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DYNAMICS OF CHANGES IN MORPHOMETRIC INDICATORS AND GROWTH OF VEGETATIVE MASS OF *MALVA SYLVESTRIS* L. DEPENDING ON THE SOWING SCHEME

Actuality. *Forest mallow (Malva sylvestris L.) is a valuable medicinal and honey plant with high ecological plasticity, a wide distribution area in Ukraine, and a rich chemical composition. Thanks to this, the plant exhibits antioxidant, anti-inflammatory, hepatoprotective, and other biological activities. Unlike previous scientific studies, which mainly focused on the chemical composition and medicinal properties of the plant, our study was the first to cover the agrotechnical approach to optimizing the sowing scheme in order to increase the amount of plant raw materials.*

The aim of the study is *to determine the effect of sowing method on the growth of mallow vegetative mass for obtaining high-quality medicinal raw materials.*

Materials and methods. *The study was conducted in 2022–2024 at the Botanical Garden of V. G. Korolenko National Pedagogical University. Plants were sown without seedlings, using four variants: 45 × 20 cm, 45 × 30 cm, 60 × 20 cm, 60 × 30 cm. Morphometric indicators (height, number of leaves, plant weight) were recorded during the main phases of vegetative mass accumulation by plants. Field, laboratory, and statistical methods were used.*

Research results. *In Malva sylvestris L., a significant dependence of plant growth dynamics on the sowing pattern was found. The best results in terms of vegetative mass growth, height, and number of leaves were recorded with a 60 × 30 cm sowing pattern, which provided optimal conditions for lighting, aeration, and nutrition. High indicators were also observed in the 45 × 30 cm variant, confirming the effectiveness of medium sowing density. The lowest results were demonstrated by the 60 × 20 cm variant due to excessive plant density in the row. The 60 × 30 cm pattern was determined to be optimal for biomass harvesting in the flowering phase.*

Conclusions. *The results of the study confirm the significant role of the sowing pattern in the formation of morphometric indicators and provide practical recommendations for optimizing the agricultural technology of growing forest mallow for pharmaceutical needs. This opens up new prospects for increasing the efficiency of medicinal raw material production, which was previously limited mainly to natural harvesting.*

Key words: *forest mallow, Malva sylvestris L., phenological phases, morphometric indicators, sowing pattern.*

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ДИНАМІКА ЗМІН МОРФОМЕТРИЧНИХ ПОКАЗНИКІВ ТА НАРОСТАННЯ ВЕГЕТАТИВНОЇ МАСИ *MALVA SYLVESTRIS* L. ЗАЛЕЖНО ВІД СХЕМИ ПОСІВУ

Актуальність. *Калачики лісові (Malva sylvestris L.) є цінною лікарською та медоносною культурою з високою екологічною пластичністю, широким ареалом поширення в Україні та багатим хімічним складом. Завдяки цьому рослина проявляє* *антиоксидантну, протизапальну, гепатопротекторну й інші біологічні активності. На відміну від раніше проведених наукових досліджень, які здебільшого зосереджувалися на вивченні хімічного складу та лікувальних властивостей рослини, наше дослідження вперше охопило агротехнічний підхід до оптимізації схеми посіву з метою збільшення кількості фітосировини.*

Мета дослідження *– визначити вплив способу посіву на наростання вегетативної маси мальви для отримання високоякісної лікарської сировини.*

Матеріали та методи*. Дослідження проводили у 2022–2024 рр. на базі Ботанічного саду ПНПУ ім. В. Г. Короленка. Рослини висівали безрозсадним способом, використовуючи чотири варіанти: 45 × 20 см, 45 × 30 см, 60 × 20 см, 60 × 30 см. Облік морфометричних показників (висота, кількість листків, маса рослини) здійснювали в основні фази накопичення вегетативної маси рослинами. Застосовано польові, лабораторні та статистичні методи.*

Результати дослідження та їх обговорення. *У Malva sylvestris L. виявлено істотну залежність динаміки росту рослин від схеми посіву. Найкращі результати щодо приросту вегетативної маси, висоти та кількості листків зафіксовано за схемою посіву 60 × 30 см, яка забезпечувала оптимальні умови освітлення, аерації та живлення. Високі показники також спостерігались у варіанті 45 × 30 см, що підтверджує ефективність середньої густоти посіву. Найнижчі результати продемонстрував варіант 60 × 20 см через надмірну загущеність рослин у рядку. Оптимальною для заготівлі біомаси у фазі цвітіння визначено схему 60 × 30 см.*

