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RESEARCH ARTICLE

# The effect of pre-sowing radiation treatment of seeds on the productivity of *Matricaria chamomilla* L. plants

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## Abstract

The study aimed to determine the effect of radiation exposure on the productivity of the above-ground mass of different cultivars of *Matricaria chamomilla* L. under the conditions of using fertilizing biological preparations. The cultivars *M. chamomilla* 'Perlyna Lisostepu' (Ukraine) and 'Goral' (Slovenia) were used in the study. Pre-sowing X-ray irradiation of seeds was carried out at doses of 5, 10, 15, and 20 Gy with a power of 1.42 cGy/s. In the variants with fertilizing, biological preparations of BTU Biotech Company (Ukraine) were used, which contain a complex of nitrogen-fixing, phosphorus-potassium mobilizing, and fungicidal bacteria: "Groundfix", "Gumifriend", "Helprost", "Organic-balance", and "Liposam". Pre-sowing irradiation of seeds in doses of 10 and 15 Gy stimulated an increase in inflorescence productivity. The collection of air-dry mass of inflorescences was the largest in the cultivar 'Goral' for irradiation in doses of 10 and 15 Gy and amounted to 153 and 152 g/m$^2$. Under the conditions of plant feeding with organo-mineral preparations, dry inflorescences of 175 and 170 g/m$^2$ were obtained in the variants of 10 and 15 Gy, respectively. Thus, after 10 Gy dose absorption, the yield of raw materials increased by 70 % compared to the reference sample. The introduction of a complex of biological preparations stimulated an increase in plant productivity: in the cultivar 'Perlyna Lisostepu', inflorescences of 82 g/m$^2$ were collected for feeding, which is 82 % more than in the reference sample (45 g/m$^2$); in the variety 'Goral' the yield of dry inflorescences increased by 8–20 %. In the budding phase, the largest above-ground mass was formed at doses of 10 Gy in the cultivars 'Perlyna Lisostepu' (26.22 g/plant) and 'Goral' (16.66 g/plant). Also, the largest underground mass and number of lateral shoots were formed under the influence of treatment at 10 Gy in the cultivars 'Perlyna Lisostepu' (1.82 g/plant and 6.4 pcs. respectively) and 'Goral' (1.04 g/plant and 4.0 pcs.). Irradiation of seeds and treatment with a complex of biological preparations stimulate a significant increase in the yield of chamomile inflorescences. The largest above-ground and underground mass, as well as lateral shoots of *M. chamomilla* cultivars 'Goral', 'Perlyna Lisostepu' were formed under irradiation at doses of 10 and 15 Gy in the budding phase. Pre-sowing X-ray irradiation of seeds is an effective method of increasing the productivity of *M. chamomilla* plants.

**Keywords:** *Matricaria chamomilla*, seeds pre-sowing irradiation, X-rays, inflorescence productivity, biologically active compounds

**Authors' contributions:** Olena Andrushchenko interpreted the results, statistical processing of the exsperimental data and wrote the manuscript. Jamal Rakhmetov developed the concept of research. Oleksandra Kravets writing methodological part of the research. Oksana Sokol collected experimental data. Nadiya Dzhurenko analyzed literary sources. Olena Palamarchuk analyzed

literary sources. Svitlana Pchelovska collected experimental data. Lyudmila Glushchenko developed a research organization scheme. Mykola Kuchuk served as editorial support in writing the article.

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## Introduction

The widespread use of plants in official medicine has led to an increase in the diversity of approaches to increasing the yield of medicinal substances from natural raw materials. Along with the search for new species that have medicinal properties and the breeding of more productive cultivars, the redirection of plant metabolism towards increasing the substances necessary for practice is used. While genetic and metabolic engineering focuses on the genetic transformation of organisms, reorientation of plant metabolism can be achieved by exposure to stress factors. One effective approach is using various radiation forms as abiotic stress (Alothman et al., 2009). Under their action, a shift in metabolic processes is observed towards forming secondary metabolic substances, which include most radioprotectors with antioxidant, anticarcinogenic, immunomodulatory, and anti-inflammatory effects, and are used in pharmacology. An example of intensive technology is using pre-sowing X-ray irradiation of medicinal plant seeds in stimulating doses to effectively increase the productivity and pharmaceutical value of medicinal raw materials. The level of irradiation in doses of 15–20 Gy is highly effective for certain plant species. For example, the content of stevioside, total phenolic compounds and flavonoids increased under the influence of γ-irradiation of callus cultures of *Stevia rebaudiana* Bertoni; the yield of camptothecin increased 20-fold upon irradiation of 20 Gy of callus cultures of *Nothapodytes foetida* (Wight) Sleumer; the content of shikonins increased four-fold in suspension cultures of *Lithospermum erythrorhizon* Siebold & Zucc. upon irradiation of 16 Gy (Vardhan & Shukla, 2017). It has also been shown that X-ray irradiation at doses of 5–20 Gy increases the chamazulene content in the essential oil of *Matricaria chamomilla* by two–four times, which is confirmed by a patent of Ukraine (U 129749) (Shilina et al., 2020).

