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RESEARCH ARTICLE

Growing table beets with the use of biological preparations in conditions of the right-bank forest-steppe of Ukraine

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Abstract
Research data on the influence of biological preparations on the cultivation of table beets are highlighted. Priority related studies were phenological observations, yield and biometric measurements of beetroots. It is proved that biological preparations and varietal features influence the phenological phases of growth and development of table beets. In the initial stages of table beet plants growth and development, there were no significant changes between phases. Further study of the phenological phases of growth and development of table beet plants showed the effect of biological preparations on their occurrence. The highest yields were recorded with the application of Organic Balance+Azotofit+Liposam: in the Chervona Kulia variety, the increase was 7.1 t/ha, in the Pablo F1 hybrid-10.3 t/ha relative to the control. The use of the Organic Balance+Azotofit+Liposam complex provided a 45 g root mass increase in the Chervona Kulia variety, in the Pablo F1 hybrid-30 g compared to the control. With the use of the Humifrend+Azotofit+Liposam complex, the increase made up 30 g in the Chervona Kulia variety and 25 g in Pablo F1 hybrid. Indicator of root diameter was in the range of 8.4 cm and 9.0 cm. The use of the Organic Balance+Azotofit+Liposam biological preparations complex contributed to the increase in this indicator, in particular in the Chervona Kulia variety by 0.4 cm, in the Pablo F1 hybrid-by 0.5 cm.

Keywords: Cultivation technology, table beets, biological preparations, phenological phases, yield

Introduction

The study consisted in studying the production of table beets for the use of biological products in the right–bank forest-steppe of Ukraine. Today, the issue of increasing the yield of agricultural plants, including table beets, is quite relevant. Given climate change, scientists are looking for the ways to create more favourable conditions for growing crops. Besides, the growth of the world's population, which leads to the increase in the production of high-quality products, is another important factor. Therefore, a significant role in the cultivation of vegetable plants is given to biological preparations, which allow obtaining organic vegetable products (Babych A.A., 1996; Bomba M.Ya., 2004; Balyan A.V., 2013; Chernikova O. et al., 2021).

In recent years, the use of intensive technologies for growing crops, for which application of high doses of fertilizers and chemical plant protection preparations were characteristic, often in inappropriate quantities, led to the deterioration of soil fertility (Vdovenko S.A., 2019; Evstigneeva T. et al., 2020). Under such conditions, the plants became weakened, and therefore more susceptible to disease and pest damage. But it is possible to increase the resistance of plants through the use of biological preparations (Vdovenko S.A., 2019; Karpenko V. et al., 2020). Therefore, studies on table beets cultivation with the use of biological products come at an opportune time.

Along with other root crops, table beet occupies one of the leading positions and is grown in all soil and climatic zones. It is considered to be one of the most valuable vegetable crops, which is characterized by high yields, precocity, long shelf life, as well as rich chemical composition, including biologically and physiologically active substances, mineral salts and quite valuable betanin pigment (Bazalii V.V. et al. 2016). It promotes metabolism, improves liver function. Varieties of table beets grown in Ukraine differ in shape, colour, yield, precocity, but have the same positive effect on the human body (Palamarchuk I.I. et al. 2019).

Table beet (*Beta vulgaris* L.) is one of the most widespread and valuable vegetable crops due to its high plasticity to growing conditions. Beet belongs to the Goosefoot family (*Chenopodiaceae*). It has a high nutritive value due to carbohydrates, mineral salts, organic acids, biologically active substances and vitamins availability. Fruits of table beet are rich in vitamins B1, B2, B6, amino acids (lysine, valine, arginine), folic acid, carotenoids, salts of iron, calcium, potassium, manganese. As to the iodine content, beetroots rank first among all vegetable crops. Table beets contain phytonutrients, i.e. substances that are a source of natural chemicals. They help prevent disease and ensure normal body function (Yakovenko K.L. et al., 2001; Stefaniuk S.V. 2014).

