RESEARCH REPORT

Development and optimization of ecological technology for the production of flowerbed and balcony plants, early spring and autumn plants under covers in environmentally friendly substrates, produced on the basis of waste wood materials

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part A

experiments at the University of Agriculture in Krakow

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Materials and methods

The research was conducted in the first half of 2024 in the experimental greenhouses of the Faculty of Biotechnology and Horticulture of the Hugo Kołłątaj University of Agriculture in Krakow.

Plant material

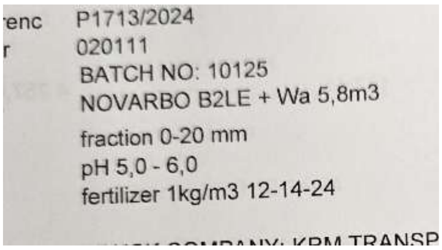
The test plants in the conducted studies were 3 species from the group of seasonal plants:
1. Marigold (*Tagetes erecta*) 'Antiqua Orange' F1
seedlings in a 480 tray, manufacturer Syngenta (Fig. 1 a), planted in the experiment in a P9 round pot, vol. 0.5 L.
2. Garden geranium (*Pelargonium hortorum*) 'Dolce Vita Gisela Dark Red'; seedling rooted in a 2 cm diameter paperpot, manufacturer Jenflor (Ethiopia FAF) in a 102 tray (Fig. 1b), licensed by Florensis, planted in a P13 pot (vol. 1.7 L).
3. Ivy-leafed geranium (*Pelargonium peltatum*) 'Decora Rood'; rooted seedling paperpot 1.5 cm, manufacturer Jenflor, tray 102 (Fig. 1c), planted in the experiment in pot P13 (volume 1.7 L).

a. b. c.

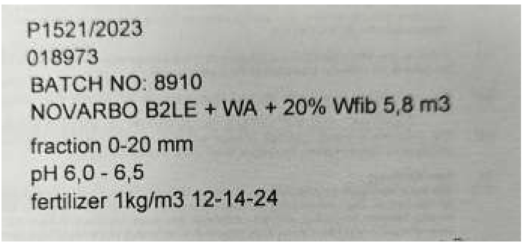
Ryc. 1. Plant material used in the experiment: a - seeding *Tagetes erecta*, b – rooted cutting *Pelargonium hortorum*, c – rooted cutting *Pelargonium peltatum*

Substrates

For the research conducted within the project, 4 ready-made substrates with limited peat content or without peat were used: Novarbo 20 (N), Klasmann 5 (K5), Agaris 2 (A2), Agaris 4 (A4) and a standard substrate prepared on the basis of high peat from Novarbo, used for the production of the above species in Jenflor, which was the control substrate (K). The characteristics of the substrates are presented in Table 1 and Fig. 2a-c.



a.



b.

c.

Ryc. 2. Substrates used in the experiment:
a – Standard Novarbo,
b – Novarbo 20 ,
c – Substrate 5 TerrActiv

Tab. 1. Characteristics of organic substrates used in experiments conducted in greenhouses of WBiO UR in Krakow.

Substrate	Symbol	Producer/ country of origin	Description
Standard, Novarbo (K)	K	Novarbo/Finland	Novarbo Substrate B2L* PEAT 100%, peat fraction 0-20 mm, pH 5,0-6,0 fig.2a.
Novarbo 20	N	Novarbo/Finland	Novarbo B2LE + WA +20%Wfib 5,8 m2, peat 80% fraction 0-20 mmm, pH 6-6,5 fig.2b.
Klasmann 5	K5	Klasmann-Deilmann/ Irlandia, Litwa	Klasmann Substrat 5 (type 5L9 Klasmann-Deilmann) fig.2c.
Agaris mix 2	A2	Agaris Poland (daw. Hollas)/ Polska	Peat-free substrate based on wood industry waste, composition kept secret by the manufacturer, in the testing phase
Agaris mix 4	A4	Agaris Poland (daw. Hollas)/ Polska	Peat-free substrate based on wood industry waste, composition kept secret by the manufacturer, in the testing phase

*Substrate Novarbo B2L https://www.novarbo.fi/en/products/novarbo-substrate-b2l-lettuce-2.html

In the study, a mushroom stimulator was used as an additive to the substrates, i.e.
- **mushroom production waste** - dried (undersized fruiting bodies and stems mixed with the substrate left after mushroom cultivation: prepared by drying the batch in dryers at 65°C for 72 hours and then grinding in a mill (homogenizer); addition of 2.5% by volume of 25 cm3/1 l of substrate (PO),
- **dried edible mushrooms**, unsterilized, ready-made product from mushroom fruiting bodies, not requiring preparation (drying and grinding), addition of 2.5% by volume of 25 cm3/1 l of substrate (P)

The properties of the substrates and stimulators used are listed in the tables in the results chapter (Tables 2-5).

Tested combinations

The experiments were conducted from March 21 to May 30, 2024 in the experimental greenhouses of the Faculty of Biotechnology and Horticulture of the University of Agriculture in Krakow (al. 29 Listopada 54, Krakow).

The effect of peat-free and peat-reduced substrates, as well as the effect of these substrates enriched with a mushroom stimulator, on the growth and development of marigold, garden pelargonium and ivy pelargonium was assessed. Four different substrates were tested, which were also enriched with a mushroom biostimulator at a concentration of 2.5% by volume (in two options: P - mushroom stimulator - production waste, PO - mushroom stimulator, ground mushroom fruit bodies).

Three experiments were conducted, separately for each species. For marigold, 9 combinations (substrate × addition of PO biostimulant) were tested, and for geranium 13 combinations (substrate × addition of PO biostimulant or P biostimulant). In each combination, 4 replicates of 25 plants each were tested.

Combinations and symbols used:

1. Kontrola (podłoże standardowe Novarbo)	K
2. Novarbo 20%	N
3. Novarbo 20%+ biostymulator odpad	NPO
4. Novarbo 20%+ biostymulator owocniki	NP
5. Klassman 5	K5
6. Klassman 5 +biostimulator odpadowy	K5PO
7. Klassman 5 +biostimulator owocniki	K5P
8. Agaris 2	A2
9. Agaris 2 +biostimulator odpadowy	A2PO
10. Agaris 2 +biostimulator owocniki	A2P
11. Agaris 4	A4
12. Agaris 4 +biostimulator odpadowy	A4P0
13. Agaris 4 +biostimulator owocniki	A4P

Cultivation condidtions

Marigold seedlings were planted in P9 pots (round, 9 cm in diameter) on 21.03.2024, geranium seedlings were planted in P13 pots (round, 13 cm in diameter) on 22.03.2024.
The plants were grown in a greenhouse on growing tables at a day temperature of 18-20°C ±2°C and at night 16-18°C ±2°C. The plants were watered regularly every 2-3 days at the beginning of cultivation, then more often from 1 to 2 times a day towards the end of cultivation - depending on the plants' needs.
For top dressing, 0.1% solutions of multi-component fertilizers were used every 7 days. The first two weeks of cultivation: yellow Kristalon (13:40:13), the following weeks: a 1:1 mixture of yellow Kristalon (13:40:13): orange Kristalon (6:12:36) in the amount of approx. 50 ml - marigold and 100 ml - geraniums, solution per pot.
Foliar retardants were used during cultivation. The plants were first treated with them on 04/04/2024, then on 12/04/2024. For marigold, the following were used: Dazide Enhance 85 SG retardant (manufacturer: Fine Agrochemicals Limited), a growth regulator containing daminozide (a compound from the hydrazide group) - 850 g/kg (85%), the concentration of the preparation used during foliar spraying was 0.25%.
For geraniums, the Pirouette retardant (produced by Fine Agrochemicals Limited) was used, a growth regulator containing paclobutrazol (a compound from the triazole group - 4 g/l), the applied foliar concentration was 0.15%. Biological protection was also carried out using yellow sticky boards for prevention and monitoring: leaf miners, honeydews, aphids, whiteflies, thrips, fungi. A single spraying with Naturalis (control of thrips, aphids, spider mites 02.04.2024) and NeemAzal®-T/S (control of aphids 25.04.2024) was also used.
All plants in the tested combinations (grown on different substrates) were treated equally according to the scheme described above.

Observations and Analysis

Before starting the experiment, the following were performed:
- physicochemical analyses of organic substrates,
- chemical analyses of dried mushrooms.

After completing the experiment, the following were performed:
- physicochemical analyses of substrates;
- chemical analyses of plant material (above-ground part);
- biometric observations of plants (i.e. plant height, number of shoots, mass of above-ground part depending on the species tested);
- observations of flowering: appearance of first flowers, flowering dynamics;
- consumer assessment of decorativeness of the flowerbed pelargonium - the final product - according to the quality scale, performed by 15 independent consumers, who assessed on a scale of 1-3: flowering, plant habit, leaves;
- the content of photosynthetic pigments was determined;
- the SPAD leaf greenness index was determined;
- chlorophyll fluorescence was determined, determining the value of the Fv/Fm coefficient

Physicochemical analyses of organic substrates

Substrate samples were collected for analysis twice, i.e. before the experiment was established and after the end of plant cultivation, from each tested combination. The substrate from 5 cultivation containers was cleaned of plant roots and mixed to create one experimental replicate. The following physicochemical properties were determined in the substrate samples:
- bulk density using the Bagg-Olsen method (Sady et al. 1994);
- water capacity using the Bagg-Olsen method (Sady et al. 1994);
- organic matter content using the annealing method (Lityński 1976);
- pH (pH in H2O) and general salt concentration in the soil (EC – electrical conductivity);
- content of soluble forms of macroelements (P, K, Mg, Ca, S) and sodium (Na) using the universal method (Nowosielski 1988, Ostrowska et al. 1991);
- total content of microelements and selected trace elements (B, Cu, Fe, Mn, Zn and Ti).

To determine the bulk density of organic substrates, the material was soaked and drained in conditions of free dripping of excess water, i.e. with full capillary capacity. The optimum volume of the substrate used was not less than 200 cm3. In the applied Bagg-Olsen method (Sady et al. 1994), the substrate was placed in cylinders and pressed with pistons, which exerted pressure on the substrate mass equal to 10 g cm-2. After the free water had drained from the cylinders with the substrate placed on the filter tank, the bulk density was determined. The water capacity of the substrates was also determined using this method.

The organic substance was oxidized by roasting the substrates to a constant mass. The percentage content of organic substance was calculated from the difference in the sample mass before and after roasting (Lityński 1976). The analysis was carried out in porcelain crucibles half filled with crushed (ground after drying in a mill) substrate. After 12 hours of drying at 105oC to remove hygroscopic water, the samples were calcined at 600oC in a muffle furnace (approx. 12 hours). Soil pH was measured in a water suspension with a soil to water ratio of 1:2. The total salt concentration Salinity (EC) was determined by conductometry. The content of assimilable macronutrients (N, P, K, Mg, Ca and S) was determined after their extraction in 0.03 mol dm-3 CH3COOH using the universal method, and microelements and trace elements after mineralization in concentrated HNO3 in a microwave oven (Ostrowska 1991). Mineral components in the dissolved substrate samples were determined using the ICP OS method (Teledyne Liman Labs).

Chemical analyses of fungal stimulants and plant material

Chemical analyses of mushroom stimulantsMushroom waste with a dry matter content of about 20% was dried at 75oC and ground (PO). The mineral composition of the air-dried material was determined using the same methods as for the plant material. Dry, purchased edible mushrooms with a dry matter content of about 93% were mineralized using the same procedure as the mushroom waste. The results of the determinations were converted to absolutely dry matter and given in % DM for N, P, K, Mg, Ca and S and in mg/kg-1 DM for Na, B, Cu, Mn, Mo, Zn and Ti.
Samples of the plant material (whole plants without flowers, after the end of cultivation in the greenhouse) were taken after the end of the greenhouse experiments. The plants were dried at 70oC

and ground. Protein nitrogen was determined in the crushed plant material using the Kjeldahl method (Ostrowska et al. 1991) and the total content of macro-, microelements and selected trace elements was determined after microwave mineralization of the sample in concentrated HNO_3. Metal elements were determined using the ICP-OES method on a Teledyne Leeman Labs apparatus.

Leaf Greenness Index Measurement SPAD

Leaf greenness index (SPAD) readings were taken from the mid-leaf area in the second week of the 7th experimental period. Measurements were taken in the greenhouse between 9:00 a.m. and 12:00 p.m. using a SPAD-502 plus instrument (Minolta, Osaka, Japan). The adaxial side of the leaf blade was always directed toward the measuring head, and the main leaf veins were avoided. In each combination, 400 leaves (4 per plant) were measured.

Chlorophyll fluorescence studies (photosynthetic apparatus efficiency)

Chlorophyll a fluorescence measurements were performed using a Handy Pea fluorimeter (Hansatech Instruments Ltd. UK). Before measurements, leaves (from the middle part of the plant, without damage) were darkened for 30 min. Measurements were performed at a saturation of radiation of 1500 $\mu mol \cdot m^{-2} \cdot s^{-1}$ for 1 s. The obtained measurements allowed to show the chlorophyll fluorescence parameter, i.e. the maximum quantum efficiency of photosystem II (Fv/Fm) (Strasser et al. 2004).

Chlorophyll content

Chlorophyll content was measured using a UV/VIS spectrophotometer (Helios Alpha, Unicam Ltd., Cambridge, Great Britain). Representative samples, obtained from several plants, taken after the end of the experiments, weighing 0.2 g were homogenized in a mortar with a small amount of quartz sand and 4 ml of 96% ethanol. Then the obtained mixture was centrifuged in a laboratory centrifuge Eppendorf Centrifuge 5415 R (Eppendorf Netheler Hinz GmbH, Hamburg, Germany) at 10,000 rpm for 15 min at 4°C. After centrifugation, 0.5 ml of extract was taken and mixed with 3.5 ml of ethanol. Photosynthetic absorption levels were determined at different wavelengths for chlorophyll a (λ=664 nm), chlorophyll b (λ=649 nm) and carotenoids (λ=470 nm) (Sumanta et al. 2014).

Statistical calculations

Samples of organic substrates and plant material were collected for tests determining chemical properties in triplicate. Biometric measurement data were also analyzed in triplicate, as were the results of SPAD, chlorophyll fluorescence and pigment content. Statistical calculations were performed using the ANOVA module of Statistica 13.1. In one-factor (substrates before cultivation) or two-factor analysis (experimental systems using different cultivation substrates with or without the addition of a mushroom stimulator), the verification of the significance of differences between means was performed using the Tukey test at $p=0.05$ (for substrates) or $p=0.01$ (for plant material).

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Research results: characteristics of mushroom substrates and stimulants

Physicochemical properties of growing media

The peat control substrate (Novarbo standard) used in the study had a bulk density of 0.153 g cm-3 and a water capacity of 53.7% wv (measured in relation to volume) and 352% ww (in relation to the mass of dry peat) (Table 2). The lowest bulk density was determined in the Novarbo 20 and Agaris 2 substrates, although they differed significantly in this feature only from the Klasmann 5 substrate, for which 0.192 g cm-3 was shown. Agaris 2 substrate had a significantly higher water capacity in relation to the control (445% ww).

Tab. 2. Physical properties of substrates used in research conducted in the experimental greenhouse conditions (WBiO URK) in spring 2024.

substrate	Bulk density g cm^{-3}	Water capacity %wv	Water capacity %ww
Standard	0,153 ab	53,7 a	352 ab
Novarbo 20	0,123 a	50,4 a	412 bc
Klasmann 5	0,192 b	52,7 a	311 a
Agaris 2	0,123 a	51,1 a	**445** c
Agaris 4	0,151 ab	49,8 a	343 ab

Post-hoc comparisons were performed using Tukey's test at p =0.05; the same letters indicate no significant differences between means; standard – substrate based on high-moor peat, Novarbo

The control substrate had a pH of 6.24 and a salt concentration (EC) of 0.73 mS cm-1 (Table 3). All substrates with limited peat content used in the study had a significantly higher pH than the peat substrate, ranging from pH 6.75 (Agaris 2) to pH 6.51 (Novarbo 20 and Klasmann 5). The highest salt concentration was noted in Agaris 4 (EC = 1.66 mS cm-1). With the exception of Novarbo 20, all substrates used in the study had a significantly higher EC than the peat substrate. The highest soluble calcium (Ca) was determined in Novarbo 20 and in the control substrate (respectively: 1621 and 940 mg Ca dm-3) (Table 3). In the remaining substrates, from 527 mg Ca (Klasmann 5) to 598 mg Ca dm-3 (Agaris 2 and 4) were found.

According to the approximate standard numbers for macroelements in peat substrate used for the production of vegetable seedlings given by Nowosielski (1988), the calcium content should be within the range of 1500-2000 mg Ca dm-3, potassium - 300-500 mg K dm-3, magnesium - 150-250 mg Mg dm-3 and phosphorus - 180-300 mg P dm-3. The potassium (K) content in the tested substrates ranged from 289 mg K (Novarbo 20) to 1121 mg K dm-3 (Agaris 2). The peat control substrate contained 315 mg K dm-3. The highest magnesium (>250 mg Mg dm-3), phosphorus (265 and 255 mg P dm-3) and sulphur (183 and 177 mg S dm-3) were contained in Agaris substrates (Agaris 2 and Agaris 4, respectively). The Novarbo 20 substrate was the least rich in Mg and P (Table 3). The lowest content of soluble sulphur was determined in Klasmann 5 substrate. Increased sodium contents in relation to the control and Novarbo 20 substrate were shown in Agaris 2 and 4 and Klasmann 5 substrates. With the exception of boron, the highest microelements were determined in Agaris 4 substrate (Table 3). The peat-free Klasmann 5 substrate was also rich in microelements, especially Fe, Mn, Mo and Zn.

Tab. 3. Salinity (EC mS cm^{-1}), pH, and the content of available macronutrients and sodium (mg dm^{-3}) and general forms of microelements (mg kg^{-1} d.m.) in the substrates selected for research in 2024.

Substrate	pH	EC	Ca	K	Mg	P	S	Na
Standard	6,24 a	0,73 a	940 b	315 a	163 b	104 b	81,7 c	33,8 a
Novarbo 20	6,51 b	0,54 a	**1621** c	289 a	*131* a	*53,1* a	58,0 b	34,6 a
Klasmann 5	6,51 b	1,09 b	527 a	889 b	166 b	84,1 ab	*35,8* a	149 c
Agaris 2	**6,75** c	1,21 b	598 a	**1121** c	**281** c	**265** c	**183** d	160 c
Agaris 4	**6,72** c	**1,66** c	598 a	901 b	**271** c	**255** c	**177** d	132 b
Substrate	**B**	**Cu**	**Fe**	**Mn**	**Mo**	**Zn**		
Standard	7,7 a	18,3 a	992 a	47 a	4,13 a	28,5 a		
Novarbo 20	7,7 a	27,3 a	1038 a	64 a	4,77 a	29,6 a		
Klasmann 5	15,5 a	27,9 a	9485 b	188 b	**18,7** d	**50,3** b		
Agaris 2	**33,1** b	**44,3** b	1205 a	100 a	14,5 c	28,7 a		
Agaris 4	10,5 a	**45,7** b	**19888** c	**234** b	10,3 b	**47,8** b		

Post-hoc comparisons were performed using Tukey's test at p = 0.05; the same letters indicate no significant differences between means; standard – substrate based on high-moor peat

Mineral composition of the mushroom stimulants used for testing

In the experiments conducted in the experimental greenhouse conditions, in order to stimulate the growth and development of plants, a 2.5% addition of mushroom waste (PO) and dried edible mushroom (P) was used in the tested substrates. The mineral composition of both fungal stimulants is given in Tables 4-5. In addition to mushroom fragments, the mushroom waste also contained remnants of the growing substrate, which influenced the content of some mineral components. A higher content of Ca, S, Fe, Mn, Mo and Ti was determined in the waste material, compared to the dried edible mushroom (Tables 3 and 4).

Tab. 4. Dry matter (%) (DM) and total mineral content (N, Ca, K, Mg, P and S in % of dry matter, Na, B, Cu, Fe, Mn, Mo, Zn and Ti in mg kg^{-1} dry matter) in mushroom waste (PO) used for research in the URK experimental greenhouse, spring 2024.

DM	N	Ca	K	Mg	P	S	Na
20,3	4,20	2,26	2,40	0,122	0,64	0,43	496
Elements	**B**	**Cu**	**Fe**	**Mn**	**Mo**	**Zn**	**Ti**
	13,0	16,5	3409	46,3	1,10	59,2	50,4

Tab. 5. Dry matter (%) (DM) and total mineral content (N, K, Mg, P and S in % of dry matter, Ca, Na, B, Cu, Fe, Mn, Mo, Zn and Ti in mg kg-1 dry matter) in edible mushrooms (P) used for research in the URK experimental greenhouse, spring 2024.

DM	N	Ca	K	Mg	P	S	Na
	7,34	354	3,98	0,17	1,47	0,33	420
Elements	**B**	**Cu**	**Fe**	**Mn**	**Mo**	**Zn**	**Ti**
	41,9	30,3	58,7	8,08	0,22	77,5	0,32

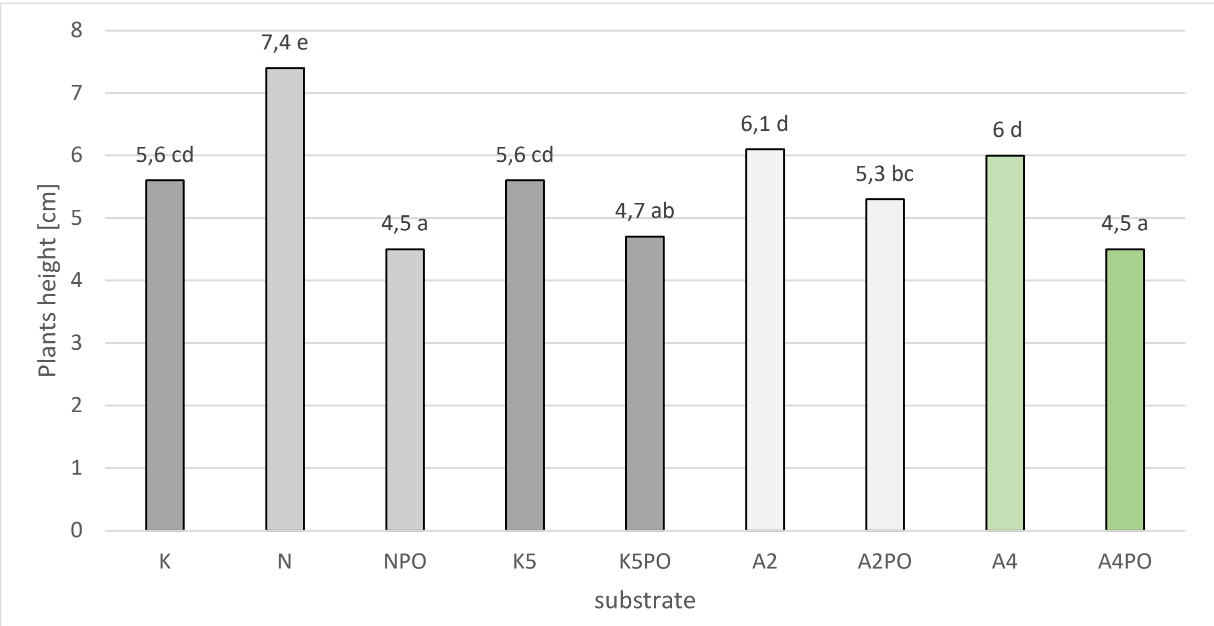
Research results: experiment 1 – cultivation of marigold

Ryc. 3. Cultivation of *Tagetes erecta* 'Antiqua Orange' F1 in experimental greenhouses of the Agricultural University in Krakow: a - first week after planting, b, c - second week of cultivation, d - fifth week of cultivation, e - seventh week of cultivation.

Marigold 'Antiqua Orange' F1 (Tagetes erecta) was grown in the experimental greenhouse of the Faculty of Biotechnology and Horticulture, University of Agriculture in Krakow from March 21 to May 8, 2024 (Fig. 3 a-d) on substrates with limited peat content and on peat-free substrates, also enriched with a mushroom stimulator, mushroom cultivation waste (PO). During the experiment, flowering observations were performed, as well as visual observations of the plants. After obtaining the final product in the 7th week of cultivation (May 8), detailed measurements and analyses were carried out, and the most important results are presented below.

Characteristics of plant morphometric parameters

The growing medium had an impact on the height of the final product (Fig. 4, Fig. 5). Marigolds obtained on the standard control medium were on average 5.6 cm high. The height of plants from the Klasmann 5, Agaris 2 and Agaris 4 media was at the same level (statistical) as in the control (5.6-6.1 cm), if they did not contain a mushroom stimulator. This stimulator added to each tested medium had an inhibiting effect on the height of the plants. The highest marigolds were obtained using the Novarbo 20 medium, but even in this case, when this medium was enriched with dried mushrooms, the plants were lower (almost by 3 cm).



Ryc. 4. Average height of Marigold plants at the end of production in the tested substrates and substrates with the addition of a mushroom stimulator.

Fig. 5. Comparison of the height of marigold plants grown in the following substrates: Klasmann 5 and Agaris 4 and with the addition of dried mushrooms (PO), the photo was taken in the 4th week of cultivation.

The best plant tillering was observed on the control substrate, as the ready-for-sale marigolds from this substrate had an average of 6.1 side shoots per plant (Fig. 6). The tested substrates with limited peat content and without peat did not increase the number of side shoots and usually limited their development. Only in the case of the Novarbo substrate enriched with a mushroom stimulator was the result identical to that of the control obtained.

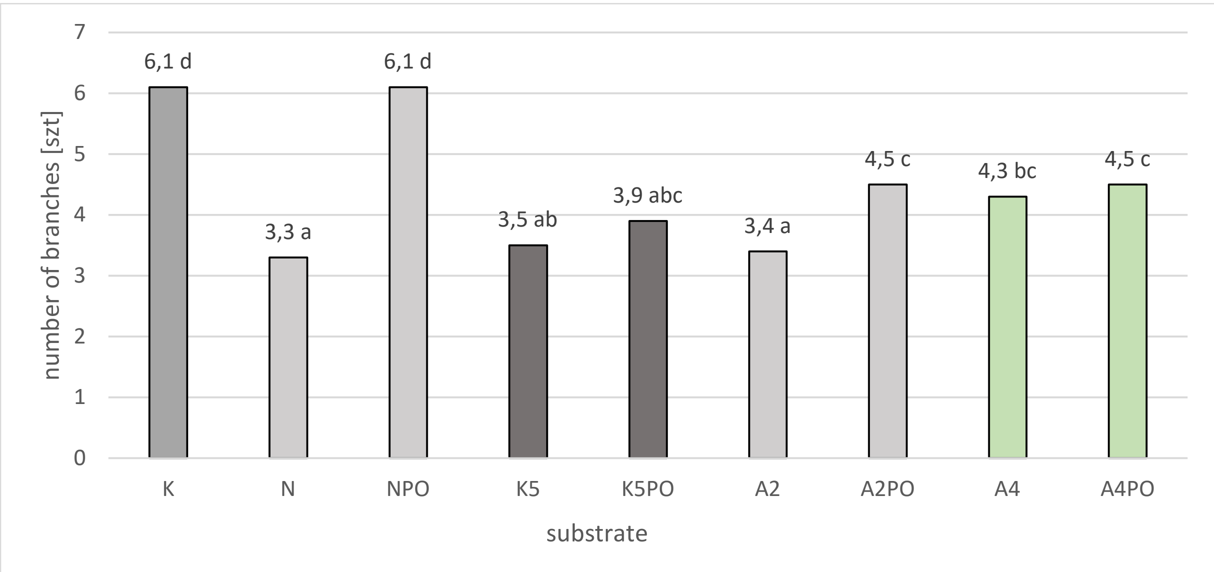


Fig. 6. Average number of branches (side shoots) of marigold at the end of production on the tested substrates and substrates with the addition of a mushroom stimulator.

Flowering characteristics

The data presented in Fig. 7 show that in the third week of cultivation all plants had formed flower buds on the main shoot (Fig. 9a). The process of forming flower buds was the fastest in plants grown on Agaris 2 and Agaris 4 substrates, because already at the end of the 2nd week of cultivation all plants had flower buds, while at that time in the control there was a lack of flower buds on almost 3% of plants, similarly to marigolds from Klasmann 5 and Klasmann 5 substrates with a mushroom stimulator and Novarbo with dried mushrooms, as well as Novarbo (over 5% of plants had no flower buds).

