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Technological Improvement of *Echinacea purpurea* Cultivation

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ABSTRACT

Echinacea purpurea is a unique plant of the North American flora. One of the reasons for the popularity of the herb is the possibility of its use to treat a multitude of diseases caused by a weakened immune system. The purpose of the research was to improve the technological support of Echinacea cultivation under irrigated conditions of the south of Ukraine. The scheme of three-factor field experiment was presented by the options of technological measures listed below: moldboard and non-moldboard methods of basic tillage to a depth of 20–22 cm; seeds processing with Ahrostymulin plant growth regulator compared to the untreated control; three sowing periods, including 3rd decade of March, as well as 1st and 2nd decades of April. Among the various combinations of the basic tillage methods and the sowing module elements, the yield of rhizomes and roots of Echinacea was maximal (2.58 t/ha) in the variant of plowing at the depth of 20–22 cm, seeds treatment with Ahrostymulin, sowing in the 3rd decade of March. The combination of such gradations of investigated factors provided the highest content of extractives in the Echinacea roots at the level of 30.2% and their conditional output of 779 kg/ha. In this option, the maturation of roots was observed at the earliest time, which is important in the technological context for both Echinacea harvesting and soil preparation for the next crop cultivation. Introduction of the best options for each of the studied factors in the technology of Echinacea cultivation will ensure a combination of their positive effects and creation of a favorable agronomic background for the formation of rhizomes and roots with a high content of extractives.

Keywords: method of basic tillage, moldboard plowing, seeds treatment with plant growth regulator, Ahrostymulin, seeding date, yield of rhizomes and roots, content of extractives, conditional output of extractives.

INTRODUCTION

Echinacea purpurea is a unique plant of the North American flora, which prevails over other species in its significance, distribution and degree of study (Collins and Berkoff 1998, Coelho et al. 2020). Its history represents a path from a remedy against snake bites and the status of the "Queen of Medicines" in the Indian tribes to worldwide recognition as a stimulator of the immune system (Conkling 1999, Manayi et al., 2015).

Echinacea was imported to Ukraine more than 70 years ago. Today, it is widespread in all regions and dominates over other medicinal plants, but its sown areas are restricted and concentrated in research institutions and enterprises, specialized on the herbs cultivation, also in some farms, and homesteads (Rudnyk-Ivashchenko et al., 2017).

Over the past half century, researchers have studied and in many cases testified to the therapeutic efficacy of Echinacea. One of the reasons for the popularity of the herb is the possibility of its use to treat a multitude of diseases caused by a weakened immune system (Hudson 2012, Seckin et al., 2018). Today, the repute of Echinacea drugs as effective remedies with a broad spectrum of action continues to grow worldwide (Parsons et al., 2018). Echinacea in various formulations is prescribed for the prevention and treatment of colds, flu, other infections, as well as wounds, skin diseases, burns etc. (Ross 2016, Nyalambisaa et al., 2017).

Much is known about the healing properties of Echinacea, but the arsenal of its pharmacological action has not yet been exhausted and not fully disclosed, as evidenced by scientific research. Due to the COVID-19 pandemic, extremely relevant studies are being conducted on the effectiveness of Echinacea for the prevention and therapy of coronavirus infection and other respiratory diseases (Aucoin et al., 2020, Kembuan et al., 2020).

Besides studying the Echinacea pharmacological value, another significant aspect of its investigation is the elaboration and adjustment of cultivation technology to increase the output of herbal raw materials, the rational use of natural and logistical resources (Attarzadehab et al., 2020, Bayer 2021). Growing crops under regulated technological conditions will provide an increase the yield of active substances and reliability of production results (Chen et al., 2016).

MATERIALS AND METHODS

The purpose of the research was to improve the technological support of Echinacea cultivation under irrigated conditions of the south of Ukraine. Echinacea was grown to obtain rhizomes and roots as a biennial crop, so the study was conducted in 2017–2020, and accounting of the yield and quality of medicinal raw materials was performed in 2018–2020. The location of experiment was the lands of Nyva farm of Vysokopillia settlement territorial community of Beryslav district of Kherson region.

The scheme of three-factor field experiment was presented by the listed below options of technological measures:

1. Factor A – method of basic tillage:
   a) moldboard tillage at the depth of 20–22 cm;
   b) non-moldboard tillage at the depth of 20–22 cm;
2. Factor B – seeds treatment with plant growth regulator:
   a) without treatment (control);
   b) Ahrostymulin;
3. Factor C – seeding date:
   a) 3rd decade of March;
   b) 1st decade of April;
   c) 2nd decade of April.

