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Original Article

The influence of biological products and growth regulators on the yield and quality indicators of pea seeds of various varieties

A influência de produtos biológicos e reguladores de crescimento nos indicadores de rendimento e qualidade de sementes de ervilha de diversas variedades

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Abstract

Peas are an important agricultural crop of great importance in human and animal nutrition. Peas, being a legume crop, help replenish nitrogen reserves in the soil. In field studies of the Federal State Budgetary Scientific Institution of the Federal Scientific Center of Legumes and Goat Crops (Oryol region), the influence of various growth regulators and biological products on the yield and quality indicators of pea seeds of the Nord and Multik varieties was studied. Pea plants are grown on dark gray forest, medium loamy soil of average cultivation. Before sowing, pea seeds were treated with solutions of Kornevin, Albit and Epin-extra by soaking for 5 hours. Solutions of the drugs were used at a concentration of 10-6 M, then dried and treated with Rizotorfin before sowing. Growth rates during the growing season and the yield of pea plants were determined. The content of protein, starch and amylose in starch was determined in the seeds. Research results have shown that the yield of pea plants depends on weather conditions. Under favorable weather conditions, the highest yield was obtained from the pea variety Nord (42.2 c/ha) in the variant with seed treatment with Kornevin, and in the Multik variety (43.0 c/ha) when treated with Rizotorfin. In arid conditions, the highest yield of peas of the Nord variety was obtained using the preparations Epin-extra and Kornevin. The highest yield of peas of the Multik variety was obtained using the preparations Rizotorfin, Kornevin and Epin-Extra. The research results, confirmed by statistical evaluation, showed that bioregulators and growth regulators help stimulate the amount of nitrogen supplied to plants, as well as the synthetic processes of protein synthesis. This contributed to improving the quality of seeds and green mass.

Keywords: pea, biological products, rhizobia, growth regulators, Rizotorfin, Albit, Kornevin, Epin-extra, protein, amylose, starch, yield.

Resumo

A ervilha é uma cultura agrícola de grande importância na nutrição humana e animal. As ervilhas, por serem uma leguminosa, ajudam a repor as reservas de nitrogênio do solo. Em estudos de campo da Instituição Científica Orçamentária do Estado Federal do Centro Científico Federal de Leguminosas e Caprinos (região de Oryol), foi investigada a influência de diversos reguladores de crescimento e produtos biológicos nos indicadores de rendimento e qualidade de sementes de ervilha das variedades Nord e Multik. As ervilha são cultivadas em floresta cinza escura, solo argiloso médio e cultivo médio. Antes da semeadura, as sementes de ervilha foram tratadas com soluções de Kornevin, Albit e Epin-extra por imersão por 5 horas. Soluções dos medicamentos foram utilizadas na concentração de 10-6 M, depois secas e tratadas com Rizotorfin antes da semeadura. As taxas de crescimento durante a estação de crescimento e o rendimento das plantas de ervilha foram determinadas. O teor de proteína, amido e amilose no amido foi determinado nas sementes. Os resultados da pesquisa mostraram que o rendimento das ervilhas depende das condições climáticas. Sob condições climáticas favoráveis, o maior rendimento foi obtido na variedade de ervilha Nord (42,2 c/ha) na variante com tratamento de sementes com Kornevin, e na variedade Multik (43,0 c/ha) quando tratada com Rizotorfin. Em condições áridas, o maior rendimento de ervilhas da variedade Nord foi obtido com as preparações Epin-extra e Kornevin. O maior rendimento de ervilhas da variedade Multik foi obtido com as preparações Rizotorfin, Kornevin e Epin-Extra. Os resultados da pesquisa, confirmados por avaliação estatística, mostraram que os biorreguladores e reguladores de crescimento auxiliam na estimulação da quantidade de nitrogênio fornecida às plantas, bem como nos processos sintéticos de síntese proteica. Isso contribuiu para melhorar a qualidade das sementes e da massa verde.

