POSPIELOV S.V., SEMENKO M.V.

FROM SEEDLINGS TO PLANTATION:
EXPERIENCE IN CULTIVATING ST. JOHN'S WORT (HYPERICUM PERFORATUM L.) IN UKRAINE

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Authors:
Pospielov S.V., Semenko M.V.

Reviewers:
Volodymyr Hangur, Doctor of Agricultural Sciences, Professor, Head of the Department of Crop Production, Poltava State Agrarian University
Volodymyr Tishchenko, Doctor of Agricultural Sciences, Professor, Professor of the Department of Plant Breeding, Seed Production and Genetics, Poltava State Agrarian University

From Seedlings to Plantation: Experience in Cultivating St. John's Wort (*Hypericum perforatum* L.) in Ukraine : Monograph / S.V. Pospielov, M.V. Semenko. Karlsruhe, 2025. 153 p.

The monograph presents the results of research on improving the cultivation techniques of common St. John's wort (*Hypericum perforatum* L.) under the conditions of the Left-Bank Forest-Steppe of Ukraine. The biological characteristics of the crop's growth and development are considered, along with the effects of pre-sowing seed treatment with growth stimulants, sowing dates, planting density, varietal traits, and plant arrangement schemes. Based on the obtained data, practical recommendations have been developed for the introduction of plantation cultivation of St. John's wort, which represents a promising approach to ensuring stable raw material production for the pharmaceutical, food, and cosmetic industries.

У монографії висвітлено результати досліджень з удосконалення агротехніки вирощування звіробою звичайного (*Hypericum perforatum* L.) в умовах Лівобережного Лісостепу України. Розглянуто біологічні особливості росту й розвитку культури, вплив передпосівної обробки насіння стимуляторами росту, строки сівби, щільність посадки, сортові особливості та схеми розміщення рослин. На основі отриманих даних розроблено практичні рекомендації для впровадження плантаційного культивування звіробою, що є перспективним напрямом забезпечення стабільного виробництва сировини для фармацевтичної, харчової та косметичної промисловості.

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ABOUT THE AUTHORS:

Pospielov Sergii Viktorovich, Doctor of Agricultural Sciences, Professor, Head of the Department of Agriculture and Agrochemistry named after V. I. Sazanov, Poltava State Agrarian University, ORCID: 0000-0003-0433-2996

Semenko Maksym Vasylovich, PhD student, Department of Agriculture and Agrochemistry named after V. I. Sazanov, Poltava State Agrarian University, ORCID: 0000-0002-9168-4238

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INTRODUCTION

Justification of the research topic.

The development of modern agrotechnical approaches in the context of sustainable production is a key factor in increasing the efficiency of growing crops, including medicinal plants. St. John's wort (*Hypericum perforatum* L.) is of considerable interest for pharmaceuticals and the food industry as a crop with high potential. The unstable yield and quality of wild populations create the need to develop plantation technologies for its cultivation. Under natural conditions, the average yield of St. John's wort aboveground raw materials is only 15-100 tons per year, which is significantly less than the annual market demand, which reaches 1050-1100 tons (Gao and al., 2022; Duppong and al., 2004). This discrepancy justifies the feasibility of introducing St. John's wort in industrial plantations.

In the context of increasing the share of natural medicines on the world market, the growth of the organic raw material segment on the market, large companies – manufacturers of pharmaceutical and cosmetic products (for example, Bionorica) are creating their own production areas of organic St. John's wort. This is not only a successful marketing move, but also a closed production of their own raw materials. Ukraine has all the necessary conditions and opportunities to follow a similar path in developing its own innovative technologies.

One of the promising directions for creating productive agrocenoses of St. John's wort is the cultivation of its seedlings (Pospelov & Solop, 2021). The use of the seedling method allows not only to increase productivity, but also to ensure the qualitative uniformity of planting material (Karimi and al., 2022). In this regard, it is important to study the composition of the substrate, sowing dates, seed stimulation methods, and planting dates in a permanent place. Increasing the effectiveness of these agrotechnical techniques will provide optimal conditions for plant growth and development.

The assessment of the area of plant nutrition on the yield and productivity of raw materials, resistance to external factors, and the quality of the resulting products remains a poorly studied issue (Kwiecień and al., 2021). The study of these features of St. John's wort will allow developing universal recommendations for growing this crop in the conditions of the Left-Bank Forest-Steppe of Ukraine.

It is also important to analyze the feasibility of growing St. John's wort by the seedling method. Optimization of growing times, reducing costs for seed preparation and plant care will help reduce the cost of production and increase its competitiveness in the market (Pryvedenyuk & Shatkovskyi, 2021). This will create new opportunities for the development of industrial cultivation of medicinal plants, help meet the needs of the pharmaceutical industry and reduce dependence on natural raw materials.

Therefore, an in-depth study of agrobiological features and improvement of the technology of growing St. John's wort (*Hypericum perforatum* L.) in the conditions of the Left-Bank Forest-Steppe of Ukraine is an urgent scientific problem.

The purpose and objectives of the research.

The purpose of the work is to substantiate the agrobiological parameters and improve the technology of growing St. John's wort by seedling method.

To achieve this goal, it is necessary to solve the following *main tasks:*

- to study the features of growth and development of *Hypericum perforatum* L.;
- to evaluate the effectiveness of various methods of seed treatment with growth stimulants;
- to study the conditions for growing St. John's wort seedlings;
- assess the impact of the timing of sowing seedlings on plant development;
- to establish the productivity of St. John's wort under the usual seedling cultivation method;
- to evaluate the productivity of different varieties of St. John's wort under seedling growing conditions
- to establish the dependence of St. John's wort productivity on plant placement schemes;
- to investigate the biological activity of raw materials of St. John's wort (*Hypericum perforatum* L.) during ontogenesis;

- to summarize research results and develop practical recommendations for growing St. John's wort in industrial conditions.

Object of research: features of plant growth and development in ontogenesis, formation of productivity and yield of medicinal raw materials of St. John's wort **(***Hypericum perforatum* L.).

Subject of study: seeds and plants of St. John's wort **(** *Hypericum perforatum* L.) in seedling culture, raw material (herb) of St. John's wort (*Hypericum perforatum* L.).

Scientific novelty of the obtained results

For the first time:

- the effect of treating St. John's wort seeds with growth stimulants in the context of growing seedlings was studied;

- in the conditions of the Left-Bank forest-steppe of Ukraine, the possibility of cultivating St. John's wort as a seedling culture has been experimentally substantiated;

- the productivity of St. John's wort depending on the feeding area was investigated;

- the dynamics of accumulation of biologically active substances in St. John's wort during cultivation was studied: the activity of agglutinins in various plant organs was researched; the novelty was confirmed by the Patent of Ukraine No. 130248.

Improved:

- assessment of the sowing qualities of St. John's wort seeds;

- a method for determining the agglutination activity of St. John's wort extracts;

Further development has been made:

- the concept of sustainable production of medicinal raw materials.

Practical significance.

The results of the conducted research allow to form justified technological solutions for the purpose of creating highly productive agrocenoses of St. John's wort. A technology for growing St. John's wort seedlings has been developed, which allows to obtain a homogeneous planting material with a developed root system. For the production of medicinal raw materials, an important element of the technology is the optimal placement of the culture, which allows to obtain a guaranteed harvest of high-quality raw materials, extend the life of the agrocenosis, and ensure effective care for crops.

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CHAPTER 1
AGROBIOLOGICAL AND PHYTOCHEMICAL EVALUATION OF ST. JOHN'S WORT (*HYPERICUM PERFORATUM* L.)

1.1 Botanical and geographical characteristics *of Hypericum perforatum* L.

The genus *Hypericum* L. belongs to the family *Hypericaceae* Juss. or *Guttiferae* auct. According to data, this family includes 47 genera and about 850 species, according to others – about 40 genera and over 1 thousand species (Bruni & Sacchetti, 2009) . Most of the representatives of this large and widespread, mainly tropical family are trees and shrubs, and only a few of them are herbs (most species of the genus *Hypericum* L. and species of the small Asian-American genus *Triadenum* Raf.). A characteristic feature of trees and shrubs of this family is the presence in their vegetative organs of schizogenic reservoirs as channels, less often cavities, which contain white, yellow or green resinous sap (Ciccarelli et al., 2001; Florea et al., 2017). Herbaceous members of the family also have receptacles, but here, as in species of the genus St. John's wort, their contents are often colored with a dark or red pigment. The St. *John* 's wort family is divided into six subfamilies*: Kielmeyeroideae; Calophylloideae*; *Clusioideae*; *Moronobeoideae*; *Lorostemonoideae; Hypericoideae* with the genera *Hypericum*, *Cratoxylum, Vismia, Psorospermum*, etc. (Barnes et al., 2010; Hosni et al., 2017).

The number of species in the genus *Hypericum,* according to various sources, varies from 200 to 400. Species of the genus *Hypericum* are characterized by a wide, almost cosmopolitan distribution, they grow both in subtropical regions and mountainous regions of the tropics, and in the temperate zone of the Earth; The greatest diversity of species is observed in the Mediterranean and West Asia (Pradeep et al., 2020). The species grow in moist places in meadows, swamps and even in shallow water on the edges of lakes and rivers (*Hypericum elodes*), and on very dry ones: in cracks of rocks, on rocky places, sands, in pine forests, shrubs, savannah, on pastures, deposits, along roads (Rychlewski et al., 2023; Saçıcı & Yesilada, 2021) . Species of St. John's wort are found in the foothills and high in the mountains, entering the alpine zone. At the same time, St. John's wort is distinguished by great plasticity of appearance, varying from herbs to low trees (Briese & Cullen, 2012; Cui et al., 2014).

12 species of *Hypericum* found in Ukraine, four species are most common in the Forest-Steppe zone: *Hypericum perforatum* L., *H. maculatum* Crantz, *Hypericum hirsutum* L. and *Hypericum montanum* L. the aerial part of which is collected by people as medicinal raw materials (Hrytsyk & Veronika, 2022; Sologub & Hrytsyk, 2011).

St. John's wort grows in dry and lighted areas. It is widespread in forest and forest-steppe zones, rising to mountains up to 2300 m above sea level. It rarely forms large thickets, more often grows in narrow strips along the forest edge or in small thickets (Chung & Deng , 2020; Crockett et al., 2011) . In the forest zone it grows in dry meadows, forest glades, along forest edges, in clearings and in sparse pine or dry coniferous small-leaved forests. In the forest-steppe zone it is found in oak groves and birch forests, as well as meadow steppes. In mountainous areas it grows in the foothills on rocky slopes, rarely rising to subalpine meadows. Sometimes it grows as a weed near roads among crops, on the outskirts of fields (Vattikuti & Ciddi, 2005).

St. John's wort is a perennial herbaceous plant in nature, 30-100 cm tall, with an erect stem, branched in the upper part, cylindrical, with two longitudinal convex edges (Ciccarelli et al., 2001). Leaves are opposite, oval or elliptical, oblong-ovate or oblong, sessile, obtuse, with numerous light and rare black glands that are translucent, 0.7-3.0 cm long and 0.3-1.5 cm wide. Flower formula: ♀♂ $*Ca_{(5)}Co_5A_{(\infty)+(\infty)+(\infty)}G_{(3)}$. Flowers are free, regular, with five-petal with a cup that does not fall off and a five-petaled corolla; petals are bright yellow, oblong-oval, obliquely cut at the top, with black-brown dots (on the lower side) (Orhan, 2022). Stamens (50-60 pcs.) grow together at the base in three bundles. Pollen grains are spherical or ellipsoidal in shape, have three furrows. The length of the polar axis is 13.6-17.7 µm , the equatorial diameter is 13.6-17 µm . In outline from the pole they are almost round-trilobate, from the equator they are round or broadly elliptical. Furrows are 3-5 µm wide, with smooth edges and pointed or blunt ends, almost converging at the poles. The furrow membrane is fine-grained. The exine is 1-1.3 µm thick . The color of the pollen is dark yellow (Gönenç et al., 2020). Ovary ovoid, 3-5 mm long. Pistil with a three-nodular upper ovary and three free, bent columns, which are twice as long as the ovary (Barcaccia et al., 2007). Flowers are numerous, collected in broadly paniculate, almost corymbose inflorescences 7-11 cm long, 5-11 cm wide. Bracts are lanceolate, 0.5 cm long, acute. Calyx is deeply divided, 5 mm long, almost two to three times shorter than the corolla. Sepals are lanceolate or narrowly lanceolate, acute or finely acuminate, equal or longer ovary, with rare glandular black oval dots, equal or slightly toothed along the edge. Corolla is golden yellow; petals oblong elliptical, mostly unequal-sided, 1.2-1.5 cm long and 0.5-0.6 cm wide, obliquely cut above, with numerous black glands along the edges and upper part. The fruit is an oblong-ovate capsule 6 mm long and 5 mm wide, opening with three valves. The seeds are numerous, very small, 1 mm long, cylindrical, brown, longitudinally finely celled (Coppock & Dziwenka, 2021; Crockett et al., 2011).

According to the structure of the shoots, St. John's wort is a winter-green perennial with wintering rosette-free shoots (renewable shoots), which after the snow melts begin to grow with the tip and summer shoots arise from the terminal bud. The peculiarity of the population model of St. John's wort behavior in forest communities is determined by the specifics of the development of the renewal buds located at the base of the anisotropic shoot. The buds can develop into enrichment shoots, which provide an increase in aboveground shoots, or "meristematic nodes", which ensures the preservation of the species in the community due to vegetative renewal (Buckley et al., 2003; Seyis et al., 2020).

The question of the life forms of St. John's wort raises controversial opinions. When the species grows in different ecological and coenotic conditions, different life forms may appear.

The underground part of St. John's wort is very developed and complex. The plant has numerous rhizomes, which vary greatly in length (from 3 to 15 cm), thickness (from 3 to 5 mm) and depth of occurrence (2-5 cm on compacted and up to 10 cm on loose soils). Large rhizomes, bearing three to five above-ground shoots, are often connected underground by thin, root-like bridges up to 15 cm long. Numerous additional roots depart from the rhizomes, in addition to which there are quite powerful deep roots, penetrating to a depth of 155-160 cm, developing well in a layer of forestlike loam (Petipas et al., 2024). Deep roots often branch, giving large lateral roots of the first order. According to the sign of the possibility of restoring an individual when its above-ground part is destroyed for any reason (general vegetative restoration), St. John's wort belongs to the type of irruptive plants, subtype - periodic life forms, group - creeping species, form - rhizomatous turf-forming .

In the north-east of Ukraine, St. John's wort is a perennial hemicryptophyte with short rhizomes. The main methods of plant reproduction are seed and vegetative (rhizome growth). Sometimes St. John's wort can also reproduce by root offspring. The species has a pronounced tendency to contagious growth, associated with rhizome growth. However, the plants do not form strong clones. By the type of formation of individuals, St. John's wort belongs to clonal individuals (Bondarenko & Dovgopola, 2021).

For the successful cultivation of this species and the creation of industrial plantations, a detailed study of its morphogenesis and life form under cultural conditions is required.

1.2 Agronomic Practices for Cultivation

Predecessors . For sowing St. John's wort, soils free from weeds are selected. The best predecessors are winter crops, as well as well-fertilized row crops. Its plantations are placed in crop rotation links designated for perennial medicinal plants (Lekbangpong et al., 2021).

Soil preparation . The main soil cultivation for St. John's wort is carried out in the same way as for other row crops. For sowing before winter, plowing is carried out 25–30 days before it. In the period between plowing and sowing, the field is cultivated and harrowed 1–2 times (Pospelov et al., 2017).

Before sowing, in case of strong soil compaction, harrowing is carried out. For spring sowing, pre-sowing soil cultivation consists of harrowing in several tracks, and if necessary, cultivation with subsequent harrowing. Before sowing, the plots are rolled (Duppong et al., 2004).

Fertilizers. Research results show that applying mineral and organic fertilizers before plowing increases the yield of raw materials by 20–30%, and fertilizing with mineral fertilizers in the second and third year of vegetation by 17–25% (Gao et al., 2022; Duppong et al., 2004).

Based on the results of research on sod-podzolic soils, 30-40 tons of manure or compost are applied under the main plowing. In case of a lack of organic fertilizers, the dose is reduced to 15-20 tons per hectare, but it is used with mineral fertilizers according to 30 kg of NRK. In the absence of organic fertilizers on the farm, only mineral fertilizers are applied in a double dose. In the second and in subsequent years of vegetation, in early spring, plants are fertilized with mineral fertilizers 30 kg per hectare (Karimi et al., 2022).

Sowing. St. John's wort is sown before winter or early spring with a grain seeder with row spacing 45 cm, superficially, without covering the seeds, the seeding rate is 2- 3 kg per 1 ha. Sowing before winter is carried out with dry seeds, in spring - stratified. The best results are obtained with winter sowing. Shoots appear 2-3 weeks earlier than when sowing in spring (Kwiecień et al., 2021). It has been established that in Ukrainian conditions the best time for sowing St. John's wort is August 20-25 under the cover of winter wheat with row spacing 30 cm without covering the seeds in the soil (Pospelov et al., 2021).

To maintain uniformity of sowing, it is recommended to mix the seeds with crushed superphosphate, nitroammofoska to particles of 1- 2 mm, or mix with sifted dry peat (1:10) (Kwiecień et al., 2021).

Due to problems with seed germination, scientists suggest sowing St. John's wort under various cover crops, both agricultural and medicinal. For example, sowing St. John's wort under the cover of medicinal chamomile is being studied (Sobhani Najafabadi et al., 2019).

Seeds germinate in the light at a temperature of 18-25 ^{0}C in 21-25 days after sowing without stratification. St. John's wort seedlings at the initial stages of ontogenesis develop very slowly and form 1-2 pairs of leaves before the first frosts.

That is why sowing under the cover of cereals prevents weeds both in the autumn and in the spring-summer period (Kwiecień et al., 2021).

During the harvest period of the cover crop, young plants take root well, form an above-ground mass, and by autumn some produce flower shoots (Sobhani Najafabadi et al., 2019).

Crop care. Because the plants of the first year of vegetation develop quite slowly, there is a need for careful care of the crops. If the sowing was carried out in wide rows (45- 70 cm), then inter-row tillage can be carried out before seedlings appear. To better ensure this measure, sowing should be carried out with a cover crop (Nunes et al., 2021).

After the emergence of seedlings, the crops should be carefully looked after, preventing weeds not only in between the rows but also in the rows. During the growing season, 2-3 manual weedings and 1-2 mechanized weedings using cultivators for inter-row tillage of the soil are carried out.

For better wintering, plants in the first year are fed with potassium and phosphorus fertilizers (PK_{30-45}) (Karimi et al., 2022).

In the spring of the second year (and also the third), the plantation is loosened before the start of regrowth with light harrows at an angle to the rows. If necessary, nitrogen fertilization is carried out (N_{90} P_{60} K_{60}). During this period, the shoots grow intensively (up to 2 3 cm per day) and require a sufficient amount of nutrients. It has been shown that foliar nutrition has a positive effect not only on the amount of aboveground mass, but also on its qualitative composition (Desseilles et al., 2011; Nunes et al., 2021).

After the first year, a mandatory element of care is loosening of soil with fertilization ($N_{60}P_{30}K_{30}$). If there are favorable weather conditions or artificial irrigation, a second mowing is possible (Becker et al., 2016).

Before wintering, the rows are loosened with chisels, which contributes to better wintering conditions (Karimi et al., 2022).

Harvesting. Harvesting begins during the period of mass flowering of plants, which occurs in late June-early July. Stems with flowers and buds are harvested. The length of the cut of the apical part of the plants during harvesting should not exceed 30 cm. Harvesting is carried out with harvesters (Sen et al., 2018).

Cut plants are dried immediately, because cut plants in piles heat up and turn black. Drying of raw materials is carried out in dryers or under cover. In dryers, they are dried at t^0 50-60 ^{0}C (Lazzara et al., 2021).

After the first mowing, the plants grow back under normal conditions and bloom in 30-40 days. The yield of the second mowing is not inferior to the first. The yield of raw materials for the second harvest with a normal grass stand in the second year of vegetation ranges from 1,5 to 2,5 tons per ha, in the third year - from 3,0 to 4,0 tons (Jamwal et al., 2018; Wang et al., 2023; Zvezdanović, 2021). Under irrigation conditions, plants develop well in both the first and second year of vegetation. Productivity reaches 5,2 t/ha (Nunes et al., 2021; Sen et al., 2018).

Seed production. To obtain seeds, special plots are set aside or the best ones are selected for sowing. Harvesting for raw materials is not carried out on these plots. The seeds ripen in the first half of September (Bagdonaitė et al., 2010). The mowed grass is transported under cover for drying, threshed with threshers or combines. The seeds are cleaned with grain cleaning machines. The seed yield is from 1 to 0,3–0,4 tons per hectare (Lazzara et al., 2021).

First class seeds must have 90% purity and 80% germination, second class seeds must have 88% purity and 65% germination, and third class seeds must have 85% purity and 40 % germination (Kızı et al., 2013).

1.3 The influence of environmental conditions and agrotechnical methods (irrigation, soil, fertilization) on the content of metabolites

St. John's wort (*Hypericum perforatum* L.) is an important medicinal plant that is widely harvested in the wild and is cultivated. As a consequence of the ecological niche that St. John's wort occupies, it is well adapted to temperate climates and a variety of soil types (Su et al., 2022). *H. perforatum* is often found in nature in disturbed habitats, which include roadsides, meadows, pastures or open scrub, as well as in open sun and poor soils (siliceous, clayey, limestone), where competition from native species is very limited (Pluhár et al., 2000). Its ability to tolerate temperatures down to -15°C allows St. John's wort to colonize habitats from 0 to 1600 m above sea level (Skyba et al., 2012). In recent decades, cultivation of *H. perforatum* has expanded, mainly in temperate climates, to provide the herbal market with sufficient material, to avoid excessive phytochemical variability inherent in plants collected in natural habitats, and to reduce costs through mechanized harvesting (Chauhan et al., 2011). In fact, cultivated St. John's wort grown under controlled agronomic conditions can yield extracts with a higher amount of biologically active polyphenols and, therefore, provide a higher market and therapeutic value (Pérez-García et al., 2006). Grass yield and phytochemical profile can be influenced by various factors related to agrotechnology: nitrogen and nutrient supply, mulching, irrigation, light, temperature, plantations, density, cultivation methods (Chauhan et al., 2011; April et al., 2021). Some of them have been studied, although a complete determination of the optimal parameters for crop has not been carried out sufficiently.

1.3.1 Water availability

It is known that the yield of flower tops increases (up to threefold) when grown on properly irrigated sandy soil rather than silty soil. However, such differences in aboveground mass productivity do not necessarily extend to the yield and profile of secondary metabolites (Gaudin and al., 2002). In contrast, summer precipitation determined a constant increase in hypericin biosynthesis, while summer drought did not affect flower bud formation (Rahnavard et al., 2012). It has been reported that during a particularly rainy and cloudy year, higher hypericin biosynthesis was observed, suggesting that dianthrone synthesis, unlike other secondary metabolites such as terpenes, may not be enhanced by water stress (Couceiro et al., 2006). Water availability was found to be a significant factor in hyperforin biosynthesis . Leaves of plants grown in a greenhouse under minimal life-supporting irrigation (50 ml/plot) produced 3–4 times more hyperforin after 62 days than individuals aged 1–2 years (Sentkowska et al., 2016; Zobayed et al., 2007). In contrast, the amount of hypericin decreased due to water stress, confirming previous findings (Eray and al ., 2020). The different levels may be related to the different physiological significance of hypericins and hyperforins and other biosynthetic pathways. It is suggested that the latter may serve as an antioxidant support to overcome the oxidative burst after water stress; the biosynthesis of the former was most likely reduced due to low carbon uptake in photosynthesis during prolonged drought. However, the duration of water stress is another factor to consider. The studies were limited to a six-day period and found the opposite response: a small increase in hypericins and a small decrease in hyperforin along with a loss of flower dry weight (Torun et al., 2021). The result of short water stress was considered negative in terms of the value of the resulting preparation: the loss of biomass outweighed the relative small increase in phytochemicals .

1.3.2 Altitudinal Effects

St. John's wort is well adapted to altitudes up to 1000-1600 m above sea level, even in Afghanistan it has been found up to 3600 m above sea level. It has been observed that the contents of rutin and quercitrin correlated with the altitude of the collection site: the former provided a negative correlation, while the latter had a positive correlation. The total flavonoid content was reported to be positively correlated with altitude (Seyis et al., 2020; Tekel'ová et al., 2000). The amount of rutin, hyperoside and total flavonoid content also had a positive correlation with height (Umek et al., 1999). Detailed data on the effect of altitude on the accumulation of naphthodianthrones have been published, confirming a significant increase in total hypericin content at high altitude in various Hypericum species, including *H. perforatum* (Xenophontos et al., 2008). The authors suggested that this may be a result of greater light input and increased UV exposure. There is no information on the effect of altitude on secondary metabolites such as phloroglucinols.

1.3.3 Fertilizer application

Nitrogen supply to *H. perforatum* plants has been shown to have a profound effect on its phenolic profile. Growth in soil or/and sand soil with low nitrogen content resulted in increased hypericin levels (2–3-fold), whereas nitrogen-enriched soil caused a 3-fold decrease in total hypericin synthesis in fresh material, but did not affect the average number of dark glands on leaves (Briskin et al., 2000). The same authors note that the relative ratio of hypericin to pseudohypericin was not affected by nitrogen addition. However, only a moderate reduction in nitrogen application is advisable to avoid induction of chlorosis and subsequent undesirable reduction in biomass formation. However, it should be noted that conflicting reports on nitrogen application rates have been reported. For example, plants grown in Iran and fertilized with 250 kg/ha N and 100 kg/ha P increased the number of flowering stems per plant and hypericin content (Azizi & Omidbaigi, 2001). Further studies conducted on plants with additional application of 150 kg/ha N and 100 kg/ha P confirmed an increase in the content of both hypericin, hyperforin and flavonoids, so a final opinion on this matter is not yet given, and in addition, soil composition has been poorly studied (Dias et al., 2001). Experiments have also been conducted to study the combined effect of light irradiation and reduced nitrogen application. The effects were found to be additive and independent, with a consistent increase in the number of red glands and hypericins (Briskin & Gawienowski, 2001).

1.3.4 Prospects for further research

It is worth noting that at present there is no comprehensive understanding of the optimization of agrotechnological methods and their correlation with the phytochemical content of St. John's wort. Increasing biomass and biosynthesis of polyphenols is a problem that should be solved using a multifactorial approach. Promising, from the cultivation side, is cultivation in greenhouses with a controlled environment, where growing conditions can be "adapted" and precisely tuned to the needs of plants. However, from an economic point of view, it is worth evaluating such a development option, whether higher yields, enhanced production of secondary metabolites and higher cultivation density (up to 15 times higher than in open ground) can cover the costs of such a cultivation method. Obviously, such a number of variable factors can explain, in addition to possible genetic differences, the constant variability of the phytochemical profile of St. John's wort from different geographical locations (Mosaleeyanon and al., 2005). In addition, the effects of intercropping with other crops and plant density on the formation of secondary metabolites have not been sufficiently studied yet.

1.4 Biotic and abiotic stress factors

If secondary metabolism is considered an integral part of the ability of plants to modify metabolic processes to thrive and grow under adverse conditions, it is not surprising that both biotic and abiotic stresses can lead to changes in the phytochemical profile *of H. perforatum*. This also becomes apparent when considering St. John's wort as an invasive and ecologically aggressive species, capable of withstanding environmental challenges and adapting to disturbed habitats such as grasslands (Drummond, 2019; Fowler et al., 2023). In different systems, biotic and abiotic elicitors have been shown to modulate the rate of production of bioactive chemicals by St. John's wort, or conversely, St. John's wort is able to plastically adapt its secondary metabolism to external stimuli. This has been confirmed in various works and includes the response of plant's polyphenolic biosynthetic system on the impact of herbivores, on various types of microbial attack and on the consequences of heavy metal exposure (Abdollahi et al., 2023; Kwon et al., 2023).

1.4.1 Heavy metal contamination

Heavy metal contamination can affect the secondary metabolism of medicinal plants, seriously affecting their quality, safety and efficacy, and St. John's wort is no exception (Chizzola et al., 2003; Zandavifard et al., 2017). According to various studies (Ayan et al., 2006; Chizzola et al., 2006; Suljić et al., 2023) *Hypericum perforatum* is a fairly good accumulator of heavy metals, in particular Cu^{2+}, and this behavior should be studied both from the safety point of view and from the point of view of possible consequences for secondary metabolism. Soils rich in Pb, Cd, Mn, Zn and Cu should generally be avoided, as they are not suitable for growing St. John's wort. It has been observed that the content of heavy metals in St. John's wort varies greatly between collection sites (Obratov-Petković et al., 2008). A decrease in seed germination (from 63 to 58%) and a significant decrease in the content of hypericin and pseudohypericins (by 21 and 15 times, respectively) in seedlings treated with nickel were observed (Murch et al., 2003). A complete inhibition of hyperforin biosynthesis was also observed. It was observed that *H . perforatum ssp. angustifolium hypocotiles* treated with different concentrations (within the mM range) of Cr (VI) for seven days induced a marked increase in the biosynthesis of protopseudohypericin (+135-404%), hypericin (+25-38%), and pseudohypericin (+5-379%) (Tirillini et al., 2006). Finally, significant effects of fluoride on plant growth parameters have been reported, but the effects of secondary metabolism have not been determined (Fornasiero , 2003).

1.4.2 Pathogens and herbivores

The production of defensive and communication substances is one of the main purposes of secondary metabolism in plants and the main reason for the existence of many of what we consider active elements. Most compounds of pharmaceutical interest are actually phytoalexins or phytoanticipins, which are produced by polyphenolic biosynthetic pathways, and their amount in the crude preparation may directly depend on the degree of exposure to pathogenic aggression as part of the induced plant defense response (Nikolic & Zlatkovic, 2010). The synthesis of anthrones and phloroglucinols is considered a defense mechanism against herbivores, e.g. causing photosensitization of grazing animals after eating grass (Sirvent et al., 2003; Stamp, 2004). Hyperforins have good antimicrobial properties and are therefore expected to vary to some extent depending on the effects of biotic stress on the plant (Kisa et al., 2023; Lyles et al., 2017). A great deal of work on this subject has been done by Sirvent et al., which confirmed a direct relationship between the amount of hypericins and the effect on insect feeding (*Chrysolina quadrigemina, Spilosoma virginica, Spilosoma congrua, Spodoptera exigua).* In particular, a 30-100% increase in hupericin was found in plants infested with a small number of larvae, while a decrease was recorded in the case of a large number of infestations, and no significant changes in the phytochemical profile were caused by mechanical wounding or feeding by specialized herbivores. The generalist larvae can only feed on organs without dark glands, while the specialized ones can bypass the light-induced toxicity of hypericin and exist on the whole plant. Such data may give hints to a higher amount of hypericins in vegetative material rather than in the reproductive parts of plants, which are rarely reported in the literature (Sirvent et al., 2003; Sirvent & Gibson, 2002).

Further work concerned the effects of exogenous chemical elicitors (phytoalexin methyl jasmonate and salicylic acid) and a pathogenic elicitor (*Colletotrichum gloeosporoides*, chosen because of its good degree of host specificity with *H. perforatum*) (Conceiçao et al., 2006). Total hypericin levels increased 3.3-fold over control levels when treated with 200 μM methyljasmonate for 14 days, while higher concentrations of hyperforin were found in plants treated with 1 mM salicylic acid or 50 μM. However, plant growth and subsequent biomass production were negatively affected by toxicity as early as 200 μM of methyljasmonate. In general, salicylic acid was found to be very effective in the biosynthesis of hyperforin. This behavior has been confirmed and studied in detail in a number of studies in vitro, in which the ability of jasmone derivatives to induce the biosynthesis of flavonoids and naphthodianthrones was observed to the detriment of anthocyanin accumulation in St. John's wort (Gadzovska et al., 2007; Richter et al., 2011). Induction of hypericins by inoculation *with C. gloeosporides* resulted in a 2-fold increase compared to the control, while higher concentrations of spores were detrimental to plant health. However, in a previous study, it was observed that both healthy controls and C. *gloeosporides*-infected plants contained similar levels of hypericins . It was observed that in vivo , and in vitro increased xanthones biosynthesis in plants exposed to *C. Gloeosporides* (Conceiçao et al., 2006) . Stimulation of hypericin biosynthesis by fungi is confirmed by various data in vitro on undifferentiated St. John's wort cells (Xu et al., 2005). St. John's wort is also reported to be affected by viral diseases, as evidenced by lower total methanol extract and statistically significant lower hypericin content in the cultivar Topas, while the cultivars Hyperiflor and Hyperimed showed little to no significant changes, except for an increase in hyperforin content in infected Hyperimed (Kegler, 2003). Treatment with conventional herbicides can provide a slight increase in hypericin content (Pradeep & Franklin, 2022). It has also been found that *Phytophthora spores capsici* and *Diploceras hypericinum* are able to modulate the hypericin biosynthesis pathway, causing an increase in hypericin biosynthesis (Aksoy et al., 2023).

Finally, according to research, *Hypericum perforatum* is frequently affected by wilt disease caused by phytoplasmas, and this pathology causes changes in secondary metabolism (Bruni et al., 2005; Marcone et al., 2016; Pavlović et al., 2012). Qualitative and quantitative phytochemical variations were actually observed in the dried flower heads of cultivated *Hypericum perforatum L.* cultivar Zorzi, infected with phytoplasmas of the "ashy yellow" class. In the affected plants, a decrease in the amount of rutin (1.96 vs. 4.96 mg/g dry weight), hyperoside (2.38 vs. 3.04 mg/g dry weight), isoquercitrin (1.47 vs. 3.50 mg/g dry weight), amentoflavone (0.12 vs. 0.39 mg/g dry weight), pseudohypericin (1.41 vs. 2.29 mg/g dry weight) was observed, while the content of chlorogenic acid doubled (1.56 vs. 0.77 mg/g dry weight) (Bruni et al., 2005). The content of hypericin , quercitrin and quercetin was not significantly affected. Host resistance may induce specific variations in the secondary metabolism of the affected tissues, inhibiting the flavonoid biosynthesis pathway. The presented net results would be consistent with these hypotheses. The information available at the moment allows us to state that hypericins and hyperforins are not phytoalexins but rather phytoanticipins (secondary metabolites that are already present in low amounts in healthy plant tissues and are induced by biotic or abiotic challenges) (Shakya et al., 2019; Tocci et al., 2018).