Висновки. *Отримані результати досліджень підтверджують вагому роль схеми посіву у формуванні морфометричних показників і забезпечують практичні рекомендації щодо оптимізації агротехнології вирощування мальви лісової для фармацевтичних потреб. Це відкриває нові перспективи для підвищення ефективності виробництва лікарської сировини, що раніше було обмежене переважно природною заготівлею.*

Ключові слова: *мальва лісова, Malva sylvesris L., фенологічні фази, морфометричні показники, схема посіву.*

Relevance. Common mallow (Malva sylvestris L.) is a valuable medicinal and honey plant with a wide distribution range and high ecological plasticity (Kulakivska, Konechna, 2023). The wide distribution of mallow, particularly within Ukraine, indicates its high ecological plasticity and ability to adapt to different climatic conditions. The species grows on well-drained, light, and nutritious soils with a neutral reaction, mainly in sunny areas protected from the wind. Malva sylvestris achieves its best development on loose sandy-loamy soils**.**

Malva sylvestris is used in folk medicine (Abdel-Ghani et al., 2013; Paul et al., 2024; İlgün et al., 2024) in the form of infusions, teas, and syrups for the treatment of skin inflammation, bronchitis, and ulcers. Its biological activity is due to its phytochemical composition, which includes phenolic compounds, flavonoids, anthocyanins, and other secondary metabolites (Mravčáková et al., 2021; Villani et al., 2023; Kulakivska, Konechna, 2023; Paul et al., 2024; Boutennoun et al., 2024; Moualek et al., 2025; Altyar et al., 2025). These components determine the antioxidant, anti-inflammatory, antimicrobial, hepatoprotective, and other pharmacological properties of mallow plants (Sharifi-Rad et al., 2020; Batiha et al., 2023; Moualek et al., 2025). The use of the plant in phytotherapy is constantly expanding, particularly in dermatology (Akbarnejad, 2024), veterinary medicine (Doğan, 2023), and the pharmaceutical industry (Beley et al., 2024).

Due to the increased demand (Sharifi-Rad et al., 2020; Xu et al., 2022) for plant raw materials, the issue of optimizing the technology for growing this crop in the conditions of the modern farming system is quite relevant.

The sowing pattern significantly affects the intensity of vegetative mass growth and allows optimizing the production of high-quality medicinal raw materials, namely the quantity and quality of extractive substances in the raw materials (Joswig et al., 2021; Gavrilescu 2021; Kunakh et al., 2022; Beley et al., 2024; Rhimi et al., 2025).

Unlike previous scientific studies, which mainly focused on the chemical composition and medicinal properties of the plant, our study was the first to take an agronomic approach to optimizing the sowing pattern in order to increase the amount of plant material.

The aim of the study is to determine the effect of sowing method on the growth of mallow vegetative mass for obtaining high-quality medicinal raw materials.

Materials and methods. The research results were obtained at the Botanical Garden of V. G. Korolenko Poltava National Pedagogical University between 2022 and 2024. Malva sylvestris L. seeds were sown in the first ten days of April using a non-seedling method, followed by the formation of sowing density in accordance with the experimental design. Observations of vegetative mass growth were carried out from the first leaf phase to the flowering phase throughout the years of the experiment**.**

Materials and methods. Determination of morphometric indicators; laboratory methods – determination of plant vegetative mass; statistical methods – identification of correlations between morphometric indicators and sowing patterns. The results obtained for 2022–2024 were averaged for statistical processing and analysis of plant mass growth depending on the sowing pattern.

Experiment setup. Option 1: 45 × 20 cm; option 2: 45 × 30 cm; option 3: 60 × 20 cm; option 4: 60 × 30 cm.

Research results. Studies show that Malva sylvestris is characterized by high ecological plasticity, unpretentiousness, and productivity in the process of accumulating phytomaterial. Its high growth rate and ability to form significant green mass make it particularly cost-effective for use in the pharmaceutical and food industries. The most active growth of mallow vegetative mass occurs during its active growth period – from the beginning of spring regrowth to flowering. At this time, there is an intensive growth of leaves and stems and preparation for flowering.