Palavras-chave: ervilha, produtos biológicos, rizóbio, reguladores de crescimento, Rizotorfin, Albit, Kornevin, Epin-extra, proteína, amilose, amido, rendimento.

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1. Introduction

Peas (Pisum sativum) are one of the most important legumes. In Russia, peas are the most common grain legume crop, the products of which are widely used for food purposes and to feed farm animals. Peas are used in feed production to solve the problem of vegetable protein deficiency. Its lack in the diet of animals leads to disruption of the normal functioning of the body, and, as a result, to a decrease in their productivity and an increase in feed consumption by 1.5-2.0 times. Obtaining high and stable yields of yields of crops is possible only with appropriate agricultural technology, including tillage, pre-sowing seed treatment, sowing, caring for crops, harvesting, etc. (Baybakova et al., 2016; Kuznetsov et al., 2020).

The world leaders in the production of green peas in the last decade are China, India, and the USA. In Russia, the cultivated area is more than 1 million hectares (Debely, 2012; Jones et al., 2016). According to Food and Agriculture Organization of the United Nations (FAO, 2022), the area under pea cultivation in 2022 was about 10 million hectares, and pea production is estimated at 33 million tons.

Peas have a unique ability to fix atmospheric nitrogen, which makes this crop economically and environmentally effective (Zotikov, 2020). It is known that peas can meet their nitrogen needs 2/3 from the atmosphere and 1/3 from the soil. At the same time, in practical conditions, nitrogen fixation may be insignificant, and in some cases even absent, which depends on the presence in the soil of specific nodule bacteria that are quite effective, virulent and competitive. These can be either local strains or imported from outside in the form of a biological product, for example, Rizotorfin. Currently, the use of biological products and growth regulators for pre-sowing treatment of seeds of leguminous plants and other agricultural crops is considered one of the most important agrotechnical techniques of modern crop production (Seregina et al., 2022a; Volobueva et al., 2023). Exogenously introduced biological products and growth regulators affect the physiological processes and metabolism of plants and rhizobia, which can affect the yield and quality of grain (Novák et al., 2004; Jager et al., 2005; Gafurov et al., 2020, p. 7-9; Volobueva et al., 2023).

The nutritional and feed value, technological properties of grain, which determine the duration of storage and the quality of further processing, depend on the chemical composition. For most pea varieties of Russian selection, the nitrogen content is 3.8-4.2%, phosphorus – 0.8-1.4%, potassium – 1.1-1.3%, crude protein in grain – up to 30%, and in green mass up to 25%, collection of crude protein or up to 0.7 tons per 1 ha, balanced in amino acid composition (Olle, 2017).

The photosynthetic potential and net productivity of photosynthesis of peas averages from 300 to 400 thousand m^2/ha×day. and 12-14 g/m^2×day (Khvoina et al., 2004).

Many researchers note the high efficiency of pre-sowing seed preparation methods aimed at accelerating their germination and increasing field germination. Pre-sowing seed treatment is one of the simplest ways to improve the quality of seed material and increase the yield of grain crops (Kolesnikov et al., 2016; Seregina et al., 2021b, 2022a). Growth regulators, including those obtained by the synthesis of organic compounds, act primarily on plant enzyme systems, accelerating biochemical reactions and, as a result, stimulating the formation of organic matter synthesized during photosynthesis (El-Shraiy and Hegazi, 2009; Boev et al., 2016; Seregina et al., 2021a, 2022a). The latter leads to an increase in the productivity of crops grown in agrocenoses. In addition, changes occur in the relationships within the agrocenosis, since the intensification of the growth processes of cultivated plants affects the formation of some of their dominance in interactions with environmental factors. The combined action of internal plant factors and external environmental factors ensures the implementation of the genetic characteristics of cultivated plants during the formation of yield (Seregina et al., 2021b; Bovin et al., 2022). Therefore, we can talk about optimizing the functioning of the agrocenosis, using pre-sowing seed treatment with growth regulators as an optimizing factor (Luisi et al., 2011; Seregina, 2018; Seregina et al., 2021a, b).

