JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2023, 24(8), 250–259
https://doi.org/10.12911/22998993/166553
ISSN 2299–8993, License CC-BY 4.0

Received: 2023.04.24
Accepted: 2023.06.16
Published: 2023.06.20

Formation of the Yield of *Matricaria recutita* and Indicators of Food Value of *Sychorium intybus* by Technological Methods of Co-Cultivation in the Interrows of an Orchard

Mykola Bakhmat[1], Tatiana Padalko[1], Tatiana Krachan[1], Oleg Tkach[1], Hanna Pantsyreva[2*], Liliya Tkach[1]

[1] Higher Educational Institution, Podillia State University, Department of Postgraduate Studies Shevchenko 12, 32316 Kamianets-Podilskyi, Ukraine

[2] Vinnytsia National Agrarian University, Faculty of Agronomy and Forestry Sonyachna St. 3, 21008 Vinnytsia, Ukraine

* Corresponding author's e-mail: apantsyreva@ukr.net

ABSTRACT

This study was aimed at theoretical generalizations and experimental results of research on the influence of the combined cultivation of medicinal plants wild chamomile (*Matricaria recutita* L.) and root chicory (*Sychorium intybus* L.) in the rows of gardens, which actualizes the issue of increasing productivity in industrial orchards. Therefore, the authors strove to increase the efficiency of growing research crops using fruit plantations, thereby ensuring a shortened payback period for capital investments spent on their creation. The conducted scientific studies have shown that the effect of aster yield on the content of bioactive substances in medicinal plant raw materials depends on the type of soil and climatic conditions of the studied territory, the cultivar, the sowing period, the genetic characteristics of the seeds, and the sowing conditions, etc. The purpose of the conducted research was to determine the patterns of crop formation of the presented medicinal plants in the inter-row orchard according to the elements of agricultural techniques of cultivation under the agroecological conditions of the Right Bank Forest Steppe of Ukraine. As a result of the conducted research, the expediency of cultivating existing plants on the area of the allotted plot was confirmed. The optimal timing of autumn sowing for cultivar 'Perlyna Lisostepu' with a seeding rate of 6 kg/ha and a yield of dry mass of inflorescences of 1.81 $t \cdot ha^{-1}$ was studied. The main indicators of the seedless method of planting chicory root crops of the second year for wintering in the open ground were established, while 35–40 $t \cdot ha^{-1}$ of high-quality root crops were obtained. Using the methods of qualitative and quantitative analysis, the raw materials of chamomile medicinal cultivars 'Perlyna Lisostepu' and 'Bodegold' were investigated for the content of flavonoids, chamazulene and its derivatives, as one of the important indicators of the quality of the essential oil, as well as the component composition of the root chicory cultivars 'Umansky-99' and 'Umansky-97', in relation to the quantitative ratio hydroxycinnamic acids and flavonoids in a 1:1 infusion. Accumulation of inulin continued throughout the growing season of root chicory, reaching the optimal content at the beginning of technical ripeness, and the highest rate was 11.5–17.51% in the sub-winter sowing period.

Keywords: medicinal chamomile, root chicory, productivity, chemical composition, quality of raw materials, compatible plantings.

INTRODUCTION

The strategic task of Ukrainian agricultural production is to increase the demand for plant products and obtain a stable assortment of them. For the effective use of the biological potential of cultivars as well as natural and climatic resources under the conditions of the forest-steppe of the Right Bank of Ukraine, the development and implementation of innovative technologies in the elements of the production of plants of the aster family (Asteraceae): medicinal chamomile (*Matricaria recutita* L.) and root chicory (*Sichorium intybus* L.) is relevant for maximum yield and quality of raw materials. The aster family is represented throughout the world and in all climate zones. The main common feature of the plants of this family are daisy-like flowers, which, when studied in detail, have a basket inflorescence consisting of two types of flowers: tubular and reed (Shevchuk, Holunova, 2019; Haji Akber et al., 2020; Kviatkovskyi et al., 2022; Padalko, 2022).

Matricaria recutita L. – a valuable medicinal plant the raw materials of which are rich in natural antioxidants, essential oils and other bioactive metabolites with antioxidant, anti-inflammatory, antiseptic, antispasmodic, emollient and choleretic properties and other functions that have a wide range of uses. The potential of its use is based on the improvement of the elements of organic cultivation technologies, which contributes to the increase of the quantitative and qualitative potential of crop production (Hadi et al., 2015; Sah et al., 2022; (Pantsyreva et al., 2019). *Cichorium intybus* L. – medicinal, technical plant, the root of which contains polysaccharide inulin, glycoside intibin, various tannic and organic acids, proteins, pectin substances and resins. Leaves and stems contain carotene, carbohydrates, choline, vitamins, and minerals (Street, 2013; Baranovsky et al., 2017).

There is a global technological tension between the intensification of production and the rational use of natural resources in the search for safe technologies for growing agricultural crops, including garden crops. Owing to this approach, new features are created in the biome garden. A well-developed root system is a habitat for many soil organisms. They provide shade for grass to grow on hot summer days, and they also form mulch and litter to fertilize the soil (Pantsyreva et al., 2020). The intensification of the production of medicinal chamomile and medicinal chicory requires the use of new technologies to compensate for natural resources as well as ensure increased productivity and economic efficiency, therefore growing medicinal plants on garden paths is desirable.