1.4.3 Light and carbon availability

Environmental factors such as light and carbon dioxide, which affect the rate of photosynthesis and thus the production of polyphenols, were evaluated on plants grown with different photosynthetic photon flux densities, which yielded interesting results (Nishimura et al., 2006). Leaves of specimens grown in a controlled environment provided 30 and 41 times higher contents of hypericin and pseudohypericin than plants

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grown in the open field, respectively. A similar result was reported for the number of dark glands in leaves at the vegetative stage but with a limited effect at the reproductive stage (12 glands/cm^2 instead of 18) (Zobayed et al., 2006). The researchers demonstrated that hypericin content was directly related to both ambient CO_2 concentration and photosynthetic photon flux density; fresh and dry matter production also increased similarly (+30%). Such effects should be considered as a consequence of increased photosynthesis. However, no data were provided on the effects on the number and composition of flower buds, and although this approach is extremely attractive, it seems to require further fine-tuning before it can be evaluated for large-scale application. According to another study, increased light led to a linear increase in hypericin levels in leaves. Increased light also led to a parallel increase in the number of dark glands, which was also somewhat confirmed by open-field experiments in which shade reduced hypericin content (Hevia et al., 2002). In a controlled environment, St. John's wort plants grown under red light (600-700 nm) provided a dry weight greater than plants grown under blue light, but no details regarding the phytochemical effects have been made to date (Nishimura et al., 2006). It should also be noted that the samples with the highest amounts of hyperforin and hypericin ever collected in the wild were from the Armenian territory with over 300 sunny days per year (Kirakosyan and al., 2004). This behavior may be related to the enhanced conversion of protohypericins to hypericins provided by light. It has been found that the rate of photosynthesis is linearly related to both the number of dark glands and the accumulation of hypericins only during the first 6 weeks of the vegetative stage of the plant (Chen et al., 2010; Karimi et al., 2022).

1.4.4 Temperature effects

St. John's wort plants have a limited ability to respond to and tolerate high temperatures, which results in both dry weight loss and changes in phytochemical structure. In fact, temperature has been found to be a significant factor, as plants grown at 25°C have a hyperforin/hypericin ratio of 25% and a pseudohypericin/hypericin ratio of 20% higher than those grown at 30° C (Odabas et al., 2009; Su et al., 2021; Tavakoli et al., 2020). Such variations provide further evidence of the possible effects of small environmental changes (e.g., climatic and geographical) on the secondary phenolic metabolism of St. John's wort and may at least partially explain the large heterogeneity in phytochemical composition. However, temperature did not affect the ratio of phytochemical concentrations in flower buds and shoots (Couceiro et al., 2006). A two-week gradual increase in temperature (8-18-28°C) determined an increase in hypericin biosynthesis in plants cultivated in Canada. Temperature stress, both positive and negative, introduced a few days before harvest can cause low plant growth due to lower photosynthetic efficiency, while a decrease in temperature (from 35° to 15°C) determines a loss of hypericin and hyperforin biosynthesis in grown shoots in a controlled environment. There are no comprehensive data on flowers and flower buds in this regard, but a temperature of 20°C seems to be better suited for optimal biosynthesis of secondary metabolites, with better values for hypericins and worse for pseudohypericin and hyperforin in such organs at temperatures above 20°C (Kaundal et al., 2021; Zobayed et al., 2005).

Despite their value in better understanding the mechanisms underlying the biosynthesis of hypericins and hyperforins and their ecological role, the aforementioned studies have limited field reproducibility. This is mainly due to the large and significant loss in biomass production caused by biotic and abiotic stresses. However, considering that most cultivation methods of St. John's wort are organic, the consequences of pathogen exposure in vivo needs to be deepened, while most of the available data relate to in experiments in vitro.

1.5 Harvesting practices and yield stability

The variability of the chemical composition of *H. perforatum* does not stop at the level of in vivo. In fact, various works have reported the instability of polyphenolic phytocomplex of the St. John's wort at the stages after harvest, processing, and storage as a result of exposure to light, pH, and temperature (Ang et al., 2004; Bilia et al., 2001; Şahin et al., 2020). Post-harvest processing of herbal preparations in the immediate post-harvest stages, in particular, may have implications for the market value of the preparation (Böttcher et al., 2003). The quantity and quality of light after harvest was assessed on plants grown in the field, which indicated that several hours of light exposure of freshly harvested St. John's wort plants did not result in the loss of hypericins, but did alter the protopigment/pigment ratio (protohypericin versus pseudohypericin and hypericin), with a decrease in protopigments with increasing exposure to sunlight (Poutaraud et al., 2001). This suggests that drying flowers in sunlight may stop the conversion of protopigments to pigments more quickly than in buds (which are less light- permeable), and that the presence of protective substances such as flavonoids may also limit such conversion. 16 hours of light exposure of flowering tops causes 20% conversion of protohypericin and protopseudohypericin to their stable forms. Previous studies have reported that the conversion of protopigments to pigments could be achieved after 4.5 hours of exposure to sunlight or 30 minutes of artificial white light (Agapouda et al., 2019; AhmadiChenarbon et al., 2011). A comprehensive and detailed review of the modification of the appearance and composition of the herbal preparation of St. John's wort during post-harvest processing is available (Böttcher et al., 2003). Both temperature and time were taken into account, and useful determinations of the respiration rate of freshly cut *H. perforatum* cultivar Topaz were also made. The results suggest drying the plant material at 10°C for 70 hours, 20° C for 60 hours, and 30°C for 30 hours to avoid excessive reduction in the visual quality of the preparation (discoloration, hardening, wilting). The authors also identified the need for periodic (30-50% of the day) ventilation of the freshly collected material with cool (e.g., nighttime street air) rather than warm air, as a consequence of its extremely high respiration rate. The phytochemical quality of the preparation remained quite stable, with a 20% decrease in hypericin and total flavonoid content. However, at all three temperature conditions (10, 20, 30°C) in the material obtained from young plants (first cut of the first year of cultivation), a significant increase of 80% in hypericins and an increase of 50-60% in flavonoids was observed. These increases are most likely explained by a new physiological synthesis occurring in younger and thus more vital tissues. In Brazilian samples, the effects of drying and

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freezing temperatures on hypericin and flavonoid content were observed, noting that freezing may be detrimental to hypericin (whose amount was almost halved in samples frozen in liquid N_2), but not to flavonoid content (Diniz et al., 2007). The best drying results in terms of hypericin and total flavonoid content were obtained at 50°C. Economic evaluations of this behavior may be of great importance for assessing the possible advantages of early harvesting and appropriate processing, since shorter growing times can reduce production costs. The effects of air drying at room temperature on the phytocomplex were also evaluated, which showed a loss of two-thirds of flavonoid content and no statistical differences in hypericin (Bergonzi et al., 2001). This behavior, when compared with previous studies, is most likely related to the higher drying temperature. The hyperforin content showed a significant loss from 109.5 mg/g fresh weight to 6 mg/g in air-dried samples exposed to sunlight and from 101 mg/g fresh weight to 5 mg/g in air-dried samples extracted in the dark, indicating that air-drying at room temperature is not suitable for obtaining extracts rich in these compounds and exposure to light should be avoided. As a rule, hyperforin-rich extracts should be obtained from fresh rather than dried material. This may also be due to the faster degradation of the translucent glands, which are located directly under the epidermis and are more susceptible to damage by evaporation and heating (Janowska & Trelka, 2010) . Harvesting at the late bud stage is advisable to preserve the highest hypericin content after drying, while late harvest is favorable to avoid excessive losses of hyperforin . Within the range of 40-80°C, biapigenins, hypericins and hyperforins are not affected by the drastic temperature changes, while flavonoid glycosides, rutin and hyperoside may undergo a noticeable decrease. However, many works have described the formation of degradation products in crude extracts of St. John's wort mainly due to exposure to light, so the above-mentioned treatments should be carried out under strict phytochemical control (Tanko et al., 2005).

In summary, most of the literature on the degradation of major secondary metabolites of St. John's wort after harvest focuses on the extract, while actual knowledge on the crude preparation is limited and needs to be deepened for three main reasons: 1) proper drying, sufficient lighting and aging time of freshly harvested plant material can increase the polyphenol content of the final preparation; 2) different handling of the crude material can lead to disparate and unreliable reports in the literature (also in terms of polyphenol profile and pharmacological equivalence); 3) the biological activity and toxicology of the degradation products are unknown and their presence should be minimized.

1.6 Phytochemical profile

The herb *H. perforatum* has been widely used in folk medicine to treat a wide range of diseases since ancient times in Ukraine and Eurasia (Rizzo et al., 2020; Schempp et al., 2011; Scotti et al., 2019). Research on the determination of the phytochemical composition and pharmacological action of the components of the herb is currently being actively conducted in Ukraine and in European countries (Bulgaria, Germany, etc.). Thanks to this, the chemical composition of St. John's wort has been studied quite fully at the moment. More than 80 components have been isolated in different parts of the plant (Booker et al., 2018) from groups of biologically active compounds (BACs) with different pharmacotherapeutic effects.

In members of the genus *Hypericum* a wide range of phenolic compounds has been isolated. The main BACs of St. John's wort are hypericins – red pigments of St. John's wort, condensed derivatives of anthraquinone. Three red pigments have been found in the herb – hypericin , protohypericin and pseudohypericin (Carrubba et al., 2021; Crockett et al., 2011; Cui et al., 2014; Florea et al., 2017; Khare 2007; Schempp et al., 2011; Scotti et al., 2019; Wang et al., 2023) and others. Hypericin content 0.03%-0.49% (Crockett et al., 2011; Florea et al., 2017), the amount of anthracene derivatives – up to 0.89% (Bagdonaitė et al., 2012; Colak et al., 2020). Anthraglycosides emodins were also found (Carrubba et al., 2021). These compounds have a chromophore group of atoms in their composition, which makes them widely used as photosensitizers in the treatment of cancer by photodynamic therapy (Florea et al., 2017; Tawaha et al., 2010). All oxyanthraquinones are yellow-orange-red pigments, in the presence of alkalis they give intensely colored solutions and together with anthocyanins participate in the coloring of yellow flowers, provide resistance to light and the action of enzymes. They play an important role in redox reactions occurring in plants and antimicrobial protection (Carrubba et al., 2021; Khare 2007; Pogorzelska-Nowicka et al., 2021; Pradeep al et., 2020).

Anthracene derivatives – hyperforins – depending on their chemical structure, differ in pharmacological properties into chrysacin derivatives (have a laxative effect), alizarin derivatives (spasmodic and nephrolytic effects) (Rychlewski et al., 2023; Rizzo et al., 2020; Saçıcı & Yesilada, 2021). The content of hyperforins in different organs of St. John's wort ranges from 1.3% to 2.8% (Rychlewski et al., 2023; Saçıcı & Yesilada , 2021). Hyperforins are responsible for the antimicrobial and antiviral activity of St. John's wort preparations, their sedative, antidepressant effects and their toxicity due to photosensitization (Rychlewski et al., 2023; Rizzo et al., 2020).

Flavonoids (yellow pigments) are represented by the following flavonols: glycosides (Makarova et al., 2021; Rusalepp et al., 2017): rutin (Greeson et al., 2001; Rusalepp et al., 2017; Scotti et al., 2019), quercetin 0.23% (Greeson et al., 2001; Makarova et al., 2021; Rusalepp et al., 2017), quercitrin (Becker et al., 2016; Dias, 2003), isoquercitrin (Becker et al., 2016; Crockett et al., 2011), hyperoside (galactoside quercetin, or hyperin): from 0.59% to 1.89% (Dias, 2003; Erland & Saxena, 2019; Greeson et al., 2001), luteolin, kaempferol (Bruni & Sacchetti, 2009), bisapigenin and diquercetin (Dias, 2003). The total flavonoid content, according to literature data, is: 2.9%-3.5% (Crockett et al., 2011), 2.49%-5.80% (Bagdonaitė et al., 2012), 5.90%-6.93%, maximum in flowers 17.30% (Dordević, 2015). Pharmacological effects of flavonoids: antispasmodic effect on smooth muscle elements, stimulating effect on regenerative processes, P-vitamin activity, anti-inflammatory, analgesic, diuretic and choleretic effect (Florea et al., 2017; Ibrahimi et al., 2020; Schempp et al., 2011; Tusevski et al., 2019). Flavonoids have antiviral, anticarcinogenic, immunotropic and antioxidant activities, the latter higher than those of vitamins and carotenoids (Becker et al., 2016; Gioti et al., 2009; Ibrahimi et al., 2020; Schempp et al., 2011; Tusevski et al., 2019; Wang et al., 2023).

Phenylpropanoids (phenolcarboxylic acids and their derivatives) have also been identified: caffeic (0.1%), chlorogenic, ferulic, gentisic, and gallic acids (Barnes et al., 2010; Dimitrov et al., 2020; Khare, 2007); the content of cinnamic acids is 0.24%-0.26 % (Balea et al., 2020; Colak et al., 2020). According to (Becker et al., 2016; Chung & Deng, 2020) they have bactericidal properties.

Coumarins , particularly umbelliferone and scopoletin, found in St. John's wort have been shown to thin the blood, improving circulation and preventing blood clots. They also have anti-inflammatory and antiseptic properties, making them useful in treating inflammation and other conditions. These properties make St. John's wort popular in herbal remedies for improving cardiovascular health and overall well-being (Schempp et al., 2011).

The presence of anthocyanins in the raw material (5.66%-6.00%) has been proven (Cui et al., 2014; Flora et al., 2017). Catechins, leucoanthocyanidins and anthocyanidins contained in St. John's wort (Sarikurkcu et al., 2020), reduce the permeability of capillary walls (P-vitamin action) (Barnes et al., 2010; Patocka, 2003).

Condensed tannins (derivatives of pyrocatechin and leucoanthocyanidins) were also isolated: from 4.9%–5.6% (Crockett et al., 2011) up to 10.0%–12.0% with astringent, antimicrobial and anti-inflammatory effects (Barnes et al., 2010; Makarova et al., 2021).

An important component of the herb is the presence of essential oils (up to 1%). They include pinene, myrcene, cineole, limonene, geraniol, capric, isovaleric and other aldehydes, isovaleric acid and its esters (Balea et al., 2020; Bertoli et al., 2011; Dimitrov et al., 2020; Patocka, 2003; Vuko et al., 2021; Yin et al., 2004). The main components of essential oils are highly reactive terpenoid compounds, among them sesquiterpene hydrocarbons predominate, of which γ-amorphene (30.64%) is contained in the maximum amount (Bertoli et al., 2011; Yin et al., 2004), as well as fatty acids: heneicosanoic, tricosoanoic, tetracosoanoic, pentacosoanoic, hexacosanoic, heptacosanoic, octacosoanoic, nonacosanoic, triacontanoic, gentriacontanoic, dotriacontanoic, tetrathiacontanoic, 3-hydroxydodecanoic, 3-hydroxytetradodecanoic, 3-hydroxyhexadodecanoic, 9-hydroxystearic (Sirak et al., 2007; Yao et al., 2019).

Essential oils accumulate in colorless and pigmented endogenous secretory receptacles of St. John's wort, the presence of which is used in determining the authenticity of plant raw materials (Balea et al., 2020; Moleriu et al., 2017; Patocka, 2003; Rizzo et al., 2020; Yin et al., 2004). They protect plants from being eaten by animals, infected by bacteria and fungi, attract pollinating insects and take an active part in metabolic processes in plants. Essential oils are part of anti-inflammatory, bactericidal, antispasmodic and sedative drugs (Balea et al., 2020; Rizzo et al., 2020; Schempp et al., 2011; Yin et al., 2004).

The following sterols were also isolated from the raw material: β-sitosterol and ergosterol with a hormone-like effect (Bardhi et al., 2015; Kováčik et al., 2022; Schempp et al., 2011; Yao et al., 2019); triterpene saponins (Cui et al., 2014; Dordević, 2015; Rychlewski et al., 2023; Schempp et al., 2011), mainly with anti-inflammatory effects; the nitrogen-containing compound choline (Schempp et al., 2011); alkaloids (Rusalepp et al., 2017; Rizzo et al., 2020); resinous substances (up to 10%) (Dordević, 2015; Schepetkin et al., 2020); vitamins C, E, carotenoids, carotene (Crockett et al., 2011; Rizzo et al., 2020; Schempp et al., 2011). Also there is a high content of carotene (up to 55 mg/100 g) and ascorbic acid with anti-inflammatory effect (Cui et al., 2014; Schempp et al., 2011; Rizzo et al., 2020). Choline, tannins, flavonoids, hypericin were found in the plant sap (Barnes et al., 2010; Florea et al., 2017; Khare, 2007; Yin et al., 2004).

The above-ground mass is widely represented by macroelements (mg/g): K-16.8; Ca-7.3; Mg-2.2; Na-0.37; Fe-0.11; and microelements (μg/g): Mn-0.25; Cu-0.34; Zn-0.71; Co-0.21; Mo-5.6; Cr-0.01; Al-0.02; Se-5.0; Ni-0.18; Sr-0.18; Cd-7.2; B-40.4. (Kováčik et al., 2022; Oniga et al., 2022; Schepetkin et al., 2020). The plant is able to concentrate: Mo, Se, Cd, Pb and even – Mn (Moleriu et al., 2017; Velingkar et al., 2017; Yılmazoğlu et al., 2023).

In general, the pharmacological interest in the herb Hypericum is represented by phenolic compounds with a wide spectrum of action, including antioxidant and anticarcinogenic activity. Preparations based on them are used in clinical practice as antimicrobial, anti-inflammatory, choleretic, diuretic, hypotensive, astringent, laxative, tonic and adaptogenic agents in complex therapy (Barnes et al., 2010; Erland & Saxena, 2019; Khare, 2007; Oniga et al., 2022; Rizzo et al., 2020; Schempp et al., 2011; Sekeroglu et al., 2017; Wang et al., 2023; Yalçın et al., 2021).

It is worth noting that at present there is no comprehensive understanding of the optimization of agronomic practices and their correlation with the phytochemical content of St. John's wort. Increasing biomass and biosynthesis of polyphenols is a problem that should be solved using a multifactorial approach. Promising, from the cultivation side, is cultivation in greenhouses with a controlled environment, where cultivation conditions can be "adapted" and precisely tuned to the needs of the plants. However, from an economic point of view, it is worth evaluating such a development option, whether higher yields, enhanced production of secondary metabolites and higher cultivation density (up to 15 times higher than in open ground) can cover the costs of such a cultivation method. Obviously, such a number of variable factors can explain, in addition to possible genetic differences, the constant variability of the phytochemical profile of St. John's wort from different geographical locations.

Phytochemistry of the herb St. John's wort (*Hypericum perforatum* L.) has been studied quite thoroughly throughout the entire Eurasian range of the species. The main biologically active compounds of the raw material are plant pigments: anthracene derivatives anthraquinones (hypericin, pseudohypericin), flavonoids (rutin, bisapigenin, quercetin and its derivatives), phenylpropanoids (caffeic, chlorogenic acids) and phloroglucin. St. John's wort herb is a promising source of raw materials for the production of antibacterial, antiviral, anti-inflammatory, astringent, diuretic, antidepressant, antioxidant, anticarcinogenic, immunotropic and adaptogenic agents.

1.7 Seedling production technique

Medicinal and essential oil plant production as a branch of agricultural production is characterized by a number of features: a large number of species that differ greatly in their biology, which complicates the development of their industrial technology and their cultivation as agricultural crops. Many taxa are characterized by strong intraspecific chemical polymorphism, which creates difficulties in their processing, both in the pharmaceutical and food and perfume industries (De Martino et al., 2009; Mimica-Dukic & Bozin, 2008). This creates a number of problems that hinder the development of the industry as a whole and prevent the production of raw materials of a given stable quality.

The lack of industrial seed production and the acute shortage of seeds of many popular crops, in particular such large-scale crops as valerian, oregano, St. John's wort, sage, as well as rare, not widespread and also highly demanded ones – rhodiola rosea and cinquefoil, make it difficult to obtain their raw materials in sufficient quantities. This is due to the laboriousness and cost of seed production, as well as the low seed productivity of some plant species (Kučinskaitė et al., 2007).

No one doubts that woody and shrubby plants (sea buckthorn, rose hips, lavender, rosemary, etc.) reproduce in production only vegetatively, which allows preserving varietal qualities and economically valuable traits (Markovska et al., 2020; Alkurdi et al., 2013). Every year, microclonal propagation is increasingly used in medicinal crops (Grzegorczyk-Karolak et al., 2018; Jarma-Orozco et al., 2020). In some cases, this method is the only real opportunity to obtain a sufficient amount of planting material, but it is associated with the availability of qualified specialists and serious equipment. For vegetatively propagated crops, such as peppermint, narrow-leaved lavender, rosemary, etc., the use of cuttings (rhizome and green cuttings) allows you to obtain aligned plants, both in phenotype and in the biochemical composition of the raw material (Moro et al., 2011; Najar et al., 2021). Also, the seedling method is the only possible method for plants with complex stratification and very long growth, such as yellow gentian (Radanovic et al., 2016). The issue of stability of the content and composition of pharmacologically significant compounds for medicinal plants and essential oil for aromatic plants is a key problem of raw material quality, the solution of which makes it possible to fully meet the requirements and requests of processors (State Pharmacopoeia of Ukraine, 2014). In recent years, medicinal plant production has switched to the production of vegetatively propagated planting material of such species as creeping thyme and common thyme, common oregano and some other species (Zayova et al., 2018). There are also studies on medicinal crops related to this issue, in particular work on cuttings of common belladonna (Kutlymuratova & Baynyyazova, 2022), creeping thyme (Verma et al., 2011), European bugleweed (Vladimirova , 2019).

The problem of introducing seedling technologies can be conditionally divided into several areas, the comprehensive solution of which will allow building the entire production process and achieving the ultimate goal – the necessary quality of raw materials in a quantity that meets the needs of all interested industries (Pospelov & Solop, 2021). Currently, there are significant comprehensive developments in this area in a number of EU countries (Hoppe & Plescher, 2016). In the domestic literature, there are works on elements of technology for individual crops, mainly introduced ones, which are difficult to reproduce and to a greater extent highlight the biological, rather than technological, aspects of seed and vegetative propagation of medicinal and essential oil crops. As noted above, plant propagation, depending on the species, is possible either by seed or vegetative means.

When direct sowing into the soil, taking into account the small size of the seeds of many species, in particular, St. John's wort, it is necessary to increase the seeding rate, which affects costs. Accordingly, with a shortage of seeds and their high cost, if we are talking about large areas, the implementation of the project becomes impossible. The same problem may arise when planting a plantation with seeds of a new variety, which, by definition, are few at the initial stage. The use of seedling technology allows you to reduce the need for seeds per 1 ha by 10 or more times. Using the example of Echinacea purpurea, it was established that seedling culture has advantages compared to direct sowing into the soil, especially when the limiting factor is active temperatures and precipitation. In addition, a complex of agrotechnical methods for controlling weeds can be carried out in the field before the crop is planted (Pospelov & Pospelova, 2019). An additional bonus is the ability to reduce the time the crop stays in the field by a year, which is important if the raw material is roots and the field does not bring any income for two or three years, but requires significant maintenance costs. For example, many small farms in the European Union have adopted the seedling technology for growing valerian (Furukawa, 2019; Chizzola et al., 2018).

In seed propagation, at the stage of seed preparation, important operations are pickling, if necessary, stratification or scarification and treatment with growth stimulants, which allows you to prevent the appearance of black leg and get seedlings as quickly as possible. Mechanization of processes is possible through the use of complexes that include the functions of mixing peat, filling cassettes and sowing seeds. Sowing in cassettes can be mechanized using seed drills designed for growing vegetable seedlings: SEM 100 (for small and medium-sized enterprises) and more productive ones, for example, a line based on the LR1200 seed drill, equipped with electronic belt speed control. The size of the cassettes is determined by the crop and the duration of seedling cultivation.

After the emergence of seedlings, it is necessary to provide the most comfortable conditions and stimulate both the development of the root system and the formation of a stable clod in the cassette, as well as the above-ground mass. The use of complex fertilizers (Pryvedenyuk & Shatkovskyi, 2021), microfertilizers, root formation stimulants and photosynthesis activators allows you to get high-quality seedlings as quickly as possible. Amino acid preparations may be of great interest, which, thanks to the amino acids contained in them, perform not only a nutritional, but also an anti-stress and regulatory function (Jamwal and al., 2018). At the same time, they are not dangerous in operation and can be used in organic production. For example, positive results on hyssop, thyme, and oregano gave good results with 2-3-fold treatments, both with individual amino acids and amino acid preparations (Fouad et al., 2023).

Reducing the period of growing seedlings is possible by creating the most comfortable conditions for nutrition and lighting for plants. In vegetable growing, additional lighting of a certain spectral composition and duration is actively used to obtain high-quality seedlings. However, it is mainly used in seedling compartments of winter heated greenhouses and is quite expensive. This method is appropriate for plants with a very long seedling growth period and an expensive final product (Rhodiola rosea) (Ampong-Nyarko, 2014). As a cheaper option, unheated greenhouses and areas with the possibility of watering and covering with non-woven material for growing can be considered at the first stage, as well as the use of preparations that increase the stress resistance of plants, such as Vimpel-K and Vimpel 2, etc. (Pryvedenyuk et al., 2022; Lupak & Antonyak, 2020).

Reducing energy consumption for cultivation facilities consists of reducing the period of seed germination in germination chambers or heated greenhouses and as quickly as possible removing plants to unheated greenhouses or open areas. For plants planted in the summer, only open areas can be used. A similar technology is used for growing cassette seedlings of valerian, oregano, St. John's wort and some other crops (Schmatz & Dick, 2010; Schempp et al., 2011).

The use of seedlings allows for the highest quality field preparation and all necessary weed control measures. In some crops, in particular, valerian, seedlings are planted in the field in the second half of summer, which allows the area to be used for growing, for example, fodder crops or green manures, and the period of growing valerian is actually reduced by a year (when sowing, it is grown for 2 years) (Kwiatkowski, 2010). After planting, you can quickly start mechanized inter-row cultivation without fear of damaging fairly large plants. When planting seedlings in spring (late May - early June), crops such as lemon balm and oregano can yield a harvest in the first year of life (Yenkalayci et al., 2021).

Planting plants requires seedling machines as a means of mechanization. Currently, there is a fairly large selection of them and each farm will solve this problem, based on financial capabilities and area. But in any case, the equipment intended for vegetable growing is perfectly suitable for planting seedlings of herbaceous crops (melissa, mint) or shrubs (thyme, rosemary, lavender). However, it should be remembered that a number of species have rather fragile above-ground parts and a clamping-type planting device is not always suitable. It is better to give preference to machines with a vertical or revolver planting device. The presence of pre-planting irrigation makes it possible to plant almost at any time, except for a very hot and dry period in mid-summer.

Thus, the results of research on seedling technology of medicinal crops showed that it can become an important tool for solving the problem of seed shortage and ensuring a stable biochemical composition of raw materials. Growing plants using seedlings, both generatively and vegetatively propagated, gives the raw material uniformity and allows you to control plant growth processes from the very beginning. Additional advantages of seedling technology are reduced seed costs, reduced seedling growing time, simplified mechanization of sowing and planting plants, as well as a longer interval for weed control and preparation of the site for planting. Seedling technology also allows you to reduce the duration of crops in the field, which can be important for crops that require long-term care to obtain a harvest. In addition, this technology opens up opportunities for mechanized planting of plants and the use of various fertilizers and growth stimulants to improve the quality of seedlings. All this indicates the importance and prospects for using seedling technology in the cultivation of medicinal and essential oil crops.

Short conclusions:

1. Analysis of literary sources shows that St. John's wort (*Hypericum perforatum* L.) is a promising medicinal crop for cultivation in Ukraine, given its adaptability to various environmental conditions and the high value of secondary metabolites. The plant tolerates a temperate climate well and has significant resistance to low temperatures (up to -15°C), which allows it to be cultivated in various regions of Ukraine, including the Forest-Steppe and the Carpathians. High drought resistance and the ability to grow on poor soils increase the possibilities for expanding plantations.
2. It is recommended to sow St. John's wort in early spring or before winter. The best results are obtained by sowing before winter, which contributes to earlier development of seedlings and increased yield. To ensure high yield, it is important to use organic and mineral fertilizers, as well as weed control in the first years of vegetation. It is important to note that the seedling method of cultivation provides more uniform plant growth, increases their resistance to adverse conditions and contributes to a greater accumulation of biologically active substances.

Biotic and abiotic stresses, including heavy metal pollution, can significantly affect the secondary metabolism of St. John's wort. This requires careful selection of growing sites with minimal anthropogenic load.

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CHAPTER 2
EXPERIMENTAL CONDITIONS AND METHODS OF RESEARCH

Researches was carried out in 2021–2024 in the laboratory of the Department of Agriculture and Agrochemistry named after V. I. Sazanov of Poltava State Agrarian University, in 2021–2023 in the educational and scientific laboratory of protected soil technologies of the Department of Selection, Seed Production and Genetics of Poltava State Agrarian University; in 2022–2024 in the conditions of the Agricultural Cooperative "Radyansky" of the Kremenchuk district of the Poltava oblast; in 2022–2024 in the conditions of the educational laboratory of the Faculty of Natural Sciences "Botanical Garden" of National Pedagogical University named after V. G. Korolenko, Poltava.

2.1 Soil and climatic characteristics of the experimental sites

Agricultural Cooperative (AC) "Radyansky" is located in the southern part of Kremenchuk district of Poltava oblast, in the steppe zone. The cooperative's lands are located in the floodplain of Dnipro and Oryl rivers, occupying the bog and first loess terraces of Dnipro river. The terrain is characterized as flat-plain with water-erosion features. Here you can find closed saucer-shaped depressions and elongated hollows. Floodplain soils and the first loess terrace form a slightly undulating plain, where there are no steep slopes, and short gentle ledges prevent the development of water erosion. The bog terraces are mainly composed of medium- and high-hilly sands, with the height of the hills over 3 m. The depth of groundwater on the loess and bog terraces is 8–10 m, in the floodplain part this indicator decreases to 1.5–2 m.

The main soil-forming rock is field carbonate loess loam. The composition of arable land is dominated by residually deep slightly saline black soils, which in some places contain deep slightly saline black soils. These soils lie on flat areas of loess terraces and have a steepness of 0–1°. They are well humified and suitable for growing crops and perennial plantings.

Small areas are occupied by residually deep slightly saline black soils, which

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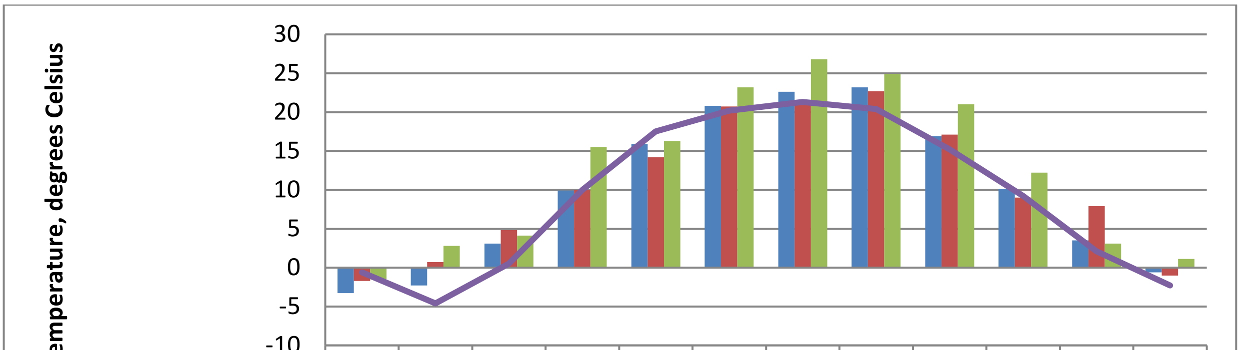
have been partially washed away. Because of this, they have a slightly lower content of humus and nutrients, but remain suitable for agricultural use provided that anti-erosion measures are taken. The farm also presents deep slightly and medium saline black soils, which have a carbonate-free structure and an acidic soil reaction. They require liming or the introduction of defecate, but in general are suitable for growing all crops.

In the north of the farm there are areas of residually deep, slightly saline black soil. medium-washed, where water erosion has partially washed away the fertile horizons, exposing less fertile layers. Because of this, these soils are mainly used for natural fodder. On the pine terraces, significant areas are occupied by sandy soils, which have a high risk of wind erosion. For their effective use, it is recommended to introduce sideral crop rotations and take measures to reduce deflation processes.

In the floodplain, meadow soils with a high level of salinity are widespread, including salt marshes of varying degrees of salinity. They are suitable for natural forage lands under the condition of normalized grazing and fertilization. Also on the territory of the Radyansky AC there are areas of meadow-chernozem alluvial saline soils located in depressions and hollows. They are best used for growing late spring or vegetable crops. However, these soils have an acidic reaction and require liming. The depth of the humus horizon varies within 40–43 cm, and the humus content is 2.0–2.3%, pH-5.7-6.4. In general, the soil conditions of the farm contribute to the cultivation of the main agricultural crops.

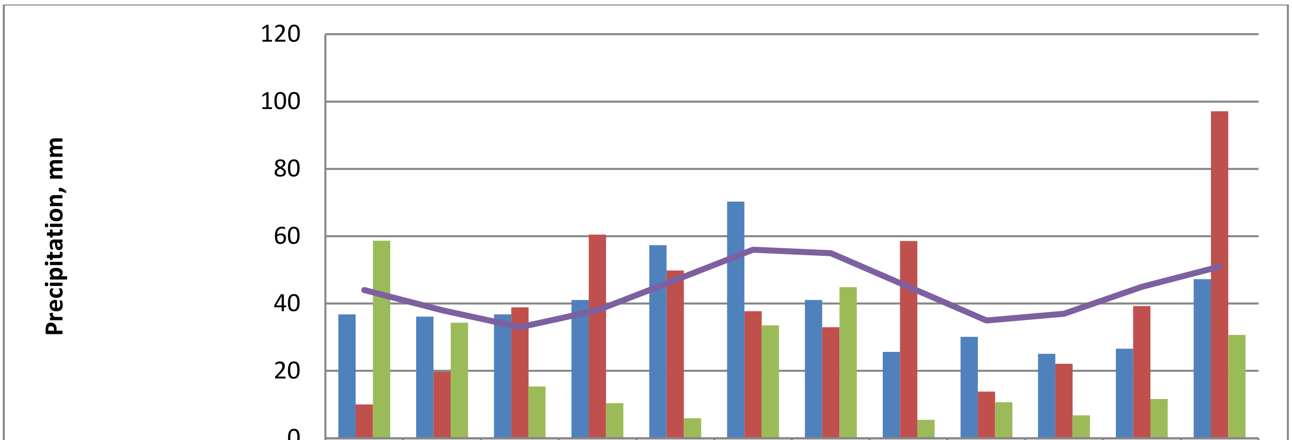
The climate of the farm is characterized by moderately continental conditions with unstable humidity. Winters are cold here, and summers can be hot and dry. The coldest month is January with an average temperature of -6.0°C, and the warmest is July (+21.3°C). Average daily temperatures above 0°C are observed from April to mid-November, and the frost-free period lasts 165–170 days. The annual amount of precipitation is 524 mm, with up to 70% of them falling in the period from April to October. The spring-summer period is characterized by the predominance of northeasterly winds, and the autumn-winter period is characterized by northwesterly winds.