Depending on the genotype, there are differences in the content and quality of storage proteins. For example, their ability to be extracted into various solvents depends on the ratio of vicilin, convicline and legumin. A higher level of vicilin and a lower level of legumin has a positive effect on protein extractability and emulsion stability. The genotype has a significant impact on the content, composition, technological and functional properties of pea proteins, which is important in the production of functional and dietary nutrition products of pea protein products (Barac et al., 2010).

Understanding the molecular mechanisms that regulate pea seed development is extremely important for pea breeding. Genes associated with soluble sugar and starch metabolism were significantly upregulated during pea seed development, coinciding with the onset of sugar and starch accumulation in the seeds. A comparative analysis of genes involved in the biosynthesis of sugar and starch in vegetable peas (high content of soluble sugar in seeds and low content of starch) and grain peas (high content of seed starch and low content of soluble sugar) showed that differential expression of related genes at later stages development leads to a negative result. A high correlation was discovered between the content of soluble sugar and the flow of starch biosynthesis in the seeds of vegetable and grain peas. RNA-Seq data were validated using quantitative real-time RT-PCR analysis for 30 randomly selected genes. The findings provide a basis to support future efforts to unravel the underlying mechanisms controlling pea seed developmental biology and serve as a valuable resource for improving pea breeding (Liu et al., 2015).

The value of legume grains has increased dramatically due to their processing into legume storage protein isolates. The study was conducted to examine the structural and functional properties and aroma profiles of major storage protein fractions isolated from green peas and chickpeas, including globulin, legumin and vicilin. Alkaline extraction-isoelectric precipitation coupled with a modified salt dissolution-precipitation method was developed to obtain the above-mentioned protein fractions on a large scale. The results showed that the purity of the globulin, legum

and vicilin fractions reached more than 90%, 80% and 90%, respectively, from the pulse type (Chang et al., 2022).

Pea grain contains high quality protein, which is a functional ingredient in the global industry due to its low allergenicity. Pea grain contains a large amount of protein, which makes it possible to obtain environmentally friendly human food products. In addition, pea protein has excellent functional properties, such as solubility, water and oil holding capacity, emulsion ability, gelation and viscosity (Fadeeva, 2013; Pakhotina et al., 2020; Guindon et al., 2021). Thus, these functional properties make pea protein a promising ingredient in the food industry. In addition, several extraction methods are used to obtain pea protein isolate and concentrate, including dry fractionation, wet fractionation, salt extraction, and mild fractionation methods. Pea protein can be used as a food emulsifier, encapsulating material, biodegradable natural polymer, and in cereals, bakery, dairy and meat products (Shanthakumar et al., 2022; Khrulev et al., 2016).

Peas (Pisum sativum) are the second most important crop of the Legume family, as they contain major components including protein (20-25%), fat (1.5-2.0%), carbohydrates in the form of starch (24-49%) and total dietary fiber (60-65%), including 10-15% insoluble fiber and 2-9% soluble fiber. They also promote the formation of non-starch carbohydrates, including sucrose, oligosaccharides and cellulose. Minor components are vitamins, minerals, phytic acid, saponins, polyphenols and oxalates. The most prominent mineral element present in peas is potassium (1.04%) found in the dry and hulled mass of peas, followed by phosphorus (0.39%), magnesium (0.10%) and calcium (0.08). %) respectively (Richard, 2003). Moreover, they are also a good source of water-soluble vitamins, especially rich in B vitamins. Essential amino acids are also present, high in lysine and threonine. However, there is a deficiency of sulfur-containing amino acids, including methionine and cysteine (Kaigorodova et al., 2022).

Pea proteins are generally hypoallergenic and have health benefits such as antioxidant, antihypertensive, anti-inflammatory properties, modulating industrial bacterial activity, and lowering cholesterol levels. It is also a good source of bioactive small peptides, which may provide antioxidant activity and inhibit angiotensin-converting enzyme (ACE) activity, providing beneficial health effects.

