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Influence of the Studied Factors on the Yield, Structure and Quality Indicators of Vegetable Peas under the Conditions the South of Ukraine

Viktoria Almashova[1*], Denys Breus[1], Vitalii Olifirenko[1]

[1] Kherson State Agrarian and Economic University, 23, Stritens'ka Str., 73006, Kherson, Ukraine
* Corresponding author's e-mail: vikadiana1981@gmail.com

ABSTRACT

The article considered the elements of the resource-saving technology for the production of vegetable peas with the use of low doses of synthetic fertilizers by stimulating the action of nitrogen-fixing nodule bacteria. They are symbionts of vegetable peas, with the help of bacteria and microfertilizers. They are much cheaper than mineral fertilizers and are not harmful for the environment and, thanks to microdoses, are absolutely safe for people. During the research, it was established that, in addition to increasing the yield of agricultural crops, such agro-techniques contribute to increasing soil fertility (due to the accumulation of a greater amount of biologically pure nitrogen in it after harvesting vegetable peas, compared to existing technologies) and make it possible to extend the period of technical maturity of seeds and the period of their processing. This is a very important and urgent problem in southern Ukraine. It was also determined that the treatment of seeds with boron, molybdenum and Rizotorfin affects the timing of the onset of the main phases of development and the duration of the growing season of vegetable peas, extending it by several days, and this, in turn, allows farmers to harvest on time without economic losses. For the first time, for the conditions of the south of Ukraine, an opportunity was found to significantly extend the term of receipt of raw materials for processing without deterioration of quality indicators and dietary properties. The proposed techniques allow, in addition to the existing technology, to accumulate up to 40–60 kg/ha of biological nitrogen in the soil. It was recorded that the highest yield of the vegetable pea crop was formed during the first sowing period, when the seeds were treated with boron and molybdenum and amounted to 9.21 t/ha, which is 2.32 t/ha higher than the control. Based on the generalization of research results, a mathematical model of vegetable pea crop programming was built based on the principle of relationships between individual factors that affect the culture and the formation of its plant productivity.

Keywords: vegetable peas, boron, molybdenum, growth stimulants, nitrogen-fixing nodule bacteria, humus, productivity.

INTRODUCTION

Leguminous crops throughout the history of mankind have occupied a prominent place in the agricultural sector of production, but recently they have begun to occupy smaller areas and provide an insufficient amount of products for the needs of the population. The demand for crops such as vegetable peas, fodder beans and others (for food and animal feed purposes) is not fully satisfied by domestic production in many countries of the world. Even though leguminous crops are the main component of high-protein resources both in human nutrition and in the diet of animals and poultry, in Ukraine today there is a significant shortage of food and animal feed protein of plant origin. This leads to an imbalance of food and feed in terms of essential amino acids and protein, to inadequate nutrition of people, as well as to a reduction in livestock and a decrease in the productivity of livestock and poultry farming. There is a need to change the structure of crop rotations in the direction of increasing leguminous crops in order to meet the full need of the population for these products. In addition, increasing the share of leguminous crops in the structure of sown areas is the cheapest and most effective way to increase soil fertility, increase the content of humus and nitrogen and protect land from degradation (Tulbek et al., 2017).

Legumes such as soybeans, peanuts and vegetable peas are important raw materials for the food industry, which provides the available capacities of canneries for the production of a variety of high-protein and high-calorie canned products – oil, sauces, dietary green peas, etc. Unfortunately, in recent decades, Ukraine has been characterized by insufficient and unstable production of grain fodder and leguminous crops. So, during the period from 1990 to 2020 grain production of leguminous crops in Ukraine decreased from 3.54 to 0.63 million tons. The deficit of protein for livestock reaches 25%, and food – 40%. Several measures to solve this problem have been outlined. Sectoral programs of the agro-industrial complex provide for a significant gradual increase in the area under leguminous crops, improvement of agricultural technology for their cultivation through the introduction of new, environmentally friendly technologies with the use of biological preparations and micro fertilizers (Boiko et al., 2018).

Vegetable peas, grown for the production of “green peas” in canned form, have a number of significant features that significantly distinguish it from the peculiarities of growing other vegetable crops. One of the significant dissonances is that, according to the requirements of State Standard Of Ukraine, the weight of 1000 grains of vegetable peas in the phase of technical ripeness should be in the range of 290–350 g and not exceed these values at the moisture content of raw materials at the level of 65–68%, and a seed diameter of 5.0–6.2 mm. The article aims to achieve an increase in yield by increasing the number of seeds per 1 plant of vegetable peas, both by increasing the productivity of beans and increasing their number. Data indicating the effect of seed treatment with boron, molybdenum and Rizotorfin on the number of flowers, beans and the distance between them in the interphase period “flowering – bean formation” (Breus et al., 2022).