Chamomile (*M. chamomilla*) is one of the most common medicinal plants in the world, belonging to the Asteraceae family, is an annual and grows naturally in Europe and Asia (Miraj & Alesaeidi, 2016). Chamomile cultivation began about 70 years ago, and it is now grown on a large scale using various, mainly tetraploid, breeding lines and registered cultivars of mostly European gene pool, which are characterized by high yields and content of essential oil and other valuable compounds (Albrecht & Otto, 2020; Dai et al., 2023). Chamomile is traditionally used in medicine (Srivastava et al., 2010; El Mihyaoui et al., 2022; Kaoudoune et al., 2022). It is one of the most common medicinal plants and a convenient, unpretentious experimental object.

Biological soil improvement, foliar fertilization, and the introduction of effective microorganisms may be used to improve the quantitative and qualitative indicators of raw materials in chamomile plants (Kwiatkowski, 2015).

The study aimed to determine the effect of radiation exposure on the productivity of above-ground biomass of *M. chamomilla* using different cultivars under the conditions of application of fertilizing biological products.

## Material and methods

The research plots were located on the territory of the M.M. Gryshko National Botanical Garden (Kyiv). The soils of the plot are dark gray, podzolized, and slightly washed out. Climatic conditions in the years of research (2023–2024) were characterized by a steady excess of the average monthly air temperature (Meteopost, 2010–2025). It was highest in July, August, and September and

**Table 1.** Average air temperature during the vegetation period of *Matricaria chamomilla* (Kyiv), °C.

| Month | | IV | V | VI | VII | VIII | IX |
|---|---|---|---|---|---|---|---|
| Average long-term rate | | 8.7 | 15.2 | 18.2 | 19.3 | 18.6 | 13.9 |
| 2023 | Average monthly | 9.6 | 16.2 | 19.6 | 21.5 | 23.8 | 18.8 |
| | max | 19.9 | 26.9 | 30.4 | 31.8 | 35.7 | 28.3 |
| | min | 1.2 | 5.3 | 8.4 | 13.6 | 13.8 | 9.6 |
| 2024 | Average monthly | 12.8 | 16.3 | 21.6 | 24.1 | 23.1 | 20.5 |
| | max | 25.9 | 27.3 | 31.3 | 35.9 | 35.1 | 32.5 |
| | min | 0.2 | 3.5 | 13.8 | 15.1 | 13.9 | 10.8 |

**Table 2.** Monthly precipitation during the vegetation period of *Matricaria chamomilla* (Kyiv), mm.

| Month | IV | V | VI | VII | VIII | IX |
|---|---|---|---|---|---|---|
| Average long-term rate | 49 | 53 | 73 | 88 | 69 | 47 |
| 2023 | 102.6 | 1.0 | 87.6 | 136.1 | 19.6 | 8.6 |
| 2024 | 79.0 | 15.3 | 136.5 | 51.9 | 24.7 | 56.9 |

deviated from the multi-year norm by 4.5–6.6 °C (Table 1).

Against the background of increased air temperature, uneven moisture supply was observed throughout the growing season. There were months with sharp deviations from the norm either toward excess or toward their deficit (Table 2). Thus, in April 2023 and June 2024, precipitation exceeded the monthly norm by twice, and in April 2023, it was almost absent. The moisture supply was characterized by unevenness and long periods of drought.

