



## RESEARCH ARTICLE

**Effect of Pre-Sowing Seed Treatment on Germination Energy, Root System Development, and Plant Stress Tolerance**Arina Eroshenko<sup>1</sup>, Anna Vershinina<sup>1</sup>, Mary Odabashyan<sup>1</sup>, Svetlana Studennikova<sup>1</sup><sup>1</sup>Don State Technical University, Rostov-on-Don, Russian Federation

ARTICLE INFO	ABSTRACT
Received: JUNE,05 2026	Pre-sowing seed treatment is one of the effective agrotechnological practices aimed at increasing field germination, accelerating initial growth, and forming a strong root system. Materials and methods. The article examines the physiological mechanisms of action of starter preparations and micronutrient complexes, including the role of zinc, boron, molybdenum, amino acids, B vitamins, and polysaccharides. Results and discussion. It is shown that these components can reduce the energy expenditure of the embryo, stimulate phytohormone synthesis, improve root and nodule formation, and increase plant resistance to abiotic stresses. Data from Russian and foreign literature confirming the effectiveness of seed dressing and seed coating for cereals, grain legumes, and industrial crops are summarized.
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**INTRODUCTION**

The initial stage of plant development is critical for subsequent productivity. It is during germination and emergence that the parameters of the future root system, the intensity of growth processes, and resistance to adverse environmental factors are established (Taiz et al., 2015). One of the most extensively studied and technologically accessible methods for improving early plant development is pre-sowing seed treatment with physiologically active substances, macro- and micronutrients, and complex formulations containing amino acids, vitamins, and polysaccharides (Savoini and Dell'Orto, 2019; Meskhi et al., 2023).

Modern studies show that seed treatment not only improves agronomic indicators but also affects the expression of genes related to plant stress response, root growth, and metabolism (Kumar and Singh, 2020). In this context, starter-action preparations are of particular interest, since they are aimed at accelerating seed swelling, supporting the embryo, and supplying the plant with nutrients during the most sensitive period of ontogenesis.

**MATERIALS AND METHODS**

For this article, a review analysis of Russian and foreign publications devoted to germination physiology, the action of micronutrients, and the role of amino acids and biologically active substances in pre-sowing seed treatment was carried out. Special attention was paid to studies concerning zinc, molybdenum, phosphorus, and compounds that improve seed interaction with soil microorganisms (Cakmak, 2008; Alloway, 2008; Marschner, 2012; Okumoto and Pilot, 2011).

The study was review-analytical in nature and was aimed at summarizing data on the effect of pre-sowing seed treatment on germination energy, root system development, and plant resistance to stress factors. The study was based on the results of Russian and foreign scientific publications

devoted to the use of starter preparations, micronutrient complexes, amino acids, vitamins, and biologically active compounds in seed treatment of agricultural crops.

Materials concerning cereal, grain legume, and industrial crops were used in preparing the article, since pre-sowing seed treatment has the greatest practical importance for these plant groups. Particular attention was paid to studies evaluating the effects of preparations containing zinc, boron, molybdenum, phosphorus, amino acids, B vitamins, and polysaccharides. Data on the influence of these components on physiological and morphological indicators of plants at early stages of development were analyzed.

The methodological basis of the study included comparative, descriptive, and analytical methods. Comparative analysis was used to compare the results of different studies in terms of germination energy, laboratory and field germination, root length, seedling mass, and plant resistance to adverse environmental conditions. The descriptive method was used to characterize the mechanisms of action of individual components of starter preparations. The analytical approach made it possible to summarize information on the most effective directions of pre-sowing seed treatment in modern agricultural technologies.

In the analysis, the following main indicators were considered: seed germination energy, laboratory germination, intensity of initial seedling growth, main root length, degree of lateral root development, accumulation of fresh and dry mass, and general resistance of young plants to abiotic stresses, including moisture deficit, temperature fluctuations, and nutrient deficiency. For leguminous crops, data on nodule formation and the activity of symbiotic nitrogen fixation were additionally considered.

Literature sources were selected according to the criteria of scientific reliability, relevance, and correspondence to the research topic. The analysis included works presenting the results of laboratory, vegetation, and field experiments, as well as publications containing information on the physiological mechanisms of action of micronutrients and biostimulating substances. Preference was given to studies in which preparation effectiveness was assessed using a set of morphophysiological indicators rather than a single trait.

When interpreting the results, special attention was paid to the initial stage of plant ontogenesis, since it is during this period that germination intensity, the rate of root system formation, and subsequent crop adaptation to growing conditions are determined. The effectiveness of pre-sowing treatment was evaluated in terms of the ability of active substances to accelerate metabolic processes, reduce consumption of seed reserves, activate enzymatic systems, and supply the plant with available forms of nutrients during the most sensitive period of development.

