PRACTICAL ANALYSES OF GENERATIVE AND VEGETATIVE PROPAGATION OF *ORIGANUM MAJORANA L.*

***N.K.Askarova**, PhD Student*
***E.T. Akhmedov**, PhD in Biology, Associate Professor*
Tashkent State Agrarian University, Tashkent, Uzbekistan
Authors' emails: asqarova633@gmail.com, egamyorahmedov@gmail.com
ORCID IDs: 0009-0003-3793-574X; 0009-0001-1917-0355

Abstract: This article presents a practical analysis of the methods of generative and vegetative propagation of Origanum majorana L. (sweet marjoram). The research was conducted at the educational and experimental field of Tashkent State Agrarian University. To determine the germination rate of seeds under laboratory conditions, 100 seeds were placed in Petri dishes in four replications. The experiments revealed that seed germination under laboratory conditions was relatively high, averaging between 80–85% across variants, with an overall average of 90%. Additionally, it was determined that when the temperature in laboratory conditions exceeded 23°C, the germination rate reached 90–95%.

In order to determine the germination rate of seeds under field conditions, seeds were sown during the first decade of May. On the experimental plots, seeds were planted in four replications at different depths (0 cm, 0.5 cm, 1 cm, and 1.5 cm). The field experiments demonstrated that the germination rate of spring-sown seeds was directly dependent on the depth of sowing.

Vegetative propagation methods were carried out using fogging devices and small greenhouses covered with polyethylene film, where cuttings were planted in two different substrates. The experiments on vegetative propagation indicated that Origanum majorana L. is highly suitable for vegetative reproduction. Root formation in cuttings depended on their type (lignified or non-lignified) and the concentration of biostimulants applied. In a 0.1 g/L solution of heteroauxin, the rooting rate of lignified cuttings was 40%, while non-lignified cuttings showed nearly 98–100%. Conversely, when treated with Silicium biostimulant at a concentration of 0.5 g/L, lignified cuttings demonstrated a rooting rate of 98–100%, whereas non-lignified cuttings showed approximately 40%.

Keywords: Origanum majorana L., propagation, seeds, germination, Petri dish, filter paper, replication, heteroauxin, silicium, substrate, cuttings, vegetative propagation, green cuttings, lignified cuttings, etc.1.

INTRODUCTION

Globally, including in Uzbekistan, the trend toward the naturalization of food and pharmaceutical products has become a major concern. The solution to this issue is directly related to the large-scale cultivation of agricultural plants—particularly food, medicinal, and other economically valuable crops—to meet the needs of the food, pharmaceutical, perfumery, paint, and other industries. One such medicinal plant is Origanum majorana L. (sweet marjoram), whose raw material is widely used in both folk and official medicine [2].

Sweet marjoram (Origanum majorana L.) is used as a spice in various foods, while its leaves, flowers, and oil have medicinal applications. The plant contains essential oils and many flavonoids such as terpineol, glycosides, linalool, sabinene, triterpenes, thujanol, and thymol [11][12].

According to the Resolution of the Cabinet of Ministers of the Republic of Uzbekistan dated January 20, 2015, No. 5, "On measures to further expand the cultivation, preparation, and processing of medicinal and edible plants for 2015–2017," paragraph 1.12 emphasizes the importance of developing this sector [1].

Currently, secondary metabolites of plants used as sources for the perfumery and chemical industries are gaining increasing attention in the context of aromatic and therapeutic programs. Among such plants is Origanum majorana L., a perennial herb or subshrub native to the Mediterranean flora. The raw material of this plant is widely used in the pharmaceutical and food industries. The main producing countries are Turkey, Chile, Peru, Mexico, Greece, Israel, Albania, Indonesia, and Egypt [13].

In Uzbekistan, Origanum majorana L. was first introduced to the F.N. Rusanov Botanical Garden in 1979. Additionally, during research conducted by the staff of the Laboratory of Medical Botany of the Tashkent Botanical Garden, aimed at substituting imported spices, several essential oil and spice plants were identified as promising for Uzbekistan [9]. According to Silva and Goleniowski [14] and Bima [15], the in vitro propagtion method allows for the mass production of healthy plants; however, the authors emphasized that this method is both time-consuming and costly [16].