Products of table beets are used in food throughout the year, in particular, in spring young leaves can be consumed, in summer leaves and roots, in autumn and winter -roots (Ketskalo V.V., 2015).

In Ukraine, among all vegetable crops, root crops account for 18% of the cropping area, and table beets occupy 44.1 thousand hectares. The average yield of root crops is 20.3 t/ha, while the potential yield of table beets is much higher. Perspective plans for the development of vegetable production provide for the production volumes increase, what will meet the need of the population in food products and the industry in raw materials (Vdovenko S.A. et al., 2018; Ulianych O.I., et al., 2018).

In order to meet those needs, it is necessary to apply new agricultural measures or methods, namely, to use drop irrigation, water-retaining granules, modern high-yielding and resistance to growing conditions, diseases and pests varieties and hybrids. A number of studies show that the use of biological preparations also provides yield growth and better product characteristics (Pantsyreva H.V., 2019; Pashkevych E.B., 2009).

In recent years, scientists are paying more and more attention to the biologization of agriculture, the basis of which is the abandonment of chemical plant protection products or the maximum restriction of their use in crop growing technologies. The use of microbial preparations to replace nitrogen fertilizers, chemical plant protection means helps to reduce the chemicalization of agriculture, decrease costs and obtain environmentally friendly crop products (Grekhova N.V. and Matveieva N.V. 2014). Introduction of the elements of agriculture biologization is an important step towards strengthening the ecological balance of agroecosystems and increasing the pace of further production of agricultural products (Ivanina V.V., 2011; Zabolotnyi G.M., et al. 2018; Zabolotnyi H.M., et al. 2020).

According to the scientific researches, there is a need for the introduction of biological products in the agricultural plants growing technology, including vegetable production. A number of studies show the much greater importance and effectiveness of biological products against chemical plant protection agents. Thus, it is possible to replace chemical fungicides, to which pathogens have become tolerant, with biological products that have a fungicidal effect (Dubka V., 2011; Istratina I.V., 2004; Minin V.B. et al., 2020).

According to Prokopchuk V.M. et al. (2018) growth stimulants have a positive effect on the rooting of the boxwood cuttings (Prokopchuk V.M., et al. 2018). The importance of growth stimulants is confirmed by their presence in the growing technology of all crops.

Germany, the USA, Italy, Spain, France and Great Britain are the leading producers in the market of organic products (Wolfgang N., 2013). The main world segments of organic products are vegetables and fruits, milk and dairy products, baby food, raw materials for further processing. Specialized markets for organic products in North America and Europe account for most of the world's revenues from the sale of organic products (about 96%). At the same time, the total segment of organic food covers only 1%–2% of the world food market, but the market for organic products is constantly growing (Zavalin M.I., 2005; Zaika S.O., 2013).

Studies of more than 30 research institutions of NAAS of Ukraine have revealed a significant positive effect of plant growth regulators on cultivated coenoses. It is proved that new growth-regulating substances of domestic production in their effectiveness are in line with the best world analogues, and in terms of technical indicators and cost levels have significant advantages over them (Bazaliy V.V., et al. 2016).

According to Didur I.M. & Tsyhanskyi V.I. (2017), on grey forest soils application of biological fertilizer Groundfix at the dose of 8 l/ha improves conditions for mineral nutrients assimilation and ensures maximum realization of the genetic potential of plants, thus contributing to the formation of high yields of corn (Didur I.M., Tsyhanskyi V.I., 2017).

As reported by Tsyhanskyi V.I. & Tsyhanska O.I. (2020), the use of pre-sowing treatment of seeds with Rhizobofit in combination with Emistim C with full-rate liming the soil for hydrolytic acidity and growing coverless alfalfa with the introduction of herbicide in the year of sowing, caused an increase in the main feed productivity indicators based on increasing the yield of alfalfa and improving its biochemical composition [Tsyhanskyi V.I. & Tsyhanska O.I., 2020].

