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The effect of treatment of vegetable pea seeds with boron and molybdenum on the growth and development of plants depending on the timing of sowing

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Abstract. Currently, the issue of preserving organic matter, which is increasingly being replaced by synthetic alternatives, is relevant and expedient. But these substitutes are alarming because of their possible threat of dangerous after-effects, because the human body generally consists of what it consumes in everyday food. All chemical elements undesirable for the body that can cause the appearance of diseases and health complications fall under the category of dangerous food. In view of this, in order to preserve the volume of production of natural food products, there is a need to increase the share of leguminous crops. In addition to the positive effect on soil fertility, legumes are naturally filled with biologically pure nitrogen. Also, this crop has a higher content of valuable plant protein compared to cereal grain crops. In order to increase the production of pea grain, it is necessary to use high-yielding varieties of the moustached morphological type. The purpose of the article is to identify the influence of sowing dates and treatment of vegetable pea seeds with molybdenum and boron fertilizers on plant development indicators in the conditions of Southern Ukraine. The research used the laboratory method, as well as the methods of field experiment and phenological observation. It was established that the effect of boron and molybdenum delays the onset of the phenological phases of crop development, and the use of two different sowing times allows to delay the onset of the technological maturity phase by 6 days. This is important during harvesting for minimal losses of the vegetable pea crop. The practical value of the results lies in the application of combinations of molybdenum and boron fertilizers to increase the yield and nutritional value of leguminous crops

Keywords: vegetable peas, nutrients, boron and molybdenum fertilizers, indicators of plant growth and development

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INTRODUCTION

Currently, the issue of preserving organic matter, which is increasingly being replaced by synthetic substitutes, is relevant. But these substitutes are confusing because of the threat of dangerous after-effects, because the human body generally consists of what it uses in everyday food. At first glance, dangerous food includes all chemical elements that are undesirable for health, which can cause the further development of diseases and health complications. The reserve is the cultivation of leguminous crops, which are able to fix nitrogen from the atmosphere or apply organic fertilizers [1].

Increasing the share of leguminous crops in the structure of planted areas is the cheapest and most effective way of increasing soil fertility, increasing humus and nitrogen content, and protecting land from degradation. In addition to increasing the yield, such agricultural methods contribute to the accumulation of a greater amount of biologically pure nitrogen in it after harvesting vegetable peas, compared to existing technologies, they allow to extend the time of technical maturity of the seed and the period of its processing, which in the conditions of the south of Ukraine is a very important and urgent problem. The technology of growing green peas as one of the important leguminous crops is energy-saving, since the energy accumulated with the crop significantly exceeds its production costs.

Peas, compared to cereal grain crops, have a number of important advantages, especially in terms of yielding valuable vegetable protein. In addition, the cultivation of peas in crop rotations significantly reduces the total cost of crop production, improves the phytosanitary condition of crops and increases the productivity of arable land. Peas differ from other legumes in that the stem of the plant is not prone to branching and grows mainly in height.

In favorable years, due to overgrowth of plants, pea crops are severely damaged, so 2-phase harvesting should be carried out, which often leads to crop losses. The priority direction of effective restoration of cultivated areas and increase of pea grain production should be the cultivation of high-yielding varieties of the moustached morphological type with high potential productivity, resistance to environmental stress factors, lodging and suitable for harvesting by direct harvesting [2]. That is why there is a need to improve the technology of growing peas that are not prone to lodging, in order to increase the yield of this crop. Therefore, in the system of measures aimed at increasing the productivity of peas, great importance is attached to the rational use of fertilizers and the norms of sowing seeds.

The high yield potential of modern pea varieties can be maximally realized when growing them using technologies that involve the complex application of intensification factors [3]. The priority direction of increasing the sown areas of peas in the south of Ukraine should be the cultivation of high-yielding varieties of the moustached morphological type with high potential productivity, resistance to diseases and lodging, suitable for harvesting by direct harvesting.