Of great importance at the present time is the provision of the population with environmentally friendly food products of dietary orientation, rich in protein. A significant role in solving this problem can belong to vegetable peas, the production of which in Ukraine tends to increase. Therefore, there was a need to develop elements of resource-saving technology for its production using low doses of fertilizers of synthetic origin by stimulating the action of nitrogen-fixing nodule bacteria, which are symbionts of vegetable peas, with the help of bacterial and micro fertilizers, which are much cheaper than mineral fertilizers, are not costly when applied, do not harm the environment and, thanks to microdoses, are absolutely safe for people (Breus et al., 2023). In addition to increasing yields, such agricultural practices contribute to increasing soil fertility due to the accumulation of more biologically pure nitrogen in it after harvesting vegetable peas, compared to existing technologies, allow to extend the period of technical ripeness of seeds and the period of their processing, which is a very important and urgent problem in the south of Ukraine.

The main purpose of the work was to develop separate agrotechnical methods for growing vegetable peas on irrigated lands in the south of Ukraine to obtain an environmentally friendly high yield of technological raw materials, the highest quality grade, to extend the harvesting period and determine the impact of the crop on soil fertility (Pichura et al., 2023).

MATERIAL AND METHODS

The experiments were carried out in the irrigated crop rotation of the Dnepr LLC of the Bilozerka district of the Kherson region, which has 2940 hectares of land, 820 hectares of which is irrigated. In this farm, peas for green peas and seeds were placed in the following crop rotation: peas for green peas and seeds, winter wheat, tomato, spring barley with alfalfa sowing, alfalfa, winter wheat.

This crop rotation considers the specialization of the farm, all crops are placed after the optimal predecessors (Skok et al., 2023). The farm has its own canning shop, where a line for the production of canned peas from vegetable peas – TM “Green Peas” – has been preserved. In this regard, the management of Dnepr LLC decided to renew the production of the above-mentioned canned food. The variety “Alpha” selected by the Krasnodar Breeding Center, chosen by us as an object of research, belongs to the mid-season with a vegetation period of 75 days, while the “germination - flowering” period was 45 days, and “flowering – ripeness” – 30 days. One of the problems, the solution of which we planned during the research, was to determine the influence of the studied factors on the length of the interphase and growing season of this variety of vegetable peas.

Experiments on the study of the effect of trace elements boron and molybdenum, restoring and sowing dates on the productivity of vegetable peas were carried out by setting up a field experiment.

Scheme of the experiment

1. Factor A. Pre-sowing seed treatment:
- without seed treatment
- seed treatment with Rizotorfin
- seed treatment with boron
- seed treatment with boron and Rizotorfin
- seed treatment with molybdenum
- seed treatment with molybdenum and Rizotorfin
- seed treatment with boron and molybdenum
- seed treatment with boron, molybdenum and Rizotorfin
2. Factor B. Sowing dates:
- Early sowing date – III decade of March
- Late sowing date – I decade of April

Peas in all variants of the experiment were sown for three years against the background of mineral fertilizers $N_{30}P_{40}$. The field experiment was accompanied by phenological observations, analysis of plant samples and soil. The dates of the onset and passage of the main phenophases were recorded: germination, three-leaf phase, whiskering, budding, flowering, seed filling, wax ripeness, technical ripeness of seeds. Field experiments and laboratory studies were carried out in accordance with the methodology of field experiments and methodological recommendations for their implementation in irrigation conditions (Pichura et al., 2024).

The experiments are based on the method of split plots in accordance with the methodology of field experiments on the study of agrotechnical methods of growing crops. When planning and conducting research, we were guided by generally accepted methodological guidelines, manuals and State Standard of Ukraine. The recurrence of the experiment is four times. The sown area of the plot is 82 m^2; the accounting area is 50 m^2. All observations were carried out on all variants of the experiment in two non-contiguous recurrences. Soil samples were taken in layers, with the step 10 cm (Devi et al., 2021).

