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 B

cultivation of seasonal plants in Jenflor greenhouses in Świbie

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Materials and methods of research

In this stage of the project, the cultivation of seasonal plants was carried out from July to December 2024 in the greenhouse facilities of the Project Leader - JENFLOR Farm in Świbie, where the biometric quality of plants was monitored and some measurements of their physiological condition were taken, and material for analysis was collected. Physiological analyses, plant nutritional status and chemical analyses of substrates were carried out in the laboratories of the Faculty of Biotechnology and Horticulture of the Hugo Kołłątaj University of Agriculture in Krakow.

Large-scale production plan

Juvenile plants – starting material for production (seedlings or seedlings) after planting in appropriate containers were grown in a new greenhouse facility starting from week 22 of the year (01.06.2024) (Table 1).

Table. 1. Length of production of seasonal plants in the new facility during experiments on the use of peat-free and limited peat content substrates

PANT SPECIES	BEGGINING OF THE CULTIVATION (year week)	THE END OF THE CUTIVATION (year week)	Pot size / capacity
pansy *Viola ×witrockiana*	29	36	9 cm / 0,35L
marigold *Tagetes patula*	28	39	9 cm / 0,35L
chryzanthemum *Chrysanthemum ×morifolium*	22	40	21 cm / 3L
ivy-leafed geranium *Pelargonium peltatum*	35	52	13 cm / 1L

Production in the new facility was carried out by rotating pot crops in order to optimally use the cultivation area and adapt it to the season (Fig. 1). The cultivation area development plan in the greenhouse facility as part of large-scale experiments on the effect of peat-free and reduced peat substrates is presented in Fig. 2.

Gatunek	Liczba doniczek	Zapełnienie terenu (m^2)	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Bratek	50290	621								621	621	621	621	621	621	621	621																
Aksamitka tura1	50700	563							563	563	563	563	563	563																			
Aksamitka tura 2	50700	1 127													1127	1127	1127	1127	1127	1127													
Chryzantema tura1	30000	1 667	1667	1667	1667	1667	1667	1667	1667																								
Chryzantema tura1	30000	4 000								4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000												
Pelargonia tura1 rooting	100000	321														164	164	321	321	321	321												
Pelargonia tura2	100000	2 174																				2174	2174	2174									
Pelargonia tura3	100000	5 435																							5435	5435	5435	5435	5435	5435	5435	5435	5435
		Suma (m^2) w tyg	1667	1667	1667	1667	1667	1667	2230	5184	5184	5184	5184	5184	5748	5912	5912	5448	5448	5448	4321	2174	2174	2174	5435	5435	5435	5435	5435	5435	5435	5435	5435

Fig. 1. Production plan of four species of seasonal ornamental plants in the new greenhouse facility, divided into weeks of the year and the size of crops.

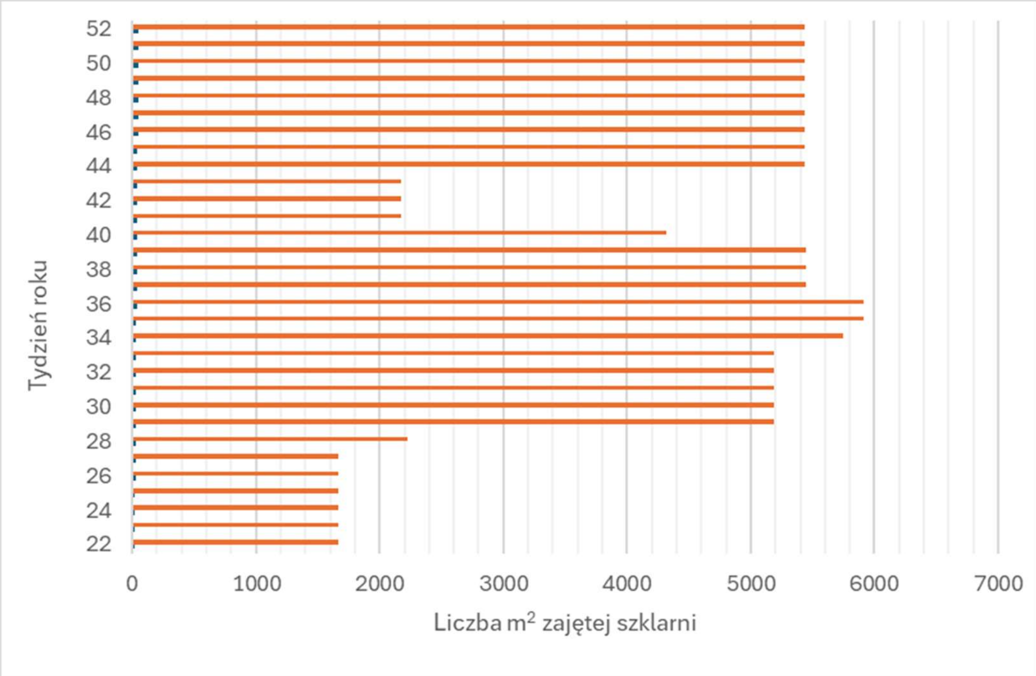


Fig. 2. Schedule of use of the cultivation area in the greenhouse facility in large-scale experiments on the influence of peat-free and low-peat substrates on the quality of the final product (weeks 22–52, 2024).

Greenhouse facility and cultivation conditions

The cultivation of plants was carried out in a greenhouse with a total area of 5930 m^2 and a volume of 36,916 m^3. The facility consists of four bays, each of which is 9.6 m wide. The greenhouse design allows for effective regulation of the microclimate thanks to the upper ventilation system, which includes ridge-length-roof opening.

A climate computer is responsible for precise management of climate parameters, such as temperature, humidity and shading, which allows the greenhouse to be divided into eight independent climate sections. Heating is provided by a floor system based on a heated concrete floor, supplemented by upper heating.

The fertigation and irrigation system operates in a closed circuit, which allows for maximum use of the nutrient solution and minimization of water and nutrient losses. This process is fully automated and is carried out in the following sequence:

1. the nutrient solution is taken from the tank using an irrigation mixer, where chlorine dioxide is added,
2. then the plants are watered using the subsurface method.
3. excess nutrient solution is drained through a pipeline system to intermediate tanks and pumped using transfer pumps.
4. initial nutrient purification is carried out by an inclined filter, and the actual purification by a sand filter,
5. the nutrient solution is disinfected using ozone, after which it is returned to the tank.

The facility was designed with an emphasis on sustainable use of resources, which includes the recovery of both water and nutrient components, in order to minimize the impact on the environment and optimize plant production (Fig. 3).

Fig. 3. Photo of a modern greenhouse facility at the Jenflor Farm in Świbie, where plant cultivation was carried out in the second half of 2024, conducting experiments on the use of peat-free substrates and those with limited peat content in large-scale production of seasonal species.

Description of the climatic conditions of the crop

The climatic conditions in the greenhouse were precisely controlled using the Hortimax CX 500 climate computer. This system enabled automatic control of environmental parameters, ensuring optimal conditions for plant growth. Temperature settings included:

• minimum heating temperature during the day: 14°C, at night: 12°C,
• minimum ventilation temperature during the day and at night: 16°C,
• relative humidity in the greenhouse did not exceed 80%,
• the shading system was activated automatically at solar radiation intensity above 700 W/m², providing 80% shading.

Irrigation and fertigation system

The nutrient flooding was adjusted to the requirements of the plants depending on the species, development stage and weather conditions. The key factor influencing the frequency of watering was solar radiation. Even at lower temperatures, intensive sunlight accelerated drying of the growth substrate, especially in container crops.

The approximate watering schedules using the subsurface method were as follows: in the summer: every 3–5 days, in the autumn-winter period: every 6–14 days.

The valve stop time, determining the subsurface time after the concrete floor was filled with water, was:
• about 6 minutes for crops in a standard substrate (control),
• 7–8 minutes for substrates with a reduced peat content,
• 8–10 minutes for peat-free substrates.

As shown by research conducted at the University of Agriculture in Krakow in the spring of 2024, peat-free substrates were characterized by a lower water capacity, which resulted in a higher risk of drying out, and this involved the need to extend the subsurface time. However, the longer time water remained in such substrates increased the risk of fungal diseases and the susceptibility of the plant root system to pathogenic infections, which is why the solution described above was chosen.
The composition of the fertilizing medium was adapted to the species being cultivated. Planta Ferty 3 Standard 15-10-15 (Planta) multi-component fertilizers with the addition of Rexolin X-60 iron chelate (YaraTerra) were used for the cultivation of pansies, marigolds and geraniums. From the middle of the production period, fertilizers with increased potassium content Universol Fiolet 10-10-30 (ICL) were introduced.

Due to the specific fertilizing requirements, chrysanthemum cultivation was carried out by applying Peters Professional AllRounder 20+20+20 (ICL) multi-component fertilizers at the beginning of production and Universol Fiolet 10-10-30 (ICL) from the middle of the production period.

Growth retardation
During cultivation, standard procedures were carried out to regulate the growth and branching of plants with compounds from the retardant group (Plant Growth Regulators - PGR). Pansy crops were sprayed with Pirouette (Fine Agrochemicals Limited) containing paclobutrazol (a compound from the triazole group), at a concentration of 0.1%, three times during the initial production period.
Marigold stunting was carried out using Dazide Enhance (Fine Agrochemicals Limited) foliarly containing the active substance daminozide (a compound from the hydrazide group) 0.3% three times every 14 days.
Similarly, chrysanthemum growth reduction was achieved using Dazide Enhance, but at a higher concentration of 0.5% every 10 days, three times during cultivation. Pelargonium was stunted with Piruette 0.1%, sprayed twice during the production period.

Biological protection
At the JENFLOR Farm, the priority is to use ecological plant protection methods that minimize the negative impact on the environment and consumer health, while ensuring effective control of pests and diseases. Biological protection methods against plant pests involve the introduction of beneficial insects, mites and microorganisms. All of the products listed below are used in accordance with the manufacturers' recommendations, which guarantees their effectiveness and safety.

Californian beetle (Amblyseius swirskii) This is a predatory mite used primarily to control thrips, greenhouse whitefly and other small sucking insects. Californian beetle is introduced by evenly distributing sachets containing mites directly on plants or by scattering loose material on leaves. The

preparation is used regularly, adjusting the doses to the level of threat to crops and environmental conditions, such as humidity and temperature.
Entonem (Steinernema feltiae) Entomopathogenic nematodes used mainly to control fungi (Sciaridae), weevils (Otiorhynchus spp.), thrips (Thrips spp.) and other pests living in the substrate. The nematodes are applied in the form of an aqueous solution. The standard dose is 500,000 nematodes/m², but it can be modified depending on the degree of pest intensity. The preparation is thoroughly mixed in water at a temperature of 15–20°C and applied using sprayers.
Montdo Mite (Neoseiulus cucumeris) is a predatory mite that effectively controls the population of thrips. Montdo Mite is distributed on plants usingsachets placed on leaves or flower stalks. The product works best in high humidity conditions (over 65%) and at a temperature of 20–25°C.

Futureco NoFly WP (Beauveria bassiana) This is a bioinsecticide containing an entomopathogenic fungus used against a wide range of pests, such as thrips, whiteflies and aphids. The fungus infects pests through contact, penetrating their cuticle and causing death within a few days.

Thrip tapes in two colours are placed throughout the greenhouse:
• yellow: They attract and reduce the population of fungi (Sciaridae) (Fig. 3).
• blue: Used to monitor and reduce the number of thrips (Thrips spp.).

These tapes act as both a control tool (monitoring) and a protective tool (reducing the number of pests). They are regularly replaced, which ensures effective operation throughout the cultivation period.

Regulation of chrysanthemum flowering - shading
Chrysanthemum is a short-day plant, which means that the flowering of this plant is initiated in response to a shortening of the day length. In horticultural practice, the shading technique is used to control the flowering phase, which allows for precise adjustment of the flowering date to the needs of the market and the production schedule. Shortening the day, i.e. acting with an appropriate photoperiod, causes chrysanthemums to move from the vegetative phase to the generative phase, which results in the formation of flower buds and their development in the next stage of production. This process is crucial for obtaining a uniform and high-quality flower crop, which is of particular importance in large-scale production and in crops grown for the needs of the potted flower trade.
Shading is carried out in accordance with the recommendations for individual varieties, which differ in terms of the requirements for the length of the day and the time needed to initiate flowering (i.e. they have a different photoperiod response). Regular monitoring of the day length and precise use of shading foil allow for obtaining optimal production effects.
A black and white foil is used for shading, which is completely impermeable to light rays. The white side of the foil reflects the sun's rays, preventing the plants from overheating, while the black side effectively blocks light.
At the JENFLOR Farm, the shading process was carried out manually, covering the plants with foil every day. The shading protocol was implemented depending on the chrysanthemum variety in weeks 29–32. The key goal was to shorten the day to a length not exceeding 13 hours, which simulates short-day conditions and stimulates the initiation of flower buds. Although this technique requires systematicity and care, it is an essential element of professional chrysanthemum cultivation.

Plant material

The seasonal plants in the studies conducted on a production scale included 4 species:

1. pansy (*Viola ×wittrockiana),*
2. marigold (*Tagetes patula*),
3. chryzanthemum (*Chrysanthemum ×morifolium*),
4. ivy geranium (*Pelargonium peltatum*).

The specification of varieties of individual species is presented in Table 2.

Table 2. Specification of species of seasonal ornamental plants used in experiments as part of the project on large-scale cultivation on peat-free substrates and with limited peat content at the JENFLOR Farm in 2024.

Gatunek	Odmiana	Dostawca/forma produktu	Tydz sadzenia	Liczba roślin	Rozmiar doniczki	Liczba doniczek	Uwagi
Chryzantema wielkokwiatowa		Spec.Gosp. Ogrod. Tyszkiewicz s.c.	27.05.2024	150 000	21 cm	30 000	Sadzone do doniczek typ misa śr. 21 cm 5 szt./don.
Chrysanthemum ×morifolium	Aurelio	1500 szt. × box 100szt.		8 000			
Chrysanthemum ×morifolium	Mayfield			7 000			
Chrysanthemum ×morifolium	Milkwaukee			40 000			
Chrysanthemum ×morifolium	Milkwaukee Red			20 000			
Chrysanthemum ×morifolium	Mount Gerlach (White)			35 000			
Chrysanthemum ×morifolium	Wilmington (Yellow)			40 000			
Bratek ogrodowy		Syngenta	16.07.2024	50 000	9 cm	50 000	Sadzone do doniczek okrągłych śr. 9 cm 1 szt./don.
Viola ×wittrockiana F1	Colosus Yellow with Blotch	tray XT 480*107= gwarantowane 107x470 = 50.290szt		11 750			
Viola ×wittrockiana F1	Colosus Pure Golden Yellow			3 760			
Viola ×wittrockiana F1	Colosus Red with Blotch			3 760			
Viola ×wittrockiana F1	Colosus Rose Surprise			2 350			
Viola ×wittrockiana F1	Colosus Tricolor			8 460			
Viola ×wittrockiana F1	Colosus White			7 050			
Viola ×wittrockiana F1	Colosus White with Blotch			7 050			
Viola ×wittrockiana F1	Colosus White with Purple			3 760			
Viola ×wittrockiana F1	Colosus Deep Blue with Blotch			2 350			
Aksamitka rozpierzchła		Syngenta	16.07.2024	50 000	9 cm	50 000	Sadzone do doniczek okrągłych śr. 9 cm 1 szt./don.
Tagetes patula nana	Aton Deep Orange	tray XT 480*130= gwarantowane 130x390=50.700szt		10 140			
Tagetes patula nana	Aton Fireball			10 140			
Tagetes patula nana	Aton Flamed (Bonanza)			10 140			
Tagetes patula nana	Aton Yellow			10 140			
Tagetes patula nana	Aton Bolero			10 140			
Pelargonia bluszczolistna		Florensis	28.08.2024		13 cm	51 200	Sadzone do doniczek okrągłych śr. 13 cm 1 szt./don.
			06.09.2024		13 cm	47 200	
Pelargonium peltatum	Medio Gabry Red	BOX 1000szt x 51,2 = 51.200					
Pelargonium peltatum	Medio Karolina Dark Red						
Pelargonium peltatum	Medio Rita Hot Pink						
Pelargonium peltatum	Sunflair Lollipop Chris Red						
Pelargonium peltatum	Medio Marlen Amethyst	BOX 1000szt x 47,2 = 47.200					
Pelargonium peltatum	Sunflair Lollipop Chris Red						
Pelargonium peltatum	Medio Ana Pink						
Pelargonium peltatum	Sunflair Lollipop Chris Red						

Plant varieties selected for biometric observations and/or laboratory tests are marked with a grey background.

Planting dates (i.e. start of production) and pot size are listed in Table 1, while the planting process, similar for all species, is illustrated in Figure 4.

Fig. 4. The process of automated planting of plants using a potting machine and a planter on the example of a garden pansy: A – filling the pots with substrate, B – leveling the substrate surface, C – planting pansy seedlings taken from the Syngenta Xtray® 480 production tray, D – automatic watering of the plants after planting by misting.

Substrates

For the research conducted as part of the project, 2 ready-made substrates with limited peat content or peat-free, recommended as suitable for large-scale research in part A of the research conducted in the experimental greenhouses of the University of Agriculture in Krakow (March-June 2024), were used.

The following substrates were used:
1. Novarbo 20 (N) with limited peat content,
2. Klasmann 5 (KLM) peat-free substrate,
3. Control (K) standard substrate used at JENFLOR prepared on the basis of high peat.

The characteristics of the substrates are presented in Table 1 and Fig. 2 a-c in part A of the report.

In addition, in the cultivation of chrysanthemum, these substrates were enriched with dried mushrooms (P), i.e. ground mushroom fruit bodies in a concentration of 2.5% by volume, as was the case in part A of the research conducted at the University.

In addition, the Bioefekt substrate (B) was tested in the cultivation of chrysanthemum. This is a peat-free substrate from a Polish manufacturer, which was decided to be tested in chrysanthemum cultivation due to its high bulk density (after initial soil analyses).

The crops were established for each species and each variety in such a way as to obtain 8 repetitions, each consisting of 10 trays filled with pots with plants, and for chrysanthemum, each repetition had 35 plants.
During cultivation, the growth and development of all cultivated groups of plants and varieties was monitored, and at the end of cultivation, after obtaining the final product, observations and analyses were carried out for selected representative taxa. Samples of substrates were also taken for physicochemical analyses..

Observations and measurements
After the cultivation was completed, the following observations and analyses of the final product were made:

- biometric:
  - plant height, number of shoots - degree of branching, mass of the above-ground part - depending on the species studied
  - flowering observations: number of flowers and flower buds
- chemical analyses of the substrate after the cultivation was completed
- chemical analyses of the plant material, indicating the nutritional status of the plants
  - content of macroelements
  - content of microelements
- physiological analyses
  - content of photosynthetic pigments
  - SPAD leaf greenness index was determined
  - Chlorophyll fluorescence was determined by examining the Fv/Fm coefficient value

The methodology of the above determinations was described in the methodology of Part A of the Report.

Statistical analysis
All collected observation and analysis results were subjected to statistical analysis, which was performed using the ANOVA module of Statistica 13.1. The significance of differences between means was verified using the Tukey test at $p=0.05$ (for the results of biometric observations and physiological analyses) or $p=0.01$ (for the nutritional status of plants).

Research results: large-scale cultivation of pansy

Fig. 5. Cultivation of garden pansies in the Jenflor greenhouse; A – placing pots in pallets after planting seedlings; B, C – description of varieties, combinations and repetitions, arrangement in the greenhouse; D-G – development stages of the vegetative part of plants.

Fig. 6. Flowering of pansies Viola ×wittrockiana: A – development of the first flowers, B, C – variety Colossus Yellow with Blotch; D – variety Colossus Tricolor; E – variety Colossus White.

Monitoring conducted during pansy production showed that the plants developed their vegetative part (Fig. 5A-G) and flowered (Fig. 6A-E) in all substrates used for cultivation, displaying characteristics typical of the varieties.

Analizy parametrów morfometrycznych roślin

Table 3 presents the results of analyses showing the effect of the tested substrate and variety on the biometric features of plants produced in different substrates and the mass of the above-ground part of the final product. The analyses showed that the varieties, regardless of the substrate used, had different heights, the Tricolor variety is the highest, and the Yellow with Blotch variety is characterized by the lowest height (Fig. 7). This feature is also influenced by the substrate, plants from the substrate containing peat, i.e. the control and Novarbo 20 were the highest, and those produced in the Klasmann peat-free substrate were about 4 cm lower (Fig. 8). Two-factor analysis (separately for each variety) confirmed this relationship, each of the analyzed varieties was the lowest when grown in the Klasmann 5 peat-free substrate (Table 3). A similar relationship was shown by analyses of the number of branches, i.e. side shoots, which translates into the decorative value of pansies, whose flowers look good on a properly built-up vegetative part. The plants grown in peat-free substrate performed the worst (Fig. 9), while limiting the peat content in the substrate did not reduce tillering, which remained at the same level as in plants grown in the peat control substrate (Control) (Fig. 9, Table 3).

Table 3. The influence of the tested substrate and pansy variety on biometric parameters and the mass of produced plants

Variety	Substrate	Plants height [cm]	Number of branches	Number of flowers	Numer of flower buds	Fresh weight [g]
Tricolor	Controll	15,6 cd*	4,42 bc	4,21 a	5,54 bc	25,7 f
	Novarbo 20	15,8 d	4,96 c	5,00 ab	6,58 c	23,6 ef
	Klasmann 5	11,7 b	3,50 a	5,54 ab	5,63 bc	12,6 b
White with Blotch	Controll	14,5 c	4,17 b	6,13 b	6,79 c	20,5 cd
	Novarbo 20	15,2 cd	4,79 bc	4,88 ab	8,62 d	21,6 de
	Klasmann 5	9,8 a	3,33 a	3,96 a	4,67 ab	8,9 a
Yellow with Blotch	Controll	12,0 b	4,33 bc	5,58 ab	6,67 c	18,9 c
	Novarbo 20	12,4 b	4,58 bc	4,29 a	8,33 d	22,1 de
	Klasmann 5	9,9 a	3,46 a	3,96 a	3,88 a	10,6 ab
Independent from substrate						
Tricolor		14,4 c	4,29 a	4,92 a	5,91 a	20,6 b
White with Blotch		13,2 b	4.09 a	4,98 a	6,69 a	17,0 a
Yellow with Blotch		11,4 a	4,13 a	4,61 a	6,29 a	17,2 a
Independent from variety						
Kontrola		14,03 b	4,31 b	5,30 a	6,33 b	21,7 b
Novarbo 20		14,45 b	4,78 c	4,72 a	7,85 c	22,4 b
Klasmann 5		10,49 a	3,43 a	4,49 a	4,72 a	10,7 a

* średnie w kolumnach oznaczone tymi samymi literami nie różnią się między sobą istotnie

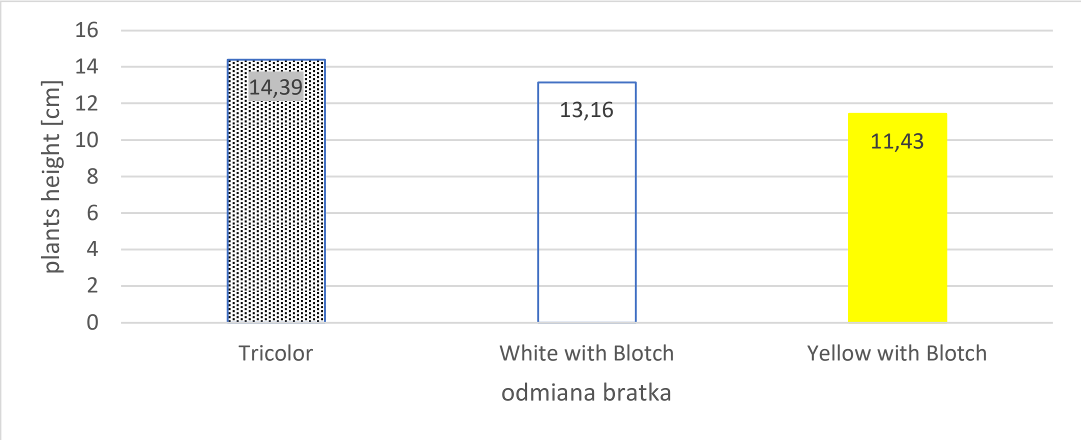


Fig. 7. The influence of the Colossus group pansy cultivar on the height of plants, regardless of the substrate used for cultivation.

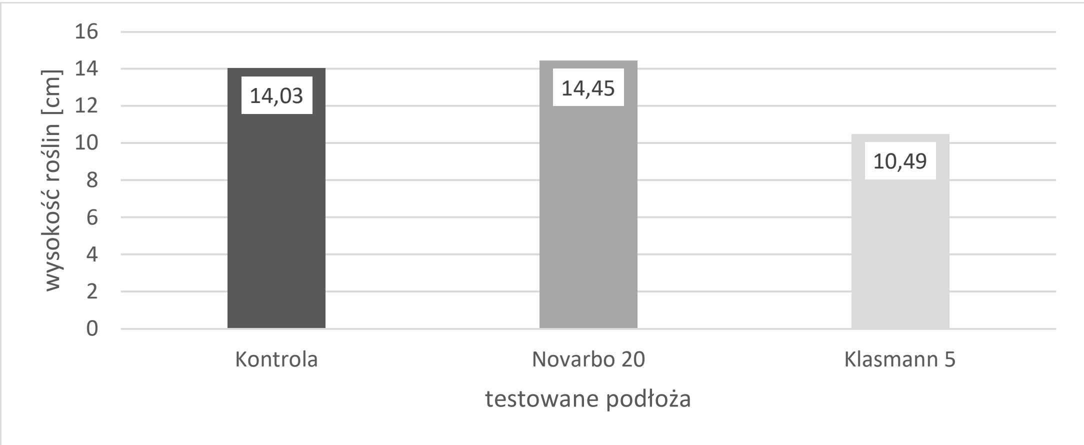


Fig. 8. The influence of the substrate on the height of the Colossus group pansies, regardless of the variety.

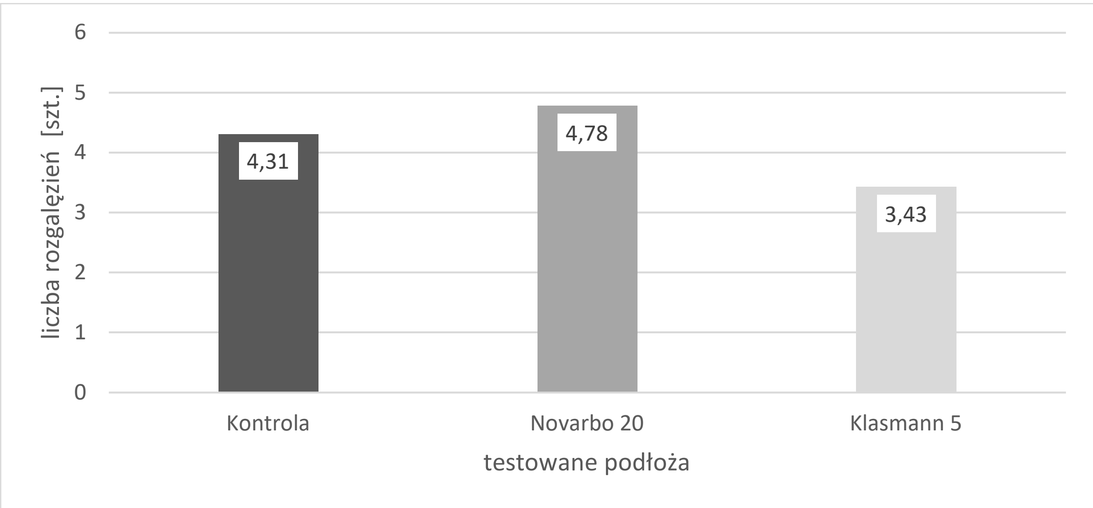
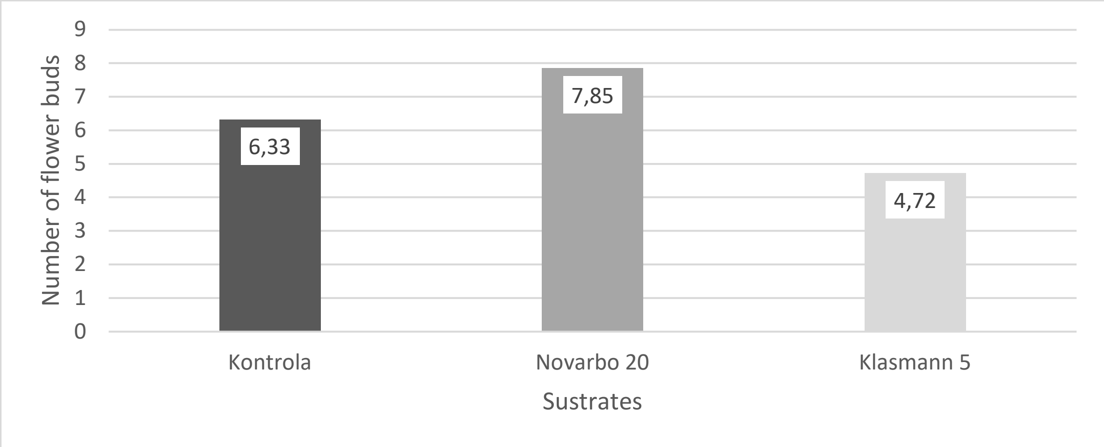


Fig. 9. The influence of the substrate on the number of branches per plant, regardless of the cultivated variety of the Colossus group pansy.

