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Growth and yield of spinach depending on absorbents' action

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Abstract. The use of absorbents from Maximarin for growing spinach contributed to its faster germination, increased plant growth and development, and resulted in an increase in yields of commodity products by 2.0–6.1 t ha^{-1} and an increase in chemical composition. The use of absorbents in open ground for spinach made it possible to obtain the highest amount of contingent net profit for making the drug Maximarin in the form of a gel and the company Eco – with small granules, and in the Krasen Polissia variety – 2,160 and 2,102 USD ha^{-1}, in the Malakhit variety for introduction the drug Maximarin in the form of a gel 1,949 USD ha^{-1} and the company Eco absorbent with potassium – 1,575 USD ha^{-1}. Profitability for the Matador variety has reached 75%, Malakhit grade – 69–75%, Keb – 3.0–3.2. It was established that in the closed ground application of the drug Maximarin in the form of gel and granules for spinach made it possible to obtain the highest amount of contingent net profit, which was Matador 3,079 and 3,025 USD ha^{-1}, in the Malakhit variety for the introduction of gel 4,304 USD ha^{-1} and granules – 4,245 USD ha^{-1}. Profitability for the use of drugs for the Krasen′ Polissia variety reached 84–77%, Malakhit – 118–116 %, the bioenergy efficiency ratio – 3.0–3.3.

Key words: spinach, varietal, absorbent, commodity products, yield.

INTRODUCTION

Setting of the problem

Production of agricultural goods in our time is hardly possible without mineral fertilizers and means of regulating growth and development of plants (Kosterna & Zaniewicz-Bajkowska, 2012). High yield of spinach in arid conditions requires optimal growth conditions. In the scientific literature, it is recommended to use absorbents to promote growth in arid conditions. Absorbents are natural or synthetic compounds that are used to make soil in order to initiate changes in their vital processes to improve the quality of plant material, increase yields, facilitate harvesting and storage. The use of absorbents leads to changes in metabolism similar to those that occur under the influence of external conditions.

That is, absorbents are not nutrients, but factors for ensuring plant growth and development. Absorbents activate the basic life processes in plants. Under their action accelerates the growth of green mass and the root system, and therefore more actively used water and dissolved in it soil and mineral fertilizers, increase the protective properties of plants, their resistance to diseases, high and low temperatures, drought. Accordingly, the yield is increased and the quality of the vegetables is improved. The use of absorbents allows to realize more fully the potential of plants, laid by nature and breeding. The use of new generation suppliers to increase the yield of spinach is an important issue and needs detailed research.

Analysis of recent studies and publications

The widespread introduction of vegetable spinach into agricultural production is hampered by the lack of sufficient variety of varieties and scientifically sound organic cultivation technology in the Right-Bank Forest Steppe of Ukraine. To this end, it is necessary to thoroughly study the agrobiological features of plants, to bring in new high-yielding varieties, to improve the organic technology of cultivation, to establish conditions for obtaining high productivity, prolongation of fresh consumption, since the existing intensive technology does not allow to obtain environmentally-friendly (Osadcuks & Pecka 2016; Kostetska et al., 2019).

The population has increased interest in consuming exclusively natural food as a way of improving the quality of life (Corbo et al., 2006; Osadcuks & Pecka, 2016). Now both professionals and consumers talk about natural products with special properties (Philipchuk, 2005; Kostetska et al., 2019).

In recent years, many scientists have dedicated their research to spinach However, its widespread introduction into production is hampered by the lack of zonal science-based cultivation technology. The urgency of existing issues leads to the conduct and justification of directions of scientific search technology (Aworh et al., 1980; Guarrera & Savo, 2013; Ulianych & Alekseichuk, 2015; Ulianych et al., 2015; Vorobiova et al., 2018).

The properties of the product is vary considerably depending on weather conditions, growing technologies and features of varieties, it requires thorough study (Kostetska & Yevchuk, 2016). In a context characterized by a growing consumer’s interest in locally produced foods, the safeguard of ancient fruit varieties appears relevant (Darby et al., 2008; Bartolini & Ducci, 2017; Kostetska et al., 2019).

MATERIALS AND METHODS

The purpose of the research was to study the conditions for increasing the yield of spinach for the introduction of absorbents and to develop technological methods for improving productivity**.**The study of influence of hydrogel firms Maximarin used in the form of tablets, gel, granules). For spinach cultivation, preparations were used in the following forms: ‘MaxiMarin’ gel-like, ‘MaxiMarin’ tableted, ‘MaxiMarin’ granular on grow and yield of cultivars spinach*:* Krasen Polissia and Malakhit.