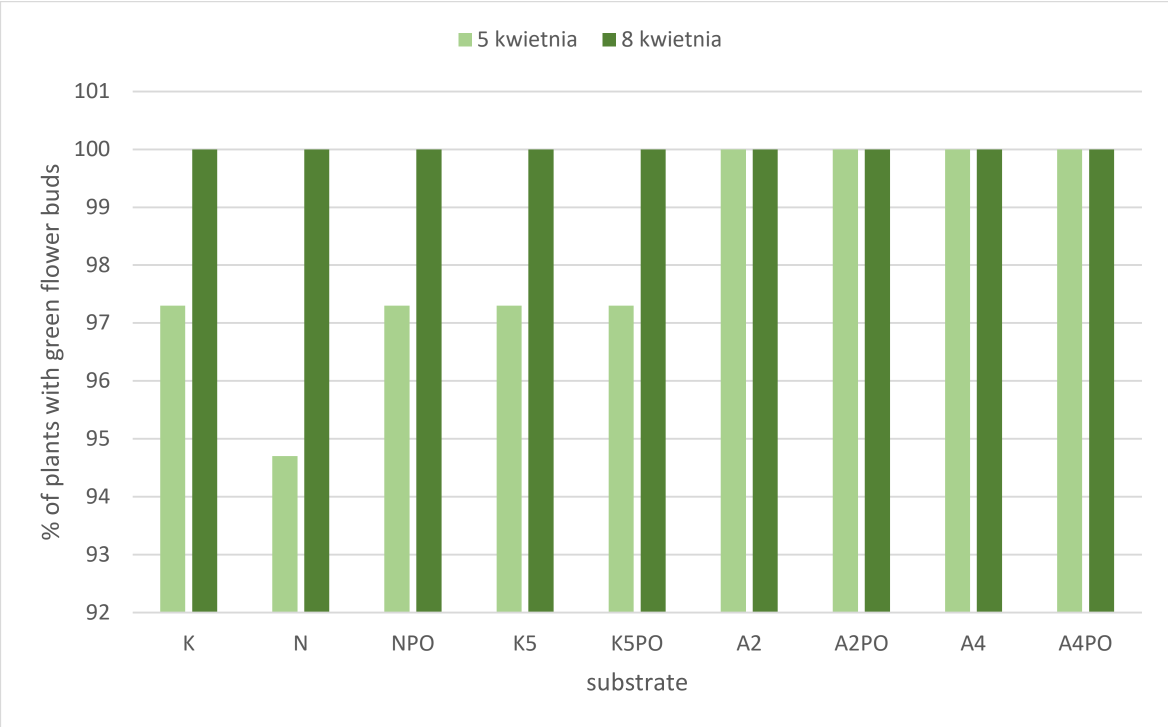


Fig. 7. Percentage of plants with formed green flower buds in weeks 2 and 3 of cultivation

In the fourth week of cultivation, marigolds had about 2 flower buds per plant, and no statistically significant differences were found, but the largest number of buds was observed in plants grown in the control substrate. In the case of Novarbo and Klasmann 5 substrates, a greater tendency to form flower buds was observed (Fig. 8).

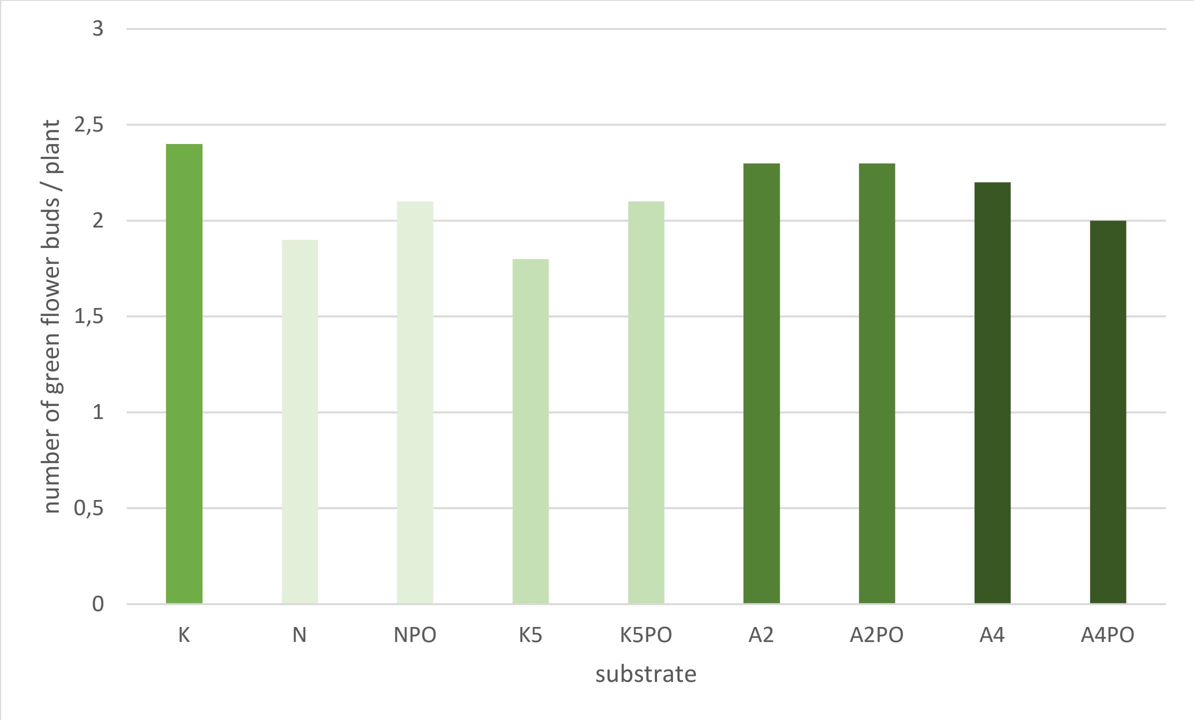


Fig. 8. Number of green flower buds per plant in the 4th week of cultivation

a. b. c.

Fig. 9. Development of flower buds in Marigold: a – green bud stage, b – bursting bud, c – fully developed flower head.

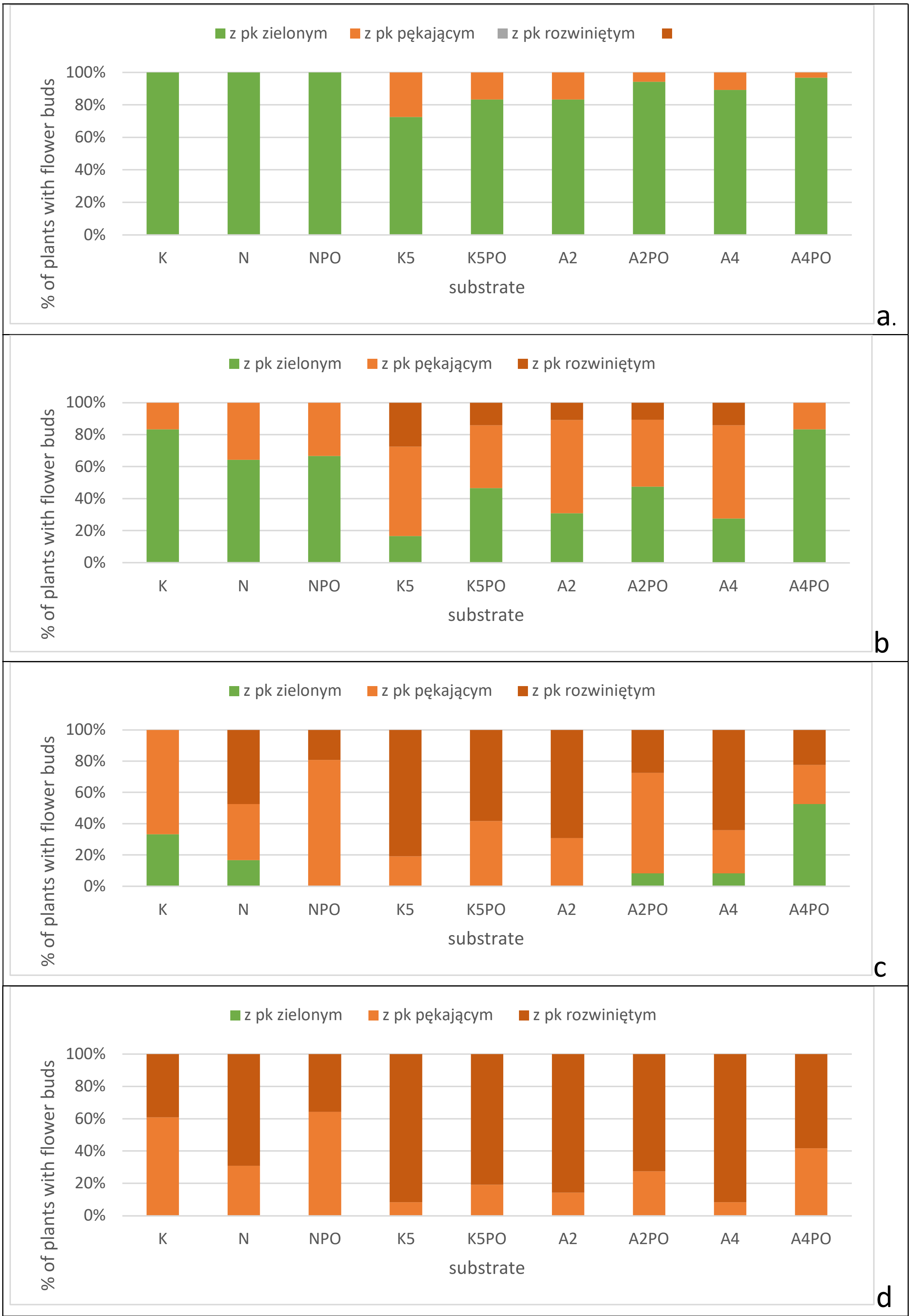


Fig. 10. Development of flower buds in marigold cultivation from the 4th to the 7th week of cultivation: a - April 18, b - April 24, c - April 30, d - May 7.

Figure 10 shows the dynamics of bud development, i.e. the structure of plants with buds at different stages: from green buds, through bursting buds, to fully developed heads (bud characteristics are shown in Figure 9), in the period from the 4th to the 7th week of marigold cultivation. The earliest appearance of bursting buds was observed in plants grown in Klasmann 5 and Agaris 2 and Agaris 4 substrates, also in combinations with dried mushrooms (Fig. 10a). Consistently, fully developed inflorescences appeared the fastest on these substrates. All tested substrates with limited peat content and peat-free, also when enriched with dried mushrooms, influenced the faster development of marigold flowers (Fig. 10 b-d). 60% of the final plants from the control substrate had bursting buds, and 40% had fully developed heads, which is a desirable feature for plants intended for sale. Plants from the tested substrates had a more advanced flowering phase (Fig. 10d). The size of the flower heads is related to the described response of the plants to the tested substrates. It was observed (Fig. 11) that in plants from the tested substrates with limited peat content or without peat (when they did not contain the mushroom stimulator), the flower heads were 1.1 to 1.7 cm larger in diameter, compared to the plants obtained in the control. Plants from all the tested substrates containing the mushroom stimulator had a diameter of flower heads smaller by 0.8 cm (from Agaris 2) to even 2.1 cm (from Agaris 4) compared to the same substrate without the biostimulator.

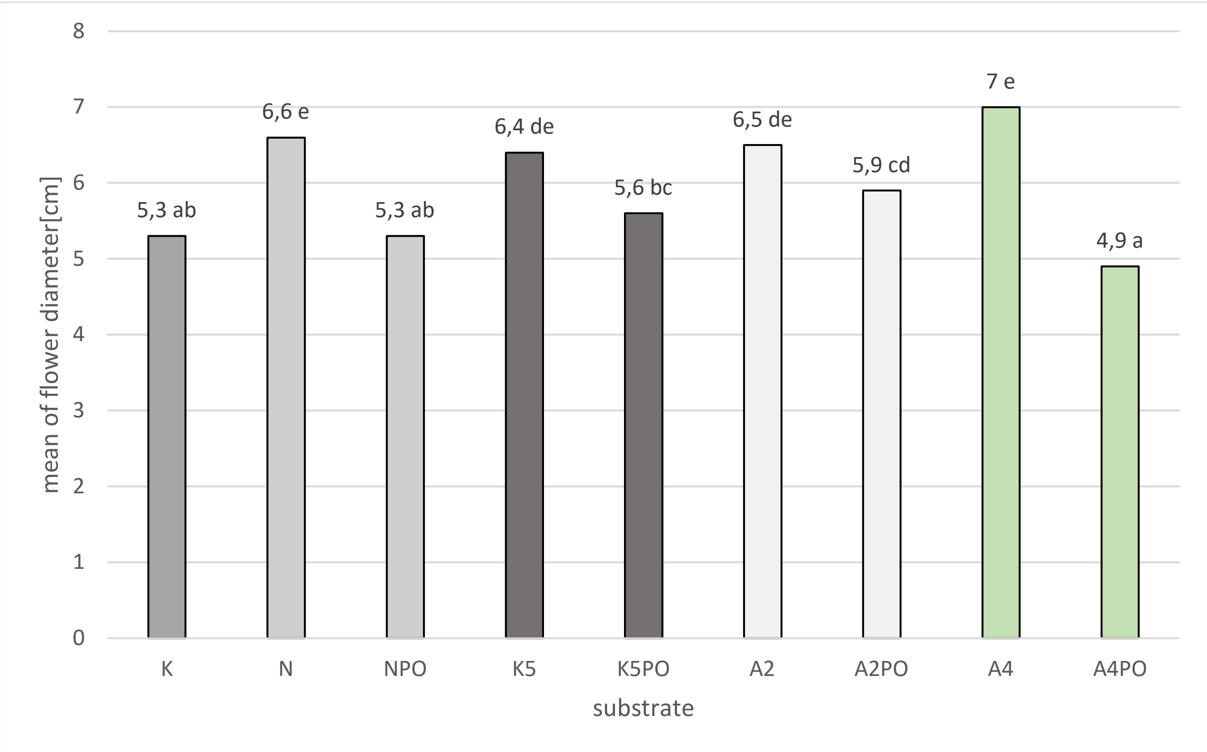


Fig. 11. Average size (diameter) of the inflorescence of the Marigold plants at the end of production

Characteristics of physiological parameters of marigold leaves

Tab. 6. The influence of the substrate and the substrate containing a mushroom stimulant on the content of photosynthetic pigments and the greenness index (SPAD) and photosynthetic efficiency of marigold leaves at the end of cultivation

Substrate	**Chlorophyll fluorescence Fv/Fm**	**SPAD**	**Chlorophyll a**	**Chlorophyll b**	**Carotenoids**
K	0,815 a*	58,68 cd	17,21 c	7,73 c	3,44 b
N	0,809 a	55,24 bc	13,58 ab	6,14 b	2,87 ab
NPO	0,810 a	**59,73 d**	**16,42 c**	**7,67 c**	**3,45 b**
K5	0,814 a	52,49 ab	11,64 a	5,16 a	2,69 a
K5PO	0,805 a	**55,37 bc**	13,41 ab	6,75 b	2,68 a
A2	0,795 a	50,28 a	12,18 ab	6,31 b	2,41 a
A2PO	0,811 a	52,63 ab	12,62 ab	6,42 b	2,56 a
A4	0,802 a	54,30 b	12,66 ab	6,44 b	2,52 a
A4PO	0,809 a	53,64 ab	13,70 b	6,78 b	2,81 a

* the means in the columns marked with the same letters do not differ significantly from each other

The conducted studies (Table 6) on the physiological condition of marigold leaves ready for sale showed that the photosynthetic efficiency of all plants, measured by the Fv/Fm index, regardless of the substrate in which they were grown, is at a correct level and ranges from 0.795 to 0.815. Although no significant statistical differences were noted, the highest value of this index is shown by plants grown on the standard control substrate. In the case of the SPAD leaf greenness index, the control was also the best, and plants from Novarbo substrate and Novarbo 20 PO (with a stimulator) and Klasmann 5 PO (with a stimulator) were characterized by a comparable result. A similar relationship is observed in the case of the content of photosynthetic pigments. The content of chlorophyll a, chlorophyll b and carotenoids was the highest in marigold leaves from the control medium, but those from Novarbo 20 with the mushroom stimulator had equally high levels of these pigments (Table 6).

Analysis of physicochemical properties of substrates

Five growing substrates were used for the cultivation of marigold, including a standard peat substrate (control). A 2.5% addition of mushroom waste (PO) was introduced to substrates with limited peat content or without peat (Klasmann 5, Novarbo 20 and Agaris 2 and 4) as a plant growth stimulator. Table 7 presents selected physical properties of the growing substrates determined after the completion of marigold cultivation. The highest bulk density was found in the Klasmann 5 substrate (0.113 g cm-3). No significant differences in bulk density were found for the other substrates used in the study. The average value of this parameter ranged from 0.072 g cm-3 (Agaris 2) to 0.089 g cm-3 (Agaris 4) and was similar to the density of the peat substrate (0.076 g cm-3). The highest water capacity was noted for the Novarbo 20 substrate (56% wv and 717% ww). These values were similar to those determined in the control substrate (peat standard).

The addition of the mushroom stimulator to the substrates significantly increased the average bulk density and water capacity of the substrates expressed as a percentage of the volume (%wv) (Table 7).

Tab. 7. Physical properties of substrates enriched with mushroom waste after the cultivation of marigold in an experimental greenhouse, 8/05/2024.

Factor		Bulk density $g \cdot cm^{-3}$	Water capacity % wv	Water capacity %ww
Controll		*0,076*	*57,2*	*749*
Klasmann 5		0,113 B	45,7 A	398 A
Novarbo 20%		0,078 A	**56,0** B	**717** D
Agaris 4		0,089 A	40,6 A	462 B
Agaris 2		0,072 A	41,7 A	578 C
Waste mushroom (PO)		**0,097** B	**50,1** B	526 A
Without muschroom (0P)		0,081 A	41,7 A	534 A
Klasmann 5	PO	0,118 a	48,8 a	396 a
	0P	0,108 a	42,7 a	401 a
Novarbo 20%	PO	0,088 a	62,6 a	707 a
	0P	0,068 a	49,4 a	728 a
Agaris 4	PO	0,104 a	43,7 a	420 a
	0P	0,082 a	39,0 a	483 a
Agaris 2	PO	0,078 a	45,2 a	582 a
	0P	0,066 a	38,1 a	574 a

Post-hoc comparisons were performed using the Tukey test at p = 0.05; the same letters indicate no significant differences between means; two-factor analysis, where factor 1 – type of substrate and factor; 2 – addition of mushroom stimulant in the form of mushroom farm waste; control – peat substrate.

Table 8 presents the results of tests of chemical properties and organic matter content in the substrates used in the cultivation of French marigold. The highest and slightly alkaline pH was found in Agaris 2 substrate (pH 7.41), especially in relation to Novarbo substrate - pH 6.54 (slightly acidic) and Klasmann 5 - pH 6.99 (neutral). The control peat substrate after the cultivation was finished had an acidic pH of 5.60. The highest salt concentration (EC) after the cultivation of French marigold was determined in Novarbo 20 substrate (782 µS cm-1). The EC of the peat substrate used as a control was 477 µS cm-1. The Novarbo substrate analyzed after the cultivation of the plants also showed the highest concentration of nitrogen in the form of nitrate (61.7 mg N-NO3 dm-3) and soluble calcium (1609 mg Ca dm-3). Similarly, the standard substrate tested after cultivation contained these components, respectively: 8.45 mg N-NO3 dm-3 and 855 mg Ca dm-3. According to Nowosielski (1988), the appropriate content of N-NO3, P, K, Ca and Mg in the peat substrate intended for growing seedlings of demanding vegetable plants should be within the ranges (mg dm-3): 80-150, 90-300, 200-500, 1500-2500 and 80-250. According to these criteria, all substrates analyzed after cultivation were distinguished by a low content of nitrate nitrogen and calcium. The determined content of organic matter in the substrates differed significantly and ranged from 50.9% (Klasmann 5) to 90.1% (Agaris 2). The control peat substrate contained 94% of organic matter (Table 8 and Fig. 12).
The addition of a mushroom stimulator in the form of dried mushroom waste (2.5%) significantly increased the salt concentration in the substrates and the content of soluble potassium and

phosphorus. In the substrates without the mushroom stimulator, a higher pH was determined (Table 6). A significant effect of the interaction of the experimental factors on the pH value, EC, N-NO3 content and organic matter in the substrates was demonstrated.

The addition of the mushroom stimulator significantly reduced the soil pH in the following substrates: Klasmann 5 and Agaris 4. The greatest increase in salinity after the use of the mushroom stimulator was demonstrated for the Klasmann 5 and Novarbo 20 substrates (Fig. 12). In these substrates, a significantly higher content of nitrate nitrogen (N-NO3) was also demonstrated than in the combinations without the addition of dried mushroom waste. The addition of mushrooms caused a significant increase in the content of organic matter in the Klasmann 5 and Agaris 4 substrates (Fig. 13).

Tab. 8. Reaction (pH), salinity (EC µS cm-1) and content of macroelements, sodium (mg dm-3) and organic matter in substrates with the addition of mushroom biostimulator after the cultivation of marigold, 8/05/2024.

Factor		pH	EC	NH_4	NO_3	Ca	K	Mg	P	SO_4	Na	SO%
Controll		*5,60*	*477*	*2,95*	*8,45*	*855*	*141*	*166*	*170*	*158*	*149*	*94,0*
Klasmann 5		6,99 B	573 B	1,79 A	42,5 B	633 A	460 A	169 A	123 A	69,2 A	155 A	50,9 A
Novarbo 20%		6,54 A	**782** C	2,18 A	**61,7** C	**1609** B	214 A	154 A	160 A	107 A	102 A	89,9 C
Agaris 4		7,05 BC	485 A	2,21 A	0,57 A	730 A	300 A	214 A	211 A	82,0 A	123 A	70,5 B
Agaris 2		7,41 C	601 B	2,50 A	0,55 A	818 A	389 A	248 A	235 A	102 A	141 A	90,1 C
Waste mushroom (PO)		6,76 A	**790** B	2,26 A	51,9	1057 A	**470** B	204 A	**218** B	100 A	136 A	77,2 A
Without mushroom (0P)		**6,91** B	440 A	2,25 A	2,34	842 A	197 A	184 A	150 A	95,6 A	129 A	**77,6** B
Klasmann 5	PO	6,58 a	829 e	1,75 a	84,3 b	739 a	555 a	170 a	147 a	78,9 a	149 a	56,9 b
	0P	7,40 cd	317 a	1,83 a	0,74 a	527 a	364 a	168 a	98,1 a	59,4 a	161 a	44,9 a
Novarbo 20%	PO	6,28 a	**1080** f	2,76 a	**122** c	1655 a	378 a	153 a	201 a	131 a	108 a	89,0 e
	0P	6,81 a-c	484 bc	1,60 a	1,41 a	1563 a	50 a	154 a	118 a	83,4 a	96 a	90,8 ef
Agaris 4	PO	6,69 ab	618 cd	1,91 a	0,26 a	865 a	471 a	235 a	272 a	102 a	149 a	73,6 d
	0P	7,41 cd	352 ab	2,51 a	0,87 a	596 a	130 a	193 a	149 a	61,9 a	97 a	67,5 c
Agaris 2	PO	7,49 d	632 d	2,64 a	0,85 a	969 a	477 a	258 a	253 a	88,7 a	140 a	89,3 ef
	0P	7,33 b-d	571 cd	2,36 a	0,26 a	668 a	300 a	239 a	217 a	116 a	143 a	90,9 f

Post-hoc comparisons were performed using Tukey's test at p =0.05; the same letters indicate no significant differences between means; control – substrate based on high-moor peat

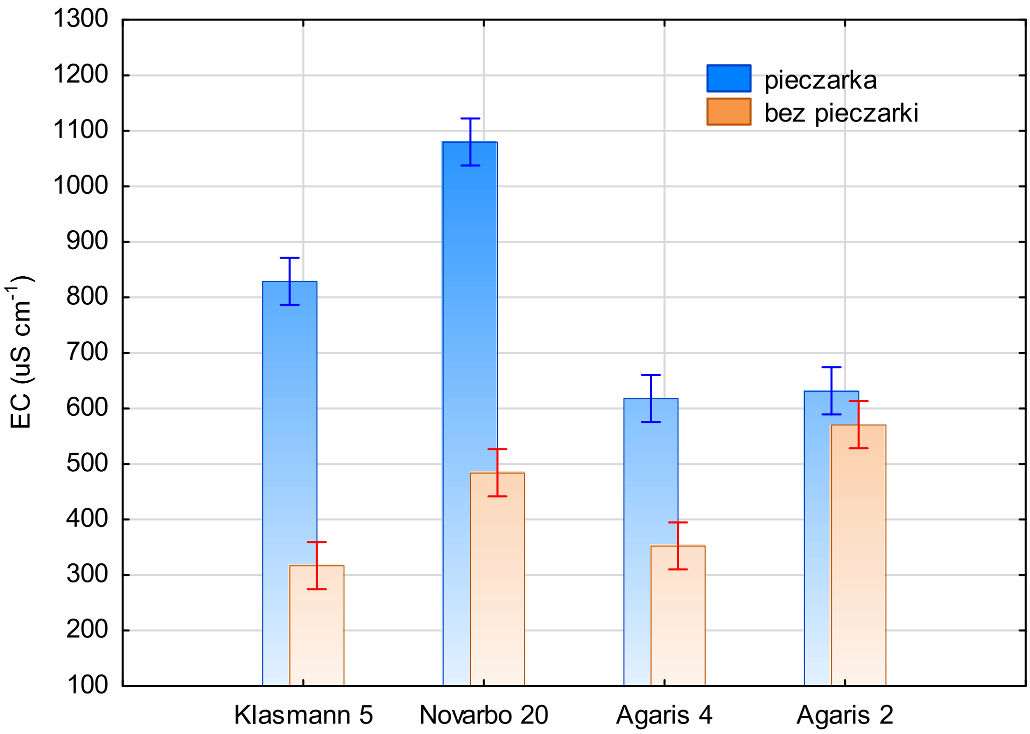


Fig. 12. The effect of the type of substrate and the addition of a mushroom stimulator on salinity (EC µS cm-1) determined after the cultivation of marigold in an experimental greenhouse, 8/05/24. Pieczarka – Mushroom, bez pieczarki – Without mushroom

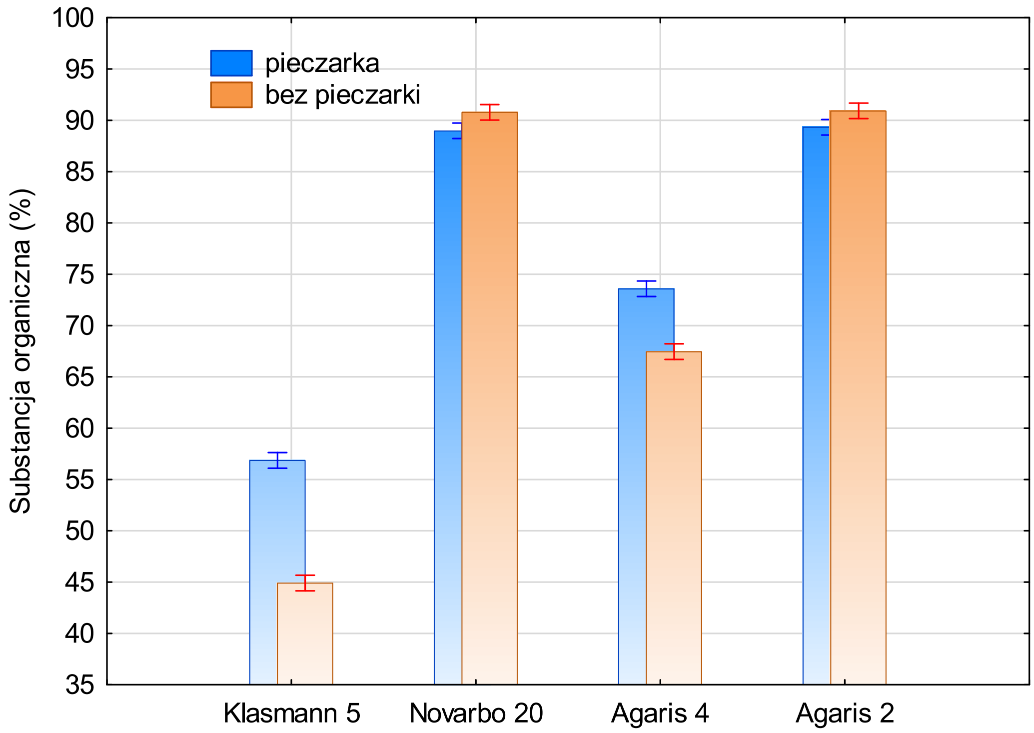


Fig. 13. The effect of the type of substrate and the addition of a mushroom stimulant on the organic matter content (%) determined after the cultivation of marigold in the experimental greenhouse, 8/05/2024. Substancja organiczna – Organic matter; Pieczarka – Mushroom, bez pieczarki – Without mushroom

The total content of microelements in organic substrates used in the study with marigold was determined after microwave mineralization of organic material in concentrated nitric acid using the ICP OES method. With the exception of boron, peat-free substrates or substrates with limited peat content were richer in microelements than the standard substrate (Novarbo peat, control) (Table 9).
The total boron content determined in substrates after marigold cultivation ranged from 1.65 mg B kg-1 (Klasmann 5) to 27.7 mg B kg-1 (Agaris 2). The highest copper and molybdenum content was found in peat-free substrates Agaris 2 and 4, 55.1 and 41.9 mg Cu kg-1 d.m. and 19.6 and 10.8 mg Mo kg-1 d.m., respectively. Significantly more total iron was determined in the Klasmann 5 and Agaris 4 substrates (18816 mg and 17349 mg Fe kg-1 d.m., respectively) than in the other substrates used for the study. Klasmann 5 substrate was also the richest in manganese (296 mg Mn kg-1 d.m.) and zinc (78.5 mg Mn kg-1 d.m.).
The addition of waste mushroom (2.5%) slightly increased the total content of boron, molybdenum and zinc in the substrates compared to the untreated combinations (Table 9).
A significant effect of the interaction of the factors used: substrate x addition of fungal stimulant on the content of B, Fe, Mn, Mo and Zn was demonstrated. In general, the addition of fungal stimulant to a substrate poor in microelements increased the substrate's content in a given component.