The use of mallow for medicinal purposes is most effective during periods when its biologically active components, which have therapeutic and prophylactic properties, are activated. One such phase is the flowering phase – this period is the best for harvesting the plant, as it contains the maximum amount of biologically active substances, such as flavonoids, ascorbic acid, and other healing components. Harvesting during the flowering phase allows you to obtain the highest quality and most effective medicinal material.

The results of observations in the first true leaf phase (April 18–22) (Table 1) of Malva sylvestris L. indicate the effectiveness of option 4 – 60 × 30. Analysis of the data obtained indicates that the 60 × 30 sowing pattern has the most favorable effect on plant parameters compared to other patterns. The increased plant height of up to 31.05 cm contributes to better photosynthesis and greater accumulation of nutrients, while the number of leaves (7.0) is optimal for ensuring maximum photosynthetic surface area and green mass growth, contributing to more intensive formation and storage of biologically active substances. The leaf weight of 8.66 g indicates a high level of accumulation of nutrients and carbohydrates, which is important for the formation of high-quality phytomass. The stem weight of 2.33 g ensures a strong and stable plant, reducing the risk of lodging and damage during the growing season. Overall, the plant weight of 10.66 g indicates a high level of biomass, which is an important factor in yield. The results obtained indicate the optimal spatial arrangement of plants and optimal nutritional conditions, which contribute not only to high productivity but also to the stability and adaptability of the crop under production conditions.

Analysis of the results during the active stem growth and bud formation phase shows that the 60 × 20 sowing pattern resulted in the lowest plant development and productivity indicators compared to other options. The plant height was 79.33 cm, which is quite low, the number of leaves was 10.66, which is insufficient to ensure sufficient photosynthetic potential, and the leaf weight was only 0.91 g, indicating a decrease in the amount of nutrients and biochemical value. The stem weight was 11.66 g, which is also significantly below optimal values and negatively affects the stability and resistance of plants to mechanical damage and lodging. The total plant weight was only 16.01 g, which is a low biomass indicator that negatively affects crop yield and produc-

Table 1

Morphometric indicators of Malva sylvestris L. plants depending on the sowing pattern (phase of formation of the first true leaves)

Years	Plant height, cm.	Number of sheets, pcs.	Leaf mass, g	Stem mass, g	Weight of the plant, g
45 × 20					
2022	25.5	5	7	2	9
2023	25	6	5	2	7
2024	18	6	5	1	6
Average	22.83	5.66	**5.66**	**1.66**	**7.33**
45 × 30					
2022	22	5	4	1	5
2023	22	8	7	2	9
2024	34.6	8	8	3	11
Average	**26.2**	**7.0**	**6.33**	**2.0**	**8.33**
60 × 20					
2022	21	5	3	1	4
2023	16.5	4	2	1	3
2024	17	7	2	1	3
Average	**18.16**	**5.33**	**2.33**	**1.0**	**3.33**
60 × 30					
2022	24.7	6	9	2	11
2023	34.6	8	8	3	11
2024	27.5	7	9	2	10
Average	31.05	7.0	8.66	2.33	10.66

tivity. Thus, this sowing pattern yielded the worst results in all key parameters, which is associated with insufficient plant density, low biomass yield, and poor plant development in general, reducing the productivity and economic efficiency of cultivation.

The 60 × 30 sowing pattern contributed to optimal plant development and high productivity. The plant height under this pattern was 80.16 cm, which indicates active growth and an effective photosynthesis process sufficient for the formation of high biomass. The number of leaves was 13.66, and the leaf weight was 9.54 g, which increases the ability to accumulate valuable biochemical compounds. The stem weight was 27.59 g, which demonstrates a high level of vegetative mass formation, which is important for maintaining plant stability and further crop formation. The total plant weight of 53.11 g indicates a high level of biomass formation, which ensures maximum crop yield and productivity under these conditions. Thus, this sowing pattern is most favorable for achieving high agronomic and economic efficiency of cultivation (Table 2).

Analysis of the results obtained during the flowering phase shows that the 60 × 30 sowing pattern has the most favorable effect on plant development and productivity indicators compared to other patterns. In particular, the plant height is 106.0 cm, and the number of leaves is 15.66, which is a high indicator and contributes to an increase in the photosynthetic surface, which in turn has a positive effect on biomass formation. The leaf weight is the highest of all the study options – 2.53 g, which indicates a good ability to accumulate nutrients.