During the analyses, at the end of the production cycle, pansies had from 4 to 6.1 flowers and from 3.9 to 8.6 flower buds, depending on the variety and the substrate in which they were grown. Statistical analyses showed that the number of flowers did not depend on the growing medium, except for the White with Blotch variety, where statistically the fewest flowers were observed in plants from the Klasmann 5 substrate, compared to the control and the substrate with limited Novarbo peat content. The same was true for flower buds, but on the Klasmann substrate, statistically the fewest buds were also observed in the Yellow with Blotch variety (Table 3). When analysing this feature, regardless of the variety, it was noticed that the most flower buds were formed by plants from Novarbo 20 - 7.9 pcs., statistically fewer from the control substrate - 6.3 pcs., and the plants grown on peat-free substrate formed the least flower buds - 4.7 pcs. (Fig. 10).



Ryc. 10. Wpływ podłoża na liczbę pąków kwiatowych przypadających na 1 roślinę , niezależnie od uprawianej odmiany.

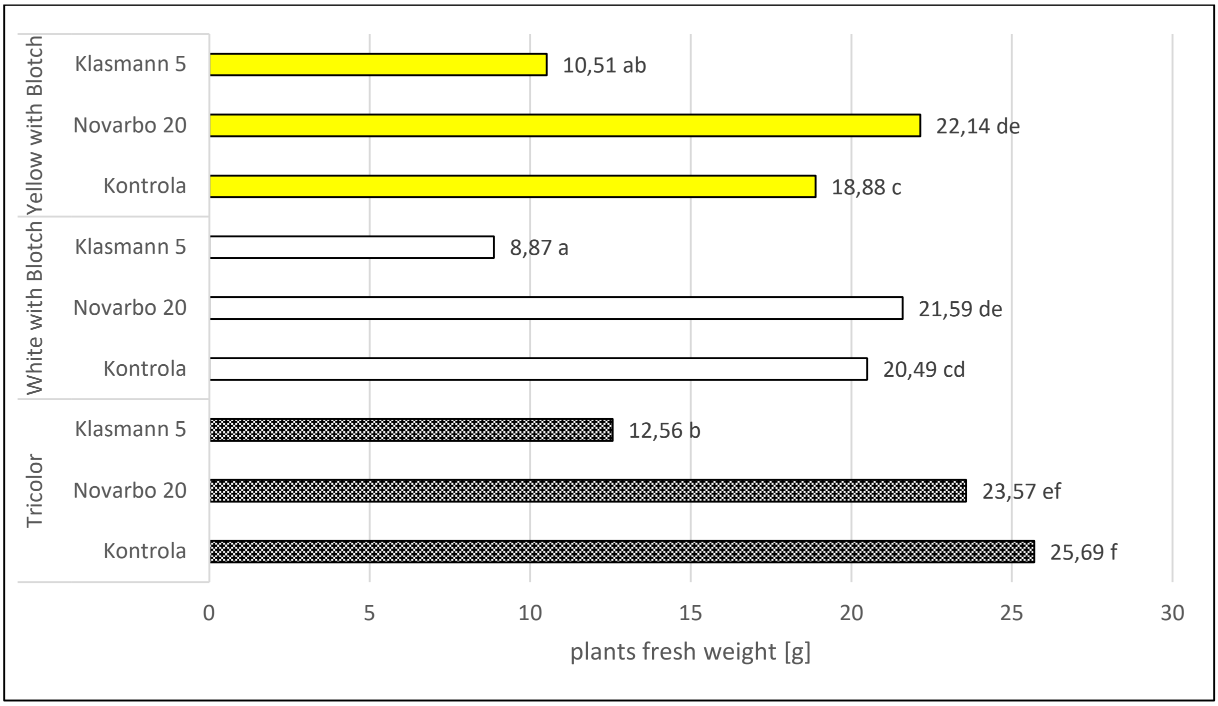
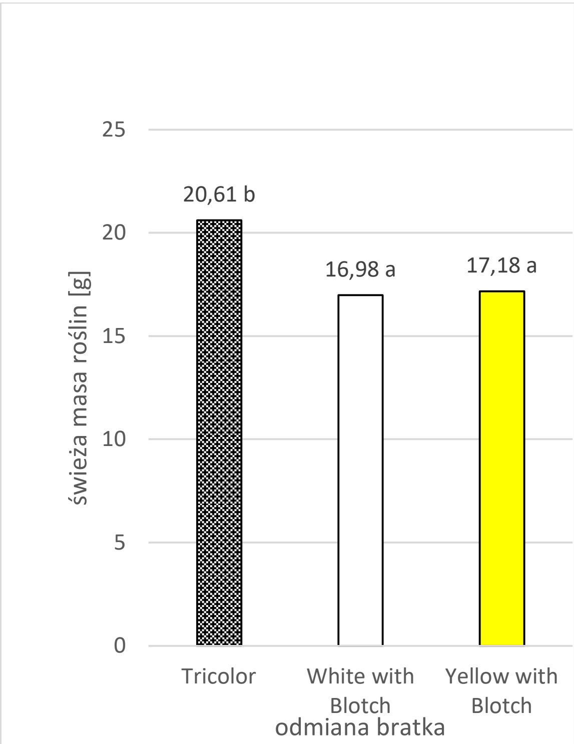
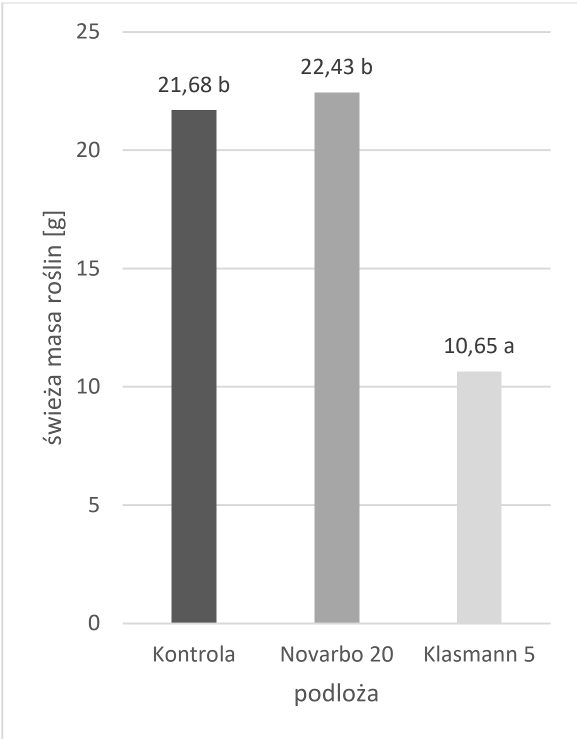


Fig. 11. The influence of the growing medium and the pansy variety on the fresh mass of plants.

The lowest fresh mass of the above-ground part of each analyzed variety from the Colossus group was characteristic of plants from the Klasmann 5 substrate (Fig. 11). The mass of plants grown in this peat-free substrate was about twice less than the control plants, which was confirmed by single-factor analyses performed independently of the variety (Fig. 12B). The fresh mass of the above-ground part of plants from the control and the substrate with limited peat content was at the same statistical level: 21.7–22.4 g, compared to plants from the peat-free substrate: 10.7 g (Fig. 12B). The studies also showed that the Tricolor variety produces the largest green mass, compared to the other two tested (Fig. 12 A).



A.



B.

Fig. 12. Fresh mass of pansy plants: A – regardless of the type of substrate, B – regardless of the variety

Physiological parameter analyses

Analyses of physiological parameters showed that the SPAD leaf greenness index does not depend on the growing medium (Table 6), but is related to the pansy variety (Table 5). Depending on the pansy variety and the medium, it ranged from 34.1 to 40.7 (Table 4). The examination carried out with the Handy PEA fluorometer indicated the correct photosynthetic efficiency of the assimilation apparatus of all cultivated plants, the Fv/Fm coefficient was 0.78-0.81. Analyses of the photosynthetic pigments content showed that the level of chlorophyll a, chlorophyll b and carotenoids was usually lower in plants grown in the Klasmann 5 medium (Tables 4-6).

Table 4. The effect of the Colossus group pansy cultivar and the growing medium on the physiological parameters: leaf greenness index (SPAD), chlorophyll fluorescence coefficient (Fv/Fm) and the content of photosynthetic pigments in plant leaves at the end of production.

Variety	Substrate	SPAD	Fv/Fm	Chlorophyll a	Chlorophyll b	Carotenoids
Tricolor	Controll	37,30 abc*	0,80 a	9,31 d	5,22 de	3,40 c
	Novarbo	35,46 ab	0,81 a	9,22 d	5,76 e	3,46 c
	Klasmann	38,88 bc	0,80 a	6,58 ab	4,21 abc	2,45 b
White with Blotch	Controll	37,09 abc	0,79 a	6,81 bc	4,77 cd	3,13 c
	Novarbo	40,66 c	0,80 a	6,61 ab	3,48 a	2,09 a
	Klasmann	38,22 bc	0,79 a	6,42 ab	4,14 abc	2,50 b
Yellow with Blotch	Controll	34,36 a	0,79 a	7,34 c	4,37 bc	2,58 b
	Novarbo	35,77 ab	0,79 a	8,99 d	5,15 de	3,42 c
	Klasmann	34,13 a	0,78 a	5,99 a	3,98 ab	2,26 ab

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

Table 5. The effect of the Colossus group pansy cultivar (irrespective of the growing medium) on the physiological parameters: leaf greenness index (SPAD), chlorophyll fluorescence coefficient (Fv/Fm) and the content of photosynthetic pigments in plant leaves at the end of production.

Variety	SPAD	Fv/Fm	Chlorophyll a	Chlorophyll b	Carotenoids
Tricolor	37,2 b*	0,80 b	8,37 c	5,06 b	2,55 c
White with Blotch	38,66 b	0,79 ab	6,61 a	4,13 a	2,55 a
Yellow with Blotch	34,76 a	0,78 a	7,44 b	4,50 a	2,76 b

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

Table 6. The influence of the growing medium (regardless of the Colossus group pansy variety) on the physiological parameters: leaf greenness index (SPAD), chlorophyll fluorescence coefficient (Fv/Fm) and the content of photosynthetic pigments in plant leaves at the end of production.

Substarte	SPAD	Fv/Fm	Chlorophyll a	Chlorophyll b	Carotenoids
Kontrola	36,25 a*	0,79 a	7,82 b	4,79 b	3,04 b
Novarbo	37,30 a	0,80 a	8,27 c	4,80 b	2,96 a
Klasmann	37,08 a	0,79a	6,32 a	4,11 a	2,41 a

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

Analysis of physicochemical properties of substrates

Table 7 presents the results of the determination of selected physical properties of the growing substrates used in autumn commercial production (at Jenflor) of three varieties of garden pansy. The highest volumetric density was determined in the Klasmann 5 substrate (0.120 g cm-3) in relation to the control (0.074 g cm-3) and the Novarbo 20 substrate (0.078 g cm-3). The substrate with limited peat content Novarbo 20 was distinguished by the highest water capacity among the growing substrates compared in the studies.

No significant effect of the variety factor on the physical properties of the growing substrates tested after cultivation was demonstrated (Table 7).

Table 7. Physical properties of substrates in commercial cultivation (Jenflor company) of pansies: Tricolor varieties – purple, Yellow with Blotch – yellow, White with Blotch – white.

Factor		Bulk density g cm^{-3}	Water capacity % wv	Water capacity %ww
Controla		0,074 A	64,5 B	837 B
Novarbo 20		0,078 A	**73,6** C	**946** C
Klasmann 5		**0,120** B	56,6 A	480 A
Purple		0,092 A	65,1 A	793 A
Yellow		0,087 A	62,9 A	737 A
White		0,087 A	62,9 A	737 A
Kontrola	Purple	0,069 a	65,5 a	950 cd
	Yellow	0,078 a	59,2 a	756 bc
	White	0,074 a	68,9 a	804 cd
Novarbo 20	Purple	0,075 a	76,0 a	1020 d
	Yellow	0,080 a	71,2 a	887 cd
	White	0,079 a	73,6 a	931 cd
Klasmann 5	Purple	0,133 c	54,0 a	408 a
	Yellow	0,103 b	58,3 a	568 ab
	White	0,124 c	57,5 a	463 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 - substrate type and factor 2 - cultivar; control - peat substrate

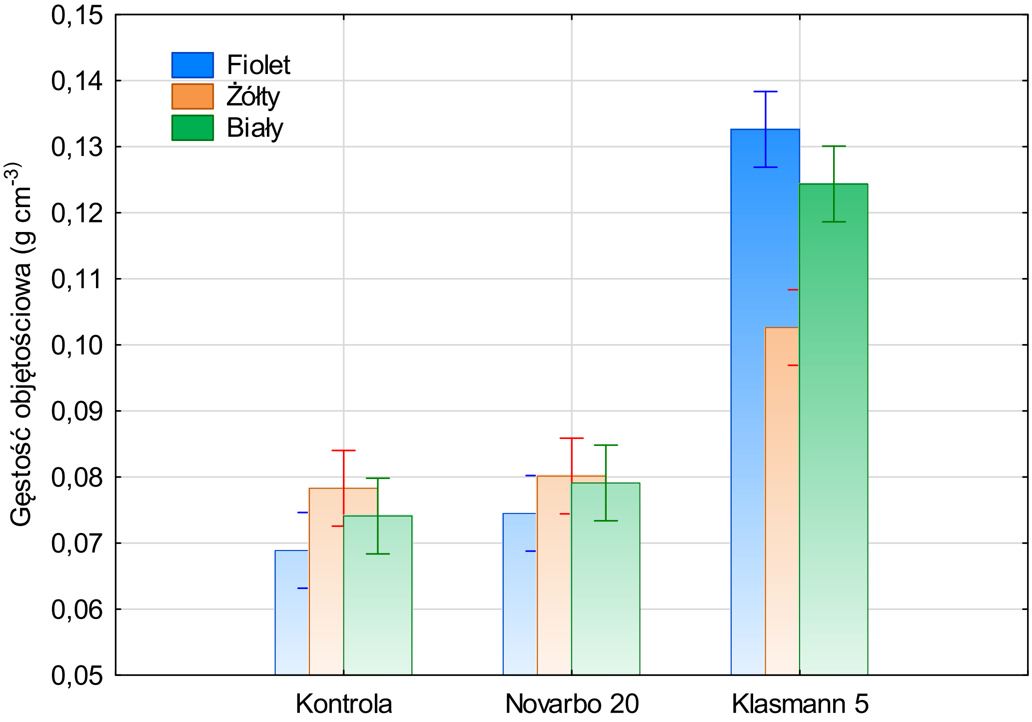


Fig. 13. The effect of the type of substrate and variety on the bulk density of the substrate (g cm-3) determined after commercial cultivation of a pansy cultivar from the Colossus group: variety designations: purple – Tricolor, white – White with Blotch, yellow – Yellow with Blotch.

The lowest water capacity expressed in relation to the dry mass of the substrate was determined in the peat-free Klasmann 5 substrate after the cultivation of the purple (Tricolor) pansy variety (408% ww) and the highest in the Novarbo 20 substrate, also after the cultivation of the purple (Tricolor) variety (1020% ww) (Table 7). Analysis of the interaction of the factors used in the experiment (substrate × variety) showed that the Klasmann 5 substrate taken for the study from the yellow (Yellow with Blotch) pansy variety was characterized by a significantly lower bulk density than in the case of the other varieties (Fig. 13). No such relationship was observed for the peat control and the substrate with limited peat content Novarbo 20. All substrates were well overgrown with plant roots, especially in the lower part of the cultivation containers (Fig. 14-16).

A. Controll

B. Klasmann 5

C. Novarbo 20

Fig. 14. Intensity of root ball overgrowth of the White with Blotch pansy (white) growing in the substrate: A - control, B - Klasmann 5, C - Novarbo 20 after completion of cultivation in the Jenflor production glasshouse.

A. Controll

B. Klasmann 5

C. Novarbo 20

Fig. 15. Intensity of root ball overgrowth of the Tricolor pansy (violet) growing in the substrate: A - control, B - Klasmann 5, C - Novarbo 20, after completion of cultivation in the Jenflor production glasshouse.

A. Kontrola

B. Klasmann 5

C. Novarbo 20

Fig. 16. Intensity of root ball overgrowth of pansy Yellow with Blotch (yellow) growing in the substrate: A - control, B - Klasmann 5, C - Novarbo 20, after completion of cultivation in the Jenflor production glasshouse.

The results of chemical properties and organic matter content of substrates determined after autumn cultivation of pansy are presented in Table 8. The lowest pH was determined in the peat control substrate (pH 5.83). Substrates with limited peat content and without peat had a neutral pH, i.e. pH 6.97 (Novarbo 20) and pH 7.03 (Klasmann 5), respectively.
The salt concentration in the Novarbo 20 substrate was significantly lower than in the control substrate. Analysis of substrates after cultivation showed a generally low content of ammonium nitrogen (the lowest in the Klasmann 5 substrate). On the other hand, the highest N-NO3 was determined in the peat control substrate (98.1 mg N-NO3 dm-3).

Table 8. Acidity (pH), salinity (EC µS cm-1) and the content of macroelements, sodium (mg dm-3) and organic matter in substrates after cultivation of pansy - varieties from the Colossus group: purple - Tricolor, white - White with Blotch, yellow - Yellow with Blotch, in the production conditions of Jenflor company.

Factor		**pH**	**EC**	**N-NH$_4$**	**N-NO$_3$**	**Ca**	**K**	**Mg**	**P**	**S**	**Na**	**SO%**
Controll		*5,83* A	865 B	3,83 B	**98,1** B	1691 B	191 B	290 A	88,5 B	323 A	67,3 A	87,7 B
Novarbo 20		6,97 B	718 A	4,41 B	4,09 A	**2169** C	*111* A	347 B	*72,2* A	465 B	85,0 A	85,5 B
Klasmann 5		7,03 B	759 AB	*0,36* A	0,23 A	1319 A	**454** C	352 B	86,3 B	338 AB	**119** B	57,8 A
Purple		6,61 AB	809 A	2,52 A	33,6 A	1661 A	250 A	306 A	88,5 B	312 A	83,1 A	76,8 A
Yellow		6,43 A	791 A	2,84 AB	40,0 A	1686 A	255 A	345 A	73,0 A	465 B	103 A	76,7 A
White		6,80 B	743 A	3,25 B	28,8 A	1832 A	250 A	339 A	85,5 AB	350 AB	85,5 A	77,4 A
Kontrola	Purple	5,79 a	871 a	3,95 b-d	97,5 a	1529 a	167 ab	245 a	87,6 bc	243 a	56,0 a	89,4 d
	Yellow	5,77 a	883 a	2,95 b	117 a	1765 a	244 b	330 a	96,3 bc	345 ab	77,7 a	84,3 c
	White	5,94 a	844 a	4,60 cd	80,2 a	1778 a	160 ab	294 a	81,6 a-c	382 ab	68,3 a	89,4 d
Novarbo 20	Purple	6,88 a	690 a	3,17 bc	3,32 a	2037 a	90 a	315 a	74,5 a-c	301 a	58,8 a	87,0 cd
	Yellow	6,94 a	684 a	4,97 d	2,85 a	2171 a	106 a	369 a	71,1 ab	658 b	100 ab	82,4 c
	White	7,10 a	779 a	5,09 d	6,10 a	2299 a	136 ab	357 a	71,1 ab	438 ab	96,0 ab	87,0 cd
Klasmann 5	Purple	7,15 a	866 a	0,43 a	0,06 a	1418 a	493 c	357 a	103 bc	393 ab	135 b	54,1 a
	Yellow	6,59 a	806 a	0,61 a	0,56 a	1121 a	415 c	334 a	51,7 a	390 ab	132 b	63,4 b
	White	7,36 a	605 a	0,05 a	0,08 a	1420 a	453 c	365 a	104 c	231 a	92,3 ab	55,9 a

Post-hoc comparisons were performed using Tukey's test at p = 0.05; the same letters indicate no significant differences between means; two-factor analysis, where factor 1 - substrate type and factor 2 - cultivar; control – peat substrate

The Novarbo 20 substrate contained the most soluble calcium and the least potassium and phosphorus. On the other hand, the most potassium and sodium were determined in the Klasmann 5 substrate (Table 8).

A slight effect of the cultivated variety on the pH of the substrate and the content of N-NH4, phosphorus and sulfur in the growing substrates was observed. A significantly higher pH was determined in the substrate taken for testing from the cultivation of the white pansy variety in relation to the yellow variety. The most N-NH4 was shown in the substrate after the cultivation of the white pansy variety in relation to the purple variety. On the other hand, the most phosphorus was determined in the substrate in which the purple variety was cultivated in relation to the yellow variety. An inverse relationship was found for the sulfur content in the substrates analyzed after the cultivation was completed.

A significant effect of the interaction of substrate × variety factors was demonstrated for the content of N-NH4, soluble potassium, phosphorus, sulfur and sodium, as well as for organic matter in the growing substrates analyzed after the completion of the pansy experiment (Table 8, Figs. 17-19).

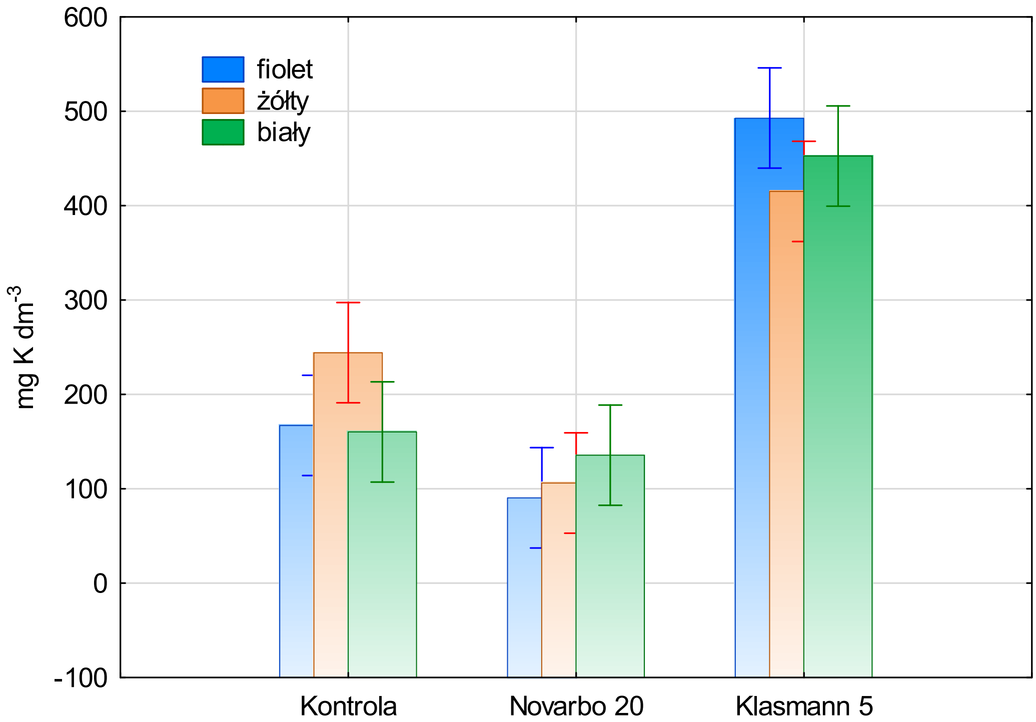


Fig. 17. The effect of the type of substrate and variety on the soluble potassium content (mg K dm-3) determined after commercial cultivation (Jenflor company) of pansy varieties from the Colossus group: purple – Tricolor, white – White with Blotch, yellow – Yellow with Blotch.

Significantly more ammonium nitrogen was determined in the control substrate after the cultivation of white pansy compared to the yellow one. In the Novarbo 20 substrate, more N-NH4 was shown for the white and yellow varieties than for the purple one. The lowest potassium content was determined in the Novarbo 20 substrate in which the purple pansy variety was grown, and the highest in the Klasmann 5 substrate for the same variety. The control substrate taken for testing after the cultivation of the yellow pansy variety was distinguished by an increased K content compared to the other varieties used in the tests (Fig. 17).

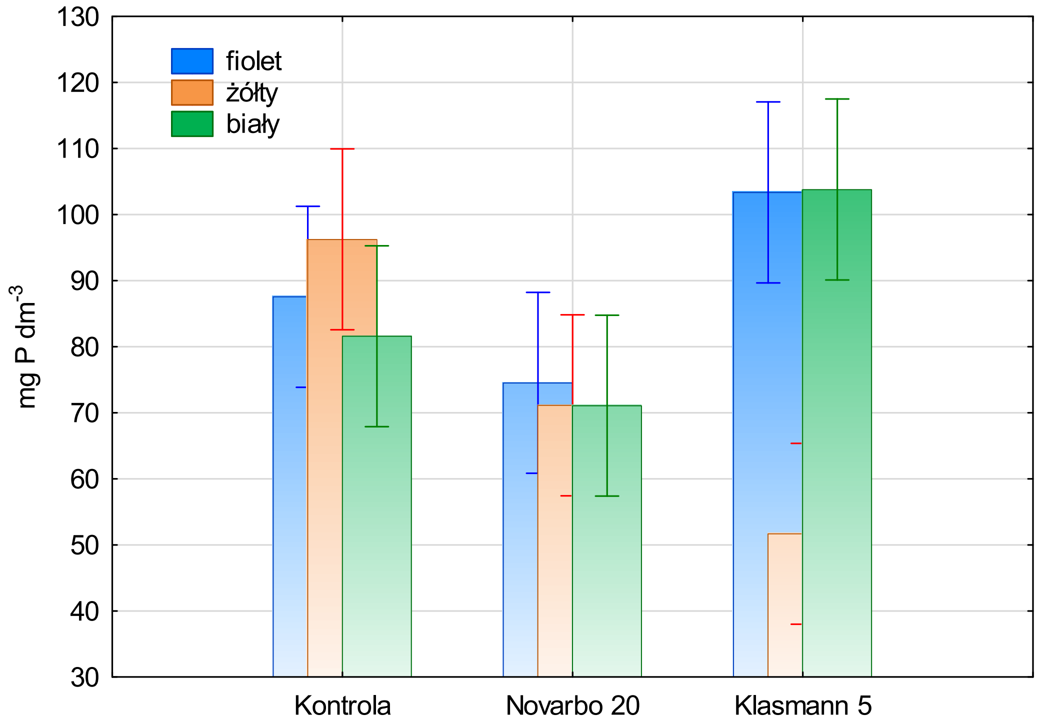


Fig. 18. The effect of the type of substrate and variety on the soluble phosphorus content (mg P dm-3) determined after commercial cultivation (Jenflor company) of pansy varieties from the Colossus group: purple – Tricolor, white – White with Blotch, yellow – Yellow with Blotch.

Very large differences were shown for the phosphorus content in the peat-free Klasmann 5 substrate tested after the cultivation of three pansy varieties (Fig. 18). The substrate in which the yellow variety was grown contained the least P (51.7 mg P dm-3) compared to the purple and white varieties (103 and 104 mg P dm-3, respectively).

In general, the least organic matter was determined in the Klasmann 5 substrate compared to the peat substrate and the Novarbo 20 substrate with limited peat content (Fig. 19). The lowest organic matter content was shown for the combination of this substrate with the purple and white pansy varieties (54.1% and 55.9%, respectively). In the case of the control substrate and Novarbo 20, a tendency towards a lower organic matter content was observed in the substrates planted with the yellow variety of the large-flowered pansy (Fig. 19).

Table 9 presents the results of microelement determinations in substrates after the end of commercial production of the garden pansy from the Colossus group.