The method of randomized parted plots was used to establish the experiment. The total and accounting areas of the subplot of the 3rd order factor were 70 and 55 m^2, respectively.

Comparative evaluation of the effectiveness of different methods of basic tillage and seeding dates, as well as analysis of the possibility of using a growth-promoting preparation for processing of sowing material, were performed on the indicators of Echinacea rhizomes and roots yield, content of extractives in medicinal raw stuff and their conditional output. In the second year of cultivation, the dates of spring regrowth of plants and roots maturity, the duration of the vegetation period were determined. The conducted records and observations, were guided by widely tested methods (Ushkarenko et al., 2020).

The agrotechnical measures of Echinacea cultivation, except for the investigated options, complied with the zonal recommendations. The elements of the crop growing technology were performed in the optimal calendar and phenological terms, which contributed to obtaining reliable results.

The variety of *Echinacea purpurea* Charivnytsia was cultivated. It was created by the scientists of Research Station of Medicinal Plants of the Institute of Agroecology and Nature Management. The cultivar is late ripening, characterized by such agronomically valuable traits as resistance to drought, diseases, shedding of seeds, and mechanized growing technology.

In crop rotation, Echinacea was placed after winter barley. Fertilizers, such as ammonium sulphate and double granulated superphosphate, were applied to the basic tillage at the rate of $N_{60}P_{60}$ reactant per ha. In the options of studying the effectiveness of growth-promoting substances, the processing of Echinacea seeds was carried out in the pre-sowing period with the Ahrostymulin preparation, developed at the National Enterprise "Agrobiotech". It is a mixture of plant growth stimulators of natural origin and synthetic analogues of phytohormones with a wide spectrum of effect. Its primary substances are the products of fungi vital activity and 2.6-dimethylpyridine-1-oxide.

The dates of the sowing were set according to the experimental scheme from the period of soil physical maturity with an interval of a decade. Sowing was carried out at the rate of 1.5 million germinated seeds per ha to a depth of 2–3 cm with the spaces between rows of 45 cm, while making P_{10}. During each year of Echinacea vegetation, three waterings at a rate of 400 m^3/ha were carried out using the frontal sprinkler machine. Soil humidity in the calculated layer of 0.7 m was maintained at 75% of the lowest moisture capacity.

Rhizomes and roots were harvested in autumn after the completion of the Echinacea vegetation period. The underground organs were dug up by the potato digger, harvested by hand, washed under running water, dried and weighed. Raw materials were analyzed for the humidity and content of organic adulterants. Besides, determination of organoleptic indicators, in particular color, odor, taste, and the linear parameters of roots, such as length, diameter, volume, was carried out. The quality of raw materials was assessed by preparing of water-alcohol extracts and determining the content of extractives.

The territory of the zone is differentiated by excessive amount of sunlight and thermal resources, a long frost-free period, and insufficient rainfall. Precipitation is distributed quite unevenly on the territory, by years and periods of the year. There are long rainless periods, seasonal soil and atmospheric droughts, dry winds, dust storms. The lack of moisture is one of the restrictive factors of the formation of high stable yields of the crops, which necessitates irrigation. Average annual air temperature is 9.8°C, the amount of rainfall – 300-360 mm, and coefficient by Selianynov – 0.6.

The soil cover of the farm is presented by a dark chestnut subtype, which occupies large areas in the zone. Substantive potential of these soils is provided by the average humus supply at the level of 2.1–3.4%, significant gross reserves of basic nutrients, but its implementation is limited by lack of moisture, low content of available forms of nitrogen and negative physicochemical parameters due to salinization. On the experimental field, the agrochemical properties of the tillable layer are characterized by the following indicators, expressed in mg per 100 g of the soil: NO_3^- – 2.7, P_2O_5 – 3.2, K_2O – 26.0.

RESULTS AND DISCUSSION

An important condition for the realization of the productivity potential of Echinacea, taking into account its cultivation in the field for two years, is conducting scientific research to select the most favorable option for the interaction of basic technological measures that would have a positive impact on the growth processes of plants from the first stages of their ontogenesis, long-term influence on the crop development, formation of rhizomes and roots, and accumulation in them of a complex of biologically active compounds.