Soil moisture was determined by the thermostat-weight method, nitrogen by the Grandval-Lage method, mobile phosphorus according to Machigin, and exchangeable potassium by a flame photometer. With the coincidence of watering and precipitation, watering was not carried out. Vegetative irrigation was carried out by the “Fregat” sprinkler machine, the irrigation rate was adjusted by changing the watering time during the stop of sprinkler, maintaining the moisture threshold in the active soil layer (0–50 cm) within 70%. Harvesting was carried out by mowing peas into rolls with a ZHRB-4 header and picking up with a special combine harvester “Rotor”. At the same time, a sheaf accounting of yield was carried out in four recurrences to determine losses during harvesting (Domaratskiy et al., 2023).

RESULTS AND DISCUSSION

Well known fact that vegetable peas have self-pollinated, butterfly-type flowers, and the studied Alpha variety has a white corolla. Pollination occurs in a closed flower. On the peduncle, varieties with an ordinary stem develop 1–2, and sometimes 3 flowers. An indicator of precocity in vegetable peas is the number of internodes to the node with the first bean. In early ripening varieties of vegetable peas, the first flowers are placed on 11 – th node and below, in mid-ripening they are on 12–15 nodes, and in late-ripening ones on 16–19 nodes. Analyzing the data of our research, it was determined that the first flowers were located at 9–11 nodes (Tulbek et al., 2024).

Therefore, the increase in yield in our experiments was due to the number of beans per plant, and not the number of seeds per bean (Table 1). Analyzing the data in the table, it can be seen that the number of beans on plants of the variant of seed treatment with boron and molybdenum was 13.5 pieces at the first sowing period, compared to the control of 7.9, that is, the increase was 1.7 times. Despite the decrease in the weight of 1000 seeds, the average yield increase over three years of research in this variant for the first sowing period was 30.3%, and for the second sowing period 30.7%. The largest increase in yield during the second period (30.7%) was in the variant with the treatment of pea seeds with molybdenum and Rizotorfin.

The data obtained indicate that during the first sowing period, pre-sowing treatment of pea seeds should be carried out with boron, molybdenum and Rizotorfin together, because it was in this variant that the highest level of yield was obtained. As for the second sowing period, it is desirable to carry out pre-sowing treatment of vegetable pea seeds with molybdenum and Rizotorfin, which

Table 1. Influence of seed treatment with micro-fertilizers on the reproductive parameters of vegetable peas in the interphase period of "flowering – bean formation"

No.	Options	Phases of development		
		Number of flowers, pcs	Distance between flowers, cm	Number of seminal rudiments, pcs
I sowing period				
1	$N_{30}P_{40}$ – background	7.9	5.3	8.1
2	Background + Rizotorfin	10.7	5.7	10.2
3	Background + boron	10.9	5.9	10.1
4	Background + boron and Rizotorfin	11.4	6.4	10.4
5	Background + molybdenum	12.5	6.5	10.7
6	Background + molybdenum and Rizotorfin	13.2	6.3	11.3
7	Background + boron and molybdenum	13.5	7.2	11.3
8	Background + boron, molybdenum and Rizotorfin	13.3	7.7	11.0
II sowing period				
1	$N_{30}R_{40}$ – background	7.5	5.1	7.4
2	Background + Rizotorfin	9.7	5.4	9.6
3	Background + boron	10.1	7.0	9.6
4	Background + boron and Rizotorfin	10.4	6.8	10.0
5	Background + molybdenum	11.4	6.0	10.5
6	Background + molybdenum and Rizotorfin	12.1	6.0	10.6
7	Background + boron and molybdenum	12.6	6.6	11.1
8	Background + boron, molybdenum and Rizotorfin	12.2	6.7	10.7

allows you to obtain the yield of seeds of technical ripeness at a moisture content of 68% at the level of 7.81 t/ha. It was found that the increase in yield in our studies was due to an increase in the number of beans per plant, rather than the number of seeds in one bean.

In the whole complex of works on the cultivation of technological raw materials of vegetable peas, the most difficult and labor-intensive is the harvesting of products. Unripe pea seeds of brain varieties for canning are harvested in the phase of milky-wax ripeness. It should be juicy, sweet, and pleasant to the taste, fragrant, uniform in size (diameter 5–6 mm) and color. The sugar content should range from 6–7 %, starch – no more than 2.3–3%. Harvesting should be started when 80% of the beans is at technical ripeness with a moisture content of about 70–80%.