In the system of measures aimed at increasing the production of peas, an important place belongs to new high-protein varieties, which must be high-yielding, resistant to diseases, lodging, suitable for direct harvesting [1]. Thus, plants of low-growing varieties with a strong stem begin to lay down only during flowering, while tall varieties with a long stem – even before the beginning of budding (in the 10-leaf phase). Short-stemmed pea varieties are characterized by a well-developed mechanical tissue, and have a developed transport system of the stem.

For the successful cultivation of vegetable peas for seeds, it is important to carry out a set of measures to increase soil fertility. Many years of research conducted by many scientists with various crops, including vegetable peas, testify that mineral fertilizers, along with improving the nutrient regime of the soil and plants, also affect the water regime, contribute to a more complete and economical use of moisture for crop formation [3].

Peas are considered a relatively cold-resistant plant. At the same time, it is demanding on soil moisture, reacts negatively to high temperatures and lack of moisture. Especially, the combination of heat and drought, which is a common natural phenomenon in the southern part of Ukraine, suppresses its growth and development. Unfortunately, peas have to experience drought and heat more and more often. Therefore, the producers of our region have to sow earlier so that half of the growing season falls on a period with moderate heat and sufficient humidity [3]. However, it is possible to sow even ordinary varieties of grain (shelled) peas very early. For example, in the Kherson region, peas can be sown during the winter or in early spring. However, there is a great risk of freezing of pea plants.

At low temperatures, pea shoots appear later (after 15-20 days) and unfriendly. Weakened seedlings are prone to diseases, suppressed by weeds and damaged by pests. This situation is especially negative for the growth and development of plants of sugar and brain pea varieties, for which the minimum germination temperature is 4°C.

It is also known that the optimal temperature for the development of seedlings is from 15 to 16°C. At low temperatures (less than 10°C), plants develop slowly and are strongly affected by fungal and bacterial diseases. The growth rate of peas at low positive temperatures is affected by the amount of reserve nutrients in the seeds, so plants that were treated with nutrients before sowing will germinate faster [4].

Seedlings of most pea varieties can tolerate short-term temperature drops to minus 6°C. However, the yield of "frozen" plants decreases by 10-30%, and the ripening of beans is delayed by 7 days. If the surface of the soil is covered with snow, then the seedlings can withstand a drop in temperature to minus 10-12°C. Seedlings can withstand a short-term drop in temperature to minus 1-2°C without a decrease in productivity.

There are several opinions among scientists who study this problem regarding the methods of sowing and the density of standing pea plants when grown for seeds and green peas. Most of them recommend, for the most part, the usual row method of sowing with a row spacing of 15 cm, which is carried out with seed drills, for example SZ-3.6, SZP-3.6. With this method of early sowing, coulters are less clogged with moist soil and seeds are sown more evenly than with narrow-row sowing [6].

Many experiments [4-6] of scientific research institutions and the practice of advanced product manufacturers have established the effectiveness of adding not only phosphorus, potassium and nitrogen fertilizers, but also organic fertilizers to peas or its predecessor. It was noted that when they are used correctly, they do not suppress, but, on the contrary, stimulate nitrogen fixation by nodule bacteria [4]. The regularity in the increase of the pea yield from the use of phosphoric fertilizers was observed in experiments by some authors, while the equivalence of terms and methods of application of these fertilizers was established for both field plowing and cultivation.

In the modern period of the development of agro-industrial production, one of the main conditions for the increase of gross harvests and peas is the constant improvement of the technological elements of cultivation in accordance with the morphological and biological characteristics of the variety. Issues of improving the grain quality of this important crop are also gaining priority. Modern cultivation technologies of grain legumes should be based on the management of all processes of ensuring high grain productivity and grain quality, as well as be directed to the maximum use of the culture's biological productivity potential. For the normal growth and development of plants, a suitable feeding area is required, in which they will have enough nutrients, water and solar energy to create the necessary vegetative mass and grain formation. By increasing or decreasing the feeding area, the effectiveness of mineral fertilizers can be increased. The productivity of peas is the highest when the optimal sowing rate is used. Its value depends on soil fertility, climatic conditions, predecessor, fertilizer, variety, terms and methods of sowing, seed quality.