Economic efficiency can be enhanced by improving cultivation techniques without the use of pesticides and harvesting organic products of appropriate quality that contain certain derived compounds. There is a great interest in this technology because today's non-observance of classic crop rotations is a consequence of an imbalance in the agroecosystem, manifested by problems of pest, disease and weed control (Mirzoieva, 2020; Smielova, 2018; Puyu et al., 2021). Chamomile was grown for three years in a row, and chicory, a perennial crop, was studied under siderate conditions. In the absence of organic fertilizers, soil fertility decreases. Therefore, since both medicinal and fruit crops need organic fertilizers, siderates ensured a positive balance of organic matter in the soil as well as improved its physical and chemical properties.

For the cultivar, the area of distribution is characteristic. This is since cultivars formed under other conditions cannot guarantee the expected yield results if they lack environmental plasticity (Caballero-Serrano et al., 2019; Wan et al., 2019). The second important issue when evaluating the yield of the studied cultivars is the profitability of the culture and the economic feasibility of its cultivation on the world market.

An important place among agrotechnical measures in the technology of growing chamomile and root chicory is the sowing period. It has been proven by many years of research that the sowing period allows obtaining friendly seedlings, to optimally form the phases of growth and development of plants, ensuring uniform technical ripeness, and carrying out mechanized or manual harvesting with high quality indicators, since the yield of these crops depends on many conditions (Mazur et al., 2018; Honcharuk et al., 2022). In Ukraine, the majority of production farms that grow medicinal and essential oil crops are private enterprises, individual entrepreneurs, farms and peasant farms. The list of cultivated crops depends solely on the market conditions: the crops grown 10 years ago are very different from those grown today. The difference lies not only in the peculiarities of the biology of crops, but also in the peculiarities of assessing the quality indicators of raw materials. Therefore, the main task of farms, industrial enterprises and research centres is to obtain the products that meet the requirements of national standardization and can be successfully sold on the world market (Mazur et al, 2021).

The purpose of the study was to investigate the features of yield formation and indicators of quality and nutritional value of modern high-yielding cultivars of chamomile and root chicory in garden and park plantations under the conditions of the Right Bank Forest Steppe of Ukraine.

MATERIAL AND METHODS

The uniqueness of this research lies in the fact that Ukrainian scientists have conducted a small number of reliable studies of the presented crops, which is of considerable value, and also in the fact that the joint cultivation of medicinal plants in horticulture can be a reserve for increasing the commercial profitability of crops in the garden (Song et al., 2010). Scientific research on the effect of technical factors on productivity has been published in scientific papers, but there is a wide range of technical methods and new research is needed. According to the generally accepted methodology, oil radish was taken; these crops were grown on siderate, and the authors were interested in the problem of determining the best factors in previous studies. According to the amount of vegetable mass of oil radish in absolute dry matter of 3% nitrogen, 1% phosphorus and 3% potassium, it is possible to obtain a yield of siderates at the level of up to 40 t/ha, when applying $N_{75-120}P_{20-30}K_{50-70}$, to the soil, as a result of ploughing in the indicated amount of radish (Doslidna sprava v ahronomii, 2016).

The object of research involves the processes of individual growth and development of plants, the productivity of chamomile and chicory in the inter-row orchard, the study of indicators of quality and nutritional value depending on the studied factors under the conditions of the Right Bank Forest Steppe of Ukraine. Experimental research was conducted in 2020–2022 as part of stationary field experiments in the Right Bank Forest-Steppe zone of Ukraine, which made it possible to make the most of the natural resources of the region and reduce the impact of adverse weather conditions on the growth and development of crops. The study of productivity indicators of medicinal crops in joint cultivation was carried out in four-fold repetition using four rows of control trees. Clean steam was provided by disking to a depth of 15 cm and manual weeding (four times during the growing season). The rest of the care was the same for each option. The care of medicinal plants consisted of manual weeding. Mineral fertilizers, synthetic chemical plant protection agents and irrigation were not used. The test for medicinal chamomile is three-factor: factor A – cultivars 'Perlyna Lisostepu' and 'Bodegold'; factor B – sowing dates: spring (III period of March), summer (III period of June), and autumn (III period of September); factor C – optimal seeding rate: 6 kg ha^{-1}. For root chicory – factor A – cultivars: 'Umansky-99' and 'Umansky-97'; factor B – sowing dates: winter I period of October-November, early spring (I period of April-May) and summer (I period of June-July). The total area of the organic garden is 1.0 ha, and half of the area (0.5 ha) has natural grass growing as a living mulch since 2019, which is mowed periodically (the mowed mass remains in place). The size of elementary plots of the presented medicinal plants is 40 m^2, accounting – 24 m^2. Cereals constituted the predecessor. The plot for chamomile was chosen for three years due to dense self-sowing. Soil cultivation was carried out in the area between the rows of apple orchards, with a short cycle in a special rotation of grain crops. The main cultivation of the soil was carried out to a depth of 22–25 cm. For ploughing the soil before sowing, a cultivator with arrow feet was used. Tillage was carried out at the same time as sowing with a tooth harrow, or rolling, if the soil was not sufficiently moist. Ploughing was carried out at an angle to cultivation, which was carried out to a depth of 4–6 cm for better levelling of the soil surface and ensuring high quality of sowing. In spring, the main tillage was pre-sowing, and sowing was carried out with a vegetable seeder to a depth of 1.5 cm, in a wide-row method against the background of applying 15 t/ha of organic fertilizers.

The soil of the experimental field is chernozem, chernozem, gilded with coarse dust and medium loam on loess-like loams. Humus content (according to Tyurin) in the 0–3 cm soil layer is 2.8–3.6%. The content of easily hydrolysable nitrogen compounds (according to Kornfield) is 9.0–11.6 mg per 100 g of soil, mobile phosphorus (according to Chirikov) 6.0–8.5 and exchangeable potassium (according to Chirikov) – 6.9–10.0 mg per 100 g of soil (Pankiv, 2017).