The indicators of a special finometer for determining the technical ripeness of vegetable peas for the highest grade are 28–41, for the first 42–58 units (degrees). Harvesting continues to a state when the total mass of beans contains up to 10–15% of overripe. As a rule, this period lasts 3–4 days. When harvesting vegetable peas for green peas, three technologies are provided: single-phase – with threshing without preliminary mowing of the vegetative mass into rolls by BK-Z, FMS combines; two-phase, which involves mowing and stacking the mass in the rolls with mowers ZBR−4.2, ZHBA−3.5 with subsequent picking up and threshing with threshing machines VNCB-F, FMS-463 or KBK-1; three-phase – mowers: the mass is put into a roll, then they are picked up and transported to the threshing floor, or canning shop to the stationary pea threshing machine NBC-75/20. Threshing machines are loaded with pea loaders PGM-30 (Table 2).

The data of Table 3 indicate the effect of seed treatment with boron, molybdenum and Rizotorfin on the yield of vegetable peas both at natural moisture (which averaged 6.8% over the years of research) and in terms of dry seed matter. The maximum yield in terms of dry matter at the early sowing period was 2.65 t/ha when treating seeds with boron and molybdenum, and at the late term – 2.49 t/ha when using molybdenum and Rizotorfin, against 2.05 t/ha and 1.87 t/ha in the control. At natural humidity, the yield was 8.30 and 7.81 t/ha, and in the variants without seed treatment – 6.37 t/ha and 5.86 t/ha, respectively.

The second and third places in terms of yield (8.07 t/ha) at the first sowing period were taken by options with seed treatment with molybdenum

Table 2. Number of seed buds and seeds in one bean by phases of development

No.	Options	Phases of development		
		Flowering − beaning	Milky ripeness	Technical ripeness
I sowing period				
1	$N_{30}R_{40}$ − background	8.1	5.4	5.2
2	Background + Rizotorfin	10.2	5.6	5.4
3	Background + boron	10.1	5.6	5.3
4	Background + boron and Rizotorfin	10.4	5.3	5.2
5	Background + molybdenum	10.7	5.6	5.4
6	Background + molybdenum and Rizotorfin	11.3	5.8	5.6
7	Background + boron and molybdenum	11.3	5.6	5.5
8	Background + boron, molybdenum and Rizotorfin	11.0	6.0	5.8
II sowing period				
1	$N_{30}R_{40}$ − background	7.4	5.0	4.7
2	Background + Rizotorfin	9.6	5.4	5.3
3	Background + boron	9.6	5.4	5.4
4	Background + boron and Rizotorfin	10.0	5.4	5.3
5	Background + molybdenum	10.5	5.7	5.7
6	Background + molybdenum and Rizotorfin	10.6	5.9	5.7
7	Background + boron and molybdenum	11.1	5.6	5.4
8	Background + boron, molybdenum and Rizotorfin	10.7	6.3	6.3

Table 3. Yield of vegetable peas at natural humidity and in absolutely dry matter depending on the studied factors, t/ha

No.	Experiment options	In natural humidity				In dry matter			
		2014	2015	2016	Average	2014	2015	2016	Average
I sowing period									
1	$N_{30}P_{40}$ − background	6.94	5.62	6.56	6.37	2.23	1.85	2.05	2.05
2	Background + Rizotorfin	7.90	6.54	7.37	7.27	2.48	2.10	2.32	2.30
3	Background + boron	7.88	6.45	7.24	7.19	2.48	2.12	2.31	2.30
4	Background + boron, Rizotorfin	8.04	6.72	7.52	7.43	2.59	2.18	2.38	2.38
5	Background + molybdenum	8.95	7.23	8.16	8.11	2.85	2.33	2.55	2.58
6	Background + molybdenum, Rizotorfin	9.06	7.04	7.98	8.03	2.86	2.25	2.50	2.54
7	Background + boron, molybdenum	9.21	7.40	8.29	8.30	2.94	2.38	2.63	2.65
8	Background + boron, molybdenum, Rizotorfin	8.96	7.18	8.09	8.07	2.84	2.29	2.57	2.57
II sowing period									
1	$N_{30}P_{40}$ − background	6.72	4.82	6.04	5.86	2.14	1.55	1.93	1.87
2	Background + Rizotorfin	7.75	5.66	6.92	6.78	2.45	1.81	2.20	2.15
3	Background + boron	8.25	6.08	7.31	7.21	2.63	1.98	2.35	2.32
4	Background + boron, Rizotorfin	8.38	6.35	7.58	7.44	2.67	2.04	2.42	2.38
5	Background + molybdenum	8.84	6.48	7.82	7.71	2.78	2.07	2.48	2.44
6	Background + molybdenum, Rizotorfin	8.75	6.64	8.04	7.81	2.77	2.14	2.57	2.49
7	Background + boron, molybdenum	8.64	6.40	7.93	7.66	2.76	2.07	2.53	2.45
8	Background + boron, molybdenum, Rizotorfin	8.78	6.58	8.00	7.79	2.80	2.11	2.54	2.48
	HIP 0,5, ц/га: − for sowing dates − for variants − for interaction	 0.24 0.26 0.21	 0.20 0.29 0.32	 0.18 0.25 0.25		 0.19 0.23 0.31	 0.23 0.13 0.21	 0.13 0.20 0.30	