The purpose of the work was to study the effect of pre-sowing treatment of pea seeds of the Nord and Multik varieties with biological preparations Rizotorfin and Albit and growth regulators Kornevin and Epin-extra on the yield and grain quality.

2. Objects and Methods of Research

The research was carried out in a field experiment at the Federal State Budgetary Scientific Institution of the Federal Scientific Center of Legumes and Goat Crops (Oryol Region). To resolve the issues raised, two field experiments were conducted (№ 1 (2006) and № 2 (2007)). The experiments were carried out in different years, when growing seasons were characterized by different weather conditions. The conditions for conducting the experiment in 2006 were characterized by favorable temperature and humidity weather indicators. In 2007, the growing season was characterized by higher temperatures compared to the long-term average and low relative air humidity.

The objects of the study were pea plants of the Nord and Multik varieties. The characteristics of the varieties were described previously (Volobueva et al., 2008). Pea plants are grown on dark gray forest, medium loamy soil of average cultivation. Agrochemical characteristics of soils: humus content in the arable soil horizon is 3.7-5.5%, nitrogen content (easily hydrolyzed) according to Kononova is 6.7-7.8 mg/100 g of soil, the content of mobile forms of phosphorus is 9.8-11.0 mg/100g (according to Kirsanov), the content of mobile forms of potassium is 7.5-7.8 mg/100 g of soil (according to Maslova), the pH of the salt extract is 5.7-6.0 (by the potentiometric method).

Seeds of pea varieties Nord and Multik were soaked for 5 hours in solutions of the preparations Kornevin, Albit and Epin-extra at a concentration of 10-6 M, then dried. The seeds were treated with Rizotorfin before sowing. Experiment options: 1 - control, without treatment; 2 - seed treatment with Rizotorfin; 3 - Albit seed treatment; 4 - seed treatment Kornevin; 5 - seed treatment with Epin-extra. The repetition was 4-fold, the location of the variants was randomized, the area of the site was 7.5 m^2. Sowing of peas was carried out using a seeder SSK-6-10, using pure steam. Mineral nutrition conditions were created by adding N10P26K26. The doses of mineral fertilizers are determined by the recommendations for conducting experiments with peas and the agrochemical properties of the soil. The seed sowing rate is 330 kg/ha. Rizotorfin (Rhizobium leguminosarum bv.viciae, strain 250a) was obtained at the All-Russian Research Institute of Agricultural Microbiology (St. Petersburg, Pushkin). Albit biological product contains purified active ingredients from Bacillus bacteria megaterium and Pseudomonas aureofaciens, developed at the Institute of Biochemistry and Physiology of Plants and Microorganisms of the Russian Academy of Sciences (Pushchino) together with the company Albit LLC (Volobueva, 2019). Kornevin is a growth regulator – a synthetic analogue of auxins (Volobueva, 2020). Epin-extra is a drug from the brassinosteroid group (Volobueva, 2019; Seregina et al., 2021b). During the process of plant growth and development, growth parameters were monitored, yield was assessed and protein content was determined using the A.I. method. Ermakov et al. (1987) determined starch using the polarimetric method and determined amylose in starch using the method of Ermakov. Yield data was recorded according to the method of Posypanov (1991). The results were statistically processed using the Statistica for Microsoft Windows program according to generally accepted methods (Kobzarenko et al., 2015).

3. Results and Discussion

Analysis of yield data showed that in experiment No. 1 (Table 1) in pea plants of the Nord variety, the maximum yield of 42.2 c/ha was obtained in the variant with seed treatment with the drug Kornevin. Plants of the Multik variety have a maximum yield of 43.0 c/ha when the seeds

are treated with Rizotorfin. The growing season when experiment No. 1 was carried out was characterized as excessively moist. This made it possible to obtain a high yield of pea plants.