Thus, the methods used in this study made it possible to comprehensively examine the effect of pre-sowing seed treatment on the early stages of plant growth and to identify the most significant components of starter preparations that improve seed sowing qualities and seedling stress tolerance.

## **RESULTS AND DISCUSSION**

### **Role of Zinc in Early Plant Development**

Zinc is an essential micronutrient required for the normal functioning of enzyme systems, auxin synthesis, and root system formation (Cakmak, 2008). Zinc deficiency leads to growth retardation, reduced germination energy, and disruption of hormonal balance. In pre-sowing seed treatment, zinc can promote faster grain swelling, activation of cell division, and the formation of a larger number of primary and lateral roots (Alloway, 2008).

This is why zinc-containing starter preparations are regarded as particularly promising under conditions of insufficient organic matter content and low levels of available micronutrients in the soil. Under such conditions, the plant experiences nutrient deficiency already at early stages, and local application of active substances to the seeds makes it possible to compensate for this deficiency (Marschner, 2012).

## **Amino Acids and B Vitamins**

Amino acids in starter preparations perform several functions at once: they are a source of nitrogen and carbon skeletons, participate in protein synthesis, and serve as precursors of biologically active compounds (Okumoto and Pilot, 2011). Their presence in a preparation reduces the seed's energy expenditure for mobilizing internal reserves, which is especially important under stress conditions, such as drought, low temperatures, or limited soil nutrient availability (Parvaiz and Satyawati, 2008).

B vitamins participate in metabolic processes, enzymatic reactions, and coenzyme synthesis. Adding them to complex preparations can accelerate metabolic reactions in the germination zone and increase the overall physiological activity of the seedling (Gholami et al., 2009).

## **Polysaccharides and Interaction with Microorganisms**

Polysaccharide components in preparations increase the adhesion of inoculants and beneficial microflora to the seed surface. This is especially important for legumes, where the formation of effective symbiosis with nodule bacteria is directly associated with nitrogen supply to the plant (Somasegaran and Hoben, 2012). A higher degree of microbial preparation adhesion to the seed promotes faster nodule formation and increased nitrogen-fixing activity (Hungria et al., 2013).

Thus, polysaccharides not only improve the technological properties of a preparation but also contribute to biological activity in the rhizosphere, creating conditions for better plant establishment.

## **Molybdenum and Leguminous Crops**

Molybdenum is an essential micronutrient for leguminous crops, since it is part of enzymes involved in nitrogen metabolism and nitrogenase activity (Kaiser et al., 2018). Its deficiency impairs symbiotic nitrogen fixation and reduces nodule formation. Therefore, molybdenum-containing preparations are especially effective for treating seeds of soybean, pea, lupine, and other legumes (Graham et al., 2001).

In some cropping systems, such preparations are also used for cereals when it is necessary to improve starter nutrition and support seedling development under unfavorable soil conditions (Fageria et al., 2009).

## **Phosphorus and Root System Development**

Phosphorus plays a key role in plant energy metabolism, is part of ATP and nucleic acids, and is also necessary for root system formation (Raghothama, 1999). Early supply of available phosphorus to the plant promotes active root growth, improves water and nutrient uptake, and increases drought tolerance (Vance et al., 2003).

In starter preparations, phosphorus is often combined with amino acids and micronutrients, which enhances the synergistic effect and provides higher effectiveness than the use of individual components (López-Arredondo et al., 2014; Rudoy, 2023).

## **Physiological Effect of Reducing Embryo Energy Expenditure**

One of the most important effects of pre-sowing treatment is the preservation of the embryo's energy potential. With an optimal supply of active substances, the seed spends fewer of its own reserves on the initial germination processes, and the released energy is directed toward root and shoot growth (Bradford, 1995). This is especially important under stress conditions, when any reduction in expenditure during the start-up phase may determine plant survival and subsequent productivity (Finch-Savage and Bassel, 2016; Rudoy et al., 2022).

## **CONCLUSION**

Pre-sowing seed treatment with complex starter preparations is an effective tool for improving seedling quality, accelerating growth, and strengthening the root system. The most pronounced effect is achieved by combining zinc, molybdenum, phosphorus, amino acids, B vitamins, and polysaccharides. Such formulations make it possible to reduce the energy expenditure of the embryo, improve interaction with beneficial microflora, and increase plant stress tolerance. A

promising direction for further research remains the study of the molecular mechanisms of action of such preparations, including their effects on gene expression and plant metabolic pathways.

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