The data show that the largest temperature fluctuations were observed in the autumn-winter and spring periods. The coldest were January and March 2022, while 2024 was marked by abnormally high temperatures. The least variable in terms of temperature were May and June, which demonstrated stable indicators throughout the entire observation period.



	1	2	3	4	5	6	7	8	9	10	11	12
2022	-3,3	-2,3	3,1	9,9	15,9	20,8	22,6	23,2	16,9	10,1	3,5	-0,6
2023	-1,7	0,7	4,8	10	14,2	20,7	21,5	22,7	17,1	9	7,9	-1
2024	-1,5	2,8	4,1	15,5	16,3	23,2	26,8	24,9	21	12,2	3,1	1,1
average multi-year	-0,6	-4,6	0,5	10	17,5	20,2	21,3	20,4	15,2	9,2	2,1	-2,3

Fig. 2.1 - Characteristics of air temperature over the years of research (Kobelyaki station)



	1	2	3	4	5	6	7	8	9	10	11	12
2022	36,8	36,1	36,8	41,1	57,3	70,3	41,1	25,7	30,1	25,1	26,6	47,3
2023	10,1	19,8	38,9	60,5	49,8	37,7	33	58,6	13,9	22,1	39,3	97,1
2024	58,7	34,3	15,4	10,4	6	33,6	44,9	5,5	10,7	6,8	11,7	30,7
average multi-year	44	38	33	38	47	56	55	45	35	37	45	51

Fig. 2.2 - Characteristics of precipitation over the years of research (Kobelyaky station)

Overwintering of St. John's wort in farm conditions was accompanied by significant temperature fluctuations, periodic thaws, the formation of crust and bloom, which, combined with winter droughts, wind erosion of snow and soil, created unfavorable conditions for plants and led to a decrease in their survival rate.

Moisture availability is a key factor in crop yields in this area. As can be seen from Figure 2.2, precipitation is unevenly distributed throughout the year. The largest amount falls on the winter and summer months, while in the fall their arrival is much smaller. According to long-term observations, the average annual amount of precipitation is 443.3 mm. At the same time, their uneven distribution in combination with high temperatures often causes stressful conditions for plants, which negatively affects the formation of the crop and the quality of raw materials. Moisture deficiency in the spring period, especially in the presence of dry winds, necessitates the prompt closure of moisture in the soil and sowing in a short time. However, in dry years, the deficiency of soil moisture can significantly reduce the field germination of seeds.

Persistent snow cover usually formed in the second half of December and melted in the first half of March, lasting an average of 75–82 days. Its thickness varied from 3 to 20 cm, and the ground freezing reached an average of 70 cm, fluctuating within the range of 14–85 cm.

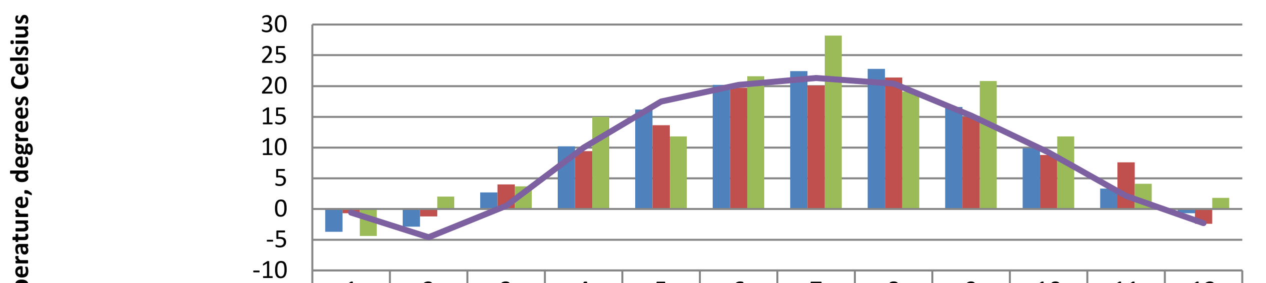
In general, the climatic conditions of the Radyansky AC are favorable for growing most agricultural crops. At the same time, agrotechnical measures should be aimed at rational preservation of soil moisture, which is a determining factor for obtaining stable yields.

The educational laboratory of the Faculty of Natural Sciences "Botanical Garden" of National Pedagogical University named after V. G. Korolenko is located in the central part of Left-Bank Ukraine, within the Poltava oblast, on the Paleogene plain. A ditch runs through its territory, along which hills rise. The highest point of the garden is at an altitude of 136 m above sea level, and part of the territory has a terraced relief. The basis of soil-forming rocks is loess – a loose, homogeneous pale -yellow rock, rich in calcium and magnesium carbonates.

The soil cover of the studied areas is represented by chernozems of a typical medium-humus leached type. By mechanical composition, these are heavy loams containing 37–43% of the dusty fraction. Due to their favorable physical properties, they provide optimal conditions for growing field crops. The soils have a neutral reaction, the hydrolytic acidity is 1.5. To maintain fertility, regular application of organic and mineral fertilizers is necessary. Due to their high agrotechnical quality, these soils are recommended for the cultivation of a wide range of agricultural crops.

The climate of the region is moderately continental with unstable humidity, cold winters and hot, sometimes dry summers. Weather conditions are characterized by significant variability. The average annual precipitation is 442 mm, and the relative humidity is 74%. The frost-free period lasts approximately 165 days, and the total duration of the growing season reaches 210 days. The coldest month is February with an average temperature of -4.6°C, and the warmest is July (+21.3°C). The period with stable average daily temperatures above 0°C begins in late April and lasts until the second half of November. (Fig. 2.3). About 70% of the annual precipitation falls between April and October.

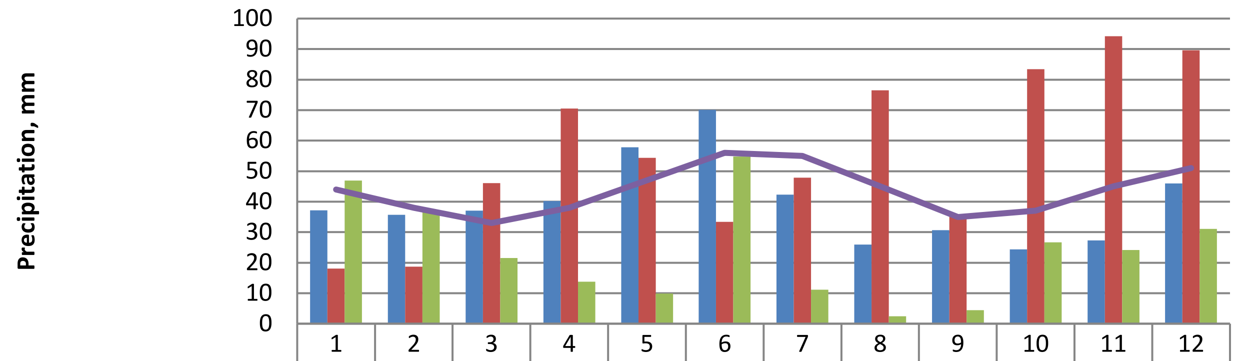
During the years of research, the minimum temperature in January was observed in 2024 (-3.7^{0}C). The maximum temperatures were recorded in July (28.2 ^{0}C). It should be noted that in all years the average annual air temperature exceeded the long-term data, which is associated with the general trend of climate warming.



	1	2	3	4	5	6	7	8	9	10	11	12
2022	-3,7	-2,9	2,7	10,2	16,2	20,2	22,4	22,8	16,6	9,9	3,3	-0,7
2023	-0,7	-1,2	4	9,4	13,6	19,7	20,1	21,4	15	8,8	7,6	-2,4
2024	-4,4	2	3,7	15	11,8	21,6	28,2	19,1	20,8	11,8	4,1	1,8
average multi-year	-0,6	-4,6	0,5	10	17,5	20,2	21,3	20,4	15,2	9,2	2,1	-2,3

Fig. 2.3 - Characteristics of air temperature over the years of research (Poltava station)

Analysis of multi-year data shows that the average annual precipitation was 442.0 mm. During the years of research, significant fluctuations in the amount of precipitation were recorded: the minimum level was observed in 2024, while in 2023 it reached a maximum. It should be noted that there is significant variability both in individual months and in the years of research. In particular, the highest precipitation fell in November 2023 (94.2 mm), and the lowest in August 2024 (2.4 mm). Overall, during the observation period, November was the wettest month, while September had the lowest precipitation (Fig. 2.4).



	1	2	3	4	5	6	7	8	9	10	11	12
2022	37,2	35,7	37,1	40,2	57,8	70,1	42,3	25,9	30,6	24,4	27,3	46
2023	18,1	18,7	46,1	70,5	54,4	33,4	47,9	76,5	35,6	83,4	94,2	89,6
2024	46,9	37,1	21,5	13,8	9,9	54,8	11,1	2,4	4,4	26,7	24,1	31,1
average multi-year	44	38	33	38	47	56	55	45	35	37	45	51

Fig. 2.4 - Characteristics of precipitation over the years of research (Poltava station)

Given the unstable level of precipitation in April and its limited volume, the effectiveness of spring field work largely depends on the timeliness of its implementation. Optimization of sowing dates and measures to preserve soil moisture are important factors for ensuring proper plant germination.

Analysis of natural conditions shows that soil and climatic indicators are typical for the region and favorable for growing agricultural crops.

2.2 Materials and research methods

Research on seed germination qualities. In this experiment, we determined germination energy, laboratory germination, germination evenness, and seed germination speed.

The research was carried out in the laboratory of the Department of Agriculture and Agrochemistry named after V. I. Sazanov of Poltava State Agrarian University during 2021–2023. The seeds of St. John's wort (*Hypericum perforatum* L.) of three varieties were used for the experiments: 'Taubertal', 'Topas' and seeds supplied by the Italian company Arcoiris (hereinafter referred to as *var.* 'Arcoiris')

Seeds were germinated in Petri dishes in triplicate.

Seed germination was calculated as an indicator indicating the number of germinating seeds as a % of the total number of seeds, on the 18-th day after the experiment was established.

Germination energy is the germination rate of seeds after 10 days of germination and is also expressed as a percentage.

The speed and evenness of seed germination were calculated based on data from daily records of germinated seeds in Petri dishes.

$$\text{Germination speed (days)} = \frac{(A1 \times 1) + (A2 \times 2) + \ldots + (An \times n)}{(A_1 + A_2 + \ldots + A_n)},$$

where A(n) is the number of seeds that germinated in 1, 2,…n days of germination;

1, 2,..n – days of seed germination.

Germination evenness is the number of seeds that have germinated in one day. This indicator is calculated using the formula:

Germination evenness (number of seeds) = A/N, where

A – the number of seeds that germinated (per 100 seeds) for the entire period of the experiment;

N is the number of days the seeds germinated.

Germination speed shows the average number of days it takes for a single seed to germinate, while germination evenness is the average number of seeds that germinated per day.

Morphometric studies of St. John's wort . Growing St. John's wort seedlings was carried out using the cassette method.

For this purpose, containers (cassettes) were used, which had 84 cells with a depth of seven centimeters. The cassettes were filled with soil mixture, watered, and then 20 seeds were sown in each cell. The seeds were pre-treated with the preparations Vimpel and Orakul seeds. After that, the cassettes were sown on top with a thin layer of soil. The sown cassettes were placed on the soil, and covered with agrofibre on top.

Table 2.1 - The influence of Vimpel-K and Orakul seeds preparations and sowing dates on the morphometric indicators of St. John's wort seedlings

Factor A Sowing dates	Factor B Seed treatment	Factor B Variety
February	Vimpel-K (500 ml/t)	Arcoiris
		Taubertal
		Topas
	Orakul seeds (1 l/t)	Arcoiris
		Taubertal
		Topas
	Vimpel-K (500 ml/t) and Orakul seeds (1 l/t)	Arcoiris
		Taubertal
		Topas
March	Vimpel-K (500 ml/t)	Arcoiris
		Taubertal
		Topas
	Orakul seeds (1 l/t)	Arcoiris
		Taubertal
		Topas
	Vimpel-K (500 ml/t) and Orakul seeds (1 l/t)	Arcoiris
		Taubertal
		Topas
April	Vimpel-K (500 ml/t)	Arcoiris
		Taubertal
		Topas
	Orakul seeds (1 l/t)	Arcoiris
		Taubertal
		Topas
	Vimpel-K (500 ml/t) and Orakul seeds (1 l/t)	Arcoiris
		Taubertal
		Topas

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In this experiment, the following were determined: stem height (mm); number of leaves (pcs.); mass of stem with leaves (mg); length of leaf blade (mm); width of leaf blade (mm); leaf surface area by mass of leaf cuttings (mm^2) (Rozhkov et al., 2016); root system mass (mg). The research was conducted in 2021–2023 in the educational and scientific laboratory of protected soil technologies of the Department Selection, Seed Production and Genetics of Poltava State Agrarian University.

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Morphometric studies of plants in the second year of vegetation. The research was conducted during 2022-2024 in the conditions of the educational laboratory of the Faculty of Natural Sciences "Botanical Garden" of National Pedagogical University named after V.G. Korolenko. Records of morphological features were carried out from the third decade of April to the second decade of July.

In this experiment, the following were determined: plant height (cm); number of internodes (pcs.); number of leaves (pcs.); mass of leaves (g); mass of the 1st leaf (g); mass of the stem (g); length of the leaf blade (cm); width of the leaf blade (cm); area of the 1st leaf (cm^2); number of flowers (pcs.), mass of flowers (g); mass of the 1st flower (g); number of fruits (pcs.); mass of fruits (g); mass of the 1st fruit (g); leaf surface area by mass of leaf cuttings (cm^2).

Research on the impact of placement schemes and its productivity . The research was conducted during 2022-2024 in the conditions of AC Radyansky of

Kremenchug district. The experiment used plants of St. John's wort *(Hypericum perforatum* L.) of three varieties: Arcoiris, Taubertal, Topas, seedlings of which were planted in open ground in May. For this, seedlings were removed from cassettes and transferred to the plot. Before planting, the soil was loosened and watered. The transplanted plants were watered twice more during the first two weeks. No observations were made during the first year of vegetation, and the plants were cut in the fall to prevent disease.

During the second year of vegetation, selections were made to determine crop productivity. The mass of the above-ground part, the number of leaves, the mass of one leaf, the mass of stems and inflorescences were determined.

When conducting experiments, agricultural techniques adopted for the crop were used. Soil plots were fertilized at the rate of nitrogen – 45 kg/ha, phosphorus – 30 kg/ha, potassium – 45 kg/ha. After planting seedlings, agricultural techniques were reduced to watering, loosening between rows and weed control.

Table 2.2 - The effect of placement schemes on the productivity of St. John's wort plants

Factor A Placement schemes	Factor B Variety
40x45 cm	Arcoiris
	Taubertal
	Topas
25x70 cm	Arcoiris
	Taubertal
	Topas

Research on the hemagglutinating activity of extracts. The laboratory part of the research was conducted on the basis of the Department of Agriculture and Agrochemistry named after I.V. Sazanov, Faculty of Agrotechnology and Ecology, Poltava State Agrarian Academy.

Hypericum perforatum L. of variety Topas of the second year of vegetation, harvested in 2022-2024 was used as the plant raw material. The collection was carried out in 4 phases: shoot formation , budding, flowering and fruiting.

The air-dried raw material was crushed, sieved on sieves with a hole diameter of 1 mm and used for extraction. For this, one part of the raw material was poured with ten parts of the extractant, infused for 2 hours at room temperature and filtered.

The activity of lectins was assessed by performing a hemagglutination reaction in immunological plates. For this purpose, 0.05 ml of physiological solution buffered with phosphate-citrate buffer to pH = 4.5, then 0.05 ml of the extract was added and a series of consecutive two-fold dilutions were prepared. After that, 0.05 ml of a 2% suspension of washed erythrocytes was added to each well and the plate was left at 25°C for 2 hours. The assessment was carried out visually on a five-point scale:

3 points – pronounced agglutination. Erythrocytes in the form of a thin film are more or less evenly distributed throughout the bottom of the well;

2 points – moderate agglutination. Erythrocytes spread along the bottom of the well to a distance exceeding 2 mm in diameter, forming a ring with pronounced graininess at the edges;

1 point – weak agglutination. Erythrocytes spread along the bottom of the well for a distance of less than 2 mm, forming a ring or disk;

0.5 points – minimal agglutination. A small gap appears in the center of the red blood cells that have settled to the bottom of the well;

0 points – no agglutination. Red blood cells accumulate in the center of the well.

After visual assessment of agglutination in each well of the dilution series, the sum was calculated in all wells where the reaction was determined. Thus, the maximum activity in eight wells can be: 8 × 3.0 = 24 points. To reduce the probability of error, each variant of the experiment was performed in triplicate.

Short conclusions:

1. Analysis of soil conditions and their characteristics show that research were carried out on soils of different origin and properties characteristic of the Forest-Steppe zones of Ukraine. Climatic conditions during the period of carrying out research corresponded to typical indicators for the region and were favorable for

cultivation of majority of agricultural crops, in particular St. John's wort.

2. In our research, we used a wide range of research methods, including classical field, laboratory, and mathematical approaches. In addition, original methods have been developed and implemented, as well as existing ones have been modified, which confirms the scientific novelty and innovation of the research approaches.

CHAPTER 3
REGULATION OF SOWING QUALITIES OF ST. JOHN'S WORT (*HYPERICUM PERFORATUM* L.) SEEDS

Figure 3.1 shows the dynamics of germination of St. John's wort seeds (*Hypericum perforatum* L.) in the control variant (without treatment with stimulants). Seeds of the Arcoiris and Taubertal varieties began to germinate on the fourth day after the start of the experiment. At the same time, germination was 4.5% for Arcoiris and only 0.5% for Taubertal . Seeds of the Topas variety gave the first shoots on the fifth day with a germination rate of 6%. The largest part of the seeds germinated in the period from the fifth to the ninth day of the experiment. At this time, the achievement of the main indicators of laboratory germination was recorded. For Arcoiris seeds, germination was 81%. Seeds of the Taubertal and Topas varieties showed a lower result – 67-68%.

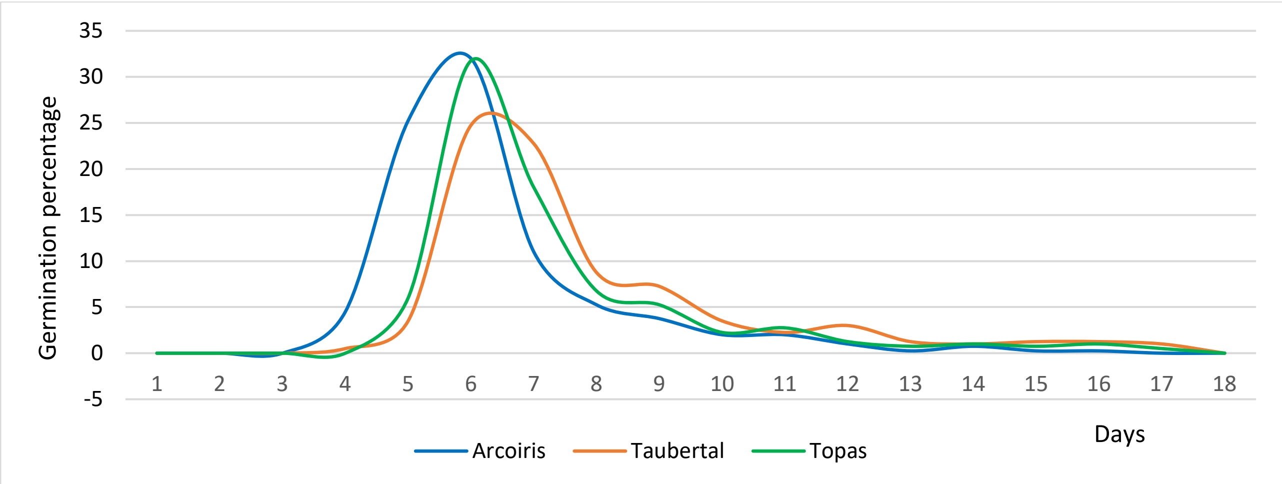

Fig. 3.1 - Germination dynamics of St. John's wort seeds (*Hypericum perforatum* L.) without seed treatment (control)

Figure 3.2 shows the dynamics of germination of St. John's wort seeds (*Hypericum perforatum* L.) after treatment with preparation Vimpel-K (500 ml/t). The first shoots appeared on the 4th day for all varieties, with Arcoiris demonstrating the highest germination (6%) compared to Taubertal (1.5%) and Topas (1%). The most active germination occurred in the period from the 5th to the 9th day, which provided a significant increase in germination in all variants: for Arcoiris the indicator reached

84%, Taubertal and Topas – 71%. Compared to the control variant, the preparation Vimpel-K improved germination indicators in all varieties.

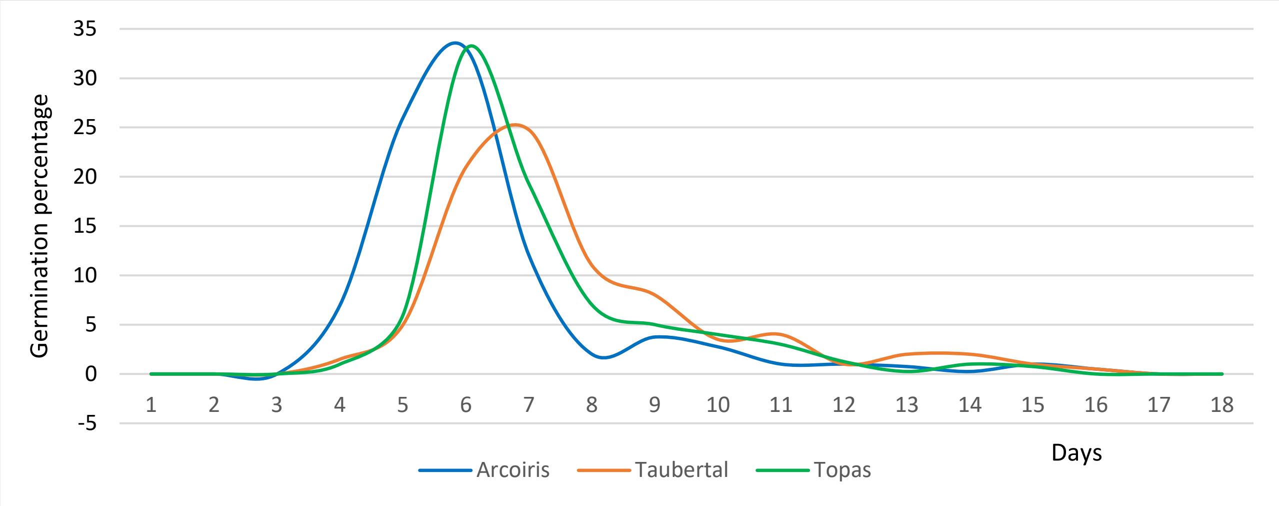

Fig. 3.2 - Germination dynamics of St. John's wort seeds (*Hypericum perforatum* L.) as a result of seed treatment with the preparation Vimpel-K (500 ml/t)

Figure 3.3 shows the dynamics of germination of St. John's wort seeds (*Hypericum perforatum L.*) after treatment with the preparation Orakul seeds (1 l/t). Already on the 4th day, the first shoots have appeared in all varieties: Arcoiris demonstrated the highest germination – 4.5%, Taubertal and Topas – 2%. In the period from the 5th to the 9th day, an intensive increase in germination was observed. By the 9th day, Arcoiris reached 87% germination, Topas – 76%, and Taubertal – 74%. The preparation Orakul seeds significantly improved the results compared to the control variant.

Figure 3.4 shows the dynamics of germination of St. John's wort seeds (*Hypericum perforatum L.*) after combined treatment with the preparations Vimpel-K (500 ml/t) and Orakul seeds (1 l/t). The first shoots were recorded on the 4th day in all varieties: Arcoiris showed germination of 7%, Taubertal – 2%, Topas – 4%. The most active growth occurred in the period from the 5th to the 9th day.

By this time, germination for Arcoiris had reached 90%, for Topas – 81%, and for Taubertal – 80%. After the 10th day, germination rates decreased. The combined use of preparations gave the best results among all treatment options, providing the highest germination rates for all varieties studied.

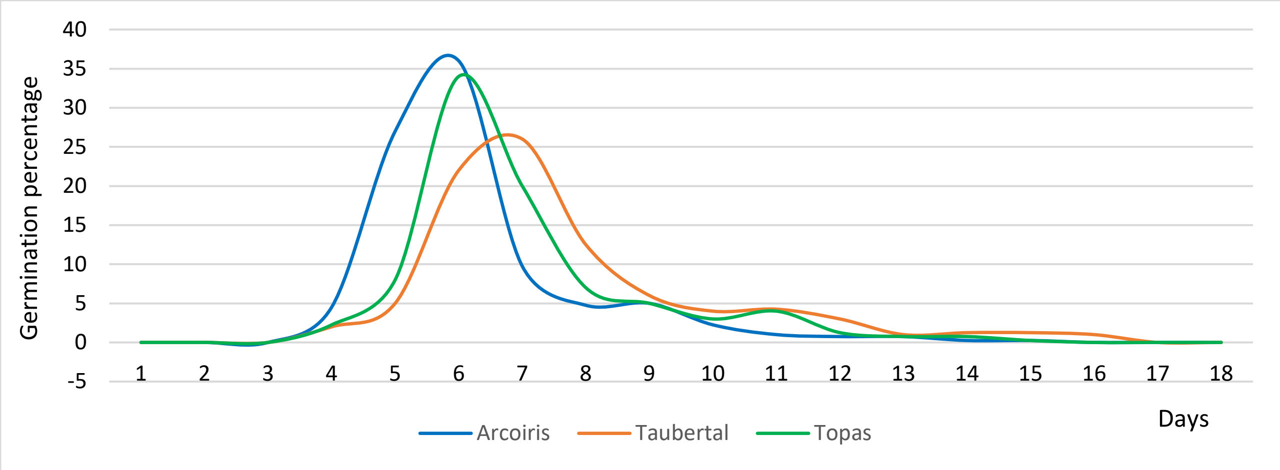

Fig. 3.3 - Germination dynamics of St. John's wort seeds (*Hypericum perforatum* L.) as a result of seed treatment with the preparation Orakul seeds (1 l/t)

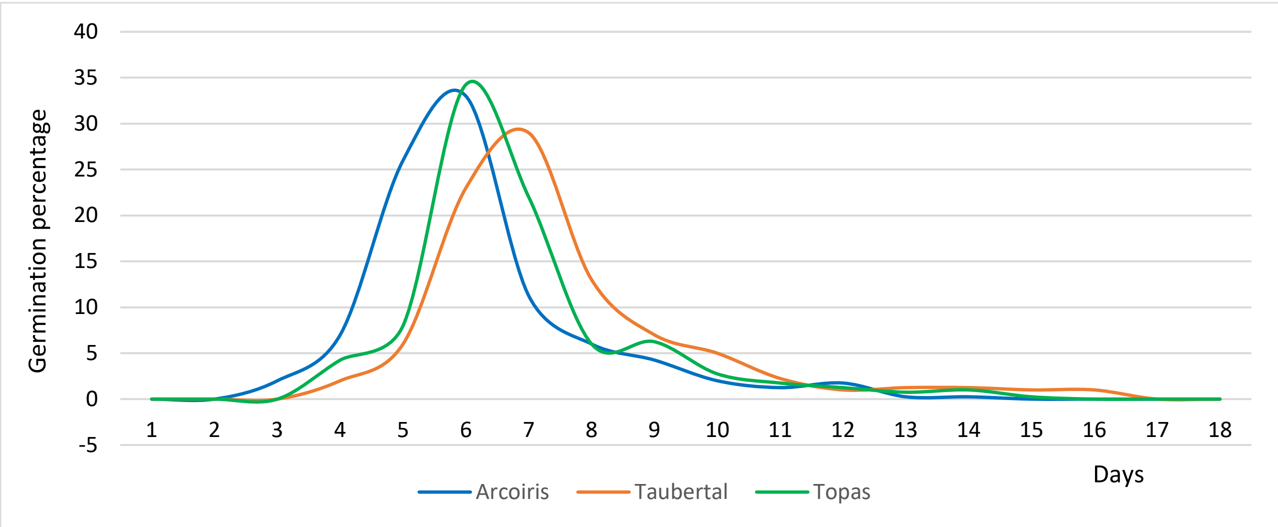

Fig. 3.4 - Germination dynamics of St. John's wort seeds (*Hypericum perforatum* L.) as a result of seed treatment with the formulation Vimpel-K (500 ml/t) and the formulation Orakul seeds (1 l/t).

The results presented in Table 3.1 demonstrate the effect of different options for seed treatment of St. John's wort of the Arcoiris variety on its sowing quality. The control option, in which the seeds were not treated with any preparations, showed germination energy at the level of 84% and germination at 88%. Treatment with the preparation Vimpel-K (500 ml/t) provided a noticeable improvement: germination energy increased to 86.5%, and germination reached 91%. The use of the preparation Orakul seeds (1 l/t) demonstrated an even more significant effect: germination energy

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increased to 89 %, and germination reached 92%. The highest indicators were observed with the combined use of the preparations Vimpel-K and Orakul seeds. In this case, germination energy reached 92%, which is 8% higher than the control, and germination increased to 95%, exceeding the control values by 7%. Analysis of the speed and evenness of germination demonstrates certain patterns.

Table 3.1 - Sowing qualities of St. John's wort seeds of the Arcoiris variety

Indicators	Control	Variant 1	Variant 2	Variant 3
Germination energy, %	84	87*	89	92
Germination, %	88	91*	92	95
Germination speed, days	6.40	6.34	6.28	6.19
Germination evenness, seeds/day	6.79	7.00	7.69	7.92

Variant 1 - seed treatment with the preparation Vimpel-K (500 ml/t); Variant 2 - seed treatment with the preparation Orakul seeds (1 l/t); Variant 3 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t).

*Note: * According to Student's t-test calculations, the difference relative to the control is not significant*

The germination speed gradually increased from 6.40 in the control variant to 6.19 with combined treatment. The germination evenness index also increased from 6.79 in the control to 7.92 in the variant with combined treatment, which confirms the positive effect of treatment with preparations on the seed germination process.

The results presented in Table 3.2 illustrate the influence of different options for seed treatment of St. John's wort of the Taubertal variety on its sowing quality. The control variant without treatment demonstrates germination energy at the level of 71% and germination at 82%. The use of the preparation Vimpel-K (500 ml/t) improves these indicators to 75% and 85%, respectively. Treatment with the preparation Orakul seeds (1 l/t) gives even better results: germination energy increases to 78%, and germination reaches 89%. The combined use of Vimpel-K and Orakul seeds provides maximum indicators: germination energy increases to 85%, and germination – to 93%. The germination speed increased from 7.86 in the control to 7.35 in the combined variant. At the same time, the germination evenness increases from 5.86 in the control to 7.13 in the combined treatment, which indicates an improvement in the synchronicity of seed germination. The data confirm the effectiveness of the preparations in stimulating the sowing qualities of the Taubertal variety.

Table 3.2 - Sowing qualities of St. John's wort seeds of the Taubertal variety

Indicators	Control	Variant 1	Variant 2	Variant 3
Germination energy, %	71	75*	78	85
Germination, %	82	85*	89	93
Germination speed, days	7.86	7.72	7.54	7.35
Germination evenness, seeds/day	5.86	6.56	6.87	7.13

Variant 1 - seed treatment with the preparation Vimpel-K (500 ml/t); Variant 2 - seed treatment with the preparation Orakul seeds (1 l/t); Variant 3 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t).

*Note: * According to Student's t-test calculations, the difference relative to the control is not significant*

The results presented in Table 3.3 demonstrate the effect of different options for seed treatment of St. John's wort of the Topas variety on its sowing quality. The control option showed germination energy at the level of 70%, and germination was 78%. Seed treatment with the preparation Vimpel-K (500 ml/t) improved these indicators to 75% and 82 %, respectively. The use of the preparation Orakul seeds (1 l/t) contributed to an even greater increase: germination energy increased to 79%, and germination reached 86%. The best results were observed with the combined use of Vimpel-K and Orakul seeds, where germination energy reached 84%, and germination – 89%. Analysis of the speed and evenness of germination also demonstrates the effect of treatment. The germination speed gradually increased: from 7.37 in the control option to 6.89 with combined treatment. The germination evenness index increased from 6.50 in the control to 7.38 in the combined variant.

Table 3.3 - Sowing qualities of St. John's wort seeds of the Topas variety

Indicators	Control	Variant 1	Variant 2	Variant 3
Germination energy, %	70	75*	79	84
Germination, %	78	82*	86	89
Germination speed, days	7.37	7.17	7.04	6.89
Germination evenness, seeds/day	6.50	6.79	7.19	7.38

Variant 1 - seed treatment with the preparation Vimpel-K (500 ml/t); Variant 2 - seed treatment with the preparation Orakul seeds (1 l/t); Variant 3 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t).

*Note: * According to Student's t-test calculations, the difference relative to the control is not significant*

Short conclusions:

1. Analysis of the dynamics of germination of St. John's wort seeds (*Hypericum perforatum* L.) shows that treatment with the preparations Vimpel-K and Orakul seeds, both separately and in combination, has a positive effect on the germination process. The combined use of the preparations gave the best results. The most active germination was observed in the period from the 5th to the 9th day of the experiment, after which the germination rate decreased. The Arcoiris variety in all treatment options demonstrated the highest germination rates, which indicates its high response to the action of stimulants. Thus, combined treatment with preparations is the most effective technology for increasing the germination of St. John's wort seeds, especially for varieties with a high response, such as Arcoiris.

2. The germination speed in all varieties increased, but moderately, maintaining consistency. For example, in the Arcoiris variety, the speed increased from 6.40 to 6.19, and the germination evenness increased from 6.79 to 7.92. A similar trend was observed in the Taubertal and Topas varieties, indicating an improvement in seed quality due to synchronization and acceleration of germination processes.

3. The results demonstrate the feasibility of using the preparations Vimpel-K and Orakul seeds to improve the sowing qualities of St. John's wort, especially when used in combination. This will contribute to increasing the productivity and efficiency of growing this crop.

CHAPTER 4
OPTIMIZATION OF CULTIVATION ST. JOHN'S WORT (*HYPERICUM PERFORATUM* L.) SEEDLINGS

In the cultivation of medicinal plants, an important role is played not only by agrotechnical conditions, but also by the use of modern growth stimulants, which allow to increase the productivity and quality of plant raw materials. Increasing the efficiency of cultivation of St. John's wort *(Hypericum perforatum* L.), in particular through seedling technology, is an urgent task of agrotechnology.

At the same time, we studied the effect of the preparations Vimpel-K and Orakul seeds on the growth and development of seedlings of different varieties of St. John's wort, as well as the dependence of the effectiveness of these preparations on the timing of sowing. The aim of the experiment was to establish the optimal parameters for growing St. John's wort seedlings in order to obtain high-quality seedlings for further plantation cultivation.