The analysis of climatic conditions and the level of their variability during the research period was carried out according to the methodology described in the recommendations "Fundamentals of applied mathematical analysis in agricultural research" (V.F. Kaminsky). According to phenological observations of the phases of plant growth and development in field experiments, 10% of plants entered the initial phase, and 75% of plants entered the full phase on the day of entry into the full phase. The study of growth of plant volume and dry matter accumulation was carried out according to the main phases of plant development by the sampling method. The soil and climatic conditions of the Right Bank Forest Steppe of Ukraine are diverse, which makes it necessary to sow chicory at different times, as this is an important factor in the technology of growing this crop. Successfully selected sowing times make it possible to obtain friendly seedlings, ensure the optimal start of the phases of growth and development of plants, uniform ripening of the crop and suitability for long-term storage, and maintain high quality indicators (Travel forecast for all populated points of Ukraine, 2019).

In order to create the most favourable conditions for the appearance of friendly and uniform chicory seedlings, their further development, the formation of high yields and the effective use of mechanization means, sowing must be carried out in the optimal agrotechnical terms, and the optimal sowing rate and depth of seed wrapping should be established. The main criterion for evaluating any technical measures, such as the method of sowing and the rate of sowing, is the germination of seeds and the yield of plants. The yield of raw materials was determined by separating and drying the inflorescences of each variant of the experiment to 100% purity and standard humidity. The results of the study were processed by the method of dispersion and correlation analysis.

When determining the productivity, the number of accounting plots was sufficient so that the error was no more than 15% during statistical processing. All raw phytomass was collected at each accounting site in accordance with the requirements of the instructions for collecting and drying this type of raw material. Germination, juvenile or damaged specimens were not subject to collection. The collected raw materials were immediately weighed with an accuracy of ±5%, calculated as air-dry raw materials. On the basis of the data on the yield of Medicinal Plant Raw Materials on individual plots, the average yield on this industrial area was calculated (Doslidna sprava v ahronomii, 2016).

Preparation of samples for analysis was carried out according to the methodology approved by the State Pharmacopoeia of Ukraine. For this purpose, 1000 g of appropriately prepared raw materials in the form of a dry powder were used: the weight indicated in the State Pharmacopoeia of Ukraine (2.8.12) was placed in a distillation flask and a solution of water and xylene was added. Distillation was carried out for 4 hours. The condensate containing the blue oil was collected. Qualitative and quantitative analysis was carried out by the method of thin-layer chromatography in compliance with the requirements of national standards of Ukraine. For the analysis, thin-layer chromatography on Sorbfil plates with a layer of silica gel F254, mobile phase – ethyl acetate-toluene solution (5:95), anisaldehyde solution and comparison solutions were used to accurately determine the content of guaiaculene, α-bisabolol and bornyl acetate in toluene. The samples for analysis were applied to thin-layer plates in strips. Identification was carried out in several stages: under UV irradiation at 250 nm, observation at 360 nm, spraying of plates with anisaldehyde solution and daytime observation after heating to 100°C, 5 min (Derzhavna Farmakopeia Ukrainy, 2021). The moisture content of all chamomile samples, measured by the gravimetric method, was 5 ± 1%.

Determination of essential oil content in plant samples and quality indicators TLC No. 040320 (sample application protocol on GAMAG Linomat 5 applicator) in accordance with the requirements of the State Pharmacopoeia of Ukraine, 2.0, volume 3, article 445, Scientific and Production Firm “Vilarus” LLC. LLC Scientific and Production Firm “Vilarus”) was carried out with the participation of LLC Scientific and Production Firm “Vilarus”. An important valuable food compound synthesized in chicory and responsible for its medicinal properties is inulin, in particular a polysaccharide with a chain of D-fructofuranose residues ending with D-glucose residues. It is obtained by grinding roasted chicory roots, extracting them with water as an extractant, and drying the extract using various methods, setting a number of requirements, in particular for organic properties and inulin content (Nigussie et al., 2021).

The quantitative determination of hydroxycinnamic acids in the studied objects is based on the spectrophotometric method (DSTU 4981:2008. Tsykorii koreneplidnyi. Zbyrannia. Pokaznyky yakosti ta metody yikh vyznachannia). According to this method, 2.0 g (exactly weighed) of the crushed raw material was placed in a flask with a capacity of 200 ml and poured with 70 ml of 20% ethanol R. The flask was connected to a reflux condenser and heated in a water bath for 15 min. The extraction was performed three times. The extract was cooled and filtered through a paper filter using a Buchner funnel. The extract was quantitatively transferred to a volumetric flask with a capacity of 250 ml and the volume of the solution was brought up to the mark with 20% ethanol P (solution A). Then, 1 ml of solution A was added to a volumetric flask with a capacity of 50 ml and brought up to the mark with 20% ethanol R. The optical density of the solution was measured on a spectrophotometer Lambda 25 at a wavelength of 327 nm in a cuvette with a layer thickness of 10 mm. For comparison, 20% ethanol R was used. The qualitative composition and quantitative content of hydroxycinnamic acids were also studied by the method of high-performance liquid chromatography (Marchyshyn et al., 2016).

The composition of chicory decoction was studied by liquid chromatography using isocratic and gradient elution. Since the mode of isocratic elution did not allow the isolation of phenolic substances in the infusion (purity factor <70%), the composition of the components was evaluated only according to the data obtained by the gradient elution method (Abbas et al., 2014).

RESULTS AND DISCUSSION

In the English-language scientific literature, the combined cultivation of fruit trees and additional crops is defined as "agroforestry improvement based on fruit trees". If the main source of income is not fruit trees, but additional crops, for example, medicinal plants, then this is called "agrolysmelioration based on medicinal plants" (medicinal plant agroforestry). In addition to commercial benefits, medicinal plants attract pollinating insects, improve soil health, and enrich it with nutrients (Chen et al., 2016; Alipour et al., 2021; Özdamar, Yücel Caymaz, 2022).