The growing season when experiment No. 2 was carried out was characterized as dry. Therefore, the plant yield in experiment No. 2 was significantly lower (Table 2) than the plant yield in experiment No. 1. In dry conditions, the yield of pea plants of the Nord variety was the highest when the seeds were treated with Epin-extra and Kornevin. Treatment of seeds of pea plants of the Nord variety with Epin-Extra resulted in an increase in yield by 39% (up to 21.1 c/ha) compared to the control (15.4 c/ha). When treating pea seeds with Kornevin, plant yield increased by 34.4% (up to 20.7 c/ha) compared to the control (15.4 c/ha). In pea plants of the Multik variety, an increase in yield was noted when treated with the drug Rizotorfin (up to 16.8 c/ha), the drug Kornevin (up to 16.7 c/ha), and the drug Epin-Extra (up to 16.1 c/ha), compared with control (10.2 c/ha). The increases were 64.7%, 63.7%, 57.8%, respectively.

Thus, we can conclude that in dry conditions the pea yield was lower. but the effect of the drugs was higher. This is due to the positive effect of the drugs in arid conditions, helping to increase the resistance of plants to stressful conditions.

The studies determined the crude protein content of pea seeds, leaves and stems of pea plants, as well as the amylose and starch content of pea seeds (Table 3). The research results showed that treatment of seeds of the Nord variety with the studied preparations contributed to an increase in the protein content in the seeds by 3-11%. Changes in protein content in the experimental variants were significant (SD05 - 1.2). The highest protein content was obtained in the variant where the drug Rizotorfin was used to treat the seeds. The increase in protein content in this variant was 11%. led to an increase in protein content in seeds by 11%. In plants of the Multik variety, an increase in the protein content in seeds was observed when using growth regulators Albite, Kornevin and Epin-extra. The increase in protein content in these experimental variants was 16%, 19% and 17%, respectively (Table 3).

The protein content in the leaves and stems of pea plants of the Nord variety increased when treated with biological products and growth regulators. The highest content of crude protein in the leaves was observed when treated with Kornevin (18.7%) and Rizotorfin (17.9%). In the Multik variety, the protein content in the leaves increased when treated with the growth regulator Epin-extra (19.8%) and the biological preparations Albit (19.0%) and Rizotorfin (18.6%). In the stems of the Multik variety, the protein content increased when treated with biological preparations and growth regulators compared to the control, but especially when treated with the biological preparation Rizotorfin (11.0%) and the growth regulator Epin-extra (10.9%) (Table 3). It can be concluded that biological products and growth regulators had a positive

Table 1. Weight of pea grains of two varieties when using growth regulators (field experiment Nº 1 (2006)).

Option	Nord		Multik	
	Productivity, c/ha	Increase in control, %	Productivity, c/ha	Increase in control, %
Control	40.3	-	40.1	-
Rizotorfin	41.3	2.6	43.0	7.2
Albite	40.3	-	39.7	-1,0
Kornevin	42.2	7.7	41.5	3.5
Epin-extra	40.7	1,0	39.8	-2.7
SD_{05}	2.0	-	2.0	-

SD_{05} - significant differences - a value that indicates the limit of possible random deviations in the experiment; this is the minimum difference in yields between the averages, which in this experiment is recognized as significant at a 5% significance level.

Table 2. Weight of pea grains of two varieties when using growth regulators (field experiment Nº 2 (2007)).

Option	Nord		Multik	
	Productivity, c/ha	Increase in control, %	Productivity, c/ha	Increase in control, %
Control	15.4	-	10.2	-
Rizotorfin	18.2	18.2	16.8	64.7
Albite	16.6	7.8	10.7	4.9
Kornevin	20.7	34.4	16.7	63.7
Epin-extra	21.1	39.0	16.1	57.8
SD_{05}	0.9	-	0.7	-

SD_{05} - significant differences - a value that indicates the limit of possible random deviations in the experiment; this is the minimum difference in yields between the averages, which in this experiment is recognized as significant at a 5% significance level.