Biostimulants are materials, other than fertilizers, that promote plant growth when applied in low quantities (Patrick du Jardin, 2015). Many biostimulant products have been classified into completely divergent groups and categories of function, use, and type of activity. For example, humate-based products are often described as soil health amendments while Plant Growth Promoting Rhizobacteria (PGPRs) could be categorized as biofertilizers, phytostimulators, and biopesticides (Martínez-Viveros O., et al. 2010; Bhattacharyya P.N., et al. 2015).

An interesting solution was proposed by researchers from the Russian Federation, who used natural microbial cenosis from koumiss for developing a biological product Microbiovit. The microbiocenosis promoted an increase in yield capacity of wheat, vegetables and potatoes by 26%–56% (Somova et al., 2017).

The plants of the glucose salad react quite actively to external factors, in particular, for the treatment of seeds and extra-root nutrition with preparations of biological origin. In the course of the research, it was established that the best merchandise quality was the products obtained for the use of Biolan and Gumysol. Calculations of economic efficiency have confirmed the expediency of the use of growth regulators in the cultivation of salad in the head crop seedlings. Thus, the level of profitability for the use of bio preparations in the experiment increased, compared with control, 44%–67% and more cost-effective were Biolan and Gumysol (Ketskalo V.V. & Shchetyna S.V. 2016).

According to research El-Mansy A.A., et al. (1973) the use of CCC significantly increased root yields. The number of leaves and their dry weight per plant were increased. The increases in leaves dry weight per plant were found not to be a result of the increase of leaves number per plant only, but the leaves dry weight percentage was also increased. Root length showed insignificant increases due to CCC treatment. In the same time, significant increments in its diameter as well as in dry weight per plant were recorded in both seasons, which might be the cause of increasing yield (El-Mansy A.A., et al. 1973).

The plant growth regulators application will increase the stimulating effect on the plant, its growth activity, physiological functions and organism protective reactions involved with metabolism increasing, stress resistance to unfavourable conditions (diseases, pests, freezing, dry period and others). It was proved that the studied preparations stimulated the plants growth and development, increased the productivity of tomatoes in hyperarid conditions of the southern Russia (Kalmykova, E.V., 2021).

Research results reveal that the application of plant growth regulators such as diniconazole (Din) and prohydrojasmon (PDJ) significantly impact potato plants growth and yield, including that of tubers. Plants treated with Din and PDJ effectively showed stunted growth and reduced development but enhance the tuber formation and its weight. Plants treated with Din and PDJ significantly reduced the GAs and ABA accumulation and increase the sucrose level and cause a significant increase in tuber development. In conclusion, higher gibberellin content in potatoes may inhibit tuberization (Jeong E.J., et al. 2021).

According to Chernetskyi V.M. (2017) growth stimulators influence the formation of the leaf surface of zucchini plants, which has a direct correlation with plant yields and contributes to its increase (Chernetskyi V.M., et al. 2017).

The modern direction of increasing the productivity of crops, including table beets, is the introduction of energy-saving technologies with the use of plant growth regulators and biological preparations. The effectiveness of biologicals depends on many factors, namely: growing conditions, variety, methods and timing of the preparation introduction. Today, the range of various biological products on the Ukrainian market is very large, and most of them have not yet passed production testing and are used according to the advertising characteristics of distributors. Among those drugs are world-famous brands and some technological developments of well-known companies. In Ukraine and the world practice in general there is a large number of biological products for vegetable plants, which are insufficiently studied, in particular in the specific growing conditions, which makes relevant the study of this issue (Ovcharuk O.V., et al. 2019; Olifirovych V.O., 2016; Cherenkov A.V. & Shevchenko M.S., 2017).