Medicinal chamomile and root chicory are high-yielding and chemically valuable crops that are of strategic importance for research in the agricultural sector from the point of view of organic crop production (Baula, 2017). Scientists S.O. Chetvernya, M.I. Djurenko and O.P. Palamarchuk stated that intensive life processes and reproduction of wild chamomile provide a sufficient amount of mineral compounds and soil moisture, and that chamomile is characterized by low competition with perennial weeds (Chetvernia, 1987). The authors Bakhmat M.I. and Padalko T.O. regulate that in joint or specialized farms, chamomile should be sown at different times to extend the flowering period of the crop from June to August, especially with a special method for drying them and reducing peak loads (Padalko et al., 2021).

Through their research, A.S. Bolotskikh, Yu.M. Andreev and N.I. Bannikov and O.V. Weavers say that chicory can be grown in a cultivar of soils, but loose, easily cultivated soils that are non-acidic (pH 5.6–5.8) and require more oxygen and moisture are preferred. Heavy clay soils and low-lying areas are not suitable for growing chicory. However, on heavy clay soils, cultivation is possible provided that organic fertilizers are applied, and in their studies, early spring, late spring, summer, sub-winter, sub-winter and winter sowing periods are distinguished (Tkach, Ovcharuk, 2020).

The authors M.I. Bakhmat and O.V. Tkach note that in the dynamics of changes in the chemical composition of the roots and leaves of root chicory and the nutritional value during the growing season, significant changes of one or another indicator are observed: the beginning of October was marked by a sharp increase in the dry matter content of the root crop; therefore, in the first period of October, it was 25%. The carbohydrate complex also increased. In young root crops, it accounted for 9% of the total carbohydrate content, reaching a level of 19% for this period. Similar changes were observed in chicory leaves, where the total carbohydrate content in the leaves on July 15 was up to 1% and 2% on October 15 (Tkach et al., 2023). The biological value of chamomile is related to its chemical composition. Active components are found mainly in fresh or dried flowers, so decoctions and essential oils are used in medicinal preparations. Up to 2% essential oil is obtained from the flowers, which contains more than 120 components (Derzhavna Farmakopeia Ukrainy, 2021). The oil is mainly composed of terpenoids, mainly sesquiterpenes and α-bisabol. According to the authors' scientific results, a number of components, organic and inorganic compounds, were found in chamomile essential oil, with a maximum content of 0.85% in the flowers. Hamazulene does not occur naturally, but proazulene and matricin, both present in chamomile flower heads, are known to be cleaved to hamazulene during steam distillation. Other components, such as flavonoids, coumarins, and phenolic acids, are water-soluble, so they can be consumed as a medicinal tea. The main flavonoids are apigenin, quercetin, patulin and luteolin; they are present in concentrations of 16.8%, 9.9%, 6.5% and 1.9% respectively, which of course also vary between species and cultivars. About 28 terpenoids and 36 flavonoids were isolated from different chamomile cultivars (Ramadan et al., 2006). The results showed that certain amounts of chamazulene, α-bisabolol, α-bisabolol oxide and β-farnesene were present. These aromatic compounds are representatives of the sesquiterpene family and are formed from azulene, particularly gamazulene, which is synthesized by decarboxylation with an intermediate step of gamazulenecarboxylic acid

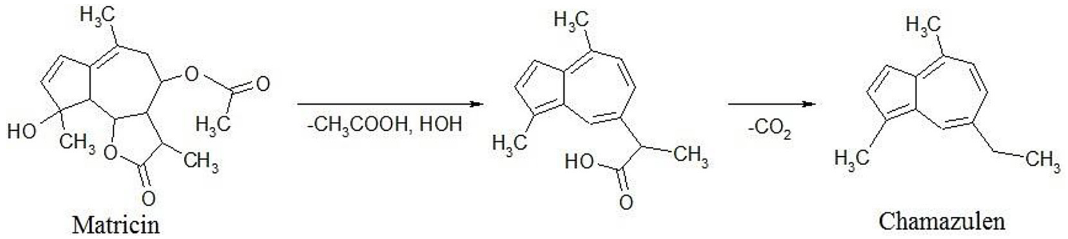

Figure 1. Schematic of the reaction of the biosynthesis of Chamazulen

formation from the sesquiterpene matricin in wild chamomile oil (Figure 1).

Other complex mixtures include the monoterpene bicyclic alcohol borneol, the flavonoids apigenin, luteolin, quercetin, isorhamnetin, kaempferol and its derivatives, the coumarins umbelliferone, guerniarin, daphnin, and daphnetin. The presence of phytosterols, choline, isovaleric acid, salicylic acid, caprylic acid, vitamin C, carotene, gum, mucilage and polyacetylene was also found. It was also noted that the plant contains selenium and some heavy metals, including zinc and copper salts. Chamomile essential oil relieves pain, inflammatory processes, reduces gas formation, normalizes the work of the gastrointestinal tract, stimulates the central nervous system, expands cerebral vessels, increases the number of contractions, and improves breathing; however, large doses of essential oil can cause headaches and general weakness. Apigenin and puerarin have a mild antispasmodic effect. Glycosides can increase the secretion of gastric and intestinal juice, stimulate appetite, and increase bile secretion. Khamazulen has pronounced anti-allergic, anti-inflammatory, local anesthetic properties, the property of enhancing regenerative processes (Srivastava et al., 2010).