– 2.58 t/ha (8.11 t/ha) and boron, molybdenum and Rizotorfin – 2.57 t/ha, the difference between which was not detected, it was within the error of the experiment.

In case of late sowing, the second and third places were taken by the variants of seed treatment with boron, molybdenum and boron, molybdenum and Rizotorfin, which provided the yield of dry matter of seeds of 2.54 and 2.45 t/ha, respectively (8.03 t/ha and 7.66 t/ha at natural moisture), which, according to the results of the variance analysis of yield data, put them on the same level with the optimal option.

An important indicator influencing the yield of vegetable peas and its quality is the yield of green peas from the total mass of beans. For the studied variety Alpha, according to some authors, it ranges from 41 to 59%. Data reflecting the effect of seed treatment with boron, molybdenum and Rizotorfin on the yield structure of vegetable peas are shown in Table 4. They indicate that in the variants seed treatment with boron and molybdenum in the first sowing period and molybdenum and Rizotorfin in the second, which formed the highest yield of this crop, the seed yield was 53.1% and 59.5%, respectively, which exceeded the control options by 1.9% and 2.8% (Figure 1).

It should be noted that the highest seed yield in the experiment was obtained during early sowing when seeds were treated with boron and Rizotorfin – 57.4% (+6.1% to the control), and when they were used for late sowing – 52.3% (+5.65), which is shown in Figure 1. However, the yield in these variants was inferior to the yield levels in the best variants, and the quality of technical raw materials did not meet the requirements of the highest grade. One of the objectives of the research was not only to establish the effect of seed treatment with boron, molybdenum and Rizotorfin on the yield of vegetable peas in technical ripeness and dry matter, but also to determine the quality of products and the time of onset of technical ripeness under the influence of the studied factors for two sowing periods. It should be noted that along with the increase in the level of yield, it is necessary to achieve an improvement in the quality of grown products. It is known that important indicators of the quality of vegetable peas are the weight of 1000 grains, the degree of ripeness of seeds (according to the indicator of the finometer) and the date of technical ripeness of vegetable peas. All these indicators were identified and analyzed (Table 5).

The data presented in Table 5 show that seed treatment with boron and molybdenum reduced the weight of 1000 grains to 294.6 g at the first sowing period (compared to the control), and the grain diameter averaged about 5.8 mm. At the second sowing period in the variant with seed treatment with boron and molybdenum, there is a decrease in the weight of 1000 seeds to (compared to the control), and the grain diameter is 5.5 mm. These indicators meet the requirements for the highest and first class of State Standard of Ukraine technological raw materials for the production of canned green peas. 277 g. The degree of ripeness of vegetable pea seeds in the above variants met the requirements of the highest class of State Standard of Ukraine. This is indicated by the mass content of alcohol-insoluble compounds of 12–14%. Due to the improvement of nitrogen nutrition of vegetable peas due to stimulation of nodule bacteria with boron, molybdenum and Rizotorfin, a delay

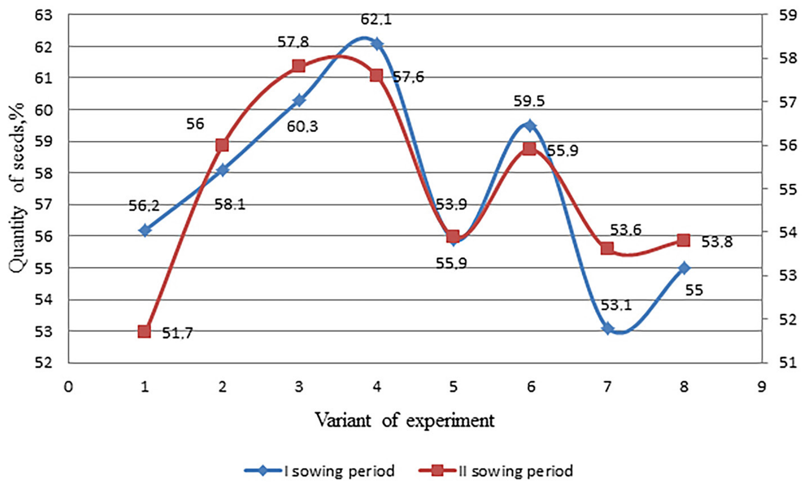

Figure 1. Influence of the studied factors on the yield of seeds of vegetable pea beans, %