The comparison of the average factor values of rhizomes and roots yield allowed analyzing the general patterns of influence of technological measures in absolute and relative terms. Plowing at the depth of 20–22 cm increased the yield of rhizomes and roots of Echinacea by 0.30 t/ha (15.7%) compared to non-moldboard tillage at the same depth. The treatment of Echinacea seeds with Ahrostymulin plant growth regulator had a positive effect in comparison with the variant without its use, which was expressed by the yield increment of rhizomes and roots at 0.19 t/ha (9.7%). When Echinacea was seeded in the 3rd decade of March, the improvement of the conditions of underground plant organs formation was confirmed by the growth in the yield of rhizomes and roots at 0.26 t/ha (12.8%) and 0.44 t/ha (23.8%) compared to the second and the third investigated periods, respectively. Thus, changing of plowing to non-moldboard tillage, using seeds untreated with plant growth regulator and sowing at a later dates adversely affected the formation of rhizomes and roots of Echinacea (Table 1).

Among the various combinations of the basic tillage methods and the sowing module elements,

Table 1. Yield of Echinacea rhizomes and roots in the second year of vegetation under the influence of the investigated factors, t/ha

Method of basic tillage, factor A	Seeds treatment with plant growth regulator, factor B	Seeding date, factor C			Average for factor A	Average for factor B
		3rd decade of March	1st decade of April	2nd decade of April		
Moldboard tillage at the depth of 20-22 cm	without treatment (control)	2.32	2.09	1.91	2.21	1.96
	Ahrostymulin	2.58	2.28	2.07		2.15
Non-mold-board tillage at the depth of 20-22 cm	without treatment (control)	2.03	1.80	1.63	1.91	
	Ahrostymulin	2.24	1.96	1.77		
Average for factor C		2.29	2.03	1.85	2.06	
LSD_{05}, t/ha: A = 0.037; B = 0.037; C = 0.054; ABC = 0.096						

the yield of rhizomes and roots of Echinacea was the maximal (2.58 t/ha) in the variant of plowing at the depth of 20–22 cm, seeds treatment with Ahrostymulin, sowing in the 3rd decade of March. The degree of influence of seeds treatment with Ahrostymulin plant growth regulator in this interaction of gradations of the studied factors was higher than the values of the other variants and amounted to 11.2%. This option can be considered the most effective in the experiment in the context of positive influence on the formation of raw materials and the highest yield of Echinacea.

Rhizomes and roots of Echinacea contain a complex of biologically active compounds, which are characterized by immunostimulatory and anti-inflammatory activity, so the quality of medicinal raw materials is determined by the content of the sum of extractives. The composition of root extracts includes chlorogenic, caftaric, cafeic, and cichoric acids, different alkamides, etc. (Gajalakshmi et al., 2012, Lim 2014).

Among the studied methods of basic tillage, the advantage of moldboard plowing was noted in the content of extractives in Echinacea rhizomes and roots, which was higher by 0.3–0.5% compared to non-moldboard tillage. The greatest positive effect on the accumulation of extractives in the rhizomes and roots of Echinacea was observed, when the Ahrostymulin plant growth regulator was used for seeds treatment before sowing. Seeds processing with Ahrostymulin provided an improvement in quality indicators as a result of increasing the content of extractives by 0.9–1.2%, compared to the variant without using of growth-regulating agents. In the option of sowing in the 3rd decade of March, extractives were accumulated in the underground organs of plants in 0.4–0.9% greater amount than in the other two studied seeding periods. The combination of such gradations of investigated factors as moldboard plowing, seeds treatment with Ahrostymulin, and sowing in the 3rd decade of March provided the highest content of extractives in the rhizomes and roots of Echinacea at the level of 30.2% (Fig. 1).

The calculations indicate the possibility of obtaining the highest yield of Echinacea extractives in the experiment at the level of 779 kg/ha in the variant of moldboard tillage to a depth of 20–22 cm, seeds treatment with Ahrostymulin, sowing in the last decade of March. The minimum conditional output of extractives (456 kg/ha) testifies to the least favorable conditions for the roots formation and accumulation of extractives in them under the influence of such gradations of the studied factors as non-moldboard tillage at the depth of 20–22 cm, using of sowing material untreated with growth-promoting preparations, and seeding in the 2nd decade of April (Table 2).

In the experiment, the influence of the method of basic tillage on the conditional output of extractives from Echinacea rhizomes and roots can be evaluated in relative terms as 17.5%, the impact of seeds treatment with growth regulator at the level of 13.8%, while the effect of sowing period as 27.5%.