Tab. 9. Total content of microelements (mg kg-1 d.m.) determined in substrates after cultivation of marigold

Factor		B	Cu	Fe	Mn	Mo	Zn
Controll		*7,27*	*21,2*	*1056*	*20,1*	*6,1*	*32,8*
Klasmann 5		1,65 A	34,6 A	18816 B	**296** D	9,2 A	**78,5** C
Novarbo 20		13,5 B	*32,8* A	1532 A	*59,3* A	7,7 A	*46,8* A
Agaris 2		**27,7** C	**55,1** C	2649 A	131 B	**19,6** C	55,4 B
Agaris 4		3,10 A	41,9 B	17349 B	183 C	10,8 B	57,6 B
Mushroom waste (PO)		**12,6** B	41,1 A	9003 A	156 A	**12,4** B	**62,4** B
No Mushroom (0P)		10,3 A	41,0 A	**11170** B	**179** B	11,2 A	56,8 A
Klasmann 5	PO	3,31 ab	36,3 a	15658 b	244 d	13,1 d	77,0 c
	0P	*ślady* a	32,8 a	21974 d	349 e	5,4 a	80,0 c
Novarbo 20	PO	13,7 c	32,3 a	2097 a	62,3 a	7,1 ab	53,5 b
	0P	13,3 c	33,2 a	967 a	56,2 a	8,4 bc	40,0 a
Agaris 2	PO	27,5 d	55,4 a	2927 a	136 b	19,0 e	61,2 b
	0P	27,9 d	54,7 a	2372 a	126 b	20,1 e	49,7 ab
Agaris 4	PO	6,06 b	40,5 a	15329 b	183 c	10,5 cd	57,8 b
	0P	0,14 a	43,3 a	19369 c	183 c	11,0 cd	57,3 b

Post-hoc comparisons were performed using Tukey's test at p = 0.05; the same letters indicate no significant differences between means; control – peat substrate

Analyses of plant material

In the plant material obtained for the study after the end of the cultivation of marigold, a significant effect of the type of substrate and the addition of the mushroom stimulator on the content of macroelements and sodium was demonstrated (Table 10). The highest nitrogen and calcium were determined in marigolds growing in the Novarbo 20 substrate, while plants growing in the Agaris 4 substrate contained the most magnesium. The highest phosphorus and sodium content was determined in the biomass of marigolds from the Agaris 2 combination.

The addition of mushrooms to the substrate in the form of dried mushroom waste significantly reduced the dry matter content in the plants, while increasing the content of nitrogen, potassium, phosphorus and sodium in the biomass. Plants growing on substrates without the mushroom additive were characterized by a higher content of magnesium and sulfur (Table 10).

Comparing the obtained results concerning the mineral nutritional status of marigold grown in a standard peat substrate, it was shown that plants grown in substrates with limited peat content or without peat were characterized by lower contents of N, Ca (except for the combination with Novarbo 20), Mg and P. However, they contained more potassium and sodium (except for the combination with Novarbo 20).

Tab. 10. Zawartość makroskładników (% s.m.) i sodu (mg kg^{-1} s.m.) w **aksamitce** uprawianej w podłożach z dodatkiem stymulatora pieczarkowego w warunkach szklarni doświadczalnej (URK), 8.05.2024 r.

Factor		**DW**	**N**	**Ca**	**K**	**Mg**	**P**	**S**	**Na**
Controll		*10,6*	*4,36*	*3,67*	*4,42*	*0,55*	*1,09*	*1,03*	*273*
Klasmann 5		10,2 A	3,50 C	1,83 B	7,23 C	0,32 A	*0,83* A	*0,62* A	325 B
Novarbo 20		9,64 A	**3,79** D	**3,70** C	*5,13* A	0,31 A	0,96 B	0,95 B	270 A
Agaris 4		10,1 A	3,38 B	1,75 B	6,46 B	**0,48** C	0,99 B	1,11 C	298 AB
Agaris 2		10,1 A	*2,85* A	*1,46* A	7,31 C	0,43 B	**1,03** C	1,09 C	**412** C
Mushroom waste (PO)		9,80 A	**3,79** B	2,11 A	**6,89** B	0,37 A	**0,98** B	0,91 A	**343** B
No Mushroom (0P)		**10,3** B	3,25 A	2,53 A	5,82 A	**0,43** B	0,96 A	**0,98** B	302 A
Klassman 5	PO	10,2 a	4,11 f	2,15 c	7,14 c	0,37 bc	0,83 a	0,62 a	324 a
	0P	10,1 a	2,88 b	1,50 a	7,33 cd	0,27 a	0,84 a	0,62 a	325 a
Novarbo 20%	PO	9,47 a	**4,28** g	3,46 d	5,69 b	0,32 ab	0,97 bc	0,79 b	305 a
	0P	9,80 a	3,30 d	**3,94** e	4,57 a	0,31 a	0,95 bc	1,11 c	235 a
Agris 4	PO	9,95 a	3,71 e	1,53 ab	7,18 c	0,41 cd	1,06 d	1,10 c	311 a
	0P	10,3 a	3,04 c	1,96 bc	5,75 b	**0,56** e	0,92 b	1,13 c	285 a
Agris 2	PO	9,54 a	3,05 c	1,31 a	**7,58** d	0,39 c	1,05 d	1,15 c	432 a
	0P	10,7 a	2,64 a	1,61 ab	7,04 c	0,47 d	1,01 cd	1,04 c	392 a

Post-hoc comparisons were performed using the Tukey test at p = 0.01; the same letters indicate no significant differences between means; two-factor analysis, where factor 1 – substrate, factor 2 – addition of mushroom stimulator, control – peat substrate

With the exception of dry mass and sodium content in plants, a significant effect of the interaction of experimental factors (substrate type x mushroom stimulator addition) was demonstrated on the mineral composition of French marigold determined after the end of the experiment (Table 10, Figs. 15-18). The greatest increase in nitrogen content in plants under the influence of the mushroom waste addition was demonstrated for the Klasmann 5 and Novarbo 20 substrate combinations (Fig. 14).

The addition of mushrooms to the substrate significantly increased the calcium content in French marigold only in the case of the Klasmann 5 substrate. In the remaining substrate combinations, a decrease in the Ca content in the biomass was demonstrated (Fig. 15). At the same time, a significant increase in potassium content in plants under the influence of the fungal stimulator application was demonstrated in all combinations except for the Klasmann 5 substrate (Fig. 16). Similar relationships were found for the phosphorus content in plants (Fig. 17). A significant decrease in sulfur content in the marigold biomass was demonstrated by the introduction of the mushroom stimulator to the growing substrate only for the Novarbo 20% substrate (Fig. 18).

During the vegetation, characteristic edge and interveinal chlorosis of older leaf blades was observed on plants growing in substrates with the addition of the mushroom stimulator, transforming into necrosis over time (Fig. 19). The cause of these disorders was probably salinity and the imbalance between antagonistic elements Ca:K:Mg in the substrates and magnesium and calcium deficit in plants with a simultaneously very high potassium content in the tissues (Table 10, Fig. 16).

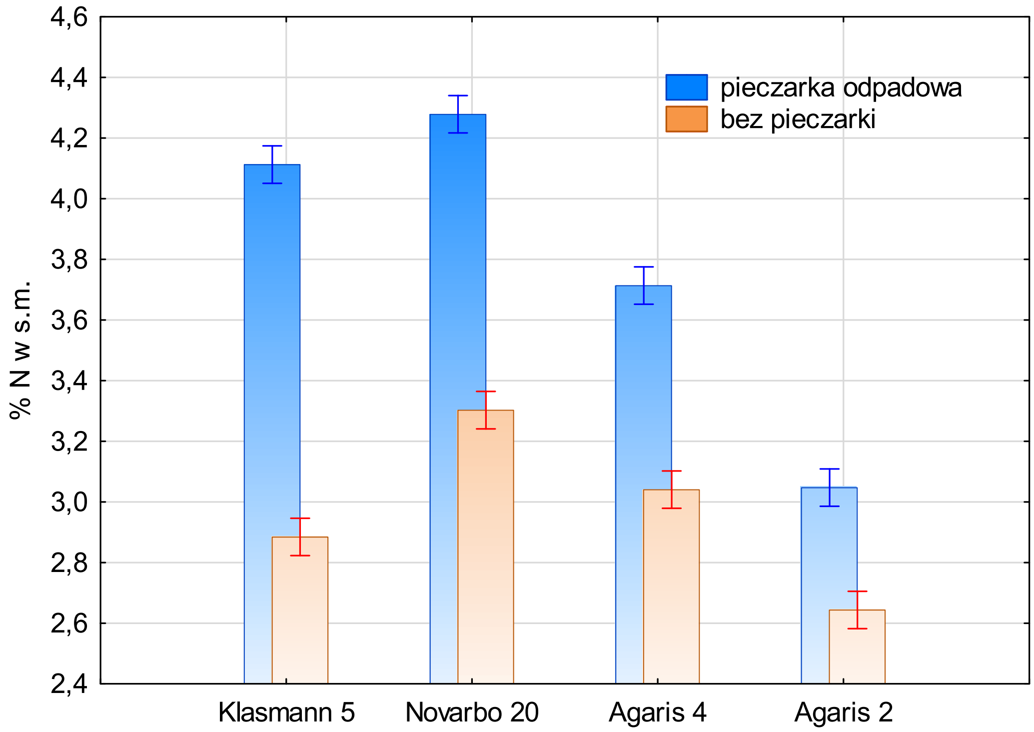


Fig. 14. The effect of the type of substrate and the addition of mushroom stimulator on nitrogen content (% N w s.m. = % N in dry matter) in the biomass of marigold grown in the experimental greenhouse conditions, 8/05/2024. Pieczarka – Mushroom, bez pieczarki – Without mushroom

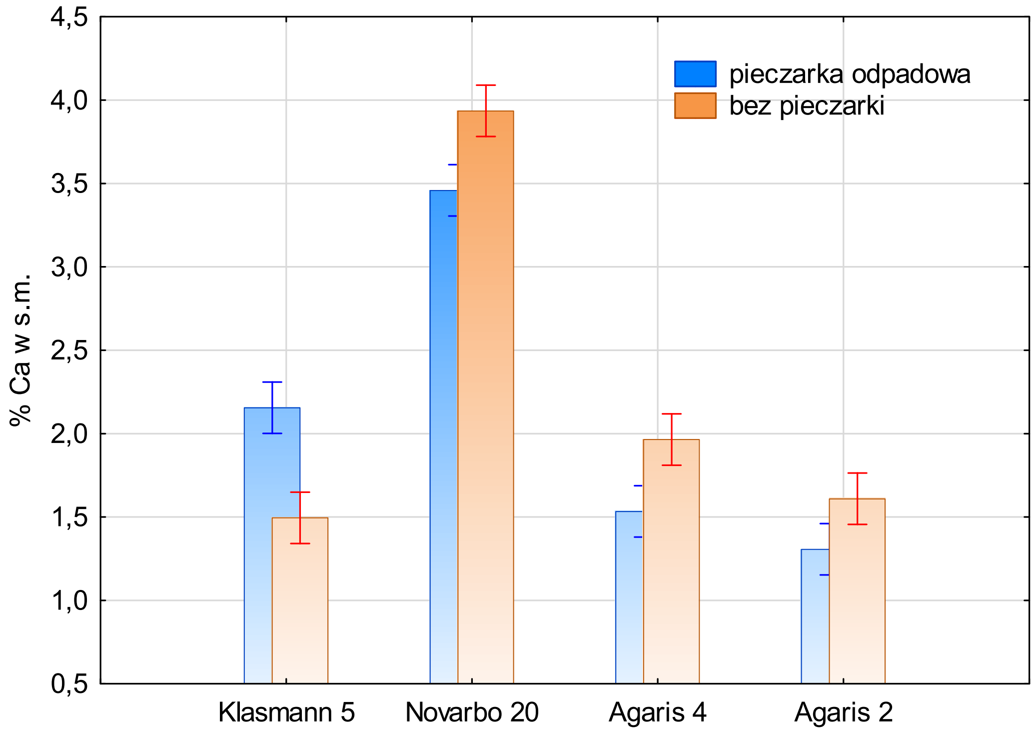
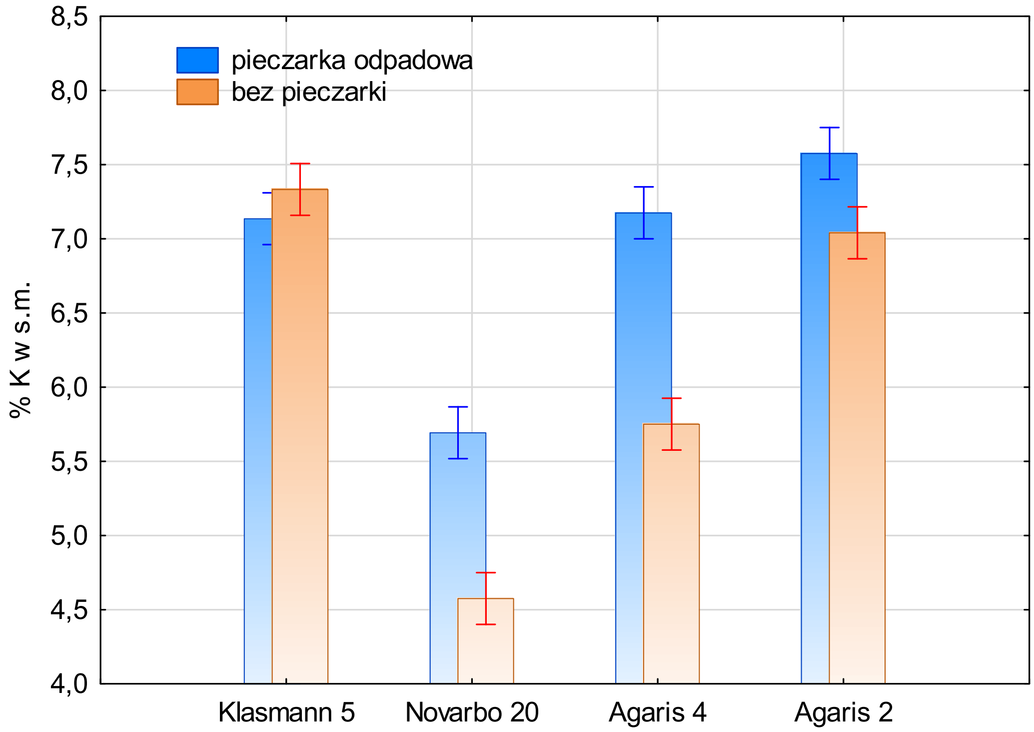


Fig. 15. The effect of the type of substrate and the addition of mushroom stimulator on the calcium content (% Ca w s.m. = % Ca in dry matter) in the biomass of marigold grown in the experimental greenhouse conditions, 8/05/2024. Pieczarka – Mushroom, bez pieczarki – Without mushroom



Ryc. 16. Fig. 15. The effect of the type of substrate and the addition of mushroom stimulator on the potassium content (% K w s.m. = % K in dry matter) in the biomass of marigold grown in the experimental greenhouse conditions, 8/05/2024. Pieczarka – Mushroom, bez pieczarki – Without mushroom.

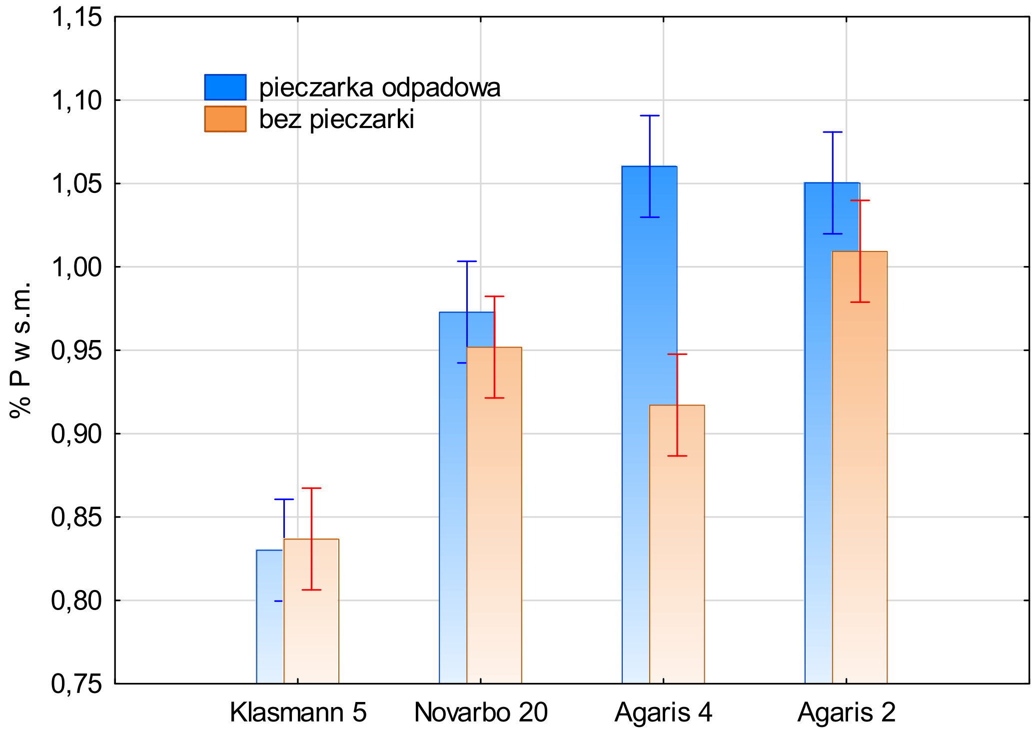


Fig. 17. The effect of the type of substrate and the addition of mushroom stimulator on the phosphorus content (% P w s.m. = % P in dry matter) in the biomass of marigold grown in the experimental greenhouse conditions, 8/05/2024. Pieczarka – Mushroom, bez pieczarki – Without mushroom

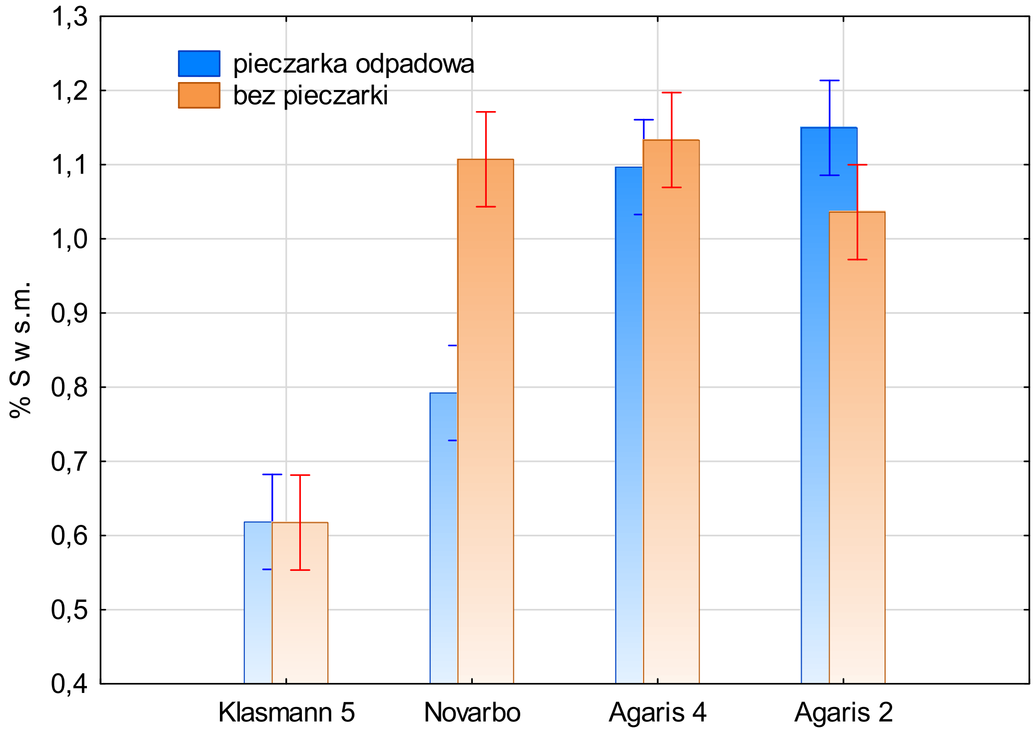


Fig. 18. The effect of the type of substrate and the addition of mushroom stimulator on the sulfur content (% S w s.m. = % S in dry matter) in the biomass of marigold grown in the experimental greenhouse conditions, 8/05/24. Pieczarka – Mushroom, bez pieczarki – Without mushroom.

Comparing the status of mineral nutrition of microelements of marigolds growing in peat-free or limited peat substrates to plants growing in the control substrate (peat), a lower content of copper, iron and manganese in the biomass and a higher content of zinc were observed (Table 11). An inverse relationship was described for the richness of the tested substrates, in which a generally higher total content of these elements was demonstrated than in the standard peat substrate. This indicates poor availability (assimilation) of micronutrients present in peat-free and limited peat substrates. The plants growing in the Klasmann 5 substrate had the lowest microelements, especially in relation to marigolds grown in Agaris 2 and 4 substrates (Table 11). Marigolds from the experimental combinations with Agaris substrates contained the most copper and zinc. The highest iron content was also determined in the biomass collected for testing from the Agaris 4 substrate.

Significantly more iron and zinc were determined in marigolds growing in substrates with the addition of mushroom waste in the form of fruiting body remains and growing medium (PO). The mushroom waste used in the form of a 2.5% additive to the substrates was rich in iron and zinc, which may indicate a rapid microbiological decomposition of the fungal stimulant in the cultivation conditions and the availability of the components contained in it to the plants. Plants grown in unenriched substrates (0P) were richer in copper, manganese (Mn) and molybdenum (Mo).

Tab. 11. Content of microelements (mg kg-1)* in the biomass of Marigold growing in substrates with the addition of mushroom biostimulant in experimental greenhouse conditions.

Factor		**B**	**Cu**	**Fe**	**Mn**	**Mo**	**Zn**
Controll		*44,5*	*11,8*	*1234*	*493*	*1,12*	*163*
Klassman 5		37,6 A	6,8 A	87 A	197 A	1,64 A	123 A
Novarbo 20		44,2 AB	8,7 B	111 B	**282** C	2,04 B	130 A
Agaris 2		42,6 B	10,0 C	113 B	200 A	2,08 B	**199** C
Agaris 4		46,8 B	10,1 C	**131** C	245 B	1,86 AB	159 B
Waste mushroom (PO)		41,9 A	8,1 A	**120** B	215 A	1,74 A	**160 B**
No mushroom (0P)		43,7 A	**9,7** B	101 A	**248** B	**2,07** B	146 A
Klassman 5	PO	41,8 a-c	6,7 a	101 b	290 cd	1,56 ab	148 bc
	0P	33,4 a	6,9 a	74 a	105 a	1,72 a-c	97 a
Novarbo 20	PO	42,5 a-c	7,2 a	111 b	241 bc	1,36 a	129 ab
	0P	45,9 bc	10,3 bc	112 b	324 d	2,71 d	131 bc
Agaris 2	PO	40,2 ab	9,6 bc	109 b	132 a	2,14 cd	199 d
	0P	45,1 bc	10,4 bc	117 b	268 c	2,03 bc	200 d
Agaris 4	PO	43,1 bc	9,1 b	161 c	196 b	1,89 a-c	163 c
	0P	50,6 c	11,1 c	101 b	295 cd	1,84 a-c	155 bc

Post-hoc comparisons were performed using Tukey's test at p = 0.01; the same letters indicate no significant differences between means; control – peat substrate

A statistically significant effect of the interaction of the studied factors (type of substrate x addition of fungal stimulant) on the content of microelements in the marigold biomass was also demonstrated (Table 11). In general, a varied response of plants growing in substrates made of waste materials to the addition of the mushroom stimulant was demonstrated. The addition of mushrooms to the peat-free Klasmann 5 substrate significantly increased the content of Fe, Mn and Zn in plants. On the other hand, in the Novarbo 20 substrate with limited peat content, higher total amounts of Cu, Mn and Mo were demonstrated in marigolds from the combination without the mushroom additive. In Agaris substrates, significantly more manganese was also determined in plants taken for testing from the combination without the mushroom stimulant..

Fig. 19. Symptoms of physiological disorders on Marigold plants, experimental greenhouse of the Faculty of Biotechnology and Horticulture, 23/04/2024.

Plants grown in Klasmann 5 and Agaris 4 substrates, showing chlorotic-necrotic changes on older leaves, also had poorer root system development (Fig. 19ab, 20ab). The assessment of the intensity of root system development was not the subject of the study, but during the collection of substrate samples for analysis, root balls were photographed to explain the poorer development of plants in more saline substrates than analogues without the fungal additive.

a. b.

Fig. 20. The intensity of root ball overgrowth of marigolds growing in Agaris 4 (a) and Klasmann 5 (b) substrates with the addition (root ball on the right) or without a mushroom stimulator (root ball on the left) after the cultivation in the experimental greenhouse of the Faculty of Biotechnology and Horticulture of the University of Krakow

Research results: experiment 2 – cultivation of flower bed geraniums

a. **b.**

c. **d.**

Fig. 21. Cultivation of flowerbed geranium (Pelargonium hortorum) 'Dolce Vita Gisela Dark Red' in the experimental greenhouse of the Faculty of Biotechnology and Horticulture: a – plants after planting on 22.03.2024, b – 9.04.2024 (third week of cultivation), c - 23.04.2024 (fifth week of cultivation), d – 15.05.2024 (eighth week of cultivation)

The flowerbed geranium ‘Dolce Vita Gisela Dark Red’ (Pelargonium hortorum) was grown in the experimental greenhouse of the Faculty of Biotechnology and Horticulture, University of Agriculture in Krakow from March 22 to May 16, 2024 (Fig. 21a-d) on substrates with limited peat content and peat-free, also enriched with a mushroom stimulator, mushroom cultivation waste (PO) and a food mushroom stimulator prepared from dried fruiting bodies (P). During the experiment, flowering observations were performed, as well as visual observations of the plants. After obtaining the final product in the 8th week of cultivation (May 17), detailed measurements and analyses were carried out, and the most important results are presented below.