Materials and Methods

Studies of the effect of biological products on the growth, development and yield of table beets were conducted in 2018-2020 in open ground at the research sites of Vinnytsia National Agrarian University. The type of soil of the experimental field is forest grey, medium loam. Soil conditions were characterized by the following indicators: humus content-2.4%, P_2O_5-21.2 mg/100 g of soil (estimated as high), K_2O-9.2 mg/100 g of soil (estimated as low). The acidity of the soil solution was neutral. The experiment consisted of 6 variants in four repetitions. Variant without treating was a control one. Experimental studies were performed with the Chervona Kulia variety and the Pablo F_1 hybrid. The following biological preparations were the variants of the experiment: Organic Balance+Azotofit+Liposam, Humifrend+Azotofit+ Liposam. In the experiment, the plants were sprayed with the solutions of biologicals: Organic Balance (0.5 l/ha), Humifrend (0.5 l/ha), Azotofit (0.3 l/ha); Liposam (0.3 l/ha) was used as an adhesive substance. The treatment was carried out in phase of 3 the true leaves (Bondarenko H.L., et al. 2001).

Table beets were grown according to the technology typical for the Forest-Steppe natural zone [DSTU 6014:2008, 2010]. Field, statistical and laboratory research methods were used in the experimental research.

According to the methodology, phenological observations of plant growth and development, biometric measurements and accounting were provided (Bondarenko H.L. & Yakovenko K.I., 2001). Phenological phases were observed visually for each repetition. Harvesting was carried out in the period of technical maturity of roots in accordance with the requirements of the current standard–"Fresh table beets. Technical conditions–SSTU 7033:2009" (SST of Ukraine 7033:2009, 2010).

Results and Discussion

The results of phenological observations are shown in Tab. 1. Analysis of the research results confirms that biological preparations and varietal characteristics have a certain effect on the phenological phases of growth and development of beets. In the initial stages of growth and development of the table beet plants, there were no significant changes between phases. However, in the Pablo F_1 hybrid, the phases occurred somewhat earlier than the calendar terms. Sporadic seedlings were observed in the Chervona Kulia variety on April 27 in all variants of the experiment. In the Pablo F_1 hybrid emergence of single seedlings was recorded on April 25 in all variants, which was 2 days earlier than the studied variety. Accordingly, mass standing was also registered 2 days earlier. The same pattern was observed with the appearance of the 1st and 3rd pairs of true leaves. In particular, the appearance of the 1st pair of true leaves was noticed on 15.05 and 13.05, depending on the studied variety and hybrid. The appearance of the 3rd pair of true leaves was observed on the 11th day after the mass appearance of seedlings. The emergence of the 5th pair of true leaves in table beet plants was noted earlier in the Pablo F_1 hybrid on the variant with Organic Balance+Azotofit+Liposam and Humifrend+Azotofit+Liposam treatment-31.05, which is 1 day sooner than control, and 1 and 3 days earlier for the studied variants of the Chervona Kulia variety. Thus, in the initial phases of growth and development of table beet plants, the variety and the hybrid, but not biological preparations, influenced the passage of phenological phases.

Further study of the phenological phases of growth and development of table beet plants showed the effect of biological products on their occurrence (Tab. 2). The onset of the moulting phase was observed sooner in the Chervona Kulia variety under the use of Organic Balance+Azotofit+Liposam on 05.06, which is 2 days earlier than the control variant. In the Pablo F_1 hybrid in the same variant, the moulting phase was observed on 03.06, which is also 2 days earlier than on the variant without biological products treatment. Somewhat earlier, compared to the untreated variant, this phase was recorded in the Chervona Kulia variety and the Pablo F_1 hybrid under the use of Humifrend+Azotofit+Liposam.

The phase of intensive root growth and that of technical maturity were also noted earlier under the use of Organic Balance+Azotofit+Liposam: in the variety Chervona Kulia it came on 09.06 and 17.07, in the Pablo F_1 hybrid–on 07.06 and 15.07, which is 2-3 and 3 days earlier compared to the control. The phase of technical maturity in all variants of the experiment was recorded on different dates. Earlier, the phase of technical maturity was observed on the variant with the use of the Organic Balance+Azotofit+Liposam biological product-on 17.07 in the Chervona Kulia variety and 15.07 in the Pablo F_1 hybrid. In the variant without treatment, this phase was observed later than all. Taking into account the varietal characteristics and weather conditions prevailing during the years of the research, harvesting was carried out on 15.09.