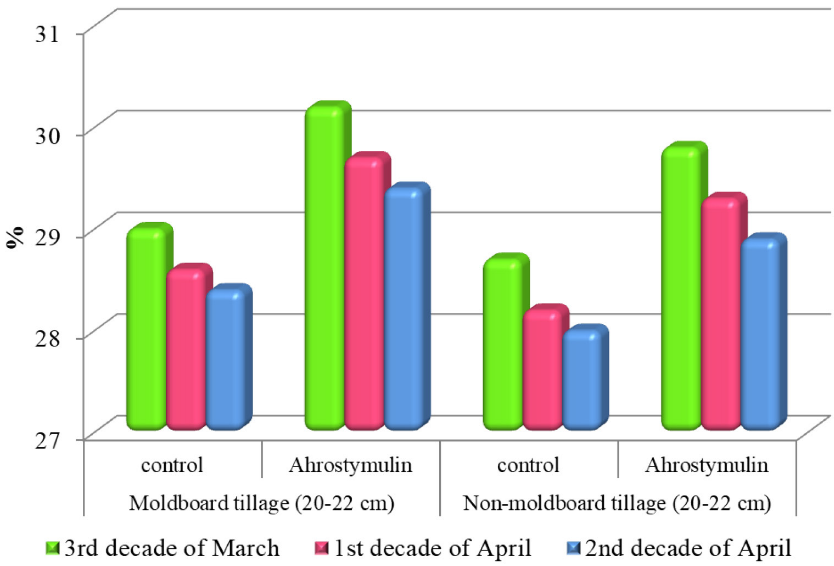

Figure 1. Content of extractives in Echinacea rhizomes and roots in the second year of vegetation under the influence of the investigated factors, %

Table 2. Conditional output of extractives from Echinacea rhizomes and roots in the second year of vegetation under the influence of the investigated factors, kg/ha

Method of basic tillage, factor A	Seeds treatment with plant growth regulator, factor B	Seeding date, factor C			Average for factor A	Average for factor B
		3rd decade of March	1st decade of April	2nd decade of April		
Moldboard tillage at the depth of 20-22 cm	without treatment (control)	673	598	542	646	560
	Ahrostymulin	779	677	609		637
Non-mold-board tillage at the depth of 20-22 cm	without treatment (control)	583	508	456	550	
	Ahrostymulin	668	574	512		
Average for factor C		676	589	530	598	

When elaborating the technology of Echinacea cultivation, it is necessary to take into account not only increasing the yield of rhizomes and roots, improving their quality characteristics, but also the timing of maturity, which determines the dates of harvesting. Prolongation of the harvesting period in autumn can lead to a greater negative impact of precipitation, lower temperatures, root rot on the quality of raw materials, complicate the digging of roots as a result of changes in the physical stage of the soil. In addition, the quality of the tillage for growing the next crop in rotation depends on the time of field release (Table 3).

Spring regrowth of Echinacea plants in the second year of cultivation was observed in late March – early April, rhizomes and roots matured in the 1-2nd decades of October. The vegetation period lasted under the influence of agrotechnical measures from 189 to 197 days. The earliest revival of spring vegetation of Echinacea plants in the second year of cultivation was provided by moldboard plowing and sowing in the 3rd decade of March with seeds pre-treated using Ahrostymulin growth regulator. The rhizomes and roots in this plots also matured the first in the experiment – the 2nd of October, and the vegetation period was the shortest, its duration was 189 days. This option provided the best results in the yield of rhizomes and roots, content of extractives and their conditional output, as well as roots dynamic formation and maturation at the earliest time, which is important in the technological context for both Echinacea harvesting and soil preparation for the next crop cultivation.

The variant of non-moldboard tillage, sowing in the 2nd decade of April with the seeds untreated with growth-regulating preparations was

Table 3. Dates and duration of the Echinacea vegetation period in the second year of growing under the influence of the investigated factors

Method of basic tillage, factor A	Seeds treatment with plant growth regulator, factor B	Seeding date, factor C	Date of spring regrowth	Date of maturity of rhizomes and roots	Duration of the vegetation period, days
Moldboard tillage at the depth of 20-22 cm	without treatment (control)	3rd decade of March	31.03	09.10	193
		1st decade of April	01.04	11.10	194
		2nd decade of April	03.04	14.10	195
	Ahrostymulin	3rd decade of March	28.03	02.10	189
		1st decade of April	29.03	05.10	191
		2nd decade of April	31.03	08.10	192
Non-mold-board tillage at the depth of 20-22 cm	without treatment (control)	3rd decade of March	01.04	10.10	193
		1st decade of April	03.04	14.10	195
		2nd decade of April	05.04	18.10	197
	Ahrostymulin	3rd decade of March	29.03	04.10	190
		1st decade of April	30.03	08.10	193
		2nd decade of April	31.03	11.10	195

characterized by the latest dates of spring regrowth of Echinacea plants and rhizomes and roots maturity – on the 5th of April and 18th of October, respectively. The duration of the vegetation period on such agrotechnical background reached 197 days and was the longest in the experiment.