4.1 Evaluation of Seed Treatment Efficacy for *H. perforatum* var. 'Topas'

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the stem height of St. John's wort seedlings (*Hypericum perforatum* L.) of the Topas variety are presented in Figure 4.1. The control variant had the lowest average seedling stem height, which was 28.93-32.80 mm, depending on the sowing date. Seed treatment with the Orakul seeds preparation increased the stem height compared to the control by 0.36-6.53 mm, indicating the effectiveness of this preparation in stimulating plant growth. The stem height when treated with the preparation Vimpel-K also exceeded the control by 0.96-3.75 mm, but this effect is less pronounced compared to Orakul seeds. The highest stem height indicators were recorded with combined seed treatment with Vimpel-K and Orakul seeds preparations – increase by 1.93-8.78 mm. This indicates a synergistic effect from the joint use of both preparations, which significantly exceeds the effects of their separate use. The dependence of stem height on sowing dates is also clearly expressed. The results show that earlier sowing dates contribute to an increase in the height of the seedling stem.

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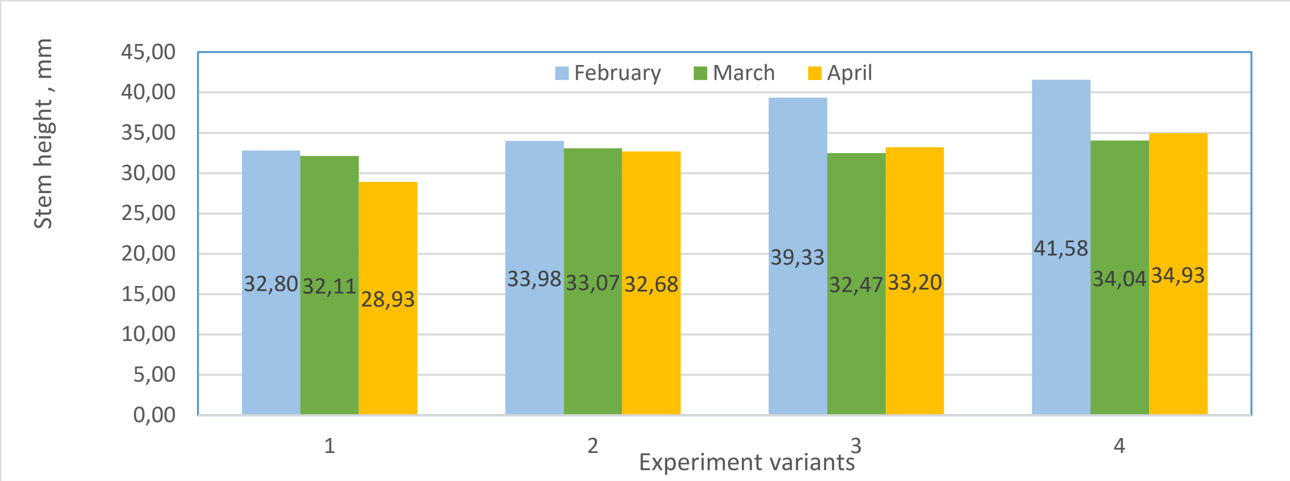

Fig. 4.1 – The influence of preparations and sowing dates on the stem height of St. John's wort seedlings (*Hypericum perforatum* L.) of the Topas variety, mm (average for 2021-2023).

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

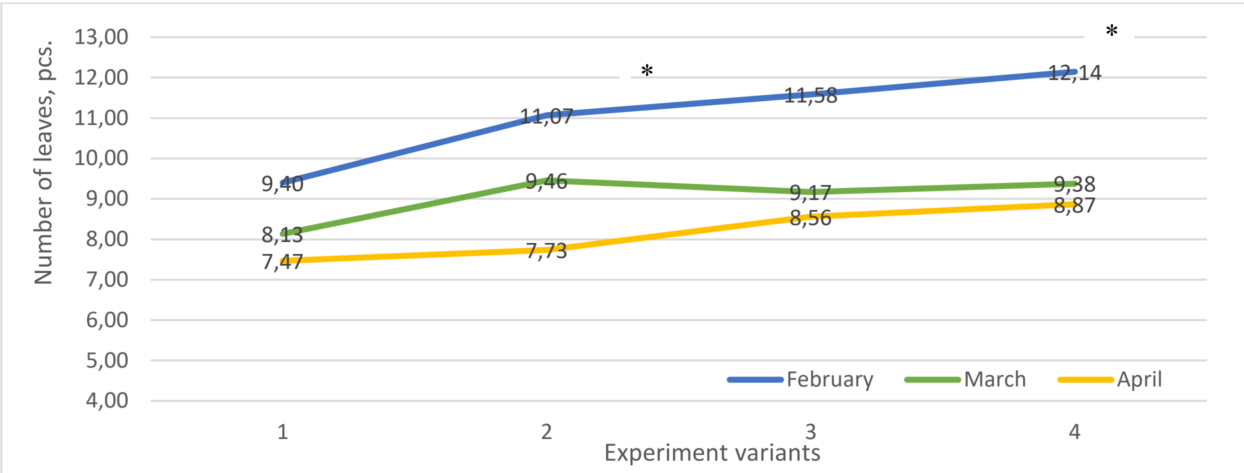

Fig. 4.2 – The influence of preparations and sowing dates on the number of leaves of St. John's wort seedlings (*Hypericum perforatum* L.) of the Topas variety, pcs. (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

*Note: * According to Student's t-test calculations, the difference between the variants is not significant*

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the number of leaves of seedlings of St. John's wort of the Topas variety is illustrated in Figure 4.2. In the control variant, the smallest number of leaves was observed – 7.47-9.40 pcs., which again confirmed the low level of plant development without the use of stimulants. Seed treatment with the preparation Vimpel-K increased the number of leaves by 3.5-17.8% compared to the control, the preparation Orakul seeds improved this indicator by 14.6-23.2%. The largest number of leaves was recorded during combined seed treatment with Vimpel-K and Orakul seeds (8.87-12.14 pcs.), which is 15.4-29.1% more than in the control.

Analysis of the dependence of the number of leaves on the sowing dates showed that earlier sowing dates contribute to an increase in the number of leaves on plants. Late sowing dates, on the contrary, were characterized by a smaller number of leaves.

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the length of the leaf of St. John's wort seedlings of the Topas variety is shown in Figure 4.3. The data indicate that in the control variant, plants have the smallest leaf length – 5.58-6.22 mm. Seed treatment with the preparation Vimpel-K increased the length of the leaf compared to the control by 0.07-0.38 mm, which indicates a positive effect of this preparation on the development of leaves. The preparation Orakul seeds increased the length of the leaf by 0.42-0.67 mm. The greatest increase in leaf length was observed with the combined treatment of seeds with the preparations Vimpel-K and Orakul seeds – 0.69-1.25 mm. As for the timing, early sowing dates performed best.

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the leaf width of St. John's wort seedlings of the Topas variety is shown in Figure 4.4. In the control variant, the smallest leaf width was observed – 4.00-4.16 mm, which indicated insufficient development of the leaf blade without stimulants. Seed treatment with the preparation Vimpel-K increased the width of the seedling leaf by 0.11-0.28 mm compared to the control. The preparation Orakul seeds had an even greater effect, increasing the width of the leaf by 0.09-0.42 mm. The highest indicators of leaf width were achieved with combined seed treatment with the preparations Vimpel-K and Orakul seeds – 4.27-4.93 mm, which exceeded the control indicators by 0.27-0.77 mm.

As for the timing of sowing, early terms contributed to an increase in leaf width.

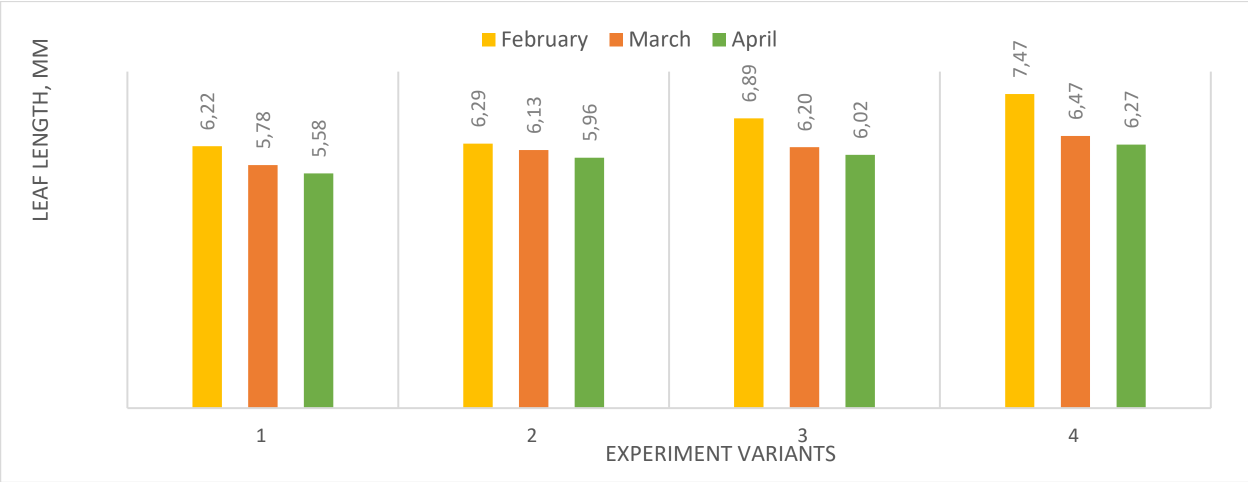

Fig. 4.3 – The influence of preparations and sowing dates on the leaf length of St. John's wort seedlings (*Hypericum perforatum* L.) variety Topas, mm (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

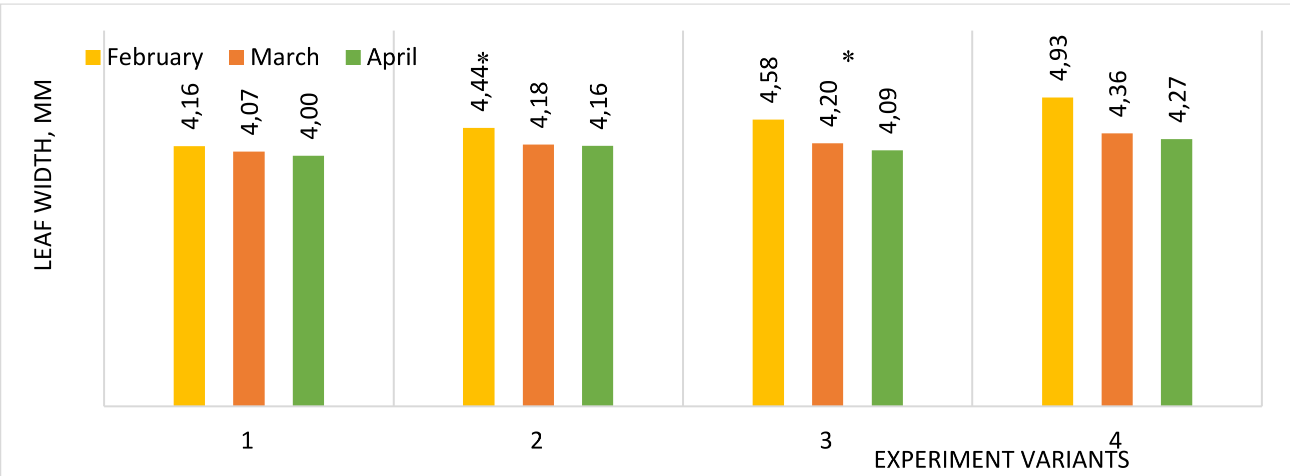

Fig. 4.4 – Influence of preparations and sowing dates on leaf width of St. John's wort seedlings (*Hypericum perforatum* L.) variety Topas, mm (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

*Note: * According to Student's t-test calculations, the difference between the variants is not significant*

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the leaf area of St. John's wort seedlings of the Topas variety is illustrated in Figure 4.5. In the control, the leaf area was the smallest – 17.49-20.35 mm². Seed treatment with the Vimpel-K preparation increased the leaf area by 1.68-2.00 mm². The Orakul seeds preparation also significantly improved this indicator, increasing the leaf area by 1.86-4.34 mm². The combined use of the Vimpel-K and Orakul seeds preparations gave the best results, increasing the leaf area by 3.60-7.87 mm². Early sowing dates were the most effective for increasing the leaf area.

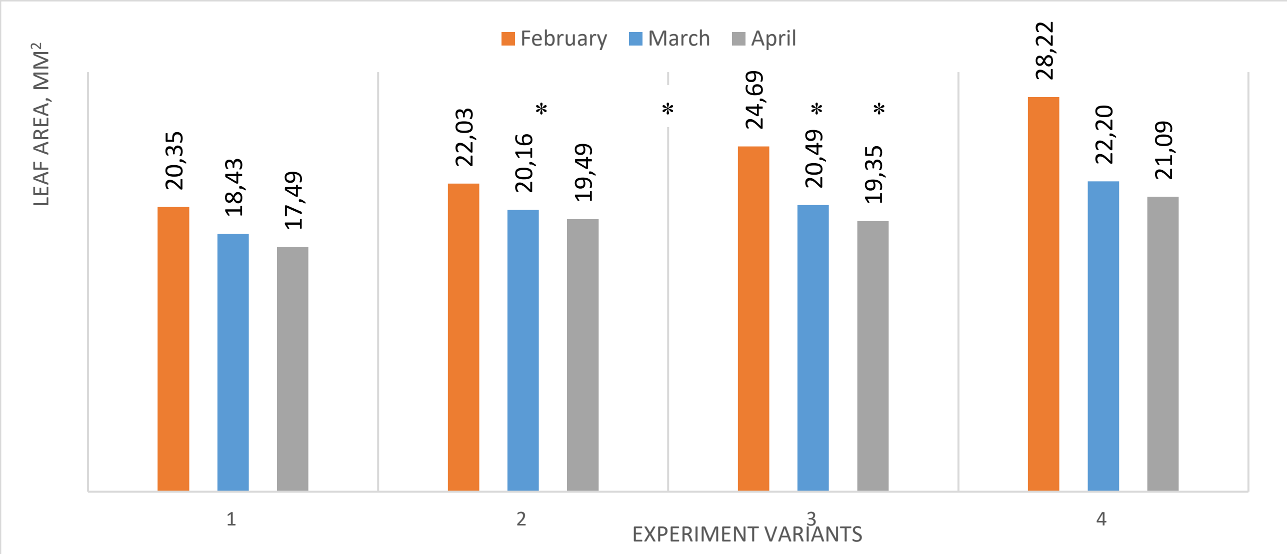

Fig. 4.5 – Influence of preparations and sowing dates on the leaf area of St. John's wort seedlings (*Hypericum perforatum* L.) of the Topas variety, mm ^{2} (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

*Note: * According to Student's t-test calculations, the difference between the variants is not significant*

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the phytomass of the above-ground part of St. John's wort seedlings of the Topas variety is shown in Figure 4.6. The control variant had the lowest phytomass – 11.64-17.38 mg. Seed treatment with the preparation Vimpel-K increased phytomass by 7.1-

21.6% compared to the control. The preparation Orakul seeds improved this indicator by 2.2-37.7%. The highest values of phytomass of the aboveground part – 14.07-27.13 mg – were achieved with combined seed treatment with both preparations. The dependence of phytomass on sowing dates showed that early sowing dates contributed to better development of the aboveground part of the plant.

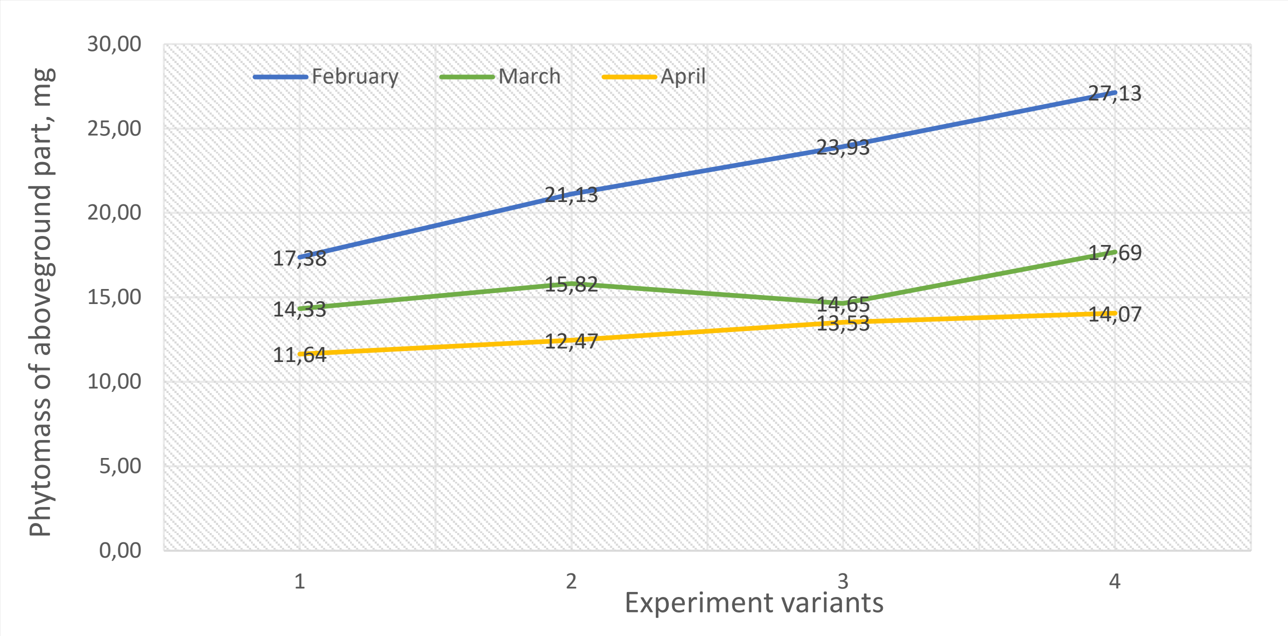

Fig. 4.6 – Influence of preparations and sowing dates on the phytomass of the above-ground part of St. John's wort seedlings (*Hypericum perforatum* L.) variety Topas, mg (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the mass of the root system of St. John's wort seedlings of the Topas variety is illustrated in Figure 4.7. The control variant showed the smallest mass of the root system – 39.67-91.00 mg. Seed treatment with the formulation Vimpel-K increased the mass of the root system by 2.8-14.2% compared to the control. The formulation Orakul seeds improved this indicator by 7.6-15.1 %. The largest mass of the root system was achieved with the combined treatment of seeds with the formulations Vimpel-K and

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Orakul seeds – 48.67-109.00 mg. Early sowing dates contributed to better development of the root system.

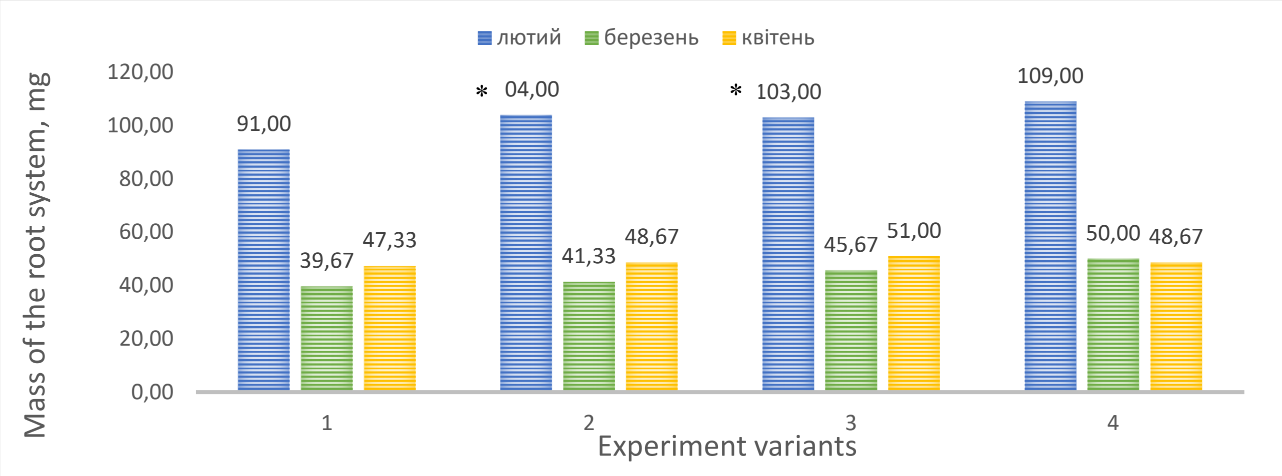

Fig. 4.7 – The influence of preparations and sowing dates on the mass of the root system of St. John's wort seedlings (*Hypericum perforatum* L.) variety Topas, mg (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

*Note: * According to Student's t-test calculations, the difference between the variants is not significant*

Table 4.1 presents the results of a two-factor analysis of variance of the mass of the above-ground part of St. John's wort of the Topas variety depending on the timing of sowing seeds in pellets and the use of growth stimulants. It allows us to conclude that the best option is to sow in February. At the same time, regardless of the use of preparations, the mass significantly exceeded the seedlings sown in March and April by 43.6%-73.6%. The calculations also confirm that all the stimulants studied gave a positive proven effect, the greatest increases were observed with the combined use of the preparations Vimpel-K and Orakul seeds, regardless of the timing of sowing.

Table 4.1 - Analysis of variance of the mass of the above-ground part (mg) of seedlings of St. John's wort of the Topas variety depending on the use of growth stimulants and sowing dates

Factor A – sowing dates	Factor B – growth stimulants				Average factor A	
	Control	Vimpel-K	Orakul seeds	Vimpel-K + Orakul seeds		
February	*17.38*	21.13	23.93	27.13	**22.39**	
March	*14.33*	15.82	14.65	17.69	**15.62**	
April	*11.64*	12.47	13.53	14.07	**12.93**	**LSD_{05} A=0.395**
Average factor B	**14.45**	**16.47**	**17.37**	**19.63**	**LSD_{05} B=0.456**	LSD_{05} AB=0.790

4.2 Evaluation of Seed Treatment Efficacy for *H. perforatum* var. 'Taubertal'

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the stem height of St. John's wort seedlings (*Hypericum perforatum* L.) of the Taubertal variety are presented in Figure 4.8. In the control variant, the average stem height was 32.38-36.07 mm. Treatment with the preparation Vimpel-K increased the height by 0.66-3.60 mm, which indicates a stimulating effect of the preparation on stem growth. The preparation Orakul seeds showed similar results, with an increase of 1.37-6.78 mm compared to the control. The greatest increase in height was observed with combined treatment with two preparations, where the stem height increased by 1.38-8.00 mm. Early sowing dates were most effective for increasing the stem height.

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the number of leaves of seedlings of St. John's wort of the Taubertal variety is illustrated in Figure 4.9. In the control variant, the number of leaves was 7.78-10.49 pcs., depending on the sowing date. When seeds were treated with the preparation

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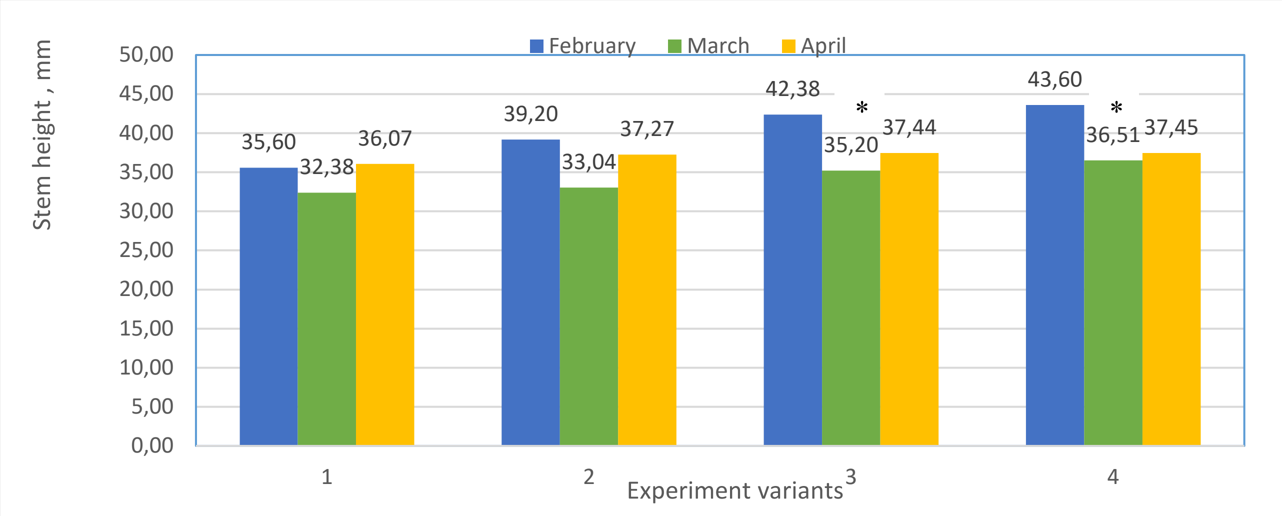

Fig. 4.8 – Influence of preparations and sowing dates on the stem height of St. John's wort seedlings (*Hypericum perforatum* L.) variety Taubertal, mm (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$*, which indicates the reliability of the research results*

*Note: * According to Student's t-test calculations, the difference between the variantss is not significant*

Vimpel-K, the number of leaves increased by 4.5-17.1% compared to the control, reaching 8.13-11.29 pcs. Seed treatment with the preparation Orakul seeds provided an even greater increase: the number of leaves increased by 8.0-18.7%, to 8.40-12.45 pcs., which indicates a more pronounced stimulating effect of this preparation on plant growth. The highest increase in the number of leaves was recorded with the combined use of two preparations – the number of leaves increased by 10.3-22.0% compared to the control, reaching 8.58-12.80 pcs.

The effect of the preparations Vimpel-K and Orakul and sowing dates on the leaf length of St. John's wort seedlings of the Taubertal variety is shown in Figure 4.10. According to the data obtained, in the control variant, the plants had the smallest leaf length – from 5.71 to 6.44 mm. Seed treatment with the preparation Vimpel-K increased this indicator by 0.12-0.65 mm, which indicates a positive effect on leaf

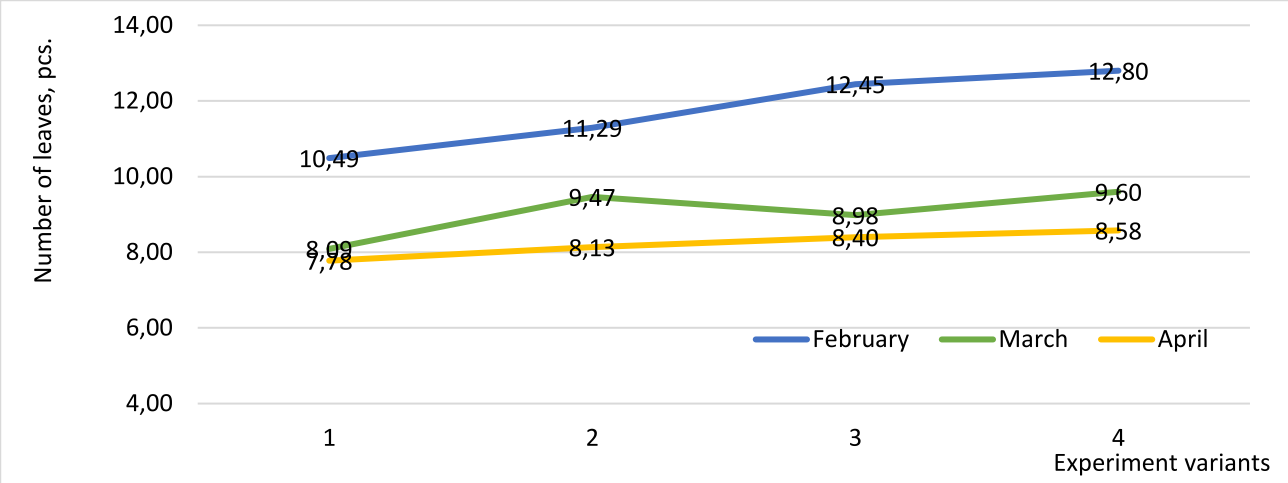

Fig. 4.9 – The influence of preparations and sowing dates on the number of leaves of St. John's wort seedlings (*Hypericum perforatum* L.) of the Taubertal variety, pcs. (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

development. When using the preparation Orakul seeds, the leaf length increased by 0.25-1.14 mm. The greatest increase in leaf length was observed with the combined treatment of seeds with the preparations Vimpel-K and Orakul seeds – 0.34-1.36 mm. Early sowing dates showed themselves best.

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the leaf width of St. John's wort seedlings of the Taubertal variety is shown in Figure 4.11. In plants on the control variant, the smallest leaf width was observed – 4.00-4.58 mm, which indicated insufficient development of the leaf blade without stimulants. Seed treatment with the preparation Vimpel-K increased the width of the seedling leaf by 0.11-0.36 mm compared to the control. The preparation Orakul seeds was even more effective, providing an increase in leaf width by 0.20-0.55 mm. The maximum values of leaf width were observed with combined treatment with the preparations Vimpel-K and Orakul seeds, where the indicators ranged from 4.33 to 5.40 mm, which exceeded the control data by 0.33-0.82 mm. Early sowing dates contributed to an increase in leaf width compared to late ones.

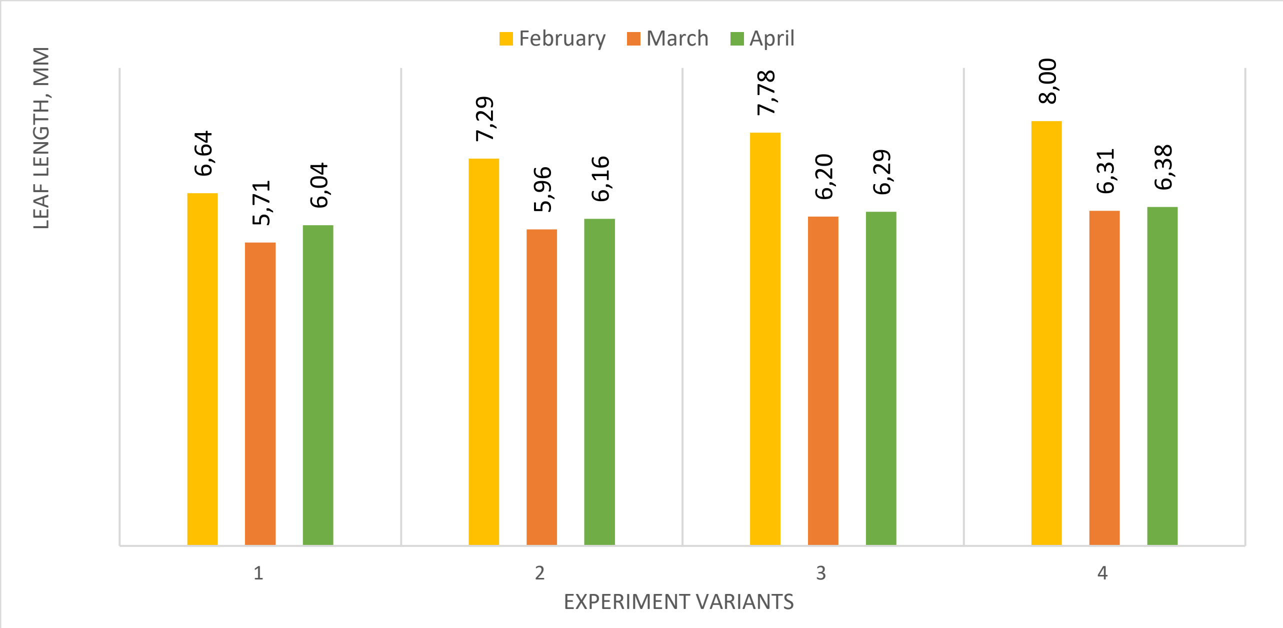

Fig. 4.10 – Influence of preparations and sowing dates on the leaf length of St. John's wort seedlings (*Hypericum perforatum* L.) variety Taubertal, mm (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the leaf area of seedlings of St. John's wort of the Taubertal variety is shown in Figure 4.12. In the control variant, the leaf area was the smallest – 17.90-23.66 mm². Seed treatment with the preparation Vimpel-K increased the leaf area by 1.34-4.05 mm². The preparation Orakul seeds improved this indicator even more, increasing the leaf area by 2.52-8.04 mm². The combined use of the preparations Vimpel-K and Orakul seeds gave the best results, increasing the leaf area by 3.39-10.05 mm². Early sowing dates contributed to the maximum increase in the leaf area.