The experiments used seeds of *M. chamomilla* cultivars: ‘Perlyna Lisostepu’ (Ukraine) and ‘Goral’ (Slovenia) from the collection of the Research Station of Medicinal Plants of the Institute of Agroecology and Environmental Management of the NAAS of Ukraine. Seeds of the 2022–2023 harvest.

Pre-sowing irradiation of seeds was carried out on an X-ray machine RUM-17 in four doses – 5, 10, 15, and 20 Gy, with a dose rate – 1.42 cGy/s. Seeds (20–30 g of each option) were placed in polyethylene bags.

In the experiment with fertilization, a complex of organic preparations from BTU Biotech company (Ukraine) was used: pre-sowing application of the phosphorus-potassium mobilizer “Groundfix” to the soil at a dose of 5 l/ha, which increases the availability and mobility of macroelements in the soil; during sowing, soil treatment with a complex of preparations “Helprost” (2 l/ha), “Organic-balance” (0.5 l/ha) and “Liposam” (0.5 l/ha) (a complex of nitrogen-fixing, phosphorus-potassium mobilizing and fungicidal bacteria); root application three times during the growing season with an interval of two weeks – “Helprost” (1 l/ha), “Organic-balance” (0.5 l/ha), “Gumifrend” (0.3 l/ha) and “Liposam” (0.3 l/ha) to improve nutrition, stimulate development and resistance to fungal diseases. The area of each plot was 5 m$^2$. The placement of the variants was randomized in three replications.

Plant productivity indicators were determined in the budding phase (BBCH 50). Inflorescences were collected weekly during the entire flowering period (BBCH 60), and the accumulated air-dried raw material was weighed. The number of inflorescences was counted in the fruiting phase (BBCH 80) (Fig. 1).

Statistical analysis of the obtained data was carried out by the method of analysis of variance (ANOVA). The obtained data were expressed as mean ± standard deviation and


**Figure 1.** *Matricaria chamomilla* plants in different phases of development: **A** – budding (BBCH 50); **B** – flowering (BBCH 60); **C** – fruiting (BBCH 80).

were calculated using Microsoft Excel. The reliability of the results was assessed using the Student's t-test, the level of reliability ($p < 0.05$).

## Results and discussion

The possibility of increasing the productivity of *M. chamomilla* by pre-sowing acute irradiation of seeds was investigated. The height of the main shoot and the root length were measured, and the number of lateral shoots and the above-ground and underground mass of plants were counted. The experiment considered different irradiation doses, genotypic differences, and fertilization with biological products.

According to research results in Table 3, the 'Goral' samples had the highest mass of dry inflorescences. The mass of inflorescences of this cultivar was greater at 10 and 15 Gy, which was 161 and 160 % compared to the reference sample. Under fertilizing conditions with organo-mineral preparations, the largest number of dry inflorescences was obtained in the variants 10 and 15 Gy – 175 and 170 g/m$^2$, respectively. However, the greatest stimulation of inflorescence productivity was observed in the 'Perlyna Lisostepu' without using biological preparations – 193–196 % compared to the reference values for irradiation of 10 and 15 Gy. There is a big difference in the increase in the production of inflorescences of 'Perlyna Lisostepu' compared to 'Goral'. In the variant without biological product use, the productivity increased by irradiation to the level of the reference sample of a variant with biological product use – up to 82–88 g/m$^2$. Compared to the reference sample, there was a sharp increase of up to 196 % for plants without biological products application. However, such rapid growth was not observed in plants treated with biological products. In our opinion, this is due to the wider limits of modification variability of the productivity of 'Perlyna Lisostepu' inflorescences and greater trophic demandingness than the 'Goral'.

It should be noted that irradiation at the level of 20 Gy has a significantly smaller effect on increasing the yield of *M. chamomilla* inflorescences compared to lower irradiation doses. Plants that grew without the use of biological products formed less dry biomass. A particularly pronounced difference was found in reference samples of the cultivar 'Perlyna Lisostepu': without fertilizing – 45 g/m$^2$, fertilized with biological products

**Table 3.** Effect of irradiation of seeds of different varieties of *Matricaria chamomilla* and use of biological products on the collection of inflorescences of experimental plants (air-dry mass).