Many publications are devoted to the study of indicators of nutritional value, chemical composition and antimicrobial activity of chicory root. However, there is little data on the component composition of chicory in the available literature; thus, research in this direction is important and relevant. To date, scientists have focused on compounds belonging to coumarins, flavonoids, sesquiterpenoids, triterpenoids, steroids, organic acids and other chemical components. Pharmacological effects such as photoprotective, hepatoprotective, antidiabetic and hypolipidemic, antioxidant, anti-inflammatory, antifungal, antimalarial, bone mineral density-increasing, and vasodilator and antitumor effects have been widely reported (Haji et al., 2020). Medicinal plants did not compete with garden fruit crops during the growing season. When planning the harvesting of root chicory and medicinal chamomile, the results of yield accounting for each year of the study were calculated for both crops. Yield accounting in the conducted studies was carried out for each variant of the experiment and the average values of all four indicators were determined in repetitions. The horizontal distribution of plants on the sown area, that is, the method of sowing, largely determined the future yield for crops.

It should be noted that similar scientific studies have not been conducted in the Right Bank Forest Steppe until now. The obtained results are unique and original as well as indicate that the yield of medicinal chamomile and root chicory depends on the cultivar, the time of sowing and the growing conditions of the temperate climate zone. To obtain crops of root chicory (Baranovsky, 2017), the time of sowing is important, which strongly depends on the climate, biology of the culture, etc. The main biological feature of growing a two-year crop is that it does not enter the growth phase under normal conditions of development during the first year of life, which is associated with a delay in this process.

Technical maturity of root crops during early spring sowing is important for chicory production. The development of the above-ground mass of the chicory root can be observed to make a preliminary prediction of the future harvest. Roots of chicory form a sufficient assimilation surface after about 40-80 days. For chicory roots with an average leaf area, active plant growth lasts about 100 days. Studies have shown that high yields are possible even with a small leaf area. At the same time, the dependence between the area of the leaf surface and its yield was clearly demonstrated. With an increase in the leaf surface, the yield of chicory root crops of the 'Umansky-99' cultivar increased to 34.6 t/ha, according to the research results (Figure 2). The ability to harvest up to three times a year from one plot is characterized by a high

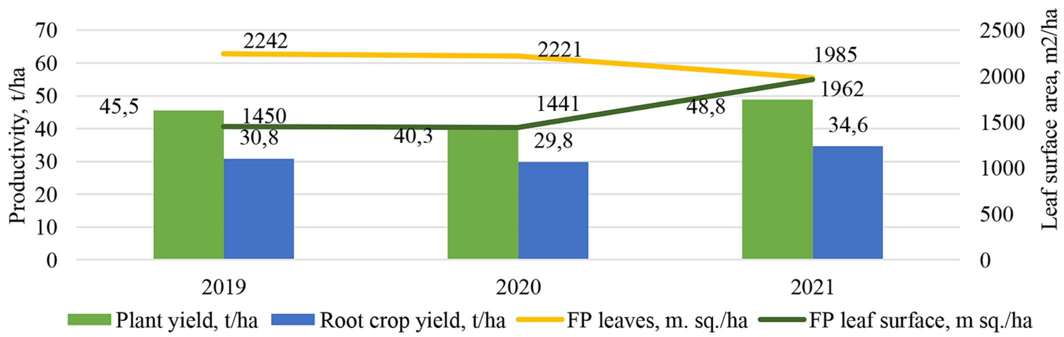

Figure 2. Dynamic indicators of root chicory yield formation according to the area of the sheet

intensity of management, which can increase the productivity of 1 ha of area up to 80% (Figure 3). The yield of medicinal chamomile after harvesting was lower than that of chamomile sown in the spring. On the other hand, the chamomile sown in summer has vigorous growth, which accelerates the phenological process and leads to earlier flowering and fruiting.

Taking into account more favourable climatic conditions for the formation of generative organs of the chamomile plant: the average temperature in 2021 was 21.90°C, in 2022 it was 20.30°C, and the amount of precipitation was 129.9 mm, while in 2022 the plant withstood drought up to 115.5 mm per year. During the studied period, the yield of raw materials of 'Perlyna Lisostepu' and 'Bodegold' ranged from 0.68 to 1.81 t/ha and from 0.57 to 1.65 t/ha, respectively. The maximum yield of inflorescences was provided by the 'Perlyna Lisostepu' cultivar (1.81 t/ha) during the autumn sowing period at the sowing rate of 6 kg/ha in 2020. It should be noted that the indicators of quality and nutritional value of plant material are one of the main evaluation criteria and are therefore evaluated according to the general technical and chemical composition of the material (Table 1).

Chamomile quality indicators varied from a minimum flavonoid content of 1.34% to a maximum of 6.89 ml kg of essential oil. The presence of α-bisabol, borneol, bornyl acetate, chamazulene, guaizaulene and other cultivars was revealed. Both cultivars meet the requirements of

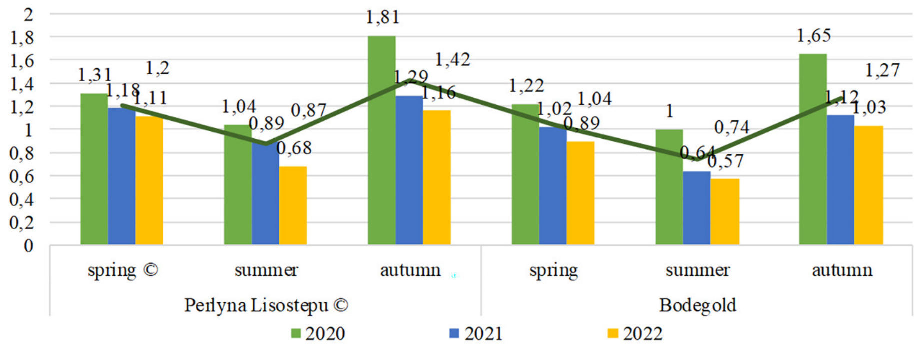

Figure 3. Dynamics of yield formation of medicinal chamomile depending on research factors