Khromova (1984) noted that indolebutyric acid (IBA) is an effective agent for the rooting of lignified stems. The author also mentioned that since IBA is imported, its application to plants is economically disadvantageous. Currently, biogenic regulators are widely used as stimulants that play an essential role in metabolism and accelerate the rooting process while promoting the active growth of the aerial parts of plants [17].

According to Galaktionov (1988), in addition to stimulating cell elongation, heteroauxin affects many other physiological processes by enhancing cell division. The author also stated that heteroauxin, at low concentrations, stimulates plant growth, while at high concentrations, it acts as an inhibitor [18].

Researchers have found that silicon deficiency is one of the limiting factors in the development of the plant root system. Studies have shown that supplying plants with silicon can increase the rooting process (secondary and tertiary roots) by 20–

100%. Moreover, optimizing plant nutrition with silicon enhances photosynthetic efficiency and root activity.

At present, meeting the demand of the pharmaceutical industry for medicinal plant raw materials remains one of the most urgent issues. This is particularly true for introduced species, as developing methods for their cultivation under controlled conditions holds great theoretical and practical significance. Based on the information mentioned above, in our research, we aimed to study the influence of various biostimulants on the vegetative propagation methods of Origanum majorana L.

2. Materials and Methods

The object of this scientific research was the plant Origanum majorana L., which belongs to the Lamiaceae family. The study was carried out at the educational and experimental field of Tashkent State Agrarian University (TSAU). Soil samples for agrochemical analysis were taken from the arable layer of the experimental plot (0–30 cm depth). The agrochemical composition of the soil was analyzed as follows:

Table 1

Classification of soil based on humus (organic matter) content, color, and level of fertility

№	Humus content (%)	Color	Level of fertility
1	0,00-0,45	Light yellow	Very low
2	0,46-0,90	Yellow	Low
3	0,91-1,35	Light green	Moderate
4	1,36-1,80	Brown	High
5	>1,80	Dark brown	Very high

According to the results of the agrochemical analysis, the humus content in the experimental field soil was 1.496%, which corresponds to the “high fertility” category based on the humus content scale (Table 1).

Table 2

Classification of soil based on the content of available phosphorus, color, and level of fertility

№	**Available phosphorus (mg/kg)**	Color	**Level of fertility**
1	0-15	Light green	Very low
2	16-30	Green	Low
3	31-45	Light blue	Moderate
4	46-60	Blue	High
5	More than 60	Purple	Very high

According to the agrochemical composition of the experimental field soil, the phosphorus content was 51.55 mg/kg, which corresponds to the “high fertility” category on the phosphorus content scale (Table 2).

Table 3

Classification of soil based on the content of exchangeable potassium, color, and level of fertility

№	Exchangeable potassium (mg/kg)	Color	Level of fertility
1	0-100	Light yellow	Very low
2	101-200	Yellow	Low
3	201-300	Golden	Moderate
4	301-400	Brown	High
5	More than 400	Dark brown	Very high

According to the agrochemical analysis, the potassium content of the soil was 130 mg/kg, which places it in the "low fertility" category on the exchangeable potassium scale (Table 3).

Table 4

Classification of soil by total nitrogen content (%) and color indicators

№	Total nitrogen (%)	Color	Degree of supply
1	0,0-0,4	Yellow	Very low
2	0,5-0,8	Light green	Low
3	0,9-0,12	Blue	Medium
4	0,13-0,16	Light purple	High
5	>0,16	purple	Very high

The nitrogen content in the soil of the experimental area was **0.081%**, which corresponds to the **low supply level** according to the total nitrogen scale (Table 4).