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the phytomass of the above-ground part of the seedlings of St. John's wort of the Taubertal variety is shown in Figure 4.13. The control variant had the lowest phytomass – 12.11-21.55 mg. Seed treatment with the preparation Vimpel-K increased

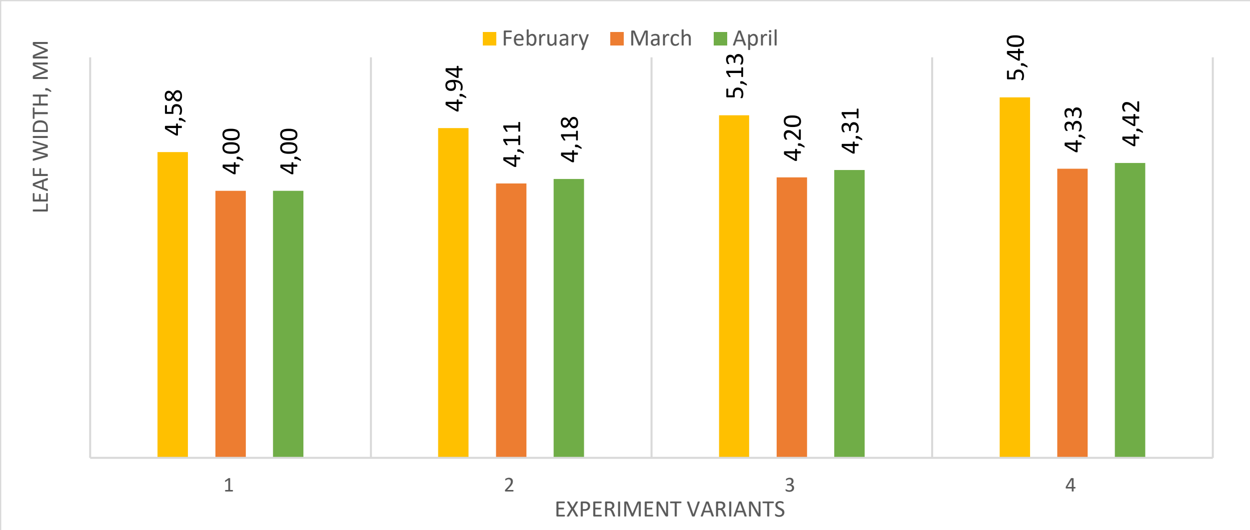

Fig. 4.11 – Influence of preparations and sowing dates on the leaf width of St. John's wort seedlings (*Hypericum perforatum* L.) variety Taubertal, mm (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, which indicates the reliability of the research results

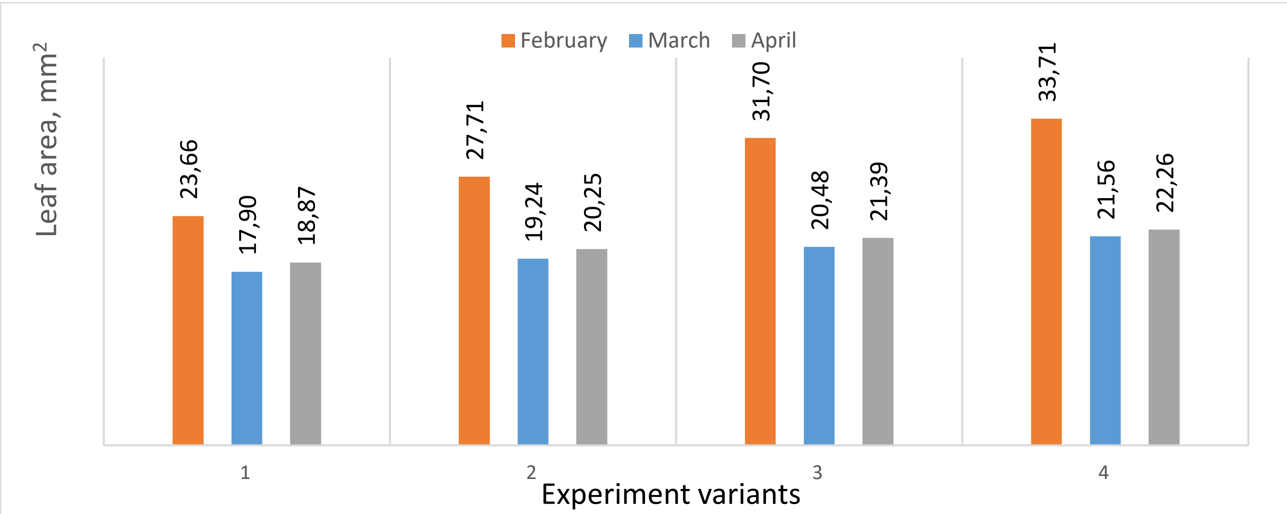

Fig. 4.12 – Influence of preparations and sowing dates on the leaf area of St. John's wort seedlings (*Hypericum perforatum* L.) variety Taubertal , mm ^{2} (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, which indicates the reliability of the research results phytomass by 7.7-11.3% compared to the control. The preparation Orakul seeds improved this indicator by 15.1-36.6%. The highest values of phytomass of the aboveground part – 15.33-30.69 mg (an increase of 20.6-42.4%) – were achieved with combined seed treatment with both preparations. Analysis of the dependence of phytomass on sowing dates showed that early dates contributed to a more active development of the aboveground part of plants.

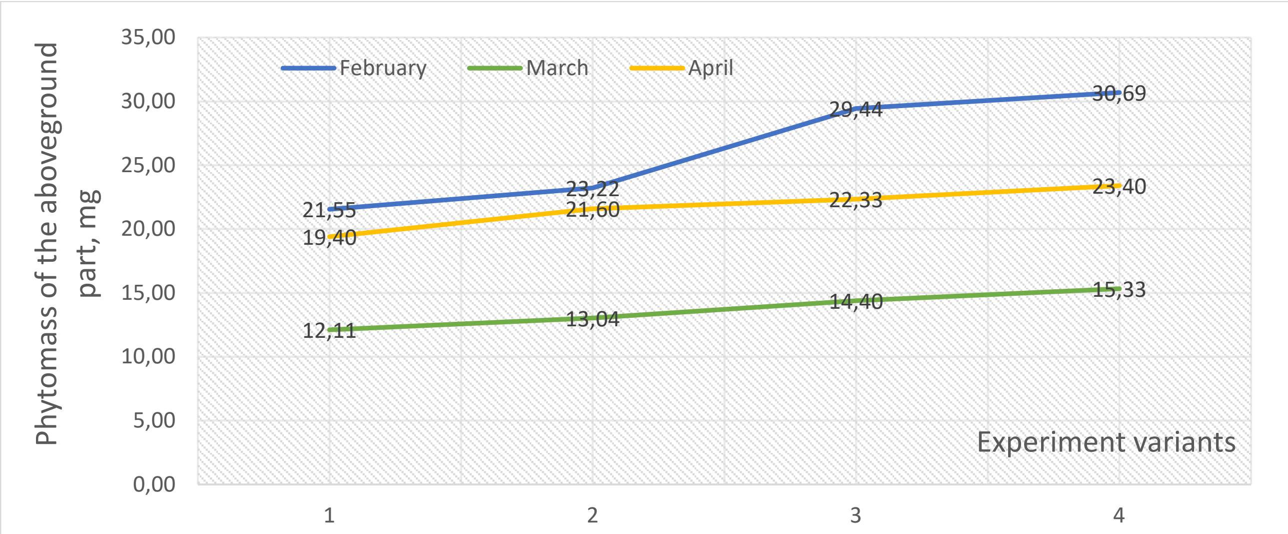

Fig. 4.13 – Influence of preparations and sowing dates on the phytomass of the above-ground part of St. John's wort seedlings (*Hypericum perforatum* L.) variety Taubertal, mg (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$*, which indicates the reliability of the research results*

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the mass of the root system of seedlings of St. John's wort of the Taubertal variety is presented in Figure 4.14. The lowest indicators of the mass of the root system were observed in the control variant – 34.67-84.00 mg. Seed treatment with the preparation Vimpel-K contributed to an increase in the mass of the root system by 3.2-38.5% compared to the control. The preparation Orakul seeds also showed a significant effect, increasing this indicator by 1.4-38.9%. The greatest mass of the root system was achieved with the combined treatment of seeds with the preparations Vimpel-K and

Orakul seeds – 41.00-131.67 mg (an increase of 10.9-56.8%). As in the case of other indicators, early sowing dates contributed to better stem growth, and late dates were characterized by a decrease in height.

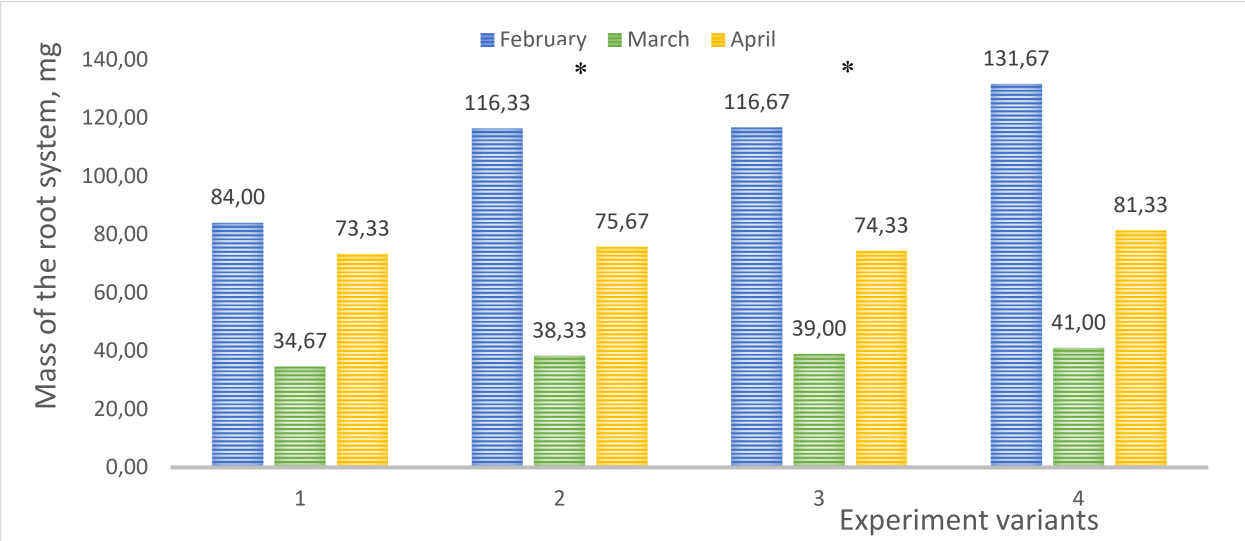

Fig. 4.14 – The influence of preparations and sowing dates on the mass of the root system of St. John's wort seedlings (*Hypericum perforatum* L.) variety Taubertal, mg (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

*Note: * According to Student's t-test calculations, the difference between the variants is not significant*

Table 4.2 presents the results of a two-factor analysis of variance of the mass of the above-ground part of St. John's wort of the Taubertal variety depending on the timing of sowing seeds and the use of growth stimulants. It allows us to conclude that the best option is to sow in February. At the same time, regardless of the use of preparations, the mass significantly exceeded the seedlings sown in March and April by 20.9%-91.1%. It is worth noting that seedlings grown since April exceeded the indicators of plants grown from March. The calculations also confirm that all the stimulants studied gave a positive proven effect, the greatest increases were observed with the combined use of the preparations Vimpel-K and Orakul seeds, regardless of the sowing dates.

Table 4.2 - Analysis of variance of the mass of the above-ground part (mg) of seedlings of St. John's wort of the Taubertal variety depending on the use of growth stimulants and sowing dates

Factor A – sowing dates	Factor B – growth stimulants				Average factor A	
	Control	Vimpel-K	Orakul seeds	Vimpel-K + Orakul seeds		
February	21.55	23.22	29.44	30.69	**26.22**	
March	12.11	13.04	14.40	15.33	**13.72**	
April	19.40	21.60	22.33	23.40	**21.68**	**LSD_{05} A=0.290**
Average factor B	**17.69**	**19.29**	**22.07**	**23.14**	**LSD_{05} B=0.335**	LSD_{05} AB=0.580

4.3 Evaluation of Seed Treatment Efficacy for *H. perforatum* var. 'Arcoiris'

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the stem height of seedlings of St. John's wort (*Hypericum perforatum* L.) of the Arcoiris variety is presented in Figure 4.15. The figure illustrates the dependence of the stem height of seedlings on seed treatment and sowing dates. In the control variant, the average stem height was 31.67-37.62 mm. Treatment with the preparation Vimpel-K increased the height by 0.57 mm in the variant of the experiment with an early sowing date, in both variants of the experiment with later sowing dates the stem height decreased by 0.36 mm and 1.58 mm. The preparation Orakul seeds showed similar results, with an increase in stem height by 11.00 mm compared to the control in the variant with an early sowing date and a decrease by 0.47 mm and 1.24 mm in the variants of the experiment with later sowing dates. With combined treatment with the two preparations, the stem height increased in all variants of the experiment: by 0.33 mm and 0.09 mm in the variants of the experiment with later sowing dates and by 14.53 mm in the variant of the experiment with early sowing dates.

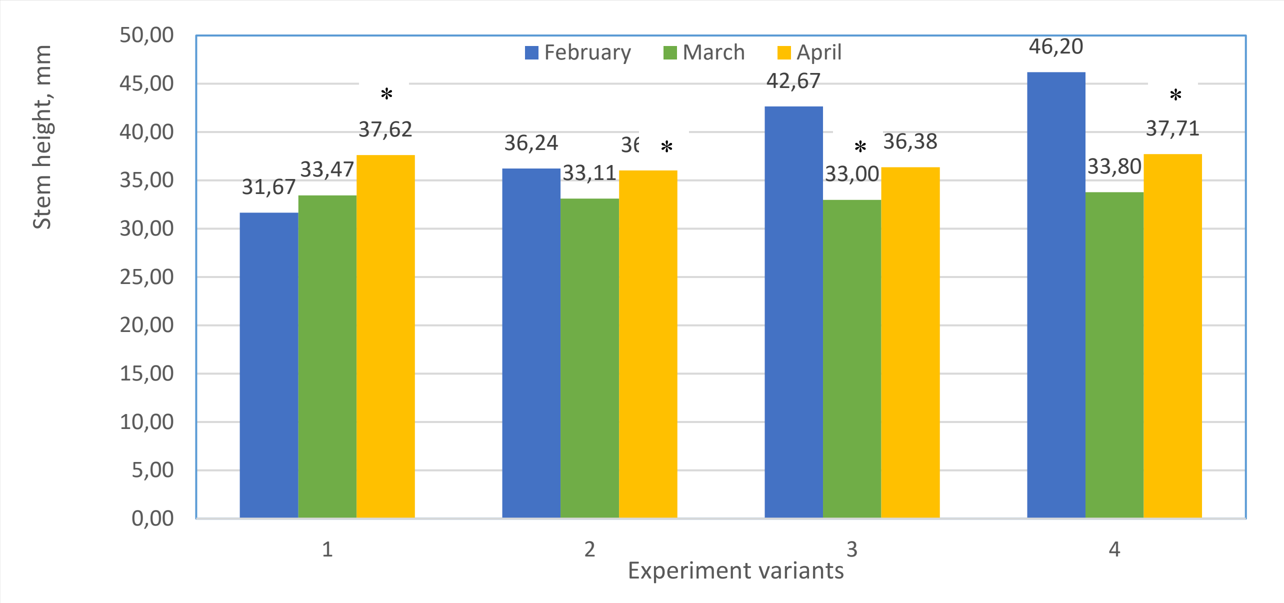

Fig. 4.15 – Influence of preparations and sowing dates on the stem height of seedlings of St. John's wort (*Hypericum perforatum* L.) of the Arcoiris variety, mm (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

*Note: * According to Student's t-test calculations, the difference between the variants is not significant*

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the number of leaves of seedlings of St. John's wort of the Arcoiris variety is illustrated in Figure 4.16. The control variant had the lowest number of leaves – 8.00-8.98 pcs. Seed treatment with the Vimpel-K preparation increased the number of leaves by 2.2-27.2% compared to the control. The Orakul seeds preparation improved this indicator by 3.9-40.0%.

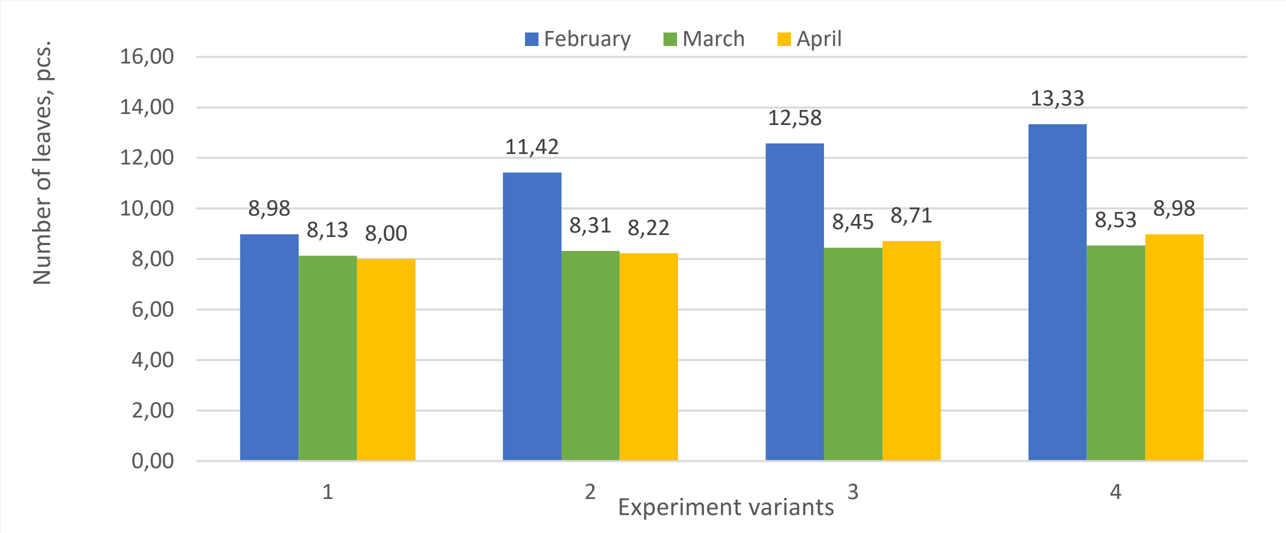

Fig. 4.16 – The influence of preparations and sowing dates on the number of leaves of seedlings of St. John's wort (*Hypericum perforatum* L.) of the Arcoiris variety, pcs. (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

The highest number of leaves was recorded with the combined treatment of seeds with the Vimpel-K and Orakul seeds preparations (8.53-13.33 pcs.), which is 4.9-48.4% more than the control. Analysis of the dependence of the number of leaves on the sowing dates showed that earlier sowing dates contribute to an increase in the number of leaves on plants. Late sowing dates, on the contrary, were characterized by a smaller number of leaves.

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the leaf length of St. John's wort seedlings of the Arcoiris variety is shown in Figure 4.17.

The data indicate that in the control variant, plants have the smallest leaf length – 5.91-6.67 mm. Seed treatment with the preparation Vimpel-K increased the leaf length compared to the control by 0.05 mm and 0.44 mm in two variants of the experiment with earlier sowing dates and reduced this indicator by 0.07 mm in the variant with a later sowing date. The preparation Orakul seeds increased the leaf length

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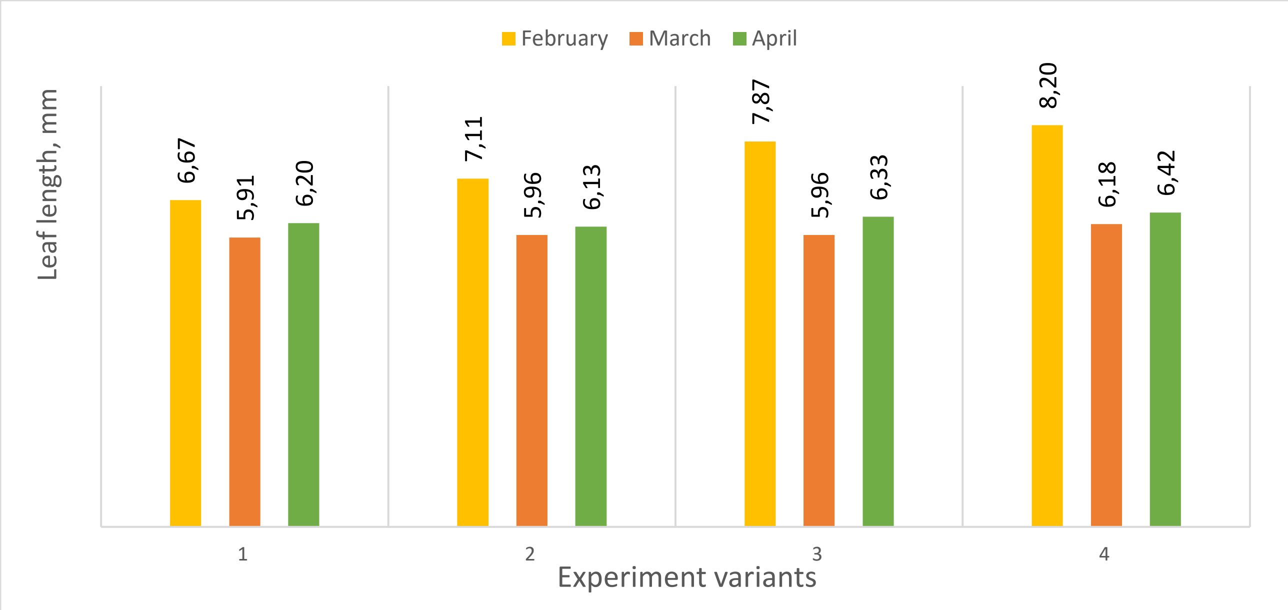

Fig. 4.17 – Influence of preparations and sowing dates on the leaf length of St. John's wort seedlings (*Hypericum perforatum* L.) of the Arcoiris variety, mm (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

by 0.05-1.20 mm. The greatest increase in leaf length was observed with combined seed treatment with the preparations Vimpel-K and Orakul seeds – 0.22-1.53 mm. Early sowing dates showed themselves best.

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the leaf width of St. John's wort seedlings of the Arcoiris variety is shown in Figure 4.18.

The control variant had the smallest leaf width – 4.00-4.33 mm. Seed treatment with the preparation Vimpel-K increased the width of the seedling leaf by 0.01-0.34 mm compared to the control. The preparation Orakul seeds had an even greater effect, increasing the leaf width by 0.09-0.74 mm. The highest leaf width was achieved with combined seed treatment with the preparations Vimpel-K and Orakul seeds – 4.20-5.29 mm, which exceeded the control values by 0.12-0.96 mm. As for the sowing dates, early dates contributed to an increase in leaf width.

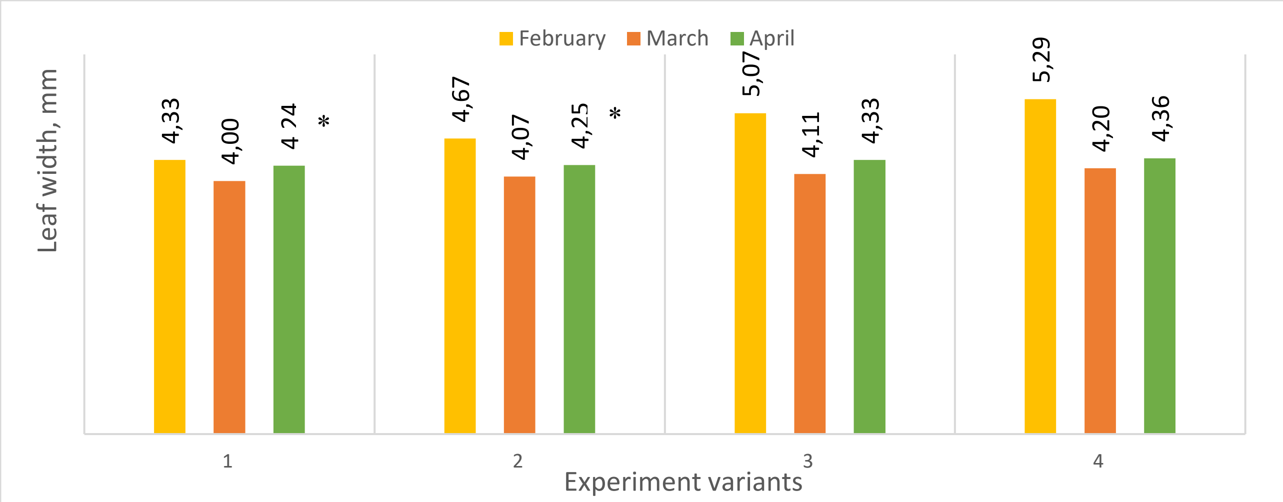

Fig. 4.18 – Influence of preparations and sowing dates on the leaf width of St. John's wort seedlings (*Hypericum perforatum* L.) of the Arcoiris variety, mm (average for 2021-2023)

*Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, which indicates the reliability of the research results. Note: * According to Student's t-test calculations, the difference between the variants is not significant*

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the leaf area of a seedling of St. John's wort of the Arcoiris variety is presented in Figure 4.19.

The control variant showed the smallest leaf area – 18.53-22.69 mm². Seed treatment with the Vimpel-K preparation increased the leaf area compared to the control by 0.45 mm² and 0.44 mm² in two variants of the experiment with earlier sowing dates and reduced this indicator by 0.25 mm ^{2} in the variant with a later sowing date. The Orakul seeds preparation improved this indicator, increasing the leaf area by 0.71-8 .48 mm². The combined use of the Vimpel-K and Orakul seeds preparations gave the best results, increasing the leaf area by 1.33-12.94 mm². Early sowing dates were the most effective for increasing the leaf area.

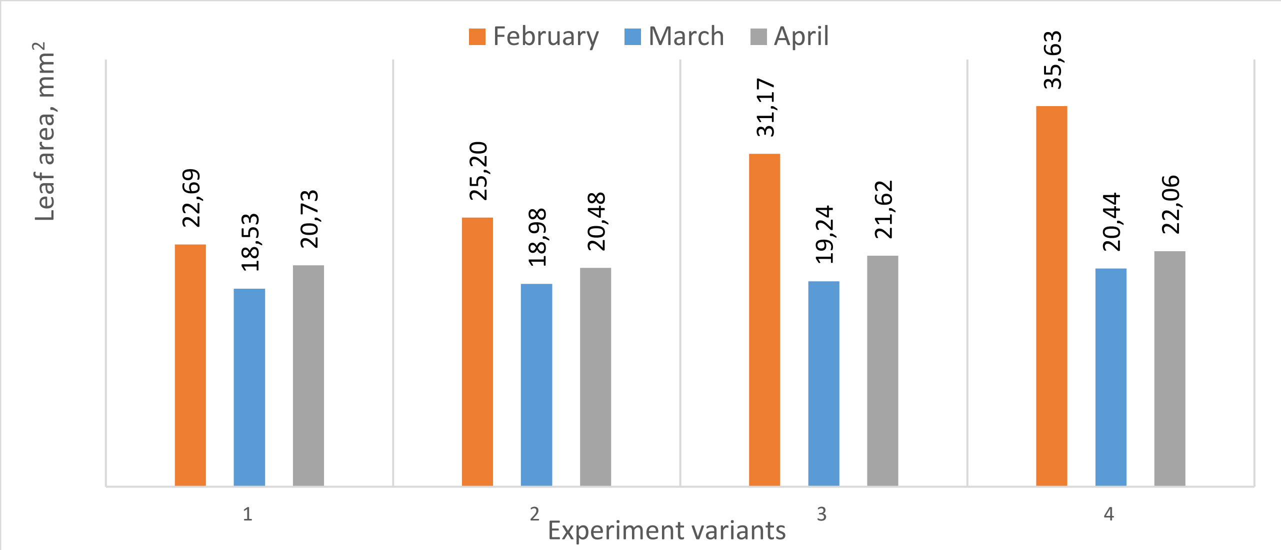

Fig. 4.19 – The influence of preparations and sowing dates on the leaf area of St. John's wort seedlings (*Hypericum perforatum* L.) of the Arcoiris variety, mm ^{2} (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the phytomass of the above-ground part of seedlings of St. John's wort of the Arcoiris variety is shown in Figure 4.20.

The control variant had the lowest phytomass – 12.00-20.02 mg. Seed treatment with the preparation Vimpel-K increased phytomass by 2.5-48.2% compared to the control. The preparation Orakul seeds improved this indicator by 5.3-69.0%. The highest values of phytomass of the aboveground part – 14.33-28.54 mg – were achieved with combined seed treatment with both preparations. The dependence of phytomass on sowing dates showed that early sowing dates contributed to better development of the aboveground part of the plant.

The effect of the preparations Vimpel-K and Orakul seeds and sowing dates on the mass of the root system of seedlings of St. John's wort of the Arcoiris variety is illustrated in Figure 4.21.

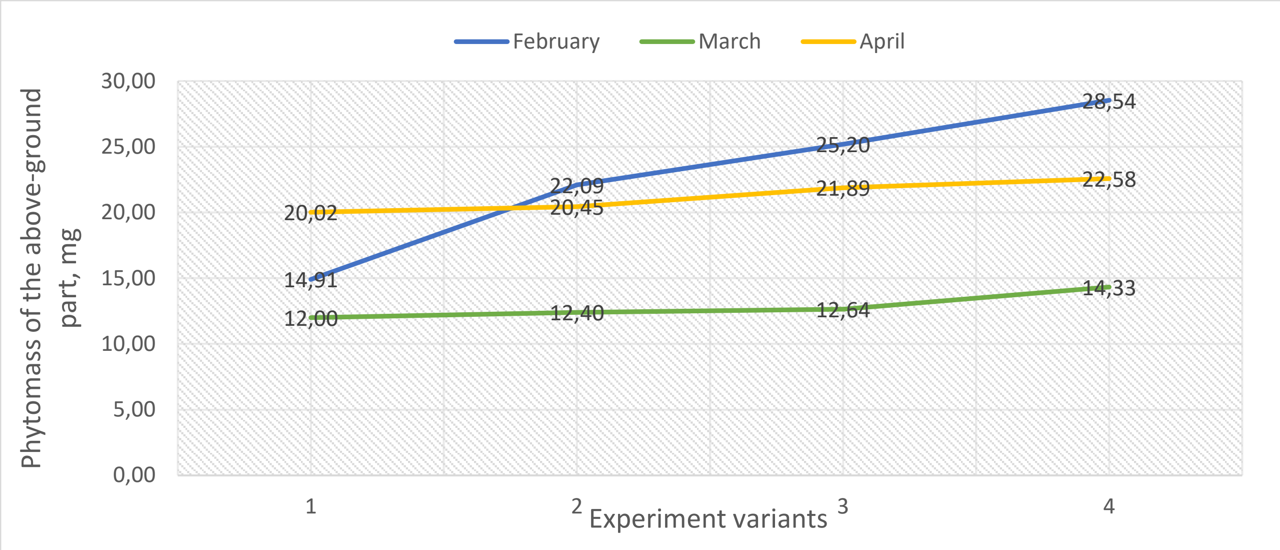

Fig. 4.20 – Influence of preparations and sowing dates on the phytomass of the above-ground part of seedlings of St. John's wort (*Hypericum perforatum* L.) of the Arcoiris variety, mg (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

The control variant showed the smallest root system mass – 35.00-69.00 mg. Seed treatment with the preparation Vimpel-K increased the root system mass by 4.8% and 61.8% compared to the control in two variants of the experiment with earlier sowing dates and reduced this indicator by 3.7% in the variant with a later sowing date. The preparation Orakul seeds improved this indicator by 9.2-68.9%. The largest root system mass was achieved with combined seed treatment with the preparations Vimpel-K and Orakul seeds – 39.00-132.67 mg. Early sowing dates contributed to better development of the root system.

Table 4.3 presents the results of a two-factor analysis of variance of the mass of the above-ground part of St. John's wort of the Arcoiris variety depending on the timing of sowing seeds in pellets and the use of growth stimulants. It allows us to conclude that the best option is sowing seeds in February. At the same time, regardless of the use of preparations, the mass significantly exceeded the seedlings sown in March and April by 6.7%-76.6%.

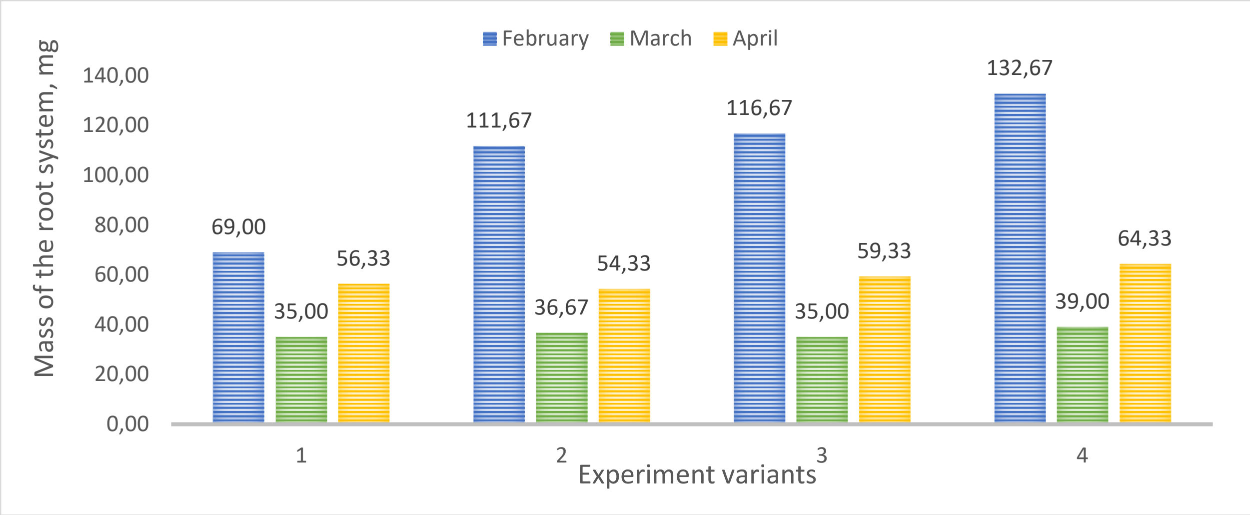

Fig. 4.21 – The influence of preparations and sowing dates on the mass of the root system of seedlings of St. John's wort (*Hypericum perforatum* L.) of the Arcoiris variety, mg (average for 2021-2023)

Variants: 1 - control; 2 - seed treatment with the preparation Vimpel-K (500 ml/t); 3 - seed treatment with the preparation Orakul seeds (1 l/t); 4 - seed treatment with the preparation Vimpel-K (500 ml/t) and the preparation Orakul seeds (1 l/t). According to the calculations of the Student's t-test, the difference between the variants $t_{theor.} > t_{fact.}$, *which indicates the reliability of the research results*

Table 4.3 - Analysis of variance of the mass of the above-ground part (mg) of seedlings of St. John's wort of the Arcoiris variety depending on the use of growth stimulants and sowing dates

Factor A – sowing dates	Factor B – growth stimulants				Average factor A	
	Control	Vimpel-K	Orakul seeds	Vimpel-K + Orakul seeds		
February	14.91	22.09	25.2	28.53	**22.68**	
March	12.00	12.40	12.64	14.33	**12.84**	
April	20.02	20.47	21.89	22.58	**21.24**	**LSD_{05} A=0.279**
Average factor B	**15.64**	**18.32**	**19.91**	**21.81**	**LSD_{05} B=0.322**	LSD_{05} AB=0.557

Calculations also confirm that all the stimulants studied had a positive and reliable effect, the greatest increases were observed with the combined use of the preparations Vimpel K and Orakul seeds, regardless of the sowing dates.

Short conclusions:

1. The preparation Vimpel-K demonstrated a moderate positive effect on plant growth compared to the control, increasing stem height by 2.8-14.2%, leaf number by 3.5-27.2%, leaf area by 1.34-4.05 mm², aboveground mass by 7.1-21.6%, and root mass by 2.8-61.8% depending on the variety and sowing date. This preparation was most effective in influencing the number of leaves (up to 27.2% in the Arcoiris variety) and the root mass (an increase of up to 61.8% in the Arcoiris variety).

2. Orakul seeds showed a more pronounced effect compared to Vimpel-K, increasing stem height by 5.3-69%, leaf area by 2.52-8.48 mm², number of leaves by 8.0-40.0%, phytomass of the aboveground part by 15.1-69.0%, and mass of the root system by 9.2-68.9%. Particularly noticeable was the increase in leaf area (up to 8.48 mm² in the Arcoiris variety) and phytomass of the aboveground part (up to 69.0% in the Arcoiris variety), which indicates its high efficiency in stimulating photosynthetic activity of plants.

3. Sowing dates have a significant impact on plant development. Early sowing dates contributed to better seedling development, which was expressed in an increase in all morphological indicators. For example, stem height increased by 8.78 mm in the Topas variety and by 14.53 mm in the Arcoiris variety, which indicates the advantage of early sowing dates. On the other hand, late sowing dates led to a decrease in stem height by 1.58 mm (Arcoiris variety) and a decrease in other indicators, such as leaf area and root system mass, which may be the result of a limited growth period before the onset of cold weather.