The substrate with limited peat content Novarbo 20 contained the most copper and molybdenum. On the other hand, the peat-free Klasmann 5 substrate was the richest in boron, iron, manganese and zinc.The substrates taken for testing from the cultivation of the Colossus Yellow with Blotch pansy contained the most molybdenum.

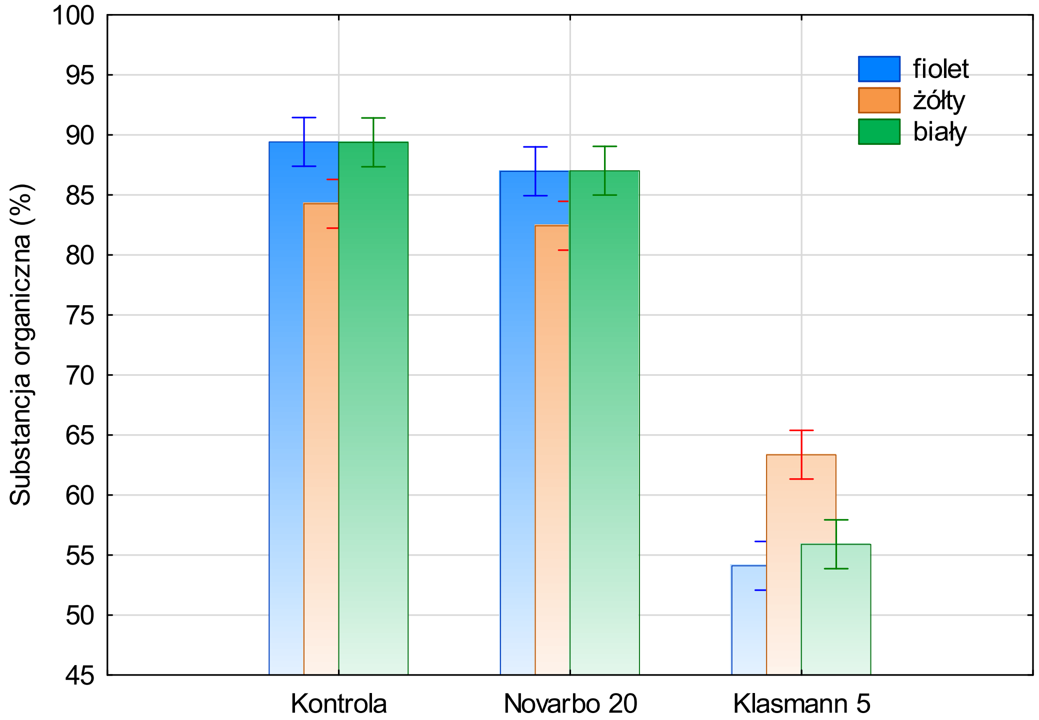


Fig. 19. The influence of the type of substrate and variety on the content of organic matter in substrates determined after commercial cultivation (Jenflor company) of pansy varieties from the Colossus group: purple – Tricolor, white – White with Blotch, yellow – Yellow with Blotch.

Table 9. Content of microelements (mg kg-1) in substrates after cultivation of pansy in production conditions (Jenflor), varieties from the Colossus group marked as purple – Tricolor, white – White with Blotch, yellow – Yellow with Blotch.

Factor		B	Cu	Fe	Mn	Mo	Zn
Controll		6,4 A	28,9 A	2429 A	70,0 A	12,9 A	37,4 A
Novarbo 20		9,8 B	**36,0** B	3310 A	88,8 A	**21,3** B	40,3 A
Klasmann 5		**15,3** C	32,0 A	**9326** B	**181** B	15,9 A	**64,8** B
Purple		10,3 A	33,6 A	4835 A	106 A	15,6 A	44,2 A
Yellow		10,8 A	31,7 A	4621 A	111 A	**19,4** B	49,5 A
White		10,5 A	31,6 A	5610 A	122 A	15,0 A	48,9 A
Controll	Purple	5,8 a	28,8 a	2477 a	62,3 a	12,7 a	33,5 a
	Yellow	7,6 a	27,0 a	2948 a	82,6 a	12,5 a	41,6 a
	White	5,7 a	31,0 a	1861 a	64,9 a	13,5 a	37,1 a
Novarbo 20	Purple	9,4 a	36,4 a	2175 a	61,1 a	18,7 a	32,1 a
	Yellow	8,8 a	36,2 a	3253 a	93,7 a	28,4 b	43,6 a
	White	11,2 a	35,4 a	4503 a	112 a	16,8 a	45,2 a
Klassman 5	Purple	15,6 a	35,7 a	9852 a	194 a	15,3 a	67,0 a
	Yellow	15,9 a	31,9 a	7661 a	158 a	17,4 a	63,2 a
	White	14,4 a	28,5 a	10465 a	190 a	14,8 a	64,4 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 - substrate type and factor 2 - cultivar; control - peat substrate

Analyses of the nutritional status of plants

Both the dry mass and mineral composition of the three varieties of garden pansy were significantly dependent on the growing media used in the study (Table 10). The highest dry mass was determined in pansies growing on Klasmann 5 substrate (14.4%). Both plants taken for the study from the peat control substrate and from the substrate with limited content of Novarbo 20 peat had a similar dry mass of approx. 11%. In the plants from the control, the least nitrogen, magnesium, phosphorus and sulphur were determined, and the most sodium. The biomass of pansies growing in the peat-free substrate and with limited content of peat had a similar mineral composition (Table 10).

Table 10. Content of macroelements (% DM) and sodium (mg kg-1 DM) in 3 varieties of large-flowered pansy grown in organic substrates in the conditions of a production greenhouse (Jenflor); variety designations: purple – Tricolor, white – White with Blotch, yellow – Yellow with Blotch.

Czynnik		**DM**	**N**	**Ca**	**K**	**Mg**	**P**	**S**	**Na**
Controll		11,0 A	*2,26* A	1,02 A	4,63 B	*0,33* A	*0,62* A	*0,24* A	**541** B
Klasmann 5		**14,4** B	3,04 B	1,42 B	4,32 A	0,42 B	0,77 B	0,28 B	343 A
Novarbo 20		11,2 A	3,08 B	1,46 B	4,31 A	0,42 B	0,75 B	0,28 B	348 A
Purple		12,6 B	2,88 B	1,27 A	4,23 A	0,38 A	0,68 A	0,26 A	425 A
Yellow		*11,5* A	*2,52* A	1,37 A	4,43 AB	**0,42** B	0,69 A	0,27 A	425 A
White		12,5 B	2,99 B	1,26 A	4,61 B	0,37 A	**0,78** B	0,27 A	382 A
controll	Purple	10,8 a	2,36 a-c	1,01 a	4,81 c	0,31 a	0,60 a	0,26 ab	631 d
	Yellow	11,0 a	2,15 a	1,10 a	4,39 a-c	0,39 a	0,62 a	0,23 a	485 b-d
	White	11,2 ab	2,27 ab	0,95 a	4,70 c	0,30 a	0,63 a	0,23 a	506 cd
Klasmann 5	Purple	**15,7** d	3,22 e	1,44 a	4,02 ab	0,43 a	0,74 a	0,28 ab	327 ab
	Yellow	13,8 c	2,66 b-d	1,45 a	4,40 a-c	0,43 a	0,71 a	0,28 ab	393 a-c
	White	13,6 c	3,25 e	1,38 a	4,55 bc	0,40 a	0,86 a	0,29 b	310 a
Novarbo 20	Purple	11,2 ab	3,05 de	1,36 a	3,85 a	0,40 a	0,69 a	0,25 ab	316 ab
	Yellow	9,81 a	2,73 cd	1,57 a	4,51 bc	0,46 a	0,73 a	0,30 b	398 a-c
	White	12,7 bc	3,45 e	1,45 a	4,56 bc	0,40 a	0,84 a	0,30 b	330 ab

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 - substrate type and factor 2 - cultivar; control - peat substrate

Analyzing the effect of the second factor, it was shown that the content of dry mass, nitrogen, potassium and magnesium was significantly dependent on the variety used in the experiment. The highest dry mass and nitrogen content were found in purple and yellow pansies. On the other hand, the white pansies had the highest magnesium content. Yellow plants had a significantly higher phosphorus content (Table 10). Plants in this color also had a high potassium content, but they differed significantly in this feature only in relation to the purple variety. With the exception of calcium, magnesium and phosphorus, a significant effect of the interaction of the experimental factors (substrate × variety) was shown on the content of dry mass and other macroelements in plant biomass (Table 10). The yellow pansy variety growing in the Novarbo 20 substrate was distinguished by an increased dry mass (12.7%) in relation to the other varieties grown in this substrate combination (Fig. 20). The purple pansies produced the highest dry mass when grown in the peat-free Klasmann 5 substrate (15.7%). The yellow pansies grown in the Novarbo 20 substrate contained the most nitrogen (3.45%), while the white pansies grown in the peat substrate contained the least (2.15%) (Fig. 21). The white plants generally had a lower nitrogen content, regardless of the substrate used in the study.

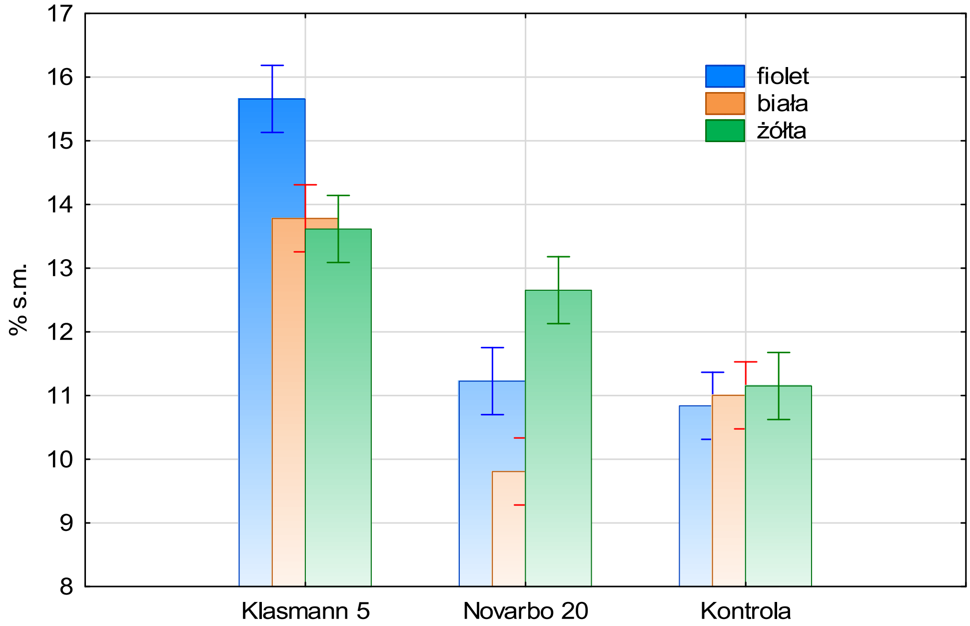
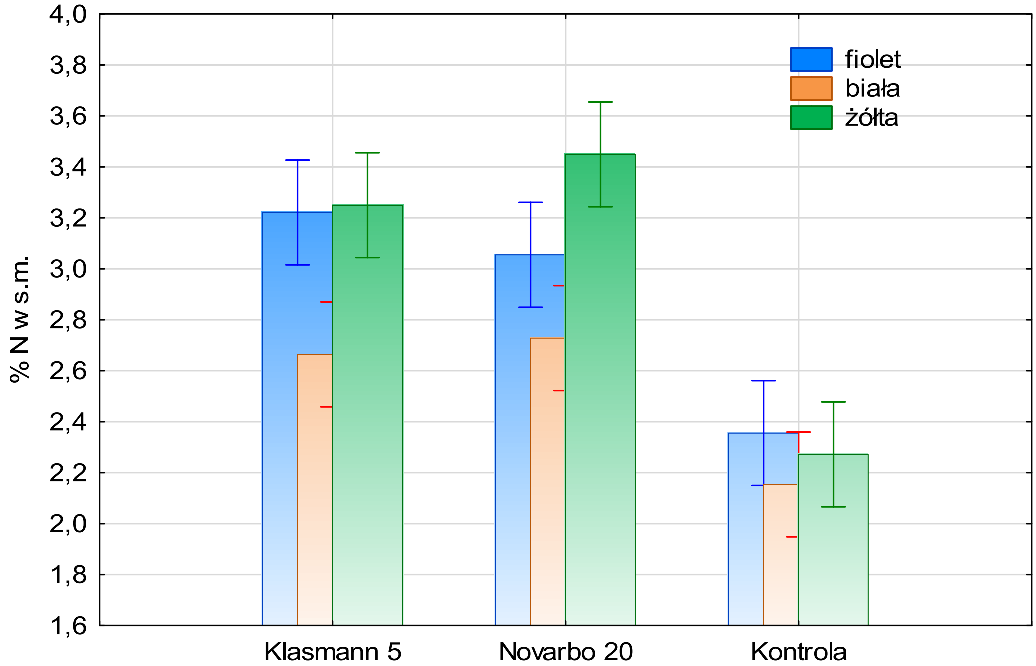


Fig. 20. The effect of the type of substrate and variety on the dry matter content (% d.m.) in the biomass of pansy grown under production conditions (Jenflor) of the Colossus group varieties: purple – Tricolor, white – White with Blotch, yellow – Yellow with Blotch.



Ryc. 21. Wpływ rodzaju podłoża i odmiany na zawartość azotu (% N w s.m.) w biomasie bratka - odmiany z grupy Colossus: fiolet – Tricolor, biała – White with Blotch, żółta – Yellow with Blotch, uprawianego w warunkach produkcyjnych (Jenflor).

The white and yellow pansy varieties contained the most potassium when grown in the Novarbo 20 substrate. A similar trend was shown for the Klasmann 5 substrate (Fig. 22). In the case of the Klasmann 5 substrate, this corresponded to the abundance of this component in the control substrate (Table 10).

The white and yellow pansy varieties grown in the control peat substrate were distinguished by a low sulfur content, especially in relation to their analogues grown in the Novarbo 20 substrate (Fig. 23). This substrate was distinguished by a significantly higher content of soluble sulfur compared to the control (Table 10).

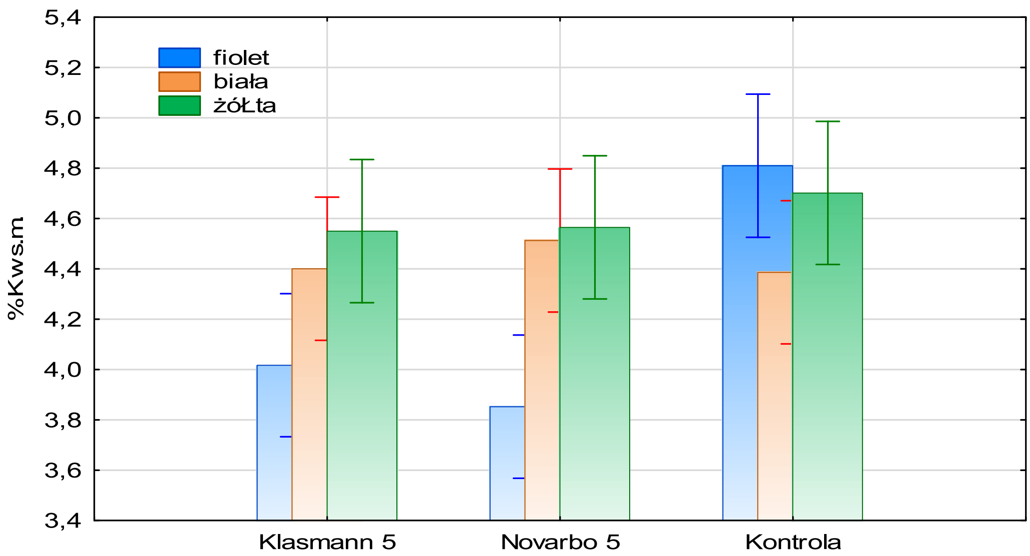


Fig. 22. The effect of the type of substrate and variety on the potassium content (% K in dry matter) in the biomass of pansy - varieties from the Colossus group: purple - Tricolor, white - White with Blotch, yellow - Yellow with Blotch, cultivated under production conditions (Jenflor)

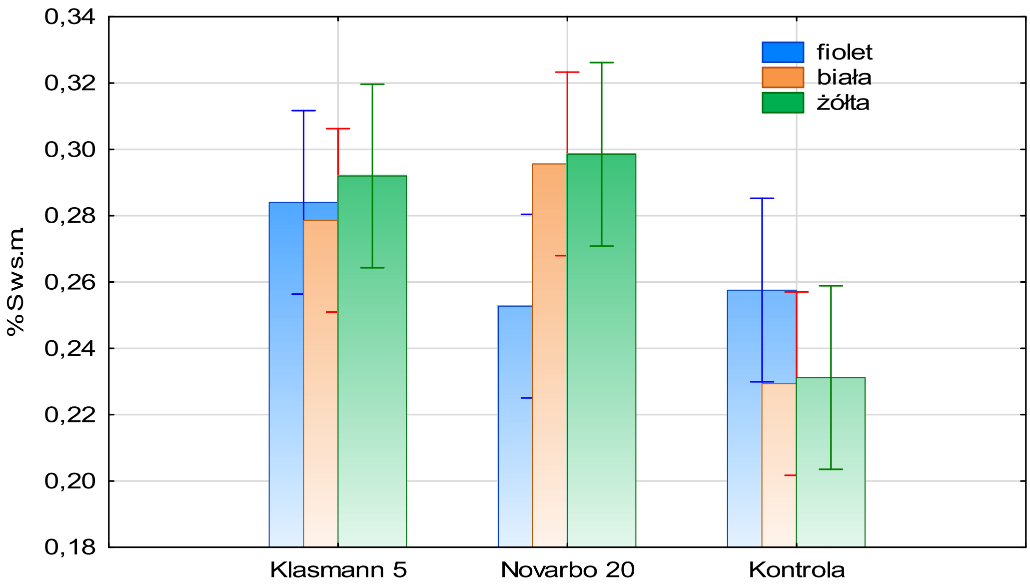


Fig. 23. The effect of the substrate type and variety on the sulfur content (% S in dry matter) in the biomass of pansy - varieties from the Colossus group: purple – Tricolor, white – White with Blotch, yellow – Yellow with Blotch grown under production conditions (Jenflor).

Table 11 presents the results of microelement content determinations in the biomass of three varieties of garden pansy from the Colossus group grown under production conditions in peat-free substrates and with limited peat content. Pansies grown in a control substrate based on high peat contained the least boron, copper and zinc. In general, pansies grown in substrates prepared from organic waste materials (Klasmann 5) and with limited peat content (Novarbo 20) were distinguished by significantly higher boron, copper, manganese and zinc content. It was shown that the yellow variety pansies contained significantly less manganese compared to the purple and white varieties and significantly more zinc, especially to the purple variety.

A significant effect of the interaction of the experimental factors type of substrate x variety on the content of boron, manganese and zinc in pansy plants was also demonstrated (Table 11). However, from the production point of view, these relationships seem to have no greater practical significance. In the medium with limited peat content Novarbo 20 significantly more boron was determined in pansies of the white variety than in the purple one. Control pansies in the white variety were distinguished by the highest manganese content (98 mg Mn kg-1 d.m.), especially in relation to the yellow variety (29.9 mg Mn kg-1 d.m.). On the other hand, in the peat-free Klasmann 5 medium the purple variety accumulated the most manganese in comparison to the yellow and white ones. The least zinc was determined in pansies of the yellow variety grown in peat (control) in comparison to the Klasmann 5 and Novarbo 20 media (Table 11).

Table 11. Micronutrient content (mg kg-1 d.m.) in 3 varieties of pansy grown in organic substrates in a production greenhouse (Jenflor). Varieties: purple – Tricolor, white – White with Blotch, yellow – Yellow with Blotch.

Factor		**B**	**Cu**	**Fe**	**Mn**	**Zn**	**Ti**
Controll		*18,9* A	*3,1* A	147 B	60,6 A	*54,4* A	2,94 A
Klasmann 5		22,3 B	4,7 B	100 A	69,1 B	68,0 B	2,46 A
Novarbo 20		21,4 B	4,6 B	104 AB	68,8 AB	65,4 B	2,63 A
fiolet		19,9 A	3,9 A	125 A	76,6 B	59,8 A	2,53 A
biała		21,6 B	4,2 A	122 A	71,8 B	60,4 AB	2,79 A
żółta		21,2 AB	4,4 A	105 A	*50,2* A	67,5 B	2,72 A
	fiolet	18,3 a	3,0 a	163 a	53,8 ab	48,5 a	2,84 a
Controll	biała	19,8 a-c	3,5 a	167 a	98,0 d	64,7 ab	2,93 a
	żółta	18,7 ab	2,9 a	113 a	29,9 a	49,9 a	3,05 a
	fiolet	22,0 bc	4,6 a	114 a	94,1 d	69,8 ab	2,75 a
Klasmann 5	biała	22,0 bc	4,4 a	91,9 a	59,0 bc	58,3 ab	2,40 a
	żółta	22,9 c	5,2 a	94,5 a	54,3 ab	75,7 b	2,25 a
	fiolet	19,2 ab	4,1 a	96,9 a	81,8 cd	61,1 ab	2,00 a
Novarbo 20	biała	23,0 c	4,7 a	107 a	58,3 bc	58,2 ab	3,04 a
	żółta	22,0 bc	5,0 a	108 a	66,3 bc	76,9 b	2,86 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 - substrate type and factor 2 - cultivar; control - peat substrate

Research results: large-scale cultivation of French marigold

Fig. 24. Cultivation of Tagetes patula in the Jenflor production greenhouse: A, B – labelled plots with the tested combinations, C, D – development of the vegetative part.

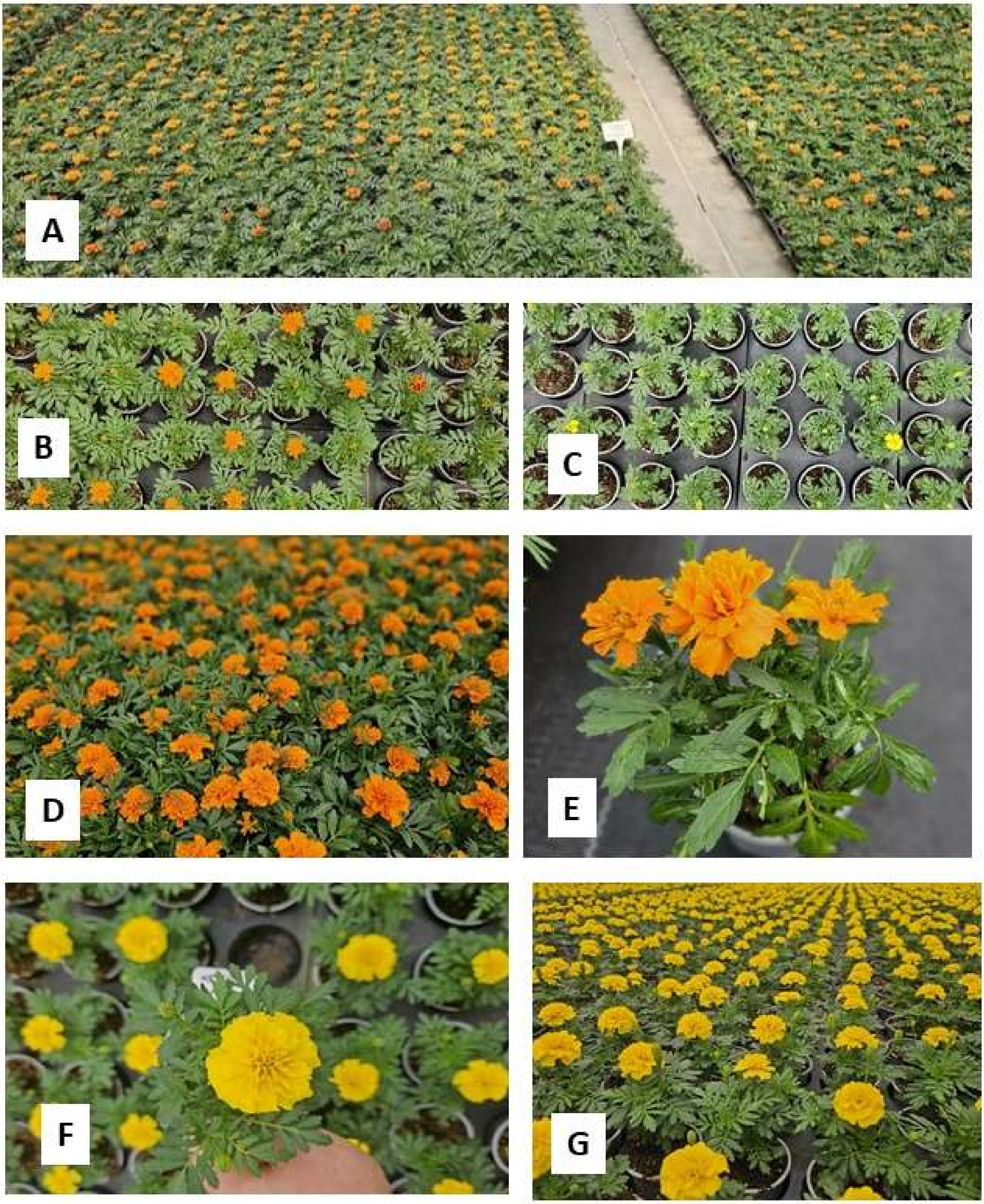


Fig. 25. Generative development stages of Tagetes patula in the Jenflor production greenhouse: A - C – beginning of flowering, D, E – full flowering of the Bonanza variety, F, G – full flowering of the Aton Yellow variety.

All Tagetes patula plants started growing after being planted in pots with the tested substrates. In the first stage of growth, lateral shoots and leaves developed (Fig. 24 A-D), then flower buds appeared, and the inflorescence basket on the main shoot was the first to bloom (Fig. 25 A-G).

Analysis of plant morphometric parameters

Statistical analyses showed that the tested marigold varieties differed in height, the Aton Yellow variety in the control substrate reached 17 cm in height, while the Bonanza variety, in the same substrate, was 1.5 cm lower (Table 12). This relationship was confirmed for varieties grown in substrates with limited peat content (Novarbo 20) and without peat (Klasmann 5), the yellow variety was always higher. It was observed that substrates with limited peat content and without peat inhibit plant growth, especially the Bonanza variety. Statistical analyses performed independently of the variety showed that plants from the tested substrates (Novarbo 20 and Klasmann 5) were 2-2.5 cm lower, compared to those from the peat substrate (Control). It was observed that with the decrease in the peat content in the substrate, the number of side shoots decreases in the tested marigold varieties, i.e. they branch to a lesser extent, and in the Aton Yellow variety this relationship is statistically significant. The univariate analysis showed that the Aton Yellow variety branches better compared to the Bonanza variety and that the plants branched best in the control substrate (Table 12).

Table 12. The effect of the growing substrate and variety on the height of plants and branching of two Tagetes patula nana varieties (bivariate and univariate analysis).

Variety	**Substrate**	**Plant height [cm]**	**Number of branches**
Aton Yellow	Controll	17,5 d*	6,25 c
	Novarbo 20	14,9 b	6,13 bc
	Klasmann 5	16,7 cd	5,75 b
Bonanza	Controll	16,0 bc	4,71 a
	Novarbo 20	13,3 a	4,50 a
	Klasmann 5	13,1 a	4,29 a
Independent of the Substrate			
Aton Yellow		16,4 b	6,04 b
Bonanza		14,1 a	4,50 a
Independent from Variety			
Controll		16,7 c	5,48 b
Novarbo 20		14,1 a	5,31 ab
Klasmann 5		14,9 b	5,02 a

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

Observations of the number of developed flower heads and flower heads in buds showed that regardless of the substrate used, the final product of the Aton Yellow variety has a greater potential for flowering. Although the number of flowers is at the same level as in the Bonanza variety, the plants of this variety have significantly more flower buds (Table 13, Fig. 26). Studies have shown that substrates with limited peat content and peat-free have an inhibiting effect on the formation of flower buds and the development of flowers (Fig. 27).