Table 5

Classification of soil by acidity and alkalinity (pH)

Group №	Acidity level	pH indicator
Color	**Classification**	**Indicator**
1	Very acidic	3,0-4,5
2	Acidic	4,6-5,5
3	Slightly acidic	5,6-6,5
4	Neutral	6,6-7,0
5	Slightly alkaline	7,1-7,5
6	Alkaline	7,6-8,5
6	Strongly alkaline	More than 8,5

According to the agrochemical laboratory analysis of the second soil sample taken from the experimental field of Tashkent State Agrarian University, the **pH value was 6.9**, indicating a **neutral soil reaction** (Table 5).

Table 6

Classification of soil by the amount of mobile microelements (mg/kg)

№	Content in soil	Boron (B)	Copper (Cu)	Manganese (Mn)	Molybdenum (Mo)	Zinc (Zn)	Cobalt (Co)
1	Very low	0,0-0,1	0,0-0,3	0,0-1,0	0,0-0,05	0,0-0,2	0,0-0,2
2	Low	0,1-0,2	0,3-1,5	1,0-10	0,05-0,15	0,2-1,0	0,2-1,0
3	Moderate	0,3-0,5	2,0-3,0	20-50	0,20-0,25	2,0-3,0	1,5-3,0
4	High	0,6-1,0	4,0-7,0	60-100	0,3-0,5	4,0-5,0	4,0-5,0
5	Very high	>1,1	>7,1	>101	>0,5	>5,1	>5,1

In addition, the soil contained microelements such as **Boron (B)**, **Copper (Cu)**, **Manganese (Mn)**, **Molybdenum (Mo)**, **Zinc (Zn)**, and **Cobalt (Co)** (Table 6).

To study the morphological characteristics of the plants, the monograph "Atlas of Descriptive Morphology of Higher Plants" by Z.T. Artyushenko [3] was used. Methods by I.N. Beydeman [4] and G.N. Zaitsev [21] were applied to examine the growth, development, and seasonal rhythm of Origanum majorana L. The biomorphological features of O. majorana were studied based on the works of I.G. Serebryakov [20]. From the moment the seedlings appeared, observations were made every 3–5 days until they were well established, and then every 7–10 days depending on the growth rate.

The morphobiological characteristics of the plants were studied in 10 plant clusters for each ontogenetic phase. During the vegetative period, the beginning of growth, active growth, formation of primary and secondary branches, their number and size were recorded. During the generative period, bud formation, flowering, flower opening and duration, as well as seed formation and maturation, were observed.

During the sowing process, the 2015 guidelines developed by the Institute of Botany of the Academy of Sciences of Uzbekistan and the State Joint Stock Company "Uzpharmsanoat" were used (3,5).

The experiments were carried out in 2022 at the Educational and Experimental Field of Tashkent State Agrarian University under mist-generating devices and small plastic greenhouses. For vegetative propagation of Origanum majorana L., cuttings were prepared mainly from two-year-old marjoram plants grown on plantations. Inside the mist-generating device, cuttings were prepared in two variants – from green (non-lignified) and woody (lignified) stems.

As growth biostimulants, “Heteroauxin” and “Sila Silicon”, as well as ordinary water solutions, were used. To determine the optimal concentration of biostimulants, Heteroauxin was used at 0.1, 0.2, and 0.3 g/L, and Sila Silicon at 0.5, 1.0, and 1.5 g/L concentrations.

Before planting, the cuttings were treated in the respective solutions for 8 hours. For planting, two types of substrates were used — peat-based and soil-based.

3. RESULTS AND DISCUSSION

In the initial stage of our scientific research, special attention was paid to the seed germination of the plant. This factor is considered one of the main determinants in the successful cultivation and large-scale propagation of crops.

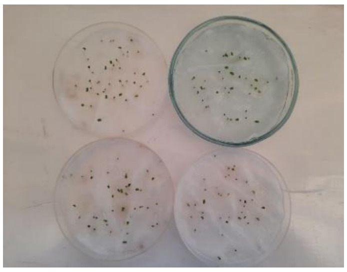
It should be noted that *Marjoram (Origanum majorana L.)* seeds possess a high germination capacity and, without any additional pre-treatment, are able to germinate completely within 2–3 weeks [7].

