteristics, resulting in a larger productivity. In this same perspective, Morais et al. (2022), studying the effects of the biostimulant via leaf and seed, in the absence and presence of water deficit, observed interesting results, since the biostimulant was able to increase the mass of a thousand grains and the final productivity of the crop.

Melo et al. (2020) when studying the agronomic performance of soybeans with seeds treated with algae-based biostimulants, observed larger profitability in both harvests, in addition to providing larger grain yield and grain mass. In summary, it can be observed the different types of studies using biostimulants in the soybean crop, which reinforces its importance to verticalize fields production of this crop.

Because it is a crop that has been highlighted in the Brazilian agribusiness scenario, the constant search for alternatives that maximize production has increased, when subjected to biostimulants, demonstrated in the previous sections, being a subject that has been studied by researchers worldwide. As observed, these products improve plant development and growth, contributing to the hormonal balance, directly reflecting on the expressive performance of the potentially genetic crop and increasing its productivity.

Final considerations

The use of biostimulants in soybeans is a potential alternative input for increasing the growth and development of the crop.

Studies point out that the application of biostimulants (via leaf or seed) in the soybean crop is capable of providing increments in its productive variables.

It is understood that further research is needed in order to provide better information on agronomic interests.

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