Of the microelements, the role of molybdenum and boron should be especially noted. With a lack of molybdenum, nodules of nitrogen-fixing bacteria are weakly formed, the synthesis of free amino acids is disrupted in them, and the synthesis of leghemoglobin is inhibited [7]. With boron deficiency, vascular bundles are not formed in nodules, as a result of which the development of bacterial tissue is disturbed [8]. Also, the lack of boron leads to a deterioration in the quality of the harvested crop of products in the phase of technical ripeness.

In order to increase the yield of pea, its seeds are treated with boron – 2.7 kg/t, nitrogen and molybdenum-acidic ammonium (25 g per hectare seed rate). Inoculation of seeds with rhizorthorphin increases yield by 2.0-4.2 c/ha and improves its quality. The protein content increases by 2-5% [3].

British scientists [9; 10] believe that fertilizers should not be applied to peas, even on poor soils, because nodule bacteria will not develop, and the use of fertilizers will be ineffective. In their opinion, the use of nitrogen fertilizers is justified in small doses (N_{30}) and only on late sowing of peas. High efficiency on pea crops is ensured by the application of ammophos or superphosphate enriched with boron and molybdenum. The rate of P_2O_5 is 10-20 kg/ha. On the chernozem soils of the Steppe, molybdenum combines with alkalis and alkaline cations, turning into compounds that are soluble in water and inaccessible to plants [6].

It is known that boron plays an important role in the processes of plant fertilization: it enhances the germination of pollen, the growth of pollen tubes and is necessary for the formation of the vital activity of pollen. Boron is a necessary element of mineral nutrition of plants. In addition, depending on the type of plants and soil and climatic conditions, its amount in plants varies within fairly wide limits. If the dry mass of grain crops contains only 1-3 mg of boron per 1 kg of completely dry mass of plants, then in sunflower leaves – 50-60 mg, and in leguminous crops – 30-60 mg per 1 kg of completely dry mass [11; 12]. The development of ovaries and seeds due to a lack of boron lags behind normal, and the processes of seed maturation are disturbed, therefore boron has a positive effect on the seed productivity of many agricultural crops and the formation of fruits and berries in fruit and berry plants [13]. It also plays an important role in the synthesis of carbohydrates, which is necessary for establishing a normal symbiosis between nodule bacteria and the plant.The best results are provided by boron in combination with molybdenum, since the latter is necessary for the biochemical processes of fixing molecular nitrogen.

Being in the tissues of plants, boron can create complex compounds with organic oxyacids, carbohydrates and polyatomic alcohols. Vitamins - riboflavin and ascorbic acid also combine with boron. A number of experiments established the effect of boron on the activity of enzymes: catalase, dehydrase, invertase, etc.

Boron also affects osmotic processes and hydration of colloids. A positive effect of boron on drought resistance and salt resistance of plants was established. And with a lack of boron, the content of vitamins in the leaves decreases: ascorbic acid, thiamine, and riboflavin. Lack of boron in plant nutrition delays the synthesis of proteins and nucleic acids.

The effect of boron fertilizer on leguminous crops was studied in Latvian collective farms in 1961-1962. For dusting, 1-2 kg of fertilizer was used per 1 t of seeds, and when applied to the soil, 60 kg/ha. Boron increased the yield of peas by 2.5-3.0 t/ha. Favorable results were obtained when pre-sowing treatment of seeds with boron was combined with poisons [4].

Molybdenum fertilizers are also increasingly used in the cultivation of legumes, vegetables and some other crops. This is explained by the fact that molybdenum significantly affects the nitrogen metabolism of plants, nitrogen-fixing bacteria, as well as some algae and fungi. Molybdenum is involved in the fixation of molecular nitrogen by nodule bacteria in symbiosis with leguminous plants. It is also an active component of enzymes involved in the reduction of nitrates in tissues to ammonia, which is subsequently used in the processes of formation of amino acids and proteins. Molybdenum, changing its valency, participates in oxidation-reduction reactions and is an important link in the chain of element transfer from the oxidizing substrate (electron or hydrogen donor) to the substance being reduced.