Analysis of the results shows that the 60 × 20 sowing pattern resulted in the lowest plant development and productivity indicators compared to other options. The plant height was 79.33 cm, which is quite low and indicates insufficient growth and photosynthesis intensity. The number of leaves (10.66) is insufficient to ensure optimal photosynthetic potential, and the leaf weight (only 0.91 g) reflects their low nutritional and biochemical value. The total weight of the plant is only 16.01 g, which is the lowest biomass indicator of all research options and negatively affects the yield and productivity of the crop (Table 3).

The morphometric indicators of Malva sylvestris L. plants in the flowering phase varied significantly depending on the sowing pattern. The lowest average plant weight gain was observed in the 60 × 20 cm pattern – only 16.01 g, which is taken as the baseline (0%). The highest plant mass (38.49 g on average) was observed with the 60 × 30 cm sowing pattern, which is 140.5% more than with the least productive pattern. This indicates that optimizing the feeding area significantly affects plant biomass during the flowering phase. The 45 × 20 and 45 × 30 cm schemes also showed a moderate increase in mass (+49.5% and +76.9%, respectively), but were inferior to the 60 × 30 scheme. Thus,

Table 2

Morphometric indicators of Malva sylvestris L. plants depending on the sowing pattern (phase of active stem growth and bud formation)

Years	Plant height, cm.	Number of sheets, pcs.	Leaf mass, g	Stem mass, g	Weight of the plant, g
45 × 20					
2022	88.6	8	7.32	21.69	33.01
2023	63.4	6	1.23	8.97	13.48
2024	84.8	9	3,42	21.34	33.46
Average	**78.93**	**7.66**	**3.99**	**17.33**	**26.65**
45 × 30					
2022	57	3	0.36	6.23	11.19
2023	72	8	6.86	10.15	21.57
2024	81	6	4.16	14.86	26.36
Average	**70**	**5.66**	**3.79**	**10.41**	**19.71**
60 × 20					
2022	69	3	0.87	12.27	22.4
2023	81.2	6	3.67	13.18	21.62
2024	47.8	6	2.42	4.86	10.2
Average	**66**	**5**	**2.32**	**10.1**	**18.07**
60 × 30					
2022	80.3	16	10.14	29.24	59.97
2023	81.6	10	8.16	24.86	46.36
2024	78.6	15	10.32	28.69	53.01
Average	80.16	13.66	9.54	27.59	53.11

the highest plant biomass in the vegetative mass harvesting phase is achieved when using the 60 × 30 cm sowing scheme, which indicates the positive effect of increasing the feeding area on the growth and development of Malva sylvestris L. for obtaining phytomaterial (Fig. 1).

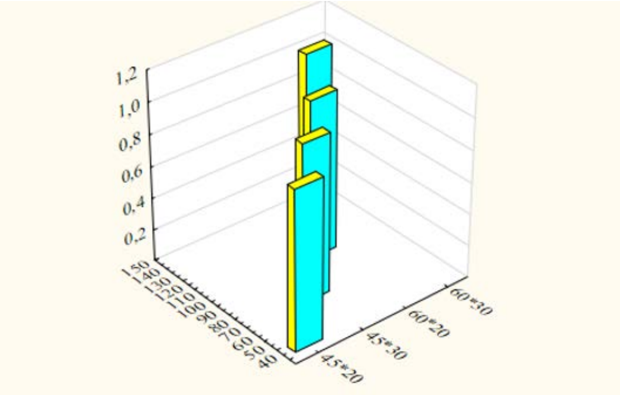

Fig. 1. Vegetative mass growth of Malva sylvestris L. depending on the sowing scheme

During the study (Fig. 2), a correlation analysis was performed between the main morphometric indicators of plants. Statistical calculations included mean values, standard deviations, and pairwise correlation coefficients between the following variables: plant height (cm), number of leaves (pcs.), leaf weight (g), stem weight (g), and total plant weight (g). Significant correlations ($p < 0.05$ highlighted) were found for the following biometric indicators: plant height has a strong positive correlation with stem weight (r = 0.8059); a strong positive correlation with total plant weight (r = 0.8256); a moderate correlation with number of leaves (r = 0.5706); a weak correlation with leaf weight (r = 0.2643). The number of leaves has weak correlations with all other variables, the highest being with plant mass (r = 0.2905), but it is not statistically significant. Leaf mass has a moderate positive correlation with stem mass (r = 0.4905); it has a moderate positive correlation with total plant mass (r = 0.5494). Stem mass has a very strong positive correlation with total plant mass (r = 0.9718) – the highest coefficient among all pairs of variables.