Table 1. Quality indicators of chamomile inflorescences, depending on the studied factors, (average for 2020–2022)

Cultivar	Term of sowing	Index	
		Flavonoids in terms of rutin in dry raw materials, %	Essential oil in terms of dry raw materials, Ml/kg
Perlyna Lisostepu	Spring (c)*	1.74	5.98
	Summery	1.56	5.44
	Autumn	2.28	6.89
Bodegold	Spring	1.58	5.67
	Summery	1.34	5.18
	Autumn	2.09	6.03
Coefficient (*V*), %		20,01	10.02

the State Pharmacopoeia of Ukraine 2.0 Volume 3 (Figure 4).

The obtained chromatograms had several absorption bands corresponding to the content of the component. The retention factor (Rf) was defined as the ratio of the distance from the sample application point to the centre of the spot on the chromatogram to the distance travelled from the application point to the solvent front. The main spot on the chromatogram obtained with the test solution and the corresponding spot on the chromatogram obtained with the reference solution were visually compared in terms of colour, size, and retention (Rf) of both spots. The qualitative index of flavonoids in terms of rutin in the completely dry root material of chicory ranged from 2.0 to 29.4%, while the highest inulin was observed in the 'Umansky-97' cultivar during the sowing period of August 25–28 – 18.4% (Table 2). The mode of gradient elution of liquid chromatography for the detection of 10 components from

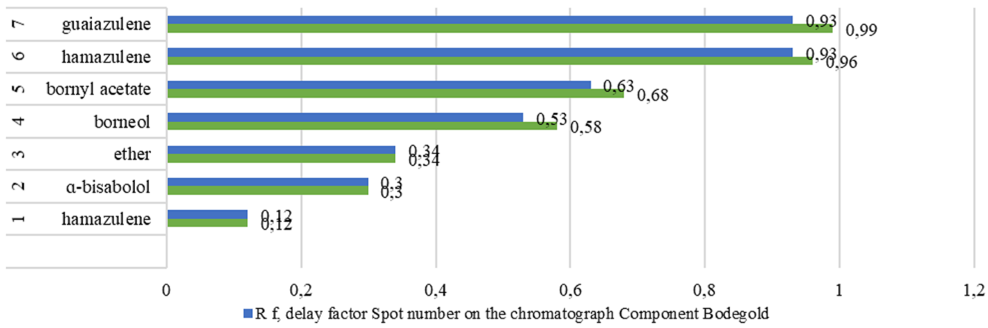

Figure 4. Identification of chamomile cultivars depending on the studied factors

Table 2. Indicators of root chicory quality depending on the studied factors (average for 2020–2022)

Term of sowing	Cultivar	Index	
		Flavonoids in terms of rutin in dry raw materials, %	Essential oil in terms of dry raw materials, ml/kg
10–13.07	Umansky-99	29.04	16.08
25–28.07		8.09	17.03
05–08.08		11.09	18.04
15–18.08		18.01	16.09
25–28.08		12.03	17.03
10–13.07	Umansky-97	10.01	14.76
25–28.07		7.04	11.50
05–08.08		6.03	16.09
15–18.08		4.01	16.85
25–28.08		2.02	17.51
Coefficient (*V*), %		71.08	11.09

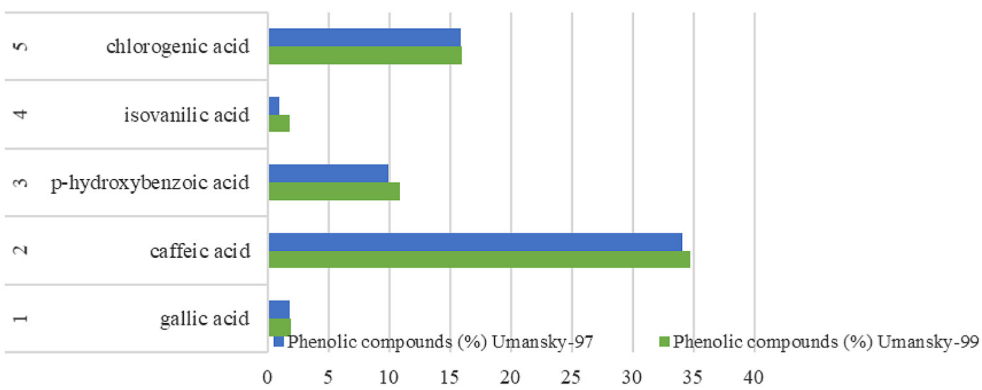

Figure 5. The ratio of hydroxycinnamic acids to phenolic compounds in root chicory

the infusion of chicory root, the detection wavelength of 360 nm shows the indicators of acids that had minor errors in the result (Figure 5).

The ratio of hydroxycinnamic acids to flavonoids was 1:1. Among hydroxycinnamic acids, caffeic acid prevailed. Their sum was up to 34% of the total content of phenolic compounds. Individual hydroxycinnamic acids – chlorogenic, isonilic, caffeic, gallic, and hydroxybenzene – were detected in the researched chicory raw material using the method of high-performance liquid chromatography, and their quantitative content was determined, so it can be recommended for the standardization of raw materials.