The main role of molybdenum is that it enhances the activity of proteid enzymes associated with nitrogen metabolism and participates in the enzymatic activation of molecular hydrogen. Thus, according to some authors [5; 9], the green mass of leguminous plants contains from 1.9 to 9.1 mg, and in nodules on the roots of clover and lupine plants up to 17 mg per 1 kg of raw mass [7].

The purpose of the study is to establish the influence of early and late sowing and treatment of pea seeds with boron and molybdenum fertilizers on the onset of the main phases of plant development, based on a field experiment accompanied by phenological observations and analysis of plant samples.

MATERIALS AND METHODS

Experiments on the study of the influence of sowing dates and the use of boron-molybdenum fertilizer were conducted in the field crop rotation of the Kherson State Agricultural and Economic University in 2017-2018 according to the following scheme:

Factor A. Pre-sowing treatment of pea seeds:

1. $N_{30}P_{40}$ – background
2. Background + treatment of seeds with boron
3. Background + seed treatment with molybdenum
4. Background + treatment of seeds with boron and molybdenum

Factor B. Sowing dates:

1. The early term – the third decade of March
2. Late period – the first decade of April

The high-yielding variety "Alfa" was chosen as the object of research, which is characterized by a high response to the use of trace elements, and therefore has a large area of cultivation. This variety is zoned in the Steppe and Forest Steppe.

Experiments were carried out using the method of split plots in accordance with the methodology of field research. The experiment was repeated four times. The total area of the plot was 72 m^2, and the accounting area was 50 m^2. All observations were carried out on the basis of the above options in two non-adjacent repetitions. The field experiment was accompanied by phenological observations. Plant height was determined on fixed plants in two non-adjacent replicates. The results of the obtained experimental data were subjected to variance analysis [14].

RESULTS

Various external factors (environmental factors or the influence of human activity) can within certain limits change the timing of the transition from vegetative to generative phases [7]. Studying the possibility of influence of various current factors on the above process is important, first of all, for producers of agricultural products.

It is known that the phase of technical ripeness of green peas is very short and lasts an average of 3-5 days in the south of Ukraine, and producers of canned goods must have time to collect the harvest from the field in such a short time. This leads to the limitation of the production of high-quality products and the irrational use of expensive equipment of canneries during the season. There are other ways to extend the terms of receipt of raw materials for processing: the use of different sowing times, the use of varieties of different maturity groups, the introduction of increased doses of nitrogen fertilizers.

The research was carried out with the nitrogen and phosphorus indicator in the soil at the level of N30P40. It has been previously established that with the onset of the bean formation phase, a sharp change in the direction of physiological and biochemical processes in all plant organs occurs. Leaves, stems and roots work only on beans until the end of the growing season. The mass of above-ground vegetative organs and roots increases to a small extent. The roots, and therefore the tubers, receive less and less carbohydrates. Potatoes, experiencing energy hunger (deficiency of carbohydrates), reduce the activity of nitrogen fixation, the outflow of nitrogen and other elements from vegetative to reproductive organs increases, plants grow old, begin the process of self-destruction. The plant mobilizes all resources to produce the maximum possible number of high-quality seeds. About 70-80% of the nitrogen accumulated before flowering in the vegetative organs of legumes is redistributed to the seeds. Therefore, the variant of the experiment chosen by us - background $N_{30}P_{40}$ is scientifically justified.

The studies studied the effect of trace elements boron and molybdenum on the timing of the onset of phenological phases of development and the length of interphase periods of vegetable peas. It was established that the studied factors had a certain influence on these indicators. Data on the influence of boron and molybdenum on the timing of the onset of the main phenophases of pea for both sowing periods are given in Table 1. The analysis of the data in the table shows that the time of sowing had a significant effect on the time of onset of the phase of technical ripeness of green peas, which was also observed by other researchers.

It was established that the treatment of pea seeds with boron in the first period of sowing did not affect the length of its growing season, and in the second, when the temperatures were high, it accelerated its development by an average of 2 days.