Table 1. Dates of phenological phases of table beets depending on the variety and biological preparation (average for 2018-2020).

Variety, hybrid	Biological preparation	Seedlings		The emergence of true leaves pairs		
		sporadic	mass	1th	3th	5th
Chervona Kulia	Without treatment (control)	27.04	12.05	15.05	23.05	03.06
	Organik balance+Azotofit+ Liposam	27.04	12.05	15.05	23.05	01.06
	Humifrend+Azotofit+Liposam	27.04	12.05	15.05	23.05	01.06
Pablo F_1	Without treatment (control)	25.04	10.05	13.05	21.05	01.06
	Organik balance+Azotofit+ Liposam	25.04	10.05	13.05	21.05	31.05
	Humifrend+Azotofit+Liposam	25.04	10.05	13.05	21.05	31.05

Table 2. Dates of the next phenological phases of table beets depending on the variety and biological preparation (average for 2018-2020).

Variety, hybrid	Biological preparation	Moulting phase	Phase of intensive root growth	Phase of technical maturity	Harvesting
Chervona Kulia	Without treatment (control)	07.06	11.06	20.07	15.09
	Organik balance+Azotofit+Liposam	05.06	09.06	17.07	15.09
	Humifrend+Azotofit+Liposam	06.06	10.06	19.07	15.09
Pablo F_1	Without treatment (control)	05.06	10.06	18.07	15.09
	Organik balance+Azotofit+Liposam	03.06	07.06	15.07	15.09
	Humifrend+Azotofit+Liposam	04.06	09.06	17.07	15.09

Table 3. Duration of the interphase periods of table beets growth depending on the variety and biological preparation, days (average for 2018-2020).

Variety, hybrid	Biological preparation	Mass seedlings-the moulting phase	Mass seedlings-the beginning of intensive root formation	Mass seedlings-the end of the growing season
Chervona Kulia	Without treatment (control)	26	30	69
	Organic Balance+Azotofit+Liposam	24	28	66
	Humifrend+Azotofit+Liposam	25	29	68
Pablo F_1	Without treatment (control)	26	31	69
	Organic Balance+Azotofit+Liposam	24	28	66
	Humifrend+Azotofit+Liposam	25	30	68

The influence of biological preparations on the duration of interphase periods of table beets was revealed as well (Tab. 3). The studied period of the "mass seedlings-moulting phase" was shorter than under the use of the Organic Balance+ Azotofit+Liposam biologicals: in the Chervona Kulia variety and Pablo F_1 hybrid-24 days, which is 2 days shorter than control.

The "mass germination–the beginning of intensive root formation" interphase period was shorter with the application of Organic Balance+Azotofit+Liposam, in the variety and the hybrid it lasted 28 days, which is 2 and 3 days less than the control variants. In the Pablo F_1 hybrid without treatment, this interphase period was the longest–31 days. The interphase period "mass seedlings–the end of the growing season" was also shorter on the variant with Organic Balance+Azotofit+Liposam application–66 days, whereas on the variant without treatment it was 69 days.

It should be noted that the duration of the interphase periods was influenced by the nature of the variety, hybrid, weather conditions of the research years and biological preparations used.

The final indicator, that shows the result of one or another research factor action, is the yield. It depends on the studied factors, growing and weather conditions of the research years. Studies have shown a positive effect of biological preparations on the table beets yield formation. The highest yields were recorded under Organic Balance+Azotofit+Liposam application: in the Chervona Kulia variety, the increase was 7.1 t/ha, in the Pablo F_1 hybrid-10.3 t/ha relative to the control (Tab. 4). A positive effect was also obtained with the application of Humifrend+Azotofit+ Liposam preparation, where the increase was 4.9 t/ha and 8.4 t/ha, respectively. The significance of the obtained difference is confirmed by the results of the analysis of variance over the years of the research.