To determine the seed germination rate of the plant under laboratory conditions, 100 seeds were placed in Petri dishes in four replications and tested accordingly (Table 7).

Table 7

Seed germination of *O. majorana* under laboratory conditions (%)

№	Sown on May 2, 2022, with control days								Number of germinated seeds
	1	3	5	10	15	20	25	30	
1	-	12	16	40	68	72	80	80	80
2	-	12	20	40	40	60	80	80	92
3	-	8	16	64	60	84	92	96	88
4	-	12	16	48	52	76	84	88	96
Average germination									95%



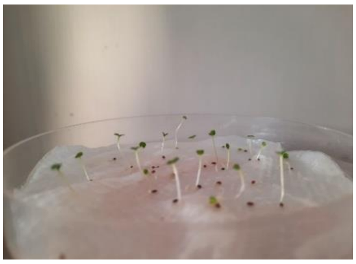


Fig. 1. Seed germination of *O. majorana* under laboratory conditions

According to the experimental data, the seed germination rate under laboratory conditions was observed to be relatively high — ranging from 80% to 85% across different variants, with an average rate of 90%. Furthermore, it was revealed that when the temperature exceeded 23°C, the germination rate of *Origanum majorana L.* seeds increased up to 90–95%, as demonstrated during the course of the research (Table 1, Figure 1).

It is well known that in the field of agriculture, the sowing periods of crop seeds have been extensively studied by numerous researchers. Based on scientific evidence, it has been established that under Uzbekistan's climatic conditions, there are two optimal sowing seasons — autumn and spring [7]. Although our preliminary experiments were conducted relatively late compared to these standard agricultural terms, the positive results obtained were considered significant enough to be analyzed further.

To determine the seed germination rate under field conditions, the experiment was carried out in the first decade of May. For this purpose, 100 seeds were sown per row, in four replications, at different depths — 0 cm, 0.5 cm, 1.0 cm, and 1.5 cm, respectively (Table 8).

Table 8

Field germination of seeds sown in spring (%)

№	Normal soil conditions							
	Sowing depth							
	0 cm		0.5 cm		1 cm		1.5 cm	
	Sown on May 2, 2022, with control days							
	Date of emergence	Date of completion	Date of emergenc	Date of completio	Date of emergenc	Date of completio	Date of emergenc	Date of completio
1	09.05	16.05	12.05	20.05	15.05	28.05	15.05	30.06
2	09.05	19.05	10.05	19.05	17.05	29.05	15.05	29.05

3	08.05	15.05	11.05	20.05	17.05	30.05	18.08	01.06
4	10.05	15.05	11.05	20.05	16.05	29.05	18.05	02.06
Medi.	77,2%		56,7%		37,2%		18,5%	

The sown seeds were watered once every 2–3 days until full germination and were recorded once every 5–10 days.

The initial field experiments conducted in spring (May) revealed that the seed germination rate of Origanum majorana L. was directly influenced by the depth of sowing. Specifically, in the first variant (seeds sown on the surface), the average germination rate reached 77.1%, while in the second variant, it decreased to 56.4%. In the third variant, it was 37%, and in the fourth variant, it dropped to approximately 18–20% (Table 2, Figure 2).

This tendency can be explained by the small seed size and the mechanical structure of the soil — the deeper the seeds were sown, the lower the germination rate observed.

When seeds were sown on May 2, the first seedlings appeared 5–6 days later (on May 8). During this period, the morning air temperature averaged +24°C with 40% relative humidity, while the daytime temperature reached +31°C with 30% humidity, and in the evening, +28°C with 31% humidity. The soil moisture was between 70–80%.

Mass germination occurred between May 11–12, when the average air temperature was around +25°C with a relative humidity of 37%, and the soil moisture remained at approximately 75%. The final germination occurred between May 15–19, when the air temperature ranged from +25°C to +29°C, the relative humidity averaged 26.3%, and the soil moisture was 75%.