The pattern described above was also observed during the second term of sowing vegetable peas, but in this case, the most noticeable effect on delaying the onset of the technical maturity phase was obtained by treating the seeds with molybdenum alone. The duration of the interphase period of vegetable peas, depending on the studied factors, is given in Table 2. It should be noted that the passing of the interphase period "blooming – seed pouring" and "seed pouring – technical maturity of seeds" in all variants of the experiment practically did not depend on the studied factors and differed little from the control for both methods of sowing.

Table 1. *Calendar date of the onset of phenophases depending on the elements of agricultural technology (2017–2018)*

Research options	The term of onset of phenophases according to the terms of research							
	The first sowing period (the third decade of March)				The second sowing period (the first decade of April)			
	Sowing	Seedlings	Flowering	Technical maturity	Sowing	Seedlings	Flowering	Technical maturity
$N_{30}P_{40}$ – background	19.03	02.04	28.05	18.06	02.04	12.04	03.06	24.06
Background + treatment of seeds with boron	19.03	02.04	28.05	18.06	02.04	12.04	01.06	23.06
Background + seed treatment with molybdenum	19.03	03.04	04.06	24.06	02.04	14.04	08.06	23.06
Background + seed treatment with boron and molybdenum is compatible	19.03	04.04	03.06	24.06	02.04	14.04	09.06	30.06

Table 2. *The duration of the interphase period of vegetable peas depending on agricultural technology (2017–2018)*

Research options	The duration of the interphase period, days							
	Sowing – seedling	Seedling - whisker formation	Whisker formation – budding	Budding – flowering	Flowering – pouring seeds	Pouring seeds – milky ripeness	Milky ripeness – technical ripeness	Seedlings – harvesting
Sowing period is the third decade of March								
$N_{30}P_{40}$ – background	12	12	29	9	8	9	2	70
Background + treatment of seeds with boron	12	12	29	8	9	8	2	69
Background + seed treatment with molybdenum	12	14	31	9	8	9	2	74
Background + treatment of seeds with boron and molybdenum	14	15	32	9	7	9	2	75
The period of sowing is the first decade of April								
$N_{30}P_{40}$ – background	8	10	28	8	8	8	2	64
Background + treatment of seeds with boron	7	10	29	7	9	8	3	66
Background + seed treatment with molybdenum	11	11	27	9	7	7	2	63
Background + treatment of seeds with boron and molybdenum	11	14	27	9	8	8	2	68

As for the duration of the period of technical maturity of the seeds, it was a maximum of 4 days in all variants, after which the phase of waxy maturity of the seeds came and it sharply lost its quality due to the change of green color to yellow, the amount of sugars in it decreased (up to 3%) and the amount of starch up to 9-12%, which, according to many authors, makes it impossible to process it into canned green peas [6]. The total duration of the vegetation period "seedlings - technical maturity of seeds" in the control version was 70 days for the first and 64 days for the second sowing period. It was the longest in the "background + seed treatment with boron and molybdenum" option during the first sowing period

The effect of molybdenum was reversed: in all cases, it delayed the onset of the technical maturity phase by an average of 4 days, both when applied in its pure form and in combination with boron.

Also, in our research for 2017-2018, we expected to achieve an increase in productivity due to an increase in the number of seeds per 1 vegetable pea plant both by increasing the productivity of beans and increasing their number. Data showing the influence of boron and molybdenum treatment of seeds on the number of flowers, beans and the distance between them in the interphase period of "flowering-bean formation" are given in Table 3.

The data indicate that the number of flowers and beans during the years of research, both in the early and late sowing periods, did not differ significantly, and the influence of the studied factors on them was significant. The yield increase in our experiments was due to the number of beans on one plant, and not the number of seeds in one bean.