Plant height and physiological condition of leaves

Pelargonium plants grown on Novarbo20 and Klasmann substrates had a similar (statistically indifferent) height at the end of the experiment as in the case of the standard control substrate. And those from Novarbo were over 1 cm higher. However, the addition of a mushroom stimulator to the substrates always had a retarding effect on the height of the plants (also in the case of Agaris 2 and Agaris 4) (Fig. 22-23).

a. b.

Fig. 22. The influence of the mushroom stimulator (fruiting bodies of edible mushrooms – P) on the height of plants grown in the substrate: a – Agaris 2, b – Klasmann 5, on the left pots with the substrate enriched with the mushroom stimulator.

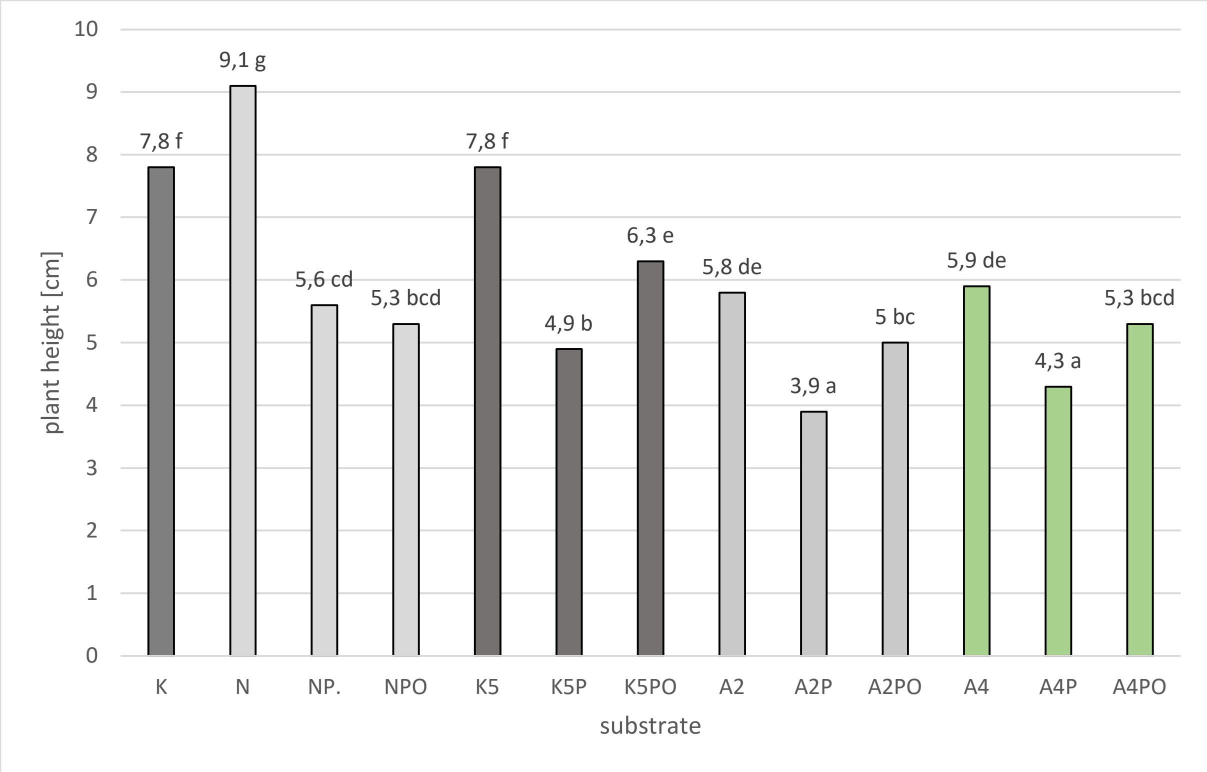


Fig. 23. Average height of bedding geranium plants at the end of production in the tested substrates and substrates with the addition of a mushroom stimulator (P, PO).

Table 12. The effect of substrate and substrate containing two types of mushroom stimulator (P, PO) on the content of photosynthetic pigments and the greenness index (SPAD) and photosynthetic efficiency of bedding geranium leaves at the end of cultivation.

Substrate	Chlorophyll fluorescence Fv/Fm	SPAD	Chlorophyll a	Chlorophyll b	CarotenoidS
K	0,836 a*	63,75 bc	**9,94 de**	**5,79 bcde**	**1,93 cde**
N	0,838 a	66,55 bcd	**9,38 cde**	**5,79 bcde**	1,72 bcd
NP	0,841 a	71,30 e	**10,46 e**	**6,06 cde**	**2,11 e**
NPO	0,832 a	68,97 de	**10,27 e**	**6,412 e**	**1,91 cde**
K5	0,845 a	63,63 bc	8,84 cd	5,56 bcd	1,65 bcd
K5P	0,839 a	66,77 cd	**10,22 e**	**6,22 de**	**1,97 de**
K5PO	0,843 a	62,66 bc	**9,30 cde**	**5,98 cde**	1,76 bcd
A2	0,829 a	62,67 bc	7,03 a	4,82 a	1,29 a
A2P	0,830 a	65,50 bcd	8,34 bc	5,29 ab	1,63 abc
A2PO	0,837 a	64,06 bc	8,43 bc	5,19 ab	1,60 abc
A4	0,810 a	62,35 b	8,34 bc	5,47 bc	1,56 ab
A4P	0,840 a	65,07 bcd	8,89 cd	5,59 bcd	1,70 bcd
A4PO	0,839 a	57,64 a	7,44 ab	4,71 a	1,33 a

* the means in the columns marked with the same letters do not differ significantly from each other

Studies of the physiological state of the leaves of flowerbed geraniums (Table 12) showed that the photosynthetic efficiency of the leaves of plants produced on all substrates, measured by the Fv/Fm index, regardless of the substrate in which they were grown, regardless of whether the mushroom stimulator P or PO was used, remained at a normal level, within the range of 0.810 to 0.841.

The SPAD leaf greenness index ranged from 57.64 to 71.30. It was observed that the addition of a food-based mushroom stimulator (ground fruit bodies) to the substrate increased this index on the leaves of plants produced in the tested substrates (P).

The highest level of photosynthetic pigments was shown in plants grown in the control substrate, as well as in Novarbo 20 and Novarbo 20 with both types of stimulators, as well as Klasmann 5, provided that they contained mushroom stimulators (PO or P). A similar trend was noted for the carotenoid content (Table 12).

Flowering characteristics

a.

b.

c.

d.

Fig. 24. Flower development stages of bedding geranium: a – green bud stage, b – bursting bud, c – fully developed flowers in the inflorescence, d – faded inflorescence

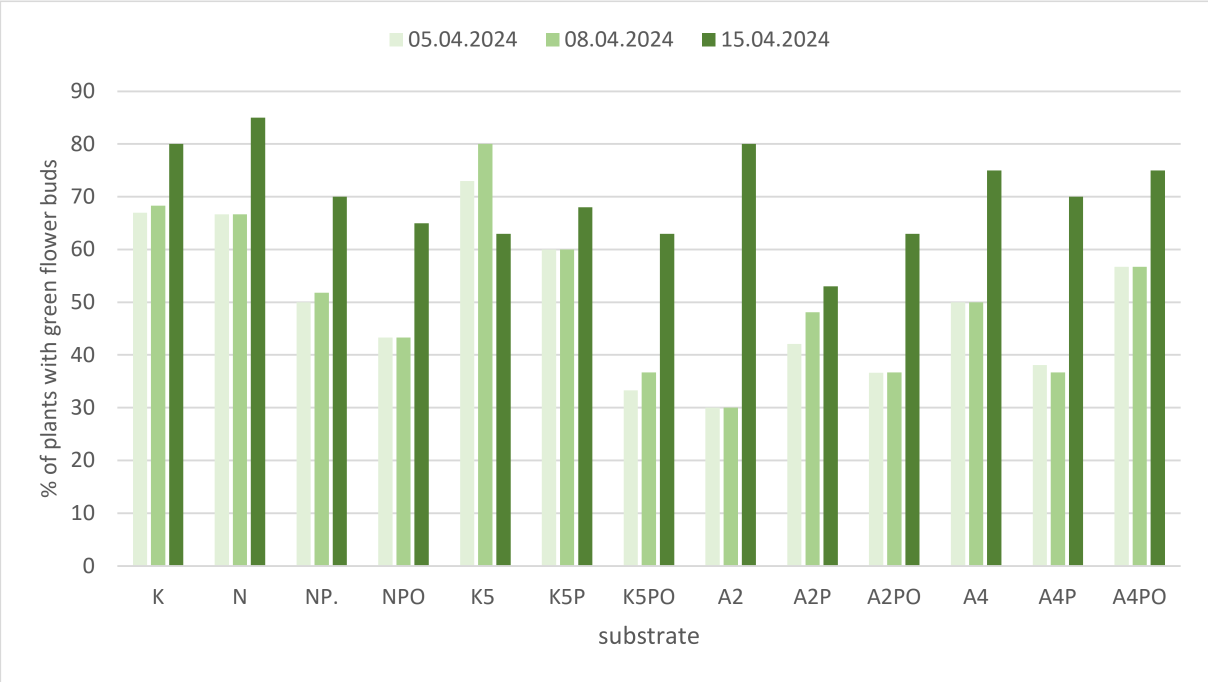


Fig. 25. Percentage of bedding geranium plants with green flower buds from the beginning of the third week of cultivation (5/04) to the fourth week (15/04) depending on the substrate

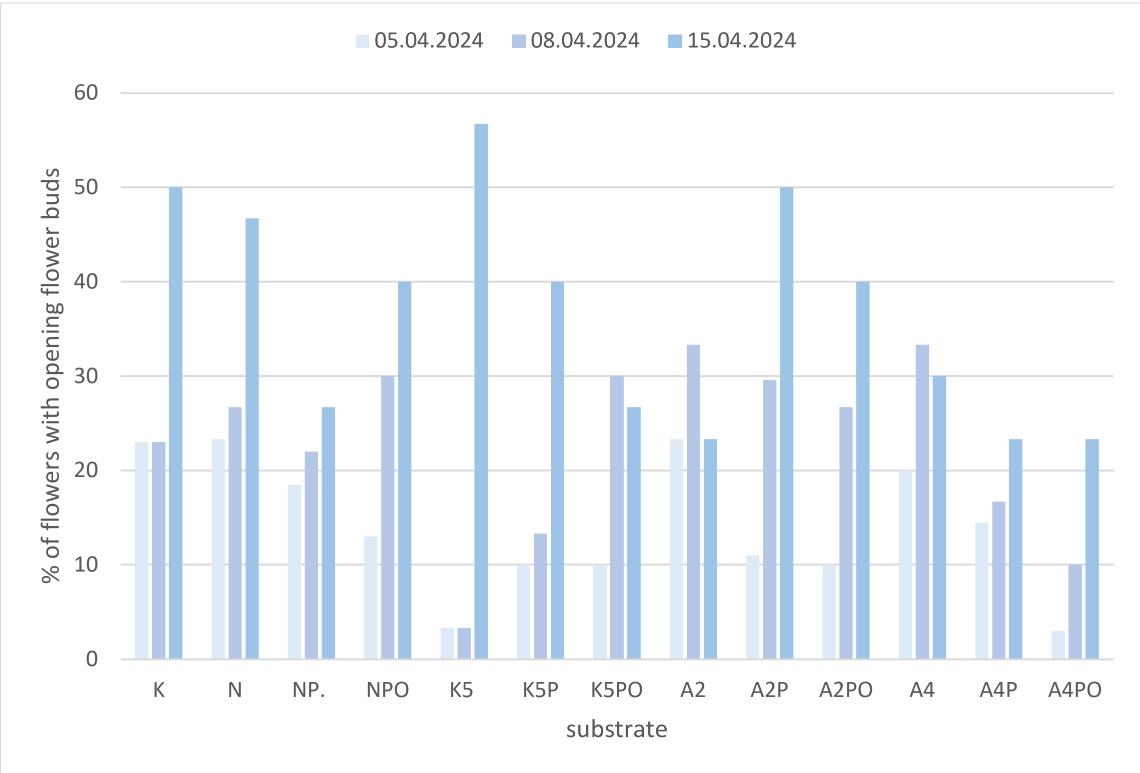


Fig. 26. Percentage of bedding geranium plants with bursting flower buds from the beginning of the third week of cultivation (5/04) to the fourth week (15/04)

Observations of geranium flowering (Fig. 25-26) carried out at the beginning of the third week of cultivation showed that almost 70% of the plants grown on the control substrate (K) had flower buds at the green bud stage (Fig. 24a), and over 20% at the bud burst stage (Fig. 24b). Buds of plants grown in Novarbo and Klasmann 5 substrates developed with similar intensity, when these substrates were not enriched with a mushroom stimulator, which, when added to the above-mentioned substrates, delayed the development of flower buds. Plants grown in Klasmann 5 substrate developed buds quickly, in the fourth week of cultivation almost 60% of geraniums already had bud bursting, which is a better result than in the control.

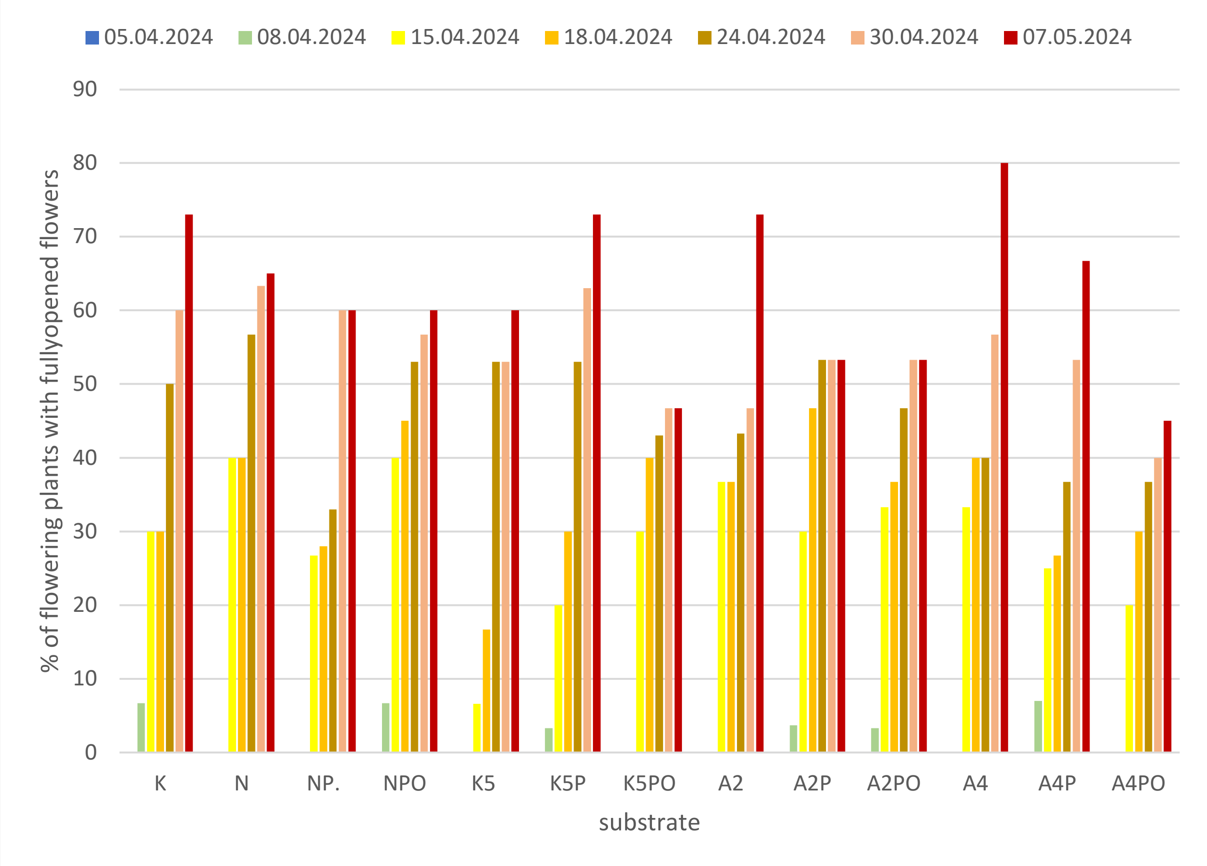


Fig. 27. Flowering dynamics of bedding geraniums depending on the substrate used. Percentage of flowering plants with fully developed flower buds from the beginning of the third week of cultivation (5.04) to the seventh week (7.05)

Fully developed geranium inflorescences appeared earliest in plants growing in the control substrate (K), Novarbo with the post-production dried fruit stimulator NPO), Agaris 4 with the stimulator food dried fruit (AP), as well as in K5P, A2P and A2PO substrates. The flowering dynamics are shown in Fig. 27. In the seventh week of production, over 70% of geraniums from the control substrate had fully developed inflorescences, similarly to those from K5P and A2 substrates. In the case of Agaris 4 substrate, almost 80% of geraniums flowered (Fig. 27). At the same time, plants produced on this substrate had the most faded inflorescences, which reduced the decorative value of the plants (Fig. 28). Plants from Novarbo and Novarbo substrates with the food mushroom stimulator and Klasmann 5 with this stimulator also faded quickly.

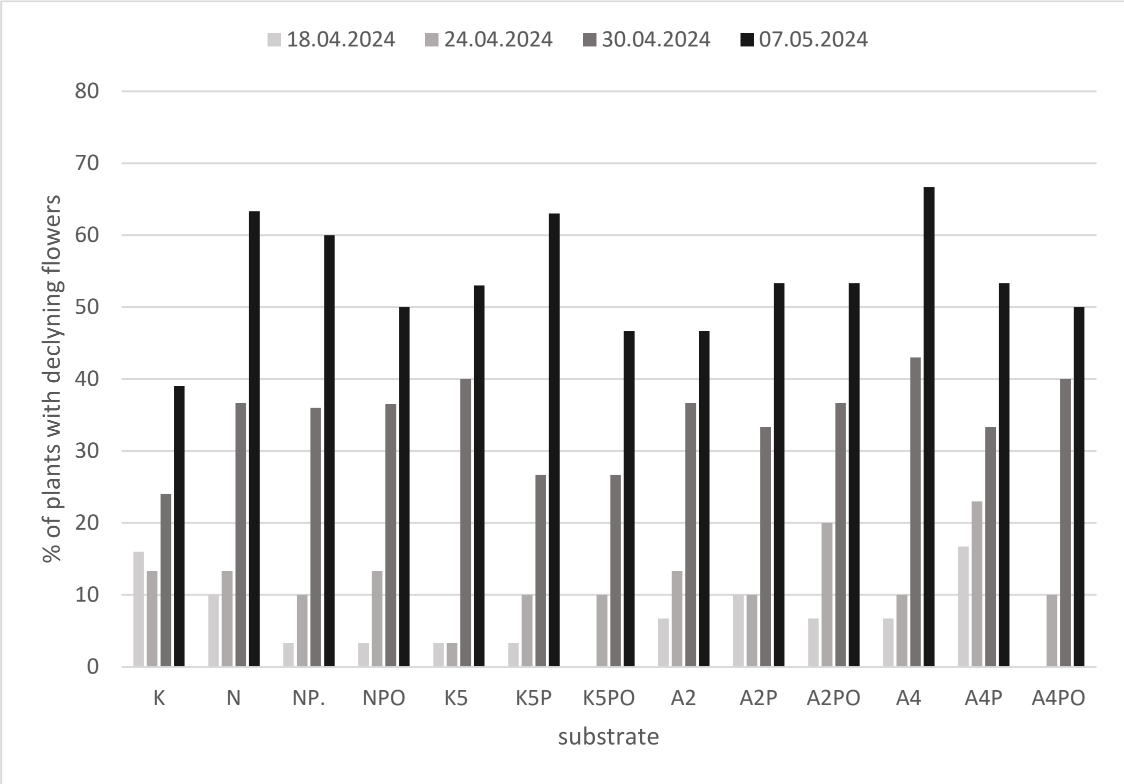


Fig. 28. Percentage of flowering geranium plants with visible fading inflorescences in the period from April 18 to May 7, depending on the substrate

Consumer analysis of the decorativeness of the final product

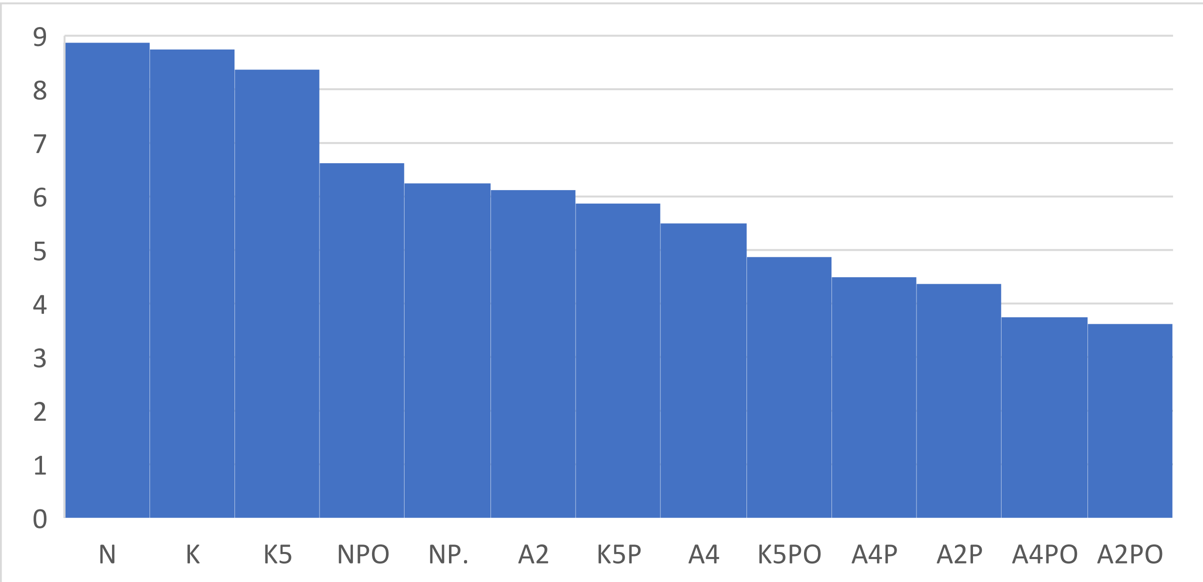


Fig. 29. Results of the consumer evaluation of the final product of flower bed geraniums (scale 3-9) growing on different substrates.

The produced bedding geraniums were subjected to consumer analysis. The decorativeness of the plants was assessed in three categories: flowering (min. 1 point, max. 3 points), plant habit (min. 1 point, max. 3 points) and leaf decorativeness (min. 1 point, max. 3 points). The best results, close to 9 points (this is the maximum value for 3 categories) were obtained for plants produced in the control standard substrate and in Novarbo and Klasmann 5 substrates. The worst in the consumer assessment were geraniums from Agaris 2 and Agaris 4 substrates and when these substrates were enriched with dried mushrooms from mushroom production waste (PO) (Fig. 29).

Analysis of physicochemical properties of substrates

Selected physical properties of substrates used in the greenhouse experiment with bedding geranium determined after the end of cultivation are presented in Table 13. The lowest bulk density, the most desirable feature of a garden substrate, was characteristic of Novarbo 20 and Agaris 2 substrates. At the same time, these substrates had the highest water capacity in relation to the dry mass of the substrate (% ww). The most compacted substrate was Klasmann 5. On the other hand, Novarbo 20 substrate was characterised by the lowest water capacity expressed in volume percentage (% wv), especially in relation to Klasmann 5 and Agaris 4 substrates.

Tab. 13. Właściwości fizyczne podłoży wzbogaconych odpadem pieczarkowym po uprawie pelargonii rabatowej w szklarni doświadczalnej, 15.05.2024 r.

Factor		**Bulk density g cm^{-3}**	**Water capacity % wv**	**Water capacity %ww**
ControlL		*0,069*	*42,4*	*616*
Novarbo 20		0,061 A	38,9 A	**633** C
Agaris 2		0,071 A	42,9 AB	**601** C
Klasmann 5		**0,116** C	44,7 B	384 A
Agaris 4		0,098 B	44,5 B	453 B
No mushroom (0P)		0,087 A	42,1 A	512 A
Dry mushroom (P)		0,089 A	43,4 A	505 A
Waste Mushroom (PO)		0,084 A	42,8 A	537 A
Novarbo 20	0P	0,059 a	38,0 ab	645 e
	P	0,063 a	37,5 ab	596 de
	PO	0,062 a	41,3 a-c	659 e
Agaris 2	0P	0,128 a	49,7 c	396 ab
	P	0,116 a	43,6 a-c	352 a
	PO	0,103 a	40,9 a-c	403 ab
Klasman 5	0P	0,064 a	34,4 a	537 cd
	P	0,078 a	49,3 c	633 de
	PO	0,071 a	44,9 bc	634 de
Agaris 4	0P	0,098 a	46,1 bc	470 bc
	P	0,099 a	43,2 bc	438 a-c
	PO	0,098 a	44,2 bc	452 a-c

Post-hoc comparisons were performed using the Tukey test at p =0.05; the same letters indicate no significant differences between means; two-factor analysis, where factor 1 - type of substrate and factor 2 - addition of a mushroom stimulator in the form of mushroom farm waste; control - peat substrate

The addition of mushroom stimulator did not statistically significantly affect the tested physical properties of the growing media (Table 13).

Significant interactions were demonstrated between the quality of the media and the addition of the mushroom stimulator in the case of water capacity (Table 13, Figs. 30-31).

In the Agaris 2 media, it was demonstrated that a 2.5% addition of the mushroom stimulator, regardless of its form, increased the water capacity of the media expressed in relation to volume (Fig. 30). The same trends were observed for the water capacity expressed in percentage by weight of the dry mass of the Agaris 2 media (Fig. 31).

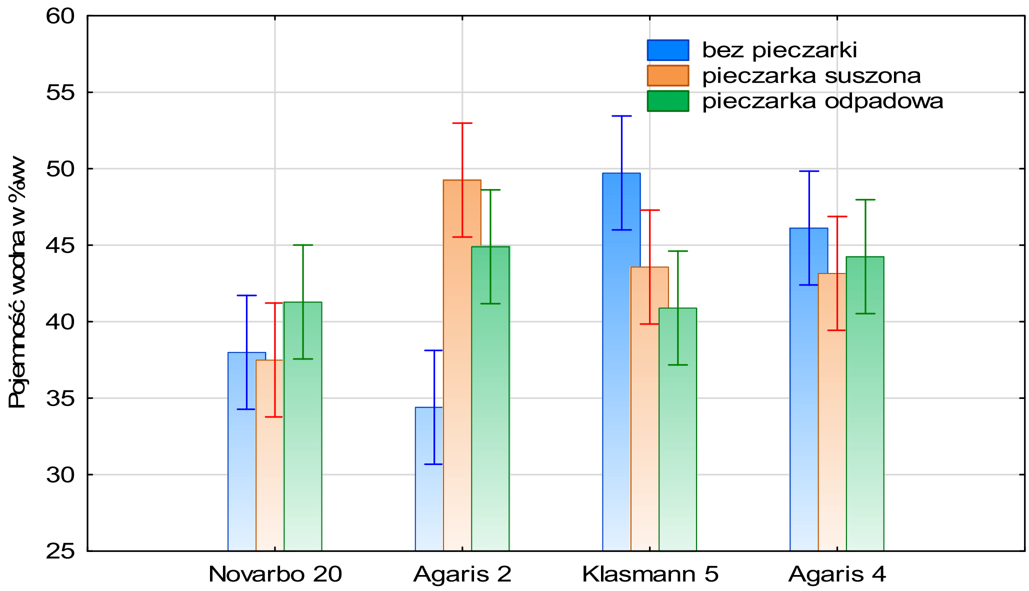


Fig. 30. The effect of the type of substrate and the addition of mushroom stimulator on water capacity (% wv) determined after growing flower-bed geranium in the experimental greenhouse, 15/05/2024.