Non-moldboard tillage caused a delay of spring vegetation recovery by 1-2 days, ripening of rhizomes and roots by 1-4 days, in comparison with plowing. An increase in the duration of the vegetation period as a result of changing the method of basic tillage from moldboard to non-moldboard was 1-3 days.

The processing of Echinacea sowing material with Ahrostymulin growth regulator contributed to a faster beginning and completion of plants vegetation compared to the option of using untreated seeds. Spring regrowth was observed earlier for 3-5 days, maturity of the plants underground organs for 6-7 days. The vegetation period was reduced by 2-4 days under the influence of the studied growth-regulating preparation.

The positive impact of seeding in the 3rd decade of March on the development of Echinacea plants was recorded in the second year of vegetation. Spring regrowth of plants began 1-2 days earlier, the phase of rhizomes and roots maturity was 2-4 days earlier compared to the variant of seeding in the 1st decade of April. The dates of the vegetation beginning and finishing were obtained 2-4 and 5-8 days earlier, respectively, in comparison with the variant of sowing in the 2nd decade of April. The duration of the plants vegetation period on the plots of seeding in the 3rd decade of March was shorter, respectively, by 1-3 and 2-5 days compared to the second and third studied periods.

The patterns of impact of the technological measures on the results of Echinacea cultivation defined in the field trials were comparable with the conclusions drawn by scientists for other crops and combinations of factors.

The yield of sugar beet was substantially decreased by direct drilling, in comparison with the moldboard plowing to a depth of 25–30 cm (Koch et al., 2009). Moldboard plowing was recognized as the best variant for the indicator of potato yield compared to the soil preparation with disk harrow and chisel plow (Al-Hamed et al., 2016). The analysis of the yield of potato tubers showed the advantage of standard tillage system that included the moldboard plowing to a depth of 30 cm (Drakopoulos et al., 2016).

When growing milk thistle, the best results of seed productivity were provided by plowing at the depth of 20–22 cm and sowing in the last decade of March in cooperation with the other factors, namely the nutrition background and the spaces between rows (Vozhehova et al., 2018). The yield of safflower seeds was also higher after plowing to the same depth, and the best results of fennel productivity were provided by the sowing in the analogous period, but the above-mentioned options were investigated in combination with diverse technological measures (Vozhehova et al., 2019, Makukha 2020).

The prospects for the use of growth regulators in the technology of Echinacea cultivation have been confirmed by the results of studies of seeds processing with gibberellic acid (Farhoudi et al., 2010). The complex of three bacteria and mycorrhizal inoculum had a favorable effect on the biometric and yield characteristics of aboveground and underground Echinacea plant organs (Hajagha et al., 2017). The seeds treatment of sweet basil, peppermint, and coriander with growth-regulating substances, in particular indole-3-acetic, gibberellic, naphthalene acetic, and indol-3-butyric acids, helped to improve its germination, but among them gibberellic acid prevailed (Elhindi et al., 2016).

CONCLUSIONS

The yield of Echinacea rhizomes and roots, as well as the content of extractives in them depend on the level of agricultural technology. Optimization of the plant growing conditions by determining the most acceptable gradations of traditional technological measures will allow purposefully adjusting the crop productivity. Among the methods of basic soil tillage, the best indicators were provided by moldboard plowing at the depth of 20–22 cm. Among the seeding dates, the 3rd decade of March was the most effective. Promising from the point of view of improving the results of production of Echinacea medicinal raw materials is the expansion of the elements of technological support due to the processing of seeds in the pre-sowing period with Ahrostymulin growth-promoting preparation. Introduction of the best options for each of the studied factors in the technology of Echinacea cultivation, namely the moldboard method of basic tillage at the depth of 20–22 cm, seeds treatment with growth regulator Ahrostymulin, early sowing in the 3rd decade of March, will ensure a combination their positive effects and creation of a favorable agronomic background for the formation of rhizomes and roots with a high content of extractives.

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