Table 13. The influence of the growing medium and the cultivar on the flowering of two cultivars of Tagetes patula nana (two-factor and one-factor analysis)

Variety	Substrate	Flower number	Flower buds number	Sum of buds and flowers
Aton Yellow	Controll	1,54 a*	4,33 c	5,88 c
	Novarbo 20	1,46 a	3,58 b	5,04 b
	Klasmann 5	1,88 ab	3,08 b	4,96 b
Bonanza	Controll	2,25 b	1,58 a	3,83 a
	Novarbo 20	1,33 a	2,17 a	3,50 a
	Klasmann 5	2,17 b	1,42 a	3,58 a
Independent of the Substrate				
Aton Yellow		1,62 a	3,67 b	5,29 b
Bonanza		1,92 a	1,72 a	3,64 a
Independent from Variety				
Controll		1,90 b	2,95 b	4,85 b
Novarbo 20		1,40 a	2,87 b	4,27 a
Klasmann 5		2,02 b	2,25 a	4,27 a

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

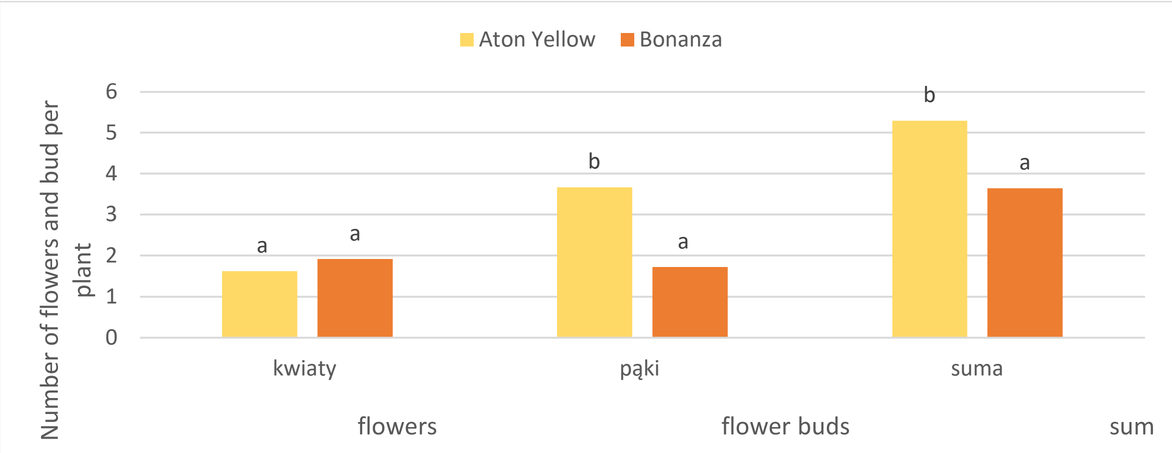


Fig. 26. The influence of the marigold variety, regardless of the substrate used, on flowering..

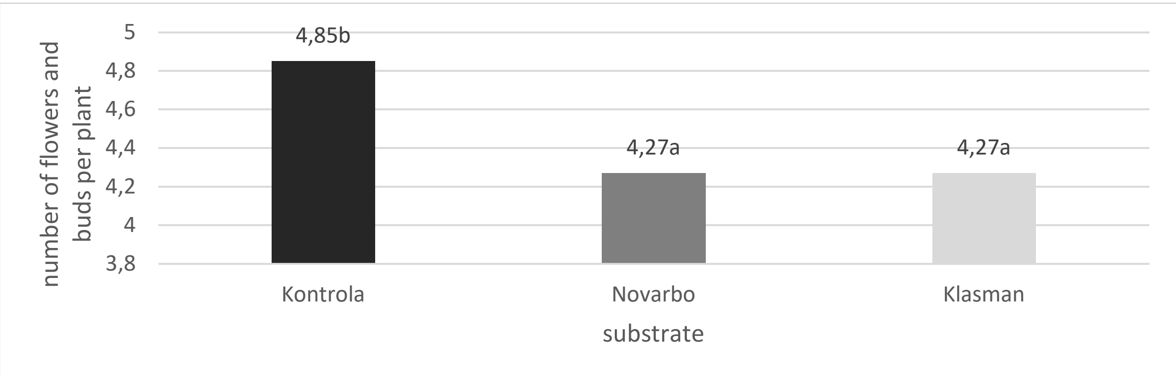


Fig. 27. The influence of the substrate, regardless of the marigold variety, on the total number of flowers and flower buds per plant.

Marigold plants grown in peat substrate (Control) had the highest fresh mass (14.2 g Aton and 20.9 g Bonanza) and it was significantly higher than that of plants grown in substrates with limited peat content and peat-free (9 - 11.4 g) (Fig. 28). Regardless of the growing substrate, Bonanza plants had an average mass of over 2 g higher, compared to Bonanza plants (Fig. 29A). In turn, regardless of the variety, the fresh mass of marigolds grown in Novarbo and Klasmann substrates was 7-7.5 g higher, compared to plants grown in peat substrate (Control) (Fig. 29B).

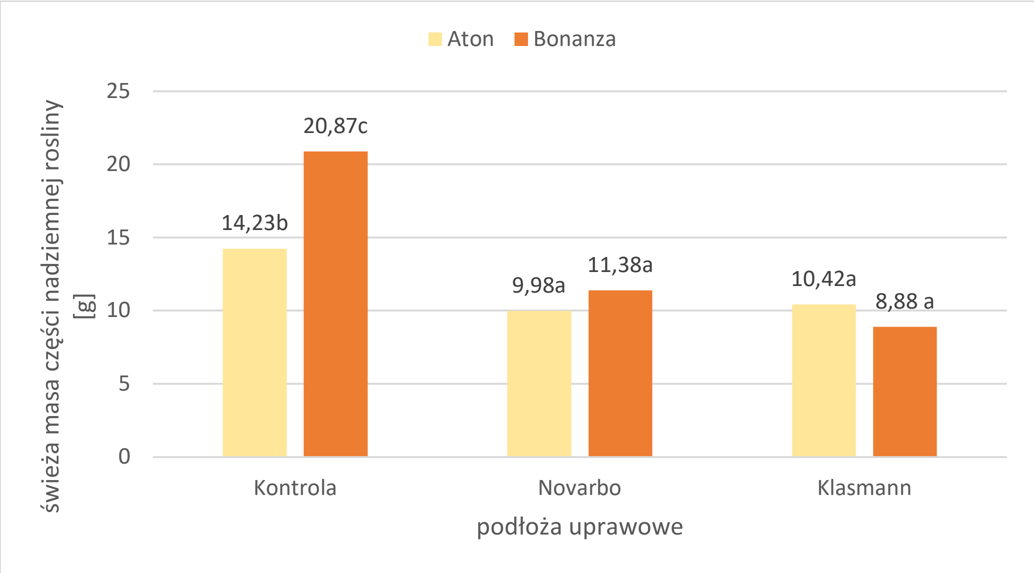
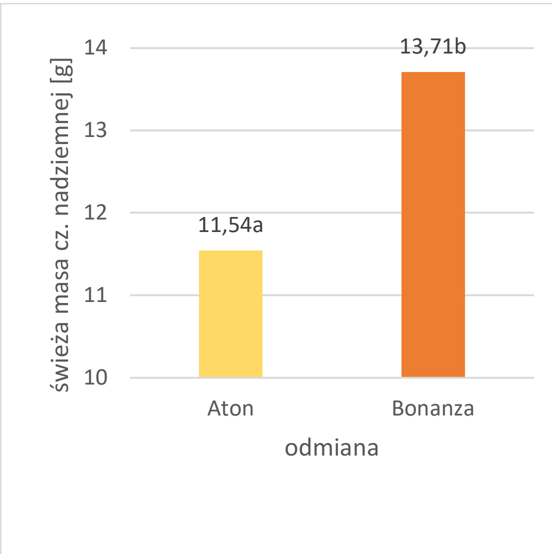
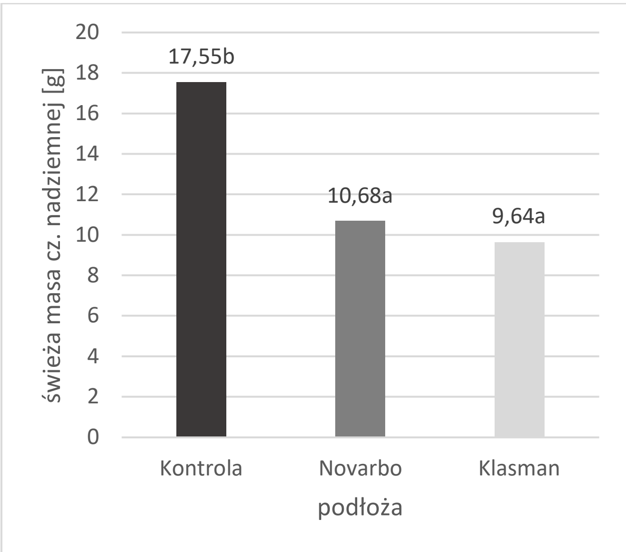


Fig. 28. Fresh mass of the above-ground part of marigold plants, depending on the growing medium and variety.



A.



B.

Fig. 29. Fresh mass of the above-ground part of French marigold: A - depending on the variety (irrespective of the growing medium); B - depending on the growing medium (irrespective of the variety).

Analyses of plant physiological parameters

Physiological condition tests of plants confirmed the good quality of the photosynthetic apparatus of the produced marigold varieties. The cultivation substrate with limited peat content and peat-free did not have a negative effect on the SPAD index or on the chlorophyll fluorescence coefficient Fv/Fm (Table 14). In the case of photosynthetic pigments, a lower content of chlorophyll a and carotenoids was noted in plants from the peat-free Klasmanm substrate. The content of carotenoids in the Bonanza variety was twice as high as in the Aton Yellow variety (Table 14).

Table 14. Influence of the growing medium and variety on the physiological parameters of two Tagetes patula varieties (bivariate and univariate analysis).

Variety	Substrate	SPAD	Fv/Fm	Chlorophyll a	Chlorophyll b	Carotenoids
Aton	Controla	48,34 cd*	0,82 ab	12,55 c	5,50 a	2,83 b
	Novarbo	49,35 cd	0,81 a	12,04 bc	6,42 c	2,41 a
	Klasmann	50,07 d	0,83 bc	11,14 a	5,83 abc	2,15 a
Bonanza	Controla	45,13 ab	0,84 c	12,41 c	6,19 bc	4,89 d
	Novarbo	47,09 bc	0,84 c	12,48 c	5,68 ab	4,81 cd
	Klasmann	44,32 a	0,83 bc	11,58 ab	5,74 ab	4,51 c
Independent of Substrate						
Aton		49,26 b	0,82 a	11,91 a	5,91 a	2,46 a
Bonanza		45,51 a	0,83 b	12,15 a	5,87 a	4,74 b
Independent from Variety						
Controll		46,74 a	0,83 a	12,48 b	5,85 a	3,86 c
Novarbo		48,22 a	0,83 a	12,26 b	6,05 a	3,61 b
Klasmann		47,20 a	0,83 a	11,36 a	5,78 a	3,33 a

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

Analysis of physicochemical properties of substrates

The peat control substrate (control) used in the cultivation of two varieties of marigold under production conditions (Jenflor company) had a bulk density of 0.074 g cm-3, water capacity of 65.5% wv and 891% ww (Table 15). Similar values of the determined physical parameters were obtained for the substrate with limited peat content - Novarbo 20. The tested peat-free substrate Klasmann 5 had a significantly higher bulk density (0.120 g cm-3) and lower water capacity than the other substrates used in the study. A statistically significant effect of the cultivated variety on the water capacity of the substrate determined after the cultivation of marigold was found. On average, the substrates in which the Aton Yellow variety was grown were distinguished by a higher water capacity than Bonanza (Table 15). Analysis of the interaction of factors used in the study (substrate × variety) showed that the greatest effect of the variety on water capacity was observed in the case of the Klasmann 5 substrate (Fig. 30 and 31). This substrate was distinguished by the lowest water retention among the compared substrates, but the cultivation of Aton Yellow marigold increased the ability of this substrate to accumulate water.

Table 15. Physical properties of substrates in commercial cultivation of two varieties of French marigold (Jenflor company)

Factor		Bulk density g cm^{-3}	Water capacity % wv	Water capacity %ww
Controll		0,074 A	65,5 B	891 B
Klasmann 5		0,120 B	*54,8* A	*461* A
Novarbo 20		0,074 A	63,1 B	893 B
Aton Yellow		0,088 A	62,5 B	763 B
Bonanza		0,092 A	*58,5* A	*721* A
Controll	Aton Yellow	0,074 a	65,0 c	893 c
	Bonanza	0,075 a	66,6 c	888 c
Klasmann 5	Aton Yellow	0,120 a	59,3 b	501 b
	Bonanza	0,121 a	45,9 a	381 a
Novarbo 20	Aton Yellow	0,072 a	63,1 bc	893 c
	Bonanza	0,079 a	63,1 bc	893 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 - substrate type and factor 2 - cultivar; control - peat substrate

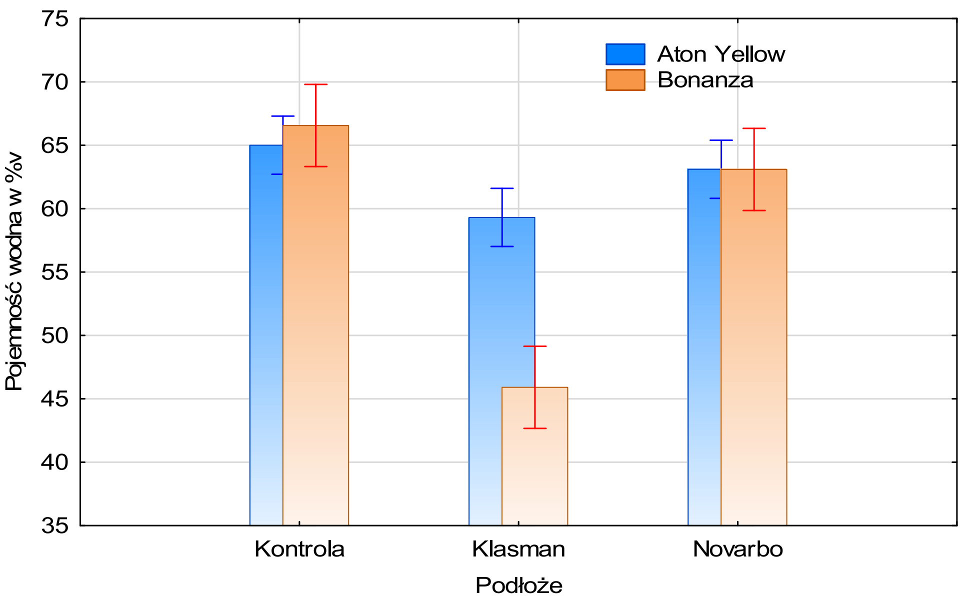


Fig. 30. The influence of the type of substrate and variety on the water capacity (% wv) determined in the commercial cultivation (Jenflor company) of two varieties of French marigold

Table 16 presents the results of the assessment of the chemical properties of the substrates and the content of organic matter determined after the completion of the cultivation of marigold under production conditions. Except for salinity (EC) and phosphorus content, the type of substrate significantly differentiated the content of soluble forms of nutrients and the content of organic matter in the cultivation substrates. The highest pH was determined in the peat-free Klasmann 5 substrate (pH 6.44) and the lowest in the peat control substrate (pH 5.76). The Klasmann 5 substrate analyzed after the cultivation of marigold also contained the most nitrogen in the ammonium form (N-NH4), potassium and sodium in relation to the other substrates used in the experiment. The control substrate showed the highest content of nitrogen in the nitrate form (N-NO3) and the highest average content of organic matter (91.7%). The content of organic matter in the substrate with limited peat content and peat-free was similar and amounted to about 72%. The peat substrate showed the lowest content of potassium, magnesium, sulfur and sodium available to plants, although the K and Mg contents were within the range of limit values given by Nowosielski as standard for peat substrates used for growing vegetable seedlings (300-500 mg K dm-3, 150-250 mg Mg dm-3).

A significant effect of the variety used in the study on the chemical properties of the growing substrates was demonstrated (Table 16). In general, with the exception of nitrogen in the form of N-NH4, the substrates tested after the cultivation of marigold variety Bonanza contained on average more nutrients than Aton Yellow. However, no effect of the variety on the pH of the substrate and the content of organic matter was demonstrated. Apart from magnesium, the analysis of the interaction of the factors substrate × variety showed its significant effect on the tested chemical properties and the content of organic matter in the substrates.

Cultivation of the Aton Yellow marigold variety caused an increase in the pH of the Novarbo 20 substrate measured after the end of the experiment, but significantly reduced the pH of the peat-free Klasmann 5 substrate compared to the Bonanza variety (Fig. 32). In the case of the substrate with limited peat content Novarbo 20, a decrease in the nitrogen content in the form of N-NO3 was demonstrated after cultivation of the Aton Yellow marigold compared to the Bonanza variety. No such regularity was demonstrated for the Klasmann 5 substrate (Fig. 33). High potassium and sodium content was determined in the Klasmann 5 substrate after cultivation of the Bonanza marigold variety (Table 16, Fig. 34) compared to the Aton Yellow variety. Such an effect of the variety on K availability was observed only for this substrate. Cultivation of the Bonanza marigold variety had a statistically significant effect on the increase in the content of organic matter in the Novarbo 20 substrate. The opposite relationship was demonstrated for the Klasmann 5 substrate (Fig. 35)

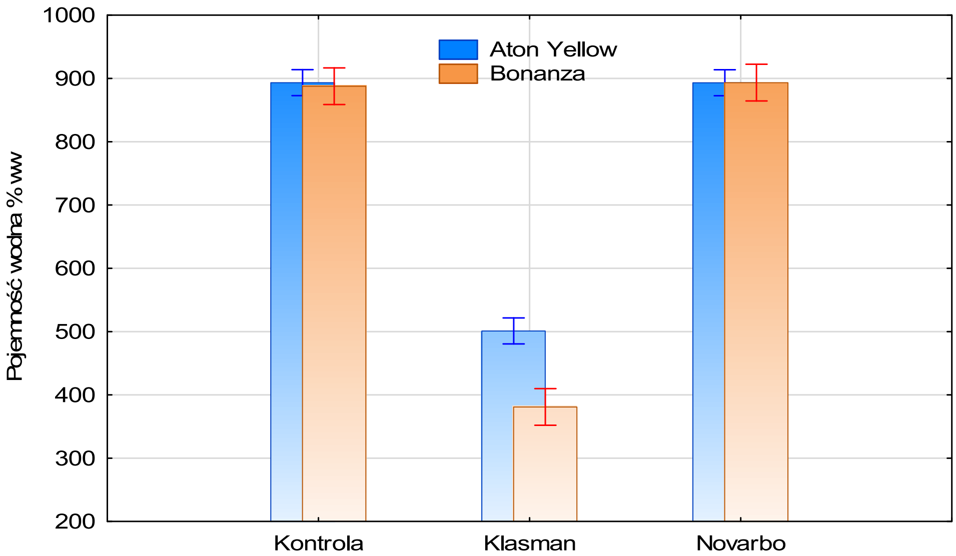


Fig. 31. The influence of the type of substrate and variety on the water capacity (% wv) determined in the commercial cultivation (Jenflor company) of two varieties of French marigold

Table 16. Reaction (pH), salinity (EC µS cm-1) and the content of macroelements, sodium (mg dm-3) and organic matter in the substrates after cultivation of two varieties of French marigold under production conditions (Jenflor).

Factor		pH	EC	$N-NH_4$	$N-NO_3$	Ca	K	Mg	P	S	Na	SO%
Controll		5,76 A	1,06 A	12,8 A	**160** C	1565 A	*359* A	*248* A	162 A	*454* A	*82,4* A	91,7 B
Klasmann 5		**6,44** C	1,14 A	**22,3** B	27,3 A	1714 AB	**685** C	308 B	191 A	591 B	**186** C	72,5 A
Novarbo 20		6,15 B	1,31 A	9,2 A	53,0 B	1918 B	515 B	315 B	182 A	612 B	153 B	72,8 A
Bonanza		6,12 A	**1,38** B	11,7 A	**91,3** B	**1837** B	**562** B	**313** B	192 B	**624** B	**159** B	78,9 A
Aton Yellow		6,11 A	0,96 A	**17,8** B	69,0 A	1628 A	478 A	268 A	165 A	481 A	122 A	79,1 A
Bonanza	Novarbo 20	5,88 ab	1,85 b	12,3 a	94,8 b	2479 c	446 ab	334 a	234 c	824 b	141 b	88,5 b
	Klasmann 5	6,70 d	1,17 a	8,7 a	12,1 a	1426 a	**893** c	347 a	182 a-c	570 a	**254** c	56,6 a
	Controll	5,79 a	1,12 a	14,2 a	167 c	1605 a	345 a	258 a	160 ab	478 a	82,8 a	91,7 b
Aton Yellow	Novarbo 20	6,18 bc	1,10 a	35,8 b	42,5 a	2002 b	476 ab	269 a	200 bc	613 ab	118 ab	88,5 b
	Klasmann 5	6,42 cd	0,77 a	6,1 a	11,1 a	1357 a	584 b	296 a	130 a	401 a	165 b	57,2 a
	Controll	5,73 a	1,01 a	11,5 a	153 c	1525 a	373 a	239 a	164 ab	430 a	82,1 a	91,6 b

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 - variety; control - substrate based on high-moor peat

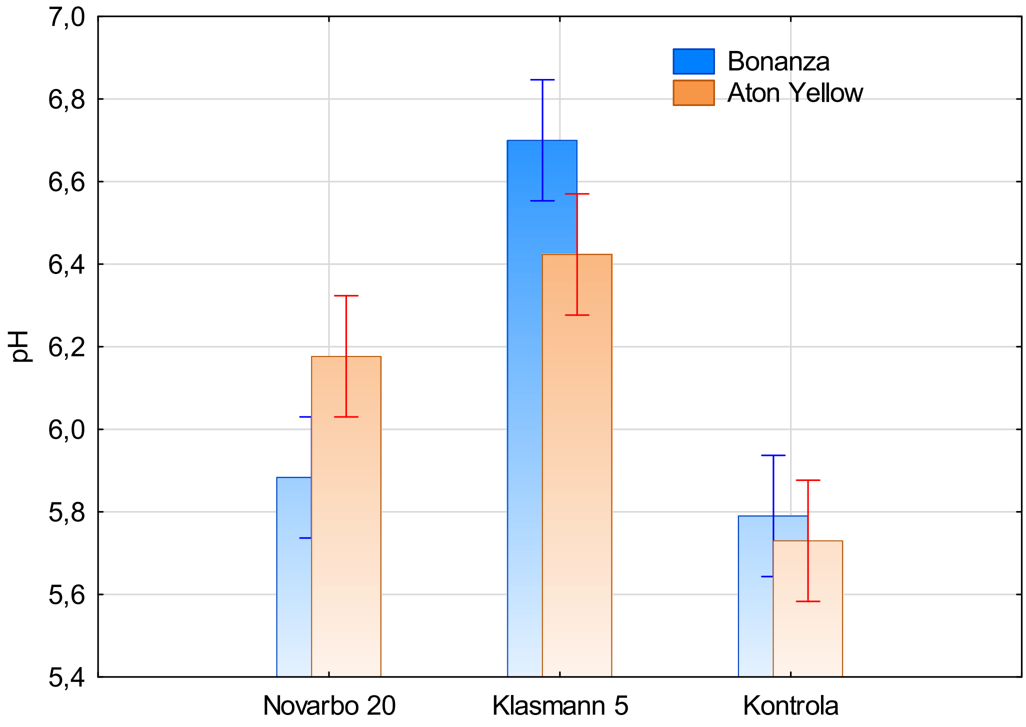


Fig. 32. The influence of the type of substrate and variety on the pH value determined in substrates after commercial cultivation (Jenflor company) of two varieties of French marigold.

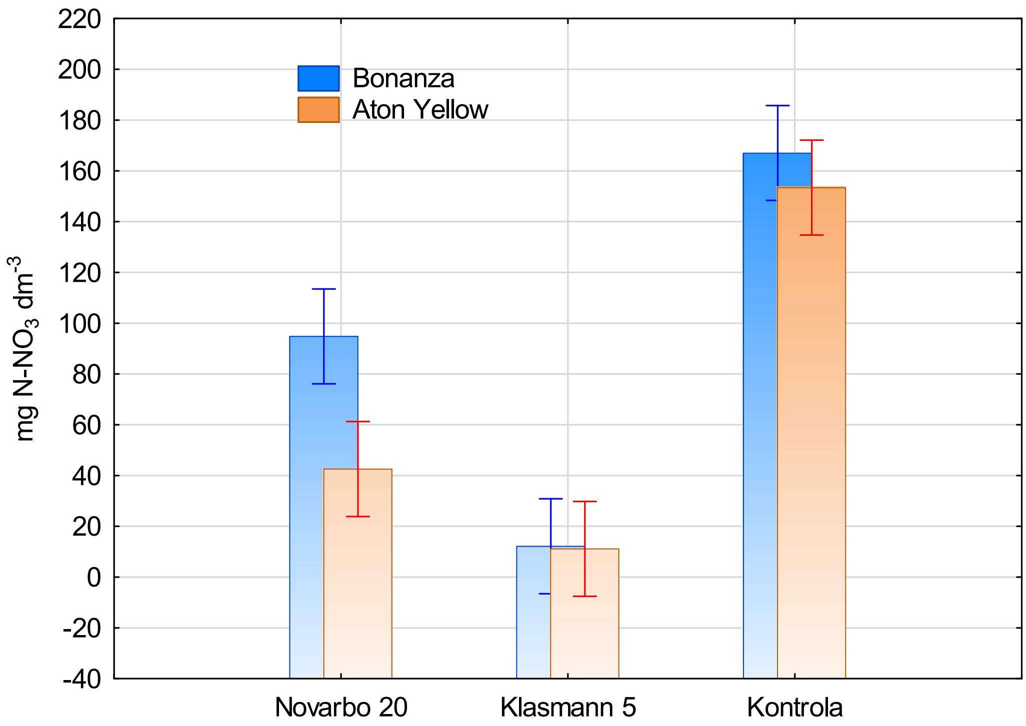


Fig. 33. The influence of the type of substrate and variety on the content of mineral nitrogen in the nitrate form (mg N-NO3 dm-3) determined in the substrates after commercial cultivation (Jenflor company) of two marigold varieties.

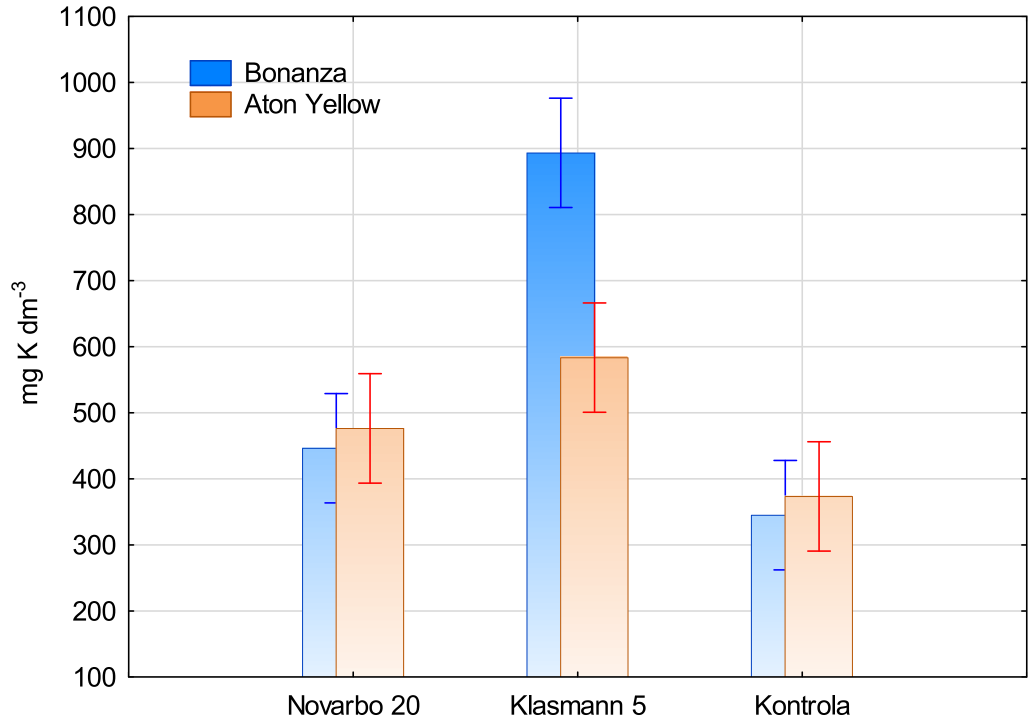


Fig. 34. The effect of the type of substrate and variety on the potassium content (mg K dm-3) determined in the substrates after commercial cultivation (Jenflor company) of two varieties of French marigold.