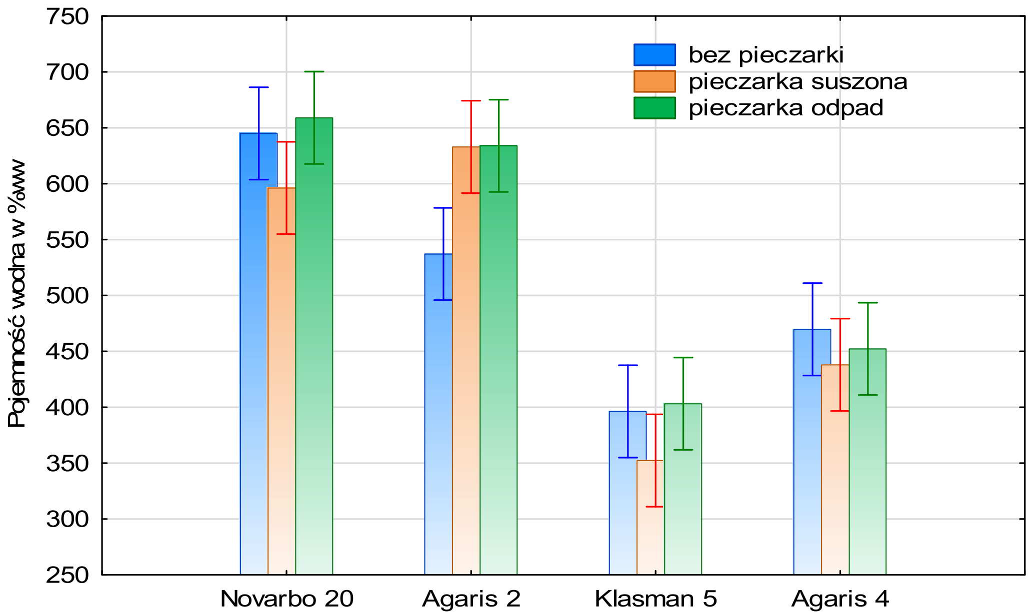


Fig. 31. The effect of the type of substrate and the addition of a mushroom stimulator on the water capacity (% ww) determined after the cultivation of flower bed geranium in the experimental greenhouse on 15/05/2024.

Table 14. Reaction (pH), salinity (EC µS cm-1) and the content of macroelements, sodium (mg dm-3) and organic matter in substrates with the addition of mushroom biostimulator after the cultivation of garden geranium, 15/05/2024.

Factor		pH	EC	NH4	NO3	Ca	K	Mg	P	SO4	Na	SO%
Kontrola		*5,27*	*797*	*3,84*	*158*	*800*	*163*	*142*	*159*	*127*	*73,3*	*94,0*
Klasmann 5		6,36 B	914 C	6,32 AB	146 B	848 B	501 B	162 B	137 A	80,0 A	120 B	66,6 A
Novarbo 20		*5,96* A	922 C	5,20 A	152 B	**1494** C	303 A	147 A	146 A	110 B	68 A	89,7 C
Agaris 4		7,22 C	*524* A	9,34 B	3,49 A	599 A	383 A	197 C	207 B	95,7 AB	83 A	72,3 B
Agaris 2		7,14 C	658 B	5,18 A	4,93 A	671 A	500 B	**231** D	221 B	106 B	107 B	90,7 C
Bez pieczarki (0P)		**6,80** C	611 A	4,03 A	6,0 A	827 A	375 A	194 A	151 A	101 A	**114** C	79,6 AB
Pieczarka suszona (P)		6,69 B	**855** C	4,18 A	**131** C	908 AB	**558** B	180 A	203 B	96,6 A	96 B	80,9 B
Pieczarka odpadowa (PO)		6,53 A	797 B	**11,3** B	92,6 B	973 B	332 A	179 A	179 B	96,2 A	73 A	79,0 A
Klasmann 5	0P	7,12 d-f	685 bc	2,62 a-c	6,08 a	530 a	542 c-e	177 a	107 a	70,2 ab	**178** e	61,9 a
	P	6,22 c	1160 e	2,08 ab	274 d	694 a	701 e	165 a	163 a	71,5 a-c	123 d	70,2 bc
	PO	5,76 a	897 d	14,3 e	158 b	1319 b	259 a	144 a	141 a	98,4 a-d	59 a	67,6 b
Novarbo 20%	0P	5,94 ab	630 bc	2,44 a-c	11,6 a	1596 b	210 a	156 a	113 a	115 cd	74 a-c	90,3 e
	P	5,83 a	941 d	1,85 a	234 cd	1460 b	385 a-c	133 a	169 a	102 a-d	58 a	88,8 e
	PO	6,11 bc	1195 e	11,3 e	209 c	1427 b	313 ab	154 a	155 a	113 b-d	72 a-c	89,9 e
Agaris 4	0P	7,17 d-f	541 b	8,94 a-e	2,31 a	559 a	355 a-c	211 a	207 a	116 d	96 a-d	76,1 d
	P	7,33 ef	647 bc	9,48 b-e	6,94 a	679 a	525 c-e	188 a	228 a	102 a-d	91 a-d	72,2 cd
	PO	7,16 d-f	386 a	9,61 c-e	1,23 a	558 a	267 a	191 a	188 a	68,7 a	61 ab	68,6 bc
Agaris 2	0P	6,96 d	589 bc	2,10 ab	4,05 a	623 a	392 a-c	234 a	178 a	103 a-d	109 b-d	90,0 e
	P	7,38 f	672 bc	3,29 a-d	8,86 a	801 a	619 de	234 a	253 a	111 a-d	113 cd	92,2 e
	PO	7,08 de	712 c	10,2 de	1,89 a	588 a	487 b-d	227 a	232 a	104 a-d	100 a-d	89,8 e

Post-hoc comparisons were performed using Tukey's test at p =0.05; the same letters indicate no significant differences between means; standard – substrate based on high-moor peat; control – peat substrate

The lowest pH determined after the cultivation of bedding geranium was determined in the Novarbo 20% substrate (pH 5.96) and the highest in the Agaris 2 and 4 substrates (Table 14). The pH of the peat substrate (control) was pH 5.27. The highest salt concentration (EC) in the soil solution was demonstrated for the Klasmann 5 and Novarbo 20 substrates (914 and 922 µS cm-1, respectively) and the lowest in the Agaris 4 substrate (524 µS cm-1). The control substrate had an EC of 797 µS cm-1.

Relatively small differences were demonstrated for the concentration of ammonium nitrogen in the tested substrates (Table 14). It ranged from 5.18 mg N-NH4 dm-3 (Agaris 2) to 9.34 mg N-NH4 dm-3 (Agaris 4). In the case of nitrogen content in the nitrate form determined after plant cultivation, high concentrations were shown for Klasmann 5 and Novarbo 20 substrates (146 and 152 mg N-NO3 dm-3, respectively). In the peat substrate analysed after cultivation, 158 mg N-NO3 dm-3 was found. The content of the nitrate form of nitrogen in peat and organic substrates intended for the cultivation of cucumber and tomato seedlings should be in the range of 80-150 mg N-NO3 dm-3 (Nowosielski 1988). The most soluble calcium was contained in Novarbo 20 substrate, more than twice as much as in Agaris 2 and 4 substrates (Table 14). Nowosielski gives a range of 1500-2500 mg Ca dm-3 of peat substrate as suitable for vegetable seedlings.

Two substrates: Klasmann 5 and Agaris 2 were distinguished by a high potassium content (500 mg K dm-3). According to Nowosielski (1988), the potassium content in peat substrates should be 250-500 mg K dm-3 for vegetable seedlings with high nutritional requirements. The highest magnesium content was determined in Agaris 2 substrate (231 mg Mg dm-3) and the lowest in Novarbo 20% substrate (147 mg Mg dm-3). The control substrate had a similar Mg content (142 mg Mg dm-3). Nowosielski (1988) gives the optimal range for magnesium as the standard content in peat substrate intended for vegetable seedlings: 80-250 mg Mg dm-3. The organic matter content in the tested substrates ranged from 72.3% (Agaris 4) to 90.7% (Agaris 2). In the control substrate, 94% of organic matter was determined (Table 14).

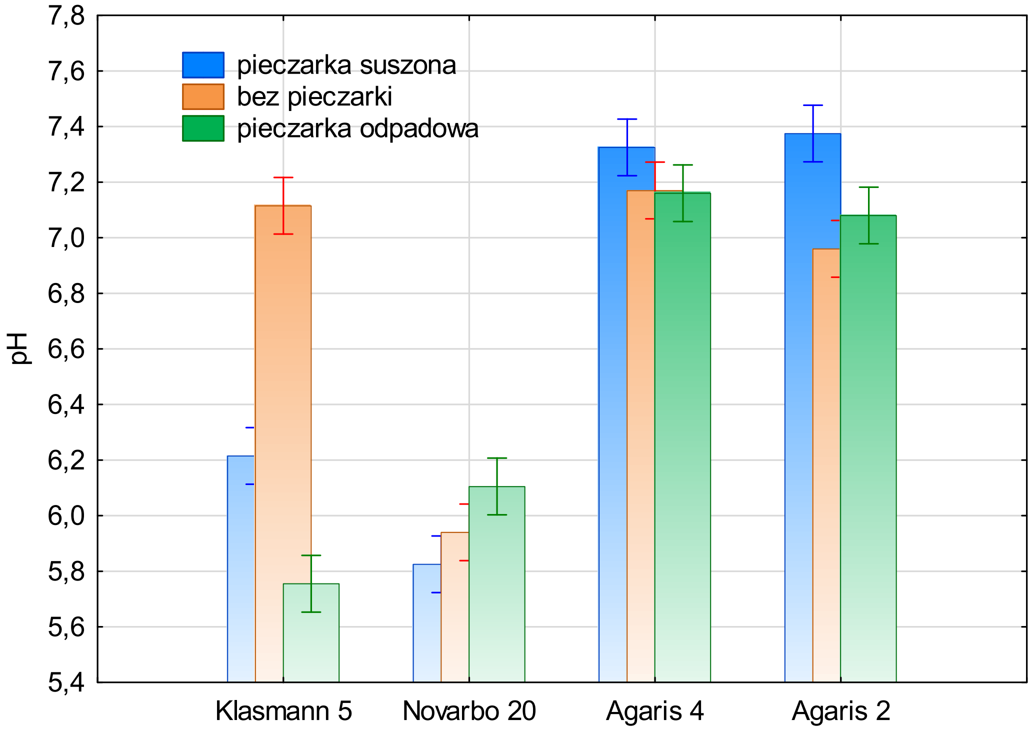


Fig. 32. The effect of the type of substrate and the addition of a mushroom stimulator on the pH determined after growing flower-bed geraniums in an experimental greenhouse, 15/05/2024.

With the exception of potassium, magnesium and sulphur, the addition of the mushroom stimulator significantly affected the pH, EC and content of mineral components in the substrates analysed after the cultivation of bedding geranium (Table 14). In general, the addition of fungi lowered the pH of the substrates and increased their salinity. The addition of dried edible mushrooms (P) significantly increased the content of nitrate nitrogen (N-NO3), potassium and phosphorus in the substrates. On the other hand, the addition of dried mushroom waste (PO) increased the level of ammonium nitrogen and phosphorus in the substrates in relation to the untreated combinations.

A significant effect of the interaction of the experimental factors on the pH, EC and content of mineral components (except for Mg and P) in the substrates analysed after the cultivation of bedding geranium was demonstrated (Table 14, Figs. 31-32). In the Klasmann 5 substrate, the addition of the fungal stimulator, regardless of its form, significantly reduced the pH of the substrate. In Agaris substrates, and especially in Agaris 2, the addition of dried edible mushrooms increased the pH of the substrate. The opposite reaction was observed for Novarbo 20 substrate (Fig. 31). The highest salt concentration was shown in Novarbo 20 substrate with the addition of mushroom waste and in Klasmann 5 substrate with the addition of dried mushrooms (Table 14). Mushroom waste (2.5% additive) increased the N-NH4 content in Klasmann 5, Novarbo 20 and Agaris 2 substrates. An increase in Ca content in Klasmann 5 substrate was shown only for the addition of mushroom waste. A tendency towards an increase in the content of soluble potassium was observed in relation to the control after the addition of dried edible mushrooms to Klasmann 5 and Agaris 2 and Agaris 4 substrates.

In Klasmann 5 substrate after the use of fungal stimulants, regardless of their form, significantly more organic matter was determined than in the substrate without additives (Fig. 33). The opposite relationship was observed for the Agaris 4 substrate, which, next to the Klasmann 5 substrate, had the lowest content of organic matter among the substrates tested in the experiment.

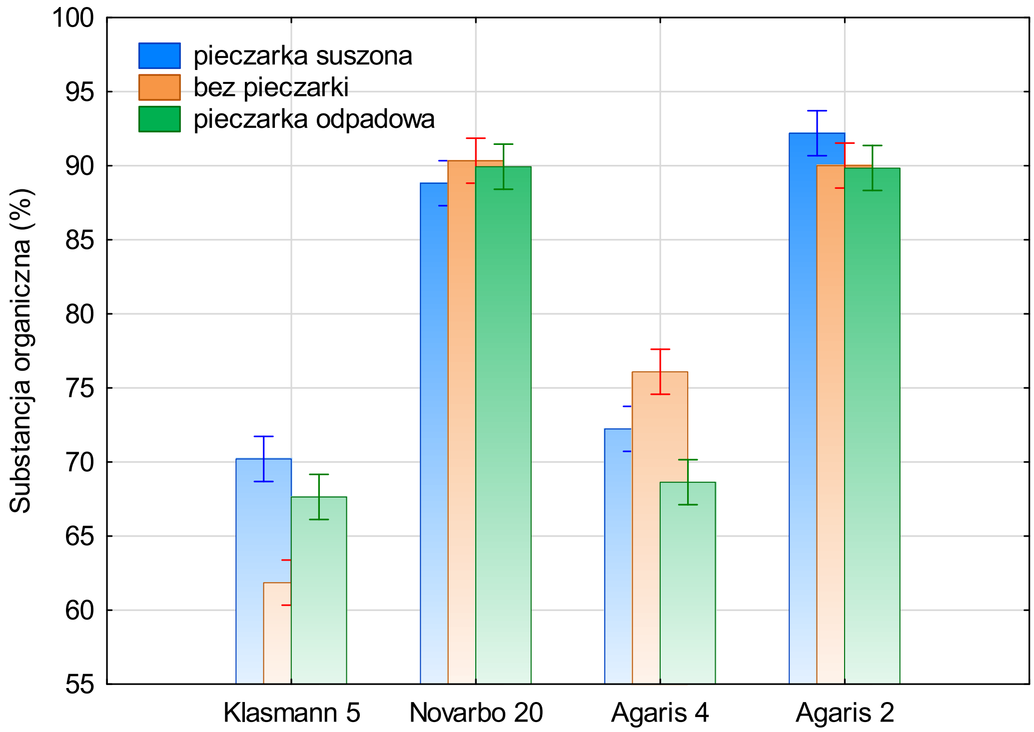


Fig. 33. The effect of the type of substrate and the addition of mushroom stimulator on the organic matter content (%) determined after the cultivation of flower-bed geranium in the experimental greenhouse, 15/05/2024.

In general, as in the case of the experiment with the marigold, with the exception of boron, the peat-free substrates and those with limited peat content contained more general forms of microelements, especially iron, manganese and zinc (Table 15). The total boron content in the substrates tested after the cultivation of bedding pelargonium ranged from 1.74 mg B kg-1 d.m. (Agaris 4) is 28.5 mg B kg-1 d.m. (Agaris 2). The highest levels of copper and molybdenum were determined in the Agaris 2 substrate, and iron in the Agaris 4 substrate. Klasmann 5 substrate contained the most zinc (Table 15). The determinations made in the substrates after the cultivation of bedding pelargonium showed that the addition of fungal stimulants increased the content of boron in the substrates, as well as zinc, in the case of dried edible mushrooms (Table 15).
The highest manganese content was found in the substrate not treated with fungal additives. A significant effect of interaction between experimental factors: substrate x fungal stimulant addition on the content of Cu, Mn and Zn in the substrates was demonstrated. The highest levels of Cu and Zn were determined in the Agaris 2 substrate with the addition of dried edible mushrooms (Table 15). In the Agaris 4 substrates, fungal stimulants reduced the total manganese content determined after the cultivation of geraniums. In the peat-free Klasmann 5 substrate, the addition of mushroom waste significantly reduced the zinc content.

Table 15. Total content (after mineralization in HNO3) of microelements (mg kg-1 d.m.) determined in substrates after cultivation of garden geranium

Factor		B	Cu	Fe	Mn	Mo	Zn
Controll		*8,15*	*20,7*	*972*	*27,2*	*5,97*	*32,1*
Klasmann 5		7,41 A	36,1 A	13065 B	227 C	12,8 B	**77,8** D
Novarbo 20		13,2 B	32,8 A	1662 A	*71,4* A	7,35 A	46,4 A
Agaris 2		**28,5** C	**55,5** C	2831 A	140 B	**17,0** C	53,2 B
Agaris 4		1,74 A	46,3 B	**17861** C	213 C	12,0 B	59,5 C
Bez pieczarki (0P)		10,1 A	43,4 A	9632 B	**175** B	11,7 A	60,3 B
Pieczarka suszona (P)		16,0 B	42,9 A	8697 AB	161 A	13,0 A	**64,5** C
Pieczarka odpadowa (PO)		12,1 AB	41,7 A	8235 A	152 A	12,2 A	*52,9* A
Klasmann 5	0P	5,85 a	42,6 bc	14424 a	245 ef	11,9 a	89,4 e
	P	10,3 a	33,0 a	12741 a	231 ef	13,6 a	82,5 e
	PO	6,0 a	32,7 a	12029 a	206 de	13,0 a	61,4 cd
Novarbo 20	0P	10,8 a	33,7 ab	1048 a	71,5 a	8,3 a	44,1 a
	P	17,1 a	31,7 a	2318 a	73,8 a	6,7 a	50,6 a-c
	PO	11,7 a	33,1 a	1619 a	68,8 a	7,1 a	44,5 a
Agaris 2	0P	23,6 a	50,5 cd	3494 a	138 b	15,2 a	47,3 ab
	P	33,2 a	**62,8** e	2863 a	153 bc	19,2 a	64,7 d
	PO	28,6 a	53,2 d	2137 a	130 b	16,6 a	47,5 ab
Agaris 4	0P	0,14 a	46,9 cd	19562 a	246 f	11,4 a	60,6 cd
	P	3,22 a	44,3 cd	16866 a	188 cd	12,3 a	60,1 cd
	PO	1,85 a	47,8 cd	17155 a	205 de	12,3 a	57,9 b-d

Post-hoc comparisons were performed using Tukey's test at p = 0.05; the same letters indicate no significant differences between means; control – peat substrate

Analyses of plant material

Table 16 presents the results of determinations of the dry matter, macroelements and sodium content in bedding geranium plants collected for testing on the day of experiment liquidation. The dry matter content in plants ranged from 11.0% (Klasmann 5) to 12.1% (Agaris 2 and 4) and was significantly dependent on the growing medium used in the experiment. Plants growing in peat substrate had 11.4% dry matter. The highest nitrogen content was determined in the biomass of geraniums growing in Novarbo 20 substrate (3.26% N) and the lowest in Agaris 2 (2.65% N). Similar relationships were demonstrated for calcium content in biomass. Pelargoniums growing in Novarbo 20 substrate had the highest Ca content, and the lowest in Agaris 2 and Agaris 4 substrates. This corresponded to the calcium content determined in these substrates after the geranium cultivation was completed. Plants collected for analysis from the control substrate contained 3.08% N and 2.52% Ca in dry mass.

The highest potassium and sodium levels were determined in plants growing in the Klasmann 5 substrate (4.46% K in dry mass and 0.17% Na in dry mass, respectively) and the lowest in the Agaris 2 and 4 substrates (Table 10). The least magnesium was determined in the biomass of pelargonium collected for testing from the Novarbo 20% combination. In general, all plants growing in substrates with limited peat content were distinguished by a lower Mg content (0.26-0.30% Mg in dry mass) than plants growing in the peat substrate (0.39% Mg in dry mass). The highest sulfur levels were determined in plants growing in the Agaris 2 substrate (Table 16).

Table 16. Content of macroelements (% d.m.) and sodium (mg kg-1 d.m.) in flower-bed geranium grown in substrates with the addition of a mushroom stimulator in experimental greenhouse conditions, 15/05/2024.

Factor		s.m.	N	Ca	K	Mg	P	S	Na
Controla		***11,4***	***3,08***	***2,52***	***3,19***	***0,39***	***0,58***	***0,22***	***0,099***
Novarbo 20		11,5 AB	**3,26** D	**2,11** D	*3,16* A	*0,26* A	0,57 AB	0,24 B	*0,11* A
Klasmann 5		11,0 A	2,86 C	1,62 C	**4,46** C	0,30 B	0,56 A	*0,22* A	**0,17** D
Agaris 2		12,1 B	2,65 A	*1,24* A	3,91 B	0,30 B	0,57 AB	**0,26** D	0,16 C
Agaris 4		12,1 B	2,82 B	1,35 B	3,66 B	0,30 B	0,60 B	0,26 C	0,15 B
Bez pieczarki 0P)		11,4 A	2,94 B	1,51 A	3,88 A	0,30 B	0,56 B	0,23 A	0,14 A
Pieczarka suszona (P)		12,1 A	2,79 A	1,60 B	3,66 A	0,26 A	0,54 A	**0,26** C	0,15 B
Pieczarka odpad (PO)		11,5 A	**2,96** C	1,62 B	3,86 A	**0,31** C	**0,63** C	0,24 B	0,15 B
Novarbo 20%	0P	11,1 a	3,28 f	**2,28** i	3,13 ab	0,30 cd	0,57 b-d	0,24 cd	0,10 a
	P	12,5 a	3,32 f	2,12 h	3,32 a-c	0,24 a	0,57 b-d	0,23 cd	0,11 a
	PO	11,0 a	3,16 e	1,93 g	3,05 a	0,25 ab	0,58 cd	0,24 d	0,12 a
Agaris 2	0P	11,6 a	2,82 ab	1,13 a	3,76 a-d	0,29 c	0,56 b-d	0,23 b-d	0,14 b
	P	12,3 a	2,14 a	1,29 a-c	3,54 a-c	0,29 c	0,49 a	0,30 f	0,18 e
	PO	12,4 a	3,00 d	1,30 bc	4,43 d	0,32 ef	0,67 ef	0,25 e	0,15 bc
Klassman 5	0P	10,0 a	2,81 ab	1,47 d	**5,26** e	0,30 c-e	0,61 de	0,216 a	0,17 d
	P	12,0 a	2,93 c	1,65 ef	4,06 cd	0,27 b	0,51 ab	0,220 a	0,17 d
	PO	10,9 a	2,85 b	1,75 f	4,06 cd	0,33 fg	0,57 b-d	0,22 ab	0,19 e
Agaris 4	0P	12,7 a	2,85 b	1,17 ab	3,39 a-c	0,31 de	0,52 a-c	0,23 a-c	0,15 bc
	P	11,7 a	2,78 b	1,37 cd	3,71 a-d	0,26 b	0,58 b-d	0,30 f	0,16 c
	PO	11,8 a	2,82 ab	1,50 de	3,88 b-d	**0,34** g	**0,69** f	0,24 de	0,15 bc

Post-hoc comparisons were performed using the Tukey test at p =0.01; the same letters indicate no significant differences between means; two-factor analysis, where factor 1 – medium, factor 2 – addition of mushroom stymulant

The addition of mushroom stimulants significantly affected the mineral composition of the biomass of flowerbed geraniums, except for potassium. Also in the case of dry mass, no significant relationship was found between the water content in plant tissues and the presence of additives in the fungal substrates (Table 16). The highest levels of N, Mg and P were determined in the biomass collected for testing from substrates with the addition of dried waste mushrooms.

Dried edible mushrooms introduced to the substrates as a stimulant significantly increased the content of Ca, S and Na in geraniums in relation to the control. With the exception of dry mass, a statistically significant effect of the interaction of the experimental factors on the content of macronutrients in the plant biomass was found. In the case of the Novarbo 20 substrate, the addition of waste mushrooms significantly reduced the N content in geraniums in relation to the remaining experimental combinations (Fig. 34). The opposite relationship was observed for the Agaris 2 substrate. The highest Ca content was found in plants growing in the Novarbo 20 substrate without fungal additives (Table 13). The addition of dried and waste mushrooms increased the calcium content in geraniums growing in the Agaris 4 substrate.

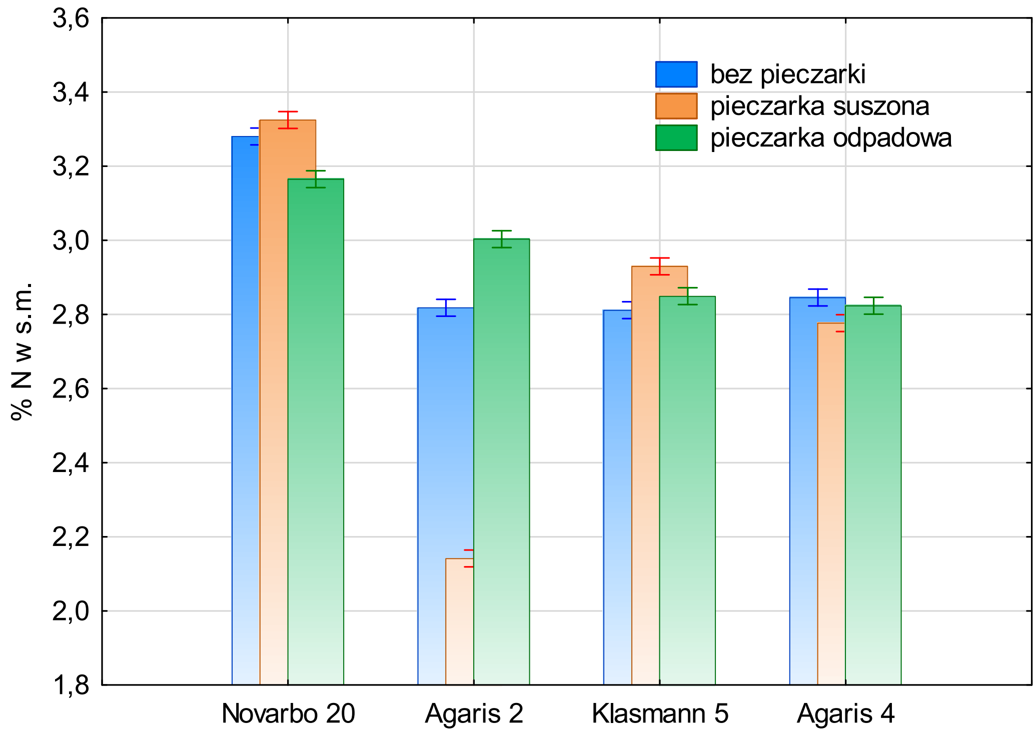


Fig. 34. The effect of the type of substrate and the addition of mushroom stimulator on the nitrogen content (% N in dry matter) in the biomass of flowering pelargonium grown in the experimental greenhouse conditions, 15/05/2024.

Plants growing in Klasmann 5 substrate without the addition of fungal stimulants contained the most potassium (Fig. 35). A tendency of increased potassium content in the biomass of geraniums was observed in the cultivation in Agaris 2 and 4 substrates with waste mushroom. Especially in Agaris 2 substrate, where statistically significantly more of this element was found in plants after the addition of waste mushroom. The least magnesium was determined in geraniums growing in Novarbo 20% substrate with the addition of mushroom stimulants (Fig. 36). In the remaining substrates, the addition of dried waste mushroom significantly increased the Mg content in the biomass.

As in the case of potassium, the most phosphorus was contained in geraniums growing in Agaris 2 and 4 substrates with the addition of waste mushroom (Fig. 37). On the other hand, in Klasmann 5 substrate, the addition of mushroom stimulants reduced the content of this element in plants. Plants growing in Agaris 2 and 4 substrates with the addition of dried mushrooms contained significantly more sulfur than in the substrate with waste mushrooms or without fungal additives (Fig. 38).