Table 4. Crop structure of vegetable peas under the influence of seed treatment with boron, molybdenum and Rizotorfin (over the years of research)

No.	Experiment options	Weight of beans and seeds, g				Seed weight from 1 plant, g				Seed yield (from bean weight),%
		2004	2005	2006	Aver	2004	2005	2006	Aver	
	I sowing period									
1	$N_{30}R_{40}$ − background	25.0	19.8	23	22.6	14.2	10.5	12.5	11.6	51.3
2	Background + Rizotorfin	25.7	24.7	25	25.1	15.8	12.5	14.1	14.1	56.1
3	Background + boron	26.0	23.5	24.2	24.5	15.6	12.3	14.1	14.0	57.7
4	Background + boron, Rizotorfin	25.7	24.5	24.7	24.9	16.0	12.7	14.7	14.3	57.4
5	Background + molybdenum	30.2	27.2	28.5	28.6	16.6	14.0	15.6	15.4	53.8
6	Background + molybdenum, Rizotorfin	28.0	27.7	28.2	27.9	17.6	13.3	15.7	15.5	55.5
7	Background + boron, molybdenum	30.5	28.5	29.3	29.4	17.1	13.8	15.9	15.6	53.1
8	Background + boron, molybdenum, Rizotorfin	31.0	27.7	28.8	29.1	17.9	13.5	15.6	15.6	53.6
	II sowing period									
1	$N_{30}R_{40}$ − background	22.7	18.5	21.2	20.8	13.8	9.7	12.0	11.8	56.7
2	Background + Rizotorfin	25.2	21.5	24.5	23.7	15.7	11.2	14.0	13.8	58.2
3	Background + boron	24.9	22.7	23.2	23.6	16.1	11.9	14.9	14.3	60.6
4	Background + boron, Rizotorfin	25.7	22.7	23.5	23.9	16.9	12.5	15.5	14.9	62.3
5	Background + molybdenum	30.5	24.0	27.0	27.1	17.0	12.6	15.9	15.1	55.7
6	Background + molybdenum, Rizotorfin	28	24.2	25.0	25.7	17.1	12.8	16.2	15.3	59.5
7	Background + boron, molybdenum	30.7	26.0	27.2	27.9	16.7	12.3	15.8	14.9	53.4
8	Background + boron, Molybdenum, Rizotorfin	30.0	25.5	26.7	27.4	17.2	12.6	16.2	15.3	55.8

in the onset of technical ripeness of seeds by 4−6 days was observed in the studied variants, which makes it possible to almost double the period harvesting in the best technological phase, obtaining products of the highest and first class.

By sowing in 2 terms, the optimal harvesting period can be extended by 10–12 days compared to the previously adopted technology, which makes it possible to increase the service life of the processing industry and the area under vegetable peas in the southern zone of Ukraine. Molybdenum in all cases delayed the onset of the phase of technical ripeness of seeds by an average of 4–5 days for early sowing both in its pure form and in combination with boron. When seeds were treated with molybdenum and Rizotorfin, the onset of the phase of technical ripeness occurred on average 5 days later than in the control version. The combination of boron, molybdenum and Rizotorfin had the greatest impact on the duration of the growing season of vegetable peas before the onset of the phase of technical ripeness, where the development delay reached 6 days compared to the control. Rizotorfin in its pure form also delayed the development of peas for an average of two days and enhanced the effect of molybdenum on this indicator and neutralized the effect of boron as an accelerator of the development of vegetable pea plants.

The pattern described above was also observed at the second (late) sowing date of vegetable peas, but in this case, the most noticeable effect on the delay in the onset of the technical ripeness phase was provided by seed treatment with molybdenum alone – for 11–12 days, compared to the control version. Modern farming makes it possible to predict the receipt of high and predictable yields of agricultural products, which are completely dependent on the factors of life that affect the growth and development of the plant.