Analyzing the years of the research, it should be noted that in addition to the studied factors, the yield was influenced by weather conditions of the research years and morphobiological features of the studied table beet variety and hybrid.

The quality of the obtained product is an important characteristic when examining the influence of the studied factor. The conducted biometric measurements of beetroots showed a positive effect of biological agents on biometric parameters (Tab. 5). The use of the Organic Balance+Azotofit+Liposam complex provided the increase in root mass in the Chervona Kulia variety–45 g, in the Pablo F_1 hybrid-30 g, respectively. Under the use of the Humifrend+Azotofit+Liposam complex, the increase was 30 g in the Red Ball variety and 25 g in the Pablo F_1 hybrid. A strong direct relationship between yield and weight of table beetroot ($r=0.94 \pm 0.05$) was proved.

The diameter of the root crop indicator was in the range of 8.4 and 9.0 cm. The increase in root diameter

Table 4. Yields of table beets depending on the variety and biological preparation (average for 2018-2020).

Variety,hybrid	Biological preparation	Yield, t/ha			Average	Gain ± to the control, %
		2018 p.	2019 p.	2020 p.		
Chervona Kulia	Without treatment (control)	62.3	58.6	62.0	61.0	–
	Organic Balance+Azotofit+Liposam	69.6	65.4	69.1	68.0	7.1
	Humifrend+Azotofit+Liposam	67.4	63.2	67.0	65.9	4.9
Pablo F_1	Without treatment (control)	66.1	62.0	65.6	64.6	–
	Organic Balance+Azotofit+Liposam	76.8	72.5	75.3	74.9	10.3
	Humifrend+Azotofit+Liposam	74.7	70.4	73.8	73.0	8.4
HIP05	A	0.9	0.8	0.9	–	
	B	1.0	0.9	1.1		
	AB	1.6	1.4	1.6		

Table 5. Biometric indicators of table beet products depending on the variety and biological preparation (average for 2018-2020).

Variety,hybrid	Biological preparation	Root weight, g	Root diameter, cm	Root length, cm
Chervona Kulia	Without treatment (control)	275	8.4	8.0
	Organic Balance + Azotofit + Liposam	320	8.8	8.5
	Humifrend + Azotofit + Liposam	305	8.5	8.3
Pablo F_1	Without treatment (control)	300	8.5	8.2
	Organic Balance + Azotofit + Liposam	330	9.0	8.7
	Humifrend + Azotofit + Liposam	325	8.8	8.4

under the use of Humifrend+Azotofit+Liposam biological preparations was slightly smaller and made up 0.1 cm-0.3 cm. Analysis revealed a strong direct relationship between yield and root diameter (r=0.93 ± 0.04).

The action of Organic Balance+Azotofit+Liposam biologicals was detected when measuring the length of the root crop, where the gain relative to the control made up 0.5 cm. The use of Humifrend+Azotofit+Liposam increased this indicator relative to the control by 0.3 cm-0.2 cm. A strong direct dependence between yield and root length was established (r=0.90 ± 0.13).

Conclusions

Thus, the research revealed the influence of biological preparations on the phases of growth and development of table beet plants, their yield and biometric parameters of products. The use of the Organic Balance+Azotofit+Liposam biological complex accelerated the passage of phenological phases of growth and development of table beet plants. The shortest period from mass germination to harvesting was recorded in the studied varieties and hybrids under the use of Organic Balance+ Azotofit+Liposam complex 66 days. The highest yield was obtained due to the use of Organic Balance+Azotofit+Liposam biological preparations, which gave a 7.1 t/ha–10.3 t/ha increase relative to the control. The largest root weight was provided by the variant using Organic Balance+Azotofit+Liposam combination: in the Chervona Kulia variety, it was 320 g, in the Pablo F_1 hybrid–330 g. Studies have shown that the Pablo F_1 table beet hybrid provided better yields and biometric parameters of products due to greater adaptation to growing conditions, which is especially relevant in climate change.

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