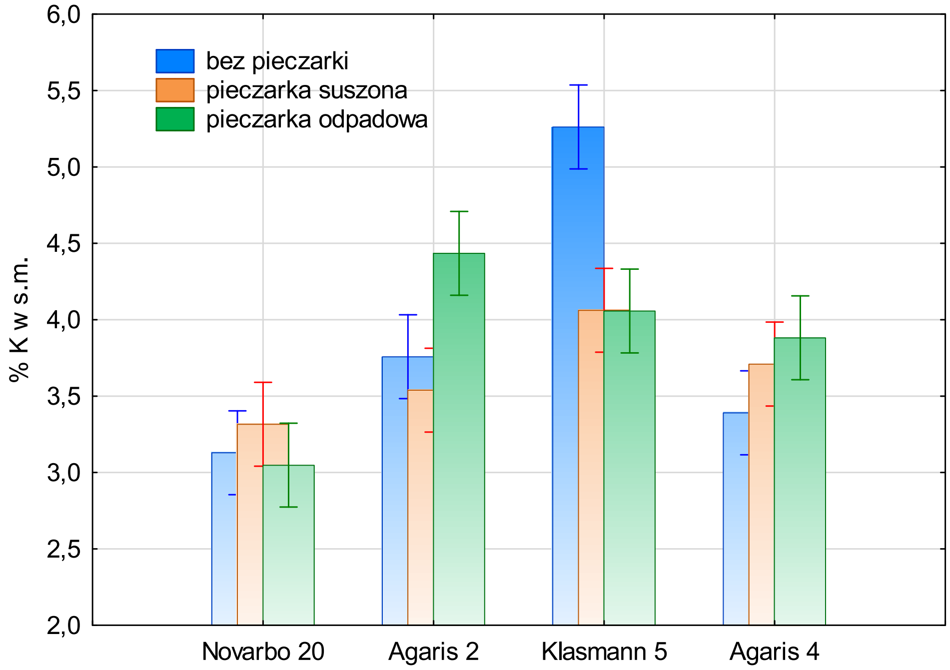


Fig. 35. The effect of the type of substrate and the addition of mushroom stimulator on the potassium content (% K in dry matter) in the biomass of flowering pelargonium grown in the experimental greenhouse conditions, 15/05/2024.

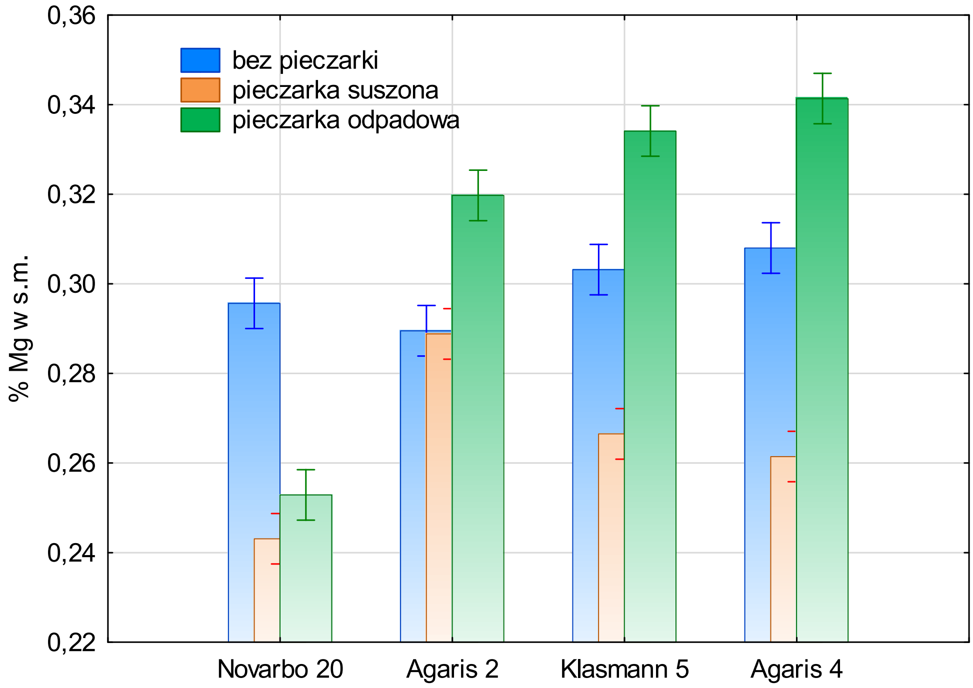


Fig. 36. The effect of the type of substrate and the addition of mushroom stimulator on the magnesium content (% Mg in dry matter) in the biomass of flowering pelargonium grown in the experimental greenhouse conditions, 15/05/2024.

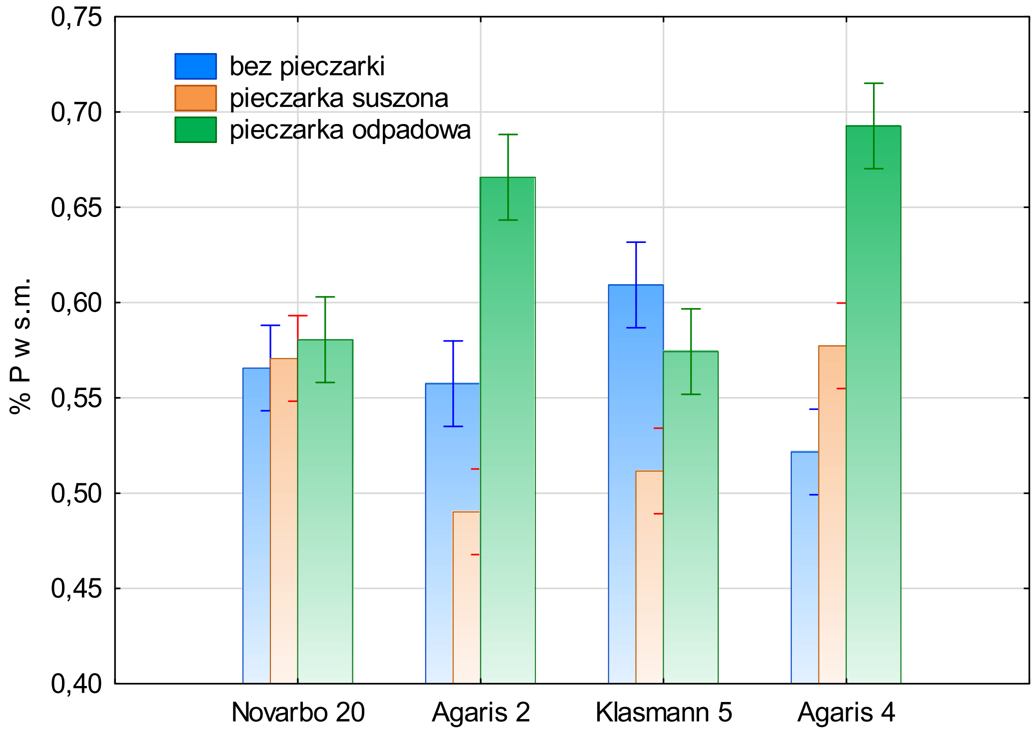


Fig. 37. The effect of the type of substrate and the addition of mushroom stimulator on the phosphorus content (% P in dry matter) in the biomass of flowering pelargonium grown in the experimental greenhouse conditions, 15/05/2024.

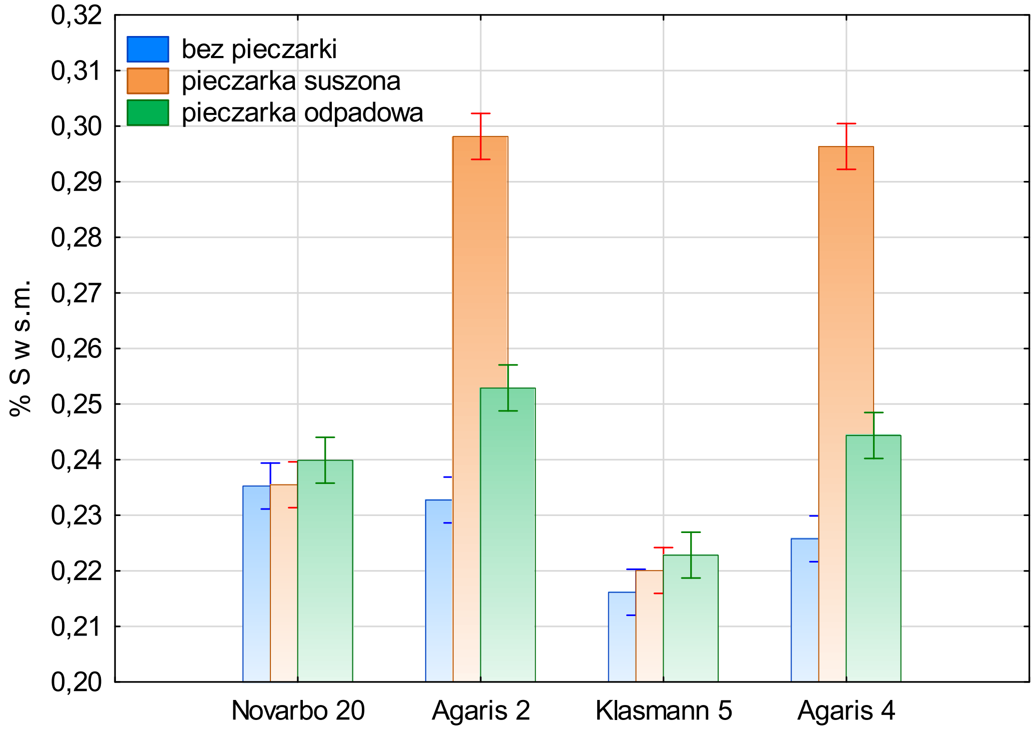


Fig. 38. The effect of the type of substrate and the addition of mushroom stimulator on the sulfur content (% S in dry matter) in the biomass of flowering pelargonium grown in the experimental greenhouse conditions, 15/05/2024.

In general, bedding geraniums growing in high peat (control) contained more copper, iron, manganese, but less molybdenum and zinc compared to plants from peat-free substrates or with limited peat content (Table 17). Comparing the substrates used in the study, it was shown that the most boron was determined in bedding geraniums grown in peat-free Klasmann 5 substrate (Table 17). Plants collected for the study from Novarbo 20 substrate with limited peat content were best supplied with Cu, Fe, Mn and Mo. On the other hand, geraniums collected for the study from Agaris 2 substrate contained the most zinc. The addition of a mushroom stimulator in the form of dried edible mushroom (P) significantly increased the iron and zinc content in plants (Table 17). On the other hand, the most copper was shown in the biomass of bedding geraniums grown in substrate with the addition of waste mushroom (PO). A statistically significant effect of the interaction of the studied factors on the content of microelements in the biomass of flower bed geranium was demonstrated (Table 17). In general, in peat-free substrates, the addition of waste mushroom (PO) improved the supply of plants with copper. On the other hand, in the substrate with limited peat content Novarbo 20, the addition of the fungal stimulator in this form reduced the availability of Cu, Mn and Zn to plants in relation to untreated substrates. A decrease in the content of Mn, Mo and Zn was also demonstrated in plants growing in this substrate as a result of the addition of the stimulator in the form of dried edible mushroom (P). Supplementation with the mushroom stimulator in the form of dried edible mushroom increased the Fe content in plants growing in the Novarbo 20 substrate. In Agaris substrates, the addition of mushroom stimulators, regardless of their form, improved the supply of plants with zinc.

Table 17. Content of microelements (mg kg-1)* in the biomass of flower bed pelargonium growing in substrates with the addition of mushroom biostimulator in experimental greenhouse conditions (URK),

FACTOR		**B**	**Cu**	**Fe**	**Mn**	**Mo**	**Zn**
Controla		*36,2*	*7,73*	*788*	*528*	*1,50*	*73,8*
Klasmann 5		**46,6** B	6,44 C	92,4 A	153 B	3,14 A	68,9 B
Novarbo 20		37,6 A	**7,12** D	**165** C	**188** C	**4,28** B	70,0 B
Agaris 2		38,9 A	6,07 B	138 B	134 A	3,06 A	**73,4** C
Agaris 4		38,8 A	5,74 A	103 A	133 A	3,14 A	58,0 A
Bez pieczarki (0P)		*37,1* A	6,46 B	91,1 A	150 A	4,23 B	67,2 B
Stymulator pieczarkowy (P)		41,6 B	5,87 A	**160** C	156 A	2,98 A	**71,1** C
Pieczarka odpadowa (PO)		42,8 B	**6,69** C	122 B	151 A	3,00 A	64,4 A
Klasmann 5	0P	35,9 a	6,80 de	63,4 a	94 a	4,16 c	73,1 d
	P	48,0 c	5,73 ab	106 b	165 d	2,67 ab	68,3 c
	PO	**55,9** d	6,78 de	108 b	199 e	2,58 a	65,3 c
Novarbo 20	0P	37,5 ab	7,49 f	113 b	223 f	6,68 d	80,0 e
	P	37,9 ab	7,07 ef	213 d	191 e	2,97 ab	72,8 d
	PO	37,5 ab	6,80 de	168 c	151 cd	3,18 b	57,2 b
Agaris 2	0P	38,1 ab	6,05 bc	90,2 ab	137 bc	2,86 ab	65,4 c
	P	41,7 b	5,40 a	211 d	146 cd	3,16 b	78,5 e
	PO	37,0 ab	6,76 de	112 b	119 b	3,15 b	76,3 de
Agaris 4	0P	36,8 ab	5,51 ab	97,6 b	144 c	3,20 b	50,4 a
	P	38,7 ab	5,26 a	111 b	121 b	3,13 b	64,7 c
	PO	41,0 ab	6,44 cd	101 b	136 bc	3,09 ab	58,9 b

Post-hoc comparisons were performed using Tukey's test at p = 0.01; the same letters indicate no significant differences between means; control – peat substrate

Research results: experiment 3 – cultivation of ivy-leafed geranium

a. b.

c. d.

Fig. 39. Cultivation of ivy-leafed geranium 'Decora Rood' (Pelargonium peltatum) in experimental greenhouses of the Faculty of Biotechnology and Horticulture, University of Agriculture in Krakow: a – 15/04/2024, b – 25/04/2024, c – 6/05/2024, d - 25/05/2024.

Ivy-leafed pelargonium 'Decora Rood' (Pelargonium peltatum) was grown in the experimental greenhouse of the Faculty of Biotechnology and Horticulture of the University of Agriculture in Krakow from March 22 to June 6, 2024 (Fig. 39 a-d) on substrates with limited peat content and peat-free, also enriched with a mushroom stimulator: waste from mushroom cultivation (PO) and food prepared from dried fruiting bodies (P). During the experiment, visual observations of the plants were made, including observations of emerging flowers. After obtaining the final product in the 11th week of cultivation (June 6), detailed measurements and analyses were carried out, and the most important results are presented below.

Characteristics of plants and physiological condition of leaves

Observations carried out during the cultivation of ivy-leaved geranium showed an inhibiting effect of the applied mushroom stimulator, both from post-production waste and food produced from mushroom fruiting bodies, on the length of developing geranium shoots (Fig. 40). These observations confirmed the previously demonstrated reaction of tall marigold and flowering geranium to the use of 2.5% of the mushroom stimulator in the growing medium, which had an inhibiting effect on the height of the plants.

a. b.

Fig. 40. The influence of the food-based mushroom stimulator on the height of ivy-leafed pelargonium plants after cultivation on different substrates

The inhibiting effect of the mushroom stimulator on plant development was confirmed by measurements of the mass of the above-ground part of ivy-leaved pelargonium taken at the end of cultivation (Fig. 41). The highest mass was characteristic of pelargoniums from the control substrate (standardly used for production), but plants produced in the Novarbo 20 substrate were at the same statistical level. The addition of the mushroom stimulator to this substrate reduced the mass of the above-ground part. An identical tendency was observed for the other tested substrates. On all Agaris substrates, i.e. A2, A2PO, A2P, A4, A4PO, A4P, the mass of the obtained plants was at least twice smaller than those obtained in the control substrate (Fig. 41).

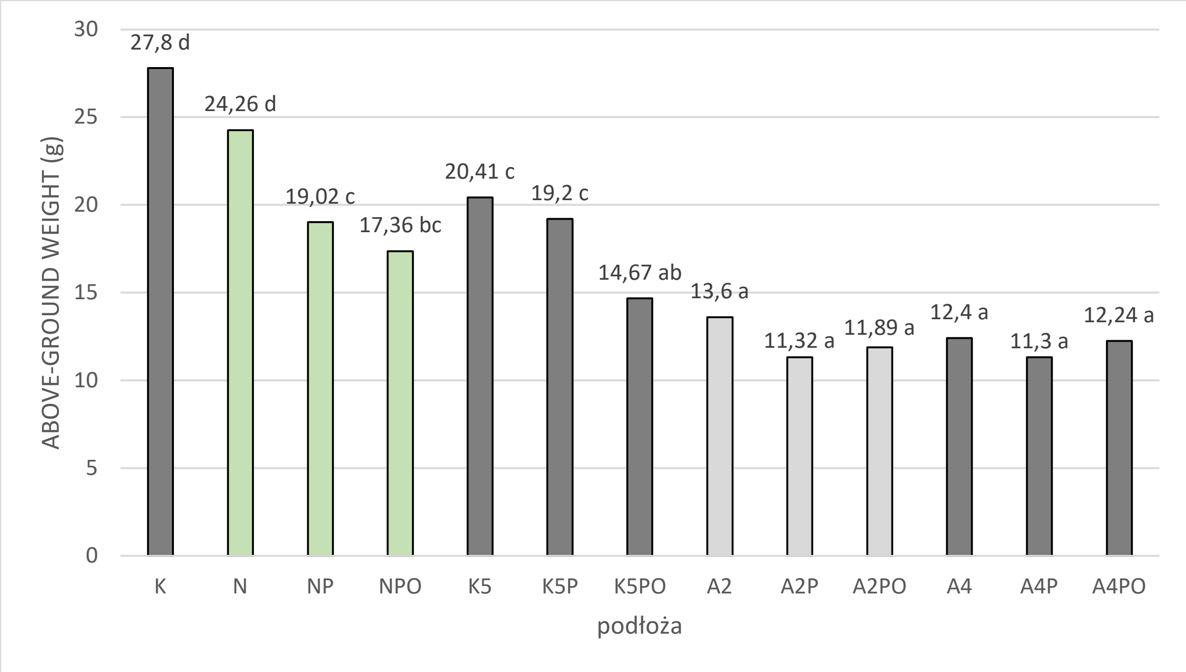


Fig. 41. The influence of the substrate on the mass of the above-ground part of the ivy-leafed pelargonium after the cultivation is finished, depending on the substrate used.

Table 18. The effect of substrate and substrate containing two types of mushroom stimulator (PO, P) on the content of photosynthetic pigments and the greenness index of ivy-leafed pelargonium leaves at the end of cultivation

Substrate	**SPAD**	**Chlorophyll a**	**Chlorophyll b**	**Carotenoids**
K	**51,20 e***	**5,1487 efg**	**3,8565 cde**	**0,6069 de**
N	**48,97 de**	**4,971 e**	**3,811 bcde**	0,481 bcd
NP	**46,25 bcd**	**5,537 fg**	**3,961 de**	**0,725 e**
NPO	43,35 bc	**5,697 g**	**4,171 e**	**0,739 e**
K5	43,63 bc	3,350 ab	3,438 ab	0,327 b
K5P	42,66 bc	3,857 bc	3,561 abc	0,472 bcd
K5PO	46,77 cd	4,887 e	3,767 bcd	0,530 cd
A2	42,88 bc	3,681 abc	3,312 a	0,326 b
A2P	**45,50 bcd**	**5,023 ef**	**4,079 de**	0,503 cd
A2PO	44,06 bc	3,989 cd	3,352 a	0,389 bc
A4	37,99 a	3,114 a	3,684 abcd	0,121 a
A4P	42,65 b	4,530 de	3,693 abcd	0,528 cd
A4PO	41,35 b	4,048 cd	3,851 cde	0,329 b

* the means in the columns marked with the same letters do not differ significantly from each other

Studies of the physiological state of ivy-leafed geranium leaves (Table 18) showed that the SPAD leaf greenness index ranged from 37.99 (on A4 substrate) to 51.2 (on the control substrate). The highest SPAD values were observed, apart from the control, in the leaves of plants from Novarbo 20 substrate, Novarbo 20 with dried food (NP) and from Agaris 2 substrate with dried food (2P). This is correlated with the highest content of photosynthetic pigments, especially chlorophyll a, the highest level of which was observed in plants from the above-mentioned substrates. Additionally, plants from Novarbo substrate with dried mushrooms from mushroom production (NPO) had a high chlorophyll content. Analysis of samples for chlorophyll b content confirmed the above results, as did analyses for carotenoid content.

Flowering characteristics

Observations carried out in the fifth week of ivy-leafed geranium cultivation showed that the majority of plants produced on the Klasmann 50 substrate had visible flower buds – 50% of plants (Fig. 41- 42a). Buds were also observed in approx. 40% of plants from the Novarbo 20 and K5PO substrates, as well as in approx. 30% of plants from the Control substrate, Agaris 4 and Agaris 4 with mushroom stimulants, and Novarbo 20 with mushroom stimulants.

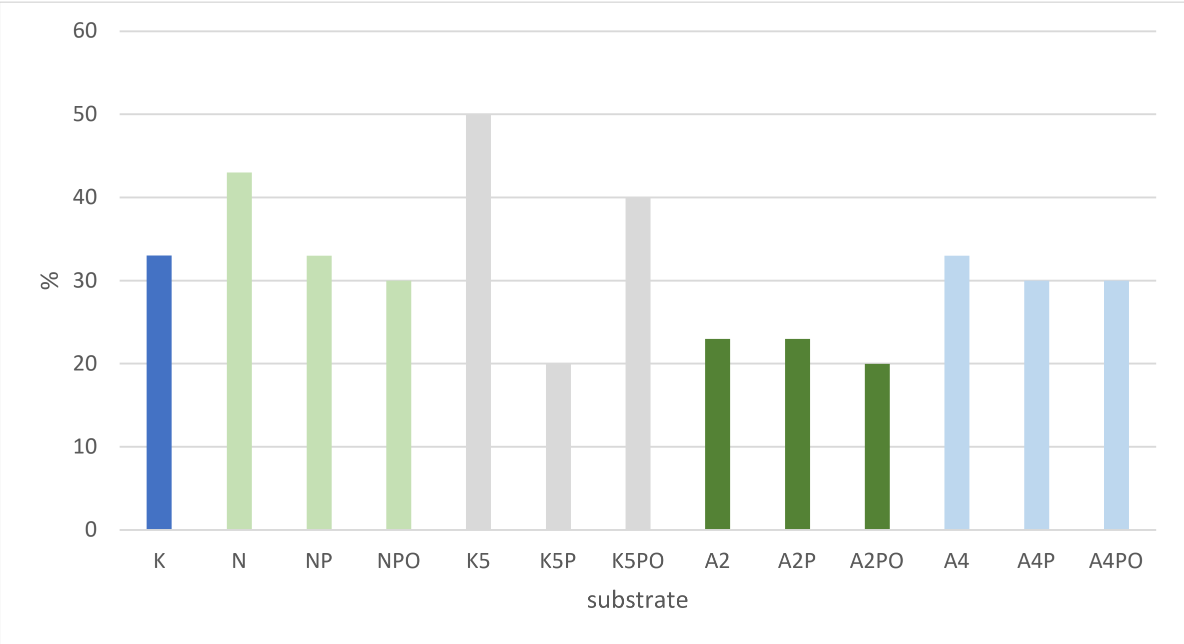


Fig. 41. Percentage of ivy-leafed geranium plants with visible flower buds (green bud stage)

a.

b.

Fig. 42. Flowering of ivy-leaved pelargonium: a – formation of flower buds (green bud stage), b - full flowering of the entire inflorescence

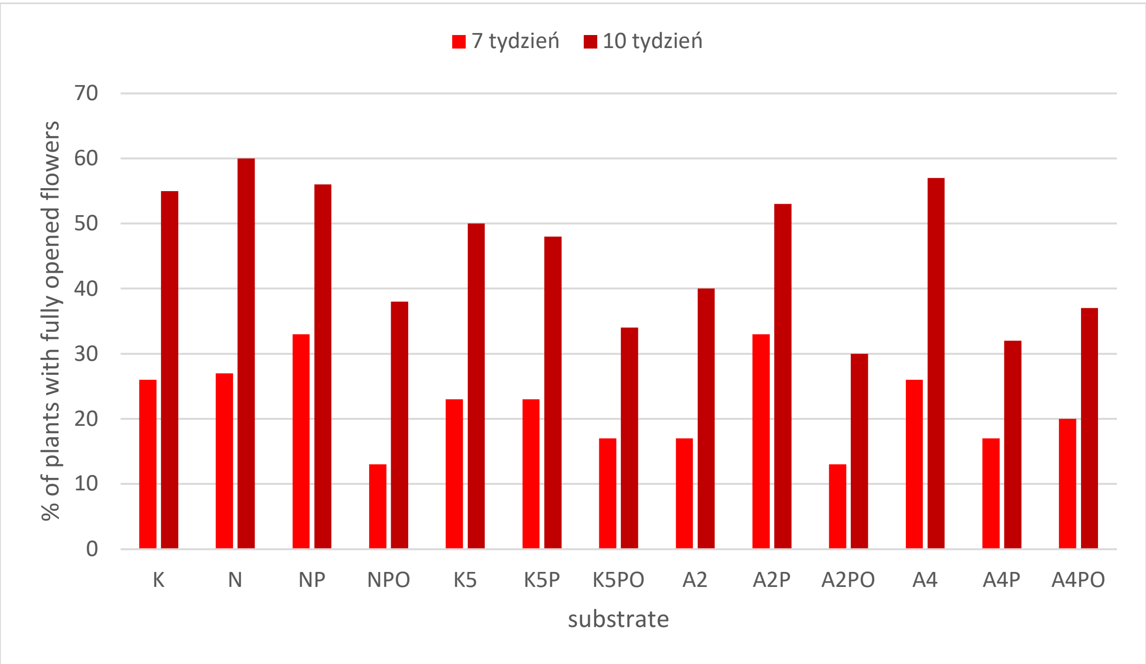


Fig. 43. Percentage of plants with developed flowers in weeks 7 and 10 of cultivation

As it results from the data presented in Fig. 43, at the end of cultivation in the greenhouses of WBiO UR in Krakow, the largest number of flowering plants was obtained on the Novarbo20 (N) substrate – 60%, as well as in the Control, in the NP and A4 substrates – approx. 55%. Approx. 50% of the plants flowered when they were grown on the Klasmann 5 and Klasmann 5 substrates with dried mushroom K5P.

Analyses of physicochemical properties of substrates

The highest bulk density was characteristic of the Klasmann 5 substrate (Table 19). This substrate also had the highest water capacity (% wv), especially in relation to the Agaris 2 and 4 substrates. The Novarbo 20% substrate with the relatively lowest bulk density (0.068 g cm-3) was distinguished by the highest water capacity expressed as water content in the dry mass of the substrate (576% ww). In the remaining substrates, up to 355% ww (Klasmann 5) and up to 494% ww (Agaris 2) were determined. The control substrate (peat) had a density of 0.063 g cm-3, water capacity of 37.5% wv and 59.5% ww. The addition of mushroom stimulants did not significantly affect the physical properties of the substrates determined after the end of the experiment with ivy-leafed pelargonium (Table 19).

The influence of the interaction of the experimental factors was demonstrated only in the case of water capacity expressed in relation to the volume of the substrate (% wv). A tendency to reduce the water capacity of the Klasmann 5 substrate was observed after the use of mushroom stimulants (Fig. 44). Inverse relationships were demonstrated for the Agaris 2 substrate.

Table 19. Physical properties of substrates enriched with a mushroom stimulant after the cultivation of ivy-leafed pelargonium in the experimental greenhouse, 6.06.2024.