When fulfilling the main task of our study, a mathematical model of programming the crop of vegetable peas was built on the basis of a certain

Table 5. The influence of seed treatment with boron, molybdenum and Rizotorfin on the quality indicators of vegetable peas and the date of technical ripeness of seeds

No.	Experiment options	Masa is 1,000 years old, g	Seed diameter, mm	Ripeness according to the finometer, deg.	Plotka Spirtone − Soluble substances, %	Onset of technical ripeness (days)
I sowing date						
1	$N_{30}R_{40}$ − background	355.6	6.7	53	22	Control
2	Background + Rizotorfin	373.3	6.3	45	18	+2
3	Background + boron	355.0	7.2	62	24	-2
4	Background + boron, Rizotorfin	374.6	7.1	56	19	+2
5	Background + molybdenum	334	5.3	40	15	+4–6
6	Background + molybdenum, Rizotorfin	316.3	5.1	32	14	+5–6
7	Background + boron, molybdenum	294.6	5.8	38	12	+4–6
8	Background + boron, molybdenum, Rizotorfin	308.0	5.5	35	13	+6
II sowing date						
1	$N_{30}R_{40}$ − background	385	6.5	50	21	Control
2	Background + Rizotorfin	373	6.3	43	19	-6–8
3	Background + boron	344	7.0	58	24	+4–6
4	Background + boron, Rizotorfin	360.0	6.9	52	17	+8–10
5	Background + molybdenum	301.0	5.2	38	12	+10–11
6	Background + molybdenum, Rizotorfin	292.0	5.0	36	13	+11–12
7	Background + boron, molybdenum	277.0	5.5	42	14	+10–12
8	Background + boron, molybdenum, Rizotorfin	297.6	5.4	40	12	+11–12

relationship between the action of individual factors that affect the crop and its productivity. Recently, with the use of computer technology in agricultural production, this mathematical model has become especially important. Thus, to build a mathematical model based on long-term data, the sum of active temperatures during the growing season of the crop was used, soil temperature for the sowing period, nutrition background, total water consumption and the impact of these factors on the level of vegetable pea yield. The results presented in the table indicate the relationship between yield and the factors studied. Processing of the obtained data by statistical methods allows to objectively reflecting the existing patterns. The main value in this method, which allows you to express the degree of influence of the acting factors, is the yield of peas, this is the correlation coefficient. Analyzing the data in Table 6, it can be concluded that the multiple correlation coefficient indicates a close relationship between the yield of pea seeds and all the studied factors and is 0.955, which is a strong indicator of interaction. Analysis of the multiple correlation coefficient shows that all influencing factors in complex interaction have a strong, almost integral connection with the main indicator – crop yield. The determined regression coefficient shows that the increase in the sum of active temperatures (> 5 °C) during the growing season increases the yield increase by 0.138 t/ha; soil temperature for the sowing period – by 0.27; increase in the rate of mineral fertilizers per 1 kg/ha of active ingredient – by 0.23 t/ha; The total water consumption increased the yield by 0.14 t/ha.

The data show that the closest correlations between the studied factors and yields make it possible to recommend these elements of the technology for use in production. The share of the influence of factor A is not significant, the share of factor B is of great importance, but the interaction of AB is also not significant (Figure 2). Analyzing the data of Figure 2, it should be noted that 91% of the dependent variation of variable Y is due to the action of factor B – the nutrition background, 6% of factor A is due to the timing of sowing, and the combined interaction of AB affects the yield data by only 3% compared to the

Table 6. Correlation and regression analysis of seed yield of vegetable peas

Which X_i does the data belong to	R is multiple and r_i are paired correlation coefficients	D – general and d_i – partial coefficients of determination	b_0 and b_i are regression coefficients
$X_1X_2X_3X_4$	0.955	0.912	-56.5
X_1	0.662	0.438	1.38
X_2	0.173	0.03	0.27
X_3	0.634	0.402	2.32
X_4	0.652	0.425	1.43

Note: X_1 – the sum of active temperatures (> 5 °C) during the growing season; X_2 – the soil temperature for the sowing period, °C; X_3 – nutrition background, kg/ha of active substance; X_4 – the total water consumption, mi/ha.