Table 3. *The influence of seed treatment with microfertilizers on reproductive indicators of pea in the interphase period "flowering – pod formation" (average for 2017-2018)*

Options	Phases of development		
	Number of flowers, pcs.	Distance between flowers, cm	The number of seed primordia, pcs.
The first sowing period			
$N_{30}P_{40}$ – background	7.9	5.3	8.1
Background + treatment of seeds with boron	10.9	5.9	10.1
Background + seed treatment with molybdenum	12.5	6.5	10.7
Background + treatment of seeds with boron and molybdenum	13.5	7.2	11.3
The second sowing period			
$N_{30}P_{40}$ – background	7.5	5.1	7.4
Background + treatment of seeds with boron	10.1	7	9.6
Background + seed treatment with molybdenum	11.4	6.0	10.5
Background + treatment of seeds with boron and molybdenum	12.6	6.6	11.1

Analyzing the data in the Table 3, it can be seen that the number of beans on the plants of the boron and molybdenum seed treatment option was 13.5 during the first sowing period, compared to the control 7.9, i.e. the increase was 1.7 times. Despite the decrease in the weight of 1,000 seeds, the average yield increase for 2017-2018 in this variant was 30.3% in the first sowing period, and 30.7% in the second sowing period. The greatest yield increase in the second term (30.7%) was found in the variant with molybdenum and molybdenum seed treatment.

When conducting biometric studies on the measurement of the height of the vegetable pea in the main phases of development, it was simultaneously established that the studied factors had a positive effect on the growth and development of the plant.

CONCLUSIONS

The analysis of experimental data shows that treatment of peas with boron and molybdenum, as well as the timing of sowing, significantly affect the timing of the onset of the technological phase of crop maturity, which is also observed by other researchers. Summarizing the above, the following conclusions can be drawn:

– the maximum delay in the onset of subsequent phenophases of the development of pea is observed during the period of intensive growth of the vegetative mass of the crop;

– during the development of generative organs, seed treatment with trace elements has almost no effect on the length of interphase periods;

– the use of two sowing periods with a difference of 14-16 days allows delaying the onset of the phase of technical seed maturity by 4-6 days, and in combination with seed treatment with trace elements in various combinations - delays this phase by 11 days compared to the control, and this allows to extend the crop harvesting period in southern Ukraine with minimal crop losses;

– the number of flowers and beans during the years of research, both during the early and late sowing periods, did not differ significantly, but the influence of the studied factors on them was significant. The yield increase in our experiments was due to the number of beans on one plant, and not the number of seeds in one bean.

The obtained data can be used at enterprises in the south of Ukraine, which are engaged in the processing of products for the cannery, in order to make pea puree for baby food and green peas for salads.

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Вплив обробки насіння гороху овочевого бором і молібденом на ріст і розвиток рослин залежно від строків сівби

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Анотація. Наразі актуальним та доцільним є питання збереження органічної речовини, на заміну якої усе частіше приходять синтетичні альтернативи. Але ці замінники насторожують своєю можливою загрозою небезпечності післядії, адже організм людини взагалі складається з того, що вона споживає у повсякденну їжу. Під видом небезпечної їжі потрапляють і всі небажані для організму хімічні елементи, що можуть спричинити появу хвороб та ускладнень здоров'я. З огляду на це, з метою збереження об'ємів виробництва натуральних харчових продуктів постає необхідність розширення частки зернобобових культур. Окрім позитивного впливу на родючість ґрунтів, бобовим властиво наповнюватися біологічно чистим азотом. Також ця культура має вищий вміст цінного рослинного білка у порівнянні із злаковими колосовими культурами. Задля збільшення виробництва зерна гороху потрібно використовувати високопродуктивні сорти вусатого морфологічного типу. Метою статті є виявлення впливу строків сівби та обробки насіння гороху овочевого молібденовим і борним добривами на показники розвитку рослин в умовах Півдня України. У дослідженні застосовувалися лабораторний метод, а також методи польового досліду та фенологічного спостереження. Встановлено, що дія бору та молібдену затримує настання фенологічних фаз розвитку культури, а застосування двох різних строків сівби дозволяє затримати настання фази технологічної стиглості на 6 діб. Це важливо при збиранні для мінімальних втрат врожаю гороху овочевого. Практична цінність результатів полягає у застосуванні комбінацій молібденових та борних добрив для підвищення врожайності та поживної цінності зернобобових культур

Ключові слова: горох овочевий, елементи живлення, борні та молібденові добрива, показники росту та розвитку рослин