The research was carried out in 2015–2018 at the experimental field of the Department of Vegetable Growing of Uman National University of Horticulture in accordance with generally accepted methods (Dospekhov, 1985; Bondarenko &Yakovenko, 2001; Hrytsaienko et al., 2003; Ieshchenko et al., 2005; Volkodav, 2016).

The soil of the experimental field is black, puddle, heavy loam with a well developed humus horizon (about 2.9% of humus) in the deep of 40–45 cm. The breeding work was carried out in accordance with the methods of the Institute of Expertise of Plants Varieties and Institute of Vegetables and Melons of NAAS (Bondarenko &Yakovenko, 2001).

The precursor of spinach was white cabbage and other varieties of cabbage. The seeds were sown in the first decade of April. The care of plants consisted of systematic loosening of the soil, mounding of plants, removal of weeds and protection against pests and diseases. Irrigation was carried out by method of drip irrigation during the vegetation period of plants – 1–2 irrigations of 60–80 m^3 ha^{-1}. After each irrigation loosening rows with simultaneous weeding was carried out.

According to Uman meteorological station the hydrometeorological conditions of 2017 were characterized by a slightly lower amount of precipitation relative to the average perennial indicator. The amount of precipitation for this period in 2018 was more relative to 2017, which is close to medium-long-term data, but the main number of them fell at the beginning and at the end of the vegetation which testifies to their lack of a phase of intensive growth and development of the plant, but it did not has a significant effect of precipitation, so the investigation was carried out under the drip irrigation (Novak, 2017; Novak & Novak, 2018; Ulianych et al., 2019).

The total area: for the experiment 500 m^2, for plot 50 m^2, for sampling – 5 m^2. The plots were arranged in a systematic order with a four replication. To characterize the structure of the crop, the green samples taken from the plots were divided into fractions – standard and non-standard. There were determined the number of leaves and plant weight of each fraction. The tradability of the yield was determined by the mass of a plant and the total green mass collected from a plot.

The No. of leaves (per plant, pcs) was determined by the method of calculation, the area of the leaf blade by a calculated (linear) method, using the parameters of the length and width of the leaf by the formula 1:

$$S_n = 0.74 \times a \times b \tag{1}$$

where *Sn* – the area of one leaf, cm^2; *a* – the largest leaf width, cm; *b* – leaf length, cm; 0.74 is the coefficient that reflects the configuration of the leaf.

The data were statistically analyzed using Analysis of variance Microsoft Office Excel (Fisher, 2006).

RESULTS AND DISCUSSION

Spinach leaf is the main product of consumption and is crucial for evaluating its quality, as for each green plant, which determines its edible properties during consumption. The number of leaves in the socket is important for spinach. The definition of this indicator in the experiment showed that in 2015, the number of leaves is in the range of 17–23 piece $plant^{-1}$ (Fig. 1).

The larger number of leaves was in plants that grew with the introduction of absorbents in the form of gel and granules – 22–23 pcs $plant^{-1}$. In 2016, the number of leaves was lower due to the worse growing conditions and ranged from 14 to 20 pcs $plant^{-1}$. In 2017 and 2018, a larger number of leaves were obtained for the application of gel and granules – 21–25 pcs plant^{-1}, which significantly exceeded the control by 6–9 pcs plant^{-1}.

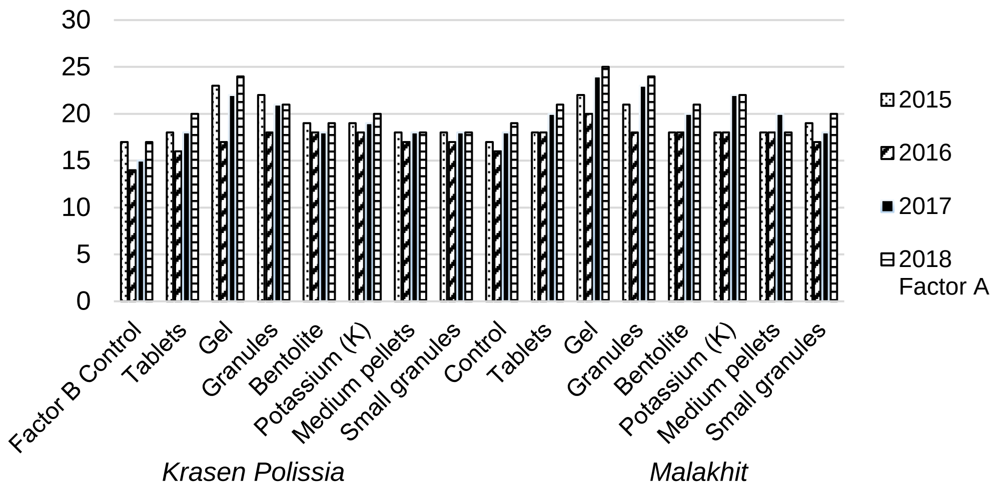

Figure 1. The number of leaves in spinach and in the phase of technical maturity, depending on the action of the absorbents, pcs plant^{-1}.