During the early germination phase, the cotyledon leaves appeared pressed against the soil surface, were round in shape, slightly concave at the base, and measured 1.5–2 mm in size. At this stage, the hypocotyl length reached 6–7 mm, and the root length was about 4–5 mm. The underground part consisted mainly of the primary root, as lateral roots had not yet developed.

As the hypocotyl elongated, the cotyledon leaves began to separate from each other. This separation was a result of the growth of the main stem and leaf petioles. After full germination, the cotyledon leaves transitioned into a horizontal position within 2–3 days.

Further morphological changes included an increase in the size of cotyledon leaves. When the plants began forming their first true leaves—marking the transition into the juvenile phase—the seedlings reached an average height of 1.7–2.1 cm, with cotyledon leaf lengths of 3–4 mm, petiole lengths of 4–5 mm, and hypocotyl lengths of 1.3–1.6 cm. The seedling stage lasted between 17–23 days, depending on the individual plant (Figure 2).

Fig. 2. Field germination and seedling formation of *O. Majorana*

In the juvenile stage, the plant begins independent nutrition, and its main vegetative organs (leaves, stem, and root system) are formed. The juvenile stage is a morphological and physiological phase in which the plant has not yet acquired the ability to flower.

The first true leaves appeared 17–23 days after sowing. During the initial true leaf formation, the hypocotyl thickened, the primary root elongated, and lateral roots actively developed. Plant height increased mainly due to epicotyl growth. The second pair of true leaves appeared within 2–3 days.

During the juvenile phase, *Origanum majorana* plants exhibited intensive growth, forming up to four pairs of true leaves. Plant height varied between 11–14 cm. At this stage, leaf dimensions were as follows: total leaf length 9–12 mm, leaf blade length 6–8 mm, leaf blade width 4–5 mm, and petiole length 3–4 mm (Fig. 3).

Fig. 3. Appearance of *Origanum majorana L.* seedlings at the juvenile stage

The epicotyl length of *Origanum majorana L.* varied between 17–20 mm among different plant specimens. The growth of the marjoram stem followed an apical (terminal) growth pattern, with the internodes elongating successively. The root system also developed rapidly, forming both primary and secondary lateral roots. The main root length ranged from 2.4 to 4.2 cm, while the number of primary lateral roots varied between 11 and 17, with lengths of 4–7 mm. The secondary roots ranged from 3 to 7 in number, with lengths between 1.5–4 mm.

The juvenile phase of the plant lasted 12–17 days, depending on individual specimens. During this stage, the cotyledon leaves reached their maximum size, indicating the end of their active growth period. At the time when the first pair of true leaves began to develop, the cotyledon petioles elongated, positioning the leaves in a way that optimized light exposure for photosynthesis. During the formation of the second pair of true leaves, no significant morphological changes were observed in the cotyledon leaves, as the newly formed leaves did not obstruct sunlight from reaching the cotyledons.

The morphometric parameters of marjoram (*Origanum majorana L.*) at this growth stage are presented in Table 9.

Table 9

Morphometric parameters of *Origanum majorana L.* at the juvenile stage

№	Vegetative organ	Length (mm)	Width (mm)
1	Cotyledon leaf	1.5-2.0	1.4-1.9
2	Hypocot yl	1.5-1.6	1.3-1.4
3	Epicot yl	18-22	17-19
4	First pair of true leaves	1.8-2.2	1.7-2.1
5	Fourth pair of true leaves	2.1-2.2	2.0-2.1

The experiments indicated that *Origanum majorana L.* is well suited for vegetative propagation, and the rooting capacity of its vegetative organs depends on the type of cuttings (woody or non-woody) and the concentration of applied biostimulants (Fig. 4).