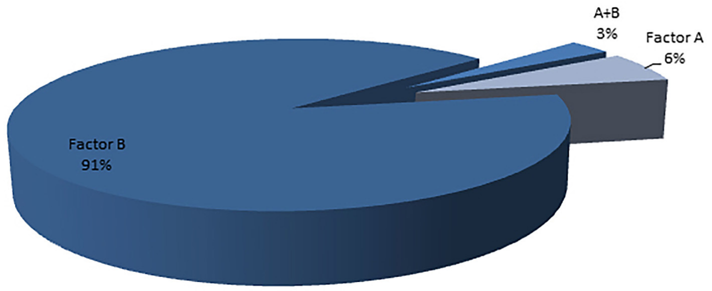

Figure 2. Share of the influence of the studied factors on the formation of the crop of vegetable peas, %; the proportion of factors influencing; Factor A – sowing time; Factor B – nutrition background (fertilizers, trace elements and Rizotorfin; Factor AB – interaction of factors

control variant of the experiment. To represent the yield of pea seeds in the form of a dependent variable, a linear multiple regression equation has been developed, which can be represented in the form of the formula:

$$y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + ... + b_NX_n \quad (1)$$

where: Y – the dependent variable; b_0 – the free term of the model; b_i – coefficients of the model; X_i – the factors of the model.

The coefficients of the model bi show the degree of average change in the dependent variable Y, provided that factor X_i changes by one, if the other factors included in the model remain constant. According to the data of the regression coefficients and the free term, a mathematical model of the yield of pea seeds was built.

$$Y = 1.38X_1 + 0.27X_2 + 2.32X_3 + 1.43X_4 – 56 \quad (2)$$

We used an exponential curve on the basis of which conclusions can be drawn about the influence of factors on the level of the plant's yield. This makes its forecasting more accurate to real-world growing conditions. The equation of the mathematical model for predicting the yield

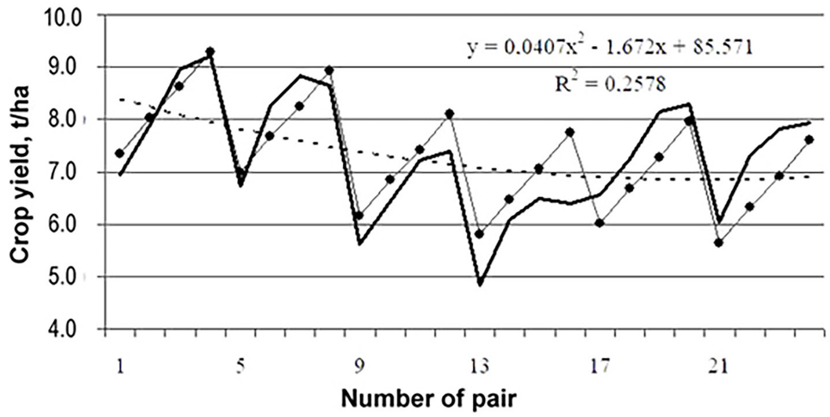

Figure 3. Mathematical model of research

according to our studied factors is shown in the graph and has the following value:

$$Y = 0.0407x^2 - 1.672x + 85.571$$
$$R^2 = 0.2578 \quad (3)$$

The indicators of the formula clearly explain and confirm the yield data we have obtained. Based on the preliminary conclusions about the mathematical model, Figure 3 was constructed, which illustrates a significant percentage of deviation in the value of the yield of pea seeds and calculated values for three years of the study, which are in the range from 0.67 to 1.43. The use of the yield formula under similar agrometeorological conditions of the experiment in the regions, and the implementation of all agrotechnical measures and the availability of the necessary resources, allows you to program the crop with a certain accuracy.

CONCLUSIONS

Based on the above data obtained in field experiments with vegetable peas, it can be noted that the maximum yield of technical products of vegetable peas of 26.5 and 24.9 c/ha of dry matter is provided by pre-sowing seed treatment with boron and molybdenum and Rizotorfin during the second sowing period. In the above variants, the seed yield from beans: by 1.9% for early sowing and 2.8% for late sowing was higher than high-quality technical indicators. Treatment of pea seeds with molybdenum in combination with Rizotorfin and boron reduced the weight of 1000 seeds at the stage of technical maturity by 45–60 g, the diameter of seeds by 0.9–1.6 mm and brought it in line with the requirements of the highest grade. The lowest level of ripeness was ensured when determined on a financial meter (32–38°) compared to the control (50–530), which also corresponds to the standard of the highest grade. The mass of alcohol-insoluble compounds when using the studied preparations was 12–14%, against 21–22% in the unprocessed versions, which indicates a high content of sugars in the raw materials. The highest yield of the crop is formed at the first sowing date, when seeds are treated with boron and molybdenum, and is 9.21 t/ha, which is 2.32 t/ha higher than the control. On the basis of correlation and regression analysis, a mathematical model of vegetable pea yield has been built. Using the formula with accuracy makes it possible to predict the level of yield by analyzing the close convergence of the experimental and calculated curves. The deviation of two curves (one from the other) is negligible.

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