During the years of research, the number of leaves in the Krasen Polissia variety without making absorbent (control) was 16 pcs plant^{-1}. Growing spinach against the background of the use of various forms of absorbents contributed to the increase in the number of leaves. And for the introduction of tablets in the Krasen Polissia variety up to 18 pcs plant^{-1}, in the Malakhit variety – 19 pcs plant^{-1}, which was significantly higher than the control by 2–3 pcs plant^{-1}. The application of the gel contributed to the increase in the number of leaves in the Krasen Polissia variety up to 22 pcs plant^{-1}, in the Malakhit variety – up to 23 pcs plant^{-1}, which also dominated the control by 6–7 pcs plant^{-1}. The introduction of the pellets caused a slightly lower effect, but the advantage to control was quite high and was 5–6 pcs plant^{-1}.

The use of Eco products of different size and composition showed that the number of leaves in the spinach garden variety Krasen Polissia in accordance with the form of the drug corresponded to different indicators. The introduction of pellets with potassium contributed to the receipt of more leaves against control – 19–20 pcs plant^{-1}, which is higher than the control by 3–4 pcs plant^{-1}.

Growing spinach against the background of the use of various forms of absorbents helped to increase the area of the leaf. For making tablets in the Krasen Polissia variety it was 108.9 cm^2, in the Malakhit variety – 104.8 cm^2. The introduction of the gel in the Krasen Polissia variety increased the leaf area up to 113.1 cm^2, in the Malakhit variety – up to 112.5 cm^2, which exceeded the control by 6.9–7.3 cm^2 was quite high and was 3.3–6.9 cm^2.

The use of Eco products of different size and composition showed that the leaf area in Krasen Polissia varied according to the form of the preparation corresponded to different indicators and for the application of granules with potassium the leaf area was obtained 109,4–112,4 cm^2, average granules – 110,8–108.5 cm^2.

An important indicator of the growth of spinach plants, which determined its value as a green plant, was the total leaf area, the determination of which we carried out in the technical maturity phase of green (Table 1).

Table 1. The area of spinach leaves, depending on the absorbent, thousand m^2 ha^{-1}

Variety (Factor A)	Absorbent (Factor B)	Year				Average per
		2015	2016	2017	2018	2015–2018
Krasen Polissia	Without making absorbent	26.3	21.2	24.5	26.5	24.6
	Tablet	29.4	24.3	29.5	33.2	29.1
	Gel	39.4	27.3	37.6	40.1	36.1
	Granule	36.6	29.5	36.0	34.6	34.2
	Granule with Concrete	30.8	26.8	30.5	32.9	30.3
	Granule with Potassium	31.6	29.0	32.5	33.5	31.7
	Medium pellets	29.4	27.8	30.0	29.4	29.2
	Small granules	29.7	27.7	29.7	30.5	29.4
Malakhit	Without making absorbent	27.8	23.6	29.2	29.4	27.5
	Tablet	29.9	24.6	31.6	33.4	29.9
	Gel	37.9	30.1	41.1	43.2	38.1
	Granule	34.1	26.6	38.2	40.6	34.9
	Granule with Concrete	27.5	26.8	32.1	33.4	30.0
	Granule with Potassium	30.0	27.3	36.1	36.5	32.5
	Medium pellets	29.5	29.0	32.2	28.2	29.8
	Small granules	29.4	25.6	28.2	32.7	29.0

It is established that the area of spinach leaves in the variety Malakhit in the phase of technical maturity of the plant without the introduction of absorbent reached the level of 24.6 thousand m^2 ha^{-1}. The variants with the introduction of gel and granules of the company Maximarin – 34.2–38.1 thousand m^2 ha^{-1}, which exceeded the control by 9.6–13.5 thousand m^2 ha^{-1}, were higher indicators. The introduction of potassium pellets and medium pellets of Eco produced a positive result and the leaf area corresponded to 29.2–32.5 thousand m^2 ha^{-1}, which was higher than the control by 4.6–7.9 thousand m^2 ha^{-1}.