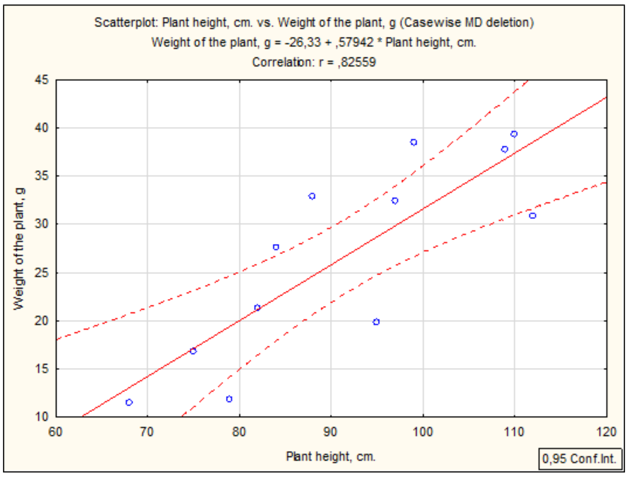

Fig. 2. Correlation dependence of the total mass of Malva sylvestris L.

Table 3

Morphometric indicators of Malva sylvestris L. plants depending on the sowing pattern (flowering phase)

Years	Plant height, cm.	Number of sheets, pcs.	Leaf mass, g	Stem mass, g	Weight of the plant, g
45 × 20					
2022	84	13	3.01	18	27.57
2023	79	12	06.4	4.12	11.81
2024	97	11	3.17	23	32.42
Average	**86.66**	**12.0**	**2.27**	**15.04**	**23.93**
45 × 30					
2022	82	12	2.56	10	21.26
2023	88	4	0.72	23	32.9
2024	112	22	0.87	20	30.78
Average	**94.0**	**12.66**	**1.38**	**17.66**	**28.31**
60 × 20					
2022	95	14	0.92	16	19.8
2023	68	7	0.95	8	11.46
2024	75	11	0.87	11	16.79
Average	**79.33**	**10.66**	**0.91**	**11.66**	**16.01**
60 × 30					
2022	110	27	2.03	28	39.28
2023	109	8	2.12	25	37.78
2024	99	12	3.45	27	38.42
Average	106.0	15.66	2.53	26.66	38.49

The total mass of the plant depends most on the mass of the stem (r = 0.9718) and the height of the plant (r = 0.8256), which indicates the dominant role of these morphometric indicators in the formation of biomass. The number of leaves has no significant effect on the overall morphometric characteristics of plants, as evidenced by low correlation values. Leaf mass shows moderate correlations with stem mass and total plant mass, but is less influential than stem height and mass. The strongest and statistically significant correlations are observed between: stem weight and total plant weight (r = 0.9718); plant height and total weight (r = 0.8256); plant height and stem weight (r = 0.8059). According to the results of the correlation analysis, a relationship was established between the following indicators: plant height, number of leaves, leaf and stem weight, which affect the total weight of the plant. A 60 × 30 cm sowing pattern promotes better growth and accumulation of vegetative mass.

Conclusion. During the phases of vegetative mass accumulation in Malva sylvestris L., a significant dependence of growth dynamics on the planting pattern was observed. The best results in terms of vegetative mass growth, height, and number of leaves were recorded with a 60 × 30 cm planting pattern, which provided optimal conditions for lighting, aeration, and nutrition. High indicators were also observed in the 45×30 cm variant, confirming the effectiveness of medium planting density. The lowest results were demonstrated by the 60 × 20 cm variant due to excessive plant density in the row. The 60 × 30 cm pattern was determined to be optimal for biomass harvesting in the flowering phase.

The results of the study confirm the significant role of the sowing pattern in the formation of morphometric indicators and provide practical recommendations for optimizing the agricultural technology of growing forest mallow for pharmaceutical needs. This opens up new prospects for increasing the efficiency of medicinal raw material production, which was previously limited mainly to natural harvesting.

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