CHAPTER 5
PRODUCTIVITY OF ST. JOHN'S WORT (*HYPERICUM PERFORATUM* L.) IN ONTOGENESIS

5.1 Productivity of *H. perforatum* var. 'Arcoiris' During Ontogenesis

In order to optimize the growing conditions and regulate the productivity of St. John's wort, we conducted studies of its varietal characteristics in ontogenesis. Table 5.1 shows the dynamics of changes in the main morphometric and biometric indicators of the above-ground part of St. John's wort of the Arcoiris variety during the growing season (average indicators for 2022–2024).

The data indicate a gradual development of plants from the early phases of vegetation to the reproductive phase and fruit ripening. As observations show, the height of the stem increased significantly before the beginning of fruit formation. At the end of April it was 18.87 cm, in May it increased fourfold, reaching 83.62 cm, and by the end of June it reached a maximum of 102.44 cm. In July, a slight decrease in height to 101.80 cm was recorded, which may be due to the transition of plant energy from growth processes to the formation of generative organs.

The number of internodes also gradually increased. At the end of April, it was 11.52 pieces, and in May, it was already 19.97 pieces. This indicates active stem growth, typical of the spring period. By July, the number of internodes reached its maximum of 24.57 pieces.

The mass of the stem without leaves at the end of April was only 1.25 g, while in May it increased to 11.85 g, and in June it reached the highest value – 14.78 g. In July, the mass of the stem slightly decreased to 13.17 g, which is probably due to the redistribution of nutrients in the plant.

The mass of leaves increased from the beginning of the growing season, reaching its peak of 4.51 g in June. After that, the indicator decreased to 2.60 g in July, which is explained by the beginning of the death of some leaves due to the increase in temperature and the formation of generative organs.

The results of the research show that the formation of generative organs began in the first decade of June. The mass of flowers was 4.58 g, which corresponds to the period of mass flowering. Subsequently, the mass of flowers gradually decreased, reaching its minimum of 0.51 g at the end of July, which indicates the transition of the plant to fruit formation.

The mass of fruits was first recorded by us in July, reaching a value of 8.16 g. This indicates the completion of the generative cycle, when the plant directs its main resources to seed formation.

Table 5.1 - Dynamics of development of the above-ground part of St. John's wort of the Arcoiris variety (average for 2022-2024)

Indicators	Dates of samples						
	1	2	3	4	5	6	7
Stem height, cm	18.87	38.30	60.65	83.62	95.82	102.44	101.80
Number of internodes, pcs.	11.52	11.87	14.57	19.97	20.13	23.83	24.57
Stem mass, g	1.25	3.63	9.00	11.85	14.78	13.02	13.17
Mass of leaves, g	0.75	1.31	3.39	4.51	4.16	3.07	2.60
Mass of flowers, g	-	-	-	-	4.58	1.35	0.51
Mass of fruits, g	-	-	-	-	-	5.88	8.16

Table 5.2 presents data on the dynamics of the development of the leaf surface of St. John's wort of the Arcoiris variety during the growing season (average figures for 2022–2024). The number of leaves gradually increased from 24.07 pcs. at the beginning of the study to a maximum value of 347.07 pcs. at the end of May, after which a gradual decrease was observed to 247.63 pcs. by the end of July.

The mass of leaves also increased, reaching a peak of 4.51 g in the period 25–28 May. Later, a decrease in this indicator to 2.60 g was observed in July, which may be associated with plant aging. The mass of one leaf varied throughout the entire period of recording: at the beginning it was 0.031 g, and the maximum value of 0.098 g was reached in mid-May. Later, it decreased to 0.011 g in the final stages of vegetation.

Table 5.2 - Dynamics of leaves development and their area of St. John's wort of the Arcoiris variety (average for 2022-2024)

Indicators	Dates of samples						
	1	2	3	4	5	6	7
Number of leaves, pcs.	24.07	23.13	34.70	347.07	309.27	338.20	247.63
Mass of leaves, g	0.75	1.31	3.39	4.51	4.16	3.07	2.60
Mass of one leaf, g	0.031	0.057	0.098	0.013	0.013	0.009	0.011
Leaf blade length, cm	2.26	2.78	3.28	2.51	3.24	2.37	1.98
Leaf blade width, cm	1.14	1.40	1.90	1.39	1.61	1.17	1.00
Leaves area, cm^2	66.69	88.89	197.39	217.00	212.12	156.50	132.82
Area of one leaf cm^2	2.77	3.85	5.67	0.63	0.69	0.46	0.54

The length and width of the leaf blade show a similar trend: having reached maximum values in mid-May (3.28 cm and 1.90 cm, respectively), the indicators gradually decreased to 1.98 cm and 1.00 cm at the end of July. The leaves area reached a maximum at the end of May (217.00 cm^2) and gradually decreased to 132.82 cm^2 at the end of July. The area of one leaf increased from the initial 2.77 cm^2 to a maximum of 5.67 cm^2 in mid-May, after which it decreased to 0.54 cm^2 in July.

Table 5.3 shows the dynamics of flower and fruit formation in St. John's wort of the Arcoiris variety during the growing season. The data show that the first flowers appear in early June, and in the first decade of June the maximum number is 152.02 pcs. The mass of flowers at this time reaches 4.58 g, and the mass of one flower is 0.030 g. A further decrease in the number of flowers is observed in the periods of the third decade of June and mid-July, where their number decreases to 43.43 and 18.76 pcs. respectively. At the same time, the mass of flowers also decreases to 1.35 g and 0.51 g. The mass of one flower remains quite stable, fluctuating within the limits of 0.027–0.031 g.

Table 5.3 - Dynamics of flower and fruit formation in St. John's wort of the Arcoiris variety (average for 2022-2024)

Indicators	Dates of samples						
	1	2	3	4	5	6	7
Number of flowers, pcs.	-	-	-	42.1	152.02	43.43	18.76
Mass of flowers, g	-	-	-	1.22	4.58	1.35	0.51
Mass of one flower, g	-	-	-	0.029	0.030	0.031	0.027
Number of fruits, pcs.	-	-	-	-	-	111.13	128.98
Mass of fruits, g	-	-	-	-	-	5.88	8.16
Mass of one fruit, g	-	-	-	-	-	0.053	0.063

The fruits began to form in the third decade of June, during this period their number reached 111.13 pieces, and their mass was 5.88 g. In mid-July, the number of fruits increased to 128.98 pieces, and their mass was 8.16 g. The mass of one fruit increased from 0.053 g to 0.063 g.

5.2 Productivity of *H. perforatum* var. 'Taubertal' During Ontogenesis

Table 5.4 presents data on the dynamics of the development of the above-ground part of the common St. John's wort variety Taubertal during the growing season (average data for 2022–2024). The growth of the stem height was gradual: at the initial stage (third decade of April) the height was 18.92 cm. Later, in May, the indicators grew rapidly: 29.16 cm at the beginning of the month and 48.68 cm in the middle. At the end of May, the stem height reached 72.33 cm, and in the first decade of June – 81.37 cm. By the end of the growing season, in July, the maximum value was 86.53 cm.

The data presented in Table 5.4 indicate that the number of internodes also gradually increased during the growing season. In April there were 10.67 of them, in May – from 11.17 to 17.37. In June there was a slight increase to 19.50, and in July the number of internodes reached a maximum – 20.97.

The mass of the stem without leaves shows an active increase during the first half of the growing season. In April it was only 1.07 g, in May – from 2.17 g to 6.47 g. In June the mass reached a peak (8.70 g), after which it decreased to 6.71 g in July.

Table 5.4 - Dynamics of development of the above-ground part of St. John's wort of the Taubertal variety (average for 2022-2024)

Indicators	Dates of samples						
	1	2	3	4	5	6	7
Stem height, cm	18.92	29.16	48.68	72.33	81.37	81.90	86.53
Number of internodes, pcs.	10.67	11.17	13.10	17.37	18.70	19.50	20.97
Stem mass, g	1.07	2.17	4.50	6.47	8.70	6.71	9.67
Mass of leaves, g	0.57	0.80	1.68	2.90	3.10	2.58	3.01
Mass of flowers, g	-	-	-	0.37	2.98	1.04	0.46
Mass of fruits, g	-	-	-	-	-	75.14	141.42

The mass of leaves steadily increased until the beginning of June, reaching 3.10 g, but later decreased to 2.58 g, and in July slightly increased to 3.01 g. At the same time, at the end of May, the formation of flowers began – 0.37 g, which reached a maximum in June (2.98 g). In July, the indicators decreased to 0.46 g. The formation of fruits began in June (75.14 g), and at the end of July, the mass of fruits was 141.42 grams. These indicators indicate the active completion of the generative cycle of the plant.

Table 5.5 shows the dynamics of leaf surface development of St. John's wort of the Taubertal variety during the growing season. The number of leaves gradually increased from the beginning of the growing season. In April, there were 21.83 leaves on the plant, while by mid-May this figure had increased to 109.83. The maximum number of leaves (276.57) was recorded at the end of June. After that, a decrease in the number of leaves to 254.07 was observed at the end of July.

The mass of leaves increased steadily during the first half of the growing season. At the beginning of the period (April) this indicator was 0.57 g, by the first decade of June it reached a maximum of 3.10 g, but later decreased to 2.58 g, and in July it slightly increased to 3.01 g.

The mass of one leaf varied depending on the developmental phase. In April it was 0.026 g, increasing to a maximum of 0.038 g in the first decade of May. Then this indicator remained relatively stable and fluctuated between 0.009 g and 0.015 g.

Table 5.5 - Dynamics of leaf development and area of St. John's wort of the Taubertal variety (average for 2022-2024)

Indicators	Dates of samples						
	1	2	3	4	5	6	7
Number of leaves, pcs.	21.83	21.03	109.83	220.03	272.53	276.57	254.07
Mass of leaves, g	0.57	0.80	1.68	2.90	3.10	2.58	3.01
Mass of one leaf, g	0.026	0.038	0.015	0.013	0.011	0.009	0.012
Leaf blade length, cm	2.27	2.46	2.57	2.17	2.16	2.04	1.75
Leaf blade width, cm	1.07	1.12	1.35	1.08	1.04	1.06	0.88
Leaves area, cm^2	31.61	44.59	88.21	150.00	168.19	137.50	160.31
Area of one leaf cm^2	1.45	2.13	0.80	0.68	0.62	0.50	0.63

The length and width of the leaf blade gradually increased until mid-May, reaching 2.57 cm and 1.35 cm, respectively. Later, the size of the leaf blade gradually decreased, and by the end of July, the length was 1.75 cm and the width was 0.88 cm.

Leaves area increased significantly at the beginning of the growing season, reaching a maximum of 168.19 cm^2 at the beginning of June. After that, there was a decrease in the area to 137.50 cm^2 at the end of June, but in July the indicator increased to 160.31 cm^2.

The area of one leaf in April was 1.45 cm^2, increasing to a maximum of 2.13 cm^2 in the first decade of May. Then this indicator remained relatively stable and fluctuated between 0.50 g and 0.80 cm^2.

Table 5.6 presents the dynamics of flower and fruit formation of St. John's wort of the Taubertal variety during the growing season. The data show that flowering begins at the end of May, when the number of flowers reached 9.68 pcs. and their mass was 0.37 g.

Table 5.6 - Dynamics of flower and fruit formation in St. John's wort of the Taubertal variety (average for 2022-2024)

Indicators	Dates of samples						
	1	2	3	4	5	6	7
Number of flowers, pcs.	-	-	-	9.68	83.64	40.72	19.02
Mass of flowers, g	-	-	-	0.37	2.98	1.04	0.46
Mass of one flower, g	-	-	-	0.038	0.036	0.026	0.024
Number of fruits, pcs.	-	-	-	-	-	75.14	141.42
Mass of fruits, g	-	-	-	-	-	4.34	10.06
Mass of one fruit, g	-	-	-	-	-	0.058	0.071

The maximum flowering was observed at the beginning of June, when the number of flowers increased to 83.64 pcs. and their mass was 2.98 g. Subsequently, the number of flowers gradually decreased: by the end of June there were 40.72 pcs. and in July only 19.02 pcs. The mass of flowers decreased to 1.04 g and 0.46 g, respectively. The mass of one flower remained relatively stable: at the beginning it was 0.038 g, and by the end of July it decreased to 0.024 g.

The fruits began to form in the third decade of June, when their number reached 75.14 pieces, and their mass was 4.34 g. By mid-July, the number of fruits increased to 141.42 pieces, and their mass was 10.06 g. The mass of one fruit also increased: from 0.058 g in June to 0.071 g in July.

The results obtained demonstrate a clear phase dynamic of the development of generative organs of the Taubertal variety, which emphasizes the importance of periodic monitoring of plant growth and development to optimize agrotechnical measures.

5.3 Productivity of *H. perforatum* var. 'Topas' During Ontogenesis

Table 5.7 shows the dynamics of the development of the above-ground part of the St. John's wort of the Topas variety during the growing season. The height of the plant stem gradually increased throughout the entire period of study. At the beginning of the observation in April, it was 20.39 cm. By the end of May, the indicator reached 74.90 cm, and the maximum – 88.42 cm – was reached in July. A slight slowdown in growth in June (85.06 cm) may be associated with the transition of the plant to generative development.

The number of internodes also gradually increased: from 10.30 pcs. in April to a maximum of 21.93 pcs. in the third decade of June. In July, this indicator slightly decreased to 21.20 pcs., which may indicate the end of active growth.

Table 5.7 - Dynamics of development of the above-ground part of St. John's wort of the Topas variety (average for 2022-2024)

Indicators	Dates of samples						
	1	2	3	4	5	6	7
Stem height, cm	20.39	31.29	49.04	74.90	85.39	85.06	88.42
Number of internodes, pcs.	10.30	11.20	13.77	17.10	19.77	21.93	21.20
Stem mass, g	1.13	2.49	4.17	6.70	8.66	7.95	11.88
Mass of leaves, g	0.61	1.10	1.59	2.88	2.70	2.84	3.64
Mass of flowers, g	-	-	-	0.54	3.09	1.40	0.58
Mass of fruits, g	-	-	-	-	-	4.18	11.58

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The stem mass without leaves was initially only 1.13 g, but reached maximum values in July – 11.88 g, demonstrating the gradual accumulation of biomass. Similar dynamics were observed for the mass of leaves, which increased from 0.61 g in April to a maximum of 3.64 g in July.

The mass of flowers began to increase with the appearance of the first flowers in the third decade of May (0.54 g), reaching a peak of 3.09 g in June. Later, this indicator decreased, reaching 0.58 g in July. Such dynamics indicate the completion of the flowering period in July and the transition to fruiting.

Fruit formation began at the end of June, during this period the weight of the fruits was 4.18 g, and their number was 78.54 pcs. In July, a significant increase in these indicators was observed: the number of fruits reached 207.97 pcs., and the weight was 11.58 g. The weight of one fruit gradually increased from 0.053 g to 0.056 g in July, which indicates the active formation of generative organs.

Table 5.8 presents data on the dynamics of the development of the leaf surface of St. John's wort of the Topas variety during the growing season. Data analysis indicates significant changes in the main indicators of the leaf apparatus, which reflect the overall dynamics of plant growth and development.

The number of leaves at the beginning of the growing season was 21.27 pcs. and remained stable in the first week, reaching only 20.53 pcs. by the beginning of May. In mid-May, the number of leaves increased sharply to 113.67 pcs. and by the end of May it reached a maximum value of 214.93 pcs. In early June, this indicator decreased slightly to 200.47 pcs. and by the end of the month it increased again, reaching a maximum of 286.17 pcs. and ended at 277.13 pcs. in July. This dynamics indicates an active process of leaf formation in the middle of the growing season.

The mass of leaves gradually increased from 0.61 g at the end of April to 3.64 g in July. The maximum mass value (2.88 g) was recorded at the end of May, which corresponds to the intensive growth of plants during this period. The mass indicator of one leaf at the beginning of the observation was 0.029 g and reached a maximum of 0.054 g at the beginning of May. Subsequently, this indicator decreased, dropping to 0.013 g in July, which may be associated with plant aging and physiological exhaustion.

Table 5.8 - Dynamics of leaf development and area of St. John's wort of the Topas variety (average for 2022-2024)

Indicators	Dates of samples						
	1	2	3	4	5	6	7
Number of leaves, pcs.	21.27	20.53	113.67	214.93	200.47	286.17	277.13
Mass of leaves, g	0.61	1.10	1.59	2.88	2.70	2.84	3.64
Mass of one leaf, g	0.029	0.054	0.014	0.013	0.013	0.010	0.013
Leaf blade length, cm	2.42	2.58	2.63	2.03	1.88	2.10	1.74
Leaf blade width, cm	1.14	1.30	1.32	1.03	0.93	1.10	0.84
Leaves area, cm^2	32.09	57.69	86.40	144.60	131.61	149.27	182.74
Area of one leaf cm^2	1.51	2.81	0.76	0.67	0.66	0.52	0.66

The length of the leaf blade also varied during the growing season. In early April, it was 2.42 cm and increased to 2.63 cm in mid-May, but then began to decrease to 1.74 cm in late July. The width of the leaf blade varied in a similar way: the maximum value of 1.32 cm was recorded in mid-May, after which it gradually decreased to 0.84 cm.

The leaves area gradually increased during the growing season. In April, this indicator was 32.09 cm^2, increased to 144.60 cm^2 at the end of May and reached a maximum of 182.74 cm^2 at the end of July. At the same time, the area of one leaf at the beginning of the study was at the level of 1.51 cm^2, increased to 2.81 cm^2 in May, and then decreased to 0.66 cm^2 in July.

These data indicate active development of the leaf apparatus of the Topas variety in the middle of the growing season, when the peak of the number and area of leaves was observed. The decrease in some indicators in July may be a consequence of plant aging and preparation for the completion of the growing cycle.

Table 5.9 shows the dynamics of flower and fruit formation of St. John's wort of the Topas variety during the growing season. The number of flowers shows a clear dynamics. At the end of May, 11.46 pcs. of flowers were recorded, which indicates the beginning of flowering. The maximum value of the number of flowers was noted in the first decade of June – 66.37 pcs., after which the number sharply decreased to 21.27 pcs. as of the end of July. This trend confirms active flowering at the beginning of the summer season, with a further decrease in the number of flowers due to the transition to fruiting.

Table 5.9 - Dynamics of flower and fruit formation in St. John's wort of the Topas variety (average for 2022-2024)

Indicators	Dates of samples						
	1	2	3	4	5	6	7
Number of flowers, pcs.	-	-	-	11.46	66.37	54.98	21.27
Mass of flowers, g	-	-	-	0.54	3.09	1.40	0.58
Mass of one flower, g	-	-	-	0.047	0.047	0.025	0.027
Number of fruits, pcs.	-	-	-	-	-	78.54	207.97
Mass of fruits, g	-	-	-	-	-	4.18	11.58
Mass of one fruit, g	-	-	-	-	-	0.053	0.056

The mass of flowers also changes dynamically during the observation period. The first values were 0.54 g at the beginning of flowering, then there was a sharp increase to 3.09 g as of the third decade of June, and then a sharp decrease to 0.58 g in July. This pattern indicates the stages of the largest flowering and the subsequent transition to the generative stage of seed formation.

The mass of one flower also demonstrates certain dynamics, fluctuating within 0.047-0.027 g. The highest value was recorded in the first decade of June at the level of 0.047 g, which indicates the greatest development of generative biomass at the stage of active flowering.

As for fruits, the number of their formation increases significantly after the third decade of June, when 78.54 pcs. were recorded as of mid-July, up to 207.97 pcs., which confirms the final stage of the plant's generative cycle. The mass of fruits during this period also increased significantly, reaching 11.58 g as of July. The mass of one fruit in the final period was 0.056 g, which indicates an intensive process of biomass accumulation by the plant during the process of seed formation.

5.4 Comparison of the productivity of flowers of St. John's varieties in ontogenesis

Figures 5.1-5.3 show the dynamics of flower formation in St. John's wort varieties Arcoiris, Taubertal and Topas during the growing season. The indicators include the number of flowers, their mass and the mass of one flower at different sampling times – from the beginning of formation in late May to mid-July, when flowering ends.

Arcoiris variety is characterized by rapid formation and development of flowers starting from mid-May (42.10 pcs.), and their number rapidly increases to 152.02 pcs. during the period of mass flowering (first decade of June). Further, a decrease is observed to 43.43 pcs. in the third decade of June and 18.76 pcs. in July. Similar dynamics are characteristic of the Topas variety , which also reaches a peak of 152.02 pcs. in the first decade of June. The Taubertal variety has less intensive flower development. At the end of May, their number is only 9.68 pcs., and during the period of mass flowering – 83.64 pcs., which is almost half as much as in the other two varieties. By July, the number of flowers in Taubertal decreases to 19.02 pcs.

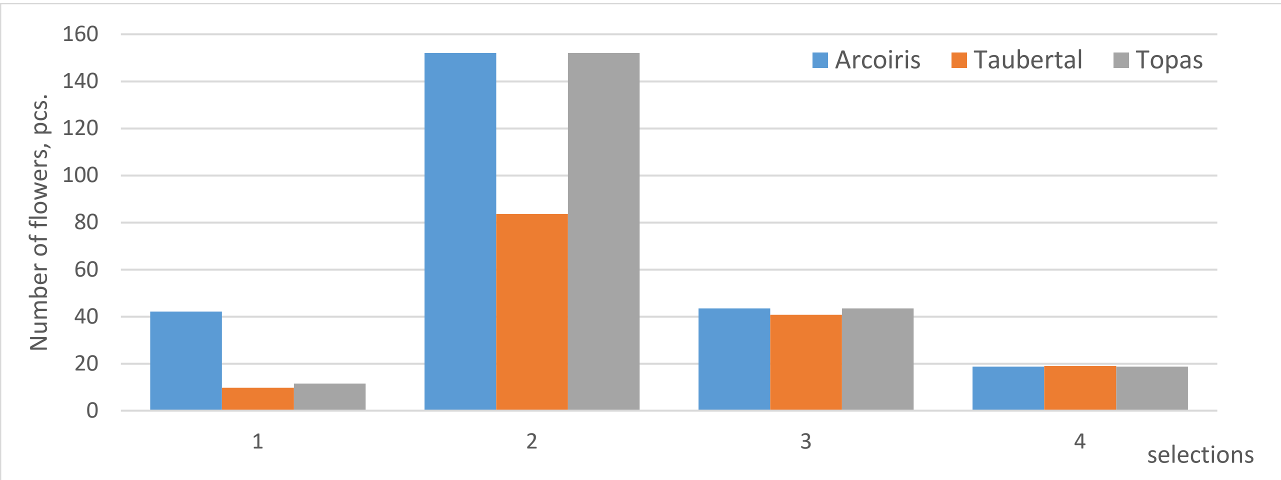

Fig. 5.1 - Dynamics of flower formation in St. John's wort varieties (average for 2022-2024).

The highest flower mass in the Arcoiris variety is observed during maximum flowering in early June (4.58 g). Later, the mass gradually decreases to 1.35 g in the third decade of June and 0.51 g in July. In the Topas variety, the flower mass dynamics is similar: the maximum value in June (3.09 g), and in July – a decrease to 0.58 g. The Taubertal variety demonstrates the lowest flower mass in all selection periods: from 0.37 g at the end of May to 0.46 g in July.

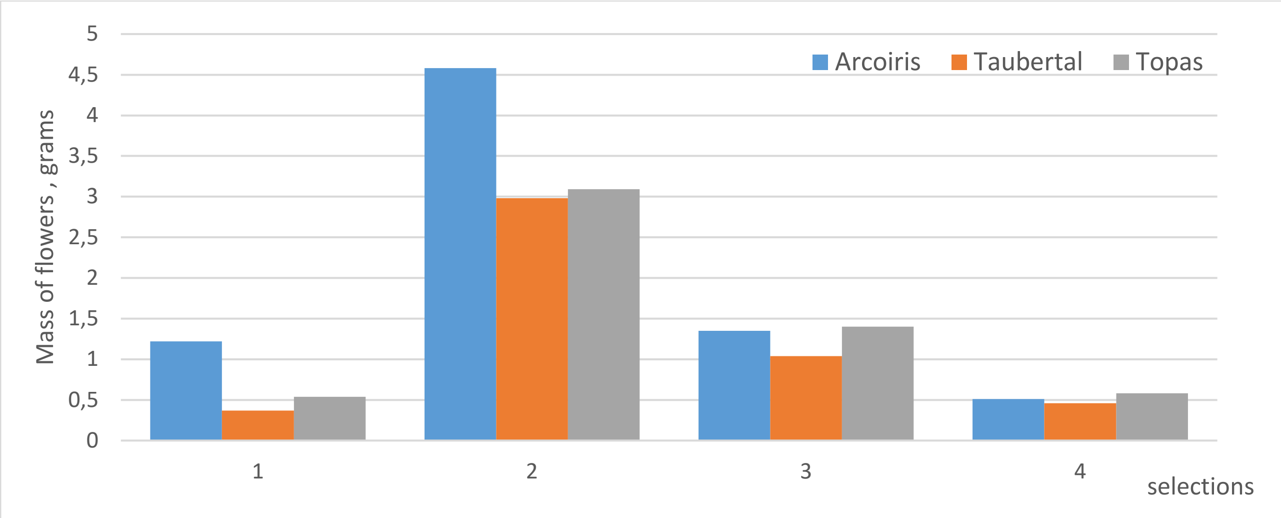

Fig. 5.2 - Dynamics of formation of flower mass in St. John's wort varieties (average for 2022-2024).

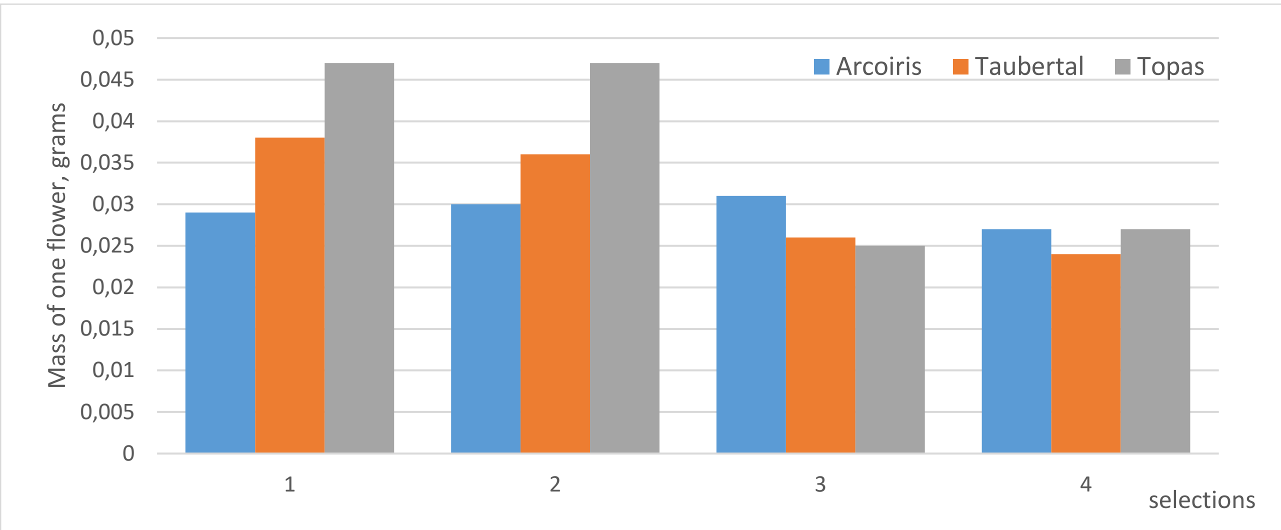

Fig. 5.3 - Dynamics of formation of mass of one flower in St. John's wort varieties (average for 2022-2024).

Topas variety has the highest mass of one flower at the beginning of the observation (0.047 g) and maintains this indicator during the period of mass flowering. Subsequently, the mass decreases to 0.025 g in the third decade of June and 0.027 g in July. In the Taubertal variety, the mass of one flower varies from 0.038 g in May to 0.024 g in July. The lowest mass of one flower is observed in the Arcoiris variety – from 0.030 g in the first decade of June to 0.027 g in July.

The varieties Arcoiris and Topas show similar flower formation dynamics, with a peak in June, significantly outperforming the Taubertal variety in all respects. The highest flower mass and number are characteristic of Arcoiris and Topas , while these figures are significantly lower in Taubertal. The mass of one flower is also the highest in the Topas variety, which may indicate its advantage in forming heavier flowers. The decrease in the number and mass of flowers in July is associated with the completion of flowering and the transition to fruiting.

Short conclusions:

1. Studies of the dynamics of the formation and development of productivity elements of St. John's wort varieties allowed us to establish certain varietal features. All three varieties demonstrated a gradual increase in stem height from the beginning of vegetation to mass flowering. The maximum height indicators were observed in late June and early July: the Arcoiris variety reached 102.44 cm, Taubertal – 86.53 cm, Topas – 88.42 cm. The number of internodes also increased, reaching a maximum in July: Arcoiris – 24.57 pcs., Taubertal – 20.97 pcs., Topas – 21.93 pcs.

2. The mass of the stem and leaves increased until June, after which a decrease was observed due to the beginning of the formation of generative organs and the dying off of part of the leaves of the lower tier. The maximum mass of the stem was recorded in the first decade of June in the variety Arcoiris – 14.78 g, in mid-July in Taubertal and Topas varieties – 9.67 g and 11.88 g, respectively. The leaf mass reached its maximum values in May - early June.

3. The leaf surface developed most intensively in May, reaching its maximum at the end of June: in the variety Arcoiris – 338.20 pcs., Taubertal – 276.57 pcs., Topas –

286.17 pcs. Further, their number decreased in July, which is associated with the natural dying off of part of the leaves. The mass of one leaf and the area of the leaf blade were the largest in May, after which the indicators decreased.

4. Flower formation began in the third decade of May. The Arcoiris variety showed the highest indicators of the number of flowers (152.02 pcs.) and their mass (4.58 g). The Taubertal and Topas varieties showed slightly lower indicators: the maximum number of flowers – 83.64 pcs. And 66.37 pcs., flower mass – 2.98 g and 3.09 g, respectively. The Topas variety stood out with the largest mass of one flower (0.047 g). The number and mass of fruits increased from the third decade of June, reaching a maximum in July. The Topas variety showed the highest productivity in fruit formation, with a mass of up to 11.58 g.

5. The Arcoiris variety showed the best results in most morphometric traits. It turned out to be the most productive variety among those we studied. Topas showed relatively high rates of individual flower and fruit mass, but overall productivity was inferior to Arcoiris. Taubertal was characterized by the lowest scores on all morphometric and biometric indicators.

St. John's wort seeds

St. John's wort seedling emergence

St. John's wort seedling development

first-year St. John's wort plants grown by seedling technology

St. John's wort plants planted according to schemes

end of the first growing season, shoot formation observed for the next year's harvest

beginning of spring vegetation of St. John's wort

St. John's leaves with glands

formation of generative shoots

St. John's wort bud formation

beginning of St. John's wort flowering

St. John's wort flower

St. John's wort in full bloom

end of flowering: fruit formation observed alongside flowers

St. John's wort fruit formation

St. John's wort plants in autumn of the second growing year: mass formation of underground shoots for the next year's harvest

CHAPTER 6
PRODUCTIVITY OF ST. JOHN'S WORT (*HYPERICUM PERFORATUM* L.) DEPENDING ON PLANT DENSITY

An important factor in the yield and quality of medicinal plant raw materials is the cultivation methods and plant density in agrocenoses. Therefore, one of the tasks of our research was to study the yield of St. John's wort depending on the placement schemes. Table 6.1 shows the data on the biological productivity of St. John's wort of the Arcoiris variety during the mass flowering period according to the average indicators of 2022–2024 depending on the plant placement scheme (45x40 cm and 70x25 cm).

Table 6.1 -Yield structure of St. John's wort of the Arcoiris variety depending on placement schemes (average for 2022-2024)

Indicators	Placement scheme	
	45x40	70x25
Number of shoots per seedling unit, pcs.	30.00	29.00
Mass of fresh above-ground part of the 1st shoot, g	23.52	20.55
Mass of dry above-ground part of the 1st shoot, g	5.23	4.57
Mass of dry above-ground mass of a seedling unit, g	156.81	132.43
Yield of raw materials, t/ha	3.05	2.58

The results show that the number of shoots on a plant in the experimental schemes was almost the same (30 and 29 pieces). The mass of the fresh above-ground part of one shoot in the 45x40 cm scheme was 23.52 g, while at 70x25 cm this figure was lower – 20.55 g. A similar trend is observed for the mass of the dry above-ground part of one shoot: 5.23 g in the 45x40 cm variant and 4.57 g in the 70x25 cm variant.

The mass of dry aboveground mass per plant was also higher for the 45x40 cm scheme and was 156.81 g, which exceeded the figure of 132.43 g for the 70x25 cm scheme. The yield of raw materials per hectare varied depending on the placement scheme: when grown with row spacings of 45 cm, it was 3.05 t/ha, while for the 70x25 cm scheme it decreased to 2.58 t/ha.