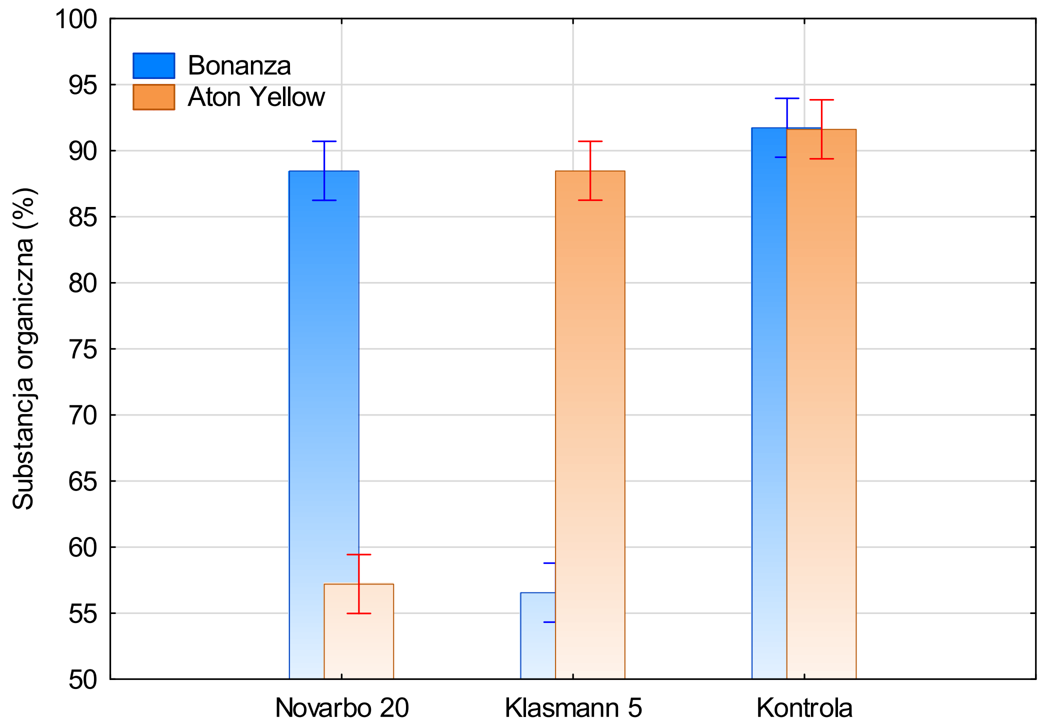


Fig. 35. The influence of the type of substrate and variety on the content of organic matter (%) in substrates after commercial cultivation (Jenflor company) of two varieties of French marigold.

Table 17 presents the results of determinations of the total content of microelements in substrates after the end of commercial cultivation of two varieties of French marigold. The peat-free Klasmann 5 substrate was the richest in boron, iron, manganese, molybdenum and zinc. The peat control substrate had the lowest content of iron, manganese and zinc compared to the tested substrates based on waste organic materials. In general, the Novarbo 20 substrate with limited peat content was similar in terms of microelement composition to the control substrate. A statistically significant effect of the interaction of the experimental factors substrate x variety on the boron content in the cultivation substrates was demonstrated (Table 16). Both the Bonanza and Aton Yellow varieties showed significantly more boron after the end of marigold cultivation in the peat-free Klasmann 5 substrate compared to the substrate with limited peat content Novarbo 20.

Table 17. Total content of microelements (mg kg-1 d.m.) determined in substrates after commercial cultivation (Jenflor company) of two varieties of French marigold.

Factor		B	Cu	Fe	Mn	Mo	Zn
Controll		5,85 A	23,8 A	*1228* A	*55* A	8,54 A	*36,5* A
Novarbo 20		8,23 B	26,6 A	5979 B	73 B	9,01 A	42,1 B
Klasmann 5		**14,9** C	**30,1** B	5269 B	**189** C	**13,1** B	**62,5** C
Bonanza		9,86 A	26,2 A	3985 A	102 A	9,8 A	47,0 A
Aton Yellow		9,46 A	27,4 A	4332 A	109 A	10,7 A	47,0 A
Bonanza	Controll	5,40 a	22,9 a	1297 a	52 a	7,47 a	35,9 a
	Novarbo 20	7,72 ab	29,6 a	1571 a	69 a	9,30 a	42,9 a
	Klasmann 5	16,4 d	26,0 a	9087 a	184 a	12,5 a	62,4 a
Aton Yellow	Controll	6,29 ab	24,7 a	1160 a	58 a	9,60 a	37,1 a
	Novarbo 20	8,74 b	30,6 a	1450 a	76 a	8,81 a	41,4 a
	Klasmann 5	13,3 c	27,1 a	10387 a	193 a	13,7 a	62,5 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 - substrate type and factor 2 - cultivar; control - peat substrate

Analyses of plant material

With the exception of magnesium, the type of substrate used in the experiment significantly affected the mineral profile of two varieties of French marigold cultivated under production conditions (Table 18, Fig. 36). No statistically significant differences were found in the dry matter content of plants depending on the growing substrate used. It ranged from 7.40% (Klasmann 5) to 8.09% (control). The lowest nitrogen, calcium, phosphorus and sulfur content was determined in the biomass of French marigolds cultivated in the Klasmann 5 substrate. However, these plants contained the most potassium (7.11% K in DM). The highest calcium content was found in plants harvested from the Novarbo 20 substrate (2.27% Ca in DM), and the highest sodium content (135 mg kg-1 DM) in the control plants.

Table 18. Content of macroelements (% of dry matter) and sodium (mg kg-1 dry matter) in two varieties of French marigold grown in organic substrates in a production greenhouse.

Factor		DM	N	Ca	K	Mg	P	S	Na
Controll		8,09 A	6,03 B	2,06 B	6,19 A	0,49 A	0,92 B	0,81 B	**135** B
Klasmann 5		7,40 A	*4,90* A	*1,71* A	**7,11** B	0,50 A	*0,77* A	*0,77* A	94 A
Novarbo 20		7,57 A	6,17 B	**2,27** C	5,94 A	0,53 A	0,94 B	0,92 B	82 A
Bonanza		7,84 A	5,50 A	1,90 A	6,52 A	0,49 A	0,84 A	0,74 A	**121** B
Aton Yellow		7,53 A	5,90 A	**2,13** B	6,31 A	0,52 A	**0,91** B	**0,92** B	87 A
Controll	Bonanza	8,02 ab	5,77 ab	2,03 bc	6,26 a	0,49 a	0,90 a	0,67 a	144 a
	Aton	8,17 b	6,29 b	2,10 b-d	6,12 a	0,49 a	0,94 a	0,94 c	126 a
Klasmann 5	Bonanza	7,96 ab	4,92 a	1,48 a	7,16 a	0,48 a	0,73 a	0,77 b	129 a
	Aton	6,83 a	4,89 a	1,95 b	7,05 a	0,52 a	0,82 a	0,78 b	60 a
Novarbo 20	Bonanza	7,54 ab	5,80 ab	2,20 cd	6,13 a	0,50 a	0,91 a	0,78 b	89 a
	Aton	7,60 ab	6,53 b	2,33 d	5,75 a	0,56 a	0,98 a	**1,05** d	75 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 - substrate type and factor 2 - cultivar; control - peat substrate

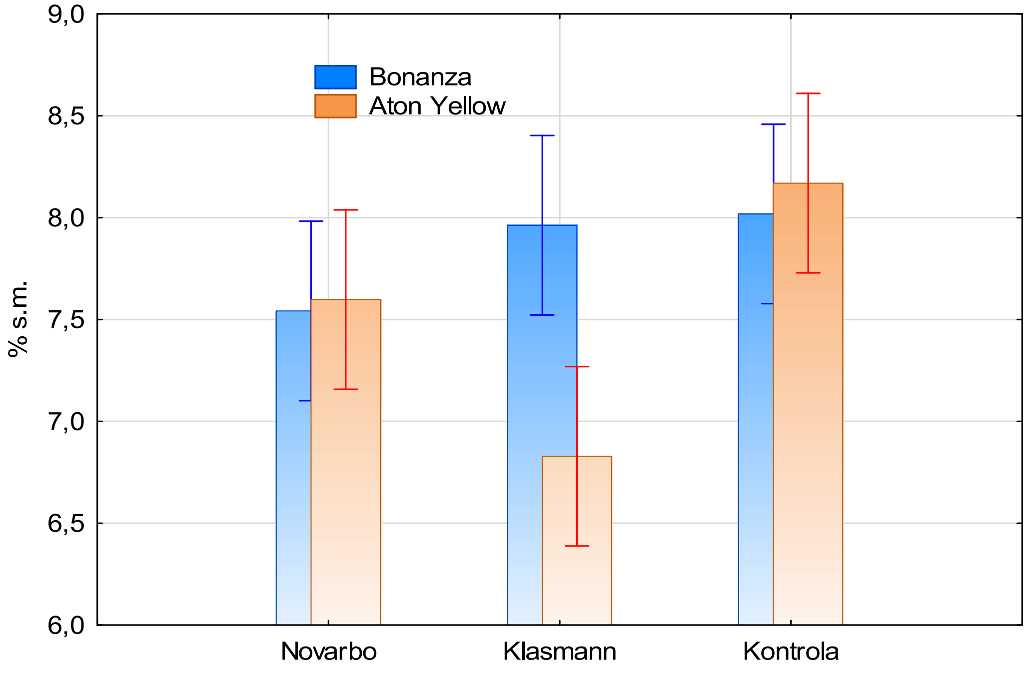


Fig. 36. The influence of the type of substrate and variety on the dry matter content (% DM) in the biomass of two marigold varieties grown under production conditions

Analyzing the effect of the variety factor on the mineral composition of biomass, it was shown that the Aton Yellow variety contained more calcium, phosphorus and sulfur, while the Bonanza variety contained more sodium (Table 18). With the exception of potassium, magnesium, phosphorus and sodium, a significant effect of the interaction of the studied factors (substrate × variety) on the content of dry mass and macroelements in biomass was demonstrated. The lowest dry mass was determined in the Aton Yellow variety growing in the peat-free Klasmann 5 substrate, and the highest in the control plants of the same variety (Fig. 36).

Regardless of the variety, the least nitrogen was determined in the plants growing in the Klasmann 5 substrate (Fig. 37). A tendency towards a higher N content was observed in the Aton variety plants growing in the substrate with limited content of Novarbo 20 peat and in the peat substrate (control) than in the Bonanza variety plants. The greatest differences in calcium content in plants depending on the variety were shown for the peat-free Klasmann 5 substrate (Fig. 38). In the peat-free substrate, the Aton Yellow variety contained significantly more Ca than the Bonanza variety (Fig. 38).

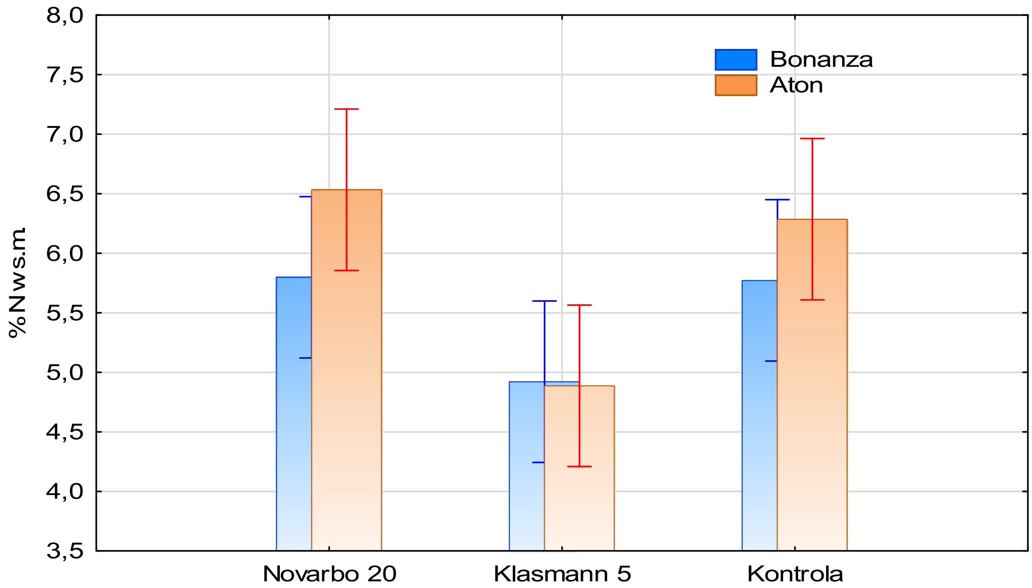


Fig. 37. The effect of substrate type and cultivar on nitrogen content (% N in dry matter) in the biomass of two marigold cultivars grown under production conditions (Jenflor).

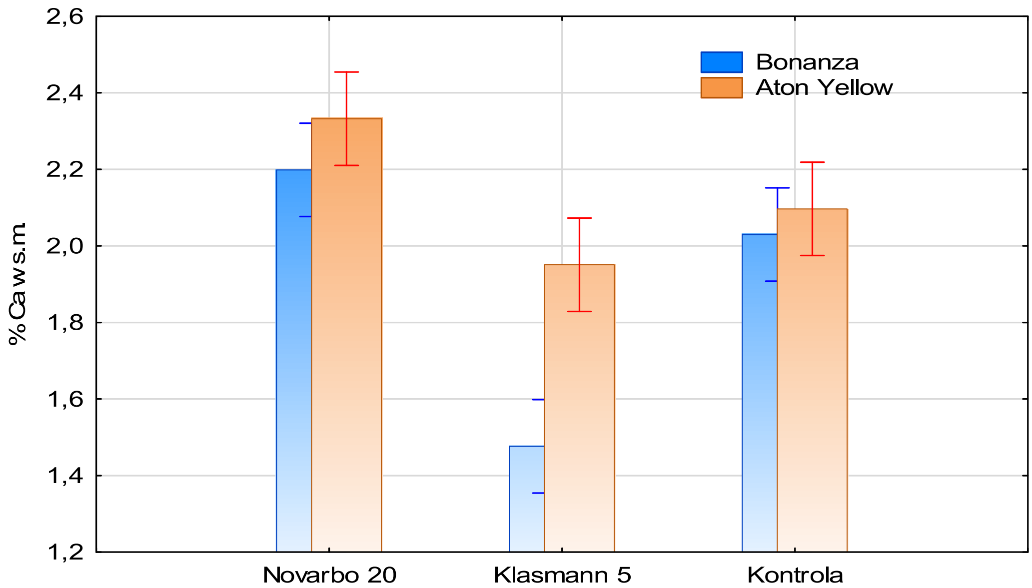


Fig. 38. The effect of substrate type and cultivar on calcium content (% Ca in dry matter) in the biomass of two marigold cultivars grown under production conditions (Jenflor).

Table 19. Total content of microelements (mg kg-1 d.m.) in the biomass of two marigold varieties grown in organic substrates in a production greenhouse.

Factor		**B**	**Cu**	**Fe**	**Mn**	**Mo**	**Zn**
Controll		41,1 A	10,7 A	94,5 AB	68,4 A	1,10 A	76,2 B
Novarbo 20		43,1 A	9,9 A	102 B	**84,1** B	1,16 A	77,6 B
Klasmann 5		45,2 A	10,4 A	89,4 A	64,4 A	1,11 A	*56,7* A
Bonanza		40,1 A	9,3 A	94,6 A	**86,2** B	1,11 A	64,5 A
Aton Yellow		**46,1** B	**11,3** B	96,2 A	58,4 A	1,14 A	**75,8** B
Controll	Bonanza	39,0 a	10,9 b	94,5 a	88,3 bc	1,11 a	72,9 bc
	Aton Yellow	43,2 a	10,6 b	94,5 a	48,4 a	1,09 a	79,5 c
Novarbo 20	Bonanza	38,6 a	9,7 ab	101 a	109 c	1,13 a	74,5 bc
	Aton Yellow	47,6 a	10,1 b	103 a	59,0 a	1,19 a	80,6 c
Klasmann 5	Bonanza	42,9 a	7,4 a	88,3 a	61,1 a	1,08 a	46,1 a
	Aton Yellow	47,6 a	**13,3** c	90,6 a	67,8 ab	1,14 a	67,2 b

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 - substrate type and factor 2 - cultivar; control - peat substrate

Marigolds grown in the Novarbo 20 substrate contained the most manganese among the growing substrates compared in the experiment (Table 19). A higher iron content was also determined in plants from this combination, but significantly higher only in relation to the peat-free Klasmann 5 substrate. The least zinc was shown in the biomass of marigolds collected for testing from the Klasmann 5 substrate. Plants of the Bonanza variety contained significantly more manganese than the Aton Yellow variety, while marigolds of the Aton Yellow variety were distinguished by significantly higher boron, copper and zinc content (Table 19). A significant effect of the interaction of the experimental factors on the content of copper, manganese and zinc in marigolds was demonstrated. More copper and zinc were determined in the Aton Yellow plants grown in the peat-free Klasmann 5 substrate than in the Bonanza variety. Such regularity was not demonstrated for the peat control substrate and Novarbo 20 with limited peat content. Marigolds of the Bonanza variety grown in peat (control) and in a substrate with limited peat content Novarbo 20 contained significantly more manganese than the Aton Yellow variety. No differences in manganese content were observed between the varieties grown in the peat-free substrate Klasmann 5 (Table 19).

Fig. 39. Cultivation of potted chrysanthemum. Rooted seedlings planted 5 pieces in pots: A, B – arranged in a greenhouse according to the tested combinations, A – shading foil visible between the beds, C, D – development of lateral buds, E – root ball of the plants, on the right side visible rapid drying of the Klasmann 5 substrate, on the left control peat substrate.

Fig. 40. Cultivation of potted chrysanthemum, generative phase: A, B – plants with visible flower buds, C – Mount Gerlach variety (White), D – Wilmington variety (Yellow).

After rooting, chrysanthemum seedlings were planted in pots of 5 pieces and placed on the beds, with the tested combinations marked, necessary for statistical calculations of repetitions, as well as for all varieties (Fig. 39 A). Pinching the tip of the main shoot (breaking the apical dominance) stimulated the development of lateral shoots, which developed in the first period of cultivation, as a result of which strongly branched plants were obtained (Fig. 30 B, C). Already during vegetative growth, it was observed that chrysanthemums growing in the control substrate developed lateral shoots earlier and with greater intensity compared to those grown in the peatless Klasmann 5 substrate (Fig. 39 D). Observations of the root ball showed that the Klasmann substrate dries out faster, compared to the control (Fig. 39 E).

Analysis of plant morphometric parameters

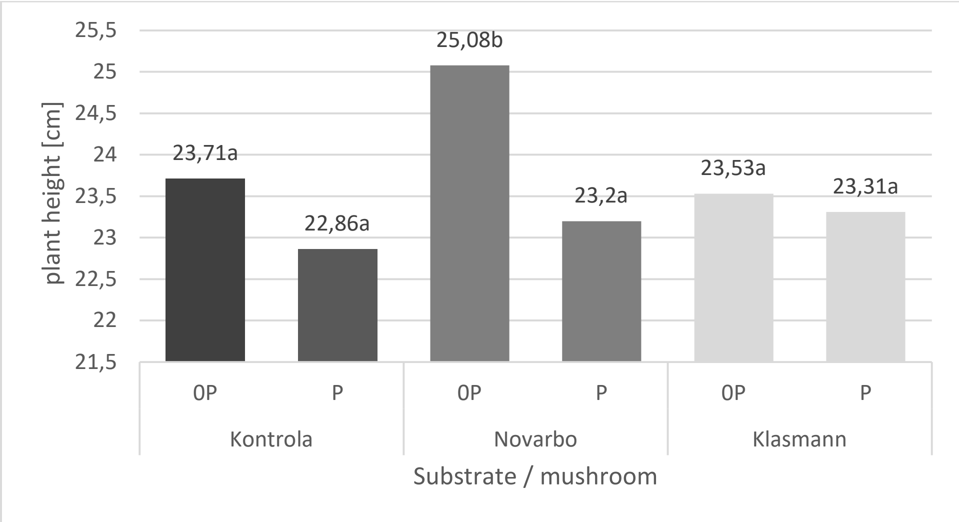
The single-factor analysis (regardless of the type of substrate and the addition of dried mushrooms to the substrate) showed that under the tested conditions of large-scale production, the Yellow (Wilmington) variety is characterized by stronger growth, forms more flower heads and fewer flower buds, compared to the White variety (Table 20).

Table 20. The effect of substrate, dried mushrooms in the substrate and chrysanthemum cultivars Mount Gerlach (White) and Wilmington (Yellow) on the biometric parameters of the produced plants (0P – substrate without mushroom biostimulator, P – substrate with mushroom biostimulator)

Variety	Substrate	Mush-room	Height [cm]	Number of branches	Number of flowers	Number of flower buds
Yellow	Controll	0P	25,5 cde*	4,85 a	36,3 d	3,30 ab
		P	24,5 bc	5,00 a	36,2 d	2,40 a
	Novarbo	0P	26,7 e	4,80 a	40,0 e	2,75 ab
		P	25,2 cd	5,30 a	38,8 de	4,00 abc
	Klasmann	0P	26,1 de	5,30 a	36,9 d	4,25 bcd
		P	25,8 de	5,85 a	32,0 c	6,95 e
White	Controll	0P	21,9 a	5,60 ab	25,3 d	5,30 cde
		P	21,2 a	6,10 ab	22,5 c	5,60 cde
	Novarbo	0P	23,5 b	7,60 b	23,1 c	5,65 cde
		P	21,2 a	7,65 b	22,5 c	5,85 de
	Klasmann	0P	20,9 a	5,65 ab	18,4 b	6,20 e
		P	21,0 a	4,80 a	21,6 c	5,35 cde
Variety						
Yellow			25,6 b	5,18 a	36,7 b	3,9 a
White			21,6 a	5,63 a	22,1 a	5,7 b
Mushroom						
0P			24,0 b	5,78 a	30,0 a	5,0 a
P			23,2 a	5,78 a	28,9 a	4,6 a
Substrate						
Controll			23,3 a	5,38 a	30,1 b	4,2 a
Novarbo			24,1 b	6,34 b	31,1 b	4,6 a
Klasmann			23,4 a	5,40 a	27,2 a	5,7 b

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

A similar analysis conducted for the presence of dried mushrooms as a biostimulator in the substrate showed that it has an inhibiting effect on plant height, but has no effect on the remaining biometric features studied (Table 20). In turn, a one-factor analysis of the effect of the substrate showed that plants grown in a substrate with limited peat content (Novarbo) were the tallest, had the best branching, and had the most flowers. The numerical differences characterizing the above features were small, but statistically significant. Statistical evaluation of the interaction between the type of substrate and the presence of dried mushrooms in it showed that the presence of this natural biostimulator in each substrate has an inhibiting effect on plant height, but significance was found only in the case of the Novarbo 20 substrate (Fig. 41). At the same time, the same analysis conducted for the number of side shoots (branches) did not show the effect of dried mushrooms in the substrate on this feature, the results were at the same statistical level for the combination of type of substrate × presence of mushroom biostimulator (Fig. 42).



ig. 41. The influence of the substrate and dried mushrooms (0P – absent in the substrate, P – present in the substrate) regardless of the chrysanthemum variety on the height of the plants.

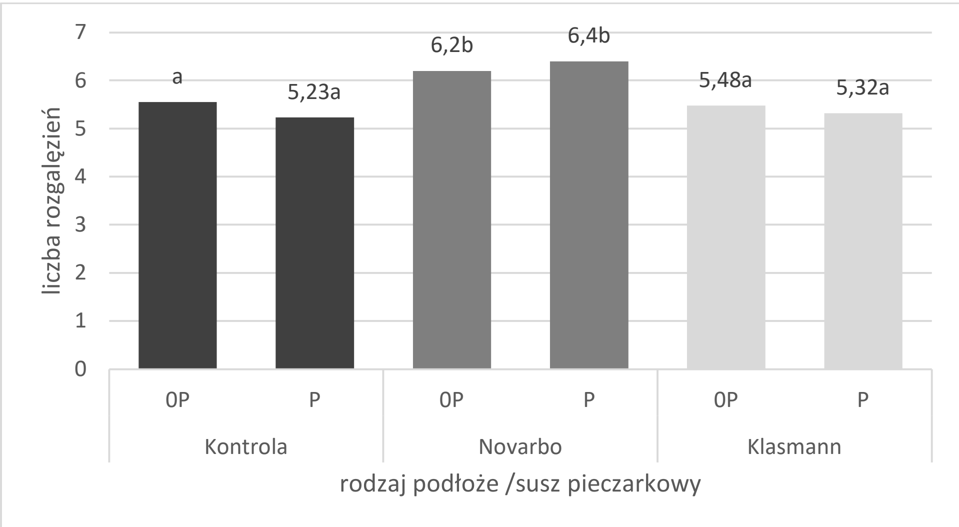


Fig. 42. The influence of the substrate and dried mushrooms (0P – absent in the substrate, P – present in the substrate) regardless of the chrysanthemum variety on the number of branches (side shoots).

The number of branches per plant in the pot was 4.8–5.8 for the Yellow variety, and 4.8–7.7 for the White variety, with the highest values obtained for plants grown in a substrate with a limited content of Novarbo 20 peat (Table 20).

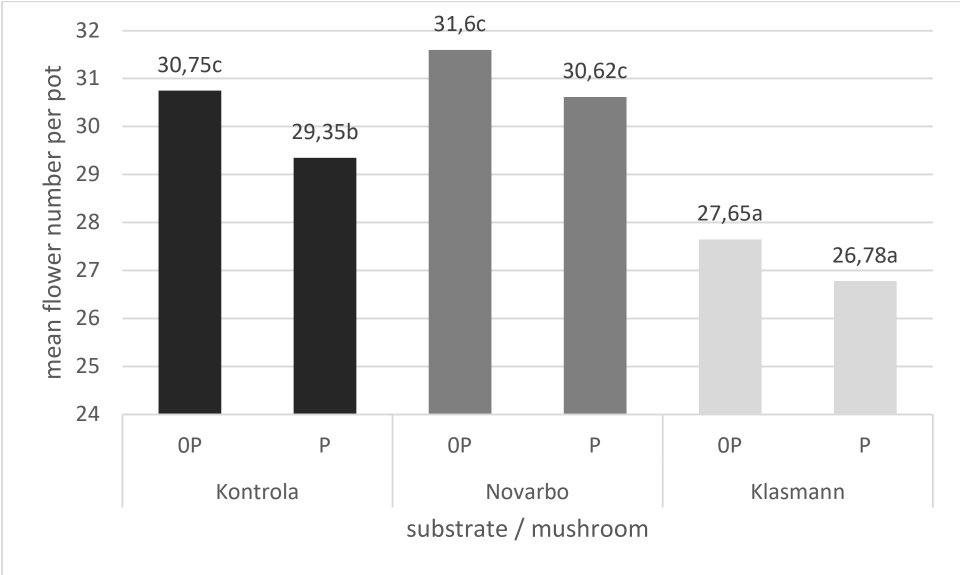


Fig. 43. The influence of the substrate and dried mushrooms (0P – mushroom absent in the substrate, P – present in the substrate), regardless of the chrysanthemum variety on the number of flowers per pot.

Regardless of the chrysanthemum variety, dried mushrooms in each tested substrate resulted in weaker flowering of plants, and the difference observed on the peat substrate (Control) was statistically significant (Fig. 43). In the Yellow variety, the addition of dried mushrooms to the Novarbo or Klasmann substrate resulted in the formation of a greater number of buds, while in plants grown in the control substrate the relationship was reversed (Table 20).

Analyses of plant physiological parameters

The analyses of the physiological parameters of the plants indicate a correctly functioning photosynthetic apparatus in the leaves of all the chrysanthemums produced (Tables 21, 22). The SPAD coefficient value was at the level of 60.10 - 61, and the chlorophyll fluorescence measured as Fv/Fm at the level of 0.85. Only in one case (Novarbo substrate with dried mushrooms) was it 0.76, and although this is a statistically lower value than the others, it is within the norm.

Referring to the variety, it can be stated that the leaves of the Yellow variety contain more chlorophyll a, b and carotenoids. Referring to the presence of the mushroom biostimulator in the substrate, it can be stated that its presence increased the content of photosynthetic pigments in the leaves. Generally, referring to the type of substrate, it can be stated that the plants grown in the Klasmann peat-free substrate had the most photosynthetic pigments in the leaves (Tables 21, 22).

Table 21. The influence of the substrate, dried mushrooms in the substrate (0P - none, P - added) and the chrysanthemum cultivars Mount Gerlach (White) and Wilmington (Yellow) on the physiological parameters of the produced plants.