| Variant | 'Perlyna Lisostepu' | | | | 'Goral' | | | |
|---|---|---|---|---|---|---|---|---|
| | without biological products application | | with biological products application | | without biological products application | | with biological products application | |
| | g/m² | % compared to the reference sample | g/m² | % compared to the reference sample | g/m² | % compared to the reference sample | g/m² | % compared to the reference sample |
| Reference sample | 45 | 100 | 82 | 100 | 95 | 100 | 103 | 100 |
| 5 Gy | 82 | 182 | 102 | 124 | 127 | 134 | 138 | 134 |
| 10 Gy | 87 | 193 | 112 | 137 | 153 | 161 | 175 | 170 |
| 15 Gy | 88 | 196 | 107 | 131 | 152 | 160 | 170 | 165 |
| 20 Gy | 48 | 107 | 85 | 104 | 125 | 132 | 150 | 146 |

**Table 4.** Productive indicators of *Matricaria chamomilla* plants in the budding phase depending on the absorbed dose of seed irradiation (without biological products application).

| Cultivar | Variant | Ground weight of the plant, g | Underground mass of the plant, g | Height of the main shoot, cm | Root length, cm | Number of lateral shoots, pcs. |
|---|---|---|---|---|---|---|
| 'Perlyna Lisostepu' | Control | 7.56±1.24 | 0.66±0.10 | 28.4±2.0 | 8.8±0.7 | 0.4±0.3 |
| | 5 Gy | 10.84±2.26 | 0.78±0.26 | 35.0±2.7 | 9.0±0.8 | 2.8±0.9 |
| | 10 Gy | 26.22±6.72 | 1.82±0.36 | 30.8±2.7 | 7.8±0.7 | 6.4±1.4 |
| | 15 Gy | 8.08±1.16 | 0.60±0.12 | 32.4±2.8 | 11.0±2.0 | 0.8±0.4 |
| | 20 Gy | 7.16±1.78 | 0.56±0.24 | 31.0±1.9 | 9.8±1.0 | 1.6±0.6 |
| 'Goral' | Control | 7.38±2.56 | 0.64±0.22 | 31.2±1.2 | 9.6±1.7 | 1.4±0.7 |
| | 5 Gy | 11.68±1.92 | 0.88±0.10 | 34.0±1.3 | 10.6±1.0 | 1.0±0.4 |
| | 10 Gy | 16.66±2.28 | 1.04±0.10 | 32.4±1.4 | 7.4±0.6 | 4.0±0.6 |
| | 15 Gy | 15.46±3.28 | 0.98±0.22 | 34.0±1.2 | 9.4±0.7 | 3.0±0.4 |
| | 20 Gy | 5.20±0.97 | 0.36±0.07 | 27.4±1.9 | 9.6±1.1 | 0.6±0.5 |

– 82 g/m² (Table 3). In the cultivar 'Goral', fertilizing contributed to an increase in the collection of dry inflorescences by 8–25 g/m². Biometric surveys of the studied plants in the budding phase confirmed the positive effect of ionizing radiation. Thus, the highest fresh above-ground mass of one plant was produced at 10 Gy irradiation in 'Perlyna Lisostepu' (26.22 g) and 'Goral' (16.66 g) (Table 4).

Also, in the 10 Gy variant, the most extensive root system was formed, and the largest number of lateral shoots was formed (Table 4). The root length did not depend on the level of irradiation. Therefore, the largest above-ground and underground mass, as well as lateral shoots of all studied *M. chamomilla* samples were formed under irradiation conditions of 10 and 15 Gy.

By the example of *M. chamomilla* 'Goral', it was investigated how many inflorescences were formed on one plant during the growing season. The application of biological products did not always ensure an increase in inflorescences – in the irradiation options of 10 and 20 Gy, reference samples prevailed (Table 5). The number of inflorescences formed on one plant ranges from 106 to

**Table 5.** Number of inflorescences of *Matricaria chamomilla* 'Goral' at the end of the growing season depending on the dose of seed irradiation and nutrition, pcs./plant.

| Variant | without biological products application | with biological products application |
|---|---|---|
| Reference sample | 130 ± 15 | 149 ± 29 |
| 5 Gy | 106 ± 9 | 179 ± 88 |
| 10 Gy | 247 ± 91 | 203 ± 55 |
| 15 Gy | 253 ± 110 | 268 ± 130 |
| 20 Gy | 177 ± 55 | 158 ± 28 |

268 pcs. It was maximum under conditions of 15 Gy irradiation against the background of application of plant nutrition. In general, the highest stimulating effect was found at 10 and 15 Gy.