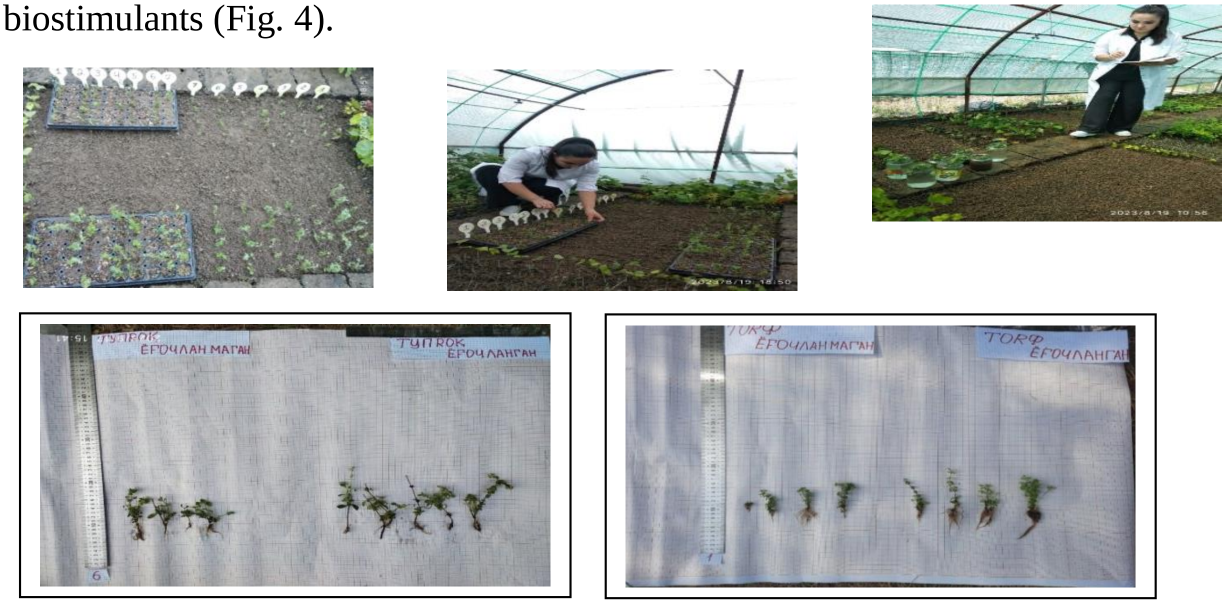
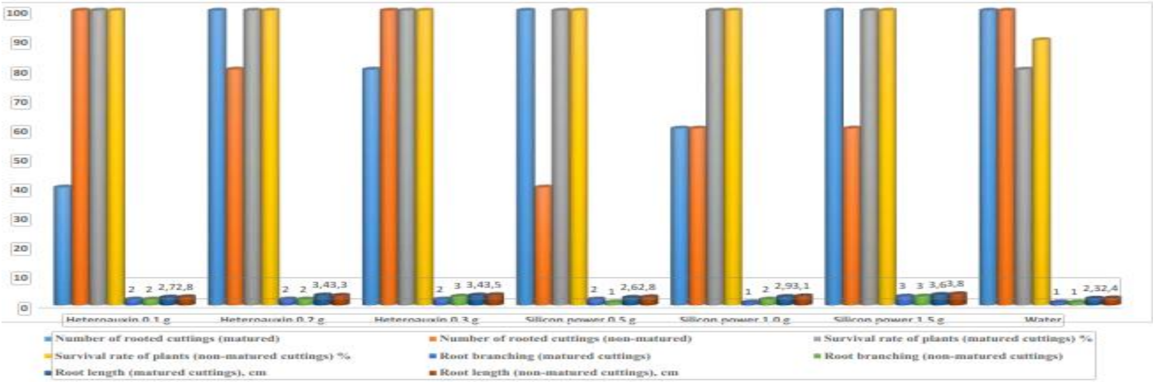


Fig. 4. Experimental setup in the ogging device and the obtained results

In particular, treatment with heteroauxin at a concentration of 0.1 g/L resulted in a rooting rate of 40% in woody cuttings, whereas non-woody cuttings demonstrated almost 100% rooting under the same conditions. In contrast, the use of the silica-based biostimulant produced the opposite effect. Specifically, treatment of woody cuttings with silica at 0.5 g/L showed a highly positive effect (nearly 100%), while in non-woody cuttings rooting did not exceed 40%.