Variety	Substrate	Mush-room	SPAD	Fv/Fm	Chlorophyll a	Chlorophyll b	Carotenoids
Yellow	Controll	0P	62,69 a*	0,85 b	4,56 a	2,89 de	2,87 bcd
		P	62,66 a	0,85 b	4,82 bc	2,76 bcd	2,89 cd
	Novarbo	0P	62,58 a	0,85 b	4,57 b	2,67 ab	2,72 ab
		P	62,11 a	0,76 a	4,97 cde	2,85 cde	2,96 cd
	Klasmann	0P	60,97 a	0,85 b	5,21 de	3,10 f	3,22 d
		P	62,06 a	0,85 b	5,28 e	2,96 e	3,18 e
White	Controll	0P	62,39 a	0,85 b	4,12 a	2,57 a	2,67 a
		P	60,11 a	0,85 b	4,98 cde	2,85 cde	3,01 d
	Novarbo	0P	61,17 a	0,85 b	4,89 bcd	2,71 abc	2,90 cd
		P	60,75 a	0,85 b	4,63 bc	2,70 abc	2,84 bc
	Klasmann	0P	61,01 a	0,85 b	4,81 bc	2,85 cde	2,98 cd
		P	60,10 a	0,85 b	4,90 bcd	2,79 bcd	2,99 cd

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

Table 22. The influence of substrate or dried mushrooms in the substrate (0P - none, P - added) or chrysanthemum varieties Mount Gerlach (White) and Wilmington (Yellow) (univariate analyses) on the biometric parameters of the produced plants.

Factor	SPAD	Fv/Fm	Chlorophyll a	Chlorophyll b	Carotenoids
Variety					
Yellow	62,18 a*	0,84 a	4,91 b	2,87 b	2,97 b
White	60,92 a	0,85 a	4,72 a	2,74 a	2,89 a
Mushroom					
0P	61,11 a	0,85 a	4,71 a	2,77 a	2,89 a
P	61,98 a	0,83 a	4,92 b	2,84 b	2,88 b
Substrate					
Controll	61,96 a	0,85 a	4,62 a	2,77 a	2,86 a
Novarbo	61,65 a	0,83 a	4,77 a	2,73 a	2,85 a
Klasmann	61,03 a	0,85 a	5,05 b	2,92 b	3,09 b

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

Testing plants produced in the Bioefekt substrate (additional)

Analyses of plants produced in the domestic producer Bioefekt substrate, compared to plants from peat substrate (Control) showed that chrysanthemums from this substrate are slightly shorter (without statistical difference). In the case of the White variety on the Bioefekt substrate, they form twice as few side shoots and flowers (Table 23).

Table 23. Influence of the substrate and the chrysanthemum cultivar Mount Gerlach (White) and Wilmington (Yellow) on the biometric parameters of the produced plants.

Variety		Height [cm]	Number of branches	Number of flowers	Number of flower buds
Yellow	**Controll**	25,5 b*	4,85 b	36,25 c	3,30 a
	Bioefekt	23,0 b	4,10 b	18,65 a	4,75 b
White	**Controll**	21,93 a	5,6 c	25,25 b	5,30 c
	Bioefekt	20,08 a	2,45 a	15,10 a	4,25 b

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

Table 24. Influence of the substrate and chrysanthemum cultivar Mount Gerlach (White) and Wilmington (Yellow) on the biometric parameters of the produced plants

Variety		SPAD	Fv/Fm	Chlorophyll a	Chlorophyll b	Carotenoids
Yellow	**Controll**	62,69 b*	0,85 a	4,56 a	2,89 b	2,87 a
	Bioefekt	58,28 a	0,853 a	4,82 a	2,79 a	2,94 ab
White	**Controll**	62,69 b	0,85 a	4,56 a	2,89 b	2,87 a
	Bioefekt	57,74 a	0,85 a	4,83 a	2,80 b	2,98 ab

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

A.

B.

Fig. 44. Flower colour of the Yellow (Wilmington) variety marked according to the RHS Colour Chart 5th edition 2007:

A. A. 5C from the Yellow Group on the Control medium,
B. B. 10A from the Yellow Group on the Bioefekt medium.

Physiological studies have shown that the cultivation of plants in the Bioefekt substrate significantly reduces the SPAD value and the content of chlorophyll b in the Yellow variety (Table 24). At the same time, a darker flower colour was observed in yellow chrysanthemums grown in the Bioefekt substrate (Fig. 44)..

Analysis of physicochemical properties of substrates

Tables 25 and 26 present the results of selected physical properties of the growing media used in autumn commercial production (Jenflor company) of two chrysanthemum varieties - Mount Gerlach (white) and Wilmington (yellow). In both experiments with chrysanthemum, the highest bulk density was determined in the Klasmann 5 medium (0.132 g cm-3) in relation to the control (0.094 g cm-3 for the yellow variety and 0.83 g cm-3 for the white variety) and the Novarbo 20 medium (0.069 g cm-3 and 0.75 g cm-3, for the yellow and white varieties, respectively).

Table 25. Physical properties of substrates in commercial cultivation (Jenflor company) of the yellow chrysanthemum variety

Factor		**Bulk density g cm^{-3}**	**Water capacity % wv**	**Water capacity %ww**
Controll		0,094 B	**78,5** B	831 B
Novarbo 20		*0,069* A	54,8 A	796 B
Klasmann 5		**0,132** C	51,3 A	*391* A
No mushroom (0P)		0,098 A	59,1 A	653 A
Mushroom (P)		0,098 A	**63,9** B	**693** B
Controll	0P	0,095 a	76,4 a	805 a
	P	0,094 a	80,6 a	857 a
Novarbo 20	0P	0,067 a	52,6 a	789 a
	P	0,071 a	56,9 a	803 a
Klasmann 5	0P	0,134 a	48,4 a	364 a
	P	0,130 a	54,2 a	418 a
Bioefekt		0,210	47,7	227

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 - type of substrate and factor 2 - addition of/without mushroom stimulator; control - peat substrate

The additional Bioefekt substrate tested in chrysanthemum cultivation had a volumetric density twice as high as the peat control substrate (Table 26). It was also distinguished by a relatively low water capacity expressed in relation to the dry mass of the substrate (227-239% ww, for the yellow and white chrysanthemum varieties, respectively).

A significant interaction of the experimental factors (type of substrate × fungal stimulator) on the water capacity of the substrates was demonstrated (Fig. 48). In general, the addition of dried edible mushrooms slightly increased (not statistically significantly) the water capacity of peat (control) and the peat-free substrate Klasmann 5. The opposite relationship was observed for the substrate with a limited content of Novarbo 20 peat.

All substrates were well overgrown with plant roots, regardless of the dried mushroom addition used (Fig. 45-47).

Table 26. Physical properties of substrates in commercial cultivation (Jenflor company) of the white chrysanthemum variety.

Factor		**Bulk density g cm^{-3}**	**Water capacity % wv**	**Water capacity %ww**
Controll		0,083 B	66,9 B	803 B
Novarbo 20		*0,075* A	61,2 B	817 B
Klasmann 5		**0,132** C	*53,6* A	*406* A
No mushroom (0P)		0,096 A	60,1 A	682 A
Mushroom (P)		0,097 A	61,0 A	669 A
Controll	0P	0,080 a	63,7 bc	796 b
	P	0,086 a	70,0 c	809 b
Novarbo 20	0P	0,076 a	64,7 bc	855 b
	P	0,074 a	57,7 ab	779 b
Klasmann 5	0P	0,132 a	51,8 a	393 a
	P	0,132 a	55,4 ab	420 a
Bioefekt		0,220	51,2	239

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 - type of substrate and factor 2 - addition of/without mushroom stimulator; control - peat substrate

A B

Fig. 45. Klasmann 5 substrate after cultivation of the Yellow chrysanthemum variety: A – without the addition of a fungal stimulator, B – with 2.5% addition of dried mushrooms.

Fig. 46. Novarbo 20 substrate after cultivation of the Yellow chrysanthemum variety: A – without the addition of a fungal stimulator, B – with 2.5% addition of dried mushrooms.

Fig. 47. Control peat substrate after cultivation of the Yellow chrysanthemum variety: A – without the addition of a fungal stimulant, B – with 2.5% addition of dried mushrooms.

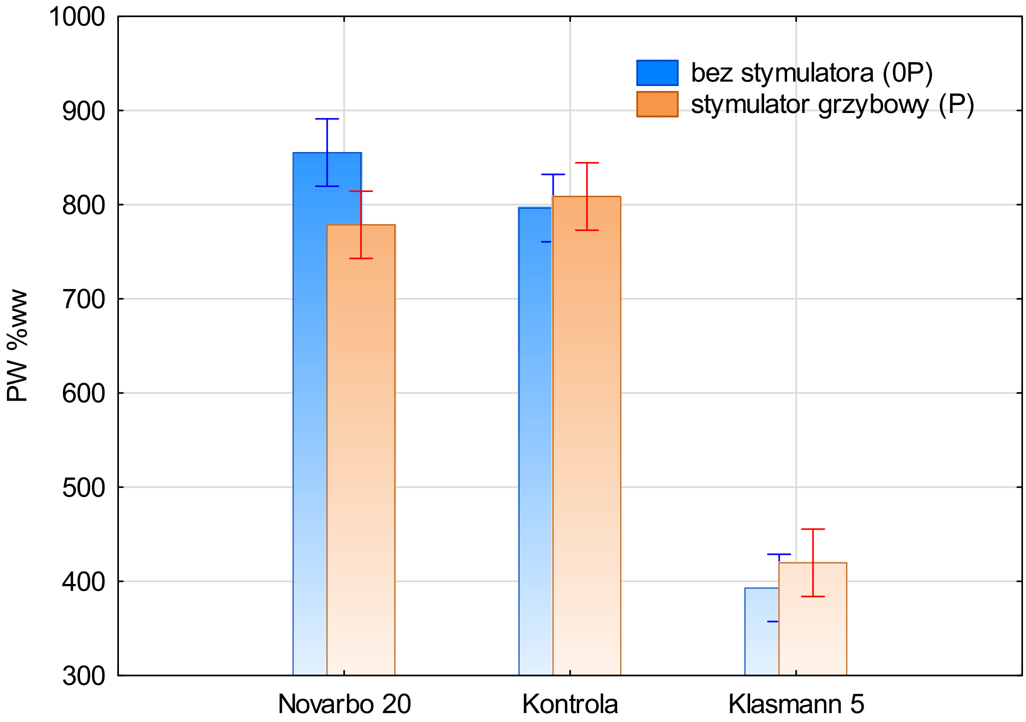


Fig. 48. The effect of substrate type and fungal stimulant addition on the substrate's water capacity (% ww) determined after commercial cultivation (Jenflor company) of a white chrysanthemum variety.

Tables 27 and 28 present the results of determinations of assimilable forms of macroelements, pH and salt concentration in substrates used for studies with two varieties of chrysanthemum. In both experiments with yellow and white varieties of chrysanthemum, the highest pH was determined in the peat-free Klasmann 5 substrate. This growing substrate also showed the highest content of potassium, magnesium and sodium. The highest amount of soluble calcium was determined in the substrate with limited peat content Novarbo 20. The peat control substrate contained the most nitrogen in the nitrate form.

The addition of a mushroom stimulator in the form of dried edible mushroom (2.5%) to the substrates in the cultivation of the yellow variety of chrysanthemum increased the content of nitrate nitrogen, assimilable potassium and the total salt concentration (EC) in the substrates. The substrates with the addition of the fungal stimulator had a significantly lower pH than the untreated substrates.

The pH of the additionally tested Bioefekt substrate in the cultivation of white and yellow chrysanthemum was slightly acidic (Tables 27 and 28). The substrate was characterized by low salinity (EC) and soluble nitrogen content and high content of potassium and magnesium available for plants compared to the peat control substrate.

The influence of the interaction of the experimental factors (substrate x addition of fungal stimulator) on the EC of the substrate (Fig. 49), N-NH4 content (Fig. 50) and the content of available Mg in the cultivation of the yellow chrysanthemum variety was demonstrated. In the experiment with the white variety, the influence of the interaction of factors was noted in the case of pH, EC, N-NO3, P and K (Fig. 51-54).

Table 27. Content of macronutrients (% d.m.) and sodium (mg kg-1 d.m.) in organic substrates used in the cultivation of yellow chrysanthemum variety in production greenhouse conditions (Jenflor)

Factor		pH	EC	$N-NH_4$	$N-NO_3$	Ca	K	Mg	P	S	Na
Controll		*4,39* A	1,27 B	6,73 A	**234** C	1180 B	265 A	171 AB	647 A	143 A	102 A
Novarbo 20		5,09 B	1,39 B	11,1 A	181 B	**1387** C	189 A	144 A	555 A	100 A	94 A
Klasmann 5		**5,68 C**	0,81 A	4,96 A	81,5 A	982 A	**500** B	**199** B	639 A	134 A	**168** B
No mushroom (0P)		**5,25** B	1,02 A	**11,5** B	98,1 A	1207 A	242 A	173 A	601 A	126 A	126 A
Mushroom (P)		4,85 A	**1,29** B	3,71 A	**233** B	1160 A	**394** B	169 A	626 A	125 A	117 A
Controll	0P	4,57 a	1,17 b	9,11 ab	160 a	1274 a	224 a	191 ab	719 a	170 a	121 a
	P	4,20 a	1,37 b	4,35 a	309 a	1086 a	306 a	151 a	575 a	115 a	83 a
Novarbo 20	0P	5,33 a	1,14 b	19,9 b	109 a	1428 a	123 a	143 a	523 a	97 a	93 a
	P	4,86 a	**1,63** c	2,29 a	254 a	1346 a	256 a	145 a	588 a	104 a	95 a
Klasmann 5	0P	5,85 a	0,76 a	5,43 ab	25,0 a	918 a	380 a	185 ab	563 a	112 a	163 a
	P	5,50 a	0,86 a	4,49 a	138 a	1047 a	621 a	212 b	715 a	156 a	174 a
Bioefekt		6,54	0,71	3,61	4,58	1346	837	300	577	213	146

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 - type of substrate and factor 2 - addition of/without mushroom stimulator; control - peat substrate

In the experiment with the yellow chrysanthemum variety, the greatest increase in salinity under the influence of 2.5% addition of the fungal stimulator was shown for the substrate with limited content of Novarbo 20 peat (Fig. 49). The tendency to increase salt concentration in the combinations treated with dried mushrooms was revealed for all substrates used in this experiment. This could be caused by the demonstrated (statistically insignificant) increase in the content of nitrate nitrogen in these cultivation objects (Table 27).

The same dependencies for EC and N-NO3 were shown in the experiment with the white chrysanthemum variety (Table 28, Figs. 52 and 53). The Novarbo 20 substrate treated with the fungal stimulator also showed the lowest content of ammonium nitrogen (Fig. 50). In the peat-free substrate Klasmann 5, the addition of dried mushrooms did not cause any significant changes in the N-NH4 concentration determined in the substrate after the cultivation of the yellow chrysanthemum variety was completed. Similar trends were demonstrated for the analogous combination (Klasmann 5 + P) in the experiment with the white chrysanthemum variety (Table 27).

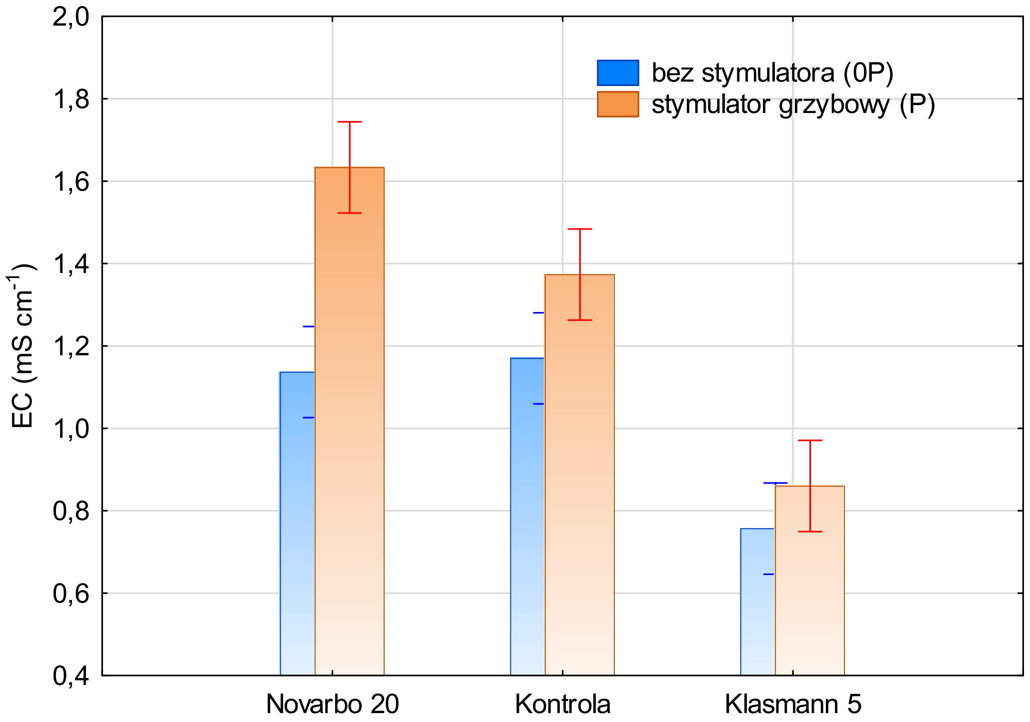


Fig. 49. The influence of the type of substrate and the addition of a fungal stimulant on the salinity of the substrate (mS cm-1) determined after commercial cultivation (Jenflor company) of a yellow chrysanthemum variety.

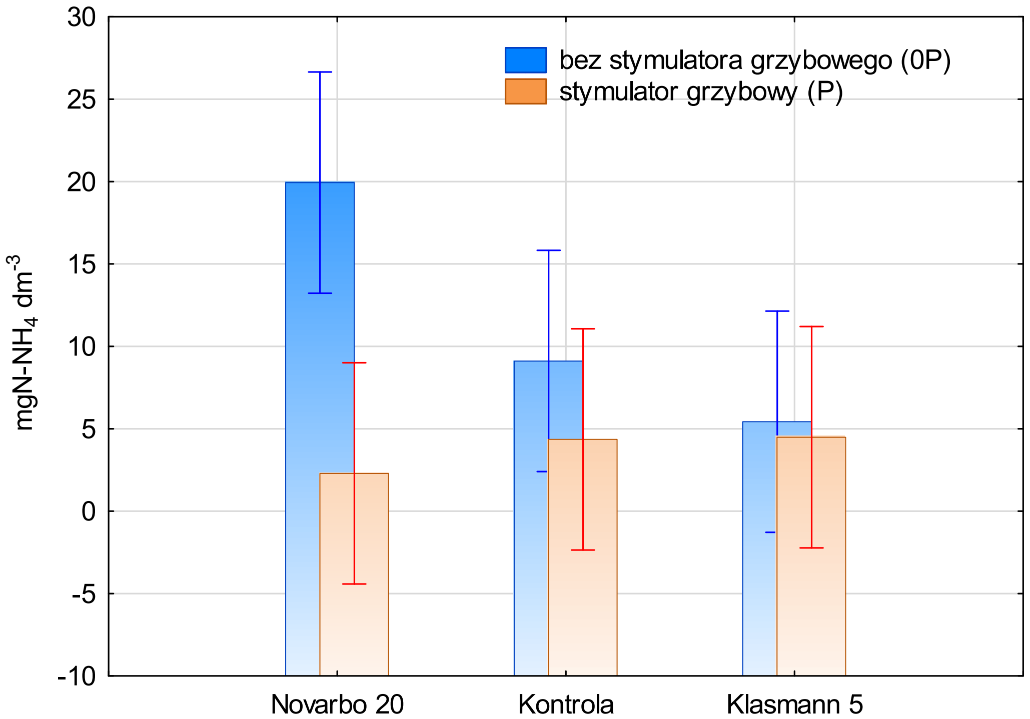


Fig. 50. The effect of the type of substrate and the addition of a fungal stimulant on the content of nitrogen in the ammonium form in the substrate (mg N-NH4 dm-3) determined after commercial cultivation (Jenflor company) of a yellow chrysanthemum variety.

Table 28. Content of macronutrients (% d.m.) and sodium (mg kg-1 d.m.) in organic substrates used in the cultivation of white chrysanthemum variety in production greenhouse conditions

Factor		pH	EC	N-NH_4	N-NO_3	Ca	K	Mg	P	S	Na
Controll		4,65 A	**1,19** C	2,25 A	**182** C	943 A	214 B	146 AB	462 B	105 B	76 A
Novarbo 20		5,57 B	0,67 A	1,19 A	116 B	**1195** B	139 A	142 A	*352* A	*54* A	70 A
Klasmann 5		**5,71** C	0,81 B	**6,37** B	*65* A	884 A	**415** C	179 B	471 B	87 B	**137** B
No mushroom (0P)		**5,45** B	0,76 A	2,15 A	76,5 A	994 A	212 A	148 A	400 A	78 A	91 A
Mushroom (P)		5,17 A	**1,02** B	**4,39** B	**166** B	1021 A	**300** B	162 A	457 A	87 A	98 A
Controll	0P	4,90 b	0,92 c	3,12 a	110 b	937 a	143 a	138 a	487 ab	106 a	79 a
	P	4,40 a	**1,45** e	1,37 a	**254** c	950 a	284 b	153 a	437 ab	105 a	73 a
Novarbo 20	0P	5,46 c	0,73 b	1,24 a	84 ab	1156 a	98 a	134 a	330 a	52 a	66 a
	P	5,67 d	0,61 a	1,13 a	148 b	1235 a	179 a	150 a	374 ab	57 a	74 a
Klasmann 5	0P	**5,98** e	0,63 a	2,08 a	36 a	890 a	394 c	173 a	382 ab	75 a	127 a
	P	5,44 c	0,99 d	10,7 b	95 ab	879 a	437 c	184 a	560 b	99 a	146 a
Bioefekt		6,50	0,81	0,53	3,64	1034	487	228	356	126	88

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 - type of substrate and factor 2 - addition of/without mushroom stimulator; control - peat substrate

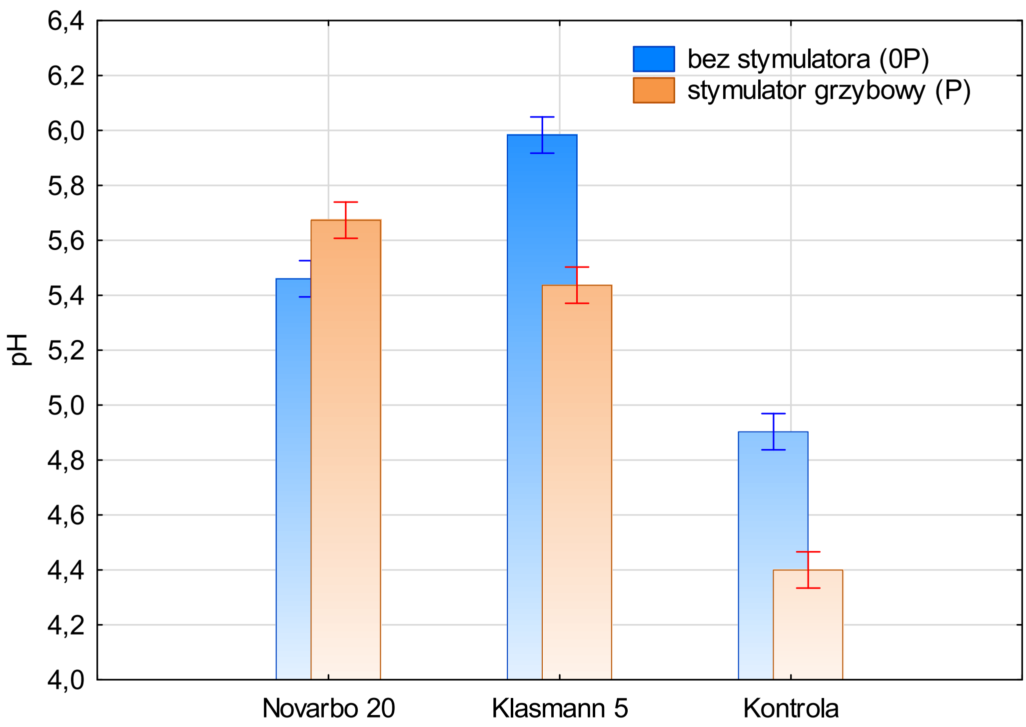


Fig. 51. The influence of the type of substrate and the addition of a fungal stimulant on the substrate reaction (pH in H2O) determined after commercial cultivation (Jenflor company) of a white chrysanthemum variety

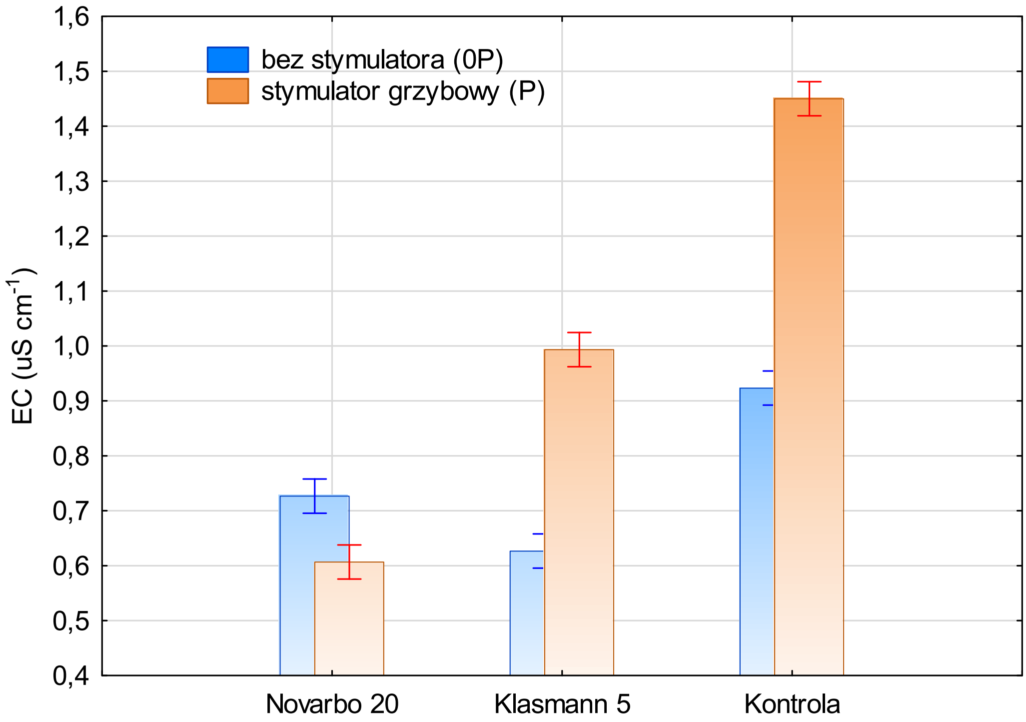


Fig. 52. The effect of the type of substrate and the addition of a fungal stimulant on the salinity of the substrate (mS cm-1) determined after commercial cultivation (Jenflor company) of a white chrysanthemum variety

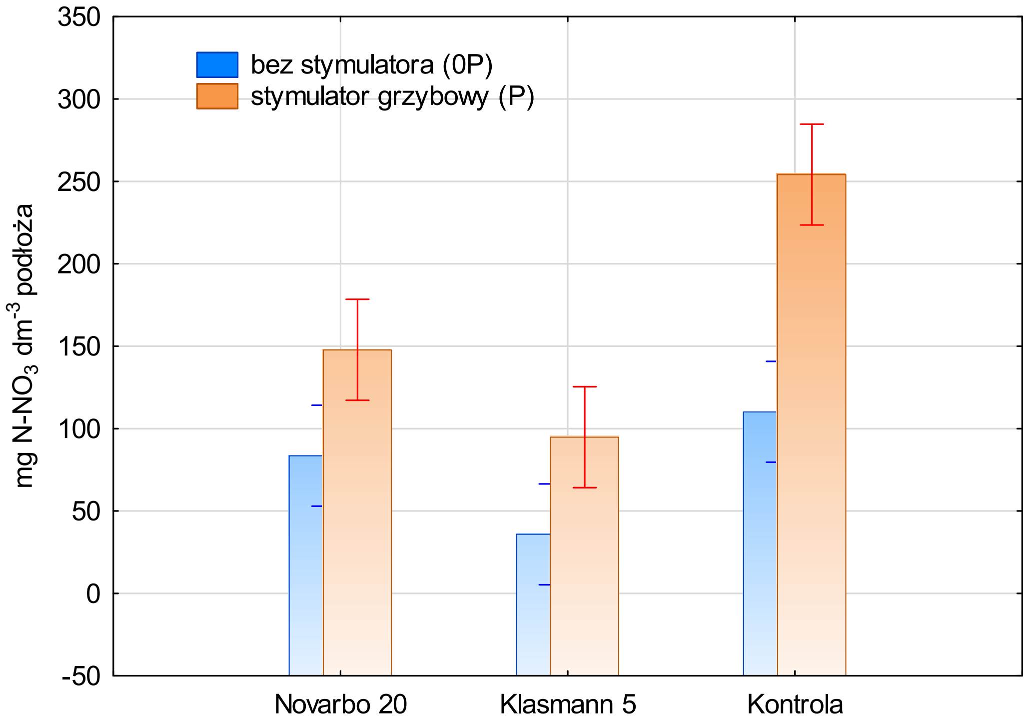


Fig. 53. The effect of the type of substrate and the addition of a fungal stimulant on the content of nitrate nitrogen (mg N-NO3 dm-3) determined after commercial cultivation (Jenflor company) of a white chrysanthemum variety

In the experiment with the white chrysanthemum variety, a decrease in the pH of the peat substrate (control) and the peat-free Klasmann 5 substrate was observed after the application of dried mushrooms (Fig. 51). The opposite reaction was observed in the case of the substrate with limited peat content Novarbo 20. It should be noted that the Novarbo 20 substrate contained the most soluble calcium among the cultivation substrates used in the experiment (Tables 27 and 28). After the completion of the cultivation of the small-flowered white chrysanthemum variety, significantly more soluble potassium was shown in the control substrate treated with dried mushrooms (Table 28, Fig. 54). Similar trends were observed in the other substrates, but statistical verification did not confirm the significance of the differences between the means in these combinations. Also in the experiment with the yellow chrysanthemum variety, despite the lack of statistical significance of differences between the means, it was observed that the addition of dried mushrooms increased the K content in the substrates analyzed after the cultivation was liquidated (Table 28).