The intensification of the formation of generative organs and the increase in yield is one of the forms of the adaptive strategy of plants (Dmytriev et al., 2018). X-ray irradiation exposed with a dose of 10 Gy resulted in a significant increase in the total yield of inflorescences in four of the eight previously studied *M. chamomilla* genotypes collected during the season (Sokolova et al., 2021). Our research confirmed the same reaction of plants to pre-sowing irradiation at 10 Gy. In addition, it was found out what caused the increase in yield. There is an increase in branching and, therefore, in the number of inflorescences formed and the production of above-ground and underground plant mass.

## Conclusions

It was found that the largest amount of above-ground and underground mass, as well as lateral shoots of *Matricaria chamomilla* cultivars 'Goral' and 'Perlyna Lisostepu' in the budding phase was formed under irradiation conditions of 10 and 15 Gy.

Irradiation and treatment with a complex of biological preparations stimulated the productivity of chamomile (*M. chamomilla*) inflorescences. The highest yield of raw materials was obtained in the variants of experiments with the cultivar 'Goral', fertilized with a complex of organomineral preparations in combination with irradiation at 10 and 15 Gy doses.

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## Вплив передпосівної радіаційної обробки насіння на продуктивність рослин *Matricaria chamomilla* L.

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Метою дослідження було встановити вплив радіаційного опромінення на продуктивність надземної маси *Matricaria chamomilla* L. на прикладі різних сортів за умов використання підживлюючих біопрепаратів. У дослідженні використано сорти *M. chamomilla* ‘Перлина Лісостепу’ (Україна) і ‘Горал’ (Словенія). Проведено передпосівне рентгенівське опромінення насіння при дозах 5, 10, 15 та 20 Гр з потужністю – 1.42 сГр/с. У варіантах з підживленням використано біопрепарати BTU Biotech Company (Україна), які містять комплекс азотфіксуючих, фосфор-калій мобілізуючих і фунгіцидних бактерій: “Граундфікс”, “Гуміфренд”, “Хелпрост”, “Органік-баланс” та “Ліпосам”. Передпосівне опромінення насіння в дозах 10 і 15 Гр стимулювало збільшення продуктивності суцвіть. Збір повітряно-сухої маси суцвіть був найбільшим у сорту ‘Горал’ за опромінення в дозах 10 і 15 Гр і становив 153 і 152 г/м$^2$. За умов підживлення рослин органо-мінеральними препаратами одержали сухих суцвіть 175 і 170 г/м$^2$ у варіантах 10 і 15 Гр відповідно. Таким чином, опромінення потужністю 10 Гр дозволило збільшити вихід сировини на 70 % від референтного значення. Внесення комплексу біопрепаратів стимулювало збільшення продуктивності рослин: у сорту ‘Перлина Лісостепу’ за підживлення зібрано суцвіть 82 г/м$^2$, що на 82 % більше, ніж у референтного зразка (45 г/м$^2$); у сорту ‘Горал’ вихід сухих суцвіть збільшувався на 8–20 %. У фазу бутонізації найбільше надземної маси формувалося за дози 10 Гр у сортів ‘Перлина Лісостепу’ (26.22 г/рослину) і ‘Горал’ (16.66 г/рослину). Також найбільша підземна маса і кількість бічних пагонів утворювалися за впливу обробки у 10 Гр у сортів ‘Перлина Лісостепу’ (1.82 г/рослину і 6.4 шт., відповідно) та ‘Горал’ (1.04 г/рослину і 4.0 шт.). Опромінення насіння та обробка комплексом біопрепаратів стимулюють суттєве підвищення урожайності суцвіть ромашки лікарської. Найбільше надземної та підземної маси, а також бічних пагонів

*M. chamomilla* сортів 'Горал', 'Перлина Лісостепу' формувалося за умов опромінення в дозах 10 і 15 Гр у фазу бутонізації. Передпосівне рентгенівське опромінення насіння є ефективним методом підвищення продуктивності рослин *M. chamomilla*.

**Ключові слова:** *Matricaria chamomilla*, передпосівне опромінення насіння, рентгенівське випромінювання, продуктивність суцвіть, біологічно активні сполуки