Factor		**Bulk density** $g\ cm^{-3}$	**Water capacity % wv**	**Water capacity %ww**
Kontrola		*0,063*	*37,5*	*595*
Novarbo 20		0,068 A	38,3 AB	576 C
Klasmann 5		**0,119** C	40,7 B	355 A
Agaris 2		0,075 AB	36,3 A	494 BC
Agaris 4		0,092 B	36,6 A	404 AB
Bez pieczarki (0P)		0,084 A	37,7 A	471 A
Pieczarka odpadowa (PO)		0,090 A	37,5 A	452 A
Pieczarka suszona (P)		0,091 A	38,8 A	448 A
Novarbo 20%	0P	0,063 a	37,5 a-c	595 a
	PO	0,069 a	35,1 ab	540 a
	P	0,071 a	42,2 bc	592 a
Klasmann 5	0P	0,125 a	44,0 c	352 a
	PO	0,120 a	39,3 a-c	363 a
	P	0,111 a	38,9 a-c	351 a
Agaris 2	0P	0,067 a	34,9 ab	519 a
	PO	0,079 a	35,9 ab	466 a
	P	0,078 a	38,2 a-c	496 a
Agaris 4	0P	0,082 a	34,4 a	419 a
	PO	0,091 a	39,8 a-c	438 a
	P	0,102 a	35,7 ab	354 a

Post-hoc comparisons were performed using the Tukey test at p = 0.05; the same letters indicate no significant differences between means; two-factor analysis, where factor 1 - type of substrate and factor 2 - addition of mushroom stimulator in the form of mushroom farm waste; control - peat substrate

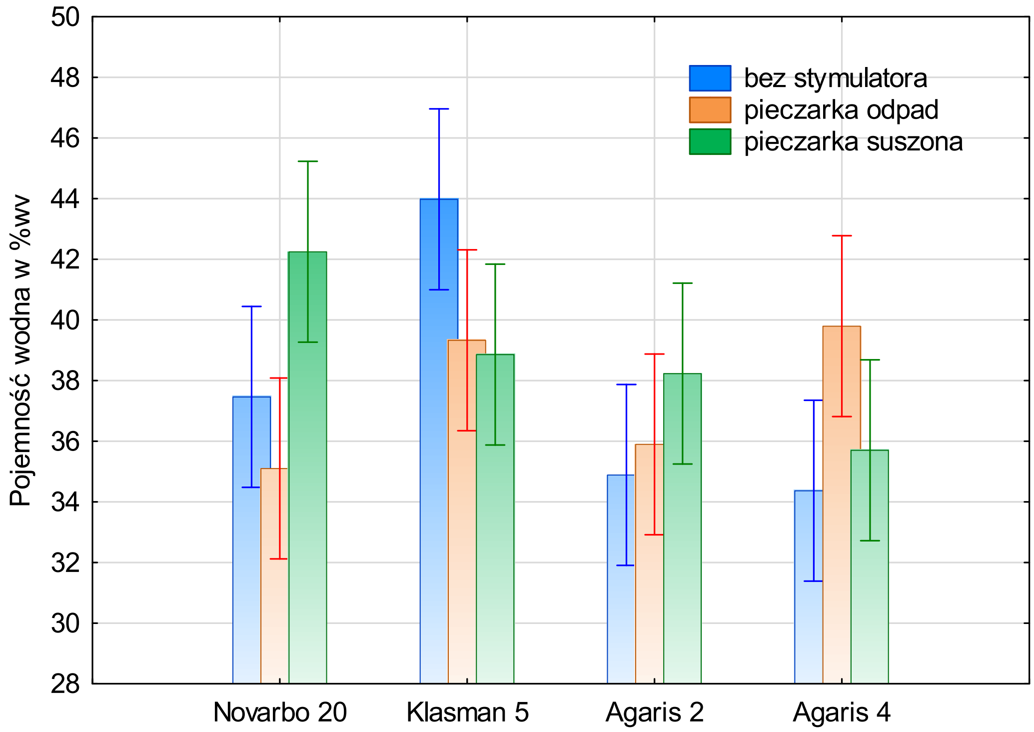


Fig. 44. Effect of substrate type and mushroom stimulator addition on water capacity (% wv) determined after ivy-leafed geranium cultivation in the experimental greenhouse, 6.06.24

Table 20 presents the results of chemical properties of the tested substrates and organic matter content determined after the end of the experiment with ivy-leafed geranium. With the exception of ammonium nitrogen and potassium, a statistically significant effect of substrate type on the content of macroelements, pH and EC of the substrate was demonstrated. The highest pH (pH 6.83) was determined in Agaris 4 substrate. After the end of ivy-leafed geranium cultivation, the peat control substrate had an acidic pH, i.e. pH 5.26. The highest salt concentration (EC) was found in the Novarbo 20% substrate (1239 EC µS cm-1) and the lowest in the Agaris 4 substrate. The EC of the peat substrate was 1055 EC µS cm-1.

High contents of nitrate nitrogen (N-NO3) were determined in the Klasmann 5 and Novarbo 20% substrates. Agaris 2 and 4 substrates contained practically no nitrogen in this form after the end of the ivy-leafed pelargonium cultivation (Table 20). Significantly more soluble calcium (1563 mg Ca dm-3) was determined in the Novarbo 20% substrate than in the other substrates used in the ivy-leafed pelargonium experiment. The peat standard used in the study contained 638 mg Ca dm-3, respectively. Analyses conducted after geranium cultivation showed that all substrates with limited peat content were significantly more enriched in potassium available to plants than the peat substrate (control). Agaris 2 and 4 substrates contained significantly more phosphorus and more magnesium (not statistically significant) than the others. Klasmann 5 substrate was distinguished by the lowest content of soluble sulfur. The addition of mushroom stimulants significantly affected the chemical properties of substrates used in the greenhouse cultivation of ivy-leafed geranium (Table 20). Substrates without additives had a higher pH and lower salt concentration (EC) than analogues enriched with fungal stimulants. The addition of dried edible mushrooms significantly enriched the substrates with nitrate

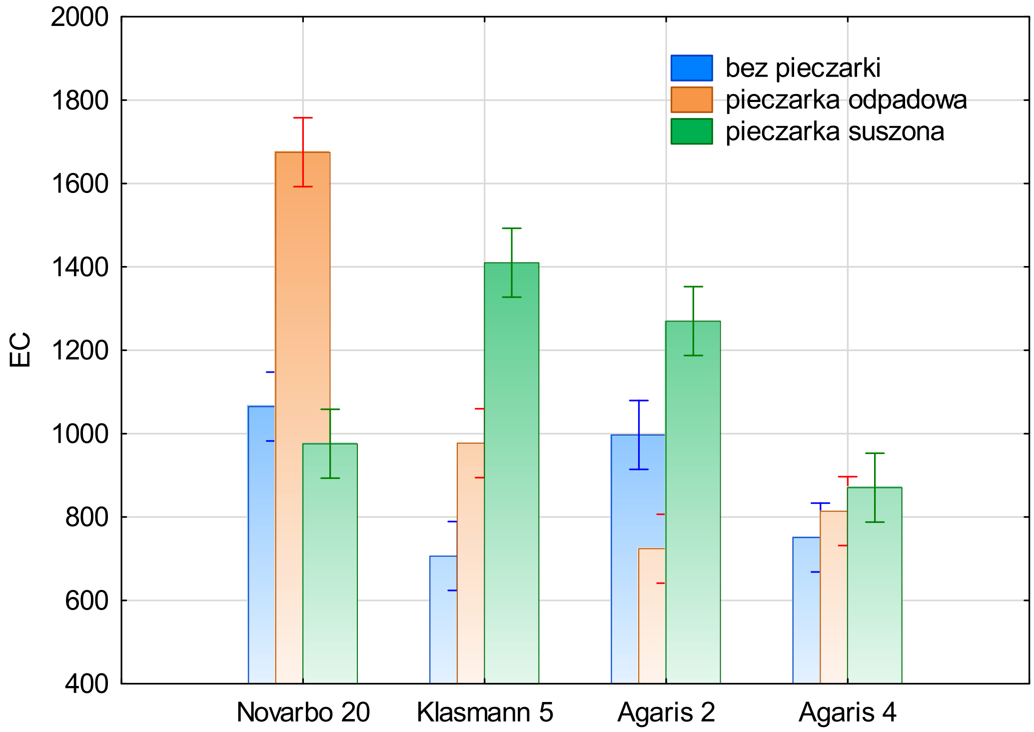
nitrogen (N-NO3), potassium and phosphorus. On the other hand, the most sulfur was contained in substrates enriched with dried waste from mushroom production.
In the case of substrate pH, EC, nitrate nitrogen content and organic matter, a significant effect of the interaction of the factors tested in the experiment (substrate x addition of fungal stimulants) was demonstrated. Klasmann 5 substrate enriched with mushroom additives had a significantly lower pH determined after cultivation. Such a substrate reaction was also demonstrated for the addition of dried edible mushrooms to the Novarbo 20% substrate. On the other hand, the pH of the Agaris 2 substrate increased after the application of mushroom stimulants (Table 20).

Dried waste mushroom increased the salinity of the Novarbo 20% substrate the most (Fig. 45). In the case of Klasmann 5 substrate, a significantly higher EC was determined after the introduction of the fungal stimulant, regardless of its form. In the Agaris 2 substrate, the addition of dried edible mushrooms caused an increase in salt concentration compared to the untreated substrate.
In general, the addition of dried waste mushrooms to the substrates in the greenhouse experiment with ivy-leafed pelargonium caused an increase in the content of organic matter compared to the control. However, this increase was statistically significant only in the case of the Klasmann 5 and Novarbo 20% substrates (Fig. 46).

Table 20. Reaction (pH), salinity (EC µS cm-1) and the content of macroelements, sodium (mg dm-3) and organic matter in substrates with the addition of mushroom biostimulator after the cultivation of ivy-leafed pelargonium, 6.06.2024.

Factor		pH	EC	$N-NH_4$	$N-NO_3$	Ca	K	Mg	P	S	Na	SO%
Controll		*5,26*	*1055*	*4,65*	*106*	*693*	*321*	*143*	*163*	*150*	*93*	*88,8*
Novarbo 20		5,99 A	**1239** C	7,71 A	156 B	**1563** B	533 A	162 AB	175 A	177 B	108 AB	87,9 C
Klasmann 5		5,98 A	1031 B	6,14 A	146 B	518 A	669 A	140 A	116 A	*70,4* A	125 AB	55,5 A
Agaris 2		6,70 B	997 B	7,30 A	8,52 A	613 A	832 A	223 B	**267** B	189 B	134 B	90,5 C
Agaris 4		**6,83** C	812 A	6,89 A	0,00 A	566 A	722 A	203 AB	**242** B	147 B	103 A	75,6 B
Bez pieczarki (0P)		**6,50** B	*915* A	6,18 A	1,07 A	767 A	496 A	176 A	167 A	150 AB	116	77,7 A
Pieczarka odpad (PO)		6,30 A	1048 B	7,14 A	65,0 A	667 A	568 A	172 A	185 A	113 A	96,0	**81,7** B
Pieczarka suszona (P)		6,32 A	**1132** C	7,33 A	**167** B	993 A	**961** B	190 A	**246** B	175 B	135	75,6 A
Novarbo 20%	0P	6,23 bc	1065 cd	7,93 a	1,33 a	1724 a	359 a	183 a	174 a	200 a	126 a	83,6 d
	PO	6,19 b	**1675** f	5,28 a	166 ab	1155 a	420 a	129 a	163 a	101 a	65,9 a	90,8 e
	P	5,56 a	976 bc	9,93 a	300 b	1809 a	821 a	175 a	189 a	231 a	130 a	89,5 de
Klasmann 5	0P	6,43 cd	706 a	5,58 a	2,13 a	398 a	540 a	124 a	71,7 a	52,3 a	125 a	52,2 a
	PO	5,44 a	977 bc	6,05 a	88,1 ab	447 a	560 a	133 a	104 a	77,2 a	112 a	67,6 b
	P	6,08 b	1410 e	6,80 a	349 b	709 a	908 a	163 a	172 a	81,8 a	139 a	46,8 a
Agaris 2	0P	6,48 d	997 bc	4,24 a	0,81 a	568 a	741 a	241 a	239 a	210 a	142 a	88,8 de
	PO	6,80 e	724 a	9,66 a	5,68 a	582 a	718 a	228 a	244 a	138 a	113 a	92,4 e
	P	6,82 e	1270 de	7,98 a	19,1 a	688 a	1039 a	199 a	317 a	218 a	147 a	90,2 de
Agaris 4	0P	6,87 e	751 a	8,51 a	0,00 a	450 a	518 a	187 a	189 a	136 a	91,8 a	75,0 c
	PO	6,79 e	814 ab	7,57 a	0,00 a	482 a	574 a	197 a	231 a	135 a	92,7 a	75,9 c
	P	6,84 e	870 a-c	4,60 a	0,00 a	765 a	1074 a	225 a	305 a	169 a	125 a	75,8 c

Porównania post-hoc przeprowadzono testem Tukey'a przy p =0.05; te same litery oznaczają brak istotności różnic pomiędzy średnimi; standard – podłoże na bazie torfu wysokiego; kontrola – podłoże torfowe



Ryc. 45. Wpływ rodzaju podłoża i dodatku stymulatora pieczarkowego na zasolenie (EC µS cm-1) oznaczony po uprawie pelargonii bluszczolistnej w szklarni doświadczalnej, 6.06.24 r.

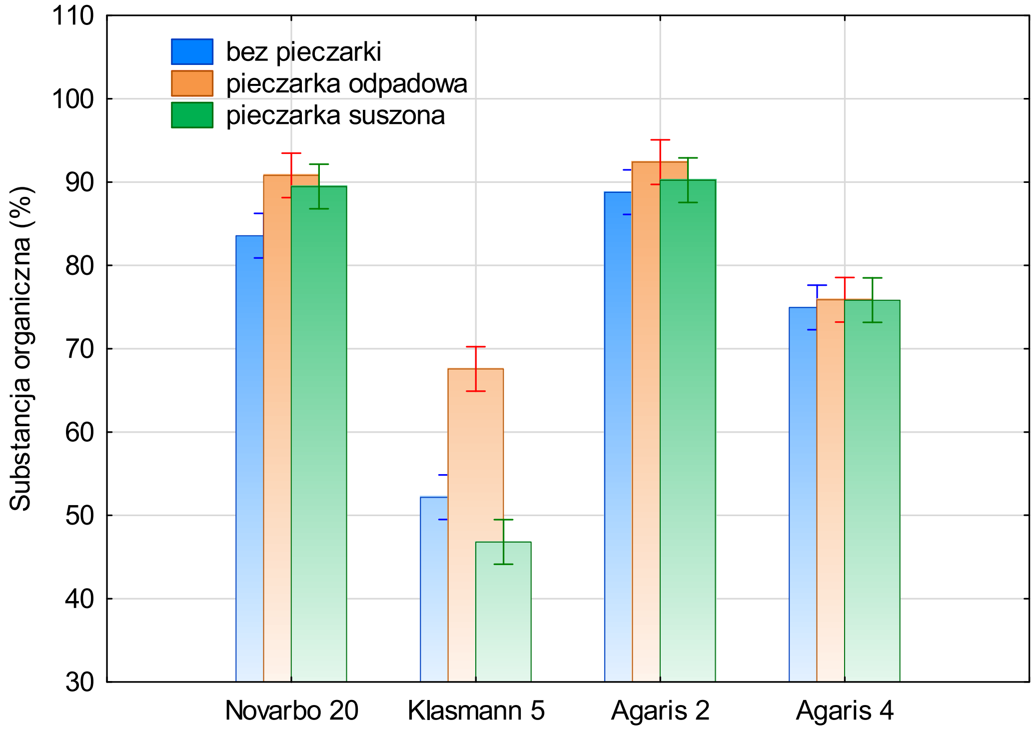


Fig. 46. The effect of the type of substrate and the addition of mushroom stimulator on the organic matter content (%) determined after the cultivation of ivy-leafed pelargonium in the experimental greenhouse, 6/06/24.

Substrates made of organic materials replacing peat used in the conducted studies with ivy-leafed geranium were richer in Cu, Mn and Zn compared to the control peat substrate (Novarbo standard) (Table 21). The greatest variation in the total content of microelements in the growing substrates analyzed after plant cultivation was demonstrated for boron, i.e. from 0.93 mg B kg-1 d.m. (Klasmann 5) to 27.2 mg B kg-1 d.m. (Agaris 2) and for iron - from 2286 mg Fe kg-1 (Novarbo 20) to 19406 mg Fe kg-1 (Agaris 4). The highest total contents of boron, copper and molybdenum were determined in the Agaris 2 substrate (Table 21). On the other hand, the Agaris 4 substrate contained the highest total iron. Peatless Klasmann 5 substrate was the richest in manganese.

The performed determinations showed that the addition of mushroom production waste (PO) caused a decrease in the content of iron, manganese and zinc in substrates after the cultivation of ivy-leafed pelargonium (Table 21) in relation to untreated substrates.

Table 21. Total content of microelements (mg kg-1 d.m.) determined in substrates after the cultivation of ivy-leafed pelargonium

Czynnik		**B**	**Cu**	**Fe**	**Mn**	**Mo**	**Zn**
Kontrola		*5,39*	*22,1*	*2497*	*45*	*9,3*	*35,6*
Novarbo 20		9,50 B	31,2 A	2286 A	73 A	14,6 C	*46,7* A
Klasmann 5		0,93 A	32,1 A	15263 B	**216** D	8,8 A	68,4 B
Agaris 2		**27,2** C	**55,0** C	2889 A	137 B	**17,4** D	59,2 B
Agaris 4		2,54 A	46,0 B	**19406** C	193 C	11,5 B	64,6 B
0P		9,99 AB	43,4 B	10615 B	165 B	**17,1** B	62,1 B
PO		11,7 B	40,9 AB	*8725* A	*135* A	11,5 A	*53,5* A
P		8,49 A	39,0 A	10544 B	163 B	10,6 A	63,5 B
Novarbo 20	0P	9,15 a	34,1 a-c	3813 a	98 ab	28,9 f	55,4 a-c
	PO	10,6 a	29,8 a	1240 a	56 a	6,7 a	40,1 a
	P	8,73 a	29,6 a	1806 a	65 a	8,2 ab	44,7 a
Klasmann 5	0P	*ślady* a	35,6 a-d	16807 c	232 ef	8,6 ab	75,0 bc
	PO	2,80 a	26,9 a	10457 b	143 c	9,6 ab	51,9 ab
	P	*ślady* a	33,9 ab	18525 c	274 f	8,3 ab	78,2 c
Agaris 2	0P	27,7 a	57,4 fg	2681 a	144 c	17,8 de	57,4 a-c
	PO	30,4 a	59,2 g	3095 a	139 bc	18,7 e	58,5 a-c
	P	23,5 a	48,3 f-g	2893 a	126 bc	15,8 c-e	61,5 a-c
Agaris 4	0P	3,08 a	46,3 c-f	19158 c	188 d	13,1 b-d	60,9 a-c
	PO	2,86 a	47,7 d-g	20107 c	203 de	11,2 a-c	63,4 a-c
	P	1,70 a	44,0 b-e	18955 c	188 d	10,1 ab	69,4 bc

Post-hoc comparisons were performed using Tukey's test at p = 0.05; the same letters indicate no significant differences between means; control – peat substrate

Plant material analyses

The type of substrate used for cultivation significantly affected the dry mass content and mineral composition of the biomass of ivy-leaved geraniums collected for testing after the end of the greenhouse experiment (Table 22). The highest dry mass was found in plants grown in Agaris 4 substrate (12.9%) and the lowest in Klasmann 5 and Novarbo 20 substrates (11.2% and 11.3%, respectively). In plants grown in peat substrate, 11.5% dry mass was determined.

The highest nitrogen content was found in plants growing in Novarbo 20 substrate (3.15% N) and the lowest in Agaris 4 substrate (1.98% N). Pelargoniums collected for testing from peat substrate contained 3.08% N in dry mass. The plant biomass produced in the Novarbo 20% substrate also contained the most calcium, which correlated with the content of this substrate in soluble Ca (Table 22). The most magnesium was determined in plants growing in the Agaris 2 substrate. All plants growing in substrates with limited peat content were characterized by a lower content of this element in the biomass compared to the peat substrate (control). On the other hand, geraniums growing in these substrates were better nourished with phosphorus than those grown in the track substrate (Table 22). The most sodium was determined in plants growing in the Klasmann 5 substrate.

Table 22. Content of macronutrients and sodium (% DM) in ivy-leaved geranium grown in substrates with the addition of a mushroom stimulator in the conditions of the experimental greenhouse (URK), 20.05.2024.

Factor		**d.w.**	**N**	**Ca**	**K**	**Mg**	**P**	**S**	**Na**
Control		*11,5*	*3,08*	*2,36*	*4,21*	*0,32*	*0,54*	*0,24*	*0,14*
Novarbo 20		11,3 A	**3,15** D	**2,26** C	4,16 A	0,23 A	0,60 B	0,25 B	0,13 A
Klasmann 5		11,2 A	2,94 C	1,60 B	**5,11** D	0,28 B	0,58 A	0,23 A	**0,18** D
Agaris 2		12,4 B	2,33 B	1,19 A	4,84 C	**0,29** C	0,60 B	0,25 B	0,17 C
Agaris 4		**12,9** C	1,98 A	1,26 A	4,33 B	0,28 B	0,57 A	0,23 A	0,15 B
Bez pieczarki (0P)		**12,4** C	1,98 A	**1,68** B	4,30 A	0,28 B	0,58 A	*0,22* A	**0,16 B**
Pieczarka odpad (PO)		*11,4* A	**2,95** C	1,54 A	4,57 B	0,28 B	**0,60** B	0,25 B	0,15 A
Pieczarka suszona (P)		12,0 B	2,87 B	1,52 A	**4,96** C	0,24 A	0,58 A	0,26 B	0,15 A
Novarbo 20%	0P	11,2 a-c	2,54 e	**2,56** f	3,78 a	0,25 b	0,59 a-d	0,24 cd	0,13 ab
	PO	11,0 ab	3,48 g	2,07 e	4,21 bc	0,22 a	0,60 b-d	0,26 de	0,14 b
	P	11,7 b-d	3,44 g	2,16 e	4,49 c-e	0,21 a	0,60 b-d	0,25 c-e	0,11 a
Klasmann 5	0P	11,1 a-c	2,37 d	1,61 d	4,94 fg	0,26 bc	0,56 ab	0,21 ab	0,19 e
	PO	10,6 a	3,49 g	1,58 cd	5,06 gh	0,30 de	0,58 a-d	0,24 c	0,17 cd
	P	11,9 b-d	2,95 f	1,61 d	5,33 h	0,28 cd	0,59 a-d	0,23 bc	0,19 e
Agris 2	0P	13,3 ef	1,59 b	1,13 a	4,44 cd	0,29 de	0,60 b-d	0,21 ab	0,17 cd
	PO	11,9 b-d	2,36 d	1,27 ab	4,76 e-g	0,31 e	0,61 d	0,27 e	0,17 cd
	P	12,0 cd	3,05 f	1,17 a	5,32 h	0,26 bc	0,59 a-d	0,29 f	0,17 cd
Agris 4	0P	14,0 f	1,43 a	1,41 bc	4,03 ab	0,30 e	0,57 a-c	0,20 a	0,17 cd
	PO	12,2 d	2,46 de	1,25 ab	4,27 bc	0,30 e	0,60 cd	0,24 c	0,14 b
	P	12,3 de	2,05 c	1,13 a	4,68 d-f	0,23 a	0,55 a	0,26 de	0,16 c

Post-hoc comparisons were performed using the Tukey test at p = 0.01; the same letters indicate no significant differences between means; two-factor analysis, where factor 1 – substrate, factor 2 – addition of mushroom stimulant, control – peat substrate

The addition of fungal stimulants to the substrates significantly modified the mineral profile of ivy-leaved geranium (Table 22). Plants growing in substrates without the addition of mushroom stimulants had significantly higher dry mass, calcium and sodium content. However, they contained less nitrogen and sulphur. The addition of dried waste mushroom to the substrates significantly increased the N and P content in the plants. The stimulant in the form of dried edible mushrooms improved the supply of potassium to geraniums in relation to the remaining combinations of the experiment. A significant effect of interaction between the experimental factors (substrate x addition of mushroom stimulants) was demonstrated on the mineral composition of ivy-leaved geranium and the dry mass content in the plants (Table 22, Figs. 47-53). The highest dry mass content was noted for geraniums grown in Agaris 2 and 4 substrates without fungal additives (Fig. 47). On the other hand, plants growing in Novarbo 20 and Klasmann 5 substrates enriched with dried edible mushrooms had significantly higher dry mass than those obtained for testing from the remaining substrate combinations. Fungal stimulants significantly increased nitrogen content in plants, regardless of the form in which they were used (Fig. 48). This was especially visible in the case of geraniums growing in Agaris 2 and 4 substrates, which were characterized by the lowest N content in biomass. The addition of fungal stimulants in the form of dried mushroom production waste or dried edible mushrooms reduced the calcium content in plants growing in Novarbo 20% substrate (Fig. 49). Such a tendency was also observed in the case of geraniums grown in Agaris 4. The potassium content in plants increased after the use of fungal stimulants, regardless of the cultivation substrate used (Fig. 50). A greater effect on plant potassium nutrition was had by the stimulator in the form of dried and finely ground edible mushrooms, used especially in the Agaris 2 and 4 and Novarbo 20% substrates (Table 22).

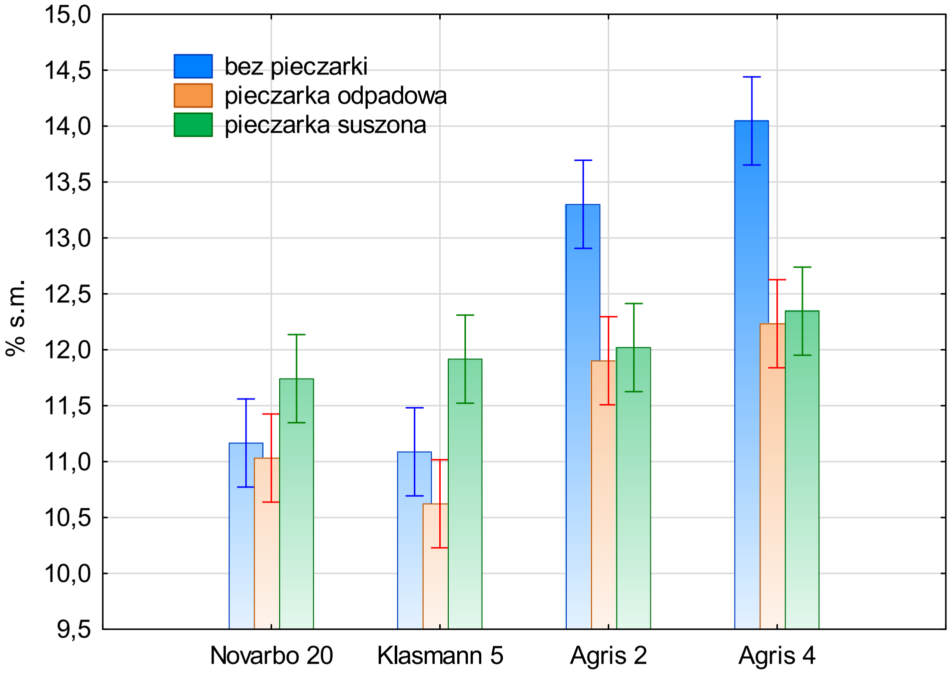


Fig. 47. The effect of the type of substrate and the addition of mushroom stimulator on the dry matter content (% d.m.) in the biomass of ivy-leafed pelargonium grown in the experimental greenhouse conditions, 6/06/2024.

Dodatek suszonej pieczarki spożywczej powodował równocześnie istotne obniżenie się zawartości magnezu w pelargoniach uprawianych w podłożach Novarbo 20 oraz Agaris 2 i 4 (ryc. 51).

Natomiast dodatek suszonej pieczarki odpadowej do podłoża Klasmann 5 zwiększał zawartość Mg w roślinach. Podobną zależność obserwowano dla podłoża Agaris 2.