Increasing the weight of spinach plants leads to an increase in yield, an indicator by which we determine the suitability of new elements of technology for growing crops. The above data showed that the use of tablets helped to increase the weight of spinach plants in the phase of technical maturity in the variety Krasen Polissia up to 132 g, in the variety Malakhit –158 g, which was significantly higher than the control by 60–72 g (SSD_{05}, by Factor B = 17 g). Malakhit plants had a greater mass for the introduction of gel and pellets of the company ‘MaxiMarin’ – 171–178 g and granules with potassium of the company Eco – 150 g, which significantly outweighed the control by 42–70 g.

Improvement of conditions for growing spinach, even in less favourable climatic conditions, allowed to get more green mass. These green plants are characterized by the fact that they form a larger average mass than other green crops, such as dill, leaf lettuce, etc. The average weight of plants was counted each time the products were harvested, and the harvested green mass, which was cut in the form of sockets, was divided by its number (Table 2).

Table 2. Weight of spinach plant before harvest depending on absorbents' action, g

Variety (factor A)	Absorbent (factor B)	Year				Average per
		2015	2016	2017	2018	2015–2018
Krasen Polissia	Without making absorbent	120	87	104	120	108
	Tablet	132	106	120	132	123
	Gel	180	167	174	180	175
	Granule	189	159	163	185	174
	Granule with Concrete	175	101	140	169	146
	Granule with Potassium	178	143	146	178	161
	Medium pellets	112	87	99	112	103
	Small granules	101	176	139	101	129
Malakhit	Without making absorbent	125	147	136	125	133
	Tablet	158	122	160	158	150
	Gel	192	153	173	192	178
	Granule	189	140	165	189	171
	Granule with Concrete	130	128	129	130	129
	Granule with Potassium	152	136	154	157	150
	Medium pellets	121	123	121	112	119
	Small granules	130	117	148	150	136
SSD_{05}	*Factor A*	*12*	*15*	*10*	*11*	
	Factor B	*17*	*20*	*23*	*25*	
	Interaction AB	*63*	*54*	*65*	*60*	

Increasing the weight of spinach leads to the increase in yield, an indicator by which we determine the suitability of new elements of technology for growing crops. The above data showed that in 2015 the use of absorbent in the form of tablets helped to increase the weight of spinach in the phase of technical maturity in the variety Krasen Polissia up to 132 g, in the variety Malachite – 158 g. Higher indicators were obtained for the fertilization of gel by the company 'MaxiMarin' and potassium granules by the company 'Eco' – 180–192 g, which was significantly higher than the control of 60–72 g (SSD_{05}, by Factor B = 17 g).

Growing spinach varieties in 2016 showed that this indicator was less than last year, but compared to the control the above pattern was revealed. In 2017, the weight of spinach in technical maturity phase of Krasen Polissia and Malachite varieties with the use of absorbent in the form of tablets was significantly higher than the control (104 g) and reached the level of 120–160 g. There were higher indicators for plants fertilized by gel and granules of the company 'MaxiMarin' and potassium granules of the company 'Eco' – 146–173 g, which exceeded the control by 42–69 g (SSD_{05}, by Factor B = 23 g). The plant weight in 2018 was higher than the control (120 g) for the use of the absorbent in the form of tablets and reached the level of 132–158 g. According to the previous years, higher indicators differ in those plants which were fertilized by gel and granules of the company 'MaxiMarin' and granules with potassium of the company 'Eco' – 178–192 g, which is above the control by 58–72 g (SSD_{05}, by Factor B = 25 g).

The analysis of the data obtained during the years of research showed that at the beginning of a socket growth there was no significant difference between the variants and therefore this data is not presented in the paper. During the period of intensive growth of a socket and before harvest, the smallest amount of spinach was in the variety Krasen Polissia and Malachite without the fertilization, which was stated as 108 and

133 g in average during the years of research. Spinach of the variety Malachite had a greater mass for the fertilization of the granules and gel of the company 'MaxiMarin' and granules with potassium of the company 'Eco' – 171–178 g, which significantly outweighed the control by 63–70 g.

The yield of spinach varied according to the influence of weather conditions during the years of research and the preparations used (Table 3).