Furthermore, the experiments revealed that increasing the concentration of bio stimulants (heteroauxin and silica) influenced rooting rates differently. For instance, woody cuttings treated with heteroauxin at concentrations of 0.2 g/L and 0.3 g/L exhibited nearly 100% rooting, while non-woody cuttings rooted at about 80%. Conversely, when treated with silica at 1.0 g/L, woody cuttings showed a 60% rooting rate, and with 1.5 g/L silica treatment, woody cuttings achieved 100% rooting, whereas non-woody cutti

Table 10



It is noteworthy that even in the control group, where cuttings were treated only with water, rooting rates remained relatively high, ranging between 96–98%. However, the survival of rooted plants under these conditions did not exceed 80–90%. At the same time, it should be emphasized that at later developmental stages—such as root branching and elongation, as well as overall plant vitality—the application of bio stimulants demonstrated a distinctly positive effect.

4. CONCLUSION

Thus, the soil of the Tashkent State Agrarian University (TSAU) educational and experimental field contains 1.49% humus, indicating a sufficient amount of organic matter. The phosphorus content is 51.55 mg/kg, corresponding to a high level of supply. The potassium content is 130 mg/kg—classified as low, and the nitrogen content is 0.081%, also low. The soil pH is 6.9, which indicates a neutral reaction.

Among the microelements, the content of boron is 1.0 mg/kg (high), copper – 1.0 mg/kg (low), manganese – 76 mg/kg (high), molybdenum – 0.15 mg/kg (low), zinc – 1.5 mg/kg (low), and cobalt – 0.2 mg/kg (very low).

The amount of microelements in the soil, whether deficient, optimal, or excessive, depends on several factors: parent rock composition, degree of soil cultivation, use of organic and mineral fertilizers, and rainfall, which influences the incorporation of microelements into the soil. A deficiency of microelements in the soil often causes various plant diseases. Therefore, the proper use of micronutrient fertilizers not only prevents such diseases but also contributes to obtaining a higher and better-quality yield.

According to the initial findings of our research, the seed germination rate of Origanum majorana L. under laboratory conditions was high, averaging 90–95%. In field experiments conducted in early May, seeds sown at a depth of 0–0.5 cm showed germination rates of 60–77%.

When studying the rooting of plant cuttings, it was observed that treatment with Heteroauxin solutions (0.2 g/L and 0.3 g/L) affected rooting differently depending on the cutting type. Conversely, treatment with Sila Silicon (1.0 g/L) produced less satisfactory results, as increasing the concentration of Sila Silicon negatively affected root formation.

In all cases, cuttings treated with plain water also demonstrated positive rooting results, with 96–98% rooting observed. Overall, all the tested biostimulators had beneficial effects on the vegetative propagation of Origanum majorana L., contributing significantly to subsequent plant development—particularly root branching, root length, and survival rate of the plants.

References

1. President of the Republic of Uzbekistan. (2017, February 7). *On the strategy for further development of the Republic of Uzbekistan* (Decree No. PF-4947). Collection of Legislation of the Republic of Uzbekistan, 6, Article 70.
2. Akopov, I. E. (1990). *Vazhneishie otechestvennye lekarstvennye rasteniya i ikh primenenie* [The most important domestic medicinal plants and their application]. Meditsina.
3. Artyushenko, Z. T., & Fedorov, A. A. (1986). *Atlas po opisatel'noi morfologii vysshikh rastenii: Plod* [Atlas of descriptive morphology of higher plants: Fruit]. Nauka.
4. Beydeman, I. N. (1974). *Metodika izucheniya fenologii rastenii i rastitel'nykh soobshchestv* [Methodology for studying the phenology of plants and plant communities]. Nauka.
5. Dospekhov, B. A. (1973). *Metodika polevogo opyta* [Methodology of field experiment]. Kolos.
6. Murdakhaev, Yu. M. (1993). *Uzbekistonda vatan topgan dorivor o'simliklar* [Medicinal plants naturalized in Uzbekistan]. Fan.
7. Nurmatov, N., et al. (2007). *Dala tajribalari uslubiyati* [Methods of field experiments]. Tashkent.
8. Tukhtaev, B. Yo., et al. (2015). *Dorivor va oziqabop o'simliklar plantatsiyalarini tashkil etish va xom ashyosini tayyorlash bo'yicha yo'riqnoma* [Guidelines for establishing plantations of medicinal and food plants]. Tashkent.