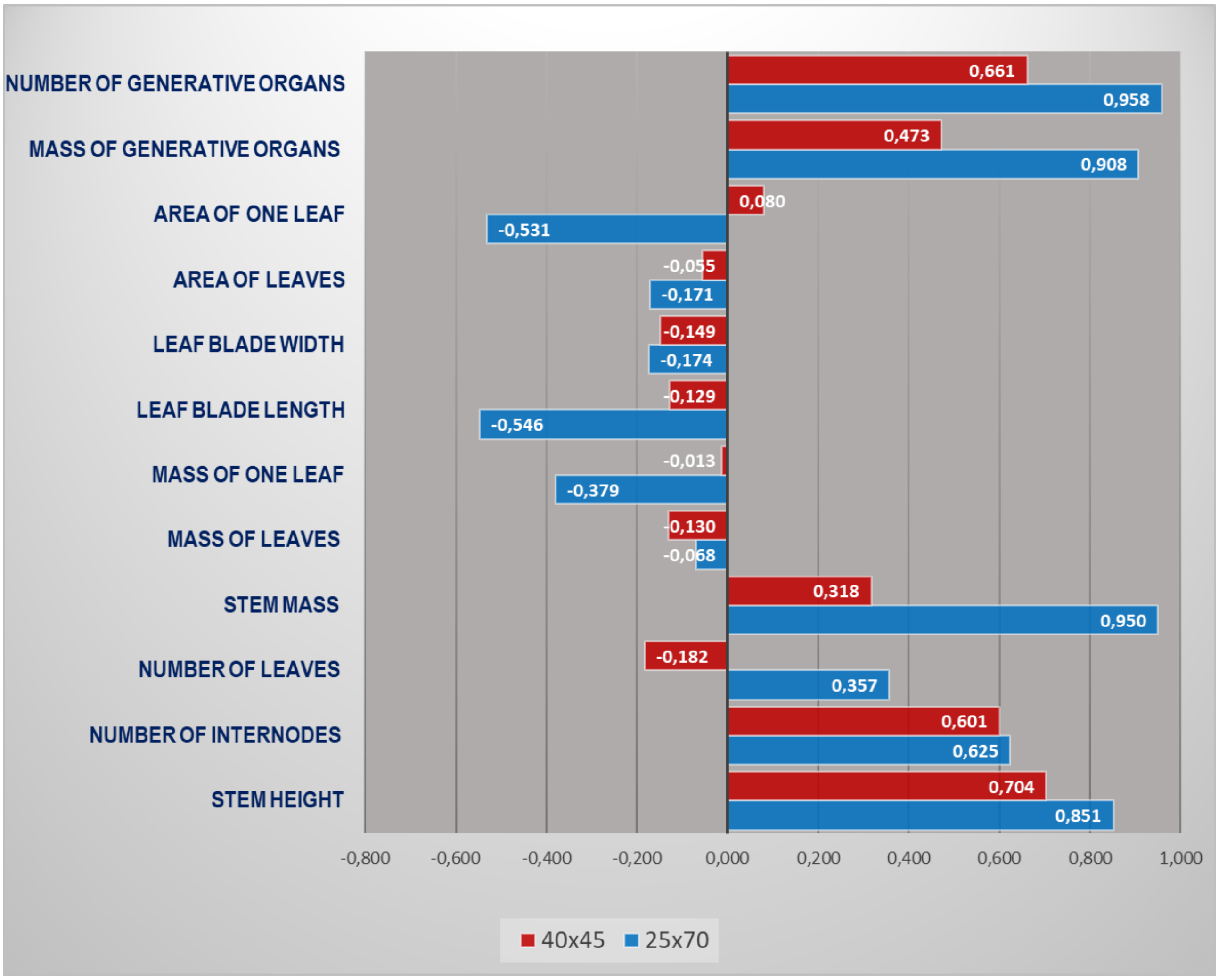

Fig. 6.1 - Correlations of aboveground mass productivity with morphometric characteristics of St. John's wort of the Arcoiris variety. (Significant at 5% level under conditions < R = 0.6664)

The correlation analysis conducted allows us to conclude that plant placement schemes affect the formation of architectonics and productivity of St. John's wort plants (Fig. 6.1). The correlations of stem height and the number of internodes on it were higher for the 70x25 scheme (R=0.851 and R=0.625, respectively) compared to the 45x40 cm scheme (R=0.704 and R=0.601, respectively). But the most significant was the difference between the correlation coefficients of the indicators of productivity and stem mass (R=0.950 for the 70x25 scheme and R=0.318 for the 45x40 cm scheme), productivity and mass of generative organs (R=0.908 and R=0.473, respectively), productivity and number of generative organs (R=0.958 and R=0.661, respectively).

It is worth noting that mass of leaves and number of leaves had low correlations with productivity (R=-0.182 – 0.318). Most leaf traits (width, length, leaf area and mass) had inverse correlation coefficients with productivity, with higher correlations in the 70x25 scheme (Fig. 6.1).

An important characteristic of St. John's wort raw material, which determines its quality, is the generative organs. The presented research results indicate that the cultivation schemes affect the number of flowers that are formed on the shoots of plants. Figure 6.2. shows that when grown according to the 70x25 scheme, the height of the plants has a high correlation with the number of generative organs (NGO) (R=0.796), while when grown with row spacings of 45 cm, the correlation between the indicators is lower (R=0.674).

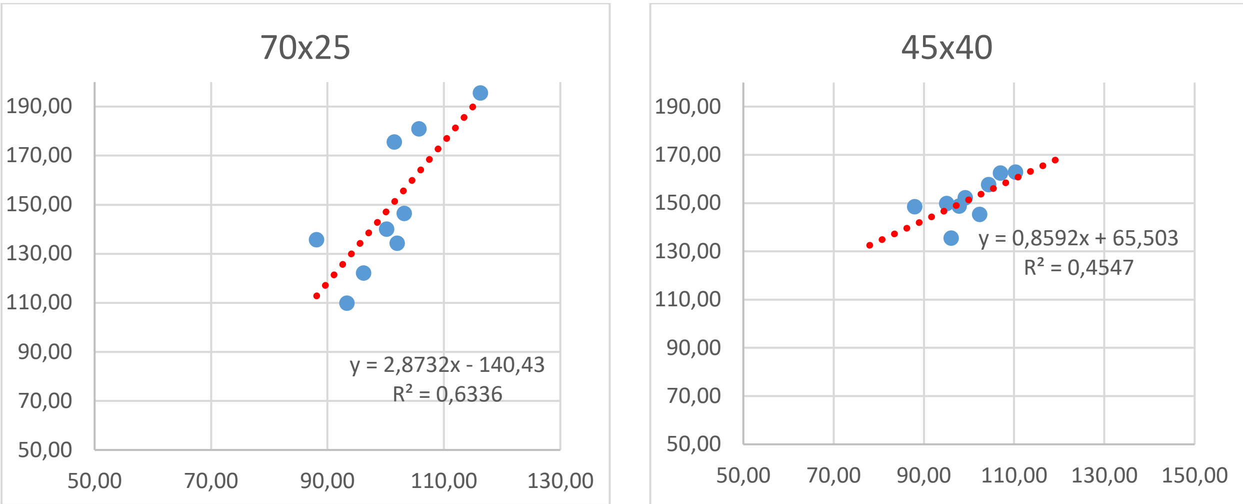

Fig. 6.2 - Dependence of the number of generative organs on the height of plants under different cultivation schemes (Arcoiris variety).

A similar pattern was found after calculating the correlation coefficient between the NGO and the number of internodes on the shoot (Fig. 6.3). When grown according to the 70x25 scheme, it was R=0.747, while the placement of plants with a row spacing of 45 cm did not reveal any correlation (R=0.333). Figure 6.4. presents the results of calculating the influence of the number of leaves on the plant on NGO. It can be concluded that increasing the row spacing reduces the influence of the number of leaves on NGO: for the 70x25 scheme R=0.367, while for the 45x40 scheme – R=0.568.

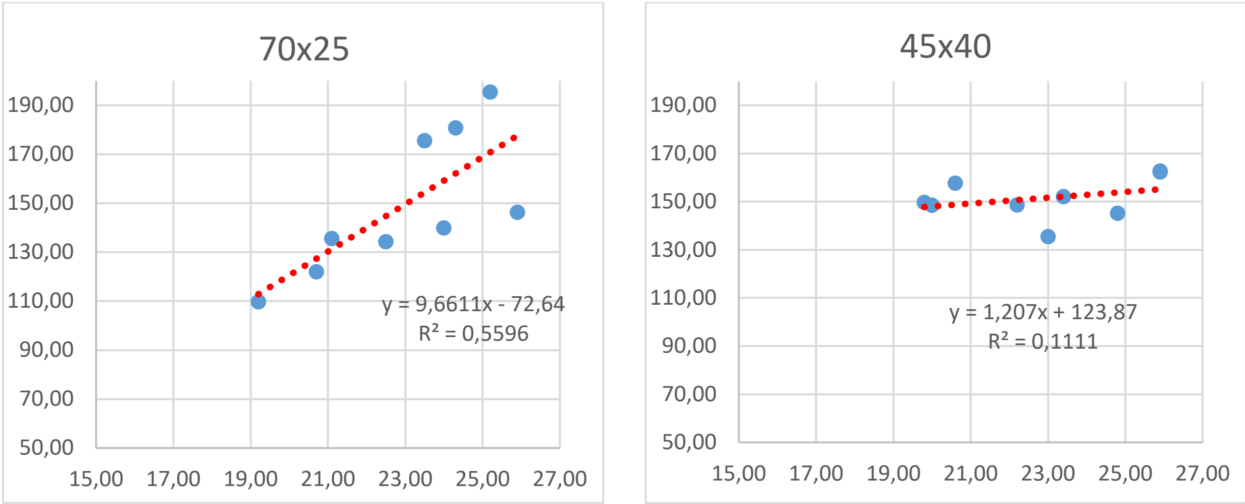

Fig. 6.3 - Dependence of the number of generative organs on the number of internodes under different cultivation schemes (Arcoiris variety).

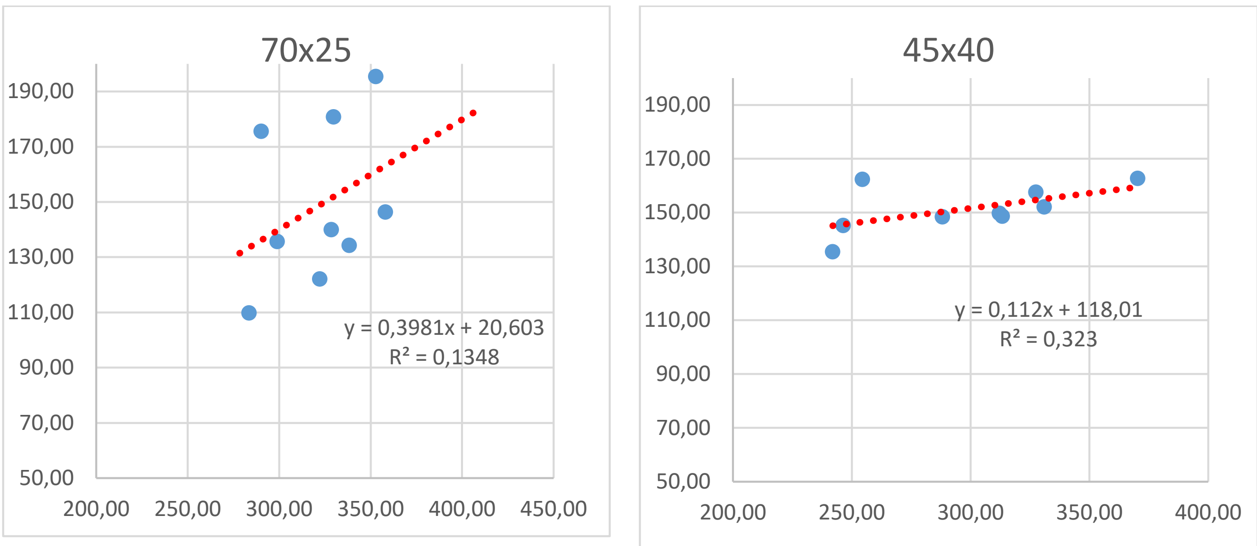

Fig. 6.4 - Dependence of the number of generative organs on the number of leaves under different cultivation schemes (Arcoiris variety).

The results presented in Table 6.1 indicate that the 45x40 cm scheme is more effective for achieving high productivity of St. John's wort of the Arcoiris variety. However, when growing St. John's wort with row spacings of 70 cm, the crop architecture changes somewhat, as evidenced by higher correlation coefficients. This may be due to the optimal ratio of crop density and plant access to nutrients and light.

Table 6.2 shows the biological productivity of St. John's wort of the Taubertal variety during the mass flowering period under different plant placement schemes

(45x40 cm and 70x25 cm) based on averages for 2022–2024. Under the 45x40 cm placement scheme, the number of shoots per seedling unit was 33.33 pcs., which is 11.1% more than under the 70x25 cm scheme (30.00 pcs.). The mass of the fresh above-ground part of one shoot in the 45x40 cm variant was lower (14.78 g) compared to 15.22 g for the 70x25 cm scheme, which may indicate less favorable conditions due to denser placement. The values of the mass of the dry above-ground part of one shoot were almost the same: 3.28 g (45x40 cm) versus 3.38 g (70x25 cm).

Table 6.2 - Yield structure of St. John's wort of the Taubertal variety depending on placement schemes (average for 2022-2024)

Indicators	Placement scheme	
	45x40	70x25
Number of shoots per seedling unit, pcs.	33.33	30.00
Mass of fresh above-ground part of the 1st shoot, g	14.78	15.22
Mass of dry above-ground part of the 1st shoot, g	3.28	3.38
Mass of dry above-ground mass of a seedling unit, g	109.50	101.46
Yield of raw materials, t/ha	2.13	1.97

In the 45x40 cm scheme, the dry weight of aboveground mass per seedling unit was higher – 109.50 g, which exceeds the productivity of the 70x25 cm scheme (101.46 g). The placement of plants in the 45x40 cm scheme provided a yield of raw materials at the level of 2.13 t/ha, which is 8.1% more than in the 70x25 cm scheme (1.97 t/ha). The data indicate that the 45x40 cm placement scheme contributes to a higher yield of raw materials by increasing the number of shoots per seedling unit and the dry weight of the aboveground part. However, in the 70x25 cm scheme, better individual productivity of shoots in terms of fresh and dry weight was observed.

Calculations show that aboveground mass productivity has high correlations with morphometric characteristics (Fig. 6.5).

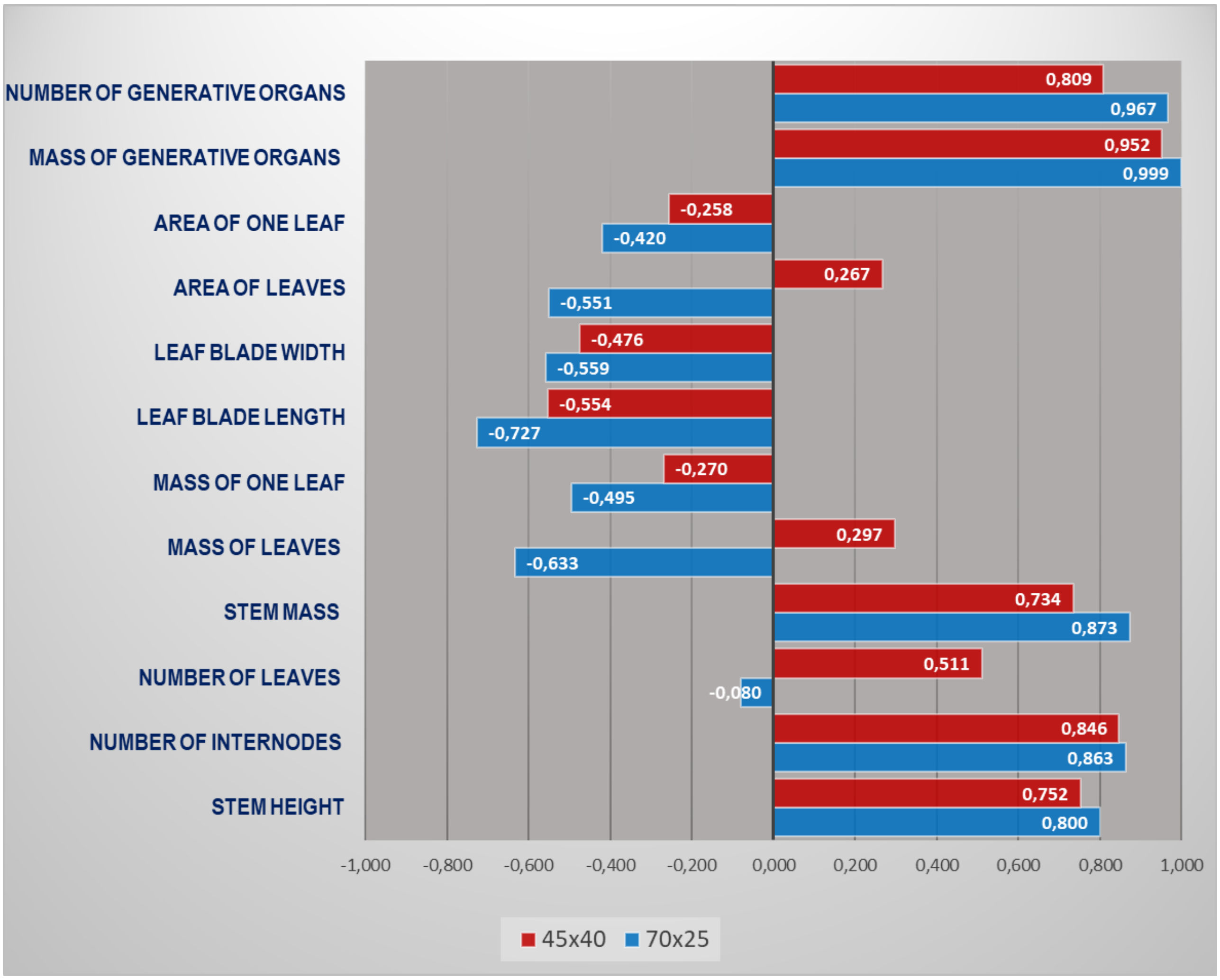

Fig. 6.5 - Correlations of aboveground mass productivity with morphometric characteristics of St. John's wort of the Taubertal variety. (Significant at 5% level under conditions < R = 0.6664)

The largest correlations were found between productivity and the mass of generative organs (R=0.952-0.999), the number of generative organs (R=0.809-0.967), the mass of the stem (R=0.734-0.873), the number of internodes (R=0.846-0.863), the height of the stem (R=0.752-0.800). It is worth noting that the mass, number and characteristics of the leaves had low direct or inverse correlations with the productivity of plants. At the same time, the mass of the leaves when grown according to the 45x40 scheme had a correlation coefficient of R=0.297, and according to the 70x25 scheme – R=-0.633. A larger leaf area when grown with a row spacing of 70 cm had a high, but inverse correlation with productivity (R=-0.551).

It was found that the formation of NGO on plants of the Taubertal variety did

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not depend on the height of the plants under different plant placement schemes (Fig. 6.7). This is evidenced by the corresponding correlation coefficients: R=0.626 for the 70x25 scheme and R=618 for the 45x40 scheme. However, the cultivation schemes affected the formation of NGO depending on the number of internodes on the shoots (Fig. 6.8). When growing under the 70x25 scheme the correlation between the indicated indicators was R=0.718, then reducing the row spacing to 45 cm led to an increase in the correlation coefficient to R=0.876.

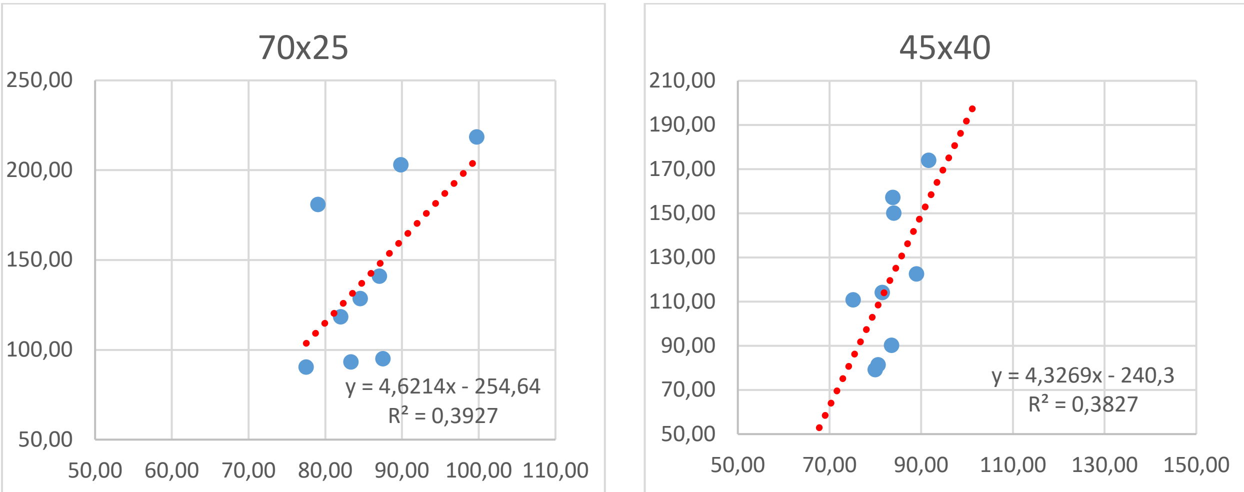

Fig. 6.6 - Dependence of the number of generative organs on the height of plants under different cultivation schemes (Taubertal variety).

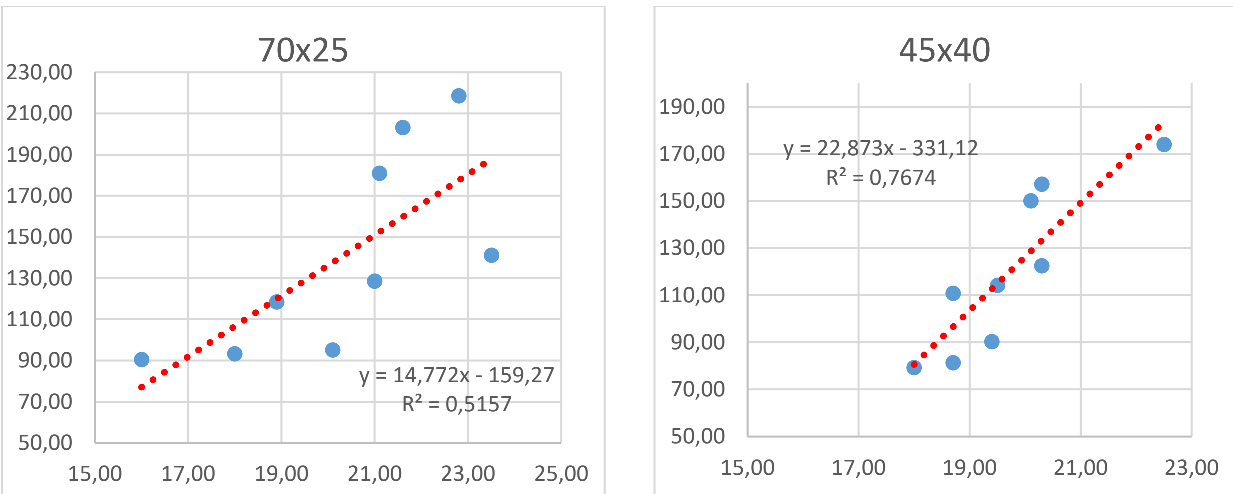

Fig. 6.7 - Dependence of the number of generative organs on the number of internodes under different cultivation schemes (Taubertal variety) .

Figure 6.8 shows that the NGO and the number of leaves on the plant have a negative correlation, and for the 70x25 growing scheme it was quite high (R =0.635). This indicates that the number of flowers formed on the plant does not depend on the number of leaves, and accordingly, the activity of the photosynthetic apparatus. In general, for the Taubertal variety, as our studies show, the placement schemes had little effect on yield.

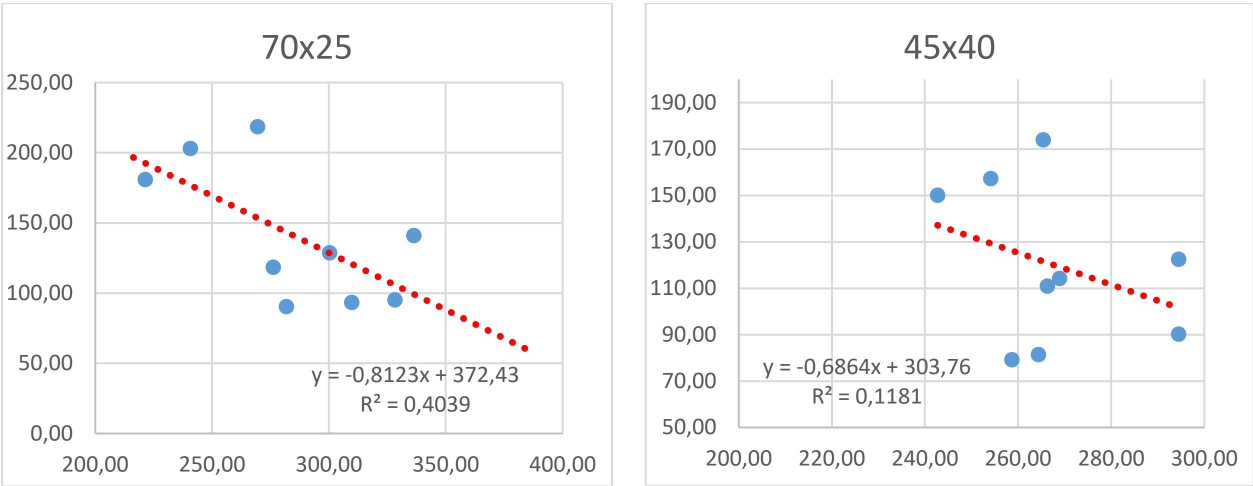

Fig. 6.8 - Dependence of the number of generative organs on the number of leaves under different cultivation schemes (Taubertal variety) .

Table 6.3 shows the calculation of the biological productivity of St. John's wort of the Topas variety during the mass flowering period (average figures for 2022–2024) under different plant placement schemes: 45x40 cm and 70x25 cm. In terms of the number of shoots per seedling unit, an increase was observed in the 45x40 cm scheme, which provided an indicator of 34 pieces, while in the 70x25 cm scheme this indicator was 31 pieces. Analysis of the mass of the fresh aboveground part of one shoot showed that the 70x25 cm scheme provides a slightly higher productivity (14.97 g) compared to the 45x40 cm scheme (14.45 g). At the same time, the mass of the dry aboveground part of one shoot almost did not differ between the schemes (3.33 g versus 3.21 g in the 45x40 cm scheme).

The mass of dry aboveground mass per seedling was also practically identical in both schemes: 109.18 g for the 45x40 cm scheme and 103.11 g for the 70x25 cm scheme. The aboveground mass yield for the 45x40 cm scheme was 2.12 t/ha, while for the 70x25 cm scheme it was 2.01 t/ha. Thus, our studies did not allow us to establish a significant effect of the placement schemes on the yield of St. John's wort of the Topas variety.

Table 6.3 - Yield structure of St. John's wort of the Topas variety depending on placement schemes (average for 2022-2024)

Indicators	Placement scheme	
	45x40	70x25
Number of shoots per seedling unit, pcs.	34.00	31.00
Mass of fresh above-ground part of the 1st shoot, g	14.45	14.97
Mass of dry above-ground part of the 1st shoot, g	3.21	3.33
Mass of dry above-ground mass of a seedling unit, g	109.18	103.11
Yield of raw materials, t/ha	2.12	2.01

Figure 6.9 shows the results of the correlation analysis of the productivity of the aboveground mass with the morphometric characteristics of St. John's wort of the Topas variety . The largest correlations were established between productivity and the number of generative organs (R= 0.987-0.992), their mass (R=0.968-0.982), and stem mass (R=0.950-0.967) regardless of the placement schemes. Stem height and the number of internodes also had positive correlations with productivity: R=0.696-0.776 and R=0.6651-0.756, respectively. Under the 45x40 placement schemes, the characteristics of mass of leaves (R=0.859), number of leaves (R=0.657), and area of leaves (R=0.854) correlated positively with productivity, while when grown with wider row spacing, the correlations decreased to minimal values. Regarding the width and length of the leaf blade, the correlations were negative for the 45x40 scheme and amounted to R=-0.622 and R=-0.615, respectively. Thus, the productivity of the aboveground part is most closely related to the characteristics of the stems and generative organs of St. John's wort.

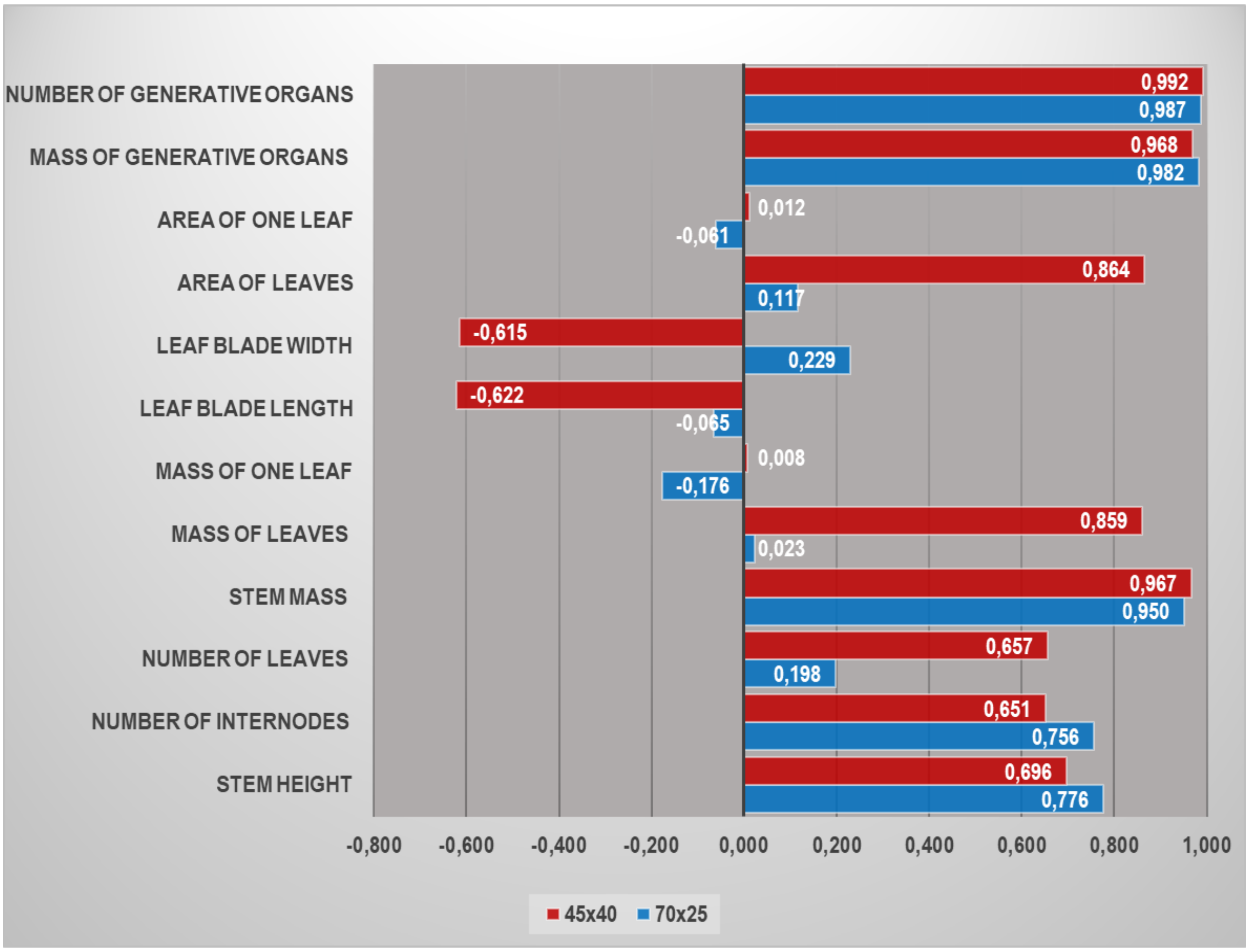

Fig. 6.9 - Correlations of aboveground mass productivity with morphometric characteristics of St. John's wort of the Topas variety. (Significant at 5% level under conditions < R = 0.6664)

Figure 6.10 presents the regression analysis calculations of the dependence of NGO on plant height. They indicate the absence of high correlations with the specified traits, regardless of the experimental designs studied.

Similar conclusions can be drawn after calculating the influence of the number of internodes on the NGO, which is shown in Figure 6.11. The placement schemes did not significantly affect the coefficients of determination of the regression equations: they were low at the level of R^2 = 0.1291-0.2913. The formation of NGO and the number of leaves on the plant (Fig. 6.12) were also poorly correlated, as evidenced by the corresponding regression equations. The option of growing plants 45x40 deserves attention, when the correlation between the traits was direct and amounted to R = 0.633, but still not reliable.

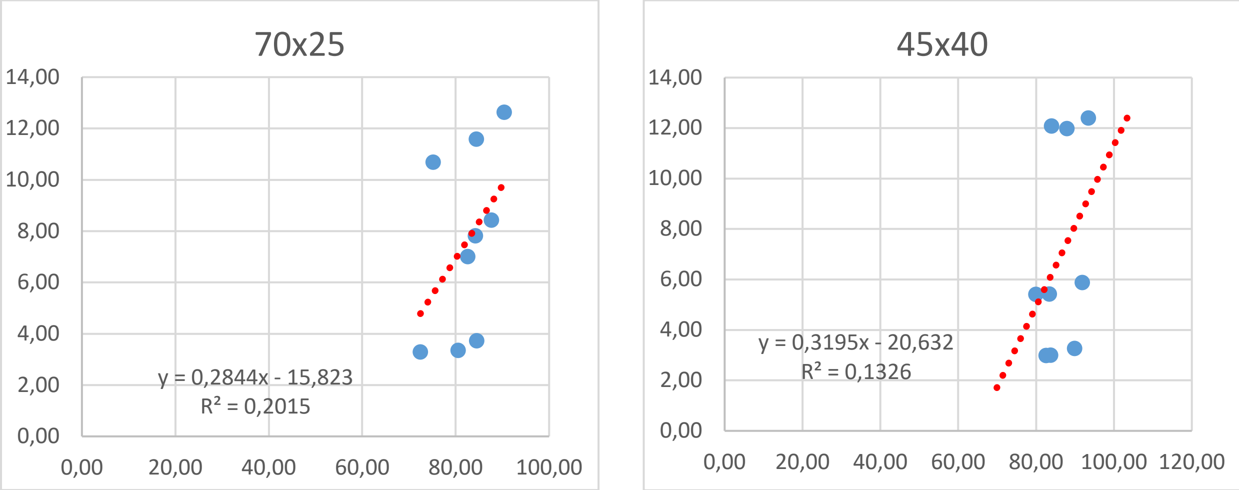

Fig. 6.10 - Dependence of the number of generative organs on the height of plants under different cultivation schemes (Topas variety)

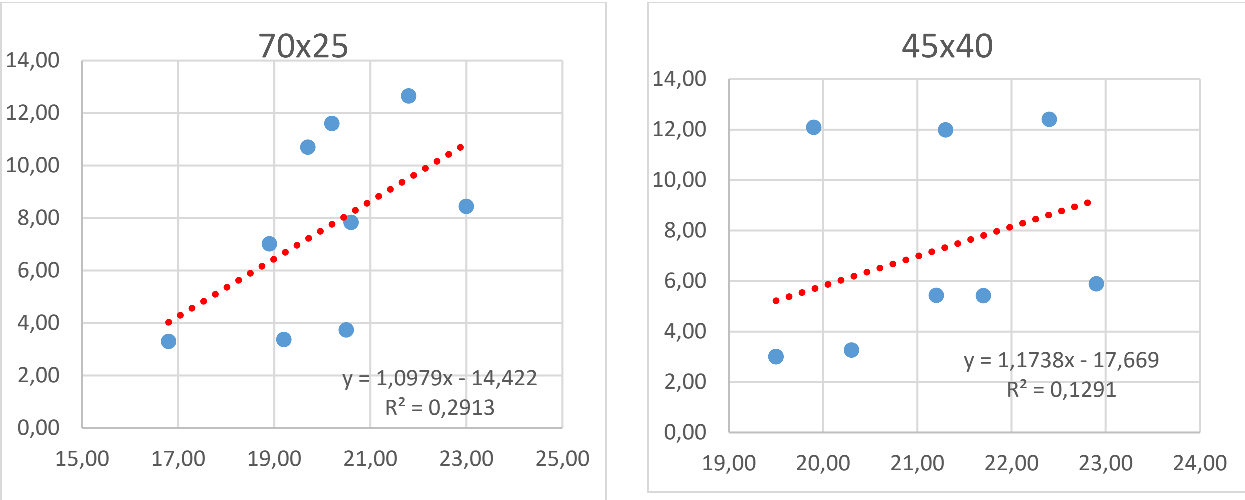

Fig. 6.11 - Dependence of the number of generative organs on the number of internodes under different cultivation schemes (Topas variety)

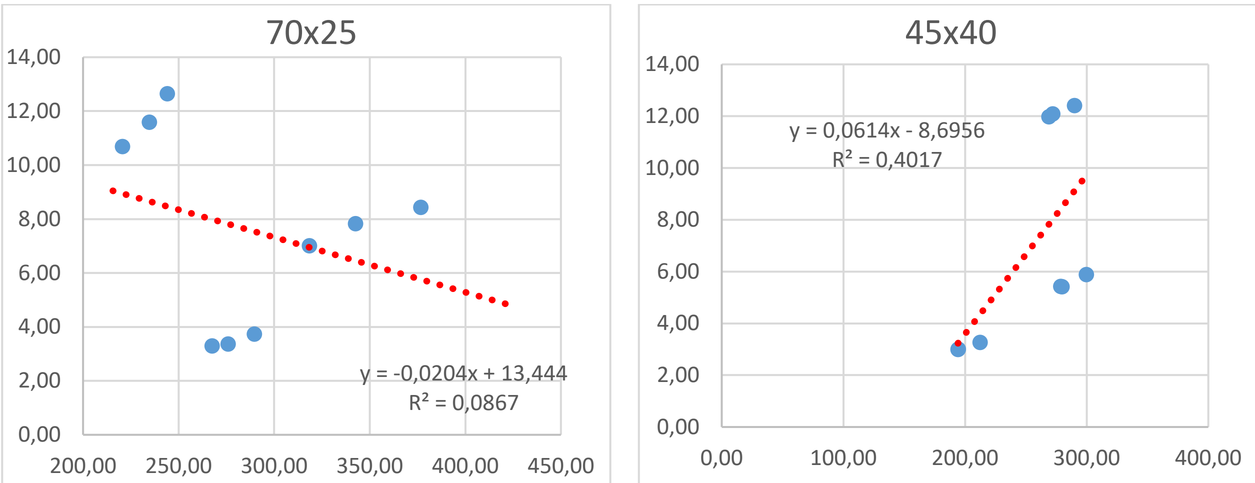

Fig. 6.12 - Dependence of the number of generative organs on the number of leaves under different cultivation schemes (Topas variety)

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Thus, it can be concluded that the formation of the productivity of the Topas variety did not depend on the plant placement schemes, which indicates ecological adaptability to environmental conditions and methods of growing the crop. It is worth adding that the proportion of stems in the raw material of this variety is 52.9%-59.9%, which favorably distinguishes it from other varieties studied: 58.86%-63.16%.