CONCLUSIONS

The maximum yield of inflorescences was shown by the wild chamomile cultivar 'Perlyna Lisostepu' cultivar of autumn sowing – 1.81 t·ha^{-1} at the optimal sowing rate of 6 kg·ha^{-1}. With an increase in the leaf surface, a high level of soil enrichment with organic and mineral compounds, the yield of chicory roots of the cultivar 'Umansky-99' cultivar increased to 34.6 t·ha^{-1}. The presence of α-bisabolol, borneol, bornyl acetate, chamazulene, guaiazulene, as well as other unidentified substances was found in the solution of essential oil of chamomile flowers of medicinal cultivars. Using liquid chromatography methods, it was found that chicory root decoction contains cinnamic acid derivatives and flavonoids in particular caffeic acid, chlorogenic acid and others. As a result of the conducted research, it was determined that the content of the most valuable component – inulin is 17.51%.

Acknowledgments

We express our gratitude to the company "Vilarus" for conducting laboratory research.

REFERENCES

1. Abbas Z.K., Saggu S., Sakeran M.I., Zidan N., Rehman H., Ansari A. 2014. Phytochemical, antioxidant and mineral composition of hydroalcoholic extract of chicory (*Cichorium intybus* L.) leaves. Saudi Journal Biological Science, 22(3), 322–326. https://doi.10.1016/j.sjbs.2014.11.015
2. Alipour M., Jafari H., Alizadeh K. 2021. The effect of cultivation of medicinal plants on the economic development of rural settlements case study: Villages of Kalat city. Propósitos y Representaciones, 9, 957. https://doi.org/10.20511/pyr2021.v9nSPE2.957
3. Baranovsky V.M., Skalsky O.Y., Pankiv M.R., Pastushenko A.S. 2017. Chicory root crops combined harvester. INMATEH Agricultural Engineering. INMA Bucharest: National Institute of research and development for machines and installations designed for agriculture and food industry, 3(53), 41–50.
4. Baula O.P. 2017. Zabezpechennia yakosti likarskykh zasobiv roslynnoho pokhodzhennia: stan ta perspektivy. Farmatsevtychnyi chasopys, (2), 79–86. [In Ukrainian] https://doi.org/10.11603/2312-0967.2017.2.7816
5. Chen S.L., Yu H., Luo H.M., Wu Q., Li C.F., Steinmetz A. 2016. Conservation and sustainable use of medicinal plants: problems, progress, and prospects. China Medical Journal, 30(11), 37. https://doi.10.1186/s13020-016-0108-7
6. Chetvernia S.A. 1987. Byolohycheskye osobennosty y sravnytelnaia otsenka deistvuiushchykh veshchestv romashky aptechnoi *(Matricaria chamomilla L.)* y romashky dushystoi, (*Matricaria suaveolens (Pursh.) Rydb*.) proyzrastaiushchykh v Ukrayne: avtoreferat dysertacii. Kiev, 18. [In Ukrainian].
7. Derzhavna Farmakopeia Ukrainy. 2021. Derzhavne pidpryiemstvo Ukrainskyi naukovyi pharmacopoeinyi tsentr yakosti likarskykh zasobiv, 2(5), 424. [n Ukrainian]
8. Doslidna sprava v ahronomii. 2016. Teoretychni aspekty doslidnoi spravy. A. O. Rozhkov, V. K. Puzik, S. M. Kalenska ta in. Kharkiv. Maidan, 1 (2), 167–169. [In Ukrainian].
9. Hadi M.R.H.S., Fallah M.A., Darzi M.T. 2015. The influence of nitrogen fertilizers and application of biohumus on the yield of flowers and essential oil of medicinal chamomile (*Matricaria chamomile* L.). JCHR, 5(3), 235–244. https://doi.org/10.22034/jchr.2015.544111
10. Haji A., Xue X., Dan T. 2020. Chemical constituents and their pharmacological activities of plants from Cichorium genus, Chinese Herbal Medicines, 12(3), 224–236. https://doi.org/10.1016/j.chmed.2020.05.001
11. Honcharuk I., Matusyak M., Pantsyreva H., Kupchuk I., Prokopchuk V., Telekalo N. 2022. Peculiarities of reproduction of *Pinus nigra* in Ukraine. Bulletin of the Transilvania University of Brasov, Series II: Forestry, Wood Industry, Agricultural Food Engineering, 15(1), 33–42.
12. Kviatkovskyi A., Kharasym E., Feledyn-Shevchyk B., Stalenha Y., Yanchak-Penёnzhek M., Buchek Y. 2022. Urozhainost y kachestvo romashky (*Chamomilla recutita* L.), výrashchennoi v orhanycheskoi systeme, v zavysymosty ot vnekornevýkh byopreparatov y shyryný mezhduriadyi. Selskoe khoziaistvo, 12(10), 1534. https://doi.org/10.3390/agriculture12101534