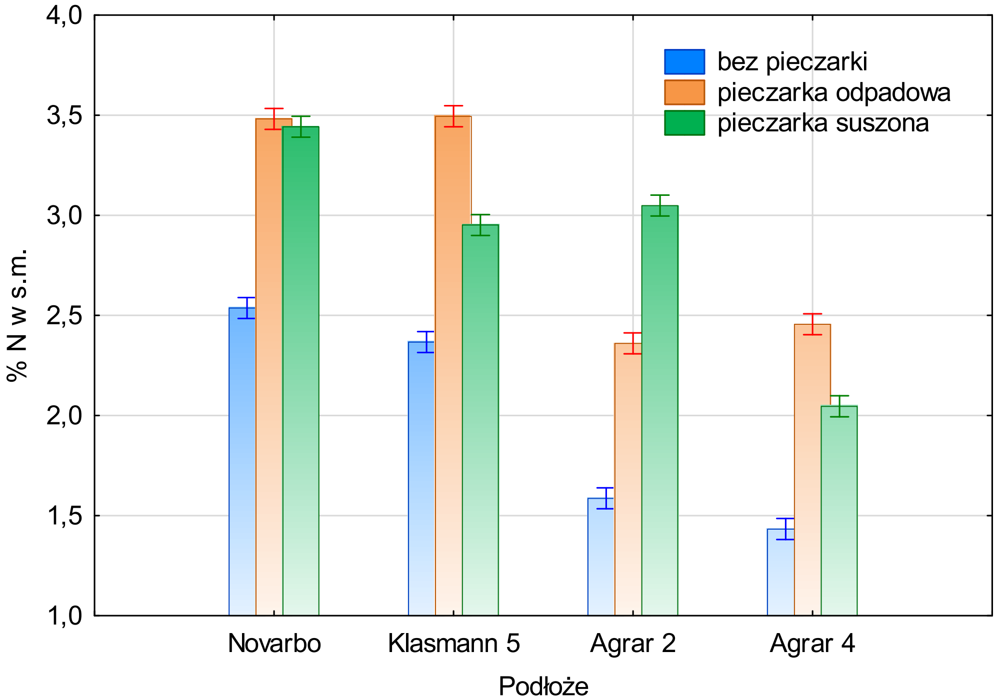


Fig. 48. The effect of the type of substrate and the addition of mushroom stimulator on the nitrogen content (% N in dry matter) in the biomass of ivy-leafed pelargonium grown in the experimental greenhouse conditions, 6/06/2024.

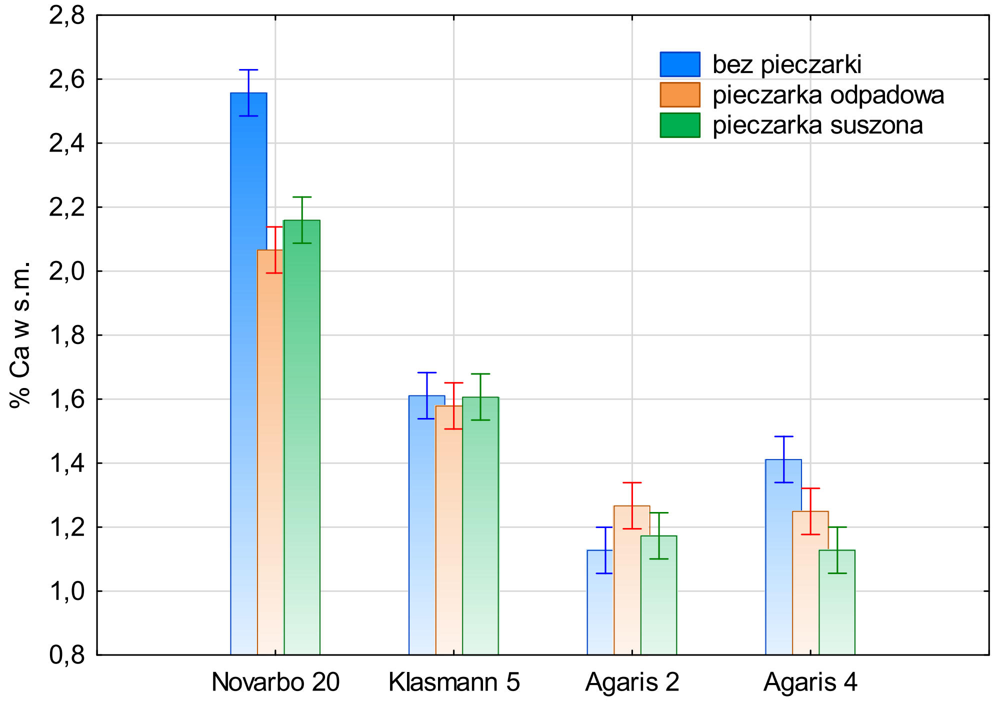


Fig. 49. The effect of the type of substrate and the addition of mushroom stimulator on the calcium content (% Ca in dry matter) in the biomass of ivy-leafed pelargonium grown in the experimental greenhouse conditions, 6/06/24.

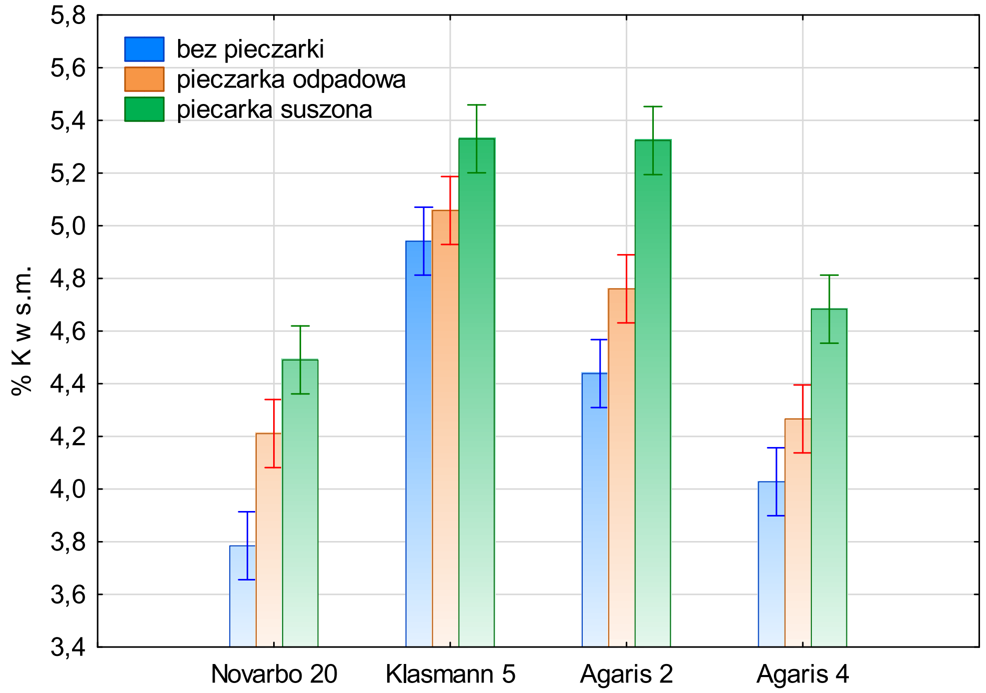


Fig. 50. The effect of the type of substrate and the addition of mushroom stimulator on the potassium content (% K in dry matter) in the biomass of ivy-leafed pelargonium grown in the experimental greenhouse conditions, 6/06/24.

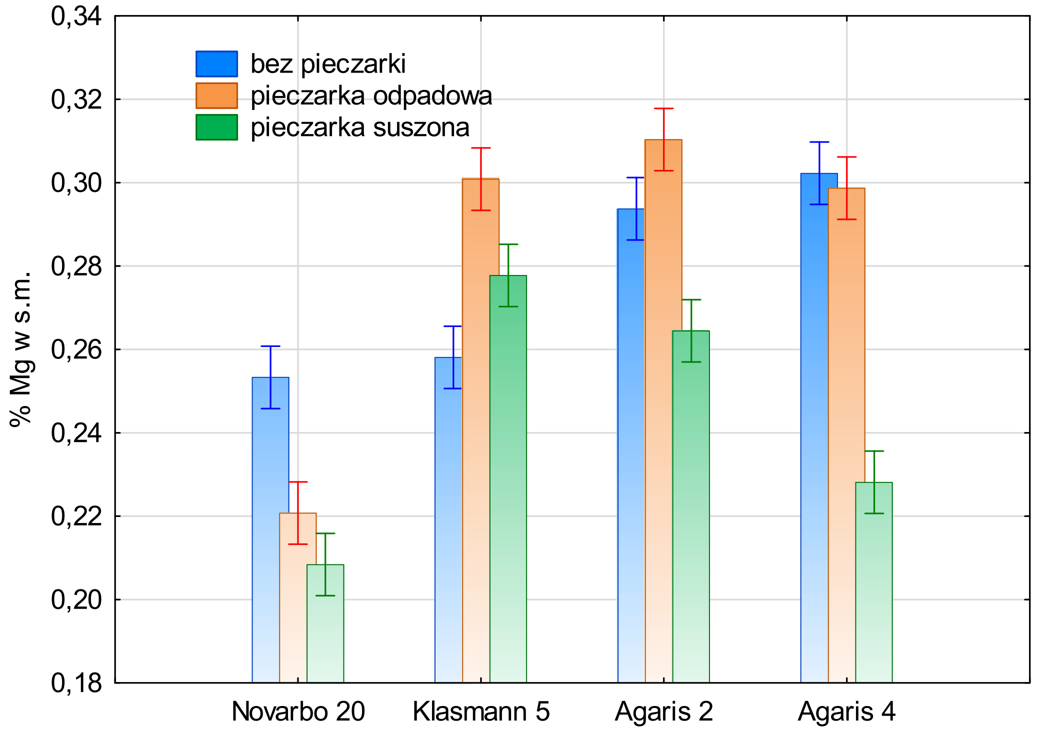


Fig. 51. The effect of the type of substrate and the addition of mushroom stimulator on the magnesium content (% Mg in dry matter) in the biomass of ivy-leafed pelargonium grown in the experimental greenhouse conditions, 6/06/2024.

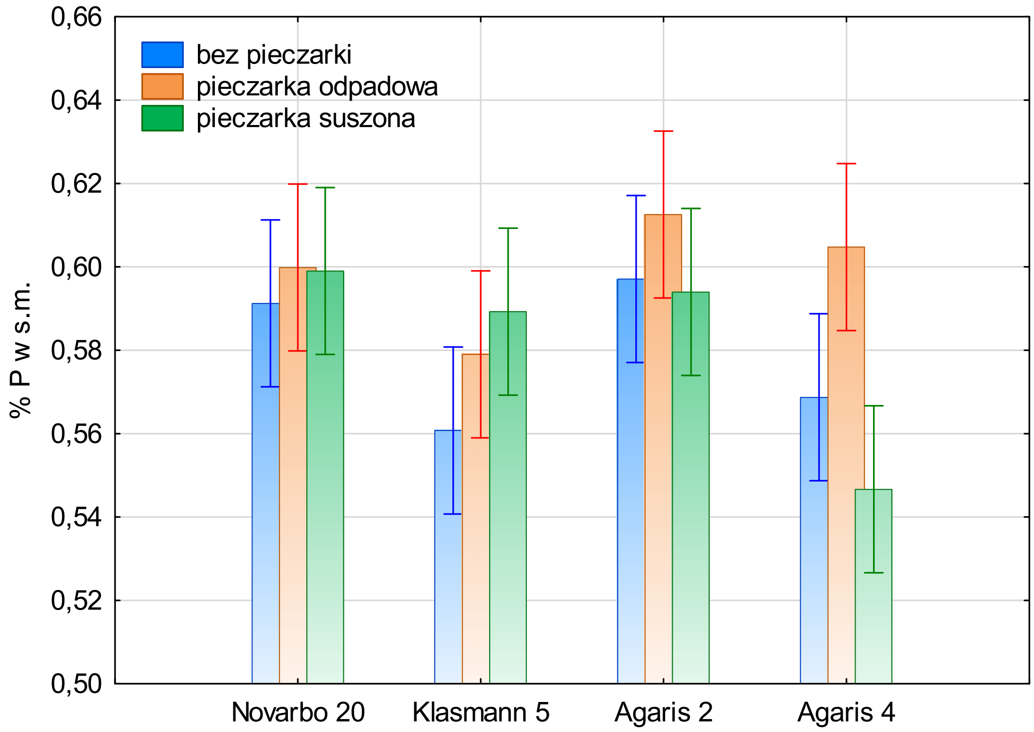


Fig. 52. The effect of the type of substrate and the addition of mushroom stimulator on the content (% P in dry matter) in the biomass of ivy-leafed pelargonium grown in the experimental greenhouse conditions, 6/06/24.

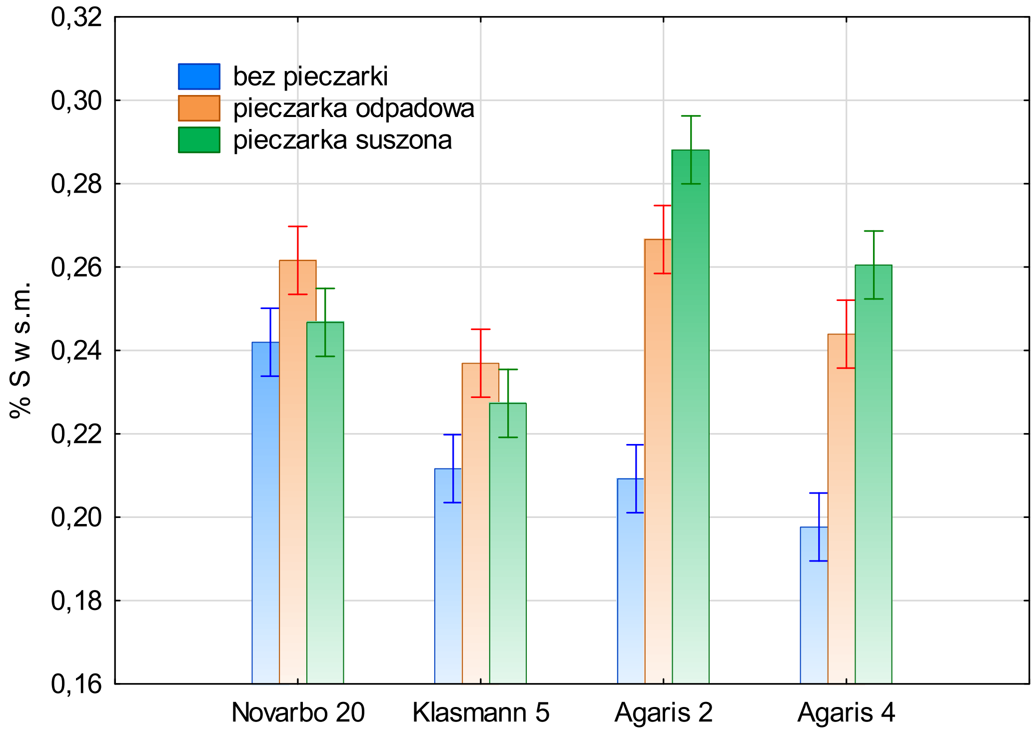


Fig. 53. The effect of the type of substrate and the addition of mushroom stimulator on the sulfur content (% S in dry matter) in the biomass of ivy-leafed pelargonium grown in the experimental greenhouse conditions, 6/06/24.

The addition of waste mushrooms to Agaris 2 and 4 substrates increased the phosphorus content in the biomass of ivy-leaved pelargonium (statistically significant only for Agaris 4) (Fig. 52). A tendency was also observed for better phosphorus nutrition of plants growing in Klasmann 5 substrate with mushroom stimulants.

A statistically significant increase in sulfur content in plants was demonstrated for crops in Agaris 2 and 4 substrates enriched with mushroom stimulants (Fig. 53). At the same time, dried edible mushrooms increased the S content in pelargoniums from these facilities to a greater extent than waste mushrooms. A tendency was also observed for improving the supply of plants with available sulfur in Novarbo 20% substrate with the addition of dried waste mushrooms.

Table 23. Content of microelements (mg kg-1)* in the biomass of ivy-leafed pelargonium growing in substrates with the addition of mushroom biostimulator in experimental greenhouse conditions (URK)

Factor		B	Cu	Fe	Mn	Mo	Zn
controll		*42,3*	*6,23*	*572*	*379*	*1,19*	*70,0*
Klasmann 5		**47,7** B	**5,92** C	70,0 AB	116 B	2,01 A	77,7 B
Novarbo 20		43,9 A	5,55 B	**78,8** C	119 B	**2,96** B	79,2 B
Agaris 2		42,8 A	5,36 B	66,1 A	**139** C	1,83 A	**84,5** C
Agaris 4		42,7 A	4,95 A	73,0 B	103 A	1,78 A	69,9 A
Bez pieczarki (0P)		45,0 B	5,70 B	65,5 A	117 B	**3,06** B	80,3 B
Pieczarka odpadowa (PO)		**47,0** C	5,72 B	**78,4** C	**143** C	1,77 A	74,0 A
Stymulator pieczarkowy (P)		40,9 A	4,92 A	72,0 B	97 A	1,60 A	79,1 B
Klasmann 5	0P	48,9 d-f	6,82 d	65,6 a-c	84 a	3,22 b	74,5 bc
	PO	53,3 f	5,90 c	86,5 de	154 e	1,15 a	70,0 ab
	P	40,9 ab	5,04 b	57,9 a	109 c	1,65 a	88,7 e
Novarbo 20	0P	49,3 ef	5,93 c	76,3 cd	105 bc	**5,44** c	86,0 de
	PO	43,5 b-d	5,54 bc	90,1 e	152 e	1,94 ab	68,7 a
	P	38,9 ab	5,18 b	70,0 bc	100 a-c	1,49 a	82,8 d
Agaris 2	0P	37,8 a	5,01 b	56,7 a	**184** f	1,85 a	89,3 e
	PO	47,6 c-e	5,97 c	70,6 bc	142 de	2,07 ab	87,9 de
	P	42,9 a-c	5,09 b	70,8 bc	92 ab	1,56 a	76,2 c
Agaris 4	0P	43,8 b-d	5,04 b	63,5 ab	95 a-c	1,74 a	71,5 a-c
	PO	43,4 bc	5,45 bc	66,2 a-c	126 d	1,93 a	69,5 ab
	P	40,9 ab	4,37 a	89,4 e	87 a	1,68 a	68,6 a

Post-hoc comparisons were performed using the Tukey test at p = 0.01; the same letters indicate no significant differences between means; two-factor analysis, where factor 1 – substrate, factor 2 – addition of mushroom stimulant; control – peat substrate

When comparing the mineral nutrition status of ivy-leafed geraniums growing in peat-free or limited peat substrates to plants growing in standard peat substrate (control), significantly lower copper, iron and manganese contents were observed in the biomass (Table 23). On average, the highest boron content was determined in geraniums growing in the Klasmann 5 peat-free substrate. Plant biomass taken from the Novarbo 20 substrate with limited peat content was distinguished by the highest Fe and Mo content. Pelargoniums growing in Agaris 2 substrate were best supplied with Mn and Zn.

The addition of waste mushrooms (PO) to the substrates significantly increased the content of boron, iron and manganese in the plants. On the other hand, the highest molybdenum content was found in plants growing in substrates without fungal additives (Table 23).A statistically significant effect of the interaction of the studied factors (substrate type x addition of fungal stimulants) on the content of microelements in the biomass of ivy-leaved pelargonium was demonstrated (Table 23). In general, in the substrate with limited content of Novarbo 20 peat, the addition of mushroom stimulants reduced the content of boron, copper, molybdenum and zinc in the plants. In the peat-free Klasmann 5 substrate, such a reaction was observed only in the case of molybdenum. In substrates made of organic waste materials Agaris 2 and 4, the addition of mushroom stimulants generally improved the supply of iron to ivy-leaved pelargonium.

As in the case of French marigold, a poorer development of the root system of ivy-leaved pelargonium plants was observed in substrate combinations with the addition of stimulants from mushrooms (especially dried edible mushrooms) (Fig. 54 a,b).

a. b.

Fig. 54. Intensity of root ball overgrowth of ivy-leaved pelargonium growing in Klasmann 5 (a) and Novarbo 20 (b) substrates after completion of cultivation in the experimental greenhouse of the Faculty of Biotechnology and Horticulture, in the photos on the left – substrates with the addition of a biostimulant, on the right – without the addition of a biostimulant

CONCLUSIONS

SUBSTRATES:

1. The peat-free substrates (Klasmann 5, Agaris 2 and 4) or those with limited peat content (Novarbo 20) used in the study, although they differed significantly in physical properties, did not differ significantly in terms of the parameters determined from the peat control substrate.

2. All peat-free substrates or those with limited peat content tested in the experiment had a significantly higher pH than the peat substrate and a generally higher concentration of soluble salts (EC). The highest salt concentration was noted in Agaris 4 substrate (EC = 1.66 mS cm-1). In general, Agaris 2 and 4 substrates contained the most soluble forms of P, K, Mg, S and Na.

3. The fungal stimulator used in the form of dried mushroom waste (fragments of fruiting bodies and remnants of the growing medium) contained significantly more Ca, S, Fe, Mn, Mo and Ti than dried edible mushrooms.

Tagetes erecta:

1. In the cultivation of marigold, the addition of a mushroom stimulator to the substrates significantly increased the average bulk density and water capacity of the substrates. In addition, the addition (2.5% by volume) of dried waste from a mushroom farm significantly increased the salt concentration in the substrates and the content of soluble K and P.
2. Comparing the obtained results regarding the mineral nutritional status of marigold cultivated in a standard peat substrate, it was shown that plants cultivated in peat-free substrates (Klasmann, Agaris 2 and 4) were characterized by a lower content of N, Ca, Mg and P. However, they contained more potassium and sodium.
3. During the vegetation period, characteristic marginal and interveinal chlorosis of older leaf blades was observed on marigolds growing in substrates with the addition of a mushroom stimulator, turning into necrosis over time. The causes of these disorders were probably: salinity, imbalance between antagonistic elements Ca:K:Mg in the substrates and magnesium and calcium deficiency in plants with a simultaneously very high potassium content in the tissues. Poorer rooting was also observed in substrates in which the mushroom stimulator was used.
4. The highest height was characteristic of marigolds from the Novarbo 20 substrate, those from the Control and Klasmann 5 Agaris 2 and Agaris 4 substrates were approx. 2 cm shorter. The addition of the mushroom stimulator to the substrates always had an inhibiting effect on the height of the plants, but increased tillering. However, no substrate achieved better results than the control, where tillering was the best.
5. Flower buds in marigolds appeared the fastest when they were grown in Agaris substrates, but in the third week of cultivation the plants on all substrates had visible flower buds.
6. Flower buds developed the fastest (visible color) and marigolds bloomed the fastest when grown in peat-free substrates (K5, A2, A4) and when these substrates were enriched with dried mushrooms.
7. The best physiological parameters (chlorophyll fluorescence, SPAD, photosynthetic pigment content) were characteristic of marigold leaves from the control substrate.

Pelargonium hortorum:

1. In the cultivation of bedding geraniums, the addition of the mushroom stimulator did not statistically significantly affect the tested physical properties of the growing media, but lowered the pH of the media and increased their salinity. The addition of dried edible mushrooms also significantly increased the content of nitrate nitrogen (N-NO3), potassium and phosphorus in the media. On the other hand, the addition of dried mushroom waste increased the level of ammonium nitrogen and phosphorus in the media in relation to the untreated combinations.
2. The highest potassium and sodium levels were determined in bedding geraniums growing in Klasmann 5 substrate and the lowest in Agaris 2 and 4 substrates. In general, all plants growing in substrates with limited peat content or without peat were distinguished by a lower Mg content than plants growing in peat substrate.
3. The highest N, Mg and P levels were determined in bedding geraniums growing in substrates with the addition of mushroom waste. Dried edible mushrooms introduced into the substrates as a stimulator significantly increased the Ca, S and Na content in geraniums compared to the control.
4. The highest height was characteristic of garden geraniums from the Novarbo 20 substrate, those from the Control and Klasmann 5 substrate were approx. 2 cm shorter, while plants from the other tested substrates, including those enriched with mushroom stimulants, were the lowest.
5. In the seventh week of production, over 70% of geraniums from the control substrate had fully developed inflorescences, similarly to those from the K5P and A2 substrates. In the case of the Agaris 4 substrate, almost 80% of geraniums flowered, but plants produced on this substrate had the most faded inflorescences, which reduced their decorative value. Similarly, plants from Novarbo 20 and Novarbo 20 substrates with a food-based mushroom stimulator and Klasmann 5 with this stimulator quickly faded.
6. In the consumer analysis of the decorativeness of the final product, taking into account flowering, plant habit and leaf decorativeness, the highest scores were given to plants produced in the control standard substrate and in Novarbo 20 and Klasmann 5 substrates. The worst in the consumer assessment were geraniums from Agaris 2 and Agaris 4 substrates and when these substrates were enriched with dried mushrooms from mushroom production waste.
7. The photosynthetic efficiency of leaves of plants produced on all substrates, measured by the Fv/Fm index, remained at the correct level. It was observed that the addition of a food-based mushroom stimulator (ground fruiting bodies) to the substrate increased the SPAD leaf greenness index. The highest level of photosynthetic pigments was shown in plants grown in the control medium, as well as in Novarbo 20 and Novarbo 20 with both types of stimulants, and Klasmann 5 with stimulants.

Pelargonium peltatum:

1. Analyses conducted after the cultivation of ivy-leafed geraniums showed that all substrates with limited peat content or without peat were significantly more enriched in available potassium for plants than the peat substrate (control). Agaris 2 and 4 substrates contained significantly more phosphorus than the others used in the study.
2. The addition of dried edible mushrooms significantly enriched the substrates in the cultivation of ivy-leafed geraniums with nitrate nitrogen (N-NO3), potassium and phosphorus, also causing a significant increase in salinity.
3. All plants growing on substrates with limited peat content or without peat were characterized by a lower magnesium content in the biomass of ivy-leafed geraniums compared to the peat substrate (control).
4. Ivy-leafed geraniums growing in substrates without the addition of mushroom stimulants had significantly higher dry mass, calcium and sodium content. However, they contained less nitrogen and sulfur. The addition of dried waste mushrooms to the substrates significantly increased the N and P content in the plants. The stimulator in the form of dried edible mushrooms improved the supply of potassium to ivy-leafed pelargonium in relation to the remaining combinations of the experiment.
5. An inhibiting effect of the applied mushroom stimulator, both from post-production waste and food produced from mushroom fruiting bodies, was demonstrated on the length of ivy-leafed pelargonium shoots and the mass of the above-ground part, i.e. shoots and leaves. The highest mass of the above-ground part was characteristic of geraniums from the control substrate (standardly used for production) and those produced in the Novarbo 20 substrate.
6. At the end of the cultivation, the largest number of flowering plants was obtained on the Novarbo 20 substrate (60%) and in the Control (56%), as well as in the NP and A4 substrates (above 50%).
7. Studies of the physiological state of ivy-leafed geranium leaves showed that the SPAD leaf greenness index was at the highest level in plants produced in the control medium and those grown in the Novarbo 20 medium, Novarbo 20 with dried mushrooms for food (NP) and in the Agaris 2 medium with dried mushrooms for food (A2P). This is correlated with the highest content of photosynthetic pigments, especially chlorophyll a.

Microelements:

1. In general, peat-free and peat-limited substrates contained more microelements, especially iron, manganese and zinc, compared to the standard peat substrate.
2. Adding the mushroom stimulator to the substrates generally improved the supply of iron to the test plants.
3. The generally poorer supply of microelements to plants growing in peat-free or peat-limited substrates compared to the standard peat substrate may indicate the presence of these nutrients in forms that are not available to plants. The high pH of these substrates favors the transformation of microelements into insoluble forms.

Recommendations for research in production conditions

1. The most similar in terms of physicochemical properties to the peat standard was the Novarbo 20 substrate, with a 20% reduced peat content. Research conducted in the experimental conditions conducted in greenhouses of the University of Agriculture in Krakow showed that the peat-free Klasmann 5 and Novarbo 20 substrates with a limited peat content can be used as alternative substrates to peat substrates in the production cultivation of seasonal, bedding and balcony plants.

2. The addition of mushroom stimulants at a concentration of 2.5% by volume is not recommended as additives to the tested substrates in the cultivation of marigolds and geraniums in the cultivation technology used at Jenflor.

3. It is recommended to increase the concentration of magnesium in the nutrients used to feed plants grown in substrates with a limited peat content or without peat, due to the low status of mineral nutrition of plants with this component.