Table 6.4 presents the results of a two-factor analysis of variance on the yield of St. John's wort varieties under the 70x25 and 45x40 cultivation schemes.

Table 6.4 - Variance analysis of yield (t/ha) of St. John's wort varieties depending on placement schemes

Factor A - variety	Factor B – row spacing		Average factor A	
	45 cm	70 cm		
Arcoiris	3.05**	2.58**	***2.82****	
Taubertal	2.13	1.97	***2.05***	
Topas	2.12	2.01	***2.06***	***LSD_{05} A=0.23***
Average factor B	**2.46***	**2.18**	**LSD_{05} B=0.19**	LSD_{05} AB=0.33

The results allow us to conclude that the row spacing has a significant effect on the yield of the crop. Under conditions of cultivation with 45 cm row spacing, the average value was 2.46 t/ha, while with 70 cm row spacing – 2.18 t/ha, which is confirmed by calculations (LSD=0.19 t/ha). As for the evaluation of the varieties, when growing the Arcoiris variety, the yield of raw materials was significantly higher than the Taubertal and Topas varieties (LSD=0.23 t/ha). This allows us to conclude that the optimization of crops allows us to obtain a positive effect in the context of the yield of raw materials.

Short conclusions:

1. The results of the study indicate that the 45x40 cm plant spacing scheme provides higher overall productivity due to an increase in the number of shoots per seedling and higher above-ground mass yield per hectare. However, the 70x25 cm

scheme contributes to improving individual shoot productivity, in particular the mass of the fresh and dry above-ground part of one shoot.

2. The Arcoiris variety in the experiments formed the highest yield of raw materials, which indicates its high adaptability to dense planting schemes. The Taubertal and Topas varieties provided consistently high productivity under both schemes, which indicates their versatility.

3. To achieve maximum productivity, it is recommended to use the 45x40 cm scheme in case of need to increase yield per unit area, which is confirmed by statistical calculations. At the same time, growing according to the 70x25 cm scheme may be appropriate in case of emphasis on individual shoot indicators, which may be important for improving the quality of raw materials.

CHAPTER 7
EVALUATION OF AGGLUTINATING ACTIVITY OF OF *HYPERICUM PERFORATUM* EXTRACTS

Raw materials of St. John's wort are widely used in the world for the production of drugs with a wide spectrum of action, including antimicrobial action. This prompted us to conduct a study of St. John's wort extracts. We drew attention to the fact that St. John's wort contains lectins, which are known to have various functions in plants, including protective ones, and have biological activity. That is why at the first stages we investigated how the extract of St. John's wort herb and its components affected the germination of a test culture (watercress) (Fig. 7.1).

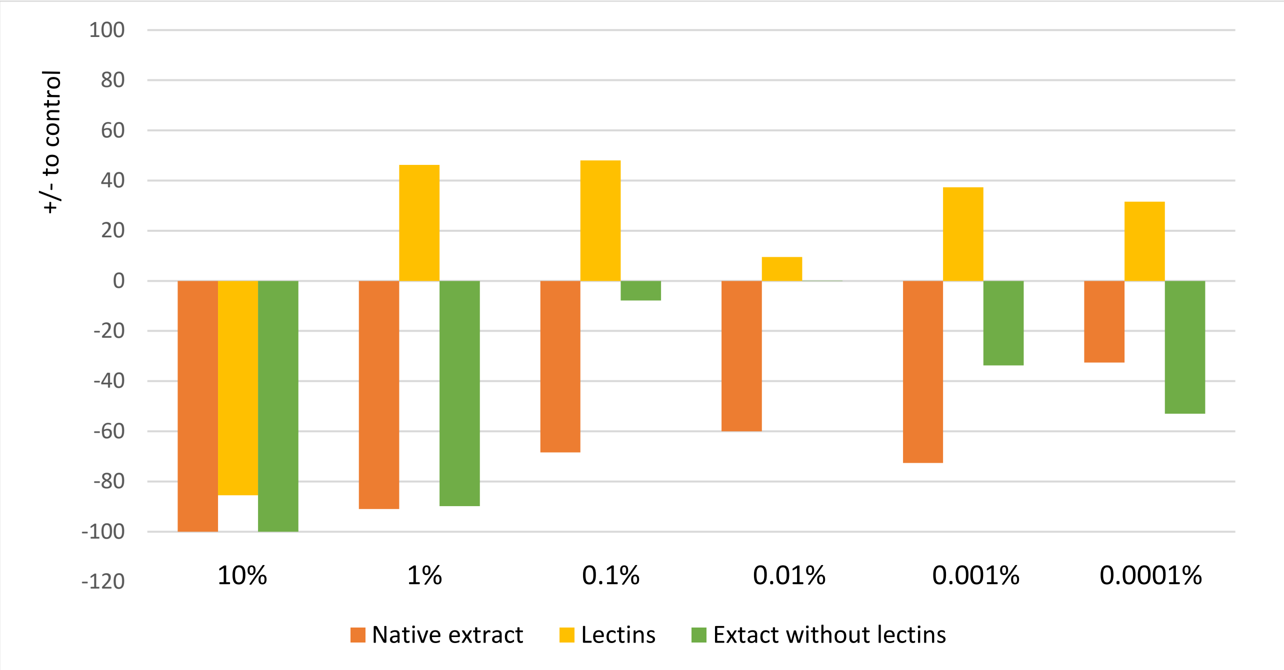

Fig. 7.1 - Evaluation of biological activity of St. John's wort extracts

The obtained results allow us to conclude that the inhibitory effect of the native extract of St. John's wort is due to the complex effect of non-lectin compounds. Lectins in the extract, with the exception of the first dilution (10%), showed a stimulating effect on the test object. It is worth noting that, probably, lectins interact with other components of the extract, which enhances its effect compared to the extract from which lectin compounds were removed (concentrations 0.1 %…0.001%). In addition, the extract without lectins demonstrates significantly higher activity compared to the lectin compounds themselves.

Considering that St. John's wort agglutinins are highly active and are contained in the above-ground part, and are quite easily extracted from it, St. John's wort can be a promising source of these compounds and used for scientific and applied research in various fields.

Analysis of the literature available to us showed that, despite the established fact of the presence of lectins in St. John's wort, many aspects remain poorly studied. The lack of systematic data on the dynamics of lectin accumulation at different stages of St. John's wort ontogenesis in Ukrainian conditions prompted us to study this issue in detail.

Figure 7.2 shows the dynamics of lectin activity in the leaves of St. John's wort of the Arcoiris variety during the growing season. In the shoot formation phase, the agglutinating activity averaged 16.5 points, during the budding period this indicator increased to 17.0 points, and reached maximum values (20.7 points) during the flowering period. During fruiting, the activity slightly decreased to 19.3 points.

In our opinion, this indicates active synthesis of lectins in leaves at the beginning of plant development, with their subsequent movement to generative organs, where they accumulate in significant quantities and remain relatively stable until the end of the growing season.

The activity of lectins in the stems was minimal at the beginning of the growing season (0 - 8.7 points), but gradually increased and reached a maximum at the end of the growing season (8.2 - 15.3 points). This fact suggests that lectins perform an important transport function due to their property of reversibly binding oligo- and polysaccharides, which are also contained in St. John's wort. This is supported by the fact that the same activity was found in dry stems as during the growing season.

The results of the studies presented in Figure 7.3 show that in the generative organs of St. John's wort of the Arcoiris variety, the accumulation of lectins was highest in the buds, where the activity was 24 points. During flowering, it decreased to 22.2 points, and in the fruiting phase – to 20.5 points. The agglutinating activity of the fruits remained at a high level, amounting to 20.0 points.

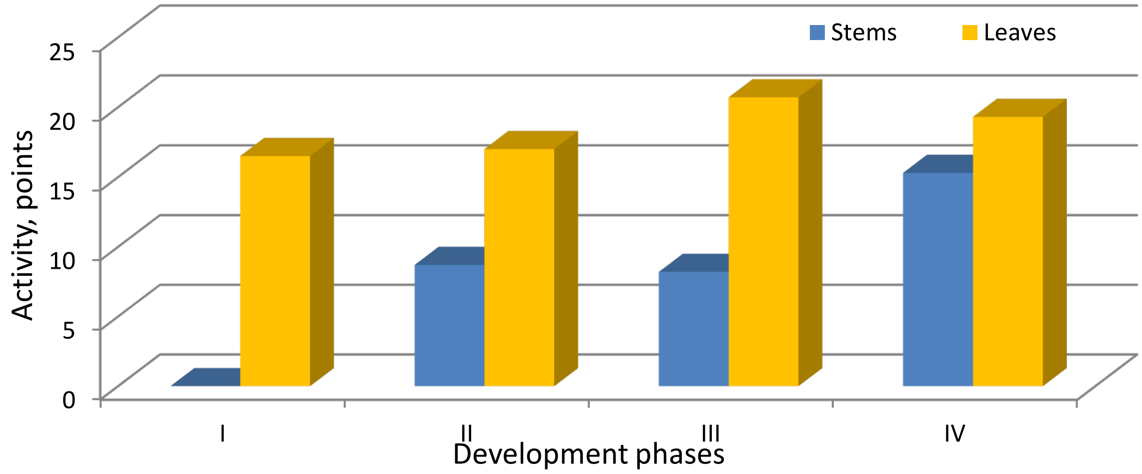

Fig. 7.2 - Dynamics of agglutinin activity in extracts of stems and leaves of St. John's wort of the Arcoiris variety in different phases of development (average over the years of research). *Development phases:* I – shoot formation; II – budding; III – flowering; IV – fruiting.

The results of the dynamics of changes in the agglutinating activity of extracts of vegetative organs of St. John's wort of *the Taubertal variety* during ontogenesis, shown in Figure 7.4, indicate that in stem extracts the agglutinating activity was the lowest among all organs at all stages of development, except for fruiting. In the shoot formation phase, the activity was 3 points, decreased to 1.3 points during budding, and only at the fruiting stage did it increase to 10 points.

In leaf extracts, agglutinating activity was higher compared to stems. During shoot formation, this indicator reached 4.5 points, which indicates active synthesis of lectins in the vegetative mass. During budding, the activity decreased to 2.8 points, increasing again to 5.2 points in the flowering phase. During the fruiting period, the activity reached a maximum of 7.7 points.

Extracts of the generative organs of St. John's wort of the Taubertal variety were characterized by the highest agglutinating activity (Figure 7.5). In buds during their formation, this indicator was close to the maximum – 18.2 points. During flowering, the activity of lectins in inflorescences remained high – 19.2 points. During the fruiting period, the activity in fruits was 8 points, and in inflorescences – 15.2 points, which indicates a redistribution of lectins during seed ripening.

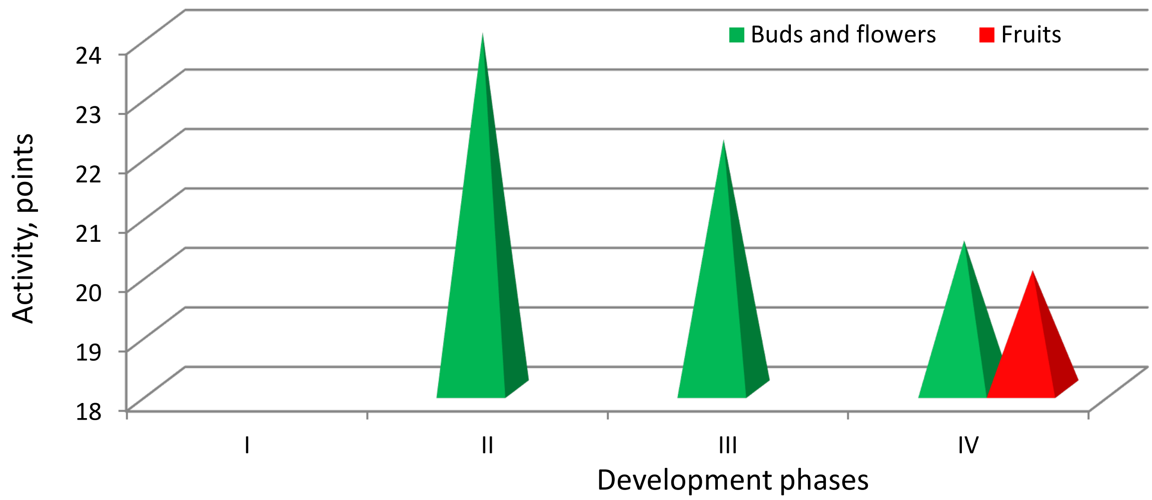

Fig. 7.3 - Dynamics of agglutinin activity in extracts of buds/flowers and fruits of St. John's wort of the Arcoiris variety in different phases of development (average over the years of research). *Development phases:* I – shoot formation; II – budding; III – flowering; IV – fruiting.

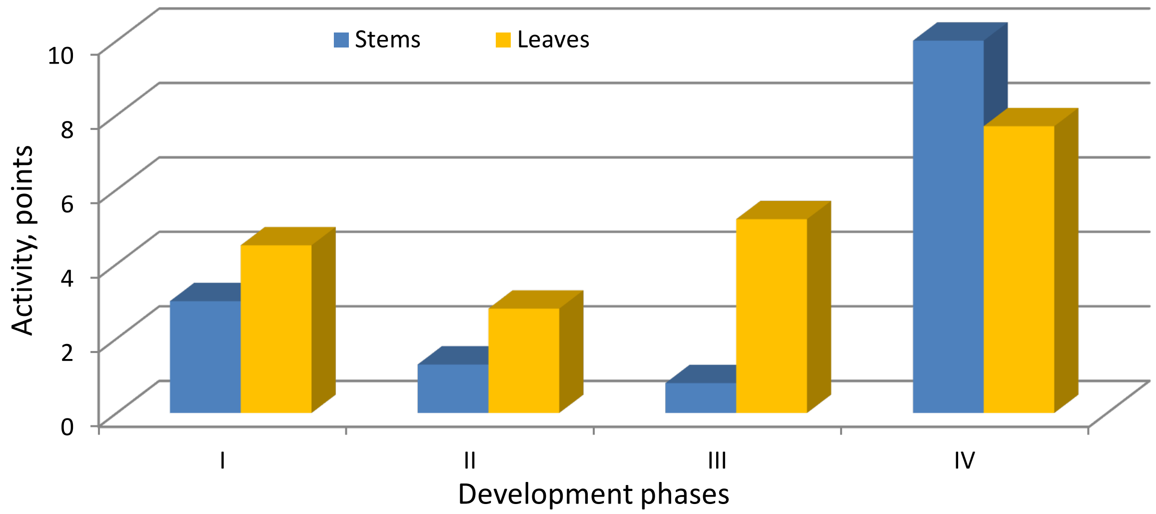

Fig. 7.4 - Dynamics of agglutinin activity in extracts of stems and leaves of St. John's wort of the Taubertal variety in different phases of development (average over the years of research). *Development phases:* I – shoot formation; II – budding; III – flowering; IV – fruiting.

In general, the highest lectin activity was observed in generative organs, indicating their key role in the formation of reproductive structures, while in stems and leaves, the activity was much lower, reflecting their auxiliary functions.

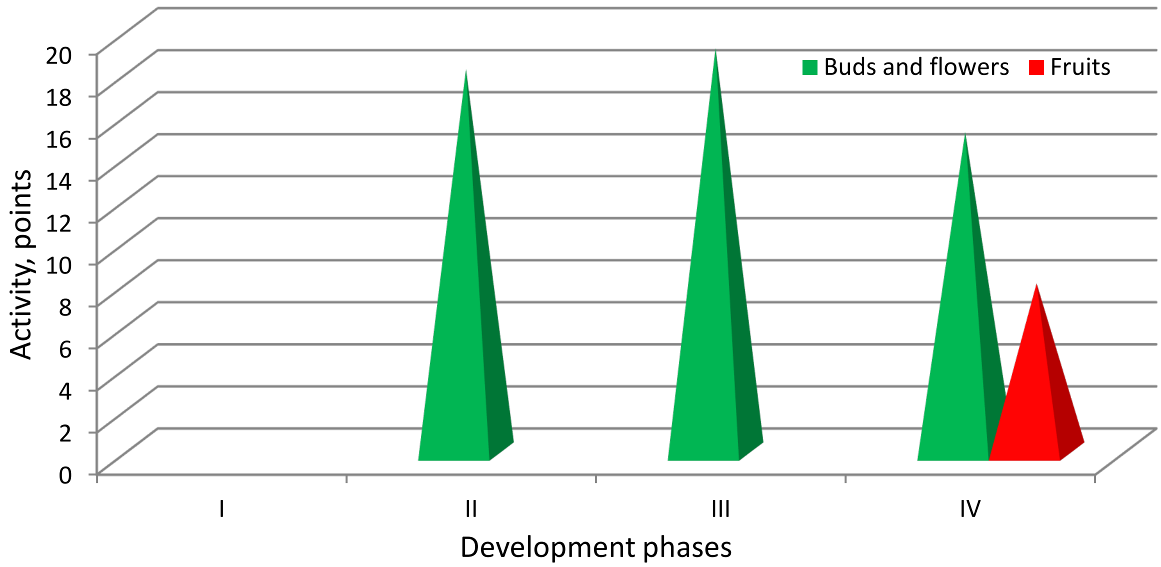

Fig. 7.5 - Dynamics of agglutinin activity in extracts of buds/flowers and fruits of St. John's wort of the Taubertal variety in different phases of development (average over the years of research). *Development phases:* I – shoot formation; II – budding; III – flowering; IV – fruiting.

Figure 7.6 shows the change in lectin activity in the leaves of St. John's wort of the Topas variety. During the period of shoot formation, the agglutinating activity of leaf extracts was on average 19.7 points. During budding, it decreased to 11.8 points, and subsequently the indicators increased again to 18.0–19.3 points. In our opinion, this indicates that during shoot formation, lectins are actively synthesized in the leaves, and during budding, they are transported to the generative parts of the plant. Later (during flowering and fruiting), their number increases and remains relatively stable until the end of the growing season.

The agglutinating activity of stem extracts at the beginning of the growing season was minimal (5.5–6.5 points), but increased with plant development and reached its maximum at the end of the growing season (14.8–16.3 points).

As indicated above, lectins accumulate in the generative organs with the greatest activity, primarily in the forming buds, and amounted to 23.3-24 points (Figure 7.7). During flowering it decreased (21.8 points), and during fruit formation – to 19.7 points.

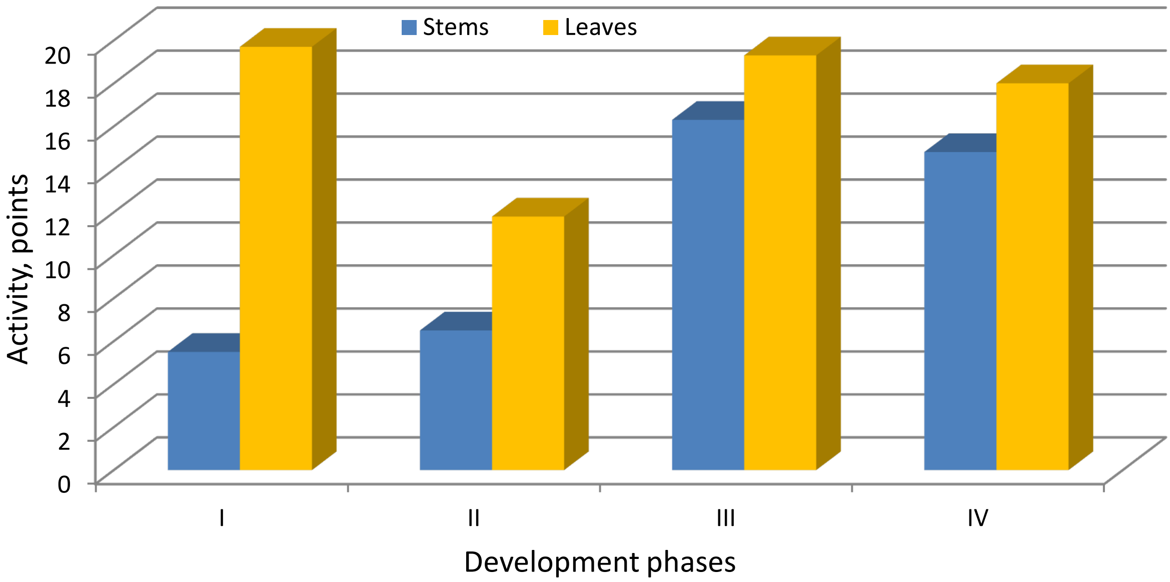

Fig. 7.6 - Dynamics of agglutinin activity in extracts of stems and leaves of St. John's wort of the Topas variety in different phases of development (average over the years of research). *Development phases:* I – shoot formation; II – budding; III – flowering; IV – fruiting.

It is worth noting that the agglutinating activity of fruit extracts was at a high level and amounted to 12.8 points.

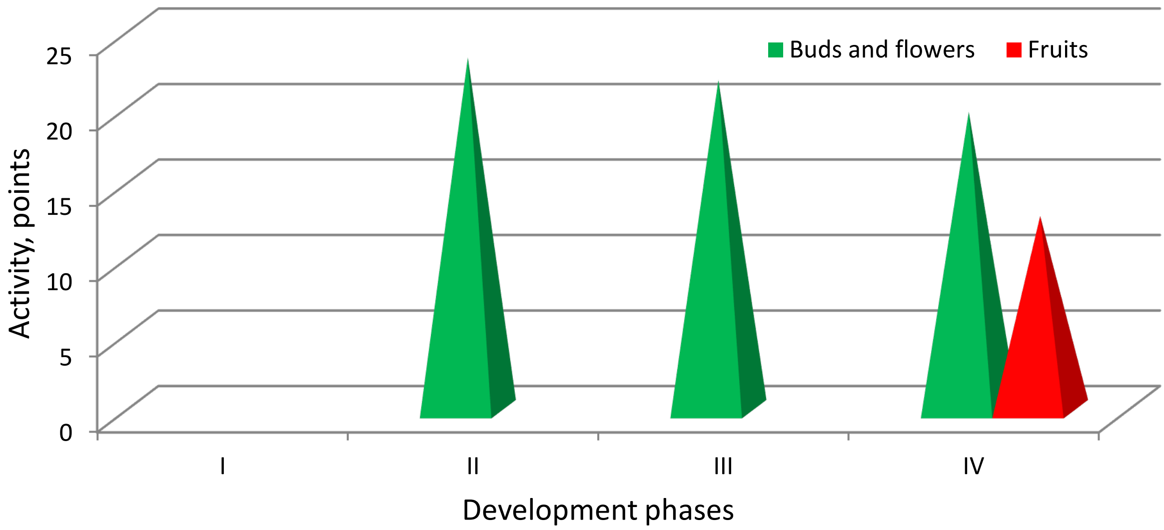

Fig. 7.7 - Dynamics of agglutinin activity in extracts of buds/flowers and fruits of St. John's wort of the Topas variety in different phases of development (average over the years of research). *Development phases:* I – shoot formation; II – budding; III – flowering; IV – fruiting.

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Based on the data obtained, it can be assumed that the main site of synthesis, and then localization, of lectins in St. John's wort should be considered the leaves. As the shoot forms and grows, phytolectins can be transported to the stems and buds. It is possible that a significant role is played by the polysaccharides of St. John's wort, which contribute to both the effective transport of proteins and their accumulation in various parts and organs.

During the flowering period, the agglutinating activity of lectins in the varieties of St. John's wort (*Hypericum perforatum L.*) – Arcoiris, Taubertal and Topas – showed significant differences between plant organs (Figure 7.8). In leaves, the Arcoiris variety had the highest level of activity, which was 20.7 points, while the Taubertal variety was characterized by the lowest indicator of 5.2 points, and in the Topas variety this indicator reached 18.0 points. In stems, the activity of lectins also varied: the Topas variety had the highest value – 14.8 points, in Arcoiris the activity reached 12.8 points, and in Taubertal it remained the lowest – 8.7 points. Generative organs, in particular inflorescences, showed the highest concentration of lectins among all organs. The maximum values were observed in the Arcoiris variety – 22.2 points, in Topas – 21.8 points, and in Taubertal – 19.2 points. In general, the Arcoiris variety was distinguished by the highest agglutinating activity of lectins in most organs during flowering, which may indicate its better ability to synthesize and accumulate these proteins.

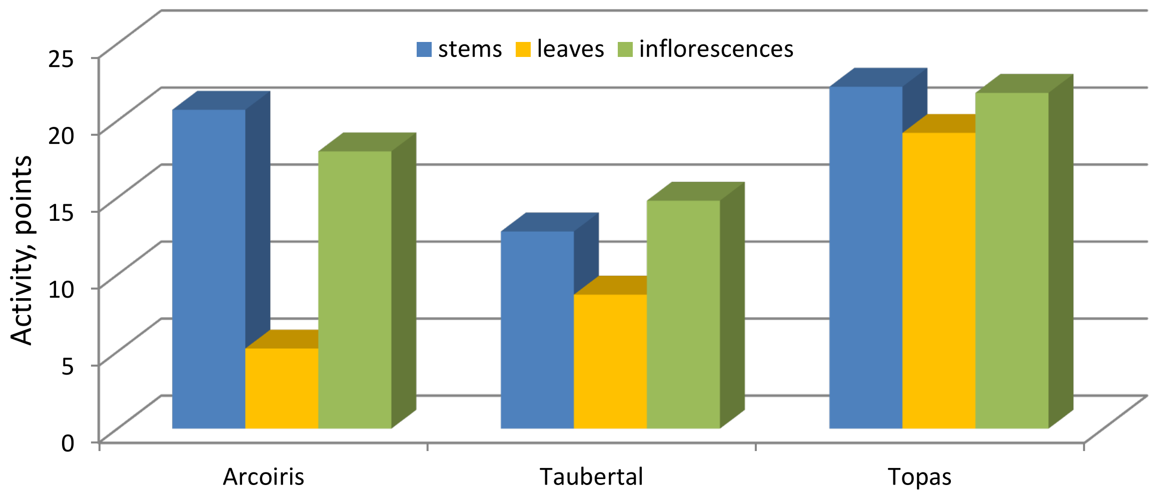

Fig. 7.8 - Agglutination activity of extracts of St. John's wort varieties in the flowering phase (average over the years of research)

The Taubertal variety showed significantly lower values, especially in leaves and stems, while Topas occupied an intermediate position in terms of agglutinating activity. The results indicate a possible relationship between the genetic characteristics of the varieties and the ability to adapt to environmental conditions, forming different amounts of lectins during the reproductive period.

Short conclusions:

1. The highest agglutinating activity of lectins was observed in generative organs (buds, inflorescences, fruits) for all studied varieties (Arcoiris, Taubertal, Topas). During the period of bud formation, the activity reached maximum values (up to 24 points), which emphasizes their key role in reproductive processes. The activity of lectins gradually decreased during flowering and fruiting, but remained at a high level.

2. Leaves are the main site of lectin synthesis in the early phases of vegetation. The maximum activity in the shoot formation phase for the Topas variety was 19.7 points. The decrease in activity during budding, and then its repeated increase in the flowering and fruiting phases indicates the transport of lectins from the leaves to the generative organs.

3. Stems were characterized by the lowest agglutinating activity among all organs, which gradually increased during the growing season. This confirms the hypothesis of the transport role of lectins, which is due to their ability to interact with polysaccharides, which contribute to the movement and accumulation of proteins in different parts of the plant.

4. The results of the studies showed that different varieties (Arcoiris, Taubertal, Topas) demonstrate similar patterns in the dynamics of lectin accumulation, but the values of agglutinating activity vary somewhat. This may be due to the genetic characteristics of the varieties.

CONCLUSIONS

1. Analysis of literary sources shows that St. John's wort (*Hypericum perforatum* L.) is a promising medicinal crop for cultivation in Ukraine due to its high ecological plasticity and significant value of secondary metabolites. The plant adapts well to moderate climate, demonstrating high frost resistance (up to -15°C), which gives opportunity to cultivate it in different natural and climatic zones, in particular in the Forest-Steppe and the Carpathians. Its resistance to arid conditions and the ability to grow on infertile soils are also noted, which expands the prospects for establishing plantations.
2. A study of the effect of seed treatment with growth stimulants on the germination dynamics of St. John's wort seeds showed that treatment with the preparations Vimpel-K and Orakul seeds, both separately and in combination, promotes their more active germination. The highest efficiency was demonstrated by the combined use of these preparations. The most intensive germination occurred on the 5th and 9th days of the experiment, after which its rate gradually decreased.
3. The preparations Vimpel-K and Orakul seeds had a positive effect on the growth and development of plants, however, after seed treatment, Orakul demonstrated a more pronounced effectiveness. Vimpel-K contributed to an increase in stem height by 2.8–14.2%, the number of leaves by 3.5–27.2%, the leaf area by 1.34–4.05 mm², the mass of the above-ground part by 7.1–21.6%, and the mass of the root system by 2.8–61.8%, especially affecting the number of leaves (up to 27.2%) and the development of the root system (up to 61.8%). Orakul seeds showed higher efficiency, increasing stem height by 5.3–69%, leaf area by 2.52–8.48 mm², number of leaves by 8.0–40.0%, aboveground mass by 15.1–69.0%, and root mass by 9.2–68.9%. Its most pronounced effect was on leaf area (up to 8.48 mm²) and aboveground biomass (up to 69.0%), indicating its high ability to stimulate photosynthetic activity of plants.
4. The study of the influence of sowing dates showed that early sowing provided better seedling formation, which was manifested in an increase in all morphological indicators. In particular, the stem height increased by 8.78 mm in the Topas variety

and by 14.53 mm in the Arcoiris variety, which confirms the advantage of early sowing dates. On the other hand, late sowing dates caused a decrease in stem height (by 1.58 mm in the Arcoiris variety), as well as a decrease in other parameters, such as leaf area and root system mass, which is probably associated with a shorter growing season.

5. Research on the productivity of different varieties of St. John's wort (*Hypericum perforatum* L.) in ontogenesis showed that all three varieties demonstrated a gradual increase in stem height and number of internodes from the beginning of the growing season to its end, reaching maximum values in late June - mid-July. The height of the plants was 102.44 cm in the Arcoiris variety, 86.53 cm in Taubertal and 88.42 cm in Topas, and the number of internodes during this period reached 24.57, 20.97 and 21.93, respectively. Weight of stems and leaves grew until June, after what decreased because of formation of generative organs and partial death of leaves. The peak of leaf mass accumulation occurred in May–June, after which it decreased, reaching 4.51 g in Arcoiris, 3.10 g in Taubertal, and 2.88 g in Topas in July.
6. Studies have shown that the 45x40 cm plant spacing scheme contributes to increased overall productivity due to an increase in the number of shoots per seedling unit and higher above-ground mass yield per hectare. At the same time, the 70x25 cm scheme provides better individual shoot productivity, in particular a greater mass of fresh and dry above-ground part of one shoot.
7. Arcoiris variety showed the highest yield – 3.05 t/ha , which indicates its good adaptation to dense planting schemes. The Taubertal and Topas varieties showed consistently high results in both placement options, indicating their versatility in different growing conditions.
8. Studies of the biological activity of raw materials of St. John's wort (*Hypericum perforatum* L.) during ontogenesis demonstrated that the highest agglutinating activity of lectins was observed in generative organs (buds, inflorescences, fruits) for all studied varieties (Arcoiris, Taubertal, Topas). During the period of bud formation, the activity reached maximum values (up to 24 points), which emphasizes their important role during the formation of generative organs.

RECOMMENDATIONS FOR AGRICULTURAL PRACTICE

The use of the seedling method, which ensures the uniformity of planting material, reduces the vegetation period and promotes uniform growth and development of plants, is considered a promising method of growing St. John's wort. To obtain conditioned seedlings, we recommend optimizing the sowing date and using the Vimpel-K and Orakul seeds growth stimulants, which increase the sowing quality of seeds and plant development. To ensure maximum yield, it is recommended to use a 45x40 cm placement scheme, which provides a higher yield of aboveground mass due to a larger number of shoots. The 70x25 cm scheme can be used to improve the individual productivity of shoots and the quality of raw materials, for example, if raw materials with a higher content of biologically active substances are needed.

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SCIENTIFIC EDITION

MONOGRAPH

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