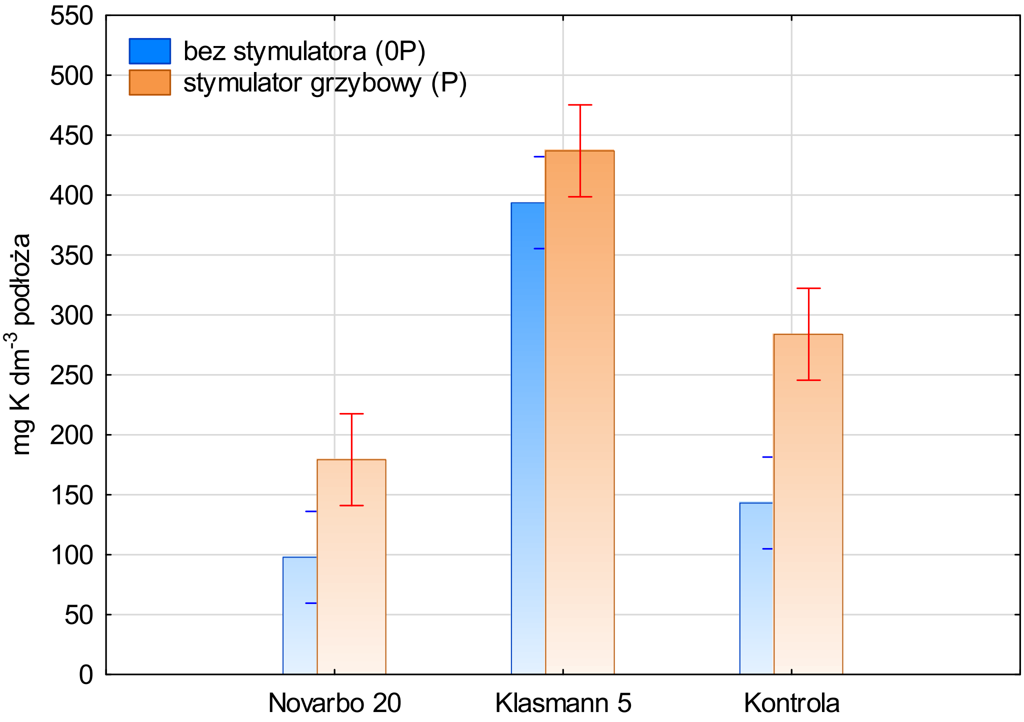


Fig. 54. The effect of the type of substrate and the addition of a fungal stimulant on the potassium content (mg K dm-3) determined after commercial cultivation (Jenflor company) of a white chrysanthemum variety

Substrates made of organic materials replacing peat used in the potted chrysanthemum studies were richer in manganese than the control peat substrate (Novarbo standard) (Tables 29 and 30). The total microelement contents determined after the cultivation period showed that the control substrate and the Novarbo 20 substrate had a similar elemental composition, except for manganese, the content of which was significantly higher in the substrate with limited Novarbo 20 peat content. With the exception of copper, the peat-free Klasmann 5 substrate was distinguished by a high total content of microelements (Tables 29 and 30). The greatest variation in the total content of microelements in the growing substrates analyzed after the cultivation of the yellow chrysanthemum variety was shown for iron - from 1002 mg Fe kg-1 (Novarbo 20) to 8441 mg Fe kg-1 (Klasmann 5) and analogously in the cultivation of the white variety 995 mg Fe kg-1 and 8050 mg Fe kg-1.

Table 29. Total content of microelements (mg kg-1 d.m.) determined in substrates after cultivation of yellow chrysanthemum under production conditions.

Factor		B	Cu	Fe	Mo	Mn	Zn
Controll		14,5 A	34,2 AB	1180 A	8,70 A	54,8 A	67,1 A
Novarbo 20		15,1 A	35,9 B	1002 A	7,90 A	75,1 B	70,7 A
Klasmann 5		**23,0** B	33,3 A	**8441** B	**15,0** B	**207** C	**81,3** B
No mushroom (0P)		16,9 A	33,8 A	3398 A	11,0 A	116 A	71,1 A
Mushroom (P)		18,1 A	35,2 B	**3684** B	10,0 A	109 A	75,0 A
Controll	0P	14,5 a	33,9 ab	1161 a	8,39 a	55,4 a	65,6 a
	P	14,6 a	34,4 b	1199 a	9,02 a	54,2 a	68,6 a
Novarbo 20	0P	14,7 a	36,1 b	1001 a	7,29 a	82,6 a	70,3 a
	P	15,4 a	35,6 b	1003 a	8,52 a	67,6 a	71,0 a
Klasmann 5	0P	21,6 a	31,3 a	8031 b	17,4 a	209 a	77,4 a
	P	24,3 a	35,4 b	8850 c	12,5 a	205 a	85,2 a
Bioefekt		28,9	34,3	8885	2,36	412	154

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 - type of substrate and factor 2 - addition of/without mushroom stimulator; control - peat substrate

Table 30. Total content of microelements (mg kg-1 d.m.) determined in substrates after cultivation of white chrysanthemum under production conditions.

Factor		B	Cu	Fe	Mo	Mn	Zn
Controll		14,7 A	33,9 A	1174 A	8,44 A	52,4 A	64,8 A
Novarbo 20		15,1 A	36,5 A	1076 A	7,63 A	87,1 B	70,6 A
Klasmann 5		**22,2** B	36,7 A	**8444** B	**11,1** B	**198** C	**78,7** B
No mushroom (0P)		18,0 A	33,5 A	3588 A	9,2 A	**120** B	69,5 A
Mushroom (P)		16,7 A	38,0 A	3542 A	8,9 A	105 A	73,2 A
Controll	0P	15,3 a	33,4 a	1144 a	8,17 a	56,6 a	63,7 a
	P	14,0 a	34,5 a	1204 a	8,71 a	48,2 a	65,9 a
Novarbo 20	0P	16,0 a	36,2 a	1091 a	7,87 a	92,3 b	70,2 a
	P	14,3 a	36,9 a	1062 a	7,39 a	82,0 b	70,9 a
Klasmann 5	0P	22,7 a	30,8 a	8529 a	11,5 a	211 d	74,6 a
	P	21,7 a	42,6 a	8359 a	10,7 a	185 c	82,8 a
Bioefekt		23,0	29,3	6635	1,47	349	136

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 - type of substrate and factor 2 - addition of/without mushroom stimulator; control - peat substrate

The determinations of the total content of microelements carried out after the completion of the chrysanthemum experiments showed that the addition of dried edible mushrooms (P) caused a significant increase in the content of copper, iron and zinc in the substrates after the cultivation of the yellow variety in relation to the untreated substrates (Table 29). In the cultivation of the white chrysanthemum variety, significantly more manganese was shown in the substrates without the addition of the mushroom stimulator (Table 30).

In the experiment with the yellow chrysanthemum variety, the increase in the content of copper and iron in the substrates with the addition of the mushroom stimulator was statistically significant in the peat-free Klasmann 5 substrate (Table 29). On the other hand, the Klasmann 5 substrate analyzed after the cultivation of the white chrysanthemum variety was richer in manganese in the combinations not treated with the mushroom stimulator (Table 30).

Regardless of the chrysanthemum variety grown, the additionally tested Bioefekt substrate was distinguished by a high content of boron, iron, manganese and zinc (Tables 29 and 30) in comparison to the peat control. In terms of the total content of microelements, this substrate was similar to the peat-free Klasmann 5 substrate.

Analysis of plant material

Wilmington large-flowered chrysanthemums (yellow) grown in the Klasmann 5 peat-free substrate had the highest dry mass, potassium content (only in relation to the Novarbo 20 substrate) and sodium (Table 31). At the same time, the lowest calcium and sulfur content were determined in these plants. The addition of the fungal stimulator generally reduced the dry mass content and significantly increased the potassium and phosphorus content in the yellow chrysanthemums (Table 31).

Table 31. Content of macronutrients (% d.m.) and sodium (mg kg-1 d.m.) in the yellow chrysanthemum variety grown in organic substrates in a production greenhouse (Jenflor).

Factor		DM	N	Ca	K	Mg	P	S	Na
Controll		9,47 A	5,47 A	2,07 B	6,78 AB	0,36 A	1,16 A	0,36 B	0,07 A
Novarbo 20		9,40 A	5,33 A	2,07 B	6,56 A	0,34 A	1,12 A	0,36 B	0,08 A
Klasmann 5		**10,6** B	5,42 A	*1,59* A	7,05 B	0,37 A	1,11 A	*0,32* A	**0,11** B
No mushroom (0P)		**10,0** B	5,47 A	1,88 A	6,60 A	0,35 A	1,06 A	0,34 A	0,09 A
Mushroom (P)		9,62 A	5,35 A	1,94 A	**6,99** B	0,36 A	**1,20** B	0,36 A	0,08 A
Controll	0P	9,37 ab	5,47 a	2,04 a	6,83 a	0,35 a	1,07 ab	0,35 a	0,08 a
	P	9,56 ab	5,47 a	2,10 a	6,73 a	0,37 a	1,26 bc	0,37 a	0,07 a
Novarbo 20	0P	9,63 ab	5,52 a	2,00 a	6,25 a	0,33 a	0,99 a	0,35 a	0,08 a
	P	9,17 a	5,15 a	2,15 a	6,87 a	0,35 a	1,25 c	0,37 a	0,07 a
Klasmann 5	0P	**11,0** c	5,41 a	1,62 a	6,73 a	0,38 a	1,13 a-c	0,31 a	0,11 a
	P	10,1 b	5,43 a	1,57a	7,37 a	0,35 a	1,09 a-c	0,34 a	0,11 a
Bioefekt		11,4	5,44	1,54	7,06	0,40	1,01	0,33	0,09

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 - type of substrate and factor 2 - addition of/without mushroom stimulator; control - peat substrate

A significant effect of the interaction of the factors substrate x fungal stimulator addition on the dry matter and phosphorus content in the plants of the yellow chrysanthemum variety was demonstrated (Fig. 55 and 56). A significantly lower dry matter content was determined in the plants of this variety grown in the peat-free Klasmann 5 substrate (Fig. 55). A similar trend was also observed for the substrate with a limited content of Novarbo 20 peat. However, in the cultivation in peat (control), no significant effect of dried mushrooms on the dry matter content in the yellow chrysanthemums was demonstrated.

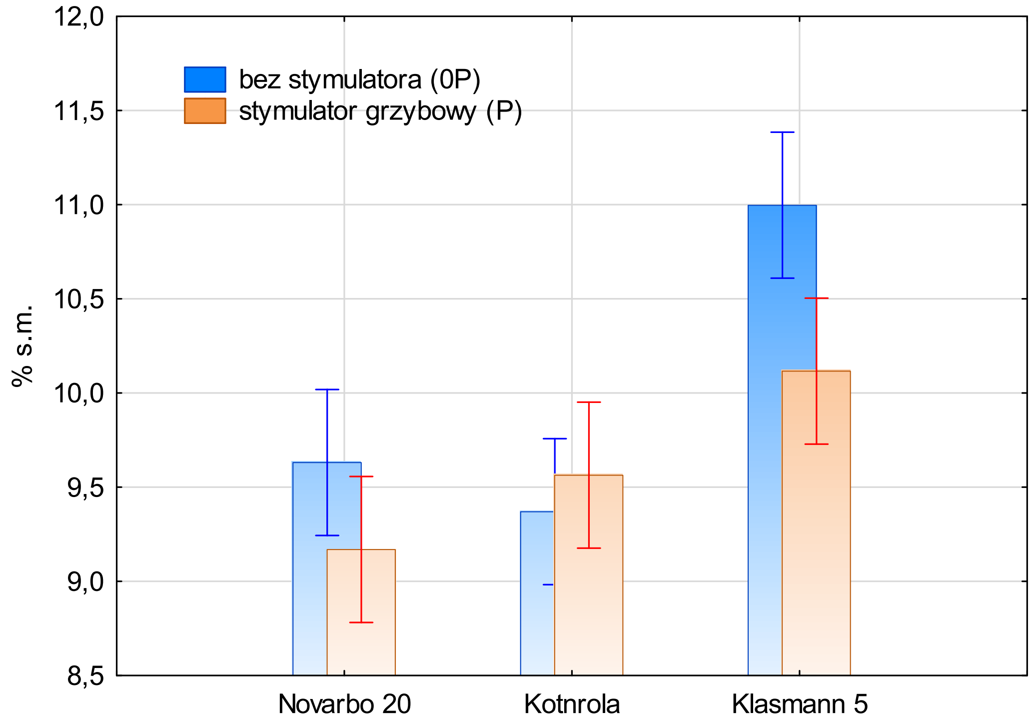


Fig. 55. The influence of the type of substrate and the addition of a fungal stimulant on the dry matter content of the yellow chrysanthemum variety in commercial cultivation (Jenflor company)

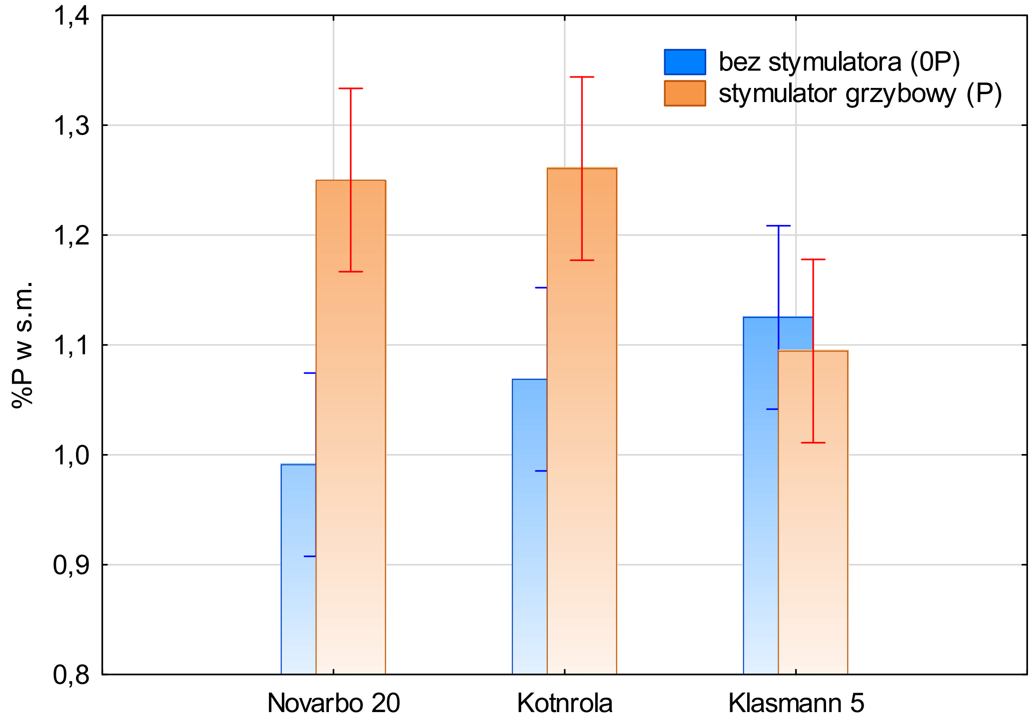


Fig. 56. The effect of the type of substrate and the addition of a fungal stimulant on the phosphorus content (% P in dry matter) in the yellow chrysanthemum variety in commercial cultivation (Jenflor company)

The addition of a fungal stimulator significantly increased the phosphorus content in yellow chrysanthemums grown in a substrate with limited Novarbo 20 peat content (Fig. 56). The same tendency was observed for the peat control substrate. However, in the cultivation in the peat-free Klasmann 5 substrate, the addition of dried mushrooms did not significantly affect the nutrition of plants with this macroelement.

Chrysanthemum varieties grown in the additionally tested Bioefekt substrate were characterized by a higher dry mass compared to the control (Table 31). In addition, less Ca and S were determined in the chrysanthemum biomass than in the control plants.

In the experiment with white chrysanthemum, a significantly higher dry mass was demonstrated in plants grown in a substrate with limited Novarbo 20 peat content compared to the other substrates used in the experiment (Table 31). The lowest dry mass was determined in plants grown in the control substrate. At the same time, chrysanthemums harvested from this substrate after the end of cultivation had the highest sulphur content. The biomass of the white chrysanthemum variety grown in the peat-free Klasmann 5 substrate contained the least calcium and the most sodium.

The addition of the mushroom stimulator to the substrates significantly increased the phosphorus content in the white chrysanthemums (Table 32).

As in the experiment with the yellow variety, a significant effect of the interaction of the factors substrate x fungal stimulator addition on the potassium and phosphorus content in plants was demonstrated (Fig. 57 and 58). In the peat-free Klasmann 5 substrate, the addition of dried mushrooms increased the K content in plants, while in the other substrates containing peat (control and Novarbo 20) an inverse relationship was observed (Fig. 57). A similar effect of the interaction of factors was demonstrated for the potassium content in the biomass of the white chrysanthemum variety (Fig. 58).

Table 32. Content of macronutrients (% d.m.) and sodium (mg kg-1 d.m.) in the white small-flowered chrysanthemum variety grown in organic substrates in a production greenhouse (Jenflor)

Factor		DM	N	Ca	K	Mg	P	S	Na
Controll		*8,30* A	5,33 A	1,97 B	7,67 A	0,32 A	1,25 B	**0,40** B	0,12 A
Novarbo 20		**9,20** C	5,25 A	2,07 B	7,87 AB	0,33 A	1,05 A	0,36 A	0,12 A
Klasmann 5		8,78 B	5,39 A	*1,53* A	8,21 B	0,35 A	1,26 B	0,36 A	**0,15** B
No mushroom (0P)		8,86 A	5,40 A	1,85 A	7,97 A	0,33 A	1,13 A	0,37 A	0,13 A
Mushroom (P)		8,66 A	5,25 A	1,87 A	7,86 A	0,33 A	**1,25** B	0,37 A	0,13 A
Controll	0P	8,30 a	5,55 a	1,98 a	7,93 ab	0,31 a	1,18 ab	0,40 a	0,12 a
	P	8,31 a	5,11 a	1,97 a	7,41 a	0,32 a	1,33 bc	0,39 a	0,13 a
Novarbo 20	0P	9,58 b	5,25 a	2,03 a	8,02 ab	0,33 a	1,06 a	0,36 a	0,12 a
	P	8,81 a	5,25 a	2,11 a	7,73 ab	0,32 a	1,04 a	0,36 a	0,12 a
Klasmann 5	0P	8,70 a	5,39 a	1,54 a	7,96 ab	0,34 a	1,16 ab	0,36 a	0,16 a
	P	8,85 a	5,39 a	1,52 a	8,45 b	0,35 a	1,37 c	0,36 a	0,14 a
Bioefekt		9,47	5,50	1,56	7,92	0,39	1,12	0,36	0,15

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 - type of substrate and factor 2 - addition of/without mushroom stimulator; control - peat substrate

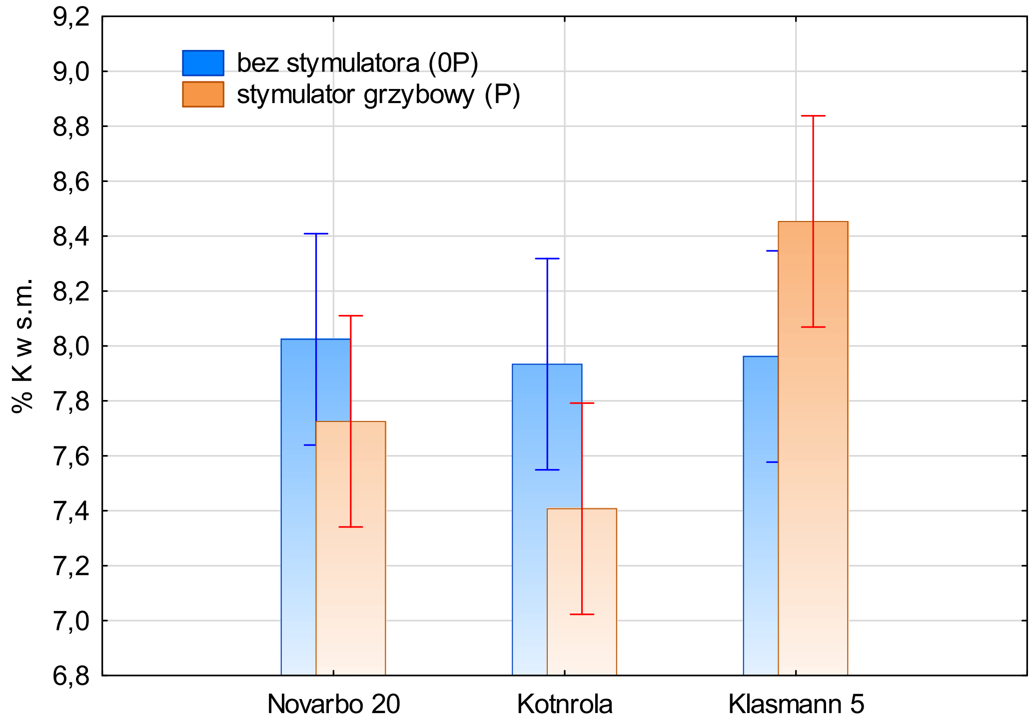


Fig. 57. The effect of the type of substrate and the addition of a fungal stimulant on the potassium content (% K in dry matter) in the white chrysanthemum variety in commercial cultivation (Jenflor company)

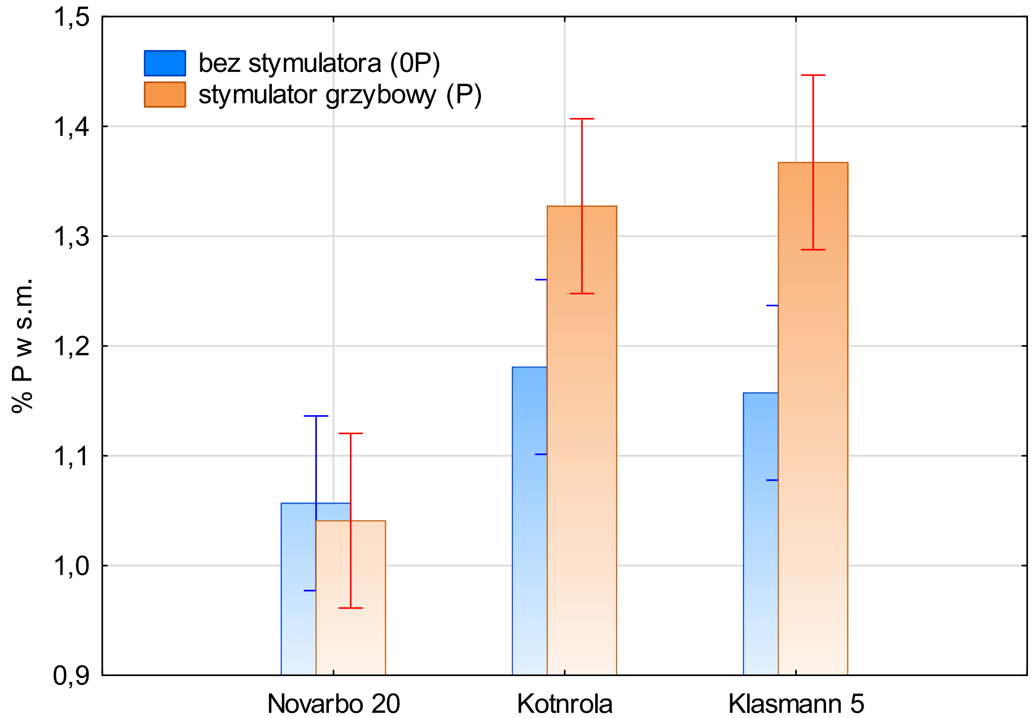


Fig. 58. The effect of the type of substrate and the addition of a fungal stimulant on the phosphorus content (% P in dry matter) in the white chrysanthemum variety in commercial cultivation (Jenflor company)

Tables 33 and 34 contain the results of micronutrient determinations in the biomass of yellow and white chrysanthemum varieties, respectively. Statistically significant interaction of the factors substrate × addition of fungal stimulator is illustrated in Figures 59-63.
Yellow chrysanthemums grown in a peat control substrate contained the most manganese and the least molybdenum and zinc in relation to the cultivation substrates with limited peat content or peat-free. The most boron was determined in yellow chrysanthemums grown in peat-free Klasmann 5 substrate (Table 33).
In general, the addition of dried mushrooms to the substrates significantly increased the manganese content in the plants of this variety. Significantly more copper, molybdenum and zinc were contained in yellow chrysanthemums collected from substrates not treated with a fungal stimulator (Table 33).
Analyzing the interaction of the experimental factors, it was shown that the addition of dried mushrooms significantly increased the manganese content in plants growing in the substrate with limited peat content Novarbo 20 and peat-free Klasmann 5 (Fig. 59). The opposite relationship was shown for zinc, the content of which decreased significantly in plants under the influence of the addition of the fungal stimulator to the substrates Novarbo 20 and Klasmann 5 (Fig. 60).