Table 3. The yield of spinach, depending on the absorbents, t ha^{-1}

Variety (factor A)	Absorbent (factor B)	Year				Average per 2015–2018	± to Control
		2015	2016	2017	2018		
Krasen Polissia	Without making absorbent	17.1	12.9	15.4	16.8	15.6	0
	Tablet	19.0	15.8	17.7	19.6	18.0	+2.4
	Gel	26.0	24.9	25.8	25.7	25.6	+10.0
	Granule	25.1	16.2	21.0	24.9	21.8	+6.2
	Granule with Concrete	18.5	15.8	19.6	18.5	18.1	+2.5
	Granule with Potassium	26.4	15.0	20.7	26.4	22.1	+6.5
	Medium pellets	14.8	25.9	20.4	15.1	19.0	+3.4
	Small granules	27.6	20.8	24.4	28.1	25.3	+9.7
Malakhit	Without making absorbent	18.5	21.2	19.1	18.5	19.3	+3.7
	Tablet	20.5	18.0	19.3	20.5	19.6	+4.0
	Gel	28.5	21.9	30.2	28.5	27.3	+11.7
	Granule	22.4	23.9	24.7	26.4	24.4	+8.8
	Granule with Concrete	19.3	18.9	19.1	19.3	19.2	+3.6
	Granule with Potassium	22.6	21.7	24.7	23.6	23.2	+7.6
	Medium pellets	17.9	18.7	18.3	17.9	18.2	+2.6
	Small granules	16.3	16.4	21.4	22.3	19.1	+3.5
SSD_{05}	*Factor A*	*0.3*	*0.4*	*0.3*	*0.2*		
	Factor B	*0.7*	*0.9*	*0.8*	*0.7*		
	Interaction AB	*0.9*	*1.4*	*1.3*	*1.6*		

A significant increase in the spinach crop was obtained from the application of the gel, where the yield of the Krasen Polissia variety was 25.6 t ha^{-1}, and the Malakhit variety – 27.3 t ha^{-1}, which was additionally 10–11.7 t ha^{-1}. The introduction of 'MaxiMarin' pellets helped increase yields to 21.8–24.4 t ha^{-1} and outperformed control by 6.2–8.8 t ha^{-1}. The introduction of Eco potassium pellets resulted in a lower yield of 22.1–23.2 t ha^{-1} and a control of 6.5–7.6 t ha^{-1}. A positive result was obtained with the use of medium and small pellets for the varieties of sMalakhit and Krasny Polissia, and the yield increased by 2.6–9.7 t ha^{-1}. The introduction of concrete pellets allowed additional 2.5–3.6 t ha^{-1}.

The results of the variance analysis of the obtained data showed that factor B or absorbent and interaction of factors had the greatest influence on the spinach yield (Fig. 2).

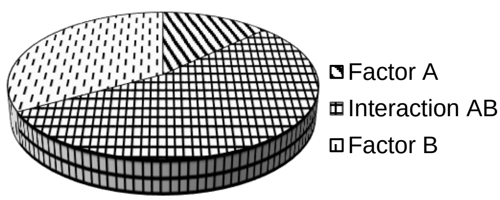

Figure 2. Effect of factors on vegetable spinach yield depending on the absorbent input (average for 2015–2018), t ha^{-1}.

Factor B or absorbent was affected the spinach yield by 33%, the interaction of factors A and B – 54% in the Malakhit variety being more influential.

The absorbents did not cause any negative changes in the plants and had a positive effect on the quality of the vegetable spinach crop and contributed to the increase of important chemical composition. Higher dry solids content in Krasen Polissia and Malakhit varieties was observed with the use of 'MaxiMarin' granules and gel absorbents – 8.1–8.9%.

The higher sugar content was different for plants grown using 'MaxiMarin' absorbents in the form of granules and gel – 2.6–2.9% and potassium granules of Eco – 2.7–2.8%. The content of vitamin C was dominated by plants grown with the use of Maximarin absorbents in the form of granules and gel – 56–62% and potassium granules of Eco – 58–64%.

CONCLUSIONS

From the use of plant growth regulators during processing of spinach seeds, a higher profitability of the Malachit variety was obtained for the use of absorbents in the form of gel and granules – 83–102 %. The bioenergy efficiency ratio was more than unity, which indicates the efficiency of growing spinach 3.0–3.1). The use of absorbents from 'MaxiMarin' for growing spinach contributed to its faster germination, increased plant growth and development, and resulted in an increase in yields of commodity products by 2.0–6.1 t ha^{-1}.

Scientific novelty and practical significance of the obtained results

In the conditions of the Forest-Steppe of Ukraine, experimental researches were carried out, which allowed to solve particular questions of spinach growing technology and proved that the absorbents in arid conditions of the modern climate are effective for increasing the productivity of spinach, for which the quality of produce is not impaired. The influence of the variety on the weight and height of the plant, the area of the leaf blade and the total area of the leaves, correlation dependence between the indices of plant growth, yield depending on the developed elements of spinach growing technology.

Based on the conducted research, it is developed and recommended for agricultural producers of industrial, private and personal sector to grow domestic early ripening varieties of spinach of the city Krasen Polissia and Malakhit. Absorbents in arid conditions of modern climate contribute to increase of spinach of vegetable garden and reception of high quality of production.

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