13. Marchyshyn S.M., Husak L.V., Berdei T.S. 2016. Doslidzhennia kyslot hidroksykorychnykh travy chystetsiu Zibolda. [Investigation of acids of hydroxycoric grass purified by Zibold]. Medical and Clinical Chemistry, 3, 13–16. [In Ukraine]
14. Mazur V.A., Mazur K.V., Pantsyreva H.V., Alekseev O.O. 2018. Ecological and economic evaluation of varietal resources *Lupinus albus* L. in Ukraine. Ukrainian Journal of Ecology, 8, 148–153.
15. Mazur V., Tkachuk O., Pantsyreva H., Kupchuk I., Mordvaniuk M., Chynchyk O. 2021. Ecological suitability peas (*Pisum sativum*) varieties to climate change in Ukraine. Agraarteadus, 32 (2), 276–283.
16. Mirzoieva T.V. 2020. Analyz vlivu spetsializatsii pidpryiemstva na efektyvnist vyrobnytstva likarskykh kultur. Ekonomika, upravlinnia ta administruvannia, 4(90), 28–32. [In Ukrainian] https://doi.org/10.26642/ema-2019-4(90)-28-32
17. Nigussie G., Ibrahim F., Neway S. 2021. A phytopharmacological review on a medicinal plant: *Cordia africana* Lam. Journal of Tropical Pharmacy and Chemistry, 5(3), 254–263. https://doi.org/10.25026/jtpc.v5i3.267
18. Özdamar E., Yücel Caymaz G. 2022. From mistletoe to anthroposophical architecture: Medicinal plants gardens. SAUC - Street Art and Urban Creativity, 8(1), 8–19. https://doi.org/10.25765/sauc.v8i1.581
19. Padalko T.O. 2022. Evaluation of the innovative aspect of agrotechnologies on yield and quality of raw materials (*Matricaria chamomilla* L.) according to the state pharmacopoeia. Modern Engineering and Innovative Technologies, 14(1), 105–109. https://doi.org.10.30890/2567-5273.2020-14-01-048
20. Padalko T.O., Bakhmat M.I., Ovcharuk O.V., Horodyska O.P. 2021. Quality of raw material from chamomile inflorescences depending on technological factors. Ukrainian Journal of Ecology, 11(1), 234–240. https://doi.10.15421/2021_35
21. Pankiv Z.P. 2017. Grunty Ukrainy: navchalno-metodychnyi posibnyk. Lviv. LNU imeni Ivan Franka, 22. [In Ukrainian]
22. Pantsyreva H.V., Mykoliuk O.O., Semchuk V.V. 2019. Suchasnyi stan kolektsii pivonii na bazi botanichnoho sadu „Podillia" Vinnytskoho natsionalnoho ahrarnoho universytetu. Scientific Bulletin of Ukrainian National Forestry University, 29(8), 46–50. [In Ukrainian]. https://doi.org/10.36930/40290806
23. Pantsyreva H.V., Myalkovsky R.O., Yasinetska I.A., Prokopchuk V.M. 2020. Productivity and economical appraisal of growing raspberry according to substrate for mulching under the conditions of podilia area in Ukraine. Ukrainian Journal of Ecology, 10(1), 210–214. https://doi.org/10.15421/2020_33
24. Puyu V., Bakhmat M., Pantsyreva H., Khmelianchyshyn Y., Stepanchenko V., Bakhmat O. 2021. Social-and-ecological aspects of forage production reform in Ukraine in the early 21st century. European Journal of Sustainable Development, 10(1), 221–228.
25. Ramadan M., Goeters S., Watzer B., Krause E., Lohmann K., Bauer R., Hempel V.R. 2006. Imping. Chamazulene carboxylic acid and matricin: a natural profen and its natural prodrug, identified through similarity to synthetic drug substances. Journal Natural Product, 69(7), 1041–1045. https://doi.10.1021/np0601556
26. Sah A., Nasif P.P., Kuruniyan M.S., Jane G.K., Zakir F., Aggarwal G. 2022. Comprehensive study of the therapeutic application of chamomile. Pharmaceutics, 15, 1284. https://doi.org/10.3390/ph15101284
27. Shevchuk O.A., Holunova L.A. 2019. Botanika. Biology. Vinnytsia, Ukraine, 83.
28. Smielova N.M. 2018. The assessment of the quality parameters of inulin active pharmaceutical ingredients according to physicochemical characteristics. Upravlinnia, ekonomika ta zabezpechennia jakosti v pharmatsii, 2(54), 6–13. https://doi.org/10.24959/uekj.18.12
29. Zhou S., Hong Y., Yun K., Jie Z., Yan L., Jing H., Yun C. 2010. Effects of intercropping with aromatic plants on the diversity and structure of an arthropod community in a pear orchard. Bio Control, 55(6), 741–751. https://doi.org/10.1007/s10526-010-9301-2
30. Srivastava J.K., Shankar E., Gupta S. 2010. Chamomile: A herbal medicine of the past with a bright future. Molecular Medicine Reports., 3(6), 895–901. https://doi:10.3892/mmr.2010.377
31. Street R.A. 2013. Cichorium intybus: traditional uses, phytochemistry, pharmacology and toxicology. Evidence-Based Complementary and Alternative Medicine, 1–13. https://doi.10.1155/2013/579319
32. Tkach O.V., Ovcharuk V.I. 2020. Vytraty vody roslynamy tsikoriiu koreneplidnoho v ahrofitotsenozi na formuvannia yii masy. Zbirnyk naukovykh prats "Ahrobiolohiia", 1, 175–180. [In Ukrainian] https://doi.10.33245/2310-9270-2020-157-1-175-180
33. Tkach O.V., Ovcharuk V.I., Ovcharuk V.I., Dzhevirz M. 2023. Osoblyvosti roli volohy hruntu v zabezpechenni vysokoi vrozhainosti roslyn tsykoriia. Podilskyi visnyk: Silske hospodarstvo, mashynobuduvannia, ekonomika, 36, 14–20. [In Ukraine] https://doi.org/10.37406/2706-9052-2022-12
34. Caballero-Serrano V., Brian M., Carrasco J., Josu G., Fiallos L., Javier A., Miren O. 2019. Traditional ecological knowledge and medicinal plant diversity in Ecuadorian Amazon home gardens, Global Ecology and Conservation, 17, e00524. https://doi.org/10.1016/j.gecco.2019.e00524
35. Wan N. 2019. Plant diversification promotes biocontrol services in peach orchards by shaping the ecological niches of insect herbivores and their natural enemies. Ecological Indicators, 99, 387–392. https://doi.org/10.1016/j.ecolind. 2017.11.047