Table 33. Content of microelements (mg kg-1 d.m.) in the yellow chrysanthemum variety grown in organic substrates in the production greenhouse conditions (Jenflor)

Factor		**B**	**Cu**	**Fe**	**Mn**	**Mo**	**Zn**
ControlL		63,4 A	12,7 A	220 A	**192** B	*1,44* A	*86,5* A
Novarbo 20		65,2 A	13,7 A	206 A	156 A	2,13 B	104 B
Klasmann 5		**84,5** B	13,1 A	192 A	165 A	2,60 B	99,1 B
No mushroom (0P)		69,0 A	**13,6** B	211 A	144 A	**2,28** B	**103** B
Mushroom (P)		73,1 A	12,7 A	202 A	**199** B	1,83 A	90,4 A
Controll	0P	62,2 a	13,2 a	219 a	182 b	1,85 a	84,7 a
	P	64,5 a	12,3 a	221 a	203 b	1,04 a	88,3 a
Novarbo 20	0P	63,2 a	14,5 a	213 a	120 a	2,34 a	113 c
	P	67,2 a	12,8 a	199 a	193 b	1,92 a	94,6 ab
Klasmann 5	0P	81,6 a	13,2 a	199 a	129 a	2,66 a	110 bc
	P	87,4 a	13,0 a	186 a	201 b	2,53 a	88,3 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 - type of substrate and factor 2 - addition of/without mushroom stimulator; control - peat substrate

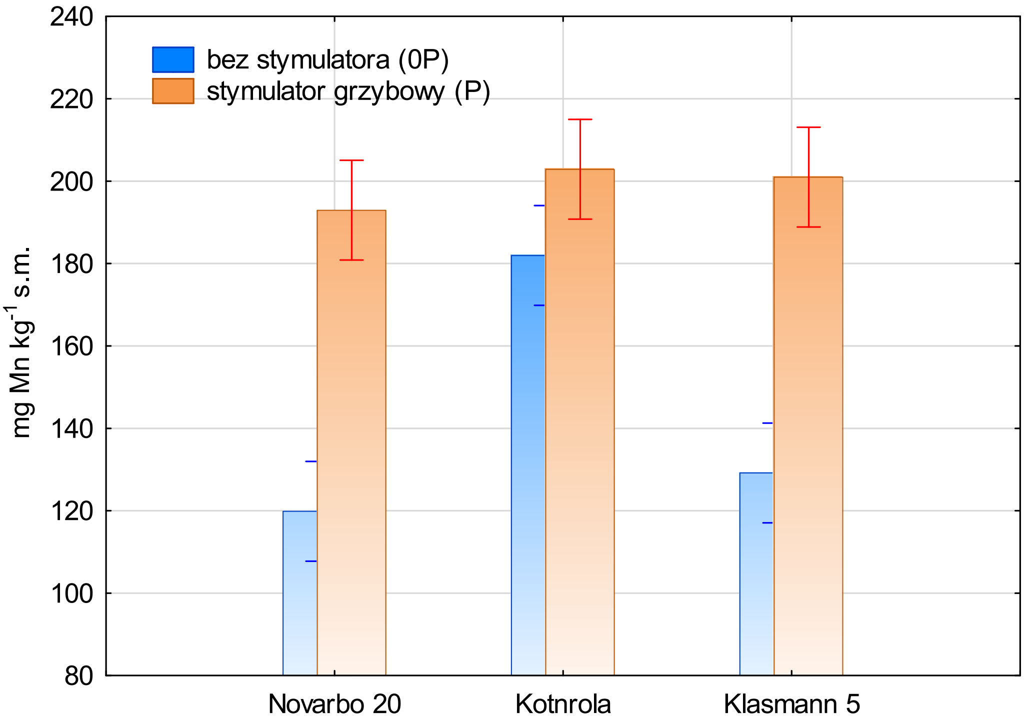


Fig. 59. The effect of the type of substrate and the addition of a fungal stimulant on the manganese content (mg Mn kg-1 d.m.) in the yellow chrysanthemum variety in commercial cultivation (Jenflor company)

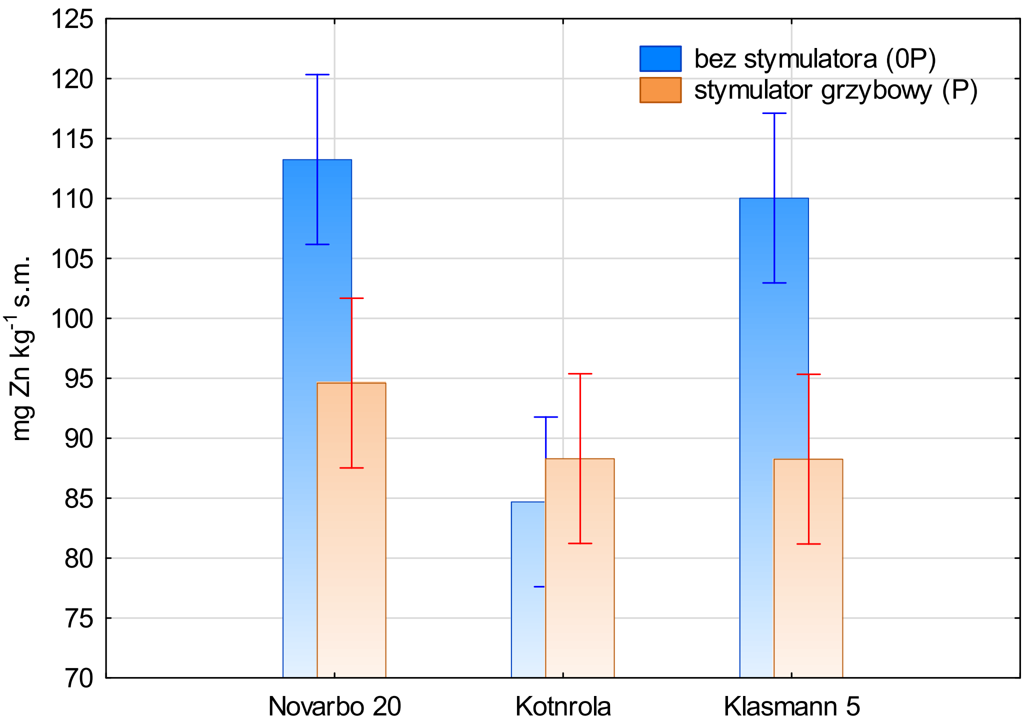


Fig. 60. The effect of the type of substrate and the addition of a fungal stimulant on the zinc content (mg Zn kg-1 d.m.) in the yellow chrysanthemum variety in commercial cultivation (Jenflor company),

White chrysanthemums grown in peat (control), similarly to yellow chrysanthemums, contained significantly less molybdenum and zinc compared to plants growing in substrates with limited peat content or without peat (Table 34). The highest boron and copper content was found in white chrysanthemums grown in the peat-free Klasmann 5 substrate. Plants growing in the Novarbo 20 substrate, containing the most soluble calcium, had the lowest manganese content.

The addition of the fungal stimulator significantly increased the content of boron and manganese in the biomass of white chrysanthemums, while it decreased the content of copper, molybdenum and zinc (Table 34).

The evaluation of the interaction of the experimental factors (substrate x fungal stimulator) showed that the addition of dried mushrooms significantly increased the content of boron, and similarly to the yellow variety – manganese, in plants growing in the peatless substrate Klasmann 5 (Fig. 61 and 62). The opposite relationship was shown for zinc, the content of which decreased significantly in plants under the influence of the addition of the fungal stimulator to the substrates Novarbo 20 and Klasmann 5 (Fig. 63).

Table 34. Content of microelements (mg kg-1 d.m.) in the white chrysanthemum variety grown in organic substrates in the production greenhouse conditions (Jenflor)

Factor		B	Cu	Fe	Mn	Mo	Zn
Controll		62,7 A	11,8 A	228 A	168 B	*2,03* A	*86,7* A
Novarbo 20		59,8 A	11,4 A	222 A	*106* A	3,15 B	117 B
Klasmann 5		**90,5** B	**12,7** B	218 A	179 B	3,00 B	118 B
No mushroom (0P)		68,7 A	**12,3** B	228 A	129 A	**3,52** B	**113** B
Mushroom (P)		**73,3** B	11,6 A	217 A	**174** B	2,25 A	101 A
controll	0P	62,6 a	12,2 a	230 a	160 c	2,30 a	86,9 a
	P	62,8 a	11,4 a	225 a	176 c	1,76 a	86,6 a
Novarbo 20	0P	59,2 a	11,8 a	231 a	96,1 a	3,93 a	125 cd
	P	60,4 a	11,0 a	214 a	117 ab	2,39 a	108 b
Klasmann 5	0P	84,3 b	12,9 a	224 a	130 b	3,41 a	128 d
	P	96,8 c	12,5 a	212 a	**228** d	2,60 a	108 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 - type of substrate and factor 2 - addition of/without mushroom stimulator; control - peat substrate

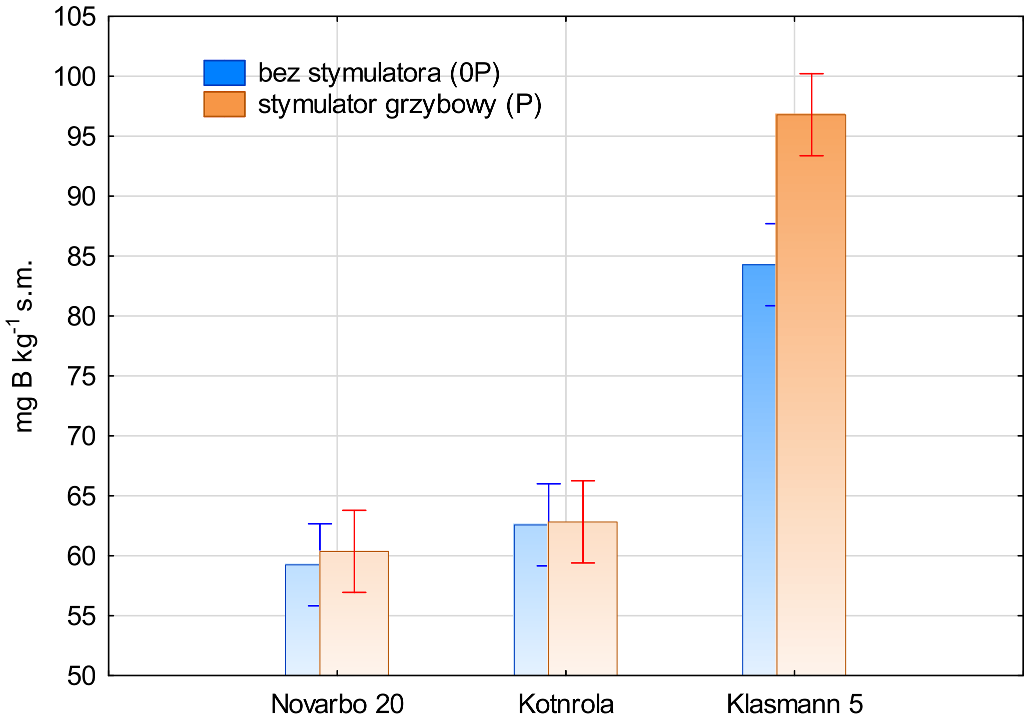


Fig. 61. The effect of the type of substrate and the addition of a fungal stimulant on the boron content (mg B kg-1 d.m.) in white chrysanthemum in commercial cultivation (Jenflor company).

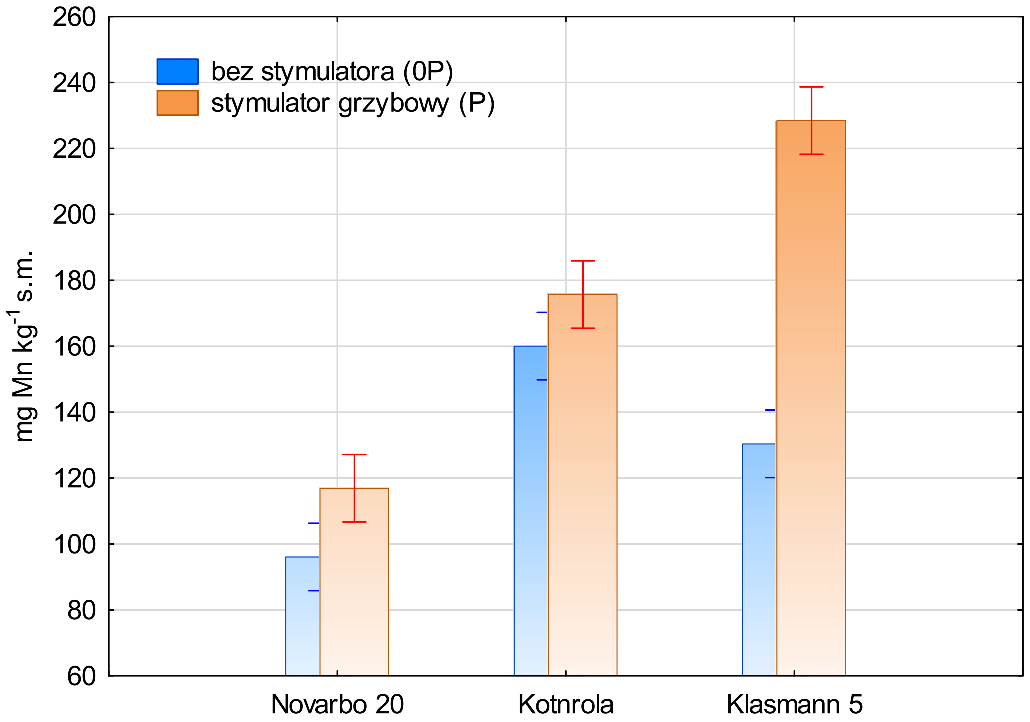


Fig. 62. The effect of the type of substrate and the addition of a fungal stimulant on the manganese content (mg Mn kg-1 d.m.) in the white chrysanthemum variety in commercial cultivation (Jenflor company).

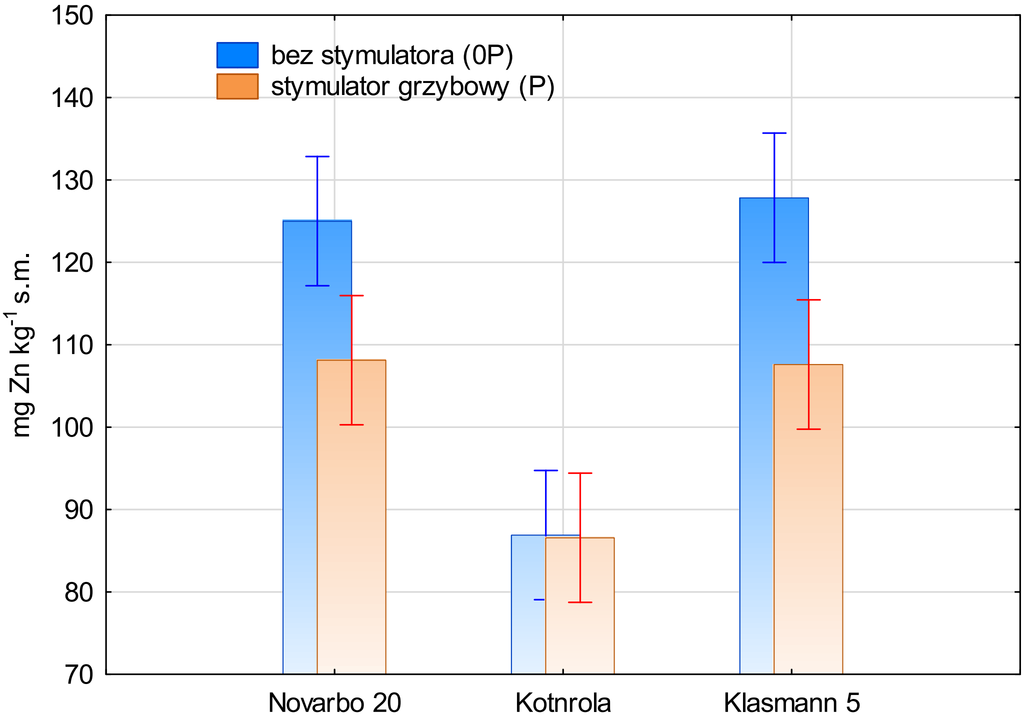


Fig. 63. The effect of the type of substrate and the addition of a fungal stimulant on the zinc content (mg Zn kg-1 d.m.) in the white chrysanthemum variety in commercial cultivation (Jenflor company).

Research results: large-scale autumn cultivation of ivy-leaved geranium

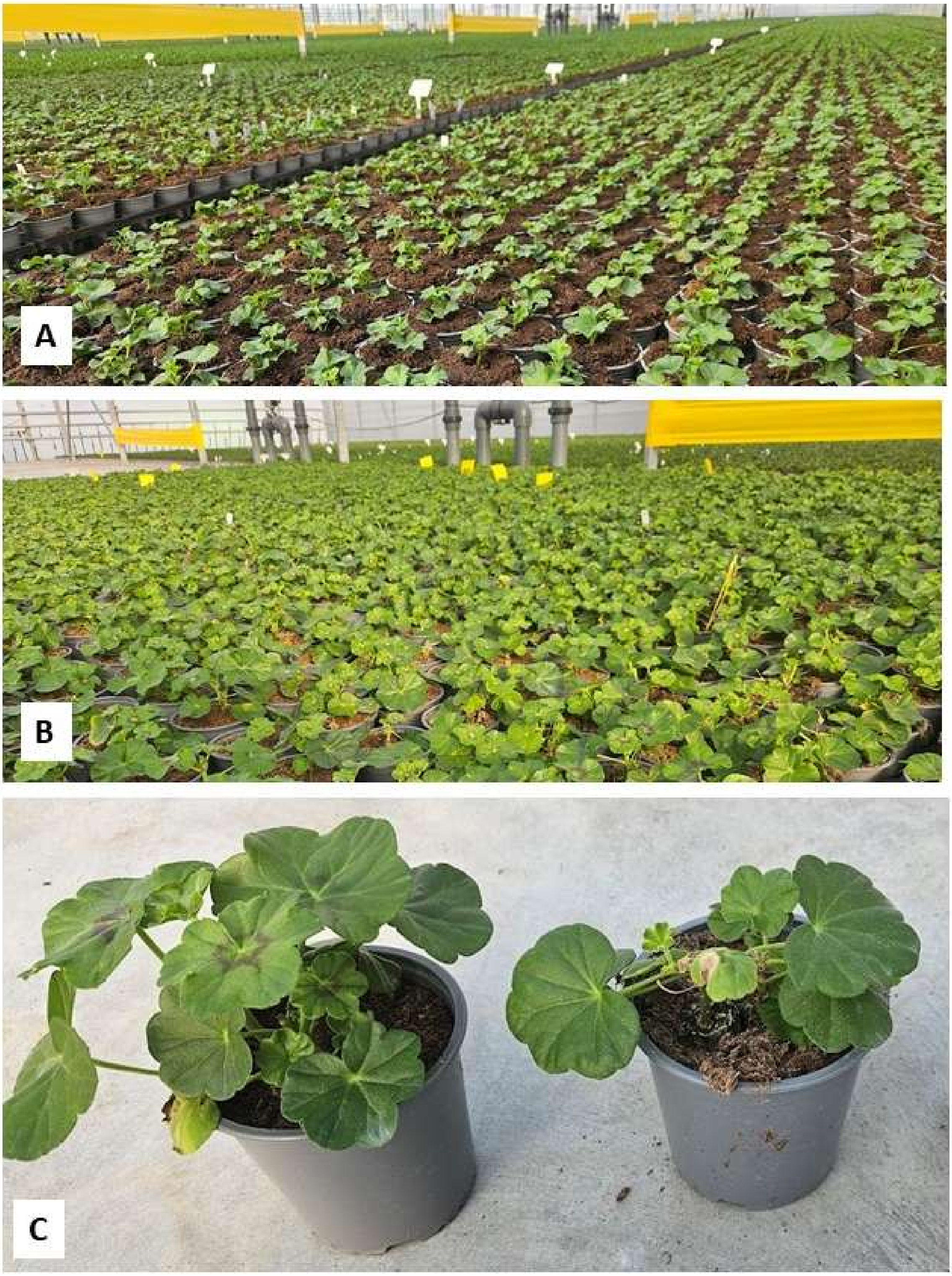


Fig. 64. Cultivation of Pelargonium peltatum in autumn-winter in the Jenflor production greenhouse, A – plants after planting in pots, B – development of shoots and leaves, C – on the right, a plant grown in a peat substrate (Control), on the left, a plant grown in a peat-free substrate Klasmann 5.

In the autumn-winter cultivation of ivy-leafed geranium, the development of shoots and leaves was observed (Fig. 64 A, B). Visual observations conducted during cultivation showed that in difficult light conditions (shortening day, low PPFD light intensity at this time of year), plants grown in a substrate with limited peat content and peat-free had less developed green mass (Fig. 64 C). Until the time of analysis, around December 20, 2024, geraniums did not bloom, and no flower bud formation was observed.

Analyses of morphometric and physiological parameters of plants

Observations and statistical analyses conducted for two selected varieties of ivy-leafed pelargonium: Medio Karolina Park Red and Sunflair Lollipop Chris Red showed that in the studied development stage, plants grown in a substrate with limited peat content (Novarbo 20) and peat-free (Klasman 5) were shorter and had a smaller mass of the above-ground part (Table 35). The level of specific physiological parameters (Fv/Fm and SPAD) does not depend on the substrate used or the variety (Table 35) and indicates a good physiological condition of the plants.

Table 35. The effect of the growing substrate on selected biometric and physiological parameters of two varieties of ivy-leafed pelargonium: Medio Karolina Park Red and Sunflair Lollipop Chris Red.

Variety	Substrate	Height [cm]	Above-ground weight [g]	SPAD	Fv/Fm
Karolina	Kontrola	12,0 c*	15,0 c	48,10 a	0,80 ab
	Novarbo	10,5 b	13,0 b	48,58 a	0,81 ab
	Klasmann	10,1 b	12,4 b	48,33 a	0,82 b
Lollipop	Kontrola	10,5 b	12,3 b	49,40 a	0,81 ab
	Novarbo	8,6 a	10,5 a	47,85 a	0,80 ab
	Klasmann	8,4 a	10,4 a	45,35 a	0,79 a
Independent from substrate					
Karolina		10,9 b	13,4 b	48,33 a	0,81 a
Lollipop		9,2 a	11,1 a	47,53 a	0,80 a
Independendt from Variety					
Kontrola		11,2 b	13,6 b	48,75 a	0,80 a
Novarbo		9,6 a	11,7 a	48,21 a	0,80 a
Klasmann		9,3 a	11,4 a	46,84 a	0,81 a

** mean values in columns marked with the same letters do not differ significantly*

Conclusions

Substrates in the commercial cultivation of garden pansy, marigold and chrysanthemum

1. Peat substrate (control) and substrate with limited peat content Novarbo 20 small similar physical properties and organic matter content. Peat-free substrate Klasmann 5 was distinguished by the highest volumetric density and the lowest water capacity and organic matter content among the compared substrates.
2. Peat substrate had the lowest pH (acidic), while the pH of peat-free substrates and substrates with limited peat content was close to neutral.
3. Substrates significantly differed in the content of macro- and microelements. Novarbo 20 substrate with limited peat content was similar in terms of elemental composition to the control substrate. Peatless Klasmann 5 substrate was the richest in available potassium and sodium and had the highest total content of boron, iron, manganese and zinc. 4. The addition (2.5%) of dried mushrooms to substrates significantly increased their water capacity, the content of nitrate nitrogen, potassium, copper, iron and zinc and caused a significant increase in the salinity of the growing substrate.

Pansy (*Viola ×wittrockiana)*

1. Pansies grown in peat-free Klasmann 5 substrate had the highest dry mass. In contrast, plants growing in peat (control substrate) had the lowest content of nitrogen, magnesium, phosphorus, sulfur, boron, copper and zinc. In general, the mineral profile of the pansy taken for testing from the substrate with limited peat content Novarbo 20 was similar to the plants grown in peat-free Klasmann 5 substrate. The low content of components in the biomass of plants grown in peat or substrate with limited peat content could be caused by the dilution effect, as these plants produced the highest yield of fresh mass. In general, pansies grown in substrate prepared from organic waste materials (Klasmann 5) and with limited peat content (Novarbo 20) were distinguished by significantly higher content of boron, copper, manganese and zinc in the biomass.
2. Varietal differences were shown in the mineral profile of the garden pansy. The highest dry mass and nitrogen content were found in the purple and yellow pansies. The yellow pansies contained significantly less manganese and more zinc compared to the purple and white varieties. The white pansies, on the other hand, contained the most magnesium.
3. A significant interaction of the variety x substrate factors was observed. The yellow pansy variety growing in the Novarbo 20 substrate was distinguished by an increased dry mass and nitrogen content compared to the other varieties grown in this substrate combination. The purple pansies, on the other hand, produced the highest dry mass when grown in the peat-free Klasmann 5 substrate. The white pansies grown in the control peat substrate contained the least nitrogen.
4. The substrate used for growing garden pansies (Klasmann 5, Novarbo 20 vs. the control peat substrate) had an effect on the biomass of the above-ground part, branching and height of mature garden pansy plants. The lack of peat in the substrate (Klasmann 5) caused the weakest tillering of these plants, and they were also the lowest on this substrate. This was reflected in

the fresh mass of the obtained plants, which was the lowest for all the analyzed varieties grown in the Klasmann 5 substrate. On the other hand, limiting peat in the substrate (Novarbo) did not affect the reduction of the fresh mass of the tested varieties, which was at the level of plants grown in the peat Control substrate.

5. The growing substrate did not affect the number of flowers in the final product of pansies of the tested varieties from the Colossus group: Yellow with Blotch, White with Blotch and Tricolor, while the fewest flower buds were observed in plants grown in the peat-free Klasmann substrate. Limiting the peat content in the substrate (Novarbo) resulted in a greater number of flower buds.
6. Physiological parameters showed the correct course of photosynthesis in the plants. SPAD, Fv/Fm (chlorophyll fluorescence) and the content of chlorophyll a and b and carotenoids were at a similar level regardless of the substrate used.

Marigold (*Tagetes patula)*

1. The biomass of marigolds grown in the peat-free Klasmann 5 substrate had the lowest nitrogen, calcium, phosphorus and sulphur content. These plants contained the most potassium. The highest calcium and manganese content were found in plants harvested from the Novarbo 20 substrate. The biomass of marigolds growing in the peat-free Klasmann 5 substrate contained the least zinc, although this substrate was distinguished by a high total content of this microelement.
2. Varietal differences in the mineral nutritional status of marigolds were found. Plants of the Aton Yellow variety contained significantly more calcium, phosphorus, sulphur, boron, copper and zinc. On the other hand, marigolds of the Bonanza variety contained significantly more sodium and manganese.
3. A significant interaction of the substrate × variety factors was noted. Aton Yellow marigolds growing in the peat-free Klasmann 5 substrate had significantly lower dry mass than Bonanza. A tendency towards higher N content was observed in Aton Yellow plants grown in a substrate with limited peat content Novarbo 20 and in a peat substrate (control) than in Bonanza plants. More copper and zinc were determined in Aton Yellow plants grown in a peat-free substrate Klasmann 5 than in Bonanza.
4. Morphological quality and biometric parameters of the final plants of French marigold depended on the variety. French marigold Aton Yellow reached greater height and branched better compared to Bonanza. These parameters also depended on the type of substrate: the best quality plants were obtained in the control substrate, while Novarbo and Klasmann substrates caused a decrease in plant height, and plants grown in a peat-free substrate (Klasmann) branched less.
5. In the control substrate, the plants formed the most flowers and flower buds compared to the substrate with limited peat content and peat-free, where this number was 0.5 flowers lower. The total flower potential was the Aton Yellow variety, which had 5.9 flowers per plant (in the control), while Bonanza had only 3.5 to 3.8 flowers per plant.
6. The chlorophyll fluorescence index (Fv/Fm) confirmed the correct photosynthetic efficiency of the marigold plants, and the remaining physiological parameters were at a level not deviating from the norm. Plants from the control substrate had the highest content of chlorophyll a and carotenoids.

Chrysanthemum (*Chrysanthemum ×morifolium)*

1. Chrysanthemums grown in the peat-free Klasmann 5 substrate had the highest dry mass, potassium, sodium, boron and copper content. This corresponded to the richness of this substrate in nutrients. At the same time, the least calcium and sulphur were determined in plants harvested from this substrate. Chrysanthemums grown in peat (control) contained the most manganese and significantly less molybdenum and zinc compared to the other substrates.
2. The addition of the fungal stimulator generally reduced the dry mass content and significantly increased the potassium, phosphorus and manganese content in chrysanthemums, especially those grown in the peat-free Klasmann 5 substrate. On the other hand, chrysanthemums harvested from substrates not treated with the fungal stimulator contained significantly more copper, molybdenum and zinc.
3. The Mount Gerlach (White) variety contained significantly more potassium, phosphorus, sulfur, copper, iron and zinc, while the Wilmington (Yellow) variety had significantly higher dry mass, magnesium, copper and manganese content.
4. The substrate with limited peat content (Novarbo20) stimulated plant height and tillering. Dried mushrooms had an inhibiting effect on the height of the plants, while their presence in the substrate had no effect on the number of branches, i.e. the degree of tillering of chrysanthemums. The tallest plants were obtained on the Novarbo substrate, which did not contain the mushroom biostimulator.
5. The presence of the mushroom biostimulator in the substrate slightly reduced the number of flowers in the tested varieties: Mount Gerlach (White) and Wilmington (Yellow). The plants from the Klasmann substrate (peatless) had the smallest number of flowers, but at the same time they had the largest number of flower buds, which indicates slower generative development when there is no peat in the peat substrate.
6. Chlorophyll fluorescence (Fv/Fm) measured on the leaves of the obtained plants was at the level of 0.85. It was observed that the mushroom biostimulator in the substrate increased the content of photosynthetically active pigments in the chrysanthemum leaves.

Ivy-leafed geranium (*Pelargonium peltatum)*

1. Growing ivy-leafed geraniums in conditions of light deficiency and short day in substrates with limited peat content and without peat resulted in a significant reduction in the mass of the above-ground parts of the plants and a reduction in their height, compared to plants grown in peat substrate, which is standardly used in production.
2. Studies of physiological parameters: SPAD and chlorophyll fluorescence coefficient Fv/Fm showed their proper level.