

Efficiency of new growth regulators in growing daikon

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Abstract. The paper presents the results of research on the effectiveness of using new plant growth regulators (PGRs) of carbamates and oxamates series on daikon when treating seed material. The effect of growth regulators on seed quality, growth, and yield of daikon (*Raphanus sativus* L. subsp. *acanthiformis* Stanken.) of Sasha variety was studied. The research was conducted in laboratory-field conditions from 2022 to 2023 at the Educational Scientific and Production Center for Horticulture and Vegetable Growing named after V.I. Edelstein. In both laboratory and field experiments, the seed material was treated once, followed by plant development using classical technology. All treatments applied had a stimulating effect on seed germination and showed statistically significant differences compared to the control variant. Treatment of seed material with growth regulators of the carbamate series had a significant effect on the size of the assimilation apparatus. The maximum root crop weight was recorded in the variant with the Kartolin-2 preparation, with a difference compared to the control variant of 15%. The obtained data over two years on average showed an increase in yield by 9% and 12% in variants treated with Oxamate and Kartolin-2 preparations.

1 Introduction

The quality of life and the health of the population depend on balanced proper nutrition. Vegetables are of great importance to humans due to their dietary and medicinal properties. In the middle zone of Russia with a long winter period, vegetables suitable for long-term storage and grown in protected ground conditions are of particular interest. For use in the autumn-winter period, daikon (*Raphanus sativus* L. subsp. *acanthiformis* Stanken.) occupies a special place among the world diversity of cultivated plants [1].

In recent years, daikon has attracted great attention due to its nutritional and medicinal value. The roots are characterized by a high content of fructose, low sucrose, the presence of pectin substances, fiber, proteins, phytoncides, calcium salts, potassium [3].

It has also been noted that this culture has a number of pharmacological and therapeutic properties [2]. Daikon roots can cleanse the liver and kidneys, including dissolve stones. There is evidence that when grown on soils contaminated with salts of heavy metals, in

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conditions of increased radiation background, daikon accumulates 10-20 times less radionuclides and heavy metals than other root crops [4].

Yield largely depends on the variety, weather conditions, season, and place of cultivation, as well as the level of applied agronomy [2]. In recent years, plant growth regulators (PGRs) have played a significant role in global practice, through which the growth and development of plants can be artificially regulated, enhancing, inhibiting, or altering morphological and physiological processes of plants at very low concentrations [5]. One of the regulators that has proven itself well in agricultural production is "Kartolin-2" - {N-(isopropoxycarbonyl)-O-(4-chlorophenylcarbamoyl) ethanolamine} - an anti-stress preparation that enhances plant resistance to adverse conditions: drought, frost, salinity, and pathogens. The use of growth regulator stimulates plant growth, contributes to the accumulation of biomass due to the activation of protein, sugar, and chlorophyll biosynthesis [6]. However, the production of this preparation is associated with certain environmental risks, in particular, the method of obtaining the preparation involves the use of gaseous phosgene, which imposes increased requirements on the organization of production. Therefore, intensive search and study of properties of new analogs of Kartolin-2 are being carried out, the production of which is safe and technologically feasible [7, 8].

The aim of the research is to study the effect of plant growth regulators on the growth and yield of daikon of Sasha variety.

2 Materials and methods

The research was conducted in laboratory-field conditions from 2022 to 2023 at the Educational Scientific and Production Center for Horticulture and Vegetable Growing named after V.I. Edelstein. In both laboratory and field experiments, the seed material was treated once, followed by plant development using classical technology.

The object of the research was Japanese radish (daikon) of the Sasha variety.

The scheme of the laboratory experiment: 1) Dry seeds (control); 2) Kartolin-2 - a classic growth regulator with cytokinin activity; 3) Carbamate - O-isopropyl-N-(2-hydroxyethylamine) carbamate (test compounds); 4) Oxamate - O-isopropyl-N-(2-hydroxyethyl) oxamate (test compounds); 5) H₂O.

The seeds for laboratory studies and field experiments were soaked for 24 hours, with a growth stimulator concentration of 0.4·10⁻⁶ mol, or in water, and then dried for 48 hours at room temperature until they reached a powdery state. In the field experiment, the control variant did not involve pre-soaking. The moisture content in the seeds was measured according to GOST [11] (both after soaking in growth regulators for 24 hours and after drying the seeds before germination) and compared with the control.

The field experiment was laid out in quadruplicate with randomized placement of variants according to the field experiment methodology [9]. The scheme of the field experiment: 1) H₂O (control); 2) Carbamate series growth regulators; 3) Oxamate series growth regulators; 4) Kartolin-2.

Seeding of seeds was carried out in the summer period: July 15 on a leveled prepared plot, row method, with a planting scheme of 70x15 cm, the area of the accounting plot was 114 m². Care for the crops included weeding, timely watering, and loosening.

During the vegetation period, phenological and biometric observations were made on the plants, and at the technical ripeness stage, yield was recorded.

Statistical data processing was performed using Excel 2010 software. The text and tables present the arithmetic mean values of the parameters and their confidence intervals at a 95% significance level.

3 Results and discussion

All applied treatments had a stimulating effect on seed germination and showed a statistically significant difference compared to the control variant. The highest germination percentage was observed after treatment with the oxamate-based growth regulator (GP = 89.92%), which had a pronounced effect on germination rate. In all variants, the germination rate decreased by half compared to the control variant (Table 1).