9. Turapov, Ch. M. (1996). Vliyanie glubiny zadelki semyan na biomorfologiyu maiorana sadovogo pervogo goda zhizni [Effect of sowing depth on biomorphology of marjoram in the first year]. In *Analiz i prognozirovanie rezultatov introduktsii dekorativnykh i lekarstvennykh rastenii mirovoy flory v botanicheskie sady* (pp. 114–115).
10. Bolotina, F. E., Gambaryan, Kh. P., & Denisova, G. A. (1963). *Pryano-aromaticheskie rasteniya* [Spice-aromatic plants]. Pishchepromizdat.
11. El-Ghorab, A. H., Mansour, A. F., & El-Massry, K. F. (2004). Effect of extraction methods on the chemical composition and antioxidant activity of Egyptian marjoram (*Majorana hortensis* Moench). *Flavour and Fragrance Journal, 19*(1), 54–61. https://doi.org/10.1002/ffj.1274
12. Edris, A. E., Ahmad, S., & Fadel, H. M. (2003). Effect of organic agriculture practices on the volatile aroma components of some essential oil plants growing in Egypt II: Sweet marjoram (*Origanum majorana* L.) essential oil. *Flavour and Fragrance Journal, 18*(4), 345–351. https://doi.org/10.1002/ffj.1225
13. Verlet, N. (1996). Situación y perspectivas del comercio de los productos aromáticos. *Boletín Plantas Aromáticas, 7.* SAGyP.
14. Ramazanova, N., & Turapov, Ch. (1999). Tsennaia dlia Uzbekistana priano-aromaticheskaia kultura – maioran sadovyi – *Majorana hortensis* Moench [A valuable spice-aromatic crop for Uzbekistan – garden marjoram]. In *Prjano-aromaticheskie i lekarstvennye rasteniya: Perspektivy introduktsii i ispol'zovaniya* (p. 142). Proceedings of the International Conference, Minsk, Belarus. Minsk: Central Botanical Garden, NAS Belarus.
15. Silva, G. L., & Goleniowski, M. E. (1993). *In vitro* culture of *Ambrosia tenuifolia* Spreng.: Psilostachyinolides production. In Y. P. S. Bajaj (Ed.), *Medicinal and aromatic plants III* (Vol. 24, pp. 41–53). Springer. https://doi.org/10.1007/978-3-662-06155-9_4
16. Bima, P. (1997). *Studio dei fattori che condizionano la micropropagazione in diverse cultivar di aglio (Allium sativum L.)* [Study of factors influencing micropropagation in different garlic cultivars] (Doctoral thesis). Università della Tuscia, Viterbo, Italy.
17. Khromova, T. V. (1984). O vliyanii regulyatorov rosta na ukorenyaemost cherenkov drevesnykh rastenii [On the influence of growth regulators on rooting of woody plant cuttings]. *Byulleten Glavnogo Botanicheskogo Sada AN SSSR, 130*, 59–63.
18. Galaktionov, S. G. (1988). *Biologicheski aktivnye veshchestva* [Biologically active substances]. Molodaya Gvardiya.
19. Samsonova, N. E. (2019). Silicon in plant and animal organisms. *Agrokhimiya, 1*, 86–96.
20. Serebryakov, I. G. (1952). *Morfologiya vegetativnykh organov vysshikh rastenii* [Morphology of vegetative organs of higher plants]. Sovetskaya Nauka.
21. Zaitsev, G. N. (1973). *Metodika biometricheskikh raschetov* [Methodology of biometric calculations]. Nauka.