Table 3. Protein content (% of crude protein) in the organs of pea plants of the Nord and Multic varieties. Field experience (secondary).

Option	Nord			Multik		
	seeds	leaves	stems	seeds	leaves	stems
Control	22.7	15.1	8.0	20.0	18.0	9.1
Rizotorfin	25.3	17,9	8.8	20.9	18.6	11.0
Albite	24.9	15.6	8.4	23.2	19.0	10.7
Kornevin	24.7	18.7	8.9	23.8	17.3	9.3
Epin-extra	23.4	16.1	9,0	23.5	19.8	10.9
SD_{05}	1.2	0.8	0.4	1.1	0.9	0.5

SD_{05} - significant differences - a value that indicates the limit of possible random deviations in the experiment; this is the minimum difference in yields between the averages, which in this experiment is recognized as significant at a 5% significance level.

Table 4. Amylose content in starch and starch in seeds of pea plants Nord and Multic varieties. Field experience (secondary).

Option	Amylose content in starch, in seeds (%)		Starch content in seeds,%	
	Nord	Multik	Nord	Multik
Control	4.7	4.7	42.0	41.8
Rizotorfin	5.0	5.4	44.2	46.7
Albite	5.2	5.2	46.3	46.3
Kornevin	5.4	5.3	47.8	47.0
Epin-extra	5.1	5.1	45.0	45.7
SD_{05}	0.3	0.3	2.1	2.3

SD_{05} - significant differences - a value that indicates the limit of possible random deviations in the experiment; this is the minimum difference in yields between the averages, which in this experiment is recognized as significant at a 5% significance level.

effect on physiological and biochemical reactions in pea plants, which enhanced the photosynthetic activity of the plant leaf apparatus. At the same time, the amount of nitrogen supplied to plants increased, which activated the synthetic processes of protein, primarily in the leaves and, as a consequence, in the seeds.

In recent years, there has been increasing interest in pea starch, especially genotypes with wrinkled seeds, which is explained by its high content of the linear polymer amylose. Peas are a promising crop for obtaining high-quality raw materials for the production of biodegradable plastics. The amylose contained in pea seeds and its spatial and molecular structure ensure the production of the highest quality plastics. In our studies, the content of starch and amylose in the seeds of the studied plants was determined polarimetrically. An analysis of the studies showed that the amylose content was higher in the seeds of the Multik variety compared to their content in the seeds of Nord varieties. Treatment with biological products and growth regulators led to an increase in the content of amylose and starch in the seeds of both varieties. The highest content of amylose and starch in pea plants of the Nord variety was observed when treated with Kornevin and Albit. The amylose content was 5.4% and 5.2%, respectively, the starch content was 47.8% and 46.3%, respectively. In plants of the Multik variety, when treated with biological preparations Kornevin, Rizotorfin and Albit, the amylose content was 5.3%, 5.4% and 5.2%, respectively. The starch content in these experimental variants was 47.0%, 46.7% and 46.3%, respectively (Table 4).

4. Conclusion

The research results showed that the studied biological products and growth regulators generally had a positive effect on the yield and quality of pea plants of the Nord and Multik varieties. However, as a pre-sowing treatment of seeds, the biological preparation Rizotorfin, which basically contains nodule bacteria, can be recommended to a greater extent. Nodule bacteria have the ability to synthesize biologically active substances and thereby have a beneficial effect on the metabolic processes occurring in the plant itself. This may be due to the positive effect of this drug on yield and quality. It was revealed that the yield of pea varieties depended on weather conditions. Under optimal moisture conditions, plant productivity is higher. However, in dry weather conditions the effectiveness of drugs and growth regulators was higher. The use of drugs and growth regulators contributed to an increase in the protein content in seeds and green mass of plants, as well as starch and starch amylose in pea seeds of both varieties.

Thus, the realization of the productive potential of pea plants of different varieties can be achieved as a result of exogenous treatment with biological products and growth regulators.

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