Table 1. Influence of seed treatments with growth regulators on germination percentage (%), mean germination time (MTG), and germination rate (RG) of daikon.

Variant		GP (% germination)	MTG (mean germination time)	RG (germination rate)
1	Control	65.56 ± 5.88	2.73 ± 0.17	36.90 ± 2.28
2	Kartolin-2	82.22 ± 2.94	1.65 ± 0.16	61.69 ± 6.24
3	Carbamate	87.78 ± 2.22	1.69 ± 0.06	59.44 ± 2.13
4	Oxamate	89.92 ± 3.78*	1.91 ± 0.34	55.75 ± 9.81
5	H ₂ O	81.11 ± 2.94	1.89 ± 0.14	53.58 ± 3.95

In the laboratory experiment, the influence of treatments on the morphometric indicators of daikon seedlings was evaluated.

Variants with high values of relative water content in the shoot leaves were identified. The ability of leaves to retain water is especially important for summer sowing, as the first decade of July is often accompanied by high air temperatures and lack of moisture [10]. The conducted studies did not reveal a statistically significant effect of growth regulators on the relative water content in shoot leaves (Table 2).

Table 2. Influence of treatments with growth stimulants on biometric indicators of seedlings and relative water content in leaves.

Variant		Root length, cm	Shoot length, cm	Fresh weight, g	Dry weight, g	RWC %
1	Control	7.26±0.64*	4.64±0.16	0.0818±0.00	0.0061±0.00	89.09±2.62
2	Kartolin-2	9.34±0.67	4.78±0.29	0.0639±0.00	0.0067±0.00	92.57±0.55
3	Carbamate	8.65±0.73	4.64±0.35	0.0899±0.01	0.0073±0.00	93.82±1.00
4	Oxamate	10.85±0.76	4.25±0.25	0.0777±0.00	0.0075±0.00	92.33±2.09
5	H ₂ O	9.34±0.64	4.56±0.22	0.0740±0.00	0.0064±0.00	93.32±2.79

In the field experiment, the influence of growth regulators on the growth, development, and yield of daikon plants was evaluated. Phenological observations were conducted during the vegetation period to determine the effect of growth regulators on the development of daikon plants. The date of mass emergence in variants using growth regulators was noted on the 4th day after sowing, while in the control variant, it was on the 5th day. The first true leaf in variants with growth regulators was formed on the 5th day after mass emergence, while in the control variant, the first true leaf appeared two days later. Harvesting of daikon roots was carried out simultaneously for all variants, on average on the 57th-58th day.

The formation of daikon root yield is directly dependent on the size of the assimilation apparatus [2]. The morphometric indicators are presented in Table 1 (data are presented as the arithmetic mean with confidence intervals at a 95% significance level).

By the beginning of commercial ripeness (on the 57th day), the maximum number of leaves was noted in the variant treated with Kartolin-2 and amounted to 8.8 leaves per plant, which significantly differed from the control. There were no significant differences in the number of leaves between the 2nd and 3rd experimental variants and the control; on average, 7.8 to 7.9 leaves were formed in these variants.

Linear leaf parameters differed when using different growth stimulators compared to the control. The largest leaves with a wide leaf blade were characteristic of the second experimental variant, with a leaf blade length of 4.5 cm and a width of 7.4 cm by the time of harvest, which significantly differed from the control (Table 3).

There were no significant differences in leaf size between the third and fourth experimental variants compared to the control.

Yield is the main criterion for a variety or hybrid, reflecting the efficiency of various factors, methods, or techniques. Previous studies have examined the effects of the compounds under consideration on wheat [11], where a positive influence on the crop was established. However, plant responses to the application of growth regulators can be specific and manifest differently. The results presented in Table 4 indicate the formation of larger root crops in variants 3 and 4, indicating an increase in diameter, length, and average root mass. The maximum root mass was observed in the variant treated with Cartolin-2, with a difference compared to the control variant of 19.7 g. The data obtained over two years show an increase in yield by 9 and 12% in variants treated with Oxamat and Cartolin-2, respectively.

Table 3. Yield and Quality Indicators of Daikon Root Crop.

Variant		Root Crop, cm		Root Mass, g	Yield t/ha	± % compared to control
		diameter	length			
1	H ₂ O (control)	6.1+0.9	6.4+1.1	131.0+52.3	12.4 +1.2	-
2	Carbomat	7.8+0.9	6.7+0.9	139.5+44.7	13.2 +1.1	+6
3	Oxamat	8.0+0.7	6.6+0.8	143.5+34.9	13.6 +0.8	+ 9
4	Cartolin-2	8.1+0.9	6.6+1.0	150.7+47.9	14.3 +1.1	+15

4 Conclusion

Pre-sowing treatment of daikon seeds with growth regulators based on carbamates and oxamates significantly increased seed moisture and germination percentage, which also positively affected seedling emergence in field conditions, accelerating their development by 1-2 days. Treatment of seed material with growth regulators of carbamates had a noticeable effect on the size of the assimilation apparatus, with linear leaf surface parameters (leaf length and width) differing from the control by 0.8 cm for both parameters. The variant treated with Cartolin-2 did not affect leaf sizes but had an advantage in leaf number by 1.1 leaf. The maximum root mass was observed in the variant treated with Cartolin-2, with a difference of 19.7 g (15%) compared to the control variant. The data obtained over two years showed an increase in yield by 9 and 12% in variants treated with Oxamat and